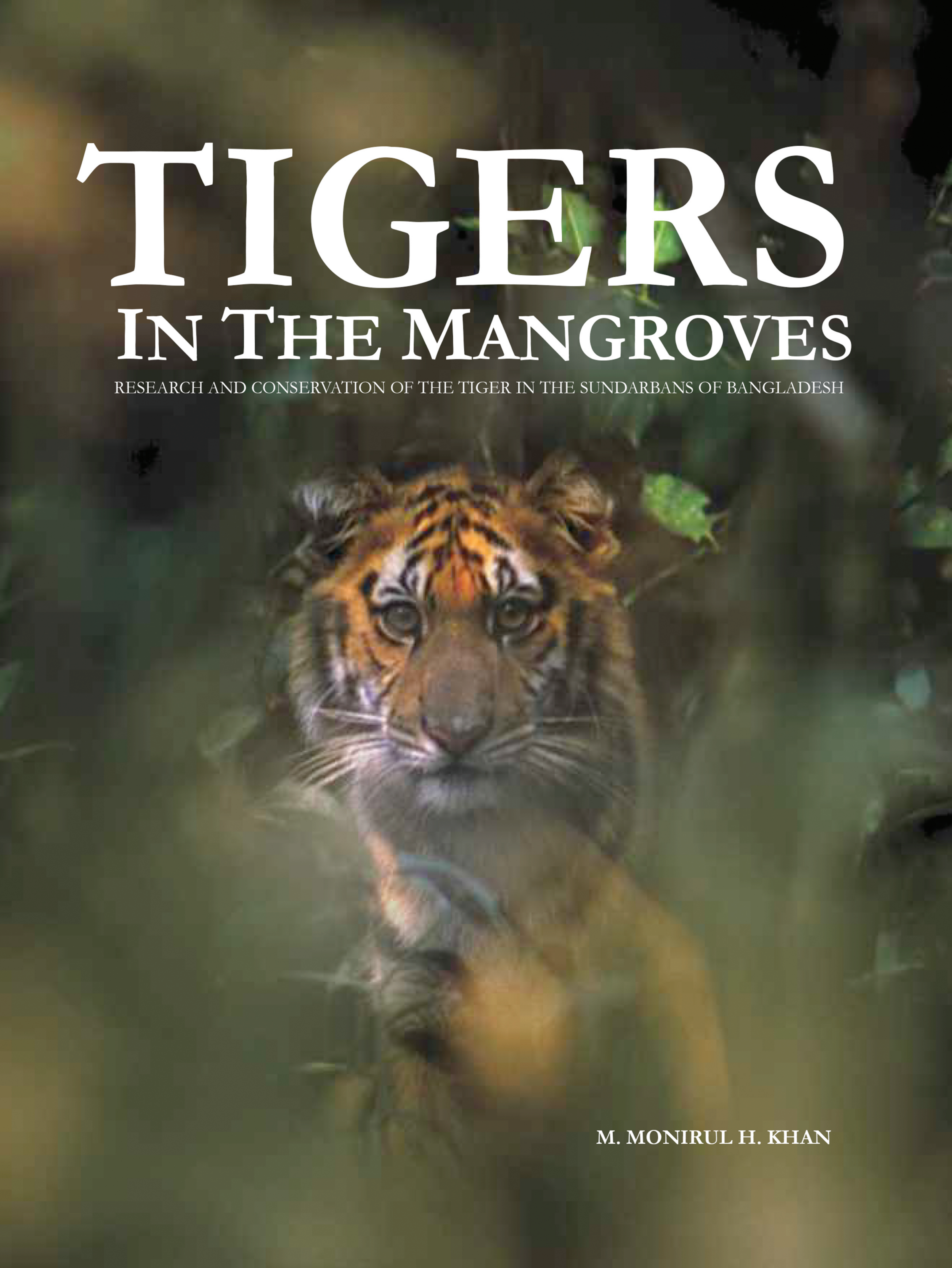
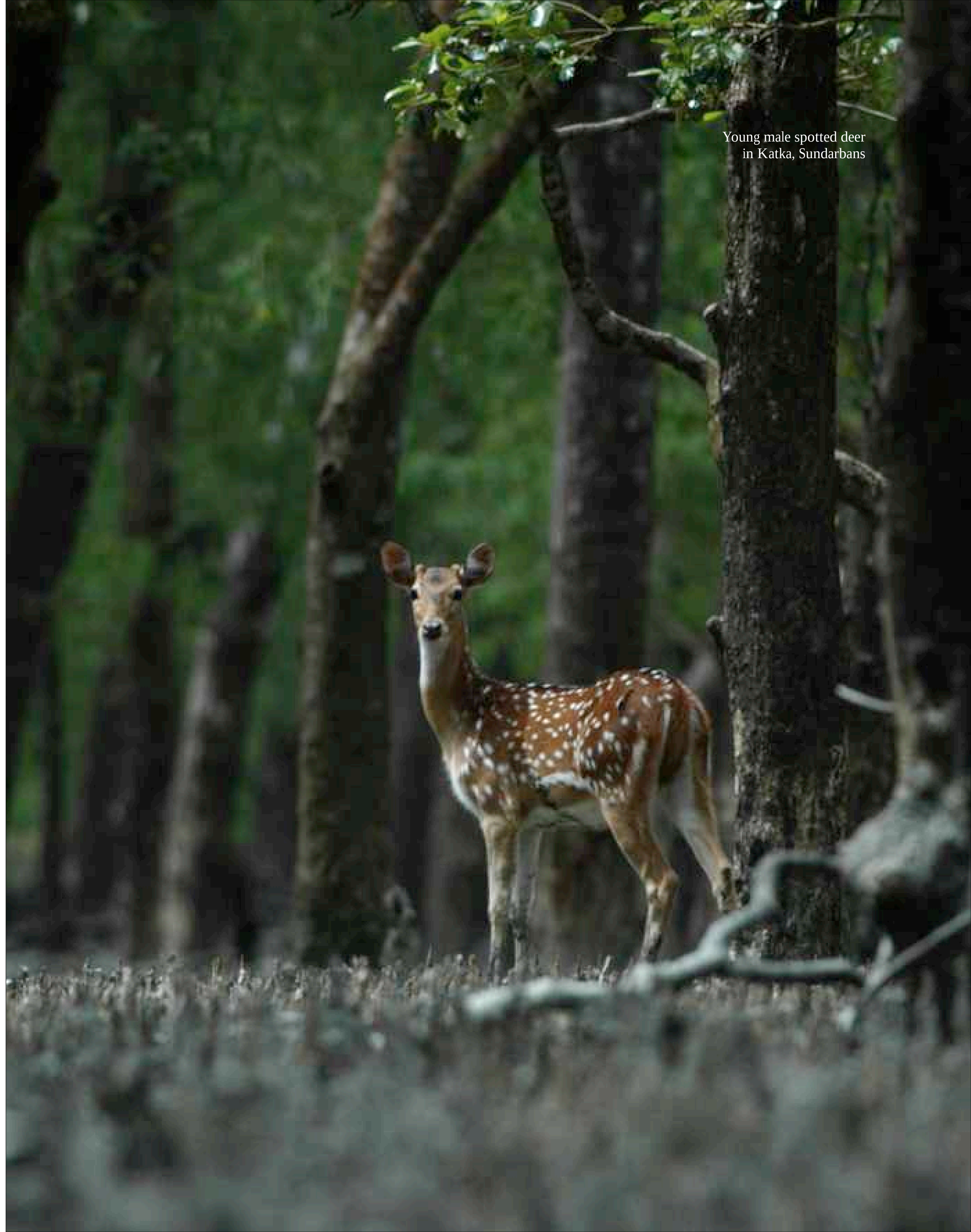
TIGERS IN THE MANGROVES

RESEARCH AND CONSERVATION OF THE TIGER IN THE SUNDARBANS OF BANGLADESH



M. MONIRUL H. KHAN



Young male spotted deer
in Katka, Sundarbans

Tiger replica is worshiped in the villages around the Sundarbans

TIGERS IN THE MANGROVES

RESEARCH AND CONSERVATION OF THE TIGER IN THE SUNDARBANS OF BANGLADESH

M. MONIRUL H. KHAN

ARANNAYK FOUNDATION

Tiger hunting in terracotta of 18th century,
Pancharatna Govinda Temple, Rajshahi

Dedicated to
The Martyred Intellectuals of
Bangladesh Liberation War, 1971

Comments and suggested edits may be sent to
the author at mmhkhan@hotmail.com

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Cover photo © M. Monirul H. Khan
Young curious tiger (*Panthera tigris*) in Supati, Sundarbans *(Front cover) ;* Male tiger in terracotta of 18th century, Rajaram Roy's Temple, Madaripur, Bangladesh *(Back cover)*

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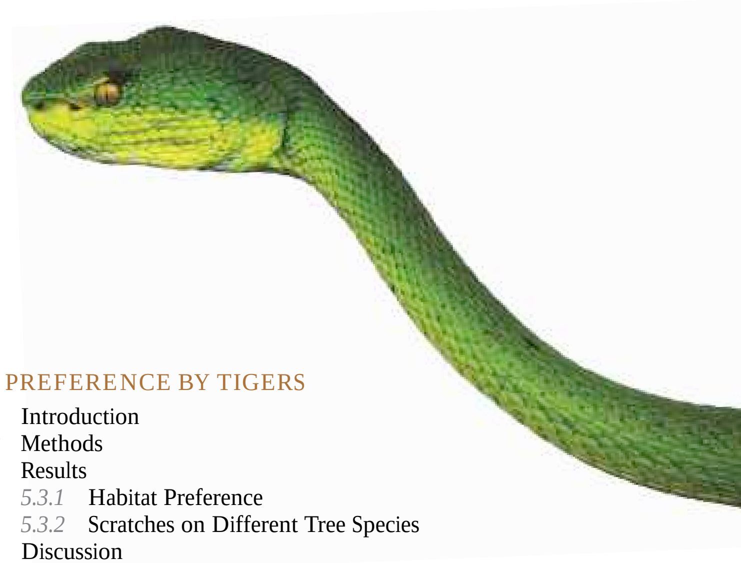


INTRODUCTION

‘ 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.’

\- Valmik Thapar (1999)

Photo: Adult male tiger on territory patrol in Katka, Sundarbans

Chapter 1 INTRODUCTION

1.1 GENERAL

The tiger (*Panthera tigris*) is the largest of the cats and is one of the world's most magnificent animals, so it is no surprise that it has been adopted as the 'National Animal' of both Bangladesh and India demonstrating that it is an intimate part of the history and culture of this region. The tiger is admired, feared and respected by humans for its beauty, grace, strength, ruthlessness as well as various supernatural qualities that have been attributed to it (Tamang 1993). The tiger is an integral part of much of the remaining Asian forest ecosystems, which in turn supply the ecological services essential to human existence. As an umbrella species, the tiger can help secure the future of the biodiversity that make up the tiger's forest home (Ahmad *et al.* 2009). As the top predator, the tiger helps to regulate the prey population, which in turn will impact forest structure, composition and regeneration (Ale and Whelan 2008, Wegge *et al.* 2009). The sheer presence of the tiger in a forest attracts a large number of ecotourists and helps to develop the local economy (Leslie 2001). Above all, the tiger has the same right to survive, as we do.

The tiger is split up into eight subspecies (Luo *et al.* 2004 suggested a nineth subspecies: *P. t. jacksoni*) across its extensive range namely the: 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*). Of these eight subspecies, three have become extinct since 1950s (Caspian, Javan and Bali tigers), two are nearly extinct (South China and Indo-Chinese tigers), and from the 100,000 tigers that might have existed a century ago, we are left with less than 4,000 animals today that living in only 7% of their former range (Thapar 1996, Dinerstein *et al.* 2007, Damania *et al.* 2008). The remaining tiger populations continue to be imperiled by prey depletion, poaching and habitat loss. Most tiger populations are too small and isolated, and have little chance of persistence in the long-term. At present, more tigers exist in captivity than in the wild (Karanth 2001).

The Bengal tiger mainly occurs in India, Bangladesh, Nepal and Bhutan where it has been categorised as globally Endangered (IUCN 2010) and as Critically Endangered within Bangladesh (IUCN-Bangladesh 2000). The Sundarbans of Bangladesh and India harbours one of the two largest unfragmented tiger populations on earth comparing only to the tiger population in the Russian Far East (WWF 1999, Khan 2002). This mangrove habitat is unfragmented and naturally inaccessible to people, which offers excellent potential for long-term conservation of the tiger, therefore the Sundarbans has been identified as a high-priority area for tiger conservation (Dinerstein *et al.* 1997, Wikramanayake *et al.* 1999), despite the fact that tidal mangrove forest is a rare habitat for the tiger (UNDP and FAO 1998). Seidensticker (1986) observed that the Sundarbans is large area, so that a sustainable 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. Since the tiger

Eight subspecies of the tiger (stuffed specimens in the Natural History Museum, Geneva). *From left :* Bali tiger (extinct), Javan tiger (extinct), Bengal tiger, South China tiger, Caspian tiger (extinct), Amur tiger, Indo-Chinese tiger and Sumatran tiger

is at the top of the ecological pyramid of the mangrove ecosystem, it is considered as the 'flagship' or 'umbrella' species and action to conserve the tiger can be the key to the preservation of the unique biodiversity of the Sundarbans.

Large carnivore species occur at naturally low densities, which make them particularly susceptible to extirpation and extinction (Lande 1988, Caughley 1994). That is why the tiger is legally protected under the 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 also banned under the provisions of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), to which Bangladesh acceded to in 1982. In 2009, the Bangladesh Tiger Action Plan 2009-2017 was published (Ahmed *et al.* 2009), but the practical conservation of tigers in Bangladesh still remains undeveloped.

Fortunately, it appears that, despite considerable human pressure on 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, scarcity of timber producing tree species and the fear of tigers, so tigers can be considered as a natural guard of the Sundarbans.

Other than the tiger, there are seven species of wild cats in Bangladesh: leopard (*Panthera pardus*), Asiatic golden cat (*Felis temminckii*), jungle cat (*Felis chaus*), leopard cat (*Felis bengalensis*), fishing cat (*Felis viverrina*), marbled cat (*Felis marmorata*) and clouded leopard (*Neofelis nebulosa*), of which the last three are globally threatened (Khan 2008a, IUCN 2010).

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 human civilization in Asia. A 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). It is even believed that the Tigris river of the Caspian region derived its name from the tiger, while many Chinese still believe that their land is blessed by the white tiger with every twelfth year dedicated to the tiger in the Chinese calendar.

The tiger is also deeply rooted in the history, culture, beliefs and myths of the Indian subcontinent. A 5000-year-old seal from the Indus valley civilization depicts a man sitting on a tree addressing a tiger waiting for him below (Karanth 2001). Another seal, 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 as well as signifying 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 with 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 emerged from Hinduism and spread throughout Asia, the tiger became an important spiritual and cultural image, which adorns splendid murals in temples in Bhutan, China and Thailand (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', his throne was decorated to resemble a tiger, and his soldiers had tiger-striped uniforms as well as tiger images and stripes on their weapons (Jackson 1999).

Today, many forest communities still worship the tiger as the lord of the jungle, such as on the Karnataka coast, in India, where the tiger is worshipped as 'Pili Bhoota' and people perform the tiger dance or 'Huli Vesha' during the Hindu festival of Dasara (Karanth 2001). While in one northern part of Bengal the Tiger God was worshipped by the people of both Hindu and Muslim communities where scroll paintings depicted the Muslim holy man astride a tiger, carrying a string of prayer beads and a staff, attacking all that was evil (Thapar 1992). Even today despite the fact that tigers kill many people in the Sundarbans, the tiger is respected by people and they seek protection with offerings to local folk deities including the tiger before entering the forest (Khan 2004a. 2004b). In secular society the tiger is also widely used as a potent brand image for many goods, Bangladesh has the image of the tiger on banknotes and in the logo of the national cricket team.

1.3 BIOGRAPHY OF THE TIGER

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 carnivores (Macdonald 1992). The early carnivores, known as miacids, lived at the time between 60 and 55 million years ago and 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. 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 and 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 fossil remains as well as from modern molecular phylogenies. The genus *Panthera* probably evolved within the last five million years or so (Hemmer 1976, 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, before the divergence of the lion (*Panthera leo*), leopard and jaguar (*Panthera onca*) (Collier and O'Brien 1985, Wentzel *et al.* 1999).

Top: Kalu – a mythical Muslim character – ruling the tiger; both are worshiped in the villages around the Sundarbans

Opposite: Bangladesh Cricket Board has the face of a tiger on its official logo – the national cricket players are called 'tigers'

Left: Fossilized skull of the ancestral large cat (sabre-toothed cat) in the natural history museum, London. It lived in most parts of the world mainly between five and six million years ago

Top: Skull of modern tiger of the Sundarbans

It is almost certain that the tiger originated in eastern Asia (Hemmer 1981, Mazak 1981, Kitchener 1999) with the oldest fossil remains of the tiger discovered in northern China and Java (Hemmer 1971, 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). The South China tiger may be regarded as the relict population of the 'stem' tiger, living in the probable area of its origin. Abundant tiger fossils from the middle to late Pleistocene periods have also been discovered from China, Sumatra and Java, but tiger fossils only appeared in the Indian subcontinent, the Altai, northern Russia and elsewhere in the late Pleistocene (Kitchener 1999).

The late arrival of the tiger in the Indian subcontinent 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 Northwest Asia via Central Asia (Hemmer 1987, Mazak 1981), or through Northeast India (Heptner and Sludskii 1992). Coming from Southeast Asia through the coastal forests is also possible. Since the soil formation of the Sundarbans is of recent origin (Hussain and Acharya 1994), it is presumed that the tiger colonised the forest there in the relatively recent past.

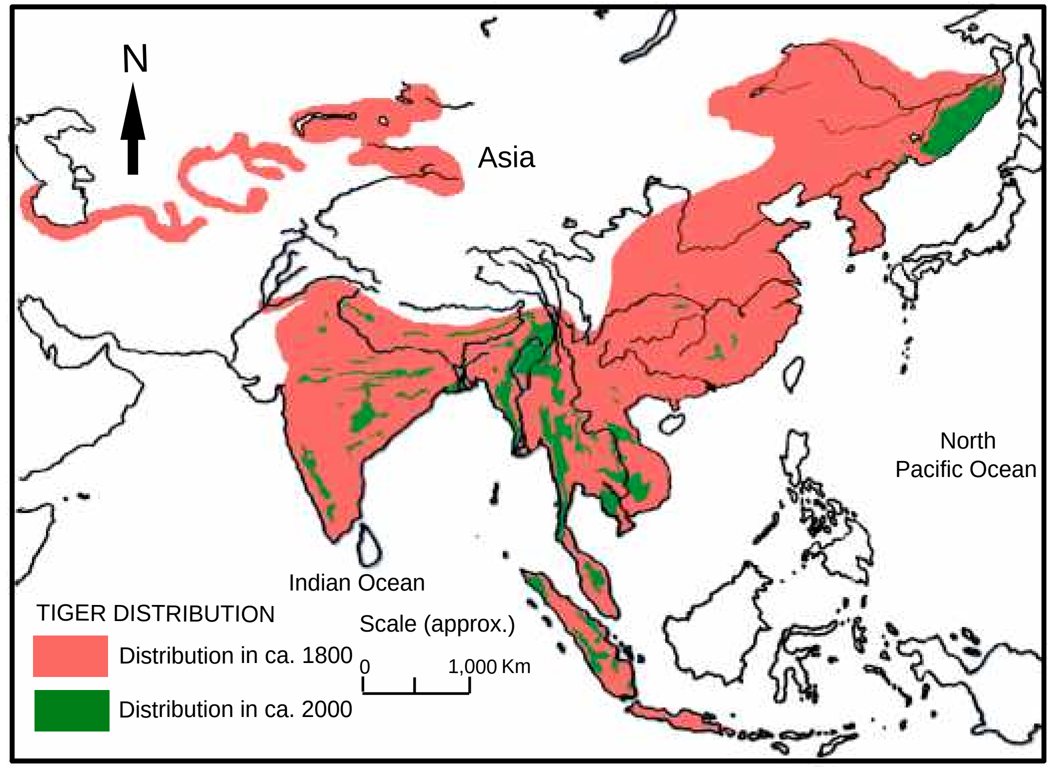


Figure 1.1 Global distribution of the tiger in ca. 1800 and ca. 2000

1.3.2 Distribution

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. Today tigers survive only in scattered populations in 14 Asian countries from India to Vietnam, and in Sumatra, China, and the Russian Far East (Figure 1.1).

The Bengal tiger was once found in all the forests and even in some village groves of Bangladesh. At present the only stable population of the tiger is found in the Sundarbans, and the population is isolated from the nearest tiger populations by about 300 km of agricultural and urban land (Figure 1.2). 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 bounty for killing them (Prater 1940) and tigers were hunted from the deciduous forests of central and northwestern Bangladesh as well as from the mixed evergreen forests of the northeast and southeast even during the 1950s-1960s (Khan 2004a) (Figure 1.3). Tigers are still occasionally sighted in mixed evergreen forests in the Sangu-Matamuhuri and Kassalong-Sajek areas in the Chittagong Hill Tracts (Figure 1.3) where the status of tigers is still unknown (Sanderson *et al.* 2006). MacKinnon and MacKinnon's (1986) assumption of the occurrence of tigers in

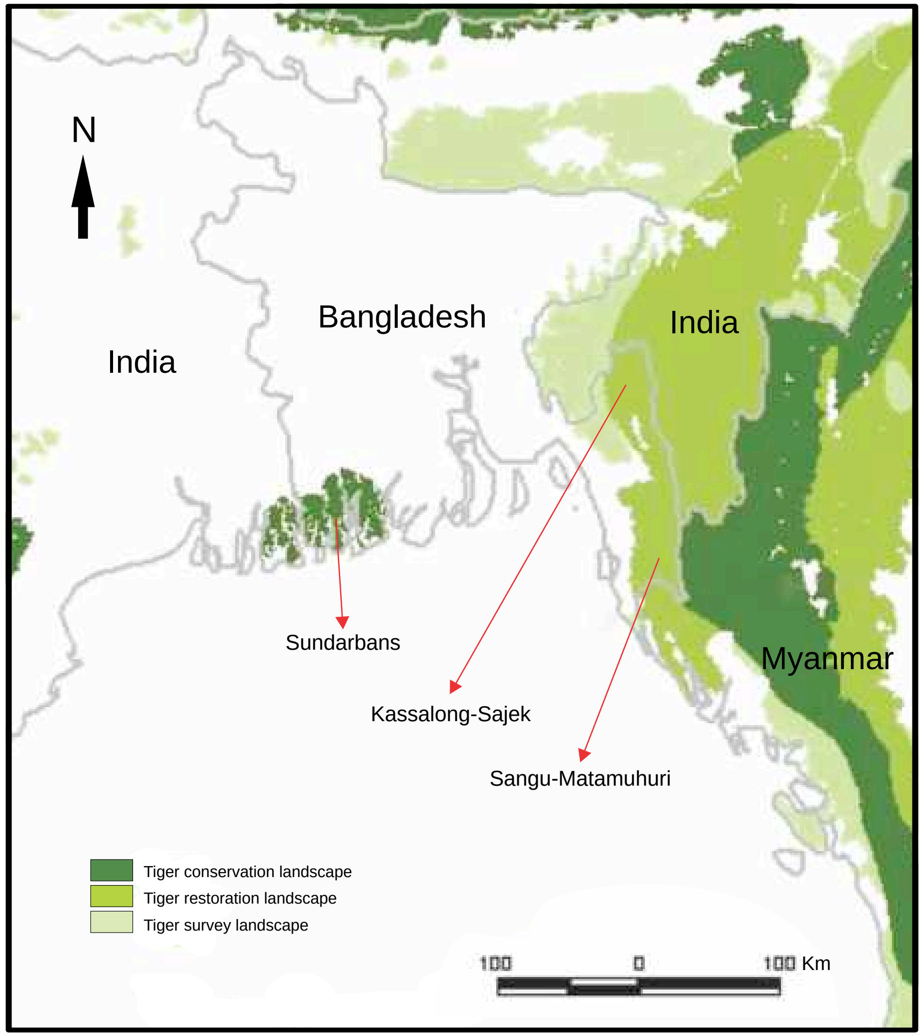
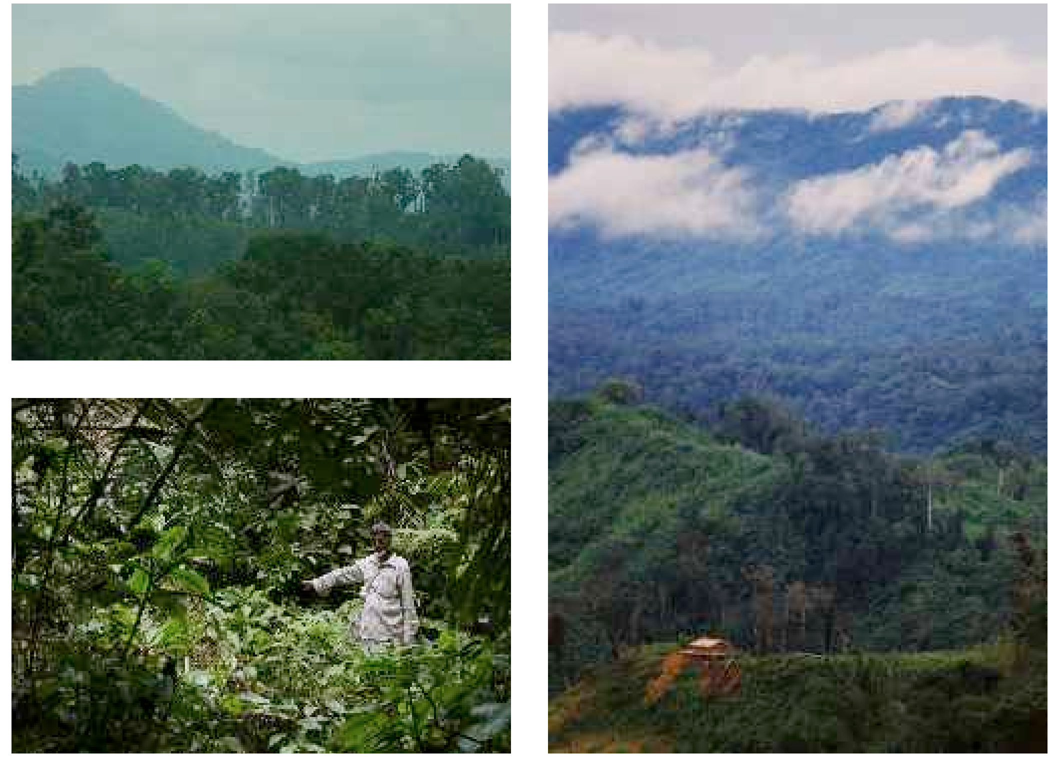


Figure 1.2 Tiger conservation, restoration and survey landscapes in and around Bangladesh (Sanderson *et al.* 2006).

Teknaf (extreme southeastern end of Bangladesh) is likely to be over-optimistic, as there have been no recent reports of tigers in this area.

Wikramanayake *et al.* (1999) classified the Sundarbans and Sangu-Matamuhuri areas as Level I Tiger Conservation Units (TCUs), as these habitats offer the highest probability for the persistence of tiger populations over the long term. While the Kassalong-Sajek area has been classified as Level III TCU, as this habitat offers only a low probability for the persistence of tiger populations over the long term due to its small size, isolation from other habitat blocks containing tigers, and fragmentation within its major representative habitat types.



Tiger habitats in Bangladesh other than the Sundarbans : Kassalong Reserved Forest, Rangamati *(top left)* and Kassalong Reserved Forest, Rangamati *(right)*, in the Chittagong Hill Tracts; and Patharia Hill Reserved Forest (Lathitila forest), Moulvibazar *(bottom left)* – a local hunter showing the location where he saw a tiger in the monsoon of 2008

1.3.3 Population

Counting tigers is difficult because they live secretively in dense forests, with pugmarks (footprints), scratches on trees, calls, and occasional sightings 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 less than 4,000, of which two-thirds are Bengal tigers in the Indian subcontinent (Damania *et al.* 2008).

Tiger ranges vary in accordance with prey densities. Thus, in areas rich in prey throughout the year, such as Nepal's 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). 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, while Bragin (1986) estimated tiger density at 1.3-8.6 / 1,000 km^2 in the Sikhote-Alin mountains of eastern Russia.

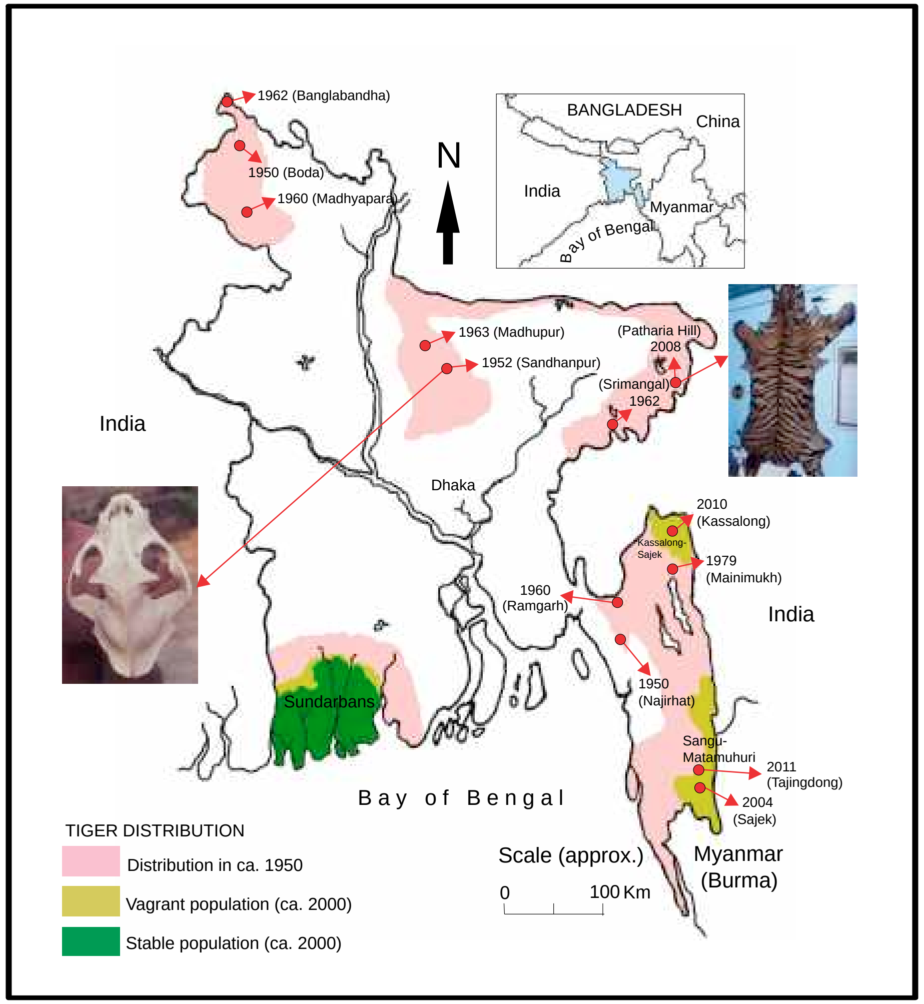


Figure 1.3 Tiger distribution in Bangladesh in ca. 1950 and ca. 2000.

Even a few hundred years ago, the forests of former Bengal (which is now Bangladesh and part of northeastern 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 1978).

There is no long-term 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, Khan 2004c) have suggested that there may be a density gradient, numbers being highest in the south and lowest in the north. The radio-collaring of two female tigers (both sadly died after several months) in the southeastern Sundarbans indicates that in the high density area the female home range size might be 14.2 km^2 (Barlow *et al.* 2009). Based on the recent pugmark census, simultaneously done in both parts of the Sundarbans, by the respective Government Departments, it was estimated that there were 419 tigers in the Bangladesh Sundarbans and 250-300 in the Indian Sundarbans (Khan 2004a). However, based on the camera-trap survey, together with the track counts, and in the light of the prey densities, the tiger population was estimated to be lower than Government estimates with around 200 tigers in the Bangladesh part and another 150 or so tigers in the Indian part of the Sundarbans (Khan 2004a, 2006).

Global Tiger Day 2010 poster published by Bangladesh Forest Department

1.3.4 Morphology

The tiger has dark reddish-ochre to pale yellow body colour with vertically arranged black stripes (young are born with stripes), more pronounced towards the rump and thighs; underparts are whitish; yellow tail has a series of black rings, ending in a black tip; and black back of ears have a clearly visible white spot. Pupil of the eyes is rounded and claws are retractile. Tigers are the only big cats with stripes, but according to one theory the stripes of tigers are actually elongated spots (Moulton and Hulsey 1999). Tiger's head-body length is 140-280 cm and the tail length is 60-110 cm; height at the shoulder is 95-110 cm. Males weigh 180-280 kg and females 115-185 kg (IUCN-Bangladesh 2000), while 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, Kitchener 1999). Kitchener's (1999) analysis shows that size and sexual dimorphism increases with latitude as indicated by the skull and tooth measurements. Males have a prominent ruff, which is especially marked in the Sumatran tiger (Nowell and Jackson 1996). The fur of the Amur tiger (as well as the

Young female tiger carrying a fish on its mouth in the Sundarbans East Wildlife Sanctuary (photo captured in remote camera-trap)

extinct Caspian tiger) differs sharply in winter and summer, with paler, or more ochraceous, long, dense hairs grown in winter (Heptner and Sludskii 1972).

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 1978). A white male tiger cub, caught in Central India in 1951, was the last record and 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. They are not albinos, but resulted from a mutation that occurred about a hundred years ago (Thorton *et al.* 1967, Roychoudhury and Sankhala 1979).

Black tigers have also been reported occasionally (Pocock 1929, Guggisberg 1975, Mazak 1981) and Pocock (1929) lists three records of black tigers, all of which are reported from the same general area of Myanmar, northeastern India and Bangladesh (Chittagong Hill Tracts), within 600 km of each other. It is not a true melanism, which is found in leopards, jaguars (*Panthera onca*), and many other cat species and it may be an expression of the agouti gene, which causes the merging of stripes (L. Lyons in litt. 1993).

1.3.5 Biology

Tigers normally mate year-round, but most frequently from the end of November to early April (Mazak 1981), although the breeding peak varies in different regions. The oestrus cycle is 15-61 days (Sadlier 1966, Sankhala 1978, Smith 1978, Sunquist 1981), the average duration of oestrus is 5-7 days (Sunquist 1981, Sunquist and Sunquist 2002) and tigers copulate frequently. A tigress' pregnancy lasts for about 103 days (Sankhala 1978, Sunquist and Sunquist 1991, Kitchener 1991) and shortly before the birth the tigress selects a secluded place to have her young. The birthing den may be in a rock crevice or cave, an impenetrable thicket, or a shallow depression in dense grass (Sunquist and Sunquist 2002), where 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 1978). In Chitwan, Nepal, Smith and McDougal (1991) found first-year cub mortality to be 34% with infanticide 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 and kills the cubs in order to bring the females into oestrus. Then he may copulate with them and that they may give birth to his own offspring.

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. Cubs are playful, they grow rapidly and males grow faster than females. Young tigers learn hunting by imitation and practice under the guidance of the mother, with both male and female tigers becoming independent from the mother when they are 18-28 months old (Smith 1984, Kerley *et al.* 2003). This stage is very important, especially for males, when they may get into serious fights with other tigers and even get killed.

The male becomes sexually mature at 3-4 years, whereas the female becomes sexually mature at about 3 years (Sankhala 1967, Smith and McDougal 1991, Christie and Walter 2000, Kerley *et al.* 2003). While the female to male ratio of adult tigers may be as much as 2:1 to 4:1 depending upon the 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), although 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). According to Smith and McDougal (1991) the average reproductive life span of tigers in Chitwan, Nepal, is 6.1 years for females, and just 2.8 years for males.

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

1.3.6 Ecology and Behaviour

The tiger is found in a variety of habitats including evergreen, deciduous and mangrove forests, and also conifer and scrub forests in Asia. The tiger has been reported to about 4,000 m altitude in the mountains of Bhutan and southeastern Tibet (Matthiessen 2000). 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). 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), but the tiger depends far more on hearing than on scent or sight, especially in closed forests where visibility is poor (Sankhala 1978). Today, wild tigers inhabit less than 5% of the 1.5 million km^2 of forest habitat available (Karanth 2001), as the lack of prey base and anthropogenic disturbances do not permit the existence of wild tigers in most of the forested areas.

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), as males associate with females for breeding and have been observed with females and cubs when feeding or resting (Schaller 1967, McDougal 1977, Sankhala 1978, Sunquist 1981). 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 active at any time of the day or night (Thapar 1992, Sunquist and Sunquist 2002). They prefer to avoid people and generally give them a wide berth and 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).

Where tigers and leopards occur sympatrically, if both large and medium-sized prey are abundant, tigers select large prey enabling the coexistence of leopards at high densities (Karanth and Sunquist 1995), but where large prey is scarce, tigers switch to medium-sized prey and reduce leopard densities through competition, as hypothesised for Chitwan, Nepal (Seidensticker *et al.* 1990). However, if both large and medium-sized prey are scarce, leopards are 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 that tigers normally prefer large ungulates, but availability also plays an important role (Schaller 1967, Johnsingh 1983, Karanth and Sunquist 1995, Miquelle *et al.* 1999). Depending on food abundance, tigers travel 7-32 km/night (Schaller 1967, Sunquist 1981), although according to Sankhala (1978), the tiger is a wanderer and apparently wanders with no definite plan in mind. They prey mainly on various species of deer and boar, and readily eat carrion, throughout their range.

Although highly skilled hunters, tigers are often unsuccessful with only one out of 10-20 attacks usually succeedful (Schaller 1967, Thapar 2000). Tigers make a stealthy approach using every available tree, rock, or bush as cover to get as close as possible to their target before they launch their attack (Sunquist and Sunquist 2002). 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. The prey is then usually dragged into cover and although they can drag or even lift kills, they never load prey on their backs as some people believe. In the Sundarbans human kills are sometimes dragged as far as 8 km (Khan 2004a) and Pocock (1939) cited an example in Myanmar of a tiger dragging the carcass of a gaur that 13 men could not move. Although lions (*Panthera leo*) and leopards also kill humans, tigers have the greatest reputation as man-eaters, the most notorious being the Champawat tiger that 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), and with greatly reduced numbers of tigers in recent times the attacks on people have been relatively rare, except in the Sundarbans, where the Sundarbans tigers have even taken people out of boats.

Tiger requires some kind of vegetation cover to hide itself and to facilitate stalking of prey

Worshiping the replica of the Bonbibi (means 'lady of the forest'; Dukhey standing on the right), Dakshin Rai, Gazi and Tiger

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 (or about 50 large ungulates) on average every year (Schaller 1967, Tamang 1982, Sunquist *et al.* 1999) and Karanth (1993) 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), while Sunquist (1981) estimated frequency of killing by females without cubs at once every 8-8.5 days in Chitwan, Nepal. 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), although 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 and during hot seasons they like to lie half-submerged in the lakes and ponds but tigers do not normally hunt in the water. In the Sundarbans, they constantly swim creeks and across broad rivers (Nowell and Jackson 1996) and in the Indian Sundarbans, tigers have been known to swim a distance of over 10 km (Chaudhuri and Choudhury 1994), while in the Bangladesh Sundarbans a tiger swum across a 3-km-wide estuary and another crossed a 0.5-km-wide river (Khan 2004a).

The social system of the tiger is maintained through a combination of visual signals, scent marks, and voice; while some signals and advertisements such as pheromones, and male-female calls, bring tigers together, others serve to maintain spatial separation (Sunquist and Sunquist 2002). Tigers have no odour, but the smell of rotten meat, which they feed on, might remain with the tiger for a while, even after leaving the kill. That is why some people think that tigers have odour. 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 and 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), but in the Bangladesh Sundarbans during the cyclone storm surges many tigers escape 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).

1.3.7 Threats

Despite the fact that the tiger has been used as a flagship species throughout the range countries, to conserve biodiversity, 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 remains a grave danger for the tiger, particularly in South and Southeast Asia, while illegal killing is considered as the immediate threat, which hastens extinction (WWF 1999). Tiger poaching and associated trade have potential to decimate a population over a short period of time (Kenny *et al.* 1995). 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, and 4) persecution by humans in response to real or perceived livestock predation and attacks on people. 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.

Tribal hunter showing the fat of tiger (used as pain healer) and the paws of Asiatic black bear (*Ursus thibetanus*) hunted from Ruma, Bandarban, Chittagong Hill Tracts. Skin and bones of the tiger were sold in Myanmar by Taka 20,000 (ca. US $ 300). Trap *(Inset)* – brought from Myanmar – used to catch tigers and other large mammals

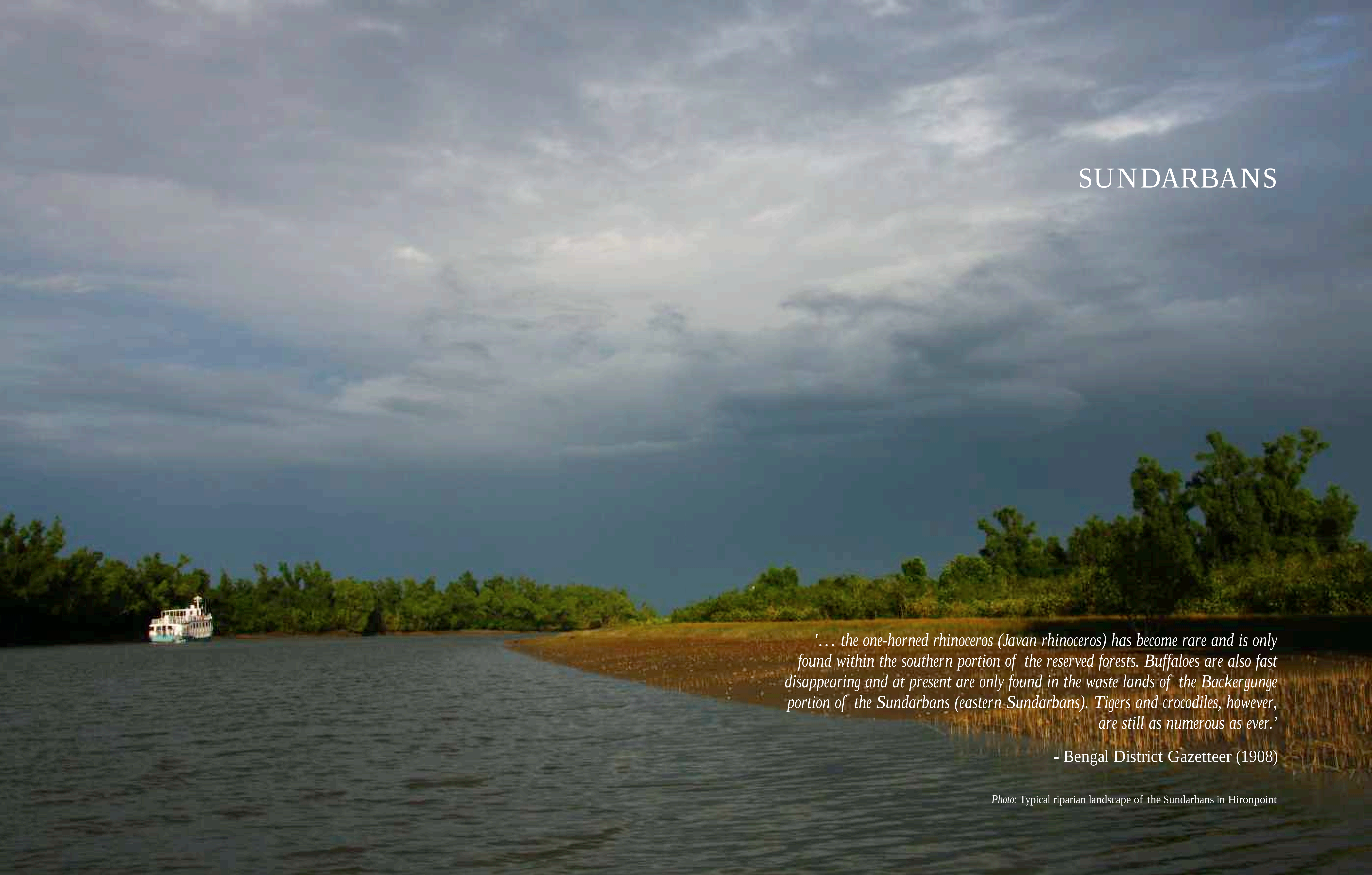
1.3.8 Conservation

Saving the tiger is a challenge for mankind (Johnsingh 1997). Although the tiger is a legally protected species all over its global range, there are threats from poaching, prey depletion and habitat loss. According to Seidensticker and Hai (1978), the three principles of tiger management are: 1) protection, 2) habitat continuity, and 3) habitat quality. The recent advances in the field research techniques 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 and the concept of tiger metapopulation management (Wikramanayake *et al.* 2004) is being promoted throughout the fragmented tiger landscapes. A total of 76 Tiger Conservation Landscapes (TCLs) have been identified in its range, each TCL is a connected habitat sufficient to harbour at least five tigers and where tigers have been confirmed in the last decade (Dinerstein *et al.* 2006). The international conservation organisations as well as national organisations of the tiger-range countries treat the tiger as the priority species for conservation.

The tiger is legally protected under the 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. 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). 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 the Forest Act 1927 and Bangladesh Wildlife Act 1974, in addition three Wildlife Sanctuaries in the Sundarbans were declared under the provisions of Bangladesh Wildlife Act 1974, mainly for the protection of tigers and prey. The total area covered by these three wildlife sanctuaries of the southern Sundarbans was declared a UNESCO World Heritage Site in December 1997. Practical tiger conservation in Bangladesh remains at a preliminary level, and no long-term and coordinated programme has ever been taken. However, in 2009 Bangladesh has published it's first-ever Tiger Action Plan 2009-2017 (Ahmad *et al.* 2009). The vision of this Action Plan is 'Protected tiger landscapes in Bangladesh, where wild tigers thrive at optimum carrying capacities and which continue to provide essential ecological services to mankind'. The goals are to: a) increase or stabilize the Sundarbans tiger population, b) maintain sufficient prey base to support the Sundarbans tiger population, c) maintain sufficient habitat to support the Sundarbans tiger and prey populations, d) assess the viability of tiger populations in the Chittagong Hill Tracts, e) improve conservation capacity in the Forest Department and mainstream tiger conservation into the Government's development agenda, f) improve law enforcement to ensure protection of tiger, prey and habitat, g) build capacity to implement awareness and education programmes, h) build capacity to conduct tiger conservation research and monitoring, and i) encourage collaboration to support the Forest Department in the implementation of the Action Plan.

TIGER

Scientific name: *Panthera tigris.*
Local name in Bangladesh: Bagh, Mama, Gobagha, Goira Goma, Loha Faitta, Machak (Garo), Khaiagri (Marma) and Tapri (Mro).
Wild population: Less than 4,000 worldwide; in Bangaldesh ca. 200 in the Sundarbans and unknown number in the Chittagong Hill Tracts.
Global distribution: In 14 Asian countries.
Length: Head-body 140-280 cm, tail 60-110 cm.
Weight: Male 180-280 kg, female 115-285 kg.
Breeding season: Year-round.
Gestation period: ca. 103 days.
Litter size: 3 (average).
Sexual maturity: Male 3-4 years, female ca. 3 years.
Life expectancy: In the wild ca. 20 years.
Prey: Mainly large ungulates; consumes 1 / week.
IUCN Red List status: Endangered globally, Critically Endangered in Bangladesh.
Threats: Prey depletion, tiger poaching and habitat loss.
Legal status in Bangladesh: Protected under the Bangladesh Wildlife Act 1974; National Animal of Bangladesh.



SUNDARBANS

'… 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)

Photo: Typical riparian landscape of the Sundarbans in Hironpoint

Chapter 2 SUNDARBANS

2.1 INTRODUCTION

The Sundarbans is the world's largest and most biodiverse mangrove swamp, which comprises about 6% of the total area of all mangroves on earth (Khan 2002, Iftekhar and Islam 2004). It is an essential and high quality wildlife conservation area of regional and international importance (Seidensticker 2004), and has been identified as Level I Tiger Conservation Unit (TCU) (Wikramanayake *et al.* 1999). In Bengali the word 'Sundarbans' means 'beautiful forests', but the name could have derived from the common tree 'sundri' (*Heritiera fomes*), which means 'beautiful lady' (Hussain and Acharya 1994, Sarkar 2010).

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 in the north of the Bay of Bengal that gave rise to the Sundarbans. Much of the present tidal delta probably stabilized between the 5th and 7th centuries AD (Sahgal *et al.* 2007). By the end of the 17th century the eastward tilt of the Bengal Basin and the shifting Ganges began to impact the Sundarbans (Eaton 1993, Sahgal *et al.* 2007). The tract is ever-changing and moving usually southward so that what is the Sundarbans now was probably in the Bay of Bengal hundreds of years ago and similarly what is now old lands north of the Sundarbans was once in the heart of the Sundarbans (Sarkar 2010).

Left: UNESCO World Heritage plaque in Hironpoint, Sundarbans

Opposite page: WWF (World Wide Fund for Nature) expedition team in Sela River, Sundarbans, in 1967. From left: John Buxton, G.M.M.E. Karim, Eric Hosking, Guy Mountfort, George Shanon, M.U. Siddiqui and Lord Fermoy. *Photo: Late G.M.M.E. Karim*

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, such as 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 most striking adaptations of the mangrove plants are various forms of aerial roots to meet the oxygen requirement for respiration (Hogarth 1999) and these holophytic tree species form most of the natural vegetation. The forest is more or less open, canopy height commonly within 10 m from the ground, and the forest floor is normally 0.9-2.1 m above the mean sea level (Tamang 1993). Three ecological zones: the 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 southwest of Bangladesh (between 21°30´-22°30´ N latitudes and 89°00´-89°55´ E longitudes) and the other 40% in the southeast 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) as shown in Figure 2.1.

Aerial view of Supati, Sundarbans, showing mangrove vegetation and water body

Remote sensing analysis suggests that the net forest area of the Sundarbans increased by 1.4% from 1970s to 1990, and then decreased by 2.5% from 1990 to 2000 (Giri *et al.* 2007). The Bangladesh Sundarbans covers an area of 5,770 km^2, of which 1,750 km^2 is under water as rivers and creeks (Hussain and Acharya 1994) as shown in Figure 2.2, while only 61 km^2 of the total land area is bare ground, scrubland, grassland or clearings (Chaffey *et al.* 1985) and the rest is forested. On the other hand, 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 44% of the total forested area of the country and contributes 50% of the revenue in the forestry sector (Tamang 1993), so 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, fish, honey, and nipa (*Nypa fruticans*) leaves for thatching (Blower 1985). It also has an important buffer function protecting the densely settled villages and 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. Nearly 100,000 tourists visit the Bangladesh Sundarbans (high season is February to April),

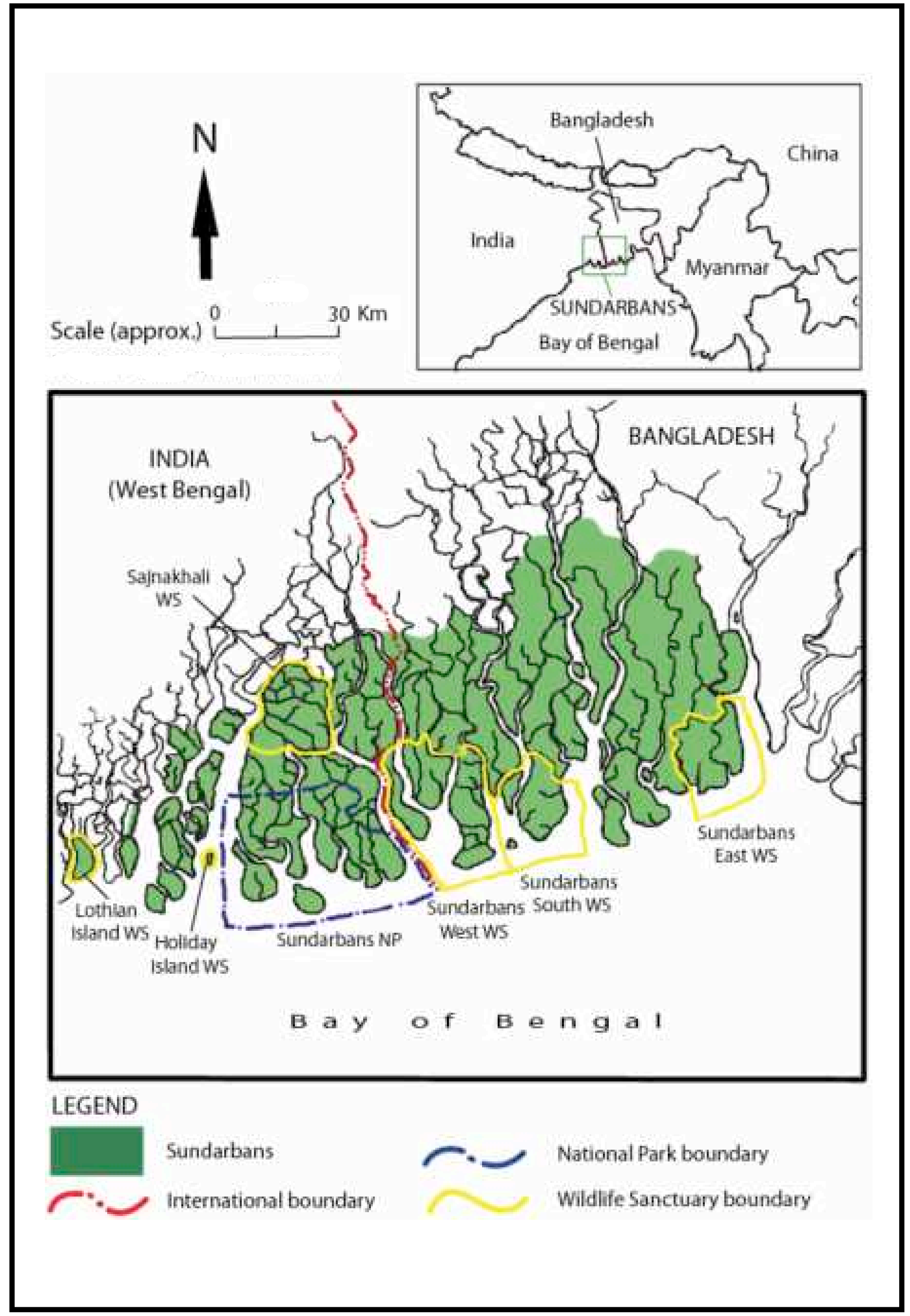


Figure 2.1 Sundarbans of Bangladesh and India showing the National Park (NP) and Wildlife Sanctuaries (WS).

Top: Sundarbans is difficult to access, making it an excellent shelter for tigers and their prey.
Left: 300-year-old temple in Sheikher Tak at the centre of the Bangladesh Sundarbans – now serves as a den for tigers

of which the foreign tourists make up less than 2% (International Resources Group 2009). Taking into account the current rate of entry fee (Taka 50 for each Bangladesh national and Taka 700 for each foreign national per day), the tourists are contributing a significant amount of revenue to the Government of Bangladesh. 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 (WS) (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, which is popularly believed as the richest part of the Sundarbans. This is an area of 312 km^2 (5% of Bangladesh Sundarbans) at the southeastern end of the Bangladesh Sundarbans, 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%) with half of the Sundarbans East WS is under deep water in the form of estuaries and large rivers.

The mean maximum and minimum temperature in the Sundarbans are 31°C (April-May) and 22ºC (December-January), respectively, while the mean annual relative humidity varies between 70 and 80%. The mean annual rainfall varies from 2,600 mm in the east to 1,600 mm in the west and there are about 120 rainy days in a year. The pH in river water varies from 6 to 8, tides are twice daily and the average tidal time difference is 12.5 hours.

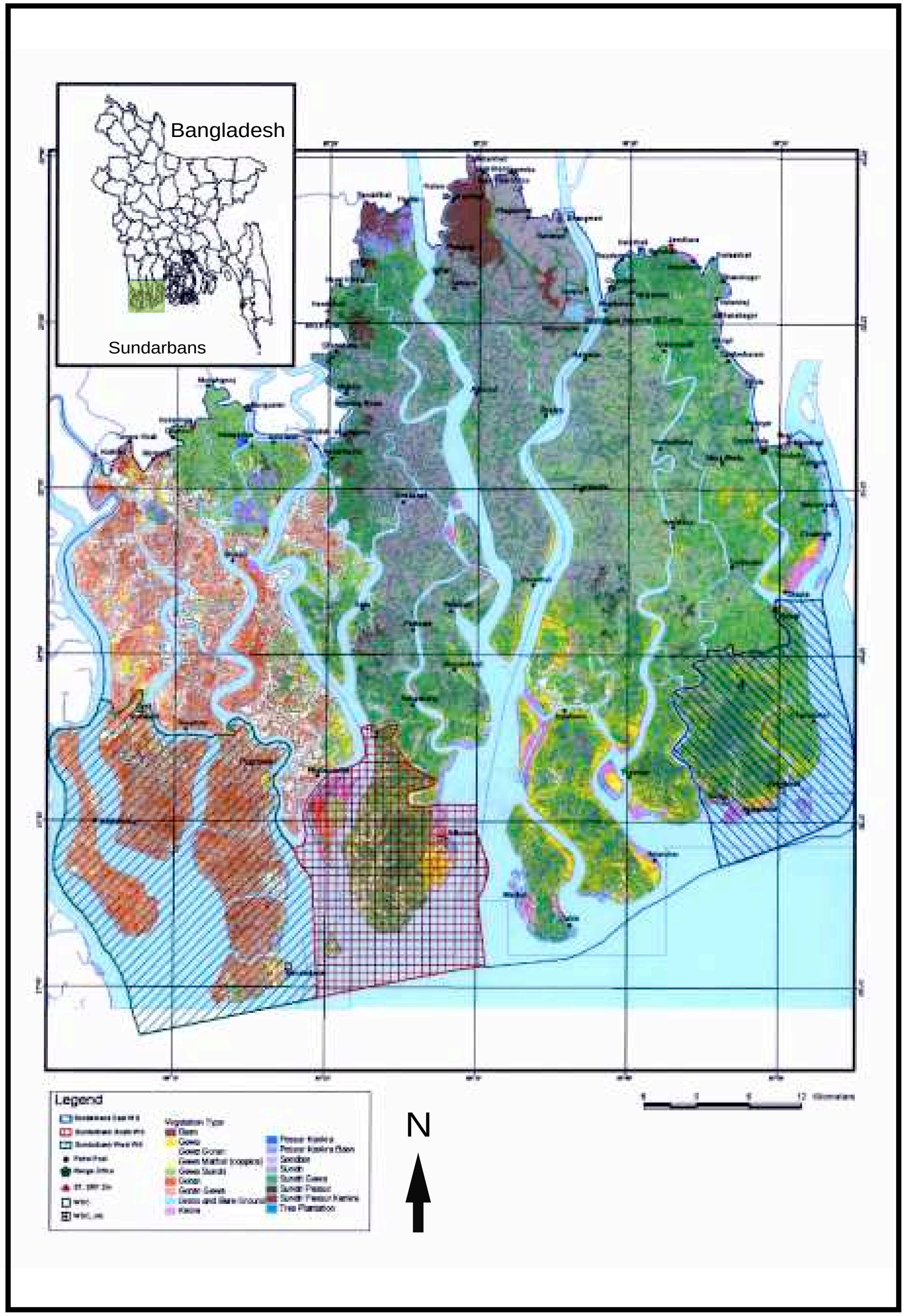


Figure 2.2 Sundarbans of Bangladesh showing three Wildlife Sanctuaries (WS).

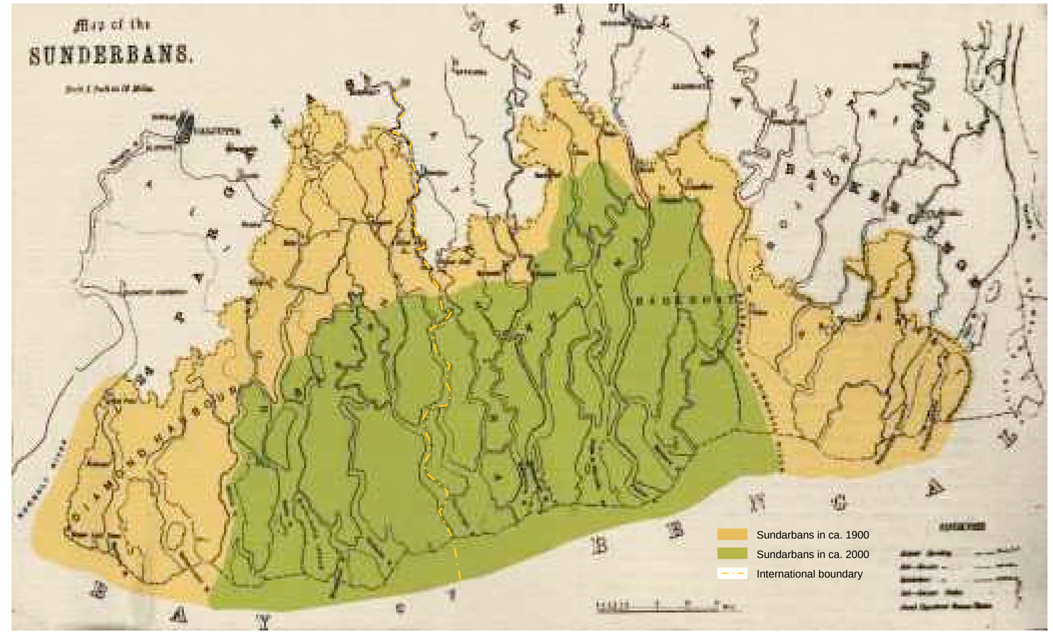


Figure 2.3 Extent of the Sundarbans in ca. 1900 and ca. 2000 showing 50% decline of the forest cover (original map from Prain 1903).

2.2 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 (Khan 2005), is that the Sundarbans is a forest as well as a wetland with mudflats, sandflats and sea beaches. That is why it can harbour both forest species and wetland species. However, there is no endemic species of wildlife or flowering plants in the Sundarbans.

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. Therefore, a rich and diverse associated mangrove community is seen in the Sundarbans with no other mangrove forest in the world offering such a variety of associated 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, however, 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).

Biodiversity in the Sundarbans *(row-wise from left)*: liana (*Flagellaria indica*) flower, nipa palm (*Nypa fruticans*) flower, crimson rose (*Pachliopta hector*) mating pair, fungus (*Polyporus xanthopus*), 'ora/soila' (*Sonneratia caseolaris*) flower, chaat slug (*Onchidium tenerum*), 'raja urchunga'/cricket (*Schizodactylus monstruosus*), angle-winged katydid (*Microcentrum* sp.), fiddler crab (*Uca urvillei*) young, giant tiger prawn (*Penaeus monodon*), spotted scat (*Scatophagus argus*), marbled toad (*Bufo stomaticus*) young, water monitor (*Varanus salvator*), mangrove whistler (*Pachycephala grisola*) juvenile and Ganges river dolphin (*Platanista gangetica*)

Oriental small-clawed otter (*Amblonyx cinereus*) in the riverbank searching for prey

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). The Bangladesh Sundarbans supports about 80% of the global mangrove tree species with 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), and *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, there are 11 species of climbers in 6 families; and Graminae, Palmae and Pandanaceae families represent the monocotolydenous herbs. There are many epiphytes like *Hoya parasitica*, *Dischidia numularia*, 13 species of Orchidaceae, and 7 epiphytic ferns including *Lycopodium* and *Psilotum* (Hussain and Acharya 1994).

The Indian part of the Sundarbans is relatively less diverse 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 with *Excoecaria agallocha* and *Ceriops decandra* as the commonest tree species in the Indian Sundarbans.

Among the fauna, there are few reports on the zooplankton in the Bangladesh Sundarbans, but Mahmood *et al.* (1987) recorded 23 species of ichthyoplanktons in

19 families and Zafar and Mahmood (1989) recorded the zooplankton belonging to 13 taxa, such as Copepoda, Amphipoda, Mysidacea, Chaetognatha, Polychaeta, Lucifera, Hydromedusae, aceters, shrimp larvae, finfish larvae, crab larvae, squilla larvae and horse-shoe crab larvae.

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 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 recorded are: Cnidaria, Annelida, Arthropoda, Echinodermata, Mollusca, Phoronida, Nemertea, Bryozoa, Hemichordata and Chordata.

Among aquatic invertebrates, 24 species of shrimps in 5 families, 7 crabs in 3 families, 2 gastropods, 6 pelecypods and 8 locust-lobsters have been recorded from the Bangladesh Sundarbans, while a total of 12 species of Arthropoda, 7 Dermeptera, 25 Odonata, 5 Neuroptera and 9 Lepidoptera have been recorded in the Indian Sundarbans (Hussain and Acharya 1994). The Indian Sundarbans also supports at least 4 species of sea anemones, 19 benthic crabs, 3 hermit crabs, 2 horseshoe crabs, 61 gastropods, 30 polychaetes, 80 nematodes, 1 acorn worm, 46 benthic insects, 4 amphipods, 14 ciliate parasites of bivalves and gastropods of which 7 are new to science, and many species of parasites of fish and mammals (Chaudhuri and Choudhury 1994).

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

There are 425 species of vertebrate wildlife in the Bangladesh Sundarbans, of which 9 are amphibians, 53 reptiles, 315 birds and 49 mammals (Hussain and Acharya 1994). 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 that number 315, including 84 migratory species (Hussain and Acharya 1994), recorded in the Bangladesh Sundarbans is nearly half of the total bird species recorded in Bangladesh, while of the 12 species of kingfishers found in Bangladesh, 8 are found in the Sundarbans (Hussain and Acharya 1994, Khan 2005). A total of four species of aquatic mammals are found in the Sundarbans water, viz. Ganges river dolphin (*Platanista gangetica*), Irrawaddy dolphin (*Orcaella brevirostris*), Indo-Pacific hump-backed dolphin (*Sotalia chinensis*) and finless porpoise (*Neophocaena phocaenoides*) (Khan 2008a, Smith *et al.* 2008).

In the Indian Sundarbans, 8 species of amphibians, 57 reptiles, 161 birds and 40 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.

King cobra - the largest poisonous snake in the world

Brown-winged kingfisher - locally common, but globally Near Threatened

Estuarine crocodile enjoying the rain during low tide

2.3 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 forest. This species is dominant in the Bangladesh Sundarbans, mainly in the eastern part, while it is uncommon in the Indian Sundarbans and is considered as a threatened species. To some extent, this species is an indicator of the level of natural resource exploitation, since it is the most important commercial species of tree in the Sundarbans.

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*) and some other plants like *Cynometra*, *Amoora cuculata* and *Rhizophora* spp. are threatened due to unregulated felling (Hussain and Acharya 1994). Prain (1903) recorded 13 species of orchids in the Sundarbans, but the survey in 2004 by IUCN-Bangladesh recorded only 7 species (Reza *et al.* 2004). In the Indian Sundarbans, 12 species of mangroves are considered to be critically endangered and a total of 57 mangrove and mangrove-associated species are considered threatened. *Rhizophora* is on the brink of extinction in the Indian Sundarbans.

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 2010) and nationally (in Bangladesh) Critically Endangered species (IUCN-Bangladesh 2000).

River terrapin - a globally Critically Endangered species that occurs in and around the Sundarbans

Another flagship species in the Sundarbans is the estuarine crocodile *Crocodylus porosus*, which has been identified as a Critically Endangered species in Bangladesh (IUCN-Bangladesh 2000). Decline of crocodile population has been observed in the Sundarbans, possibly due to indiscriminate killing (Hussain and Acharya 1994, Chaudhuri and Choudhury 1994).

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*), spoon-billed sandpiper (*Eurynorhynchus pygmeus*), white-rumped vulture (*Gyps bengalensis*), Pallas's fish eagle (*Haliaeetus leucoryphus*), greater spotted eagle (*Aquila clanga*), and lesser adjutant (*Leptoptilos javanicus*), fishing cat (*Prionailurus viverrinus*), Ganges river dolphin (*Platanista gangetica*) and hoary-bellied Himalayan squirrel (*Callosciurus pygerythrus*) (BirdLife International 2001, IUCN 2010).

Among the fauna of the Sundarbans, at least four species have become extinct since the beginning of the 20^{th} century, these are Javan rhinoceros (*Rhinoceros sondaicus*), wild water buffalo (*Bubalus bubalis*), swamp deer (*Cervus duvauceli*) and hog deer (*Axis porcinus*) (Hendrichs 1975, Blower 1985, Tamang 1993, Hussain and Acharya 1994, Khan 2008a). These species, except the hog deer, have also become extinct from whole Bangladesh. Baker (1887) had killed three rhinoceros in the Sundarbans in 1881 and 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

Top: Pallas's fish eagle - a globally Vulnerable species that occurs in the northern Sundarbans

Bottom: Masked finfoot - a globally Vulnerable and mangrove specialist bird that occurs throughout the Sundarbans

Opposite: Buffy fish owl - Sundarbans is the only area in South Asia where this species now occurs

rhinoceros in the collection of the Indian Museum, Kolkata, (Groves and Chakraborty 1983) and two of the specimens have recorded collecting sites: 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)' while groups of 8-10 wild buffalos were sighted in tall grass of the riverbanks in Sarankhola Range, Bangladesh Sundarbans, until 1925-1930 (Khan 2004a). 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, while Curtis (1933) also noted the hog deer in the northern areas of the Sundarbans. Some experts believe that leopard (*Panthera pardus*) (Curtis 1933), gaur (*Bos gaurus*) and marsh crocodile (*Crocodylus palustris*) (Blower 1985) were once found along the edge of the Sundarbans. The barking deer (*Muntiacus muntjak*) is no longer seen in the Indian Sundarbans (Sahgal *et al.* 2007).

A crab catcher preparing his evening meal on a small boat

2.4 HUMAN LIFE

Except a few villages in the Indian part, there is no permanent human settlement in the Sundarbans. However, other than the coast in the south, the entire forest is surrounded by densely populated villages. The people of these villages mainly depend on the natural resources of the Sundarbans. Moreover, 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), and several million people benefit from these activities (Islam and Wahab 2005).

The earliest reference of the Sundarbans can be traced back to the epic Mahabharata (ca. 300 BC to 300 AD) where the eldest and second Pandava brother Yudhistir and Bhima visited 'Gangasagar' (place where the river Ganges met the sea) during their pilgrimage (Dutta 1989). Still today, thousands of Hindu pilgrims visit Sagar Island to the west of the Indian Sundarbans and Dubla Island in the Bangladesh Sundarbans.

Honey gatherers smoking a honeycomb on a mangrove tree

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). Prior to the 5th century BC the Proto-Australoid group called 'veddoid' or 'kobil', started to settle in the upper parts of the delta (Sahgal *et al.* 2007). The Aryans (Proto-Nordic) invaded the area much later.

Archaeologists discovered the ruins of a walled city of 6 km^2 area in the north of the Indian Sundarbans. It dates to a period between the Maurya (4th-3rd century BC) and Gupta (6th-4th century BC) ages (De 1999). During the 10th century AD, Srichandra founded the Chandra dynasty in the northeast of the Bangladesh Sundarbans which was known as Chandradweep. Between the 17th and 19th centuries AD there thrived in lower deltaic Bengal 'punthi' literature in Bengali verse devoted to the Gods and Goddesses of the Sundarbans (Sarkar 2010). In 1582, the Sundarbans was first surveyed by the Mughal emperor Akbar's appointed Diwan-i-Ashraf (Minister of Revenue), named Todar Mall, in order to settle the revenue (Chowdhury and Vyas 2005). During the British colonial rule the rulers took over rights to the Sundarbans in 1828 and started leasing out land for mass clearance. The rate of forest clearance had increased afterwards until the formulation of the Forest Act in 1855. Under this Act some parts of the Sundarbans were declared as reserved forest in 1878.

At least from the end of the 18th century up to early 20th century AD, there were small salt-farms in many parts of the southern and central Sundarbans. The salt manufacturers were called 'malangis' and 'mahinders' (Barui 1985). Ruins of earthen pots that people once used to make salts, and the mounds of their shelters, still exist in some areas of the Sundarbans. Ruins of old temples and watchposts still exist in Sheikher Tak, central part of the Bangladesh Sundarbans, which date back to 1700s (Ahmed 1989). The recent mass settlement in this basin was started in the early 19th century AD and from the very beginning the principal occupations of the settlers of this area were woodcutting, fishing and honey gathering.

A primitive fishing technique is practiced in the Sundarbans where trained otters are used to drive fish into the net

Hindu pilgrims engaged in prayer during Rash Mela in Dubla Island, Sundarbans, which is performed every year in winter

The culture and religion developed in this area have absorbed the Sundarbans, and its plants and animals, and the tiger is a prominent figure in the culture and religion of this area. There are a number of folk deities worshipped in the Sundarbans region with the four principal folk deities being Banbibi, Dakshin Rai and Gazi-Kalu brothers. 'Banbibi' means 'lady of the forest' and she is the supreme deity. According to the legend 'Banbibir Jahura Nama', Banbibi fought against Dakshin Rai, a cruel king, to save the life of a destitute honey gatherer named Dukhey. 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's permission before entering the forest. The local Muslims do not want to go to the forest on Friday, because they believe that Bonbibi goes to Mecca on every Friday, where she was from, so people will not get Bonbibi's protection in the forest on Friday. Dakshin Rai is also worshipped because he is considered to be the 'God of the Tigers' and people believe that all tigers in the Sundarbans are under the control of him. Gazi-Kalu brothers were believed to be great Muslim leaders of the region, and the tiger and other wild animals of the Sundarbans obeyed them. Interestingly, Banbibi and Gazi-Kalu brothers are Muslim characters, but they are worshipped by Hundus and respected by Muslims living around the Sundarbans (Khan 2004a, Sarkar 2010).

Every year people sacrifice live goats and chicken, releasing them in the Sundarbans (which ultimately get killed and eaten by the wildlife of the Sundarbans). 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. Whenever people talk about the tiger, they address it very respectfully. People 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 they work in so that the tiger cannot approach them. 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 work in groups and many groups have a professional shaman, 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 don't reveal these to anyone.

Top: Firewood collection – a common practice in the Sundarbans
Bottom: Large-scale exploitation of the Sundarbans trees to meet the needs of timber and firewood

2.5 THREATS

The Sundarbans today is about half the size it was a century ago (Prain 1903, Curtis 1933, Choudhury 1968, Hussain and Acharya 1994) (Figure 2.3). The mangrove ecosystem of the Sundarbans has grown in a delicate balance between the terrestrial and the marine ecosystems. The 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 with the anthropogenic factors relatively easy to control.

Overexploitation 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 (Hussain and Acharya 1994). However, the encroachment and fragmentation have been stopped as a result of the successive growth of national and global awareness for biodiversity conservation, especially in the Sundarbans. However, studies suggest that coverage and density of larger diameter trees, canopy closure and diversity have declined over the last 100 years or so (Canonizado and Hossain 1998, Iftekhar and Islam 2004, Iftekhar and Saenger 2008). The ODA (Overseas Development Authority, UK) (1985) inventory documented overexploitation in the Bangladesh Sundarbans due to excessive harvesting (legal and illegal). It was reported that two economically important species of trees, *Heritiera fomes* and *Excoecaria agallocha*, had been depleted by 40% and 45%, respectively, since the 1959 inventory. The legal harvest of *Heritiera fomes* has been suspended since 1990 due to declining stock, but some illegal felling continues (Canonizado and Hossain 1998). A similar trend was observed in the Indian Sundarbans: a total of 322 km^2 of tidal mangroves were reported to be destroyed during 1960-1980 (Chaudhuri and Choudhury 1994).

The scattered mangroves in the private lands around the Sundarbans used to serve as buffer, but these lands have been almost entirely converted for prawn culture (Khan

Top: People cutting the fronds of nipa palm
Bottom: Traditional cargo boat loaded with the fronds of nipa palm – the fronds will be used as thatching material

2002). The effect of prawn culture is not only restricted to the buffer zones. The local people collect giant tiger prawn (*Penaeous monodon*) fry from the Sundarbans, when many non-target fish and crustacean fry are destroyed. There is no legal exploitation of the wildlife in the Sundarbans, but the spotted deer (*Axis axis*) is subjected to severe poaching. There is a good demand for its meat and hide. The deer is quite common and visible, and hence easy 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 affect the mangrove communities, which could change vegetation pattern as well as status and distribution of animals. 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 non-mangrove plant species like *Albizia procera*, *Mangifera indica*, *Artocarpus heterophyllus*, *Ficus* sp. and *Phoenix sylvestris* are rarely seen in the eastern Sundarbans. The phenology and viability of mangrove seeds and propagules largely depend on salinity. The wildlife in the mangroves show similar pattern; the feeding, breeding and 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

Spotted deer hidden on the poacher's boat – thousands of deer are poached every year for meat and skin

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 (Hussain and Acharya 1994). While 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. Freshwater flow into the Sundarbans may also be affected by climate change induced alterations in rainfall and melting of snows in the Himalayas (Agarwala *et al.* 2003, MoEF 2008).

The sea level rise due to global warming is a serious threat to the Sundarbans, with current predictions suggesting substantial land loss from increased inundation over the next 50 years (Agarwala *et al.* 2003). The predicted sea level rise of more than one metre by 2100 (Hansen 2007, Rahmstorf 2007, Pfeffer *et al.* 2008) might be disastrous for the Sundarbans. In the Indian Sundarbans at least four islands (Bedford, Lohachara, Kabasgadi and Suparibhanga) have already disappeared due to sea level rise and scientists predict that 25% of the habitable area will be lost by 2020 (Sahgal *et al.* 2007). However, huge sediment supply from the upstream, adaptation of mangroves and the natural process of deltaic development might reduce the effect of sea level rise (Stanley and Hait 2000, Allison *et al.* 2003); the coastal areas of Bangladesh are currently growing by about 20 km^2 per year (Inman 2009), and mangroves in other areas are known to have flourished despite sea level rise of at least 3.8 mm per year (Hendry and Digerfeldt 1989). 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 levels are needed for the existence of mangroves and there was no large mangrove swamps in the Holocene period or before because the sea level was unstable (Hussain and Acharya 1994).

Top: Shrimp fry harvest in Passur river – many fries of non-target species are killed for catching the shrimp fry
Bottom: Large areas have been occupied for commercial fish-drying

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 as creeks are in effect the blood vessels of the Sundarbans. Furthermore, 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). Poisoning the river water for easy fishing is often reported in the Sundarbans. is indiscriminately thrown into the river in the upstream of the Bangladesh Sundarbans. Oil spills in the Sundarbans from Mongla port (at the immediate upstream of the BangladeshSundarbans), as well as from ships and

motorboats, are occasionally reported. 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 Kolkata in the upstream are a considerable threat.

Natural disasters like cyclones also cause a lot of damage to the Sundarbans, which are beyond human control, with about one-tenth of global tropical cyclones occuring in the Bay of Bengal (Gray 1968, Ali 1980), with approximately one strong cyclone per year (Islam and Peterson 2008). It is feared that the frequency and intensity of cyclones will increase in the face of climate change. Many large trees are blown down and others face excessive loss of branches and leaves while many wild animals, including tiger and spotted deer, die during the storm, and after the storm many starve to death, or wander into villages and get killed by people.

Lack of trained manpower and necessary logistics is a major challenge for the management of the Sundarbans. The Forest Department's Wildlife and Nature Conservation Circle, formed in 2001, is yet to take charges of the three Wildlife Sanctuaries from the territorial authority. Staffs are regularly transferred between wildlife and territorial posts and also between forests, which do not help in developing trained and experienced manpower for conservation.

Top: Accidental fire in the Sundarbans causes the destruction and deaths of plants and animals

Bottom: Sundarbans is vulnerable to cyclones coming from the Bay of Bengal

Opposite: Excessive number of tourists in some popular sites like Katka is a formidable threat to the Sundarbans

2.6 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, occurrence of many economically less important species of plants, fear of man-eating tigers and growing concern for biodiversity conservation. In addition the Forest Department is involved in the Sundarbans with a network of guard posts, managing the forest and patroling regularly, so a relatively healthy biodiversity still exists in the Sundarbans.

The entire Sundarbans get legal protection under the Forest Act 1927. The forest was declared a Reserved Forest as early as 1875-1876 (Hussain and Acharya 1994). Entry without permit 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 established three Wildlife Sanctuaries (Sundarbans East, Sundarbans South and Sundarbans West) under the Bangladesh Wildlife Act 1974, covering an area

Ecotourism in the Sundarbans increases revenue earning: board walk in Karamjal *(top)* and tourist cottage in Ghagramari *(bottom)*

Opposite: Mangrove seedling production for plantation in degraded areas of the Sundarbans

totalling 324 km^2, which was 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. Since the Sundarbans is also treated as a wetland of international importance, it also gets protection under the Ramsar Convention (which Bangladesh ratified in 1992). The Integrated Forest Management Plan for the Sundarbans Reserved Forest 1998 provides a comprehensive report on current forest stocks and defines sustainable extraction levels for the next 20 years. In 1999, the Bangladesh Sundarbans was declared an Ecologically Critical Area under the buffer area of the Bangladesh Environment Conservation Act 1995.

The Bangladesh Sundarbans has been divided into two forest divisions by the Forest Department, viz. Sundarbans East Forest Division and Sundarbans West Forest Division. Each of the two Divisions has been divided into two forest ranges, viz. Sarankhola Range and Chandpai Range, and Khulna Range and Satkhira Range, respectively. Within the forest there are about 60 guard posts (Barlow 2009).

The Government of Bangladesh, with other international/national partners, have implemented several programmes and projects in the Bangladesh Sundarbans and a few of those were designed specifically for tiger conservation. Some of them are: Sundarbans Wildlife Management Plan, Integrated Resource Development of the Sundarbans Reserved Forest, Development of Wildlife Conservation and Management, Project Tiger, Forest Resource Management Project (FRMP), Sundarbans Biodiversity Conservation Project (SBCP) and Sundarbans Tiger Project. Furthermore, some short- and medium-term studies in the Bangladesh Sundarbans have given valuable information, which contributed to the success of long-term conservation projects (e.g. Hendrichs 1975, Salter 1984, Blower 1985, Tamang 1993, Khan 2004a, Barlow 2009).

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

The entire Indian Sundarbans and the surrounding area is a Biosphere Reserve (declared by UNESCO in 2001) in order to protect the biodiversity in its natural state, with the total area of the Reserve encompasing 9,630 km^2 of which mangrove forests cover 4,264 km^2 (Chaudhuri and Choudhury 1994). This Reserve has four zones: core zone, manipulation zone, restoration zone and development zone with the wildlife protected under the Wildlife Protection Act 1972. There is one National Park and three Wildlife Sanctuaries within the 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), which was declared in order to maintain a viable population of tigers. The Sundarbans

Top: Watchtower for tourists in Dobeki, Sundarbans
Bottom: Warning signboard in Kochikhali, Sundarbans, mentions that 'Tiger roaming area. Be cautious. Do not wander alone.'

National Park was declared in 1989 and the total area is 1,330 km^2, and the area has been recognised as a UNESCO World Heritage Site (from 1987) for its unique wilderness. Three Wildlife Sanctuaries (Sajnakhali, Lothian Island and Holiday Island) were established in 1976 and the total area covered by these three Sanctuaries is 406 km^2. The areas mainly serve as the refuge for the tiger and its prey such as spotted deer, wild boar and rhesus macaque.

Under the Integrated Wasteland Project, the Government of West Bengal (India), with its partners, has conducted 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 captive breeding and re-introduction programmes. The estuarine crocodile scheme was initiated in the Indian Sundarbans in 1976, based in Lothian Island, it is one of the principal crocodile breeding centres in India. This centre is working to reduce the high mortality at the egg and newly hatched stage, and by 1990 this centre had released more than 197 crocodiles in the Indian Sundarbans (Chaudhuri and Choudhury 1994). The same centre and Saptamukhi hatchery are also engaged in artificial breeding and re-introduction of the olive ridley turtle.

The future of biodiversity of the Sundarbans depends on 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.

SUNDARBANS

Meaning of the name 'Sundarbans': Beautiful forests.
Forest type: Tropical mangrove.
Area: ca. 10,000 km^2, of which 60% in Bangladesh and 40% in India; largest single mangrove forest on earth.
Climate: Tropical monsoon; temperature 22-31°C, humidity 70-80%, and annual rainfall 1,66-2,600 mm.
Species diversity: 334 plants, 24 shrimp, 250 fish, 9 amphibians, 57 reptiles, 315 birds and 49 mammals.
Number of tourists: ca. 100,000 / year in the Bangladesh Sundarbans, with only 2% of those foreign tourists.
Best season to visit: Open year-round, but the best season is December-March.
Entry fee: Taka 50 / person / day for Bangladesh nationals and Taka 700 / person / day for foreign nationals.
Employment: ca. 350,000 people work every year in the Bangladesh Sundarbans as fishermen, woodcutters, honey gatherers, etc.
Threats: Reduction of freshwater flow, sea-level rise and poaching.
Status: Reserved Forest with southern parts under protected area network that together form a UNESCO World Heritage Site; a key Tiger Conservation Unit.

TIGER AND PREY DENSITIES

' Tigers, leopards, rhinoceros, wild buffaloes, wild hogs (wild boars), wild cats, barasingha (swamp deer), spotted deer, hog deer, barking deer and monkeys are the principal varieties of wild animals found in the Sundarbans.'

– W.W. Hunter (1875)

Photo: Tiger swimming across the creek in Kochikhali, Sundarbans

TIGER AND PREY DENSITIES

3.1 INTRODUCTION

The Sundarbans of Bangladesh and India is believed to hold one of the two largest tiger (*Panthera tigris*) populations globally (Seidensticker *et al.* 1999, WWF 1999; Khan 2002, 2004a). Because unfragmented mangrove habitat is naturally inaccessible, this region offers a protected environment with the potential for the long-term conservation of tigers. Despite its importance for tiger conservation, there have been few studies which have used robust and repeatable methods to estimate the densities of tigers and prey in the region. Previous attempts to measure tiger population in this area were based on pugmark censuses (Panwar 1979) or interviews (Hendrichs 1975) which have been shown to be unreliable (Karanth *et al.* 2003; Khan 2004a, 2007a). Other studies in the region have been based on indirect evidences (Seidensticker and Hai 1978; Seidensticker 1986, 1987; Tamang 1993, Reza 2000; Khan 2004a, 2007b) or extrapolations from telemetry studies (Barlow *et al.* 2009). This chapter presents the first estimate of tiger density based on camera-trap surveys in the Bangladesh Sundarbans.

Since tigers depend on large mammalian prey(Sunquist 1981, Karanth and Sunquist 1995, Sunquist *et al*. 1999), the population densities of large mammals were assessed in order to understand the carrying capacity and long-term conservation status of tigers (Sunquist 1981, Karanth and Sunquist 1995, Sunquist *et al*. 1999). Three species of large mammals; i.e. spotted deer (*Axis axis*), wild boar (*Sus scrofa*) and rhesus macaque (*Macaca mulatta*); together comprise 95% of the biomass consumed by tigers in the Sundarbans (Khan 2008a). This study uses estimates of densities of these species to make inferences about tiger density in the wider region.

Opposite: Grazing herd of spotted deer in Kochikhali, Sundarbans – spotted deer is the commonest prey of tigers in the Sundarbans

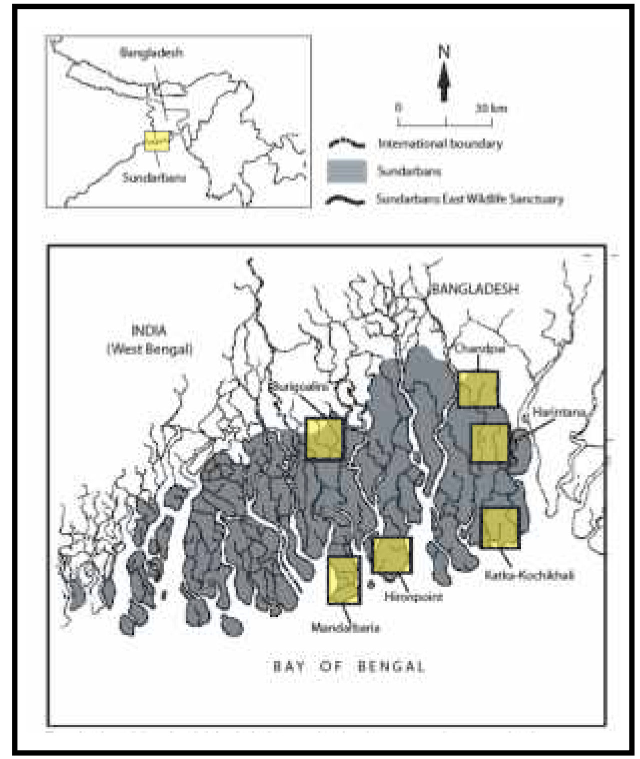


Figure 3.1 The Sundarbans of Bangladesh and India showing six sites where the survey on tiger and prey densities was conducted

An essential part of managing populations of wide ranging and rare species such as tigers is gaining an understanding of their wider distributions and population densities. Camera-traps are becoming established as one of the major tools in wildlife monitoring (Rowcliffe *et al.* 2008) and have been extremely effective at monitoring individually marked species like tigers (Karanth and Nichols 1998, Karanth *et al.* 2006). However, most camera-trap studies focus on relatively small areas (e.g. typically under 300 km^2) (Carbone *et al.* 2001, Karanth *et al.* 2004). Ideally we need information on wider spatial scales for wide ranging and rare species. Under such circumstances, it is useful to develop methods to extend camera-trapping results to wider spatial scales through the use of calibrated indices such as track counts (Stander *et al.* 1997, Stander 1998, Karanth *et al.* 2003, Stephens *et al.* 2006). This chapter presents the results of intensive monitoring methods, using mark-recapture analysis from camera-trap data (Otis *et al.* 1978, White *et al.* 1982, Rexstad and Burnham 1991) and distance sampling estimates of the main prey species (Eberhardt 1978, Burnham *et al.* 1980, Buckland *et al.* 1993), from the core study site. Then using an index-based survey of tiger tracks and sightings of their main prey species, the results were extended to the wider region.

3.2 MATERIAL AND METHODS

3.2.1 Individual Density and Biomass Density

The study took place across six sites in the Bangladesh Sundarbans, of which three were in Wildlife Sanctuaries (Sundarbans East, Sundarbans South and Sundarbans West) that form a UNESCO World Heritage Site with a total area of 1,397 km^2. The camera-trap survey was conducted in the Sundarbans East Wildlife Sanctuary (WS) (total area of 312 km^2, between 21°49´-21°56´ N latitude and 89°44´-89°52´ E longitude), covering only the southern part of this Sanctuary. In five additional sites, and in the core study area, lower intensity monitoring methods based on relative abundance of tiger tracks and prey sightings along the riverbanks were used to assess relative abundance. All of the additional sites were of roughly equal size, approximately 170 km^2 (Table 3.1 and Figure 3.1).

The field study was conducted from October 2005 to January 2007 (camera-trap survey was conducted from 06 September to 04 December 2006), but some of the data on prey were collected from September 2001 to February 2003. Individual tigers were identified using their stripe patterns (Schaller 1967, McDougal 1977, Karanth and Nichols 1998). An analysis of the capture history was used to estimate capture-recapture analysis (Otis *et al.* 1978, White *et al.* 1982, Rexstad and Burnham 1991). This technique as well as others based on the use of camera-trap data has been shown to be effective at extremely low population(Simcharoen *et al.* 2007, Lynam *et al.* 2008).

Top: Surveying tiger tracks along the bank of a creek in order to know the relative density of the tiger

Right: Fresh tiger track in the bank of a creek

Opposite: Setting remote camera-traps for tigers in two sides of a trail – one person crawling, pretending to be a tiger, so that the cameras could target the trail properly

Table 3.1 Six sites in the Sundarbans where the surveys of tiger and prey densities were conducted

Name of the site	Legal status	Geographic location
Katka-Kochikhali	Wildlife Sanctuary	21°49'-21°57' N, 89°43'-89°51' E
Hironpoint	Wildlife Sanctuary	21°45'-21°52' N, 89°21'-89°29' E
Mandarbaria	Wildlife Sanctuary	21°38'-21°47' N, 89°12'-89°18' E
Harintana	Reserved Forest	22°04'-22°11' N, 89°42'-89°49' E
Chandpai	Reserved Forest	22°18'-22°25' N, 89°38'-89°47' E
Burigoalini	Reserved Forest	22°07'-22°15' N, 89°07'-89°15' E

Table 3.2 Individual density and biomass density of tigers and potential prey in the Sundarbans East Wildlife Sanctuary

Species	Average mass (kg)*	Population density (no./100 km^2) **	Biomass density (kg/100 km^2)
Tiger	113	4.8	542
Spotted deer	47	2090	98,230
Wild boar	32	50	1,600
Rhesus macaque	4	650	2,600

* Source: Karanth (1987) for tiger and Karanth and Sunquist (1992) for prey.
** See Table 3.3

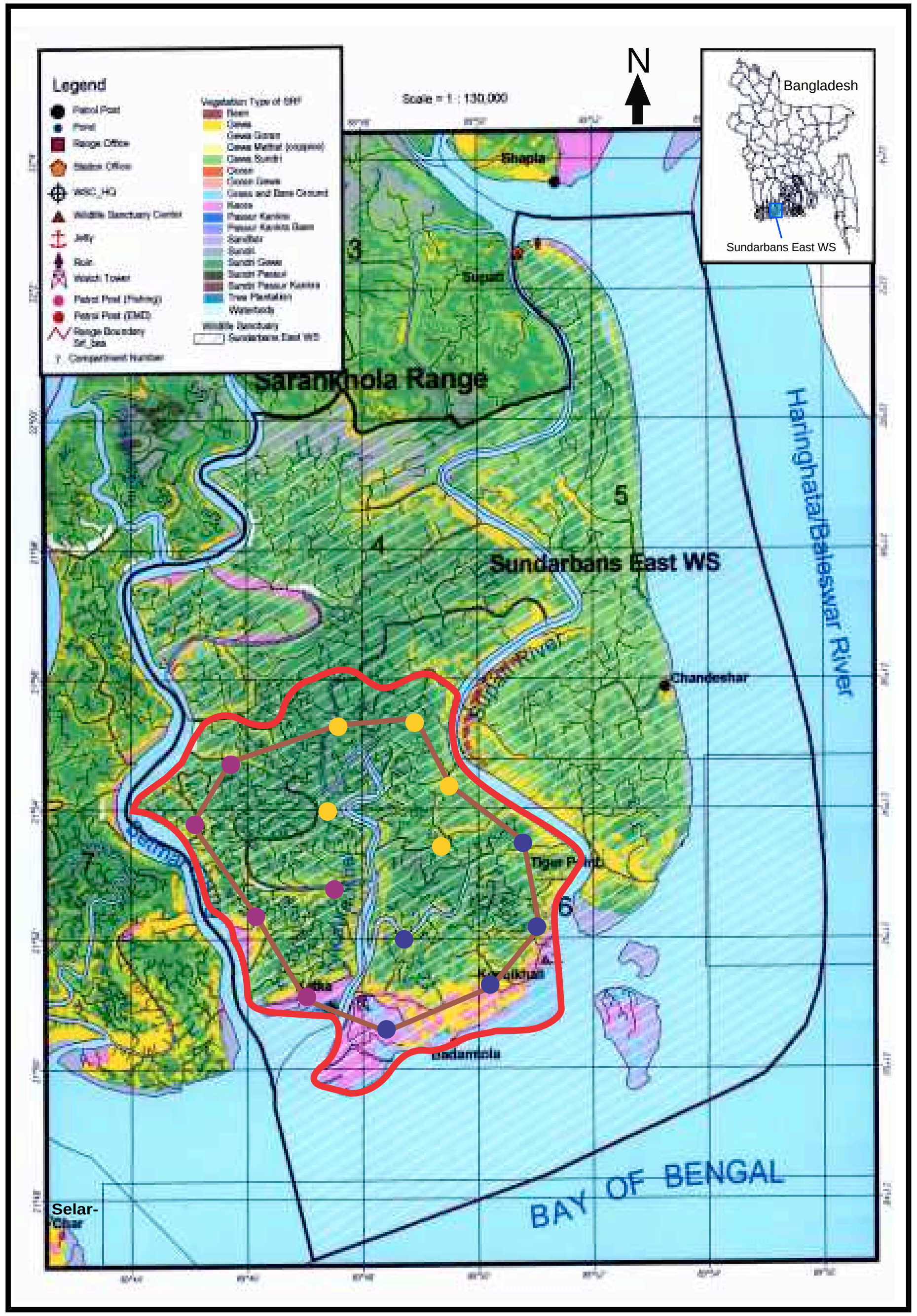


Figure 3.2 Sundarbans East Wildlife Sanctuary showing 15 trap-points (three colour dots indicating three shifts of camera-traps), trap-point polygon (brown line) and effectively sampled area (red line).

Based on the presence of earlier tiger signs (tracks, scats, kills, scrapes, scent deposits, etc.) and the intersections of trails, the location of camera-trap-points were selected to maximize the chances of obtaining tiger photos. The trap-points were set around two km apart, typical of other tiger surveys so that it was unlikely that any area in the camera-trapping plot had a zero probability of capturing a tiger (Karanth and Nichols 1998). All trap-points were marked on a map using a GPS unit (eTrex Vista C; accuracy: ± 15 m). The survey area was bounded on three sides by large rivers. On the northern side, however, I assumed the survey area included a boundary strip of two km, based on the movements of two recaptured tigers which had crossed traps of about four km distance (see Karanth and Nichols 1998). The total survey area bounded by the rivers and accounting for the boundary strip in the north was approximately 105 km^2 (Figure 3.2).

A total of ten commercially made Wildlife Pro (Forestry Suppliers, Inc.) camera-trap units were used. These have protective water-proof housing (with camouflaging colouration). Inside the housing there is a Canon Super Shot fully-automatic 35 mm camera and a motion sensor for triggering the camera. The camera-traps were mounted on wooden posts or in tree trunks about 350 cm away from the trail, set at a height of 45 cm (Karanth and Nichols 1998).

Some of the creatures 'captured' in remote camera-trap photos in the Sundarbans (*row-wise from left*): tiger (male), spotted deer (solitary stag), spotted deer (herd), wild boar (family), rhesus macaque, lesser adjutant, red junglefowl (male), Bengal monitor, and humans

A dominant male rhesus macaque displaying its bright red back, which is an expression of his high rank

During the sampling period (06 September to 04 December 2006) the camera-traps were systematically shifted in three camera-trapping sub-plots (Kochikhali, Katka and Chita Katka) in order to cover all the potential trap-points by limited number of camera-trap units (Figure 3.2). The 90-day (24-hour) survey period was subdivided into two 45 day phases, occasion 1 (when the photographed individual tigers were identified or 'marked') and occasion 2 (when both 'marked' and 'unmarked' individual tigers were photographed). For each occasion the camera-traps were deployed in three consecutive sub-plots, for 15 days each. Cameras were placed in pairs at each trap site in order to get photos of both sides of a tiger. Therefore, each sub-plot contained five trap-points with a total of 15.

Typically for tiger surveys, a maximum of two months is recommended (Karanth *et al.* 2002), but more time was required in this study because of the limited number of camera-traps and the difficulty of obtaining photographs of tigers. Trapping rates may have been reduced by the absence of obvious trails in the Sundarbans which lowers the chances of predicting their routes of travel. Since the tiger is a relatively long-living and slow-breeding animal (Nowell and Jackson 1996), I assumed that there was no significant change in the dynamics of tiger population during the 90-day sampling period. The camera-traps were checked once every day in order to record the date and location of each photographic 'capture'.

The capture history data were analysed by using CAPTURE2 software programme (www.mbr-pwrc.usgs.gov). This software was developed to implement closed-population capture-recapture models. Since it was only possible to cover a relatively small part of the Sundarbans with the camera-trap survey, tiger track surveys were used to approximate tiger density over a wider area.

The banks along the shores are cleared by tidal cycles twice per day providing ideal conditions for tiger track counts. All tracks sighted are guaranteed to be relatively fresh (maximum five days) because old tracks are washed away by the tides. Tigers in this region frequently cross the rivers, especially those that are not very wide. Thus track counts represent an estimate of recent tiger activity in the area. Counts along riverbanks

SEWS-T1

SEWS-T1

SEWS-T2

SEWS-T2

were used to estimate the relative density of tigers in the core study area and in each of the additional study plots. Since the tiger tracks are visually identifiable (Palomares *et al.* 1996, van Sickle and Linzey 1991), especially in the muddy riverbanks, all the fresh tracks (maximum five days old; oldness assessed on the basis of reference observations of the change of conditions of pugmarks and human footprints with time) were counted from the riverbanks. Very wide rivers and very narrow creeks present a problem with observation and navigation and so were not surveyed. The survey took place from a dinghy, which was driven slowly at a relatively constant speed. My field assistants and I searched for fresh tracks on both banks of the river. However,

SEWS-T3

SEWS-T4

SEWS-T5

Camera-trap photos showing the stripe patterns that was used to identify five different tigers, marked as SEWS-T1 to T5, (two 'recaptures') 'captured' in remote camera-trap photos in 105 km^2 sample area in the southeastern end of the Sundarbans of Bangladesh.

the same track, i.e. the same crossing, on two sides of the river was treated as one observation. Binoculars were used whenever necessary for searching tracks and for general observations. Since the rivers were not straight, the speed of the boat (by using a GPS unit) and the total time of observation were recorded in order to convert the travelling distance into equivalent straight distance.

Sighting rates of track were compared against the density estimate of tigers obtained from camera-traps in Sundarbans East WS to provide a rough calibration between track sighting rates and tiger density. This was then used to adjust my estimate of tiger density in the wider region.

The population density of large mammalian prey in the Sundarbans East WS was estimated using distance sampling (Eberhardt 1978, Burnham *et al.* 1980, Buckland *et al.* 1993). The transect line length was measured by using a GPS unit. Since the Sundarbans is generally flat, the aerial distance was a close representation of the actual distance covered in line transects. A total of 352 transects of variable lengths was placed that covered a total of 466.8 km length. The sampling effort was uniform for different seasons of the year. My field assistants and I walked along transects at a roughly uniform speed of 1.3 km/hr and concentrated on detecting the large mammalian prey at their initial locations. For each observation the sighting distance of the animal (when solitary), or of the centre of the group (when in group), was recorded by using a rangefinder (Bushnell Yardage Pro 800; accuracy: ± 1.8 m). The sighting angles were recorded by using a compass. The work was mainly conducted in the mornings (0600-1000 hr) and afternoons (1500-1900 hr) when the prey animals were most active and visible. Animal groups were used as the analytical unit since individual data tend to underestimate the true variance (Southwell and Weaver 1993). DISTANCE 4.0 software (www.ruwpa.st-and.ac.uk/distance) was used to analyse the data derived from line transects to determine the individual density.

The relative densities of large mammalian prey in six sites were estimated by counting them along the two banks of rivers in combination with the counts of tiger tracks. Since the vegetation conditions along the riverbanks were similar, it was assumed that the visibility of prey was uniform. As with the tiger estimates, relative sighting rates at Katka-Kochikhali were used to calibrate a density estimate for the wider area across the remaining five study sites. Sighting rates of large mammalian prey from the river surveys were also made across all six sites and these indices of prey abundance were compared against the tiger track sighting rates.

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 in a certain time, a useful index for ultimately determining the optimum carrying capacity of the range (Schaller 1967, 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

Spotted deer engaged in fighting to establish the dominance - this is how the nature selects the fittest individuals

mean population density (D) of each species by its average unit weight, which was estimated from published data on body weights. Overestimation 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).

3.2.2 Prey Grouping Tendencies and Age-sex Classes

During the line transect sampling the animal groups were used as the analytical unit (Southwell and Weaver 1993). 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 (*Axis 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 1982, Grimmett *et al.* 1998, Daniel 2002).

3.3 RESULTS

3.3.1 Individual Density and Biomass Density

A total of seven photographs of tigers were obtained from Katka-Kochikhali site during the survey period (three in occasion 1 and four in occasion 2, with two 'recaptures' in occasion 2), of which there were five different tigers (photos in page 69). Other than the tiger, the photographs of several species of wildlife and humans were also obtained (photos in page 67). Using the 'capture' history data in CAPTURE2 software programme it was estimated that the absolute number of tigers (adult and subadult) in the 105 km^2 area in the southeastern end of the Bangladesh Sundarbans is 5 (SE = 0.96, capture probability or p-hat = 0.70). This means that the tiger density in the area covered by camera-trap survey is 4.8 tigers/100 km^2. Due to the complexity and lack of correctness of estimating the variance of estimated area sampled by camera-trapping, the standard error for this density estimate was not calculated. However, due to the fact that the sampled area (105 km^2) was very close to 100 km^2, it is assumed that the standard error for the density estimate is very close to 0.96. This is the first estimate of the tiger population density in the Bangladesh Sundarbans that is based on camera-trap survey (Table 3.2).

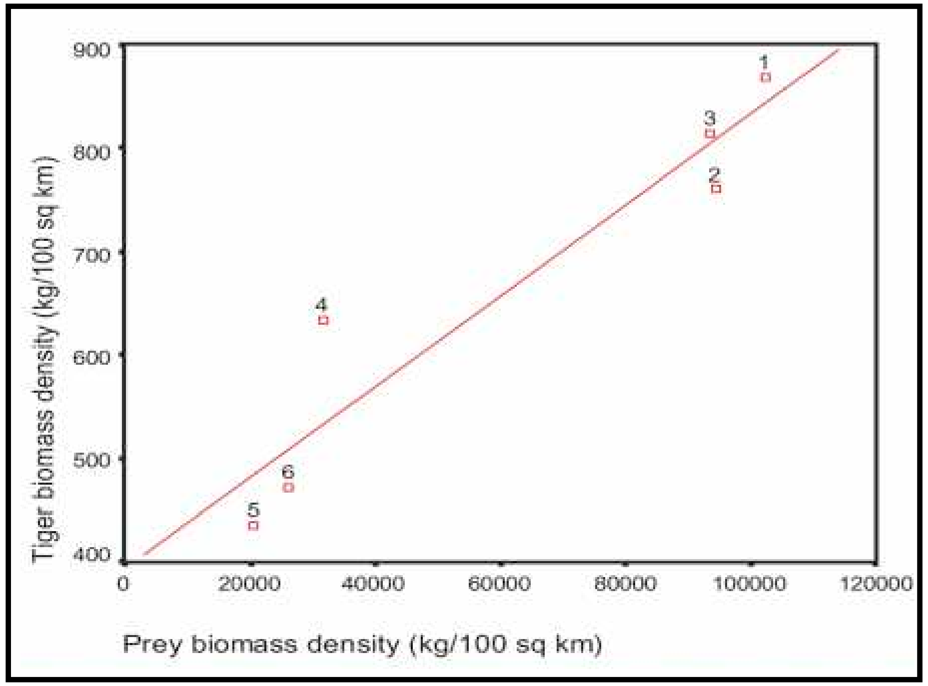


Figure 3.3 Comparison of tiger and large mammalian prey (spotted deer, wild boar and rhesus macaque) biomass densities (kg/100 km^2) across six plots (1. Katka-Kochikhali, 2. Hironpoint, 3. Mandarbaria, 4. Harintana, 5. Chandpai, and 6. Burigoalini) in the Sundarbans of Bangladesh.

Table 3.3 Tiger and prey population densities and indices of abundance in the Bangladesh Sundarbans

Area surveyed	Location in the Bangladesh Sundarbans	Legal status	Water salinity (ppt)		Relative density of prey [no. of individuals/km riverbanks (± SE)]			Absolute density of prey (no. of individuals/km^2)*			Relative density of tiger [no. of tracks/km riverbanks (± SE)]	Absolute density of tiger (no. of individuals/100 km^2)*
			Dry season	Wet season	Spotted deer	Wild boar	Rhesus macaque	Spotted deer	Wild boar	Rhesus macaque		
Katka-Kochikhali	Southeast	Wildlife Sanctuary	5-10	0-5	3.97 (± 0.80)	0.17 (± 0.07)	2.42 (± 0.77)	20.9	0.5	6.5	0.58 (± 0.12)	4.8
Hironpoint	South	Wildlife Sanctuary	20-25	15-20	3.66 (± 0.83)	0.15 (± 0.06)	2.36 (± 0.81)	19.3	0.4	6.3	0.51 (± 0.14)	4.2
Mandarbaria	Southwest	Wildlife Sanctuary	25-30	20-25	3.62 (± 0.87)	0.15 (± 0.07)	2.40 (± 0.69)	19.1	0.4	6.4	0.54 (± 0.15)	4.5
Harintana	East-Central	Reserve Forest	5-10	0-5	1.18 (± 0.61)	0.13 (± 0.07)	1.18 (± 0.59)	6.2	0.4	3.2	0.42 (± 0.17)	3.5
Chandpai	Northeast	Reserve Forest	0-5	0-5	0.76 (± 0.39)	0.11 (± 0.05)	0.83 (± 0.45)	4.0	0.3	2.2	0.29 (± 0.19)	2.4
Burigoalini	Northwest	Reserve Forest	20-25	5-10	0.96 (± 0.42)	0.12 (± 0.06)	0.85 (± 0.47)	5.1	0.4	2.3	0.32 (± 0.16)	2.6
Average for Bangladesh Sundarbans					***2.36***	***0.14***	***1.67***	***12.4***	***0.4***	***4.5***	***0.44***	***3.7***

*Based on the correlation between absolute and relative densities of tiger and prey in Katka-Kochikhali the absolute densities in other five sites were estimated.

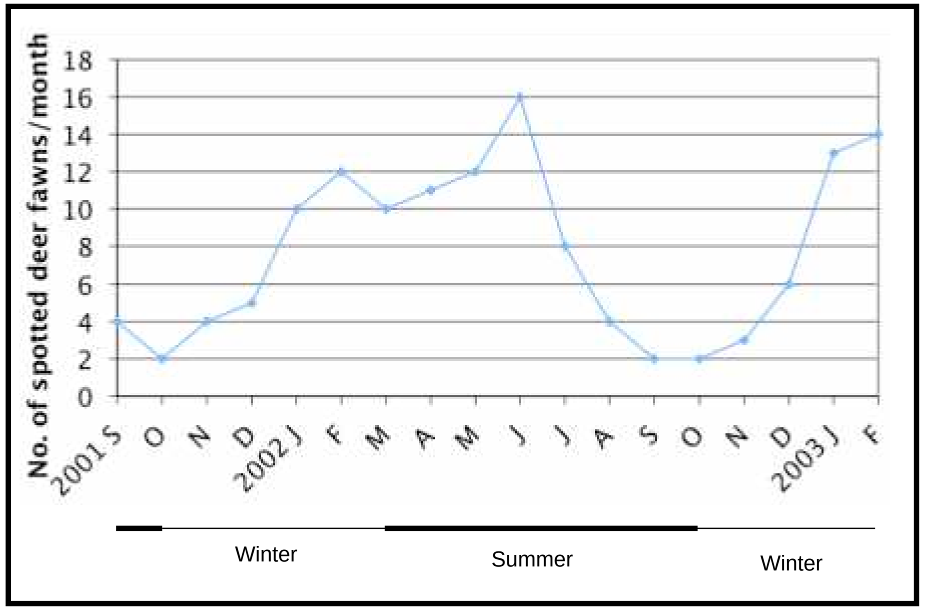


Figure 3.4 Number of sightings of spotted deer fawns (young) in different months in the Sundarbans East Wildlife Sanctuary.

Based on tiger track counts the relative density of tigers in six different sites was estimated (Table 3.3). The average of these six sites represents the average for the entire Bangladesh Sundarbans, which is 0.44 tracks/km of riverbank surveyed. The three sites in three sanctuaries clearly had higher densities of tiger tracks than the three sites outside the sanctuaries. The track densities, i.e. relative densities of tigers, were then converted to an estimate of absolute density (Table 3.3). The average of six sites provides an estimate of 3.7 tigers/100 km^2 as an average for the entire area. Since the Bangladesh Sundarbans is an area of 5,770 km^2, it is inferred that, to a rounded figure, the total tiger population size would be approximately 200. Assuming that the tiger density in the Indian Sundarbans (4,263 km^2) is similar to that in the Bangladesh Sundarbans, we might expect around 150 tigers in the Indian part, forming a single population of around 350 tigers in the entire region.

In Katka-Kochikhali the overall density of large mammalian prey (spotted deer, wild boar and rhesus macaque) was estimated at 27.9 large prey/km^2. The average number of large mammalian prey along riverbanks in six sites, i.e. the relative density of prey in the Bangladesh Sundarbans is 4.2 large prey/km riverbanks. The relative density was converted to a rough estimate of absolute density, which is 17.3 large prey/km^2 or 1,730 large prey/100 km^2. Based on this estimate the total population of three species of large mammalian prey (spotted deer, wild boar and rhesus macaque) in the Bangladesh Sundarbans is inferred at, to a rounded figure, 99,800.

The absolute densities of tigers and three large mammalian prey in the Bangladesh Sundarbans were converted to biomass densities and were found that it is 542 kg/100 km^2 for tigers and 102,430 kg/100 km^2 for three large mammalian prey combined (Table 3.2). Therefore, the biomass ratio between tigers and prey is 1:189. The biomass densities of tigers and prey show strong relationship (R^2 = 0.896) across the six sites (Figure 3.3).

3.3.2 Prey Grouping Tendencies and Age-sex Classes

The spotted deer is principally a group-living animal (Table 3.4), for which 73% of the observations were of groups of varying size. During this study, buck or doe-fawn herds were rarely sighted. The largest buck herd was of 13 individuals and the largest doe-fawn herd was of 26 individuals. The rhesus macaque is also basically a group-living animal: 54% of the observations were of groups of varying size (Table 3.4); although a large proportion (46%) of singles were sighted, most of them were stray males. The wild boar was mainly solitary (72% observations).

The proportion of pre-reproductive age classes (juveniles and young) were 28% in spotted deer, 21% in wild boar and 29% in rhesus macaque (Table 3.5). The male-female ratio was 47:100 in spotted deer, 72:100 in wild boar and 87:100 in rhesus macaque (Table 3.5).

Statistical analysis shows that the number of spotted deer fawns sighted during the study period (n = 138) were significantly different across months (χ^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 3.4), i.e., late winter and early summer.

Table 3.4 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

Table 3.5 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

3.4 DISCUSSION

3.4.1 Individual Density and Biomass Density

It is difficult to estimate the population density of a secretive animal like the tiger, which is thinly distributed throughout a large tract. It is even more difficult in the impenetrable swamp of the Sundarbans where tigers are rarely seen by people. Therefore, most of the previous 'estimates' used pugmark census (Panwar 1979) and ended up overestimating the tiger population in the Bangladesh Sundarbans (official estimates range from 350 to 450 tigers; Khan 2004a). The scenario is the same in the Indian Sundarbans where, according to the official estimate conducted in 2004, there are 274 tigers (Chowdhury and Vyas 2005), which is, in the view of present findings, too optimistic. The wide availability of the pugmarks in the Sundarbans (since the ground is soft) gives some the idea that the tiger density is very high, which is not the case (Khan 2004a).

Based on the prey density, and following Karanth and Stith (1999), and Karanth *et al.* (2004), there is a previous estimate of tiger density in the Sundarbans East Wildlife Sanctuary (Katka-Kochikhali area is the major part of this Sanctuary) (Khan 2004a) and the estimated figure (4.3 tigers / 100 km^2) is similar to that estimated in the same area during this study (4.8 tigers / 100 km^2). Notably, it is well-established fact that carnivores and their prey numbers show strong positive correlation in any undisturbed area (Schaller 1967, Sunquist 1981, Seidensticker and McDougal 1993, Carbone and Gittleman 2002, Karanth *et al.* 2004).

Wild boar - a favourite prey of the tiger in the Sundarbans

Barking deer (juvenile) - a rare prey of the tiger in the Sundarbans

Although there is no previous estimate of tiger density in the Bangladesh Sundarbans based on camera-trap survey, Karanth and Nichols (2000) reported the tiger density in the Indian Sundarbans, which was based on camera-trap survey. The density (0.84 tigers / 100 km^2), however, was less than what was found in this study.

The radio-collaring of two tigresses for a few months in the southeastern Sundarbans in Bangaldesh estimated relatively very small (14.6 and 12.8 km^2) home range sizes suggesting that the tiger density is very high, with a total population of 300-500 tigers (Barlow *et al.* 2009). However, the estimated prey density or other estimates of tiger density in the Sundarbans (Karanth and Nichols 2000, Khan 2004a, Wildlife Institute of India in litt. 2010, this study) do not support the fact that the tiger density is very high in the Sundarbans. In the Indian Sundarbans, one radio-collared tigress was reported to roam in an area of about 50 km^2 (Sharma 2009), which is very different from what was estimated for two tigresses in the Bangladesh Sundarbans (Barlow *et al.* 2009).

Despite some drawbacks, camera-trap survey represents an effective method for surveying tigers. Although radiotelemetry-derived data can be used in estimating tiger density (Smith *et al.* 1987, Quigley 1993), the small number of tagged animals, the presence of untagged animals in the population, and the excessive effort involved in capturing and radiotracking operations limit the usefulness of this method in tiger density estimation (Karanth 1995). Because of its low density and secretive nature, other methods of animal population estimation like distance or quadrat sampling (Buckland *et al.* 1993) are of limited value.

(Top): Spotted deer reaching for 'keora' leaves by standing on hindfeet – trees are often 'trimmed' up to the height that can be reached by the deer

(Bottom): Pneumatophores – the breathing organs of mangrove trees – thrusting upwards for air

The ratio of tiger and large mammalian prey biomass densities (1:189) estimated for the Sundarbans is different from those estimated (calculated from tiger and prey densities) for tiger ranges in the neighbouring countries, e.g. 1:342 in Kanha, India (Schaller 1967, Newton 1987), and 1: 391 in Chitwan, Nepal (Tamang 1982). This is an indication of insufficient prey for tigers in the Sundarbans, but tigers in the Sundarbans are known to hunt smaller prey as well (Khan 2008a).

The scientific estimate of tiger and large mammalian prey population densities in the Sundarbans that was done in this study will be the key factor in convincing different national and international organisations and communities the potential of the Sundarbans tiger and prey populations in the long-term. This will also bring an end of the wide controversy on the tiger population size, together with the population size of large mammalian prey in the Sundarbans. The estimates of absolute and relative densities will also be useful in temporal monitoring of the tiger and prey population trends in the Sundarbans, both inside and outside the sanctuaries.

The tiger is mainly dependent on the dominant prey species, because the dominant prey provides the bulk of available prey biomass (Karanth and Sunquist 1992, Karanth *et al.* 2004). The spotted deer is the dominant and most gregarious prey species in the Sundarbans. It is primarily a grazer (Mishra 1982) and one possible reason for its abundance is that it is virtually the only grazing ungulate there. Historically, there were Javan rhinoceros (*Rhinoceros sondaicus*), wild water buffalo (*Bubalis arnee*), and swamp deer (*Cervus duvaucelii*) in the Sundarbans. Because these species became extinct due to hunting over the last hundred years (Khan 2002), the entire grazing niche is open for the spotted deer without competition. The highest density of the spotted deer was in grassland-forest mosaic in the southern part

of the Sundarbans. This was probably because the spotted deer preferred grasses to the other plant species for their food (Dolon 2003). 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).

In respect of food availability, the wild boar population in the Sundarbans East WS should be higher than my estimate. One possible reason for relatively low density of the wild boar is that it is more vulnerable to hunting by the tiger because, as observed in the field, it is relatively more solitary and less careful than the spotted deer (Khan 2008a).

My estimates of the density of large prey species are more or less similar to some of the previous estimates (Hendrichs 1975, Khan 1986, Tamang 1993), but others' estimates are much higher than these (Islam 2001, Niamatullah 2001, Reza *et al.* 2002a). There are at least two reasons of possible overestimates by the latter authors: 1) biases in methods (all distances were measured arbitrarily) and 2) water bodies were not considered in density estimation.

Fresh pugmarks of a tiger on sandy ground

3.4.2 Prey Grouping Tendencies and Age-sex Classes

Prey animals that live solitarily or in small groups tend to be more vulnerable to predation (van Orsdol 1981). Hence, it is important to know the prey grouping tendencies, which are related to the tiger's hunting success.

My estimate of the average group size of the spotted deer in the Bangladesh Sundarbans is very close to Tamang's (1993) estimate, but lower than Islam's (2001) and Reza *et al.*'s (2002) estimates. The mean group size of wild boar and rhesus macaque are also lower in my estimate in comparison to Reza *et al.*'s (2002a) estimate who could not find any solitary spotted deer or rhesus macaques, but a significant proportion of solitary animals were reported in my study as well as in other previous studies in the Sundarbans (e.g., Hendrichs 1975, Tamang 1993).

Karanth and Sunquist (1992) reported the grouping tendencies of spotted deer, wild boar and rhesus macaque in the tropical forests of Nagarhole, India, where all these three species have larger group sizes than in the Sundarbans. Hendrichs (1975) mentioned that in the Sundarbans, spotted deer and rhesus macaque may live in groups; wild boar lives singly, but do congregate into groups at times.

In Panna (Chundawat 2001) and Bhadra (Jathanna *et al.* 2001) of India, the mean group sizes of spotted deer were found smaller than what I estimated in the Sundarbans, but in Nagarhole (Karanth and Sunquist 1992) and Ranthambhore (Kumar 2000) of India, the group sizes were larger than my estimate. 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).

Tigers have selectivity for prey age-sex classes (Schaller 1967, Johnsingh 1993, Karanth and Sunquist 1995, Miquelle *et al.* 1996). Hence, the feeding behaviour of tigers is related to the availability of prey in different age-sex classes. In my study the female spotted deer were found to be commoner than males. A similar ratio was reported by Hendrichs (1975) in the Sundarbans and by Chundawat (2001) in Panna, India, but others reported higher proportions of males in other areas like Kanha (Schaller 1967), Bandipur (Johnsingh 1983) and Nagarhole (Karanth and Sunquist 1992) of India.

In comparison to some relatively 'good' habitats in India such as Nagarhole (Karanth and Sunquist 1992), Kanha (Schaller 1967) and Bandipur (Johnsingh 1983), the ratio of individuals of the pre-reproductive class (juveniles and young) in spotted deer and wild boar were lower in the Sundarbans, which may indicate a lower optimum density for this habitat (Hendrichs 1975).

Schaller (1967) had seen spotted deer fawns during every month, but over two-thirds of them were born during the first half of the year; many being weaned or almost weaned at the onset of the rains in June. In Bandipur, India, Johnsingh (1983) reported that the peak of fawn sightings was during May-July after the summer rains and during the sprouting of grass. My findings roughly agree with these (Figure 3.4), because the summer rains start at the same time in both Bandipur and the Sundarbans.

CAMERA-TRAP

The camera-trap is an automated camera (fitted with a motion or infra-red sensor) used to photograph wild animals, particularly secretive, rare or nocturnal animals that are difficult to observe and study in the wild. The unit is often housed in a rain proof camouflaged box. The camera-trap unit is set beside an animal trail and is triggered by the animal itself when the sensor detects its presence. The camera also records the date and time of each photo taken. This method is non-invasive and does not normally disturb wild animals, although the animals sometimes damage the cameras. They are used to determine the status and distribution of wild animals of an area. The photos taken by camera-traps can be used to identify individual animals (based on marks on animal body) and estimate their density.

PREY SELECTION BY TIGERS

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

– Kailash Sankhala (1978)

Photo: Spotted deer stag running across the wet grassy meadow of Kochikhali, Sundarbans

Chapter 4 PREY SELECTION BY TIGERS

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). 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). Carnivores often regulate or limit the numbers of their prey, thereby altering the structure and function of entire ecosystems (Schaller 1972, Smuts 1978, Berger *et al.* 2001, Terborgh *et al.* 2002, Khan 2008b). The role tigers (*Panthera tigris*) play as top predators is vital to regulating and perpetuating ecological processes and systems (Sunquist *et al.* 1999, Terborgh 1999). The analysis of food habits provides practical and useful information for the management of a particular species and occasionally aids law enforcement and management needs (Korschgen 1971). The prey selection by tigers in the Sundarbans was studied in order to identify whether tigers have any preference for prey in terms of species, availability, age and health.

4.2 METHODS

4.2.1 Scat Analysis

The scat samples were collected from the Sundarbans East Wildlife Sanctuary (WS), on a monthly basis, during a period of 18 months (September 2001 to February 2003). 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, preserved in a tagged polythene bag, and brought to the laboratory for analyses. At first each of the dried scats were classified according to the relative volume, weighed by using a Lark JPT-2 (range: 0.1-200 g) beam balance (large scats were weighed in several parts), and were classified according to the weight. 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 1979, Amerasinghe 1983, Kitsos *et al.* 1995, 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 rare and found only in a few scats) the frequency was divided into 0.5 for each prey species.

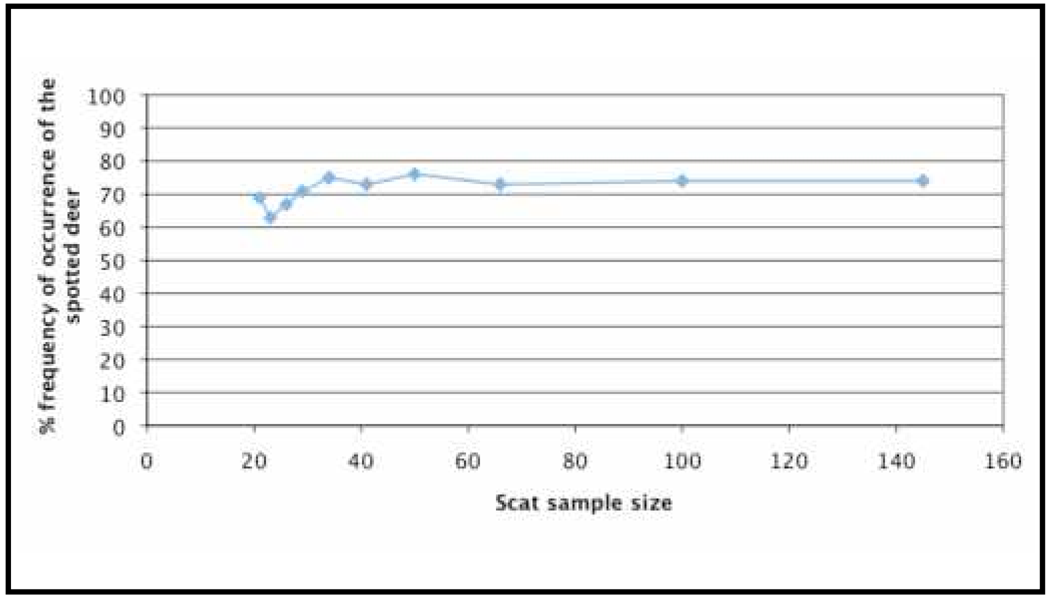


Figure 4.1 Relationship between the sample size of tiger scats and the percentage of the frequency of occurrence of the spotted deer in scats in the Sundarbans East Wildlife Sanctuary

Opposite: Striped coat of the tiger is suitable to camouflage, which enables it to stalk they prey successfully

Tiger's tongue is equipped with horny projections, enabling it to isolate the meat from bones by its tongue

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 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) that does not cause any further change in a prey with increase in sample size. 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 numbers and biomass 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, Emmons 1987, Karanth and Sunquist 1995), the method developed by Ackerman *et al.* (1984) for the puma (*Puma concolor*), to convert the frequencies of occurrence into relative numbers and biomass of individuals killed, was 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.

Spotted deer often feed at night in order to avoid humans – their large eyes have special capacity to see in low light; their eyes reflects light at night

4.2.2 Prey Selectivity Index

The selectivity index (S) (Sourd 1983, Julliot 1996) 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 –

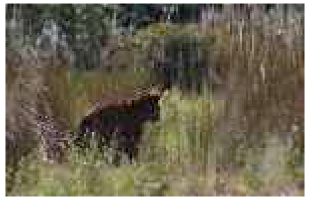
$$S = (PC_{sp} - PA_{sp}) / (PC_{sp} + PA_{sp})$$

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 (spotted deer *Axis axis* = 43.4, wild boar *Sus scrofa* = 8.5, rhesus Macaque *Macaca mulatta* = 22.2, lesser adjutant *Leptoptilos javanicus* = 8.5, red junglefowl *Gallus gallus* = 17.4, water monitor *Varanus salvator* = 0; see Results of this Chapter),

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 (spotted deer = 48.2, wild boar = 1.1, rhesus macaque = 15.0, lesser adjutant = 1.4, red junglefowl = 16.1, water monitor = 18.2; from Khan 2004a).

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).



Tiger scats can be used to know the food habits: tiger defecating in the grassy meadow *(top left)*, tiger scat in the sungrass - tigers often scratch on the ground and in the vegetation where they defecate, which is an instinct to cover the scat *(middle left)*; scat examination and isolation of indigestible remains of the prey *(top right)*; and remains of spotted deer, wild boar, rhesus macaque, Indian crested porcupine, leopard cat and lesser adjutant, and sungrass blades as non-food item *(bottom)*

Right: Half-eaten spotted deer hidden in dense undergrowth of the forest – tigers often eat part of the prey and leave the rest for later consumption

Overleaf: Tiger on the move in search of prey; once the prey is located it will crouch and will get close to the target animal for final attack

4.2.3 Kill Study

Crows and vultures are good advertisers of tiger kills in most of the tiger ranges in the Indian subcontinent (Schaller 1972, Johnsingh 1983, Karanth and Sunquist 1995), but the dense vegetation and the rarity of crows and vultures in the Sundarbans forced me to depend mainly on odour and dragging signs of kills. 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, colour and overall condition of the animal. 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, yearling/juvenile and fawn/young on the basis of eruption and wear of premolar and molar teeth (Schaller 1967, Riney 1982, van Lavieren 1983). I also tried to determine the age of kills by counting tooth cement rings (Ashby and Santiapillai 1986, Ballard *et al.* 1995, Landon *et al.* 1998), but no distinct annuli were found.

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/juvenile = 0.176 and fawn/young = 0.059; ages identified on the basis of the eruption of the teeth; see Results of this Chapter), and fL is the fraction of a given age class in the habitat (adult = 0.722, yearling = 0.205 and fawn = 0.073; from Khan 2004a). 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 Prey Selection

In terms of relative volume, there were no significant difference in the frequencies of small, medium and large scats ($\chi^2 = 0.68$, df $= 2$, $p = 0.713$), but medium-sized scats were the commonest (36%). Classes based on dry weight shows that there were significant differences in the frequencies of scats in three different weight classes ($\chi^2 = 25.00$, 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).

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.

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, rhesus macaque, Indian crested porcupine (*Hystrix indica*.), leopard cat (*Felis bengalensis*), Ganges river dolphin (*Platanista gangetica*; died in the fishing net, floated to the bank, and finally eaten by the tiger), lesser adjutant (*Leptoptilos javanicus*), red junglefowl (*Gallus gallus*), mud crab (*Scylla serrata*) and water monitor (*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 was converted to the relative numbers of prey animals killed, and was found that spotted deer was still the most frequently consumed (29.9%) (Table 4.3). 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 (80%) and wild boar is the second most consumed (11%) (Figure 4.2). These are the two species on which tigers in the Sundarbans are thriving.

4.3.2 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.) blades, 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 bi-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). Notably, the monthly total collection of scats was almost equally proportional in different seasons. The presence of a large amount of soil proves that it was not accidentally ingested.

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

Relative volume			Weight		
Class	No.	%	Class	No.	%
Small	46	32	<100 g	74	51
Medium	53	36	100+ to 200 g	46	32
Large	46	32	200+ g	25	17

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
Water monitor	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).

Male wild boar in aggressive mode – a big male wild boar is a strong animal and can even challenge a tiger

Spotted deer fawn sitting silently in order to avoid the enemy – this is the typical anti-predator behaviour of the fawn

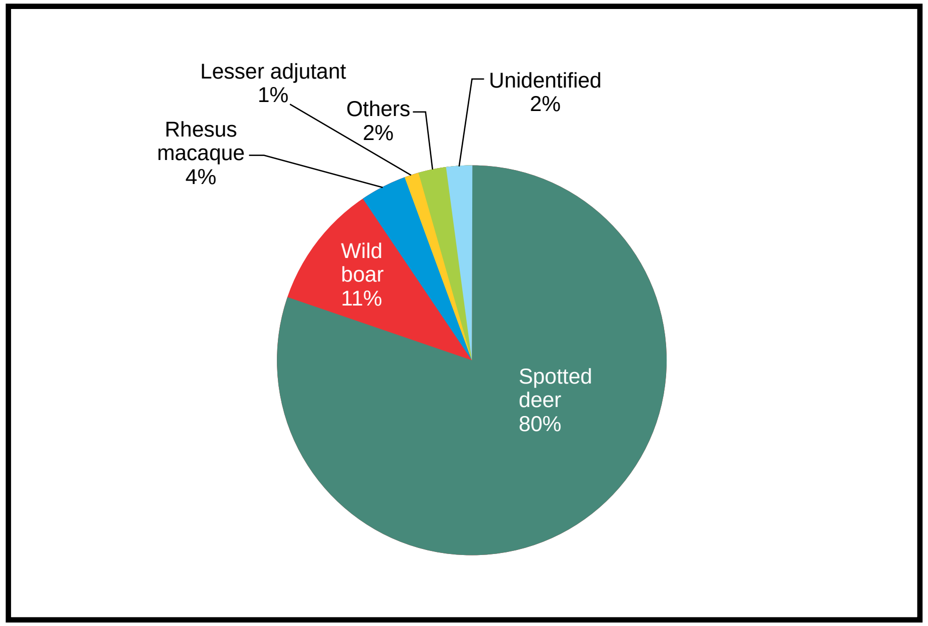


Figure 4.2 Proportions of the relative biomass of different prey species consumed by tigers in the Sundarbans East Wildlife Sanctuary.

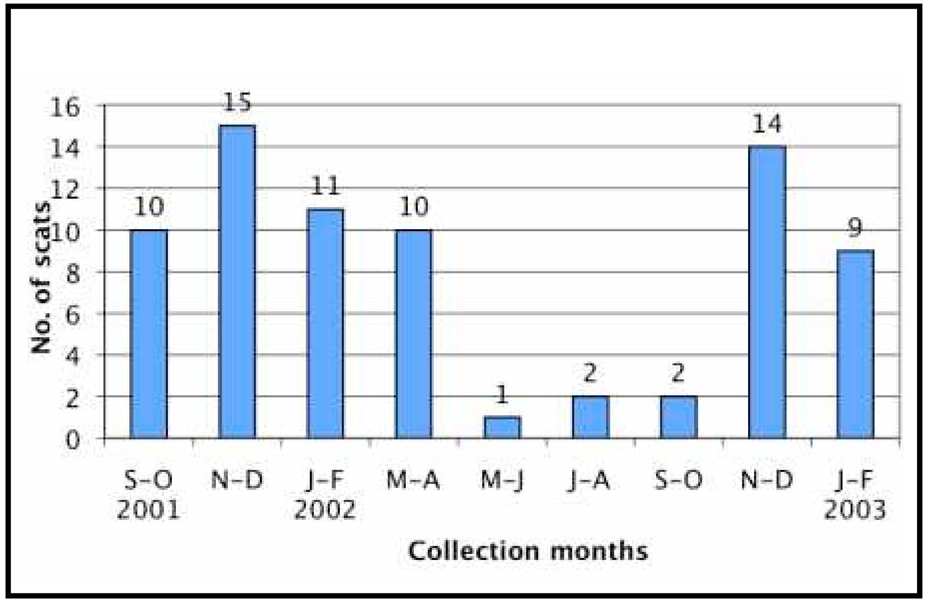


Figure 4.3 Bi-monthly occurrence of tiger scats with soil consisting of more than 50% of the volume in the Sundarbans East Wildlife Sanctuary.

4.3.3 Prey Abundance versus Prey Selection

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 water monitor 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	Selectivity index (S)	Rank of the prey species
Spotted deer	0.05	Middle
Wild boar	0.77	High
Rhesus macaque	0.19	Middle
Lesser adjutant	0.72	High
Red junglefowl	0.04	Middle
Water monitor	1.00	Non-used

4.3.4 Selectivity for Age Classes

The mean lengths of a lower jaw bone and a diastema of the spotted deer killed by the tiger 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 diastema length in both cases was 0.5 cm. Most of the spotted deer kills were adult animals (based on fresh kills – 56%, based on eruption of teeth – 76%) (Table 4.5), and were in good condition before they were killed (79%) (Table 4.6).

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.

Table 4.5 Age of spotted deer kills based on 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	Adult	26	76
Yearling	11	24	Yearling	6	18
Fawn	9	20	Fawn	2	6

Table 4.6 Condition of spotted deer kills

Condition		
Class	No.	%
Good	52	79
Moderate	14	21
Bad	0	0

4.4 DISCUSSION

4.4.1 Prey Selection

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, 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). Tiger and leopard (*Panthera pardus*) usually catch the prey that is large enough to afford more than one meal (Johnsingh 1983).

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). In the Sundarbans, tigers mainly hunt the largest available prey species, the spotted deer, despite the fact that there is no other large carnivore there.

Reza *et al.* (2001a) reported that in the Sundarbans East WS the average 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. Their method was questionable, because the weight, size and density of hairs of these three species are not uniform. Hence, the relative weights of hair samples in scats do not accurately represent either relative biomass or relative numbers of different prey species consumed, but 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.

Left: Leaping marks of a tiger on the ground - tigers can cover a long distance in one leap while catching the prey

Right: Dragging sign of a spotted deer killed by a tiger - dragging signs are produced only in soft ground

Tiger mother and cub feeding on meat – an adult tiger has to kill one large prey every week to provide enough meat

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 (*Muntiacus muntjak*), 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 India, the spotted deer is the main prey of the tiger in Kanha, Bandipur and Nagarhole (Schaller 1967, Johnsingh 1983, Karanth and Sunquist 1995), but it is the second or third main prey in Ranthambhore, Panna and Melghat (Bagchi *et al.* 2003, Gogate and Chundawat 1997, Koppikar and Sabnis 1979). In Huai Kha Kheng, Thailand, the barking deer is the main prey species (Rabinowitz 1989). In the Russian Far East, elk (*Cervus elaphus*) and wild boar were consistently the two key components of the tiger diet (Abramov 1962, Miquelle *et al.* 1996). Karanth and Sunquist (1995) reported that in Nagarhole, India, the biomass of the spotted deer, sambar (*Cervus unicolor*), gaur (*Bos gaurus*), wild boar, barking deer 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.

Solitary lesser adjutant looking for food, but sometimes the lesser adjutant itself becomes food for the tiger

4.4.2 Non-food Items in Scats

Other than typical food items, soil and sungrass blades have been reported in tiger scat samples (Powell 1957, Schaller 1967, Johnsingh 1983, Reza *et al.* 2001a). 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 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%. Other than the soil, I have found significant amount of sungrass blades in one scat. The ingestion of soil and sungrass blades by tigers is probably to meet mineral requirements, for better digestion and/or to scour the digestive system for internal parasites. In Kanha, India, one grass-blade-rich tiger scat had a tapeworm (Schaller, 1967).

Rhesus macaques are arboreal, but often comes to the ground for food and occasionally get killed and eaten by the tiger

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, which was mainly based on the prey size and encounter probability. 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). 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. 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). In general, prey size together with the abundance is the most important factor driving the prey consumption. However, there are many other factors that might be involved in tiger predation, such as anti-predator behaviour, detectability, 'profitability' in terms of energy gain, etc.

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 (Khan 2004a, 2008b), 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. Although the water monitor was common, it has been identified as a non-used species (there was no trace of it in scats) probably because of its smaller size and aquatic habitation, and like most mammalian species, tigers might be reluctant to hunt reptiles.

4.4.4 Selectivity for Age Classes

Predators may preferentially select sub-standard (juveniles and young) animals, because they are less adapted to escape (Hornocker 1970, Schaller 1972, Curio 1976, Vitale 1989). Karanth and Sunquist (1995), and Miquelle *et al.* (1996), reported that although tigers predominantly kill adult prey, the sub-standard prey are killed in relatively high proportions.

In my study most of the tiger kills were adult animals, which do not agree with above-mentioned findings. There was no tendency to prefer young or sub-standard prey, probably because 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. My 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).

Spotted deer running for its life along the beach in Katka, Sundarbans East Wildlife Sanctuary

SPOTTED DEER

Scientific name: *Axis axis*.
Local name in Bangladesh: Phota/Chitra Harin, Gaus and Gonnal (stag).
Wild population: ca. 71,500 in the Bangladesh Sundarbans.
Distribution: Indian subcontinent (native); in Bangladesh occurs in the Sundarbans and introduced populations on some coastal islands.
Length: Head-body 125 cm, tail 20 cm.
Weight: Male 30-75 kg, female 25-45 kg.
Breeding season: Mainly January-July.
Gestation period: 210-238 days.
Litter size: Usually 1.
Sexual maturity: 14-17 months.
Life expectancy: In the wild 9-13 years.
Food: Grazer; feeds on sungrass, grass, leaves, fruits and flowers.
IUCN Red List status: Least Concern globally, Not Threatened in Bangladesh.
Threats: Poaching for meat and skin, and habitat loss.
Legal status in Bangladesh: Protected under the Bangladesh Wildlife Act 1974.

HABITAT PREFERENCE BY TIGERS

‘ 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.’

– Peter Matthiessen (2000)

Photo: Pristine landscape of the Sundarbans in Kadamtala

Chapter 5 HABITAT PREFERENCE BY TIGERS

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 as well as by poaching of themselves and their prey (Woodroffe and Ginsberg 1998, Terborgh 1999, WWF 1999). The tiger's (*Panthera tigris*) main requirements are a sufficient supply of large prey, enough cover for stalking and access to water (Sunquist and Sunquist 2002). Tigers are not tied to a particular habitat type or temperature regime and they have a few ecological constraints that relate to specific habitat requirements (Miquelle *et al.* 1996). While tigers survive in a variety of habitat types, they live at higher densities in areas with high prey biomass (Sunquist *et al.* 1999, Sunquist and Sunquist, 2002). 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. Thus, examining habitat preference by tigers is important to identify the priority issues of habitat management for long-term conservation of the tiger, its prey and the habitat quality. According to Smith *et al.* (1998), good quality habitat is important for the tiger's existence: when the good quality habitat drops below 50%, tigers no longer breed successfully; when it drops below 30%, tigers no longer occur in an area.

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 (van Dyke *et al.* 1986, Nichols and Conroy 1996, Wemmer *et al.* 1996). Based on the tiger signs, this study was conducted to assess the preference of four different habitat types by tigers for their different activities.

Narrow creek traversed the mangrove forest – mangrove trees often have some sort of aerial roots

5.2 METHODS

The study was conducted in the Sundarbans East Wildlife Sanctuary (WS) where there are four major habitat types, which are 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 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 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.

Four major habitat types in the Sundarbans: mangrove woodland (*top left*), grassland (*top right*), sea beach (*bottom left*) and transitional zone (*bottom right*)

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.

This study was based mainly on the differences of the relative density of tiger signs in four major habitat types. Strip transect sampling (Burnham *et al.* 1980, Buckland *et al.* 1993) was conducted in order to record the relative abundance of tiger signs in four habitat types (mangrove woodlands, grasslands, sea beaches and transitional zones) available in the Sundarbans East WS. Since the tiger is the only large carnivore in the Sundarbans, there was no question of confusing tiger signs with the signs of other animals.

Sample bias is an obvious potential problem in measuring habitat use based on signs (Garshelis 2000). In order to avoid the potential biases, large sample sizes were derived and three local assistants continuously accompanied me in order to avoid the biases of visual observations. Since the widths of transects were always only 5 m, there was virtually no bias due to the observers' different visibilities in different habitat types.

Top: Research team in the Sundarbans always had big sticks for protection from the tiger
Opposite: Young curious tiger in Supati, Sundarbans

During the survey for tiger signs in dense forest one of the team members climbed a tree to check whether there was any tiger around

My assistants and I covered a total of 360.2 km distance by 276 transects in 18 months (September 2001 to 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 along transects was 20 km. A Garmin 12XL GPS (accuracy: ± 15 m) was used to calculate the length of each transect. The sampling effort was uniform for different seasons of the year. Using a stratified sampling design, transects were randomly placed in each of the habitat types. A few areas were very unsuitable for survey due to inaccessibility and presence of large rivers, and only those areas had to be avoided.

Transects were surveyed at a uniform speed of about 1.3 km/hr and recorded all types of tiger signs in 5 m width. Using a compass and a GPS the walk was maintained 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 and unidentified activities). 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. 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, the sign types last at least 10 days in any terrestrial habitat type in the Sundarbans, as found during the preliminary observations. The ages of signs were determined on the basis of the observations of the rate of decay of newly produced tiger signs (known to us) and our own footprints in the field in different soil types. To estimate relative abundances of tiger signs (mean number of signs/km^2), the absolute number of signs for each transect was divided by respective transect area.

Tiger scratches on trees were recorded to determine 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.

Collection of fallen hairs of the tiger from a den for DNA test – fresh scratches of the tiger are on the root at the bottom left corner of the photo

Houseboat where the research team was based and it was used as a make-shift laboratory

5.3 RESULTS

5.3.1 Habitat Preference

The mean density of tiger signs (total of all types of signs) was highest in mangrove woodlands (966.9 ± 94.2/km^2) and lowest on the sea beaches (533.9 ± 44.7/km^2) (Table 5.1), but tigers did not show habitat preference in any of the four habitat types (Kruskal-Wallis, H = 3.48, df = 3, p = 0.323).

Results varied for the mean densities of different types of tiger signs in different habitat types. For 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. For movement, scratch-scent-urinal, and 'others' (hunting, drinking and unidentified activities) 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 (Table 5.2).

The density of the movement signs and feeding signs were highest in mangrove woodlands and transitional zones, resting signs in grasslands and transitional zones, and defaecation signs in grasslands (Table 5.1). The scats were commonly found 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 the four different habitat types (Table 5.1). The density of the interaction signs was highest on the sea beaches, and scratch-scent-urinal signs in grasslands and mangrove woodlands. The density of 'others' signs was highest in the 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), and the frequencies in each of the four different habitat types were also significantly different (Table 5.3). The maximum percentage of signs was for movement irrespective of habitat types (69.1%) and in each of the habitat types.

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* sp. and *Zizyphus* sp.) and two of them (*Syzygium* sp. and *Lannea* sp.) 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 0.0 and 2.0 m, but commonly between 0.3 and 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 7.0 km away from each other.

Table 5.1 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)*	Total signs per habitat type		Sign types: Movement		Feeding		Resting		Defaecation		Interaction [with mate/cub(s)]		Scratch-scent-urinal		'Others' (hunting, drinking, unidentified activities)	
		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	499	966.9 ± 94.2	367	711.2 ± 60.7	38	73.6 ± 13.3	6	11.6 ± 2.8	43	83.3 ± 14.9	28	54.3 ± 9.1	9	17.4 ± 4.3	8	15.5 ± 4.0
GR	89.8	308	686.0 ± 52.0	175	389.8 ± 36.7	8	17.8 ± 3.9	17	37.9 ± 9.0	74	164.8 ± 18.2	20	44.5 ± 8.9	8	17.8 ± 4.4	6	13.4 ± 3.7
BE	81.3	217	533.9 ± 44.7	158	388.7 ± 36.2	2	4.9 ± 1.1	2	4.9 ± 1.0	18	44.3 ± 7.9	36	88.6 ± 15.4	1	2.5 ± 0.5	0	0 ± 0
TR	85.9	363	845.2 ± 79.9	259	603.0 ± 48.7	29	67.5 ± 11.6	14	32.6 ± 9.1	30	69.8 ± 12.5	16	37.3 ± 9.3	6	14.0 ± 3.2	9	21.0 ± 5.5
Total/Overall	360.2	1,387	770.1 ± 66.7	959	532.5 ± 44.1	77	42.8 ± 7.2	39	21.7 ± 5.6	165	91.6 ± 15.4	100	55.5 ± 10.3	24	13.3 ± 3.7	23	12.8 ± 2.5

* Transect lengths were variable, but the widths were always 5 m.

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	28.09	3	<0.001
Scratch-scent-urinal	0.79	3	0.852
'Others'	3.57	3	0.312

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

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

Tree species	Local name	Family	Bark type	No. of trees used	Height of scratches from ground level (m)
Syzygium sp.	Bon jam	Myrtaceae	Medium soft	7	0.3-2.0
Lannea sp.	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 Habitat Preference

There are very few studies on habitat preference of 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 2004a). 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. The fact that most of the tiger kills were found away from open areas is partially 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 (which is less open compared to other habitat types) 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. The density of the defaecation signs was highest in grasslands, because, as it was observed in the field, tigers preferred defaecating in small dry sand dunes and besides footpaths, both of which were more available in grasslands.

The habitat preference for movement and feeding showed a 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. The interaction signs were relatively more obvious on the sea beaches, which is an indication that tigers probably like to interact there at night (human disturbance occurred during daytime).

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. The highest proportion of tiger signs was in mangrove woodlands, which agrees with Chundawat's (2001) statement: 'on average tigers use the densely forested areas more than other habitats'.

Reza *et al.* (2001) reported the habitat preference of the tiger in Katka-Kochikhali area (20 km^2) in the Sundarbans East WS. Since they did not compare the sign frequencies in relation to the areas of different habitat types, only the sign frequencies, there is no strong basis to conclude anything on habitat preference. The results are very different from the results of this study. They found only 6% of tracks in forests, but in this study, the highest density of tracks (i.e. movement signs) was found in forests (i.e. mangrove woodlands).

Movement signs of the tiger: tiger went towards the forest *(top left)*, tiger went towards the sea *(top middle)*, tigers frequently crossed through a narrow passage in grassland *(top right)*, and tiger went and returned through the sea beach *(bottom)*

Drinking sign of the tiger beside a ditch – tigers prefer freshwater, but also drink brackish water in the creeks of the Sundarbans

Johnsingh (1983) found that in Bandipur, India, tigers prefer 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.

In Kerinci Seblat, Indonesia, Linkie *et al.* (2003) recorded the occurrence of tiger signs in 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 (Khan 2004a). 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 (Khan 2004a, 2007b).

The findings of this study reveal that tigers widely use all available habitat types for their different activities. Hence, the current management policy for the Sundarbans that emphasizes only on the woodlands should be changed to emphasize on the maintenance of the diversified landscape. Habitat diversity is also required for the maintenance of the diversified prey base, since different prey species requires different habitat types.

Tranquil sunrise in Katka, Sundarbans

Silent sunset in Hironpoint, Sundarbans

Top: Defaecation and urinal sign of the tiger

Left: Scratching sign of the tiger on 'kocha' (*Lannea* sp.) tree

5.4.2 Scratches on Different Tree Species

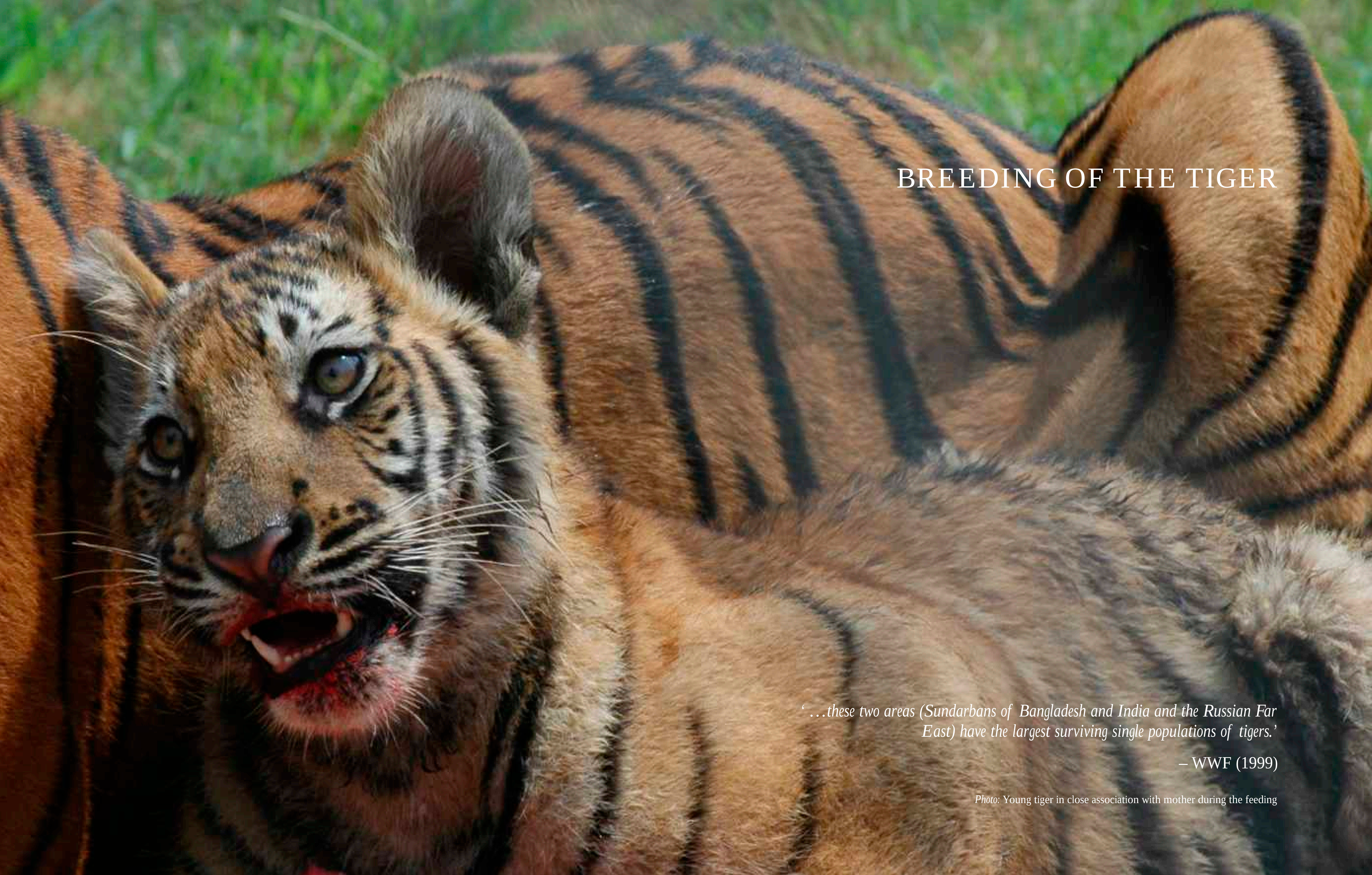
Both male and female tigers use scratching to mark their territories (Smith *et al.* 1989). This action perhaps also sharpens the claws by peeling off any thin, loose or desquamated strips of laminae from the surface that are ready to flake off, either on the top of the claw or along the sides and thickened 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 height of scratches from the ground level varied between 0.7 and 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 1978, Khan 2004a, Barlow *et al.* 2010). Moreover, whether trees were standing straight or not, also caused a variation in the heights of scratches from the ground.

Although the tiger is known to be a habitat generalist (Nowell and Jackson 1996), its preference for soft-barked trees is just one example that how different components of a diverse habitat can be useful for its daily life. This again emphasizes 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 do not yet know other minor requirements.

SUNDRI

Scientific name: *Heritiera fomes.*
Local name in Bangladesh: Sundri.
Type: Mangrove tree under the family Malvaceae.
Use: Timber is used in construction, especially in boat-building; branches are used as firewood.
Timber type: Strong and durable, dark reddish, density 960 kg/m^3.
Distribution: South and Southeast Asian coast; in Bangladesh restricted to the Sundarbans.
Height: Up to 25 m.
Red List status: Endangered globally, not threatened in Bangladesh.
Threats: Reduction in freshwater flow, sea-level rise, coastal development, cyclones and disease.
Protection in Bangladesh: Habitat of the tree is protected under the Forest Act 1927 and Bangladesh Wildlife Act 1974.



BREEDING OF THE TIGER

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

– WWF (1999)

Photo: Young tiger in close association with mother during the feeding

Chapter 6 BREEDING OF THE TIGER

6.1 INTRODUCTION

Understanding the breeding parameters of the tiger is critical for developing sound conservation strategies (Kerley *et al.* 2003), yet most of the information about the breeding of the tiger comes from captive animals (e.g. Kleiman 1974, Sadlier 1966, Seal *et al.* 1987). Aalthough there is some information on the breeding and litter size available for wild tiger populations in India (other than in the Indian Sundarbans) (Schaller 1967; Sankhala 1967, 1978), Nepal (McDougal 1977, Sunquist 1981, Smith and McDougal 1991, Smith 1993), Russian Far East (Abramov 1977, Smirnov 1986, Bragin 1989, Smirnov and Miquelle 1999, Kerley *et al.* 2003) and Manchuria (eastern Asia) (Baikov 1925, Ognev 1935), there are very few reports on the breeding of the tiger in the Sundarbans of Bangladesh and India (Sanyal 1987, Reza *et al.* 2002b). Since the tiger is a widely distributed species, breeding parameters may vary between the five extant subspecies in response to different climates, habitats, prey densities, and other environmental parameters (Kerley *et al.* 2003) and in some areas there might not be any breeding peak at all. For the same reason parameters might even vary between different populations of the same subspecies living in different habitat conditions and since the Sundarbans is the only mangrove habitat of the tiger, it is assumed that the breeding parameters might differ from other habitats. Information on how reproductive parameters vary between different areas and subspecies is essential for range-wide conservation planning (Kerley *et al.* 2003), so the general objective of this study was to determine the possible breeding pattern and number of tiger cubs seen with the mother in the Sundarbans.

Male and female tigers in close association - tigers are normally solitary except for mating

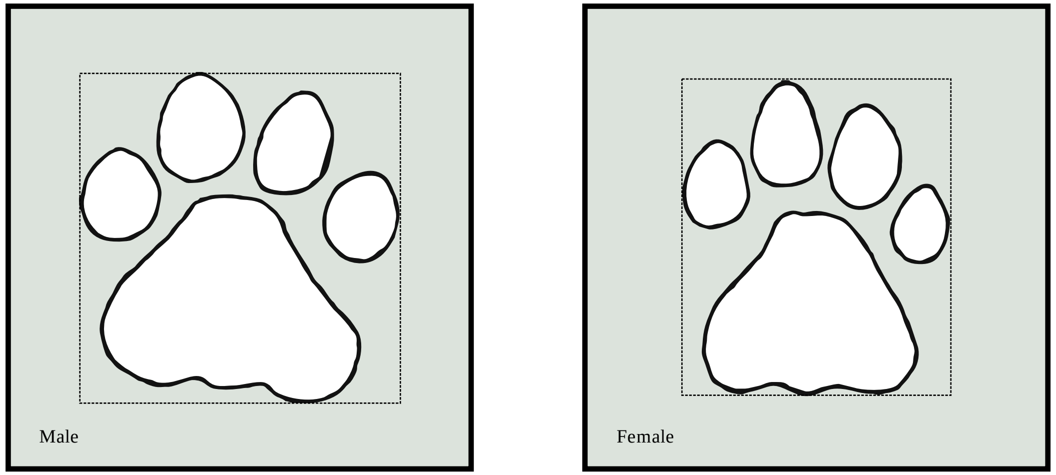


Figure 6.1 Hind pugmark of a male and a female tiger. N.B. The pugmark of a male is larger and can fit into a square box rather than a rectangle box in case of a female.

6.2 METHODS

The signs (e.g. pugmarks or tracks) of putative male-female interactions and mother-cub(s) interactions were recorded during January-December 2002 (12 months; 14 days in every month) in the Sundarbans East Wildlife Sanctuary (WS) of Bangladesh. 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 1978, Sunquist 1981, 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. The sexes were identified on the basis of the shape and size of pugmarks; details of the method is described in further detail elsewhere (Panwar 1979, Das and Sanyal 1995, Singh 1999, Smirnov and Miquelle 1999, Nath 2000, Sharma *et al.* 2003), but to summarise: the pugmarks of males are larger 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).

Similarly, mother-cub(s) interaction signs, together with the number of cubs, were recorded in the field in different months. Tiger cubs continue to live with their mothers until 2-3 years of age (Nowak 1991, Nowell and Jackson 1996) and a single mother with one or more small cubs was recorded in this study. Small cubs do not normally wander alone (Nowak 1991, Nowell and Jackson 1996) and the pugmarks of the female with cubs(s) were easily identified on the basis of measurements (Nikolaev and Yudin 1993, Smirnov and Miquelle 1999). The cubs were defined as relatively small individuals (ages ranged from about two to eight months) accompanied by the mother.

Pugmarks of a young tiger that walked extremely slowly – pugmarks can tell a lot about the walking mode and activities of the tiger

In general, observers note that tigers call (roar) more often during the peak of the mating period than any other time (Smith and McDougal 1991, Sunquist and Sunquist 2002), a trait 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 was recorded to compare 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.

6.3 RESULTS

The records of breeding parameters indicate that, in the Sundarbans, tigers 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 were during October-March, with the highest in November. However, male-female observations were not significantly different across months ($\chi^2 = 14.000$, df $= 11$, $p = 0.233$). On the other hand, most of the mother-cub(s) observations were during October-April, with the highest in December. The mother-cub(s) observations were also not significantly different across months ($\chi^2 = 15.412$, df $= 11$, $p < 0.164$). Most of the calls were heard during the probable mating season (August-October). Because of small sample size, no statistical test could be conducted to prove whether the number of calls was significantly different across months. The total number of observations for male-female, mother-cub(s) and call was 46, 34 and 28, respectively.

The records on mother-cub interaction reveal that information about single cubs are the commonest (61%), followed by two (34%) and three (5%) (Figure 6.3).

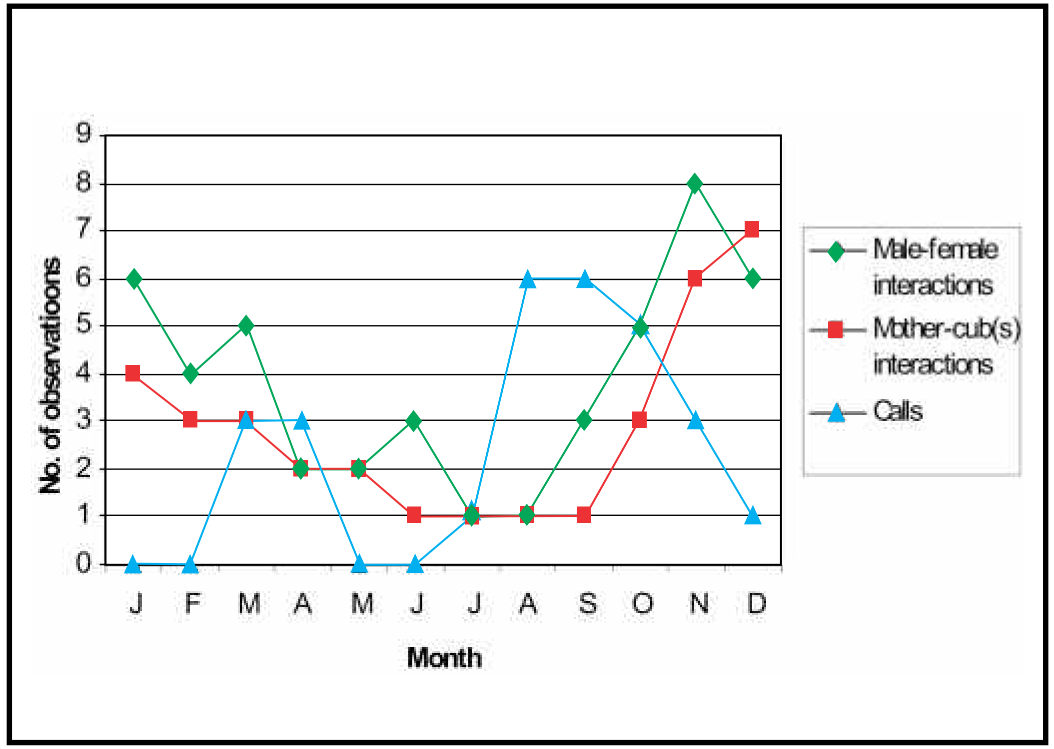


Figure 6.2 Breeding parameters of the tiger in the Sundarbans

The number of observations of one, two and three cubs was significantly different (χ^2 = 25.75, df = 2, p < 0.001). The mean number of cubs linked to mother was 1.4 (range = 1-3, n = 34, sd = 0.6). Since this result is based on observations of the small cub(s) with their mother, this does not represent the actual litter size at the time of birth.

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.

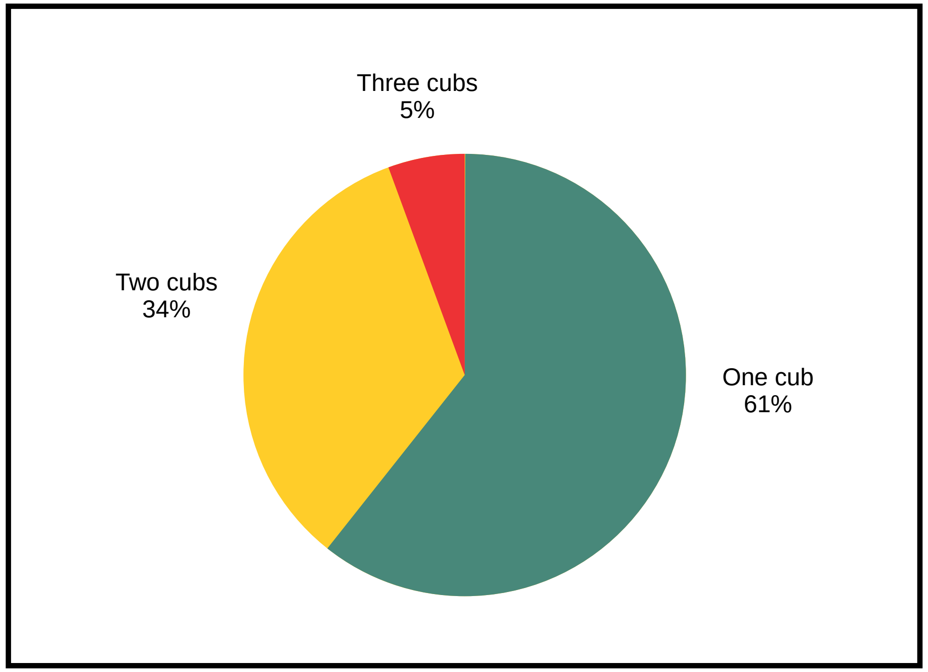


Figure 6.3 Number (expressed as % from total records) of cubs known to accompany mother tigers in the Sundarbans (n = 34).

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, and Sunquist and Sunquist (2002) mentioned that in South and Southeast Asia cubs may be born at any time of the year, but zoo data from India revealed that there was a birth peak during March-June and another smaller peak during August-October (Sankhala 1978). Schaller (1967) and Sankhala (1967, 1978) mentioned that the birth peak is November-April in India but Karanth (2001) believes

that there is no birth peak in wild tigers in India. However, Amur tigers in the Russian Far East have a more evident 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), although Kerley *et al.* (2003) found that tigers can give birth almost all through the year, but most frequently in late summer (August-October: over 50%). While 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). In Chitwan, Nepal, cubs are born throughout the year, with a birth peak from May to July (Smith and McDougal 1991, Smith 1993). According to Sanyal (1987), the mating season of tigers in the Indian Sundarbans is late monsoon, which is spring in the peninsula. Based on interviews with local people, Reza *et al.* (2002) 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 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 reduces cub mortality. Because of the seasonal characteristics and seasonal prey abundance, the breeding peak is also likely to vary in different parts of the tiger's global range. Since the gestation period of a tigress is about 103 days (Sankhala 1978, 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 be because of: a) the continuation of male-female interactions (not necessarily mating) 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, or c) the information regarding cubs accompanying a mother could be for cubs of any age ranging from about two to eight months.

Although there are very limited information on the breeding of tigers in the Sundarbans, the reproductive parameters of Amur tigers were extensively studied, based on snow tracking alone (Abramov 1977, Smirnov 1986, Bragin 1989, Salkina 1994, Smirnov and Miquelle 1999), or in combination with ground tracking, live capture, and telemetry (Kerley *et al.* 2003).

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 (Tamang 1993, Sunquist and Sunquist 2002). In the Russian Far East, Kerley *et al.* (2003) found that the mean litter size is 2.4 ± 0.6, 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). The mean litter size is 3.0 (range 2-5, n = 49) in Nepal's Chitwan National Park (Smith and McDougal 1991), although 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 1978). In Bangladesh, a tigress gave birth to four cubs in Dhaka Zoo (Moudud 1998) and two cubs in Khulna Zoo (M.M.H. Khan personal observation).

Based on the records of small cubs with mother in the Sundarbans, the mean litter size is suggested to be 1.4, which is much lower than the mean litter size in Chitwan, in Indian zoos, and in the Russian Far East. This might be either because: a) cub mortality at early life stages is probably much higher in the Sundarbans or b) the tough habitat and limited prey probably force the tiger population to produce smaller litters. Notably, mortality among pre-dispersal offspring is as high as 50%, as found in Chitwan, Nepal, and in the Russian Far East (Sunquist 1981, McDougal 1985; Kerley *et al.* 2002, 2003). 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 seen (n = 15) during this study were quite thin, which might be another cause of the smaller litter size. Ovulation in mammals is regulated indirectly by female energy reserves (Bronson and Manning 1991).

Top: Snarl of a tiger cub - the expression of annoyance

Bottom: Pugmarks of tiger mother (centre) accompanied by two cubs in two sides

National workshop on Bangladesh Tiger Action Plan

LEGAL PROTECTION OF THE TIGER AND ITS HABITAT IN BANGLADESH

Bangladesh has enacted national legislation, national strategies and action plans, and signed up to international conventions that directly or indirectly contribute to the protection of the tiger and its habitat in Bangladesh. These are –

National legislation: Forest Act 1927, Bangladesh Wildlife Act 1974, and Bangladesh Environment Conservation Act 1995.

National strategies and action plans: Integrated Forest Management Plan for the Sundarbans Reserved Forest 1998, Bangladesh Capacity Development Action Plan for Sustainable Environmental Governance 2007, Bangladesh Climate Change Strategy and Action Plan 2008, and Bangladesh Tiger Action Plan 2009-2017.

International conventions: Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Convention on Biological Diversity (CBD), Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention), and Convention Concerning the Protection of the World Cultural and Natural Heritage (UNESCO World Heritage Convention).

TIGER-HUMAN CONFLICT

' … among these islands (of the Sundarbans), 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.'

– Francois Bernier (1670)

Photo: Tiger watchpost in Chandpai on the edge of the Sundarbans - this helps reduce straying of tigers into the villages

Chapter 7 TIGER-HUMAN CONFLICT

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). Conflicts with people and their livestock are significant sources of mortality for large carnivores, and also strains relationships between the local communities and the authorities (Madhusudan 2000, Nyhus and Tilson 2004, Yu *et al*. 2006, Gurung *et al*. 2008, Sangay and Vernes 2008). Tiger-human conflicts have already contributed to the decline and extinction of two subspecies of the tiger (Bali tiger *Panthera tigris balica* and Javan tiger *P. t. sondaica*) (Hoogerwerf 1970, Seidensticker 1987) 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).

Top: People in the Sundarbans often carry a sacred bead that they believe will save them from man-eating tigers

Opposite: Young male tiger found dead in Kochikhali, Sundarbans

Unlike other tiger populations, those in the Sundarbans of Bangladesh and India are believed to be responsible for a considerable number of human deaths annually (Montgomery 1995, Karanth 2001) and 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 since at least the 17th century (Bernier 1670), 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 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. Many people and a few tigers die every year from the conflict, additionally some tigers are poached each year for their lucrative hides and other body parts.

In the Sundarbans severe poaching and consumption of the tiger's prey species (mainly the spotted deer *Axis axis*) by local people is a serious threat. 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 (Nowell and Jackson 1996, Karanth and Stith 1999). Although the decline of the prey population due to poaching is the single most severe threat to the tiger in the Sundarbans (Khan 2004a, 2010), measuring poaching levels is extremely difficult, because the poaching and marketing of the poached meat is secretive.

The objective in this study was to provide clear picture of tiger-human conflict and its intensity, together with the consumption of tiger prey by local people, in and around the Sundarbans. This will help evaluate the impact of management intervention.

Top: Gathering information on tigers by interviewing the fishermen of the Sundarbans
Opposite: Boatman of a honey gatherer group blowing horn to let others (who are searching honeycomb in the forest) know the location of the boat

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 and forest department records 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 (McDougal 1987, Herrera *et al.* 1994, Hokkaido Institute of Environmental Sciences 1995). The interviewing was conducted either in the Sundarbans or in the local villages.

A total of 123 individuals were interviewed during this study (September 2001 to February 2003). 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. The information on tigers killed by people and people killed by tigers that were recorded from the interviewees were mainly from recent years, but some information date back 30 years from the time of interviewing, so long as the interviewees could remember the main aspects of the incidences.

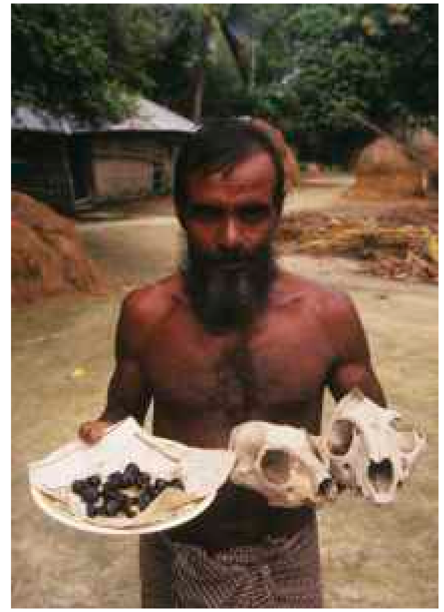
The age and sex of killed tigers were identified on the basis of physical characteristics described by the interviewees. In the cases when the companions of the human victims rescued the kill immediately, the records of dragging distance were not recorded. Only men were interviewed because women do not work in the Sundarbans interior, but they do work in the fringes.

Top: Fresh skin of a tiger that was killed by poachers in Dhangmari, Sundarbans

Opposite: Different body parts of the tiger (left: skulls and pieces of genital organ; right: canine tooth) are used as traditional medicines to cure different illnesses like pain, sexual disorder, weakness, etc.

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.

Some sampling in the field 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.



7.2.2 Protein Intake Survey

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 animal protein intake of 50 randomly selected local families was recorded, for 18 months (September 2001 to February 2003), to determine the rate of consumption of tiger prey, as well as the proportion of animal protein that comes from tiger prey. 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 (subdistrict) 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, Gaab-bunia, Joymoni, Bouddamari, Burburia, West Chila, South Chila, Goalbunia, Gilar Khalkul and South Haldibunia.

Out of these 50 families, 31 were Muslims and the rest were Hindus. 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 of the surveyed families, there were five main professional classes: day labour (8%), fisherman (22%), farmer (16%), businessman (38%) and serviceman (16%). Based on the level of monthly income of the families, these were divided into seven groups starting from Taka (Tk) 2,000 up to Tk 5,000, but the highest percentage of families were in Tk 4,000 (26%) and Tk 3,000 (24%) levels. At the time of the survey US $ 1 = Tk 57.

Two poachers arrested by the Forest Department in Kochikhali, Sundarbans – they had rope snares to catch spotted deer and a bottle of liquid poison, to use either in a half-eaten kill of the tiger or in a deer killed by themselves, to kill the tiger by poisoning

Boats of honey gatherers have gathered in front of Burigoalini Forest Office, Sundarbans, for permission – searching honey in the forest where there are man-eating tigers is one of the most risky professions in the world

7.3 RESULTS

7.3.1 Tigers Killed by People

Based on the official (Forest Department) records of 10-year period (1993-2002), an average of 3 (range = 0-5) tigers were killed per year in and around the Bangladesh Sundarbans, but the official figure is slightly under-represented since some tigers are killed secretly, especially by poachers, which are not reported officially. For example, from September 2001 to February 2003 (in 18 months), people killed a total of 7 tigers (3 were killed by poachers, others by villagers as retribution as a result of tiger-human conflict), but the official figure was 4. Therefore, the actual number of tiger deaths per year is around 5. Since the official number of tigers killed by people is different from the actual number, only the data of interviewing were used for the following results.

The information derived from interviewing local people on 30 tiger-killing incidences shows that the proportion of tigers killed by people was much higher in winter (November-February: 77%) (Figure 7.1). Among the killed tigers, most were middle-aged (68%), but there were young (21%) and old tigers (11%) as well. Most of the killed tigers were males (73%). Here 'middle-aged' tigers are those which are sexually mature and are neither young nor obviously old. The main reasons for killing tigers by people were attacks on humans and cattle (76%), but poaching was also a significant reason (19%) (Figure 7.2). 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 (Figure 7.3).

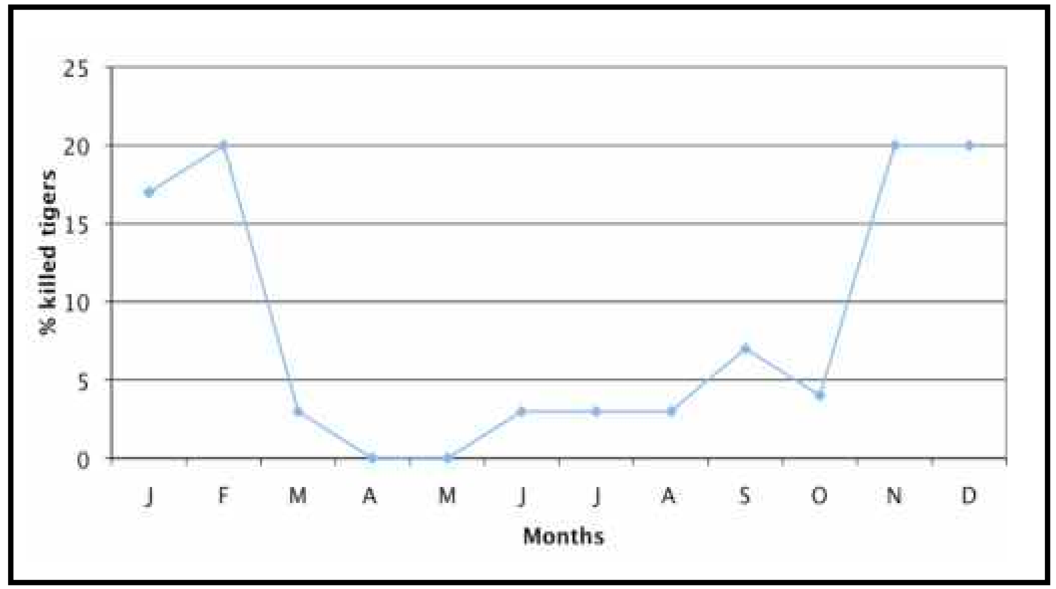


Figure 7.1 Tigers killed by people in different months in and around the Bangladesh Sundarbans (n = 30 tigers).

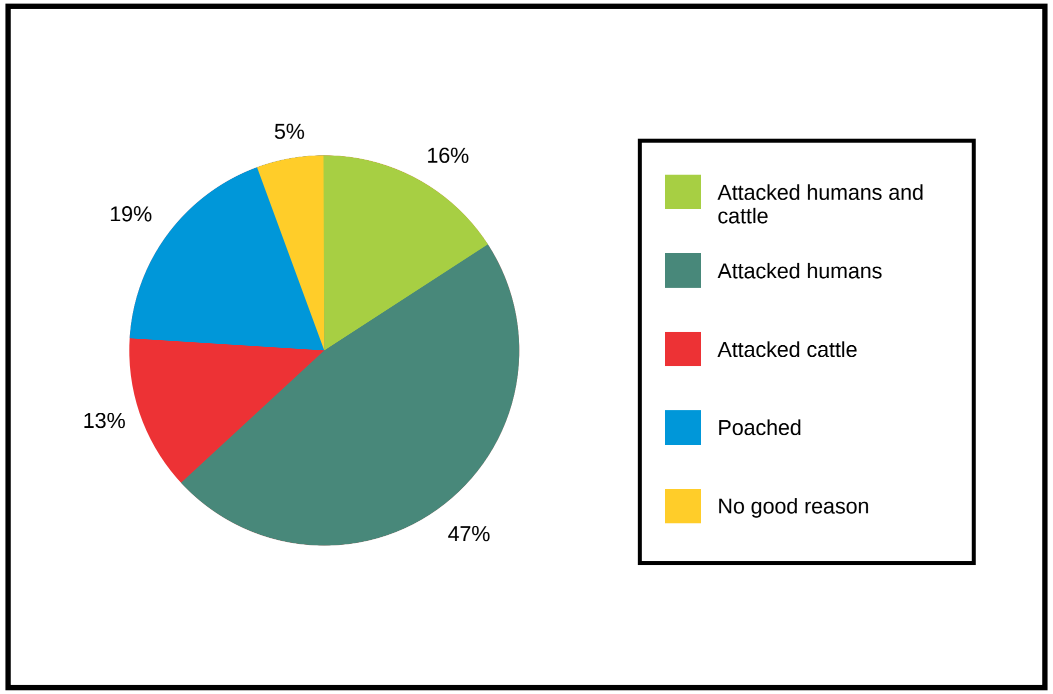


Figure 7.2 Proportions of different reasons for killing tigers in and around the Bangladesh Sundarbans (n = 30 tigers).

7.3.2 People Killed or Injured by Tigers

Based on the official (Forest Department) records of 10-year period (1993-2002), an average of 17 (range = 0-42) humans were killed per year by tigers in and around the Bangladesh Sundarbans, but the official figure is highly under-represented since many people enter the forest unofficially (withouth valid entry permit) and their deaths are not recorede officially. For example, from September 2001 to February 2003 (in 18 months), tigers killed a total of 41 people, but officially this figure turned out to be only 5. Therefore, the actual number of human deaths per year is around 27. 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 7.4). 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 comparison of available humans and attacked humans (killed/injured) 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%). However, in comparison to other two age classes, tiger-attack was relatively high in 30-50 age class (Figure 7.5). 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). In case of professional classes 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 7.6).

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 7.7). 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.

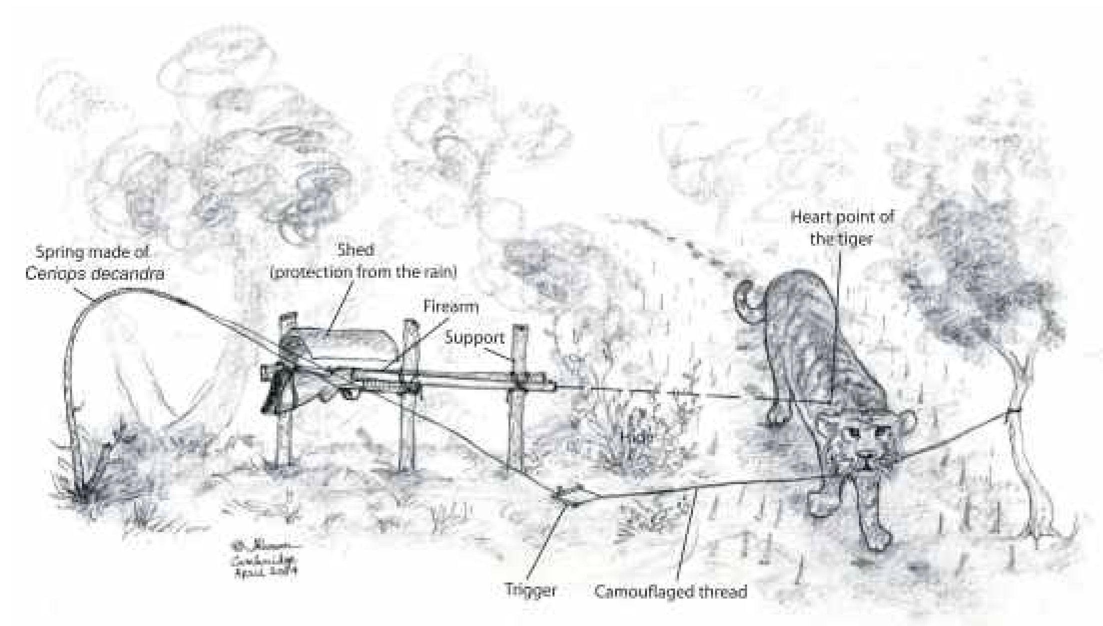


Figure 7.3 Diagram of firearm setting by poachers to kill the tiger.

7.3.3 Public Knowledge and Belief

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, 25% in the zoos, 15% in the circuses and 13% in adjacent villages. This means that the local people still familiarise with the tiger mainly in the Sundarbans.

Among the wild tigers seen by interviewed local people (n = 70), 56% were normal live, 23% killed, 16% dead (apparently not killed by people) and 5% injured. The proportion of the sightings of killed tigers indicates that perhaps local people often kill tigers.

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.

A total of 42% of the interviewed local people believed that there are medicinal uses for tiger parts while 43% were not sure about it and 15% did not believe it. People believe that the fat of the tiger 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, and the genital organ is useful to cure sexual weakness or sexual diseases of both male and female humans. 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.

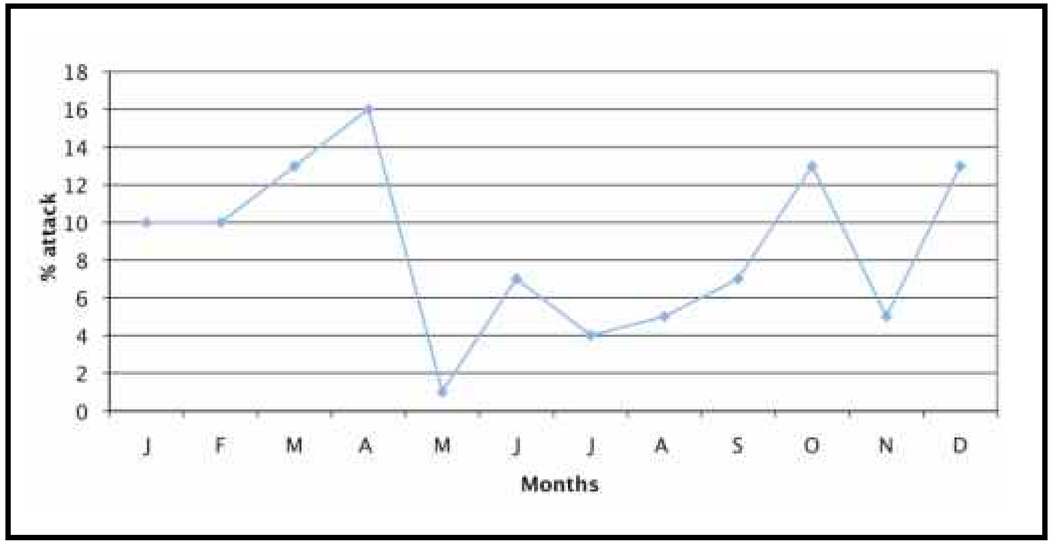


Figure 7.4 Tiger attacks on local people in different months in and around the Bangladesh Sundarbans (n = 123 humans, those known to the interviewees over the last 30 years).

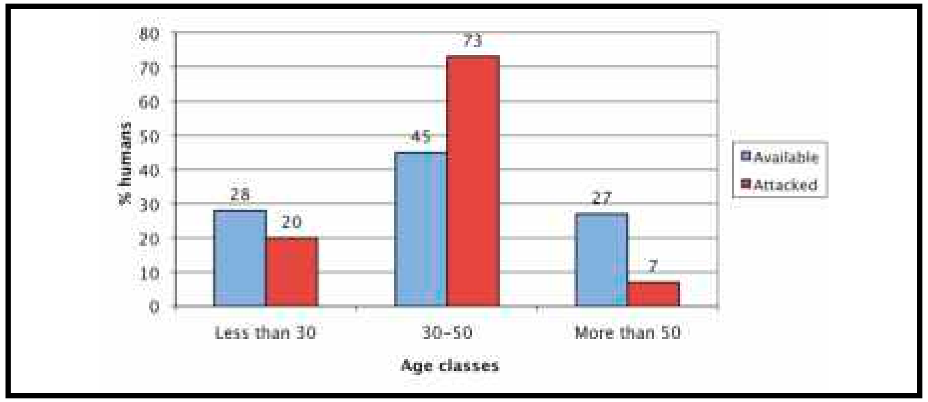


Figure 7.5 Available humans and attacked humans in different age classes in and around the Bangladesh Sundarbans (available: sample n = 623; attacked: n = 123, those known to the interviewees over the last 30 years).

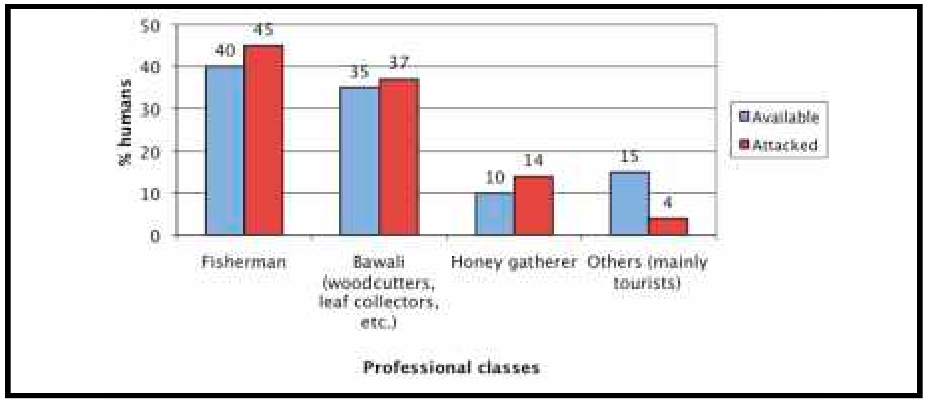


Figure 7.6 Available humans and attacked humans in different professional classes in and around the Bangladesh Sundarbans (available: sample n = 623; attacked: n = 123, those known to the interviewees over the last 30 years).

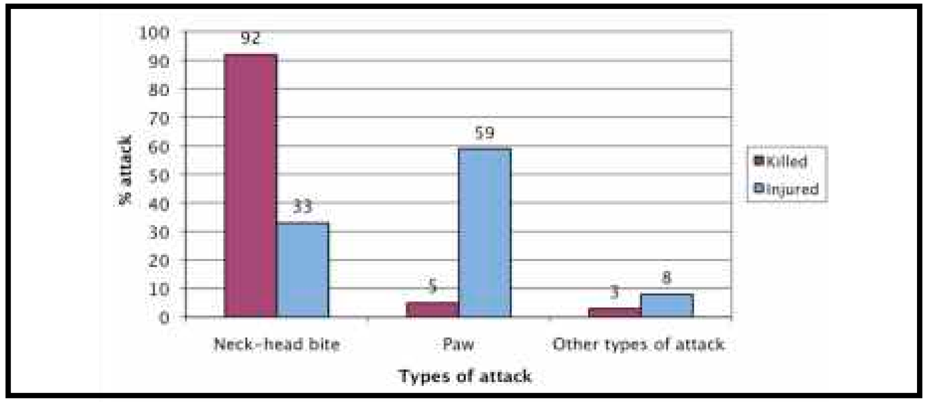


Figure 7.7 Types of initial tiger attack in killed and injured humans in and around the Bangladesh Sundarbans (n = 91 for killed and 32 for injured humans).

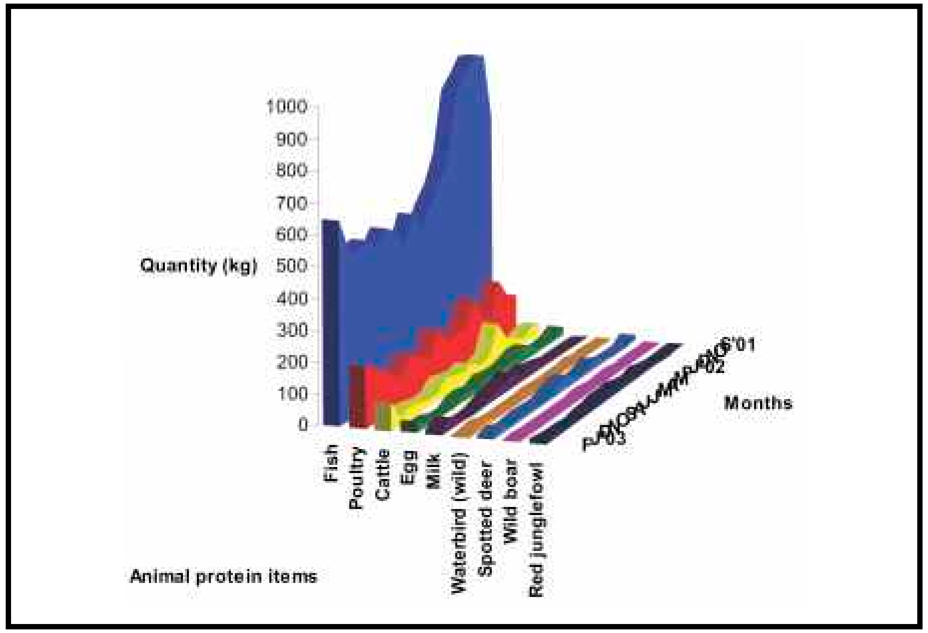


Figure 7.8 Quantity of monthly consumed animal protein items from September 2001 to February 2003 by 50 families.

Interestingly, despite many fatal encounters with tigers, 75% of the interviewed local people wanted the tiger to remain in the Sundarbans. 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, and 3% were not sure about it. It was noticed that in the area where the rate of human casualty is relatively high (i.e. 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.

7.3.4 Consumption of Tiger Prey by People

The data on 18 months (September 2001 to February 2003) of animal protein intake by 50 local families reveals that the proportions 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 proportions were 94.9% (Tk 857,279 = US $ 15,040) and 5.1% (Tk 46,250 = US $ 811), respectively. According to local poachers (n = 20), a spotted deer produces an average of 32 kg of salable meat.

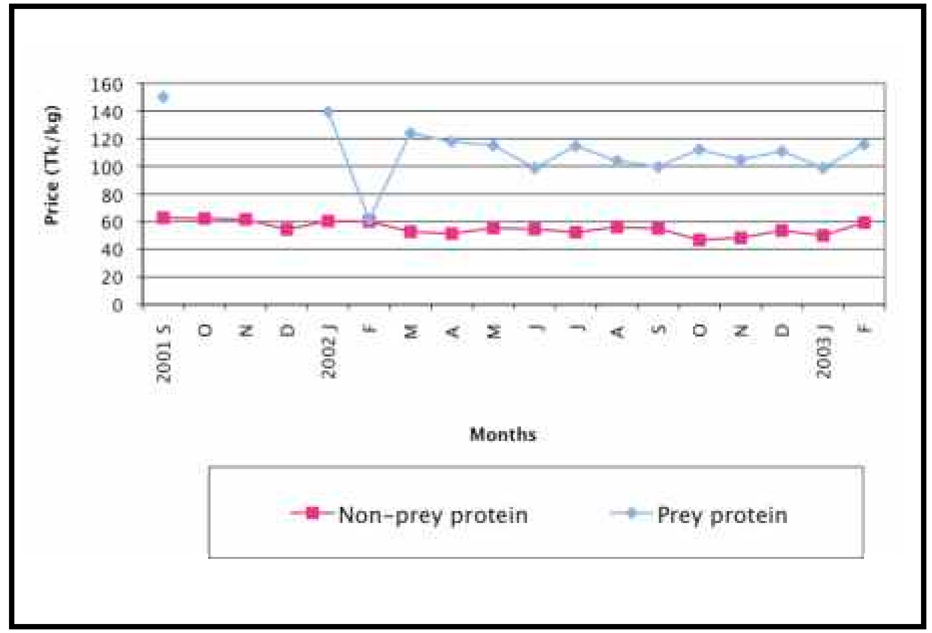


Figure 7.9 Market price of non-prey and prey protein items from September 2001 to February 2003 in the vicinity of the Sundarbans. (There was no consumption of prey protein from October to December 2001, probably because the prey protein was not available in the market.).

This means that the above-mentioned 50 families together consumed the spotted deer meat that is equivalent to 8.1 spotted deer in 18 months or 5.4 spotted deer in one year. In relation to the total animal protein consumed by local people, the proportion of protein from tiger prey is insignificant (since it is less than 5%), but if the figure is extrapolated against ca. 50,000 similar families living around the Sundarbans, whose heads venture into the Sundarbans almost every day for their livelihoods, it is inferred that the local people consume about 5,400 spotted deer every year.

It is clearly evident that fish is the main source of animal protein, but among the tiger prey items spotted deer forms the highest proportion (Figure 7.8), both in terms of quantity and market price. 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], especially the deer meat was a delicacy in the locality. The prey protein consumption fluctuated significantly in different months because the supply of poached products was not continuous (Figure 7.9). No major difference was found in the monthly consumed quantity of animal protein in different professional or income families.

Notably, the poachers who slaughter the deer take them to the nearest market where they sell the meat for at least Tk 100 (US $ 1.8)/kg. The deer skin is sold for several hundred taka. 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 towns and cities.

7.4 DISCUSSION

7.4.1 Tigers Killed by People

Siddiqui and Choudhury (1987), Helalsiddiqui (1998), Ahmed (2002a, 2002b, 2002c), JJS (Jagrata Juba Sangha; a local NGO) (2002), Reza *et al.* (2002b), Gani (2002), Khan (2004a) and Barlow (2009) reported tiger death rates and some other aspects of tiger-human conflict 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. Their results are similar to my result when based on the Forest Department records, but the actual figures of casualties, as mentioned in my survey results, are very different from the official figures. For example, based on official reports, on an average, Barlow (2009) reported that a total of 6 tigers were killed per year in the Bangladesh Sundarbans and 1 per year in the Indian Sundarbans. 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%). The retribution killing of tigers could have a sizable impact on the long-term viability of the tiger population (Chapron *et al.* 2008, Goodrich *et al.* 2008).

The proportion 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 in the Sundarbans is in winter (Khan 2004a) that caused more extreme territorial conflicts among male tigers. As a result, some of the tigers were probably forced away from the forest and these tigers may have started killing cattle, or very rarely people, in the local villages and were eventually killed by the villagers. An average of 51 livestock are killed every year by the tiger (Rahman *et al.* 2009). Most (73%) of the killed tigers were males, which is supported by the findings of Hendrichs (1975), and Nyhus and Tilson (2004). Even for females, winter is the period when they need more food to raise cubs, causing more competition.

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 virtually none of the popularly believed three main reasons (Corbett 1954, Rabinowitz 1986, Sunquist and Sunquist 1988, Linnell *et al.* 1999): 1) wounds and infirmity, 2) old age, and 3) loss of home ranges to other tigers.

A number of studies of big-cat-human interactions reported that most of the big cats that attack humans or cattle were subadult individuals displaced from their former home ranges (Seidensticker *et al.* 1976, McDougal 1987, Hanby and Bygott 1987, Saberwal *et al.* 1994, Nyhus and Tilson 2004). My results showed no indication that subadult 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.

Little is known about tiger poaching and national demand for tiger parts (Nowell 2000, Khan 2004a) in Bangladesh. However, the geographical position of Bangladesh between India and Myanmar, countries that experience rampant poaching, may further increase the vulnerability of tigers in the Sundarbans (Nowell and Xu 2007).

Left: Tiger in watching mode

Most of the people who are attacked by tigers in the Sundarbans are killed, but some return with injuries: Monu Mollah *(top left)* was pawed on head by a tiger, but the tiger left him while his companions were approaching; Siddiq Ali *(top right)* had a lethal bite on head by a tiger – his father and brother rescued him; Mostofa Howlader *(bottom left)* was bathing in a creek when a tiger jumped on him and pawed on head – the tiger left him when he tried to pull the tiger to deep water; Ziaul Gazi *(bottom right)* had a tiger-bite on his leg – when he was being dragged by the tiger towards deep forest, his father came to rescue – the tiger left him and took his father

7.4.2 People Killed and Injured by Tigers

As with the tiger, the actual number of humans killed every year is always much higher than the officially recorded (by the Forest Department) 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). Although this number is the highest in the world, considering the large number of people that work in the Sundarbans the probability of anyone being killed by a tiger is very small (Seidensticker and Hai 1983).

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; while biting the nape alone or together with the throat are less common and used only on relatively small prey. Karanth (2001) has observed kill drag distance up to 350 m in Nagarhole, India, although the average was around 50 m. In the Sundarbans I have recorded a much longer 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), Reza *et al.* (2002b), Khan (2004a) and Barlow (2009) reported the human casualties and some other aspects of tiger-human conflict in the Bangladesh Sundarbans. Since most of these reports were based on the same official 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. In comparison to their findings, my findings from the Forest Department records generally agree with the rate of human casualties, but the actual number of human casualties that I have recorded was quite different from the speculated figures reported by the above-mentioned authors. For example, based on the official records, on an average, Barlow (2009) reported that, a total of 22 humans were killed per year in the Bangladesh Sundarbans (30 per year in the Indian Sundarbans).

Based on official records of human casualties, Hendrichs (1975) found that most of the human deaths occurred in winter (November-February: 45.3%). I have also found higher proportion 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 people / 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. 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. Apart from the Sundarbans, a limited number of tiger attacks on people have been reported (Nowell and Jackson 1996, Hean 2000, Linkie *et al.* 2003, Nyhus and Tilson 2004).

My findings were quite similar to most of other previous reports on tiger attacks in different seasons (Chaudhuri and Chakrabarti 1972, Chakrabarti 1984, Siddiqui and Choudhury 1987, JJS 2002), different professional classes of people (Chaudhuri and Chakrabarti 1972, Chowdhury and Sanyal 1985a, Sanyal 1987, Siddiqui and Choudhury 1987, Reza *et al.* 2002b), and different age classes of people (Chaudhuri and Chakrabarti 1972, Chakrabarti 1984, Ahmed 2002a, Reza *et al.* 2002b, Nyhus and Tilson 2004) in the Sundarbans of Bangladesh and India.

Different authors put forward different theories about tigers turning into man-eaters in the Sundarbans. Some experts (Chaudhuri and Chakrabarti 1972, Hendrichs 1975, Sanyal 1987, Siddiqui and Choudhury 1987) suggested that drinking saline water might be the cause of tigers becoming man-eaters, but the work conducted by Chowdhury and Sanyal (1985) does not support this theory. Salter (1984) suggested a direct correlation between the man-eating habits of tigers with the availability of easy prey, i.e. the human, but others (Chowdhury and Sanyal 1985, 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 Chowdhury and Sanyal (1985) do not agree with this. Sankhala (1978) 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.

Tiger in search of prey at night in Kochikhali, Sundarbans (photo captured by remote camera-trap) – tigers prefer to hunt at night when it is easier to get close to the prey

Tigers often stray into the villages in the vicinity of the Sundarbans to kill cattle and very rarely humans: a tiger killed an elderly lady by breaking the house *(top left)*; tiger attempted to break a house *(top right)*; cattle left in open on the edge of the Sundarbans lures the tiger to stray into the villages *(bottom)*

Since none of the above-mentioned hypotheses have any conclusive evidence, I think the man-eating habit of tigers in the Sundarbans might simply be 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 it is possible 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).

Fence around Ghagramari Forest Office, Sundarbans - this type of strong fence can resist the tiger, but is rarely practiced in the villages around the Sundarbans

7.4.3 Public Knowledge and Belief

My interviewing reveals that very few of the local people had proper knowledge concerning the Bangladesh Wildlife Act 1974, which emphasizes that public awareness must be raised. The scenario is very similar in many human communities living with big cats in different parts of the world (Oli 1991, Hean 2000, Reza 2000b).

I found that a high proportion of the interviewed local people believed in the medicinal use of tiger parts (also pointed out by Reza *et al.* 2002b), 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 encouraged to poach the tiger.

Although tigers kill some people every year, my study as well as Reza *et al.*'s (2002) study reveal that people are not very hostile towards the tiger. Globally, the local people are generally hostile towards their big cat neighbours, because the big cats often turn into cattle-predators, and sometimes even attack people (Oli 1991, Oli *et al.* 1994, Saberwal *et al.* 1994).

Seeking spiritual protection from the tiger – although these do not ensure protection in reality, but help raise people's mental strength to work in a dangerous place like the Sundarbans: leader of a honey gatherer group praying to the folk deiti Bonbibi while entering the forest *(top)*, shaman or Gunin doing the ritual (collecting petioles of leaves) to ensure protection of a group of honey gatherers *(middle)*, and fishermen circled an area by spiritual red flags (treated by a Muslim spiritual leader called Hujur) so that tigers cannot enter *(bottom)*

Awareness programmes for tiger conservation organized by Project Sundarbans Tiger: discussion programme with villagers and school children *(top)*, demonstration of camera-trapping of the tiger *(bottom left)*, and competition of drawing tiger for school children *(bottom right)*

7.4.4 Consumption of Tiger Prey by 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 primarily on the fish catch. The proportions of animal protein (both non-prey and prey protein) consumed by different professional or income families was not very different. This was probably because of the wide availability and relatively cheap price of non-prey protein food items, especially fish.

The annual number of spotted deer poached and consumed in the villages around the Sundarbans was estimated following the total number of local families living very close to the Sundarbans, which was estimated by Haider (2004). The result will be different if the total number of families is different.

The rate of consumption of tiger prey reported by JJS (2002) (15,880 spotted deer, 40 wild boar, and 103 red junglefowl) appears to be an overestimate in comparison to what I have found. In other tiger ranges the rate of poaching of tigers and prey are different from the Sundarbans, depending on the local socio-economic and management conditions (Hartana and Martyr 2001, Linkie *et al.* 2003).

Pochabdi Gazi in the Sundarbans in 1982. Photo © A. Zaman Kamal

POCHABDI GAZI

Pochabdi Gazi was a hunter from a traditional tiger hunting family. He was born in 1917 in a small village called Sora in Shyamnagar, Satkhira, in the border of the Sundarbans, where he lived his entire life in a small cottage till his death on 10 October 1997. His actual name was Abdul Hamid Gazi, but he was known by his nick name Pochabdi Gazi. He had married twice and had a total of four sons and five daughters. His grandfather Kinu Gazi, father Meher Gazi (Putia) and uncle Nizamdi Gazi were all great hunters. Kinu Gazi had killed 97 tigers and Meher Gazi had killed 62 tigers until both were killed by the tiger. Nizamdi Gazi had lost one hand in tiger attack, but continued hunting until he was attacked again and was killed by a tiger. Pochabdi Gazi had killed a total of 57 tigers in his lifetime of which at least 20 were ferocious man-eaters. He had killed most of the tigers by setting gun-traps – the technique that he had mastered from his family. In this method he used to set the gun beside the tiger trail with a thread across the trail, with one end attached to the trigger of the gun. The gun was shot by the tiger itself when it unknowingly pulled the thread while walking along the trail. On 20 January 1987, Pochabdi hunted the last tiger in his life in Talpatti, Sundarbans, which had killed 26 people. Notably, until the promulgation of the Bangladesh Wildlife Order 1973, tiger hunting was not illegal and the hunter was rewarded, especially for killing man-eating tigers. Pochabdi had also guided tiger hunts for some high profile people. Therefore, he was highly respected by all and was given a job as a Boatman in the Forest Department in 1958.

DOMESTIC DOGS TO REDUCE TIGER-HUMAN CONFLICT

' 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 life indicator on a laptop computer'

– Ullas Karanth (2001)

Photo: Honey gatherers smoking the honeycomb – the domestic dog is there to warn the presence of a tiger

Chapter 8 DOMESTIC DOGS TO REDUCE TIGER-HUMAN CONFLICT

8.1 INTRODUCTION

The tiger (*Panthera tigris*) population in the Sundarbans is of particular importance for the long-term conservation of the species. Human deaths from tigers, however, make people hostile towards the species and this is one of the biggest challenges for tiger conservation in the Sundarbans. Reducing such casualties is crucial for the welfare of both people and tigers. A number of techniques (e.g. face-masks worn at the back of the head, electrified dummy humans and translocation of problem tigers) have been applied in the Indian Sundarbans (Gallagher 1983, Chowdhury and Sanyal 1985b, Sanyal 1987, Rishi 1988, Mukherjee and Tanti 2001, Mukherjee 2003), but none have been sufficiently evaluated and generally considered to be ineffective. In the Bangladesh Sundarbans, killing problem tigers seems to have been effective in the past (Hendrichs 1975), but the present status of the tiger and difficulty of correctly identifying the problem tiger make it unacceptable to kill any tiger. Limited fencing, lighting from raised watchposts and dredging water channels along the forest-village boundary have been tried in the Bangladesh Sundarbans (M.M.H. Khan personal observation), of which fencing and lighting might have had some use, but dredging could not limit tiger's movement since it can swim very well (Hendrichs 1975, Khan 2004a).

Left: Domestic dog has spotted fresh pugmarks of a tiger in the backyard in Chandpai beside the Sundarbans

Opposite: Adult male tiger in a grassy meadow in Katka, Sundarbans – a large predator like the tiger can easily kill a domestic dog, but a pack of trained dogs accompanied by their handlers can scare the tiger

It is necessary, however, to reduce the loss of human lives and property in order to increase the local support for carnivore conservation and to fulfil a moral obligation to reduce the human suffering caused by the carnivore (Dorrance 1983). It is also necessary to reduce the carnivore's unnatural mortality and decrease the population's vulnerability to extinction (Kenny *et al*. 1995, Treves *et al*. 2004, Chapron *et al*. 2008).

People living at the fringes of the Sundarbans depend either partially or completely on the area's natural resources. These people have little choice but to go into the Sundarbans, either legally (with the necessary permit from the Forest Department) or illegally. When people and tigers roam in the same area conflicts occur, and the level of tiger-human conflict in the Sundarbans is higher than anywhere else within the tiger's range (Hendrichs 1975, Nowell and Jackson 1996; Khan 2004a, 2004b).

Domestic dogs are used for various purposes, including in wildlife research and management (Zwickel 1971; Hunt 2000, 2003; Kerley 2004), but recommending their use to reduce the risk of being attacked by tigers requires experimental evidence that it is effective at a significant level. This possibility was tested in the Sundarbans of Bangladesh (Khan 2008c).

8.2 METHODS

The effectiveness of keeping one domestic dog with each group of people working in the Sundarbans to reduce the risk of being attacked by tigers was tested in 50 groups of local people of various professions ('Bawalis' or plant-product harvesters, honey gatherers and fishermen). Each group consisted of 5–7 people.

The dogs were local breeds, available in the villages along the edge of the Sundarbans. Many people keep these dogs at home both as pets and to ensure safety from intruders at night. The 40 dogs were selected out of a total of 67 and were vaccinated. Each dog was taken individually into the forest in an exploratory visit to test the dog's performance in detecting any wild animals observed. The 40 chosen dogs were selected based on their performance. Before being used experimentally the dogs were then taken to smell tiger trails and were shown any wild animal observed, with dry food given to the individual dogs immediately after any successful detection of a tiger or other wild animal.

In the Sundarbans people do not go into the forest for too lengthy periods of time and therefore 40 dogs were sufficient to accompany 50 separate groups of people at various times. This reduced the cost of maintaining the dogs. The dogs fed mainly on the residual food of humans, which is a normal practice in Bangladesh. The extra cost of keeping an individual domestic dog is thus negligible, amounting to ca. Taka 60 (US $ 0.9) per dog per month. During the 18-month study (August 2005–January 2007) all 40 dogs could not be sent to the Sundarbans and observed at the same time because of limited manpower, and thus the observations presented here took place in different seasons in different parts of the Sundarbans.

In the forest the dogs were almost always more excited than usual and were therefore leashed at all times so that they couldn't either run away or attack wildlife, but the leash was hand-held by the owner of the dog so that the dog could move with the team and check the surroundings. The signals made by the dogs were recorded as (1) signal for any wild animal, including the tiger, characterized by sudden excitement, together with quick and haphazard movements, and often with barks or grunts, or (2) signal, apparently, for tiger, characterized by fear and low noise, and moving close to the owner but not barking. The signals were verified either immediately, by observing the animals or their signs, or the next day (to avoid the risk of meeting the tiger face-to-face) by observing pugmarks or scats in case of tigers. The records were taken either by my self or by my research assistants who accompanied every group. Each dog was taken to the forest for 18 times in 18 months, spending a few days every time.

Later on, during January-December 2008 (for 12 months) three packs of dogs (five dogs in each, all were males because females often will have puppies and will not be suitable in packs) and handlers were created and trained to patrol the forest-village boundary in order to discourage the stray tigers coming into the villages. These dogs were selected through open audition and were trained by a professional dog-trainer from the USA (Marielle Schmidt) and by us. The training included basic obedience,

Training of domestic dogs and their handlers on detecting the tiger and driving the stray tiger from village to forest (*column-wise from top*): dog audition to select suitable dogs for training, detection of tiger scent in one out of four boxes, testing of performance in front of a fake tiger, handlers were trained to shout and show sticks to scare the tiger, and *(right)* testing of performance in front of real tigers in Khulna zoo

A group of honey gatherers with domestic dogs – the dogs will warn people about the presence of the tiger in the vicinity

working as a pack and tiger scent detection. The performance of the packs was tested by showing them a fake tiger (a person dressed and moved like a tiger) in the bush. Three of the dogs were taken to a nearby zoo (in Jahanabad, Khulna) to see how they react in front of the real tiger. The packs and the handlers were also trained how to systematically drive a stray tiger from the village to the forest. The patrolling took place several times a month, especially at dusk or at night when stray tigers normally try to come to the village. The handlers always kept big sticks and torches. Three packs patrolled in three areas of the forest-village boundary: Joymoni-Bouddamari in Chandpai Range, Ghagramari-Laowdob in Khulna Range, and Chandnimukha-Sora in Satkhira Range.

8.3 RESULTS

The mean number of signals apparently made in response to presence of wildlife (including the tiger) by the 40 dogs was 81.9 ± 26.7, of which 76.2 ± 26.3 (92%) were verified as being in response to a wild animal. Of a mean 12.4 ± 5.5 signals apparently made in response to presence of a tiger 8.0 ± 4.0 (62%) were verified as accurate. This suggests that the presence of domestic dogs significantly reduced the risk of being attacked by a tiger. In response to the dogs' signals people had time to assemble and shout and, if necessary, climb trees or return to their boat. The dogs' signals are, of course, their natural response, used by people as a warning. The dogs were particularly useful for honey gatherers, because when they smoke the honeycomb visibility becomes poor and they thus become especially vulnerable to attack by tiger. However, the dogs could not always distinguish tiger from wild boar (*Sus scrofa*) or spotted deer (*Axis axis*). In general the success of the dogs in signalling the presence of tiger gradually improved with time.

Table 8.1 Number of people killed by tigers and tigers killed by people in the Bangladesh Sundarbans during 2002–2006

Year	East Forest Division		West Forest Division		Total	
	No. of people killed	No. of tigers killed	No. of people killed	No. of tigers killed	No. of people killed	No. of tigers killed
2002	1	2	27	2	28	4
2003	1	2	18	1	19	3
2004	1	2	14	2	15	4
2005	2	1	11	0	13	1
2006	2	1	2	0	4	1
Total	7	8	72	5	79	13

I also interviewed 126 adult men (women normally do not work inside the forest) in and around the Sundarbans during the fieldwork to establish how they protect themselves from tigers and found that 47% of the interviewees use only spiritual protection measures such as wearing sacred beads or praying; 11% become more careful, 25% carry weapons such as large sticks, axes or guns, 5% shout, run or climb trees, 5% stop going into the forest forever after having a frightening experience, and 7% were unsure. The spiritual protection measures include keeping sacred beads and threads, hanging sacred red flags to the area they work in, worshipping the folk deities ('Banbibi' means 'lady of the forest', Gazi, Kalu, etc.), and depending on the spiritual power of a spiritual man in the team called 'Gunin' or 'Guni'. These measures have no practical use, so most of the people are potentially easy prey for a man-eating tiger. From the interviews it was clear that raising people's awareness of tigers so that they get rid of superstition is crucial. Therefore, other than advocacy for using domestic dogs, awareness campaign was conducted in the local villages to discuss tiger conservation and how to avoid confrontation with tigers. Since the livelihood of local people depends on the natural resources of the Sundarbans, they are convinced that without the tiger the forest would be cleared by poachers and they would lose their livelihood.

During the patrolling of three packs of dogs, together with handlers, it often happened that the dogs barked out towards the forest, but it was not possible to estimate the success because the patrolling took place at dusk or at night when it was very difficult to verify, in every case, whether the dogs barked out in response to a tiger or any other wild animal. The search for tiger pugmarks during the next day, however, indicates that one in every nine times the dogs barked out was probably in response to the presence of the tiger. The dog packs and handlers were ready to drive any stray tiger from the village to the forest, but there was no real situation to test them. Stray tigers did visit the villages, but they visited at night and returned to the forest before dawn.

Pack of trained dogs accompanied by their handlers are in patrol along the forest-village boundary – regular patrol like this will discourage tigers straying into villages

Firewood collectors with a domestic dog – the dog will reduce the risk of being attacked by tigers

8.4 DISCUSSION

Based on the records of the Forest Department an average of 15.8 people and 2.6 tigers were killed per year during 2002–2006 (Table 8.1). Notably, fewer people were killed in 2006, during this project, possibly because of the introduction of the use of domestic dogs and awareness raising, but there are many other factors (e.g. natural variation and erratic emerging and disappearance of notorious man-eaters) relevant to this. The actual number of human casualties, however, is always higher than the official number (Montgomery 1995, Helalsiddiqui 1998, Khan 2004a).

Using domestic dogs to save humans from tigers is innovative, although dogs have been used in related ways before. In the early 20th century Jim Corbett, the legendary hunter in Northwest India, often used his dog Robin to track tigers and leopards (Corbett 1944, 1957). In the Russian Far East trained dogs are being used to locate individual tigers by their scents (Kerley 2004), and trained dogs are also used to drive wild bears into the forest in some areas of the USA (Hunt 2000, 2003).

Using domestic dogs to save humans from tigers does not mean that humans will be saved by endangering the lives of dogs. Because each of the dogs must be leashed, a person (i.e. the owner) will always accompany the dog. Compared to a domestic dog, a human is easy to hunt and it is more gainful in terms of the amount of meat, so if a tiger decides to attack it will probably go for a human instead of a dog when both options are there. Another aspect to discuss is whether the tiger can be attracted by the dog and can increase the risk of confrontation. If we assume that noise is the main factor that drives the tiger's attention, the dog's noise is negligible in comparison to that of people. In the Sundarbans people almost always work in groups and they intentionally make a lot of noise, to 'deter' the tiger and to keep their mental strength high.

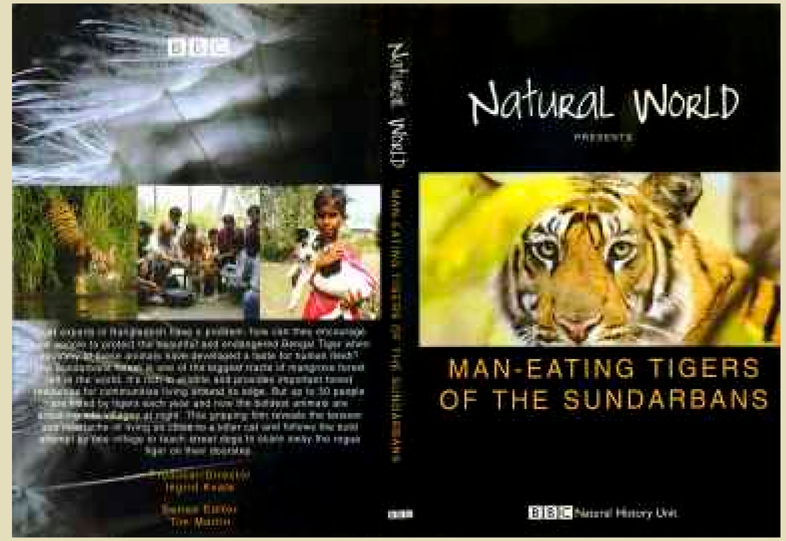
Use of domestic dogs in the Sundarbans will not only reduce human deaths but, in the long-term, will change the hostile attitude of many people towards the tiger and will improve the local support for tiger conservation. The experimental groups of people not only used dogs, but each person had a big stick. Although there is no data to prove the advantage of keeping big sticks, it raised the mental strength of people when they were in the tiger territory. The findings presented here are based on preliminary observations. As over 350,000 people work in the Bangladesh Sundarbans every year (Tamang 1993), tiger attacks on people is relatively rare in proportion to the numbers of people involved. Therefore, it was not possible to compare the risk of tiger attacks on groups that used the dogs with the groups that did not use the dogs.

Boy showing the injury mark on his dog's body due to tiger attack in Chandpai on the edge of the Sundarbans – the tiger can kill or injure any dog when the dog is alone

The local people were convinced that it was worthwile to keep the dogs with them, so many of them have started using the dogs in the fringe areas of the Sundarbans but due to administrative difficulties, they could not use the dogs in deep forest when we were not with them.

The effectiveness of patrolling with dog packs and their handlers along the forest-village boundary could not be quantified in terms of saying what proportion of stray tigers' visits to the village it reduced.

However, tiger pugmarks in areas where the dogs barked out and lack of tigers reported to visit the villages on the night of patrolling do indicate that trained dogs discourage the tiger from straying into villages. Since the trained dogs can succssfully drive bears from human habitations to the forest (Hunt 2000, 2003), it is expected that the dog packs and the handlers will be able to systematically drive stray tigers back to the forest.



MAN-EATING TIGERS OF THE SUNDARBANS

In 2009 the British Broadcasting Corporation's (BBC) Natural History Unit presented a one-hour documentary programme, entitled 'Man-eating Tigers of the Sundarbans', through BBC and Animal Planet channels. This programme had partially featured the use of domestic dogs to reduce tiger-human conflict along the boundary of the Sundarbans. The filming mainly took place in two small villages beside the Sundarbans: Chandpai in Bagerhat District and Burigoalini in Satkhira District. In Chandpai, ordinary domestic dogs and their handlers were trained to make a group in order to patrol along the forest-village boundary to discourage the stray tigers coming into the village and drive them back to the forest. The dogs were trained to work in a team, identify tiger scent and bark out when they spot the tiger. During the training the dogs had faced a dummy tiger, and real tigers in Khulna zoo. In Burigoalini, the dire situation of tiger-human conflict and the vulnerability of honey gatherers were shown in the film.

Epilogue

FUTURE FOR TIGERS OF THE SUNDARBANS

‘ Tigers ... are predestined by their perch at the top of the food web to be big in size and sparse in numbers. They live on such a small portion of life’s available energy as always to skirt the edge of extinction’

– E.O. Wilson (1993)

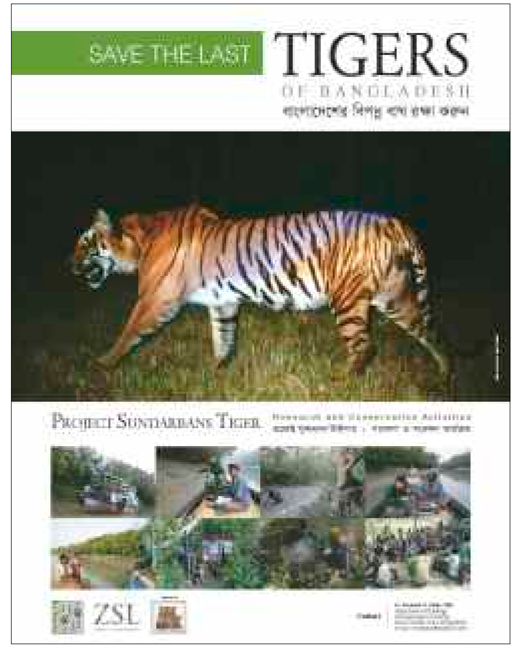
Photo: Sunset in Laowdob, Sundarbans – the crab catchers are returing home with their small boats

FUTURE FOR TIGERS OF THE SUNDARBANS

For hundreds of years people around the Sundarbans have lived with tigers (*Panthera tigris*) and today the majority of people want their children and grandchildren to do the same. In this part of the world the tiger is not just an animal of immense ecological and economic value, but also an intimate part of its history, culture and religion. In fact the tiger is so deeply rooted to the life of people that it is worshipped and respected by all communities living around the Sundarbans.

The Sundarbans is the only mangrove habitat in the world where wild tigers exist and this impenetrable swamp offers natural protection to healthy populations of tigers and their prey. Therefore, the Sundarbans tiger population is one of the very few that may survive in the long-term, provided that threats are controlled and the natural processes of the ecosystem are allowed to function.

Due to the rapid growth of human population around the Sundarbans, together with the growing need for natural resources, the tiger is now facing threats of various kinds, such as poaching, retribution killing and habitat loss. These threats can be eliminated or controlled by implementing the Bangladesh Wildlife Act 1974 and Bangladesh Tiger Action Plan 2009-2017. Scientific research and monitoring are also necessary to ensure informed management of tigers, while public awareness and public participation in conservation and management is vital. The findings that have been presented in this book will add significantly to the scientific knowledge regarding the tiger and its prey in the Sundarbans.



Opposite: Tiger occurs in various forest types in Asia, but it is threatened throughout its range

Left: Poster for raising public awareness for tiger conservation published by Project Sundarbans Tiger

Knowledge of tiger and prey densities, and prey population structure, which has been presented in this book, will be useful in reviewing the management system and in temporal monitoring of the status of tiger and prey populations in the Sundarbans. The highest density of the tiger was found in the southern Sundarbans where the spotted deer (*Axis axis*) density was higher and human disturbance was lower, therefore, poaching of spotted deer and human disturbance in tiger habitat in other areas of the Sundarbans must be better controlled in order to ensure the survival of the tiger.

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, so more emphasis should be given to the management of the spotted deer to maintain the tiger population. Scientific study of the wild boar (*Sus scrofa*) population is further required to know the reason for its relatively low density, despite apparently suitable habitats being available, so that initiatives to increase the wild boar population can also be taken so that it can provide an alternative food source for tigers. Re-introduction of the wild water buffalo (*Bubalus arnee*; 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 as a feral buffalo population, which already freely graze in the northern Sundarbans for about six months and are probably already familiar to the tiger (since tigers sometimes prey on them), would be relatively cheap and easy.

Top: Monsoon rain flooding the Sundabans

Habitat diversity in the Sundarbans should be maintained since it is crucial for the maintenance of some activities of the tiger and initiatives should be taken to increase the habitat diversity wherever possible. While mangrove woodlands are popular for tigers, so are other habitats especially grasslands. It was observed that the grassland pockets in the southern Sundarbans are good for the spotted deer (areas with grassland pockets are high density areas for the spotted deer, and so for the tiger). Therefore, sungrass cutting should be allowed, as otherwise the sungrass will die and the areas will be gradually encroached by woodlands and bushes, but the sungrass cutters should be allowed to stay and work in the Sundarbans for only two to three months as a large number of sungrass cutters for a long period of time disturbs wildlife.

Since the breeding peak of tigers is probably in winter, this season should remain undisturbed but unfortunately, winter is also the main harvest and tourist season

when the disturbance is more intense. Presently tourists can go anywhere in the Sundarbans after taking an ordinary entry permit and paying revenue but it is recommended that some tourist zones should be demarcated (which will exclude the important areas for tigers) and tourists should be allowed only in these areas, while controlled ecotourism should be developed so that both the Government and the local people benefit financially.

In order to reduce the conflict between tigers and humans, local people should be motivated and educated, alternative livelihoods should be made available (e.g. local ecotourism organisations, cottage industries, agroforestry, etc.) and existing anti-poaching regulations should be implemented properly for high rates of poaching of the spotted deer (good demand for deer meat exists in the locality) is the biggest threat to the existence of tigers. In order to strengthen local support for conservation, compensation should also be given to the families of victims of tiger attack for the loss of their relatives, serious injuries and the loss of cattle to tigers but the compensation should be strictly controlled, so that there is no fraud.

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 domestic dog on leash (so that it gives a signal to people when a tiger is around and people get some time to climb up a tree, get together or get back to the boat). Dangerous professions like honey gathering (honey gatherers are more vulnerable to man-eating tigers) should be allowed only under certain conditions so that the risk is minimised. Since winter is the main conflict season, work permits should be reduced in winter as much as possible.

Packs of trained dogs, together with handlers, should patrol along the forest-village boundary so that tigers are discouraged to stray into villages. The groups will also be able to drive the stray tigers from the village to the forest with a plenty of noise and light. This will teach the tiger not to stray into villages. Additionally some traditional practices can be helpful such as: fencing, watchposts with guards having fire-crackers and lights, and excavation /restoration of canals along the forest-village boundary (this will not stop the tiger, but will reduce the trespassing of cattle and people into the forest). Furthermore, the local people should be encouraged not to attack the stray tiger, for indiscriminate killing of stray tigers is a significant threat to tigers and people attack stray tigers even if it has not done any harm to people or cattle.

The Forest Department should strengthen its capacity (by recruiting people with proper training and motivation, and adding modern equipment and vehicles) and develop local intelligence networks to collect information to aid detection and prevention of poaching. Some community services like hospitals and schools should also be provided by the Forest Department in order to reduce the stress between the Forest Department and the local people, and more local people should be employed in the Forest Department and in the tourism industry so that the local community realises the benefits of conservation.

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

– John Seidensticker and Abdul Hai (1983)

Photo: Honey gatherers smoking the honeycomb – the domestic dog is there to warn the presence of a tiger

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Left: Tiger is one of the most beautiful creatures on earth – we simply cannot let it go extinct

Ritual for protection from
the tiger in the Sundarbans

NOTES

Tigers of the Sundarbans are the only tigers that live in mangroves, yet they have the highest probability of persistence in the long-term if we can ensure their scientific management. This magnificent creature is the icon of the natural heritage of Bangladesh where it has become the prestigious National Anima. Information on this unique tiger of unique habitat, however, is very limited. *Tigers in the Mangroves* is a comprehensive, scientific and eminently readable book that presents the basic information on tigers and the Sundarbans as well as research findings on various aspects of tigers and their conservation. The author of this book is a leading researcher of tigers and other wildlife of Bangladesh.

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