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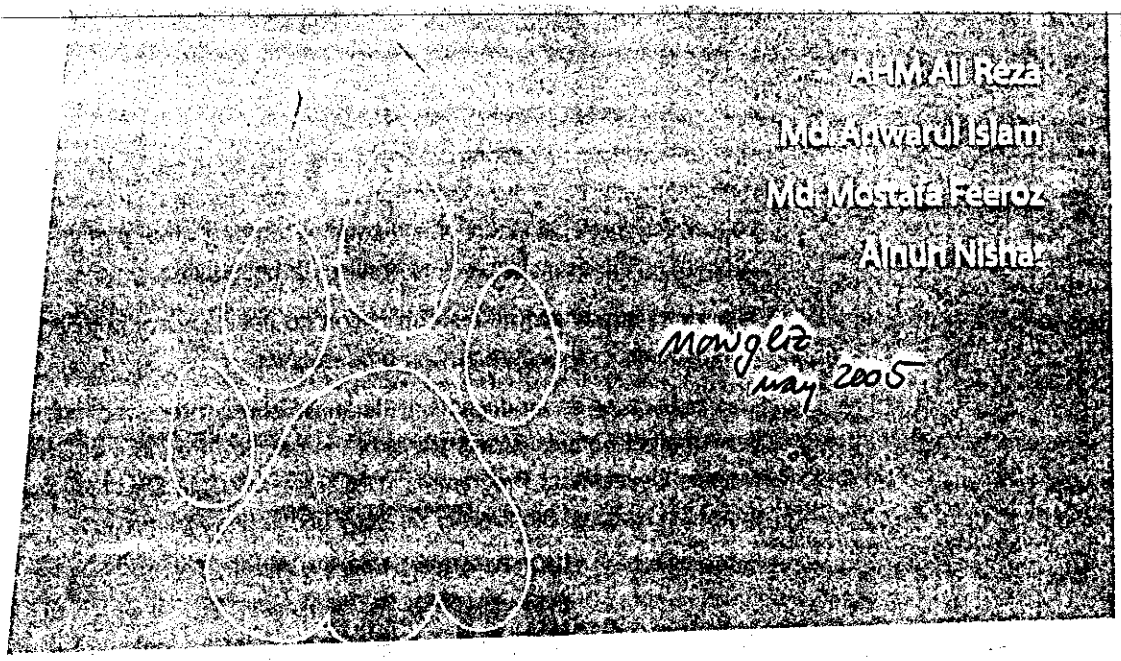
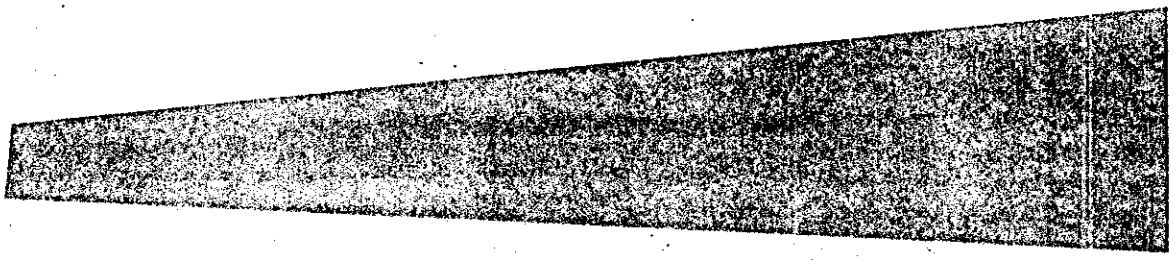


BENGAL TIGER IN THE BANGLADESH SUNDARBANS



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Bangladesh Country Office
2004

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FOREWORD

Like many of the world's most recognized and beloved creatures, tigers are in trouble. At the beginning of the twentieth century there were more than 100,000 tigers throughout most of Asia. Today, at the beginning of the twenty-first century, between 5,000 and 7,000 tigers live in the natural environment of South Asia and share the habitat with billions of poor people. Tigers used to roam across the entire Indian subcontinent, for example; but they are now restricted to increasingly isolated tracts of forest surrounded by farms, villages, and cities. Asia's human population has exploded in the past 100 years, and this has placed extraordinary pressure on remaining wilderness. As humans convert more and more land to meet their needs for settlement and food, there is less room for tigers to live, hunt, and survive. Therefore, conservation of tigers in their ranges is a global concern. Without proper scientific field knowledge, planning and management, conservation of this magnificent predator is literally impossible. Unlike the tiger range in most other countries, the tiger range in Bangladesh - the Sundarbans mangrove forest - has remained virtually unstudied.

IUCN-The World Conservation Union, Bangladesh Country Office in collaboration with Jahangirnagar University took an initiative to carry out research on the Bengal Tigers in the Bangladesh Sundarbans a few years back. With support from the British Petroleum and the British Council, Bangladesh, a study on the ecology of the Bengal Tigers was launched in January, 1999. A graduate student, the first author, AHM Ali Reza, as a part of his M.Sc. degree at the Department of Zoology, Jahangirnagar University, Dhaka, Bangladesh conducted fields studies under supervision of Professor Anwarul Islam and Dr. Mostafa Feeroz, the second and third authors respectively. This was the first ever indepth study on ecolgy of tigers in the Bangladesh Sundarbans. Afterwards, IUCN-Bangladesh received another financial grant from the WWF-International to perform a follow up study. This time emphasis was given on ecology of prey species of the tigers in the same study area and two post-graduate theses were completed. This book is mainly based on the findings of the first study with some data from the other two theses produced later on.

The book foucses on: i. the status of the habitat of the Bengal tiger in the Bangladesh Sundarbans; ii. biological details of the tigers in the Sundarbans mangrove forest; iii. the status of the principal prey species of the Bengal tigers in the Sundarbans; iv. the human-tiger interaction in the Sundarbans with a view to minimize conflicts; and v. the ways for improved management and conservation of the Bengal tigers as well as their habitat, the Sundarbans.

The terrain of the Sundarbans is totally different from terrain found in Ranthambhore and Nagarahole National Park in India or Royal Chitwan National Park in Nepal, where the Bengal Tigers have been studied extensively. The mangoves presents one of the most difficult terrains in the world for conducting scientific research. A number of books and research papers on the various aspects of ecology of the Bengal tigers are available; but their are only a few published documents on various aspects of the Sundarbans tigers. This makes the Sundarbans animal, as well as its habitat more mysterious, and difficult to understand. Hence, to fulfill the demand of the academic and scientific community, as well as the general public, this book is being published to present scientific information on the mysterious life of the Bengal tiger in the Bangladesh Sundarbans mangrove forest.

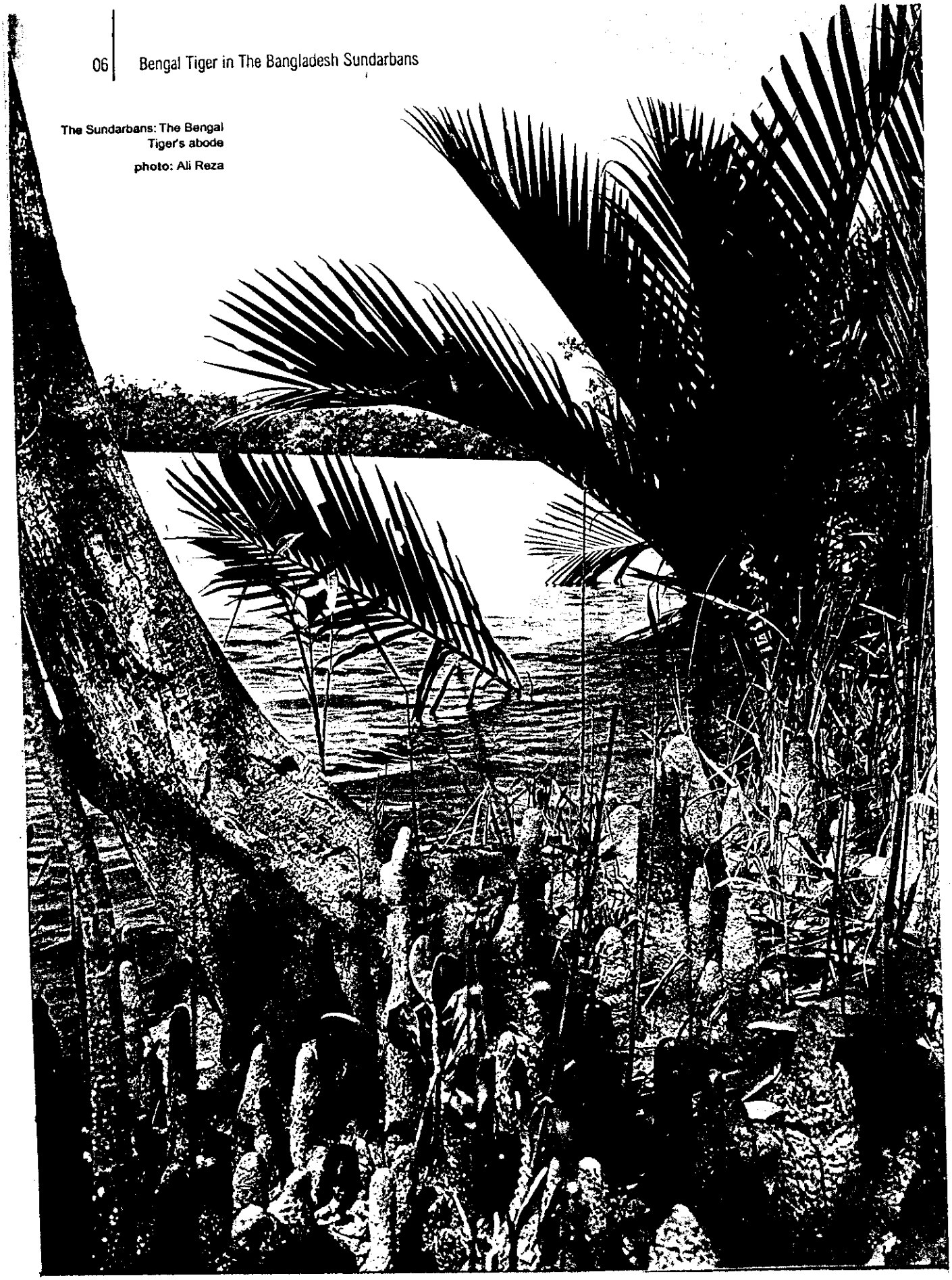
Dhaka
June 2004

Ainun Nishat
Country Representative
IUCN Bangladesh

Tigers are the only big cats with stripes, which have evidently evolved to provide a camouflage in the species' wide range of habitats. Stripes, like the spots and rosettes on many other Felid species, break up the image of an animal's body in long grass or in the dappled light of the forest. According to one theory, the stripes of tigers are actually elongated spots (Moulton and Hulsey 1999). The appearance of these large cats is unmistakable, with their striped patterning extending down the sides of the body. The ground colour is quite variable, from a pale yellow through to reddish ochre, depending on the area of origin. The underparts tend to be white. There is a large size difference between the different subspecies of tigers. The smallest subspecies was the Javan tiger, which is now extinct and the largest, and most massively built subspecies is the Siberian tiger, which has males that may weigh up to 384 kg.

The Siberian Tiger
photo: from Internet

Tigers can be found in a wide variety of environments, although they require adequate cover so that they can ambush their prey - large herbivores, which must be available in the area. They are rarely found far from water. The size and potentially aggressive nature of tigers towards people and particularly to farm livestock, has meant that their conservation, following decades of big game hunting, represents a particular challenge (Alderton 1993). The Bengal tiger may be very much similar to other subspecies of tigers in appearance and basic behaviour. However, its swampy habitat, scarcity of substantial prey species, tendency to kill humans, unique adaptibility and semi-aquatic life, and ability to



The Sundarbans: The Bengal Tiger's abode

photo: Ali Reza

drink saline water make the animal different from other tiger races. Scientists put these Sundarbans tigers alongside *Panthera tigris tigris* subspecies, but this short-furred, dark and closely striped animal of light built demands further DNA investigations.

Over the last century the tiger's landscape has changed dramatically. An expanding human population has put increased pressure on the tiger's habitat, its prey, and on the tiger itself. Forests and grasslands have been lost, degraded and fragmented, and ungulate populations have declined precipitously, both in abundance and distribution. Tiger numbers have also declined, and almost all remaining populations are now small and isolated. In the last 25 years, these changes have accelerated, increasing concern for the continued existence of the tiger (Sunquist *et al.* 1999).

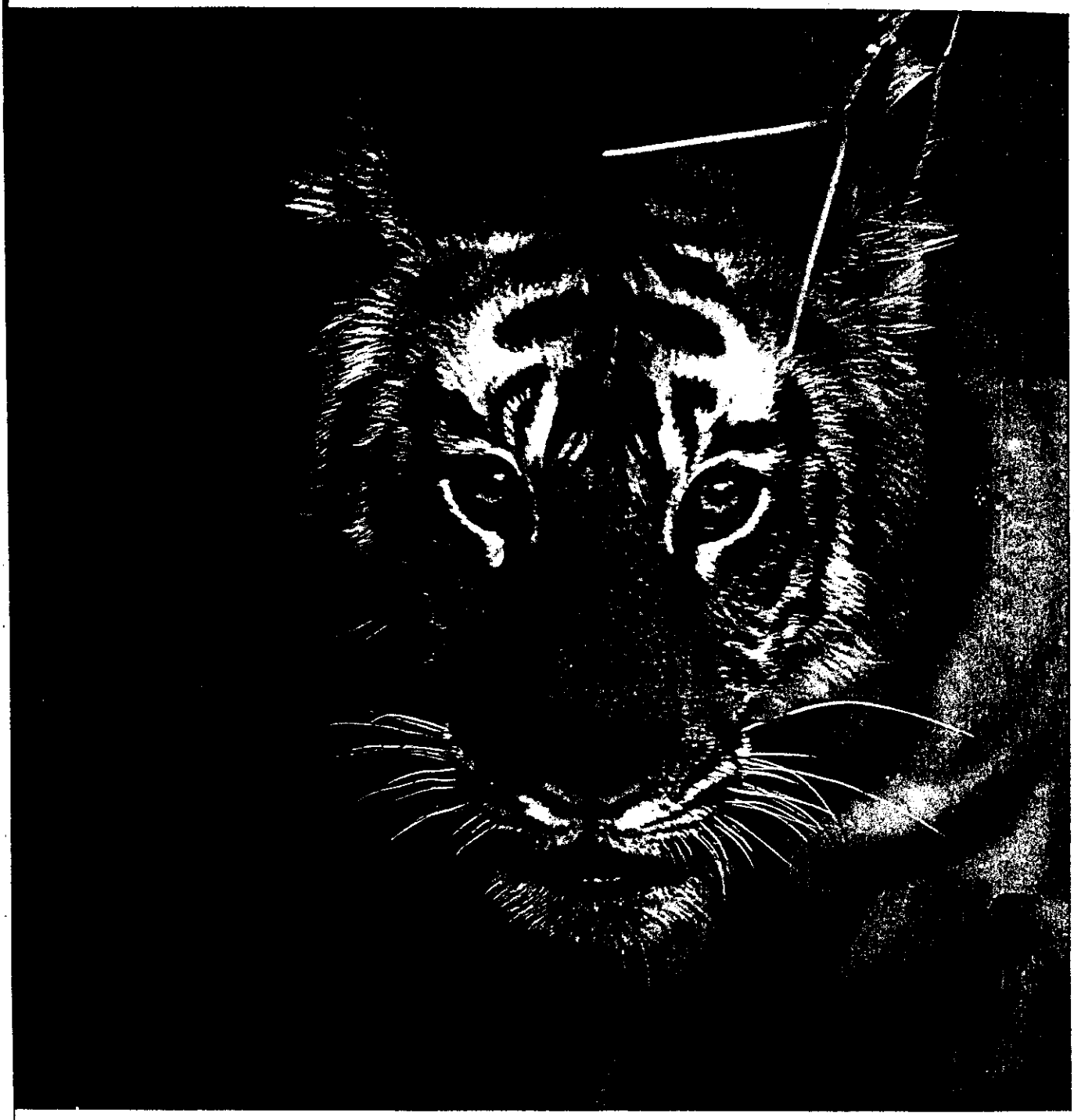
In Bangladesh, only the Sundarbans mangrove forest has a viable tiger population at the present. Although this tidal ecosystem is not a suitable habitat for the tigers, they were forced to take shelter in this habitat of Bangladesh due to the human disturbances and the loss of other types of forestlands. Mangrove forests of the world reach their maximum development and greatest luxuriance in parts of South-east Asia, Malaya, Sumatra and parts of Borneo where rainfall is high and not seasonal (Macnae 1968). The Sundarbans is the southern portion of the Ganges delta, that was extended, in eralier days, about 270 km, along the sea coast of the Bay of Bengal from the estuary of Hoogly to that of the Meghna and running inland to a distance of 96 to 128 km (Chakrabarti 1992).

THE BENGAL TIGER

The Bengal tiger is the largest obligate terrestrial carnivore in all of the mammalian assemblages in Asia (Seidensticker *et al.* 1999). The average longevity of tiger varies from 15 to 20 years. This is based on the findings of previous researchers, e.g. one female tiger was killed in Chitwan when it was at least 15.5 years old (McDougal 1977). Jones (1977) mentioned the longevity of tiger was up to 26 years. The gestation period ranges from 98 to 112 days. The average weight, total length and skull length among the tiger subspecies (adult specimens) are highly variable. The average weight of the Bengal tiger ranges from 180 to 258 kg in males and 100 to 160 kg in females. The total length measures from 2.7 to 3.1 m in males and 2.4-2.65 m in females, and the skull length ranges from 329 to 378 mm in males and 275 to 311 mm in females (Mazak 1981).

Evolution

Evidence for the evolution of the tiger comes from fossil remains and phylogenies.



The tiger (*Panthera tigris*) is the largest of all the thirty-seven species of wild cats
photo: S.K. Tiwari / Sanctuary

Cats of the genus *Panthera* probably evolved within the last five million years or so. On the basis of a cladistical analysis of various skeletal and anatomical characters, fossil remains and biogeography, Hemmer (1981) suggested that the original pantherine radiation occurred in eastern Asia, although there is fossil evidence to support an African origin for the lion and leopard. However, the tiger is thought to have an east Asian origin (Kitchener 1999).

Reconstructing the fossil history of tigers is difficult owing to the fragmentary nature of remains, risk of confusion with closely related species, and uncertain dating of finds. The oldest fossils are from northern China and Java (Hemmer 1971). Early tiger fossils have also been recorded from the Jetis Beds of Java, which have recently been dated to between 1.66 and 1.81 million years old (Hemmer 1971). Therefore, by the beginning of the Pleistocene and possibly as long as two million years ago, the tiger already had a wide distribution in eastern Asia. It is commonly stated that the center of evolution for tigers was northern China (Mazák 1981; Hemmer 1987), but the fossil evidence is equivocal about the wide distribution of the species at the beginning of the Pleistocene. Although it is unclear where the tiger first diverged from other *Panthera* cats in eastern Asia, it is presumed to have spread north into northeast Asia, and south into the Sunda Islands and the Indian subcontinent (Hemmer 1987).

Taxonomy

Like most other groups of organisms, felids have been the subject of a number of revised classifications since Linnaeus (1758), who in the 10th edition of his *Systema Naturae*, laid down the first foundations by naming the genus *Felis*. The modern age of felid classification began with Severtzov (1857-58). He discussed the evolution of carnivores in general and felids in particular, with special emphasis on biogeography and their relationship to felid classification. It should be noted that most of the names used by Severtzov, whether newly coined by him or adopted from earlier authors, are still in use for various felid taxa. While Severtzov was publishing his work, Gray (1867) was completing his studies of felid classification. In Gray's classification, the pantherines are separated into four genera: *Uncia* for the snow leopard; *Leo* for the lion; *Tigris* for the tiger; and *Leopardus* for the leopard, jaguar, African golden cat and puma. Some semblance of order was created out of the nomenclatural confusion by Pocock (1917). He separated the Felidae into three subfamilies: Felinae for the small cats, Pantherinae for large (roaring) cats, and Acinonychinae for the Cheetah. Within the Pantherinae, Pocock (1917) distinguished two genera: *Panthera* for the lion, tiger, leopard, and jaguar; and *Uncia* for the snow leopard. Within the Felinae, he tried to arrange Severtzov's and Gray's genera in an orderly manner. In summary, Pocock's genera are to a

great extent congruent with those recognized at present. His *Panthera, Felis*, and *Lynx* (almost) are those currently in use as are many of his smaller groups. However, Pocock's aim was strictly a classification, and he did not go beyond this scheme to look at the interrelationships of the groups he produced. On the other hand, Hemmer's *Panthera* includes the same four species as Pocock's, but he considers the tiger more distantly related than the other three, along with the snow leopard, *Uncia*. Another recent work in the field of Felid systematics and classification is that of Salles (1992). Salles' second large group is the pantherine, which beside *Panthera* also includes the clouded leopard, cheetah, snow leopard, puma, and jaguarundi. The view of the Felidae as including only the genera *Felis, Panthera,* and *Acinonyx* is only seen in the non-specialist literature and should be laid to rest once and for all.

So, after this long debate, it is best to say the Bengal Tiger, *Panthera tigris tigris* (Linnaeus 1758) is a large cat under the order Carnivora; family Felidae and sub-family Pantherinae. Also it is known as 'Royal Bengal tiger' possibly due to its place of pride among the fauna of the Bengal. In very few occasions, it is also referred to as the Indian tiger.

The Clouded leopard (*Neofelis nebulosa*), a critically endangered native cat

photo: Ali Reza

Population

The population of 5 existing tiger subspecies in the world is estimated to contain between 5,183 and 7,277 individuals (Table 1.2). The world's Bengal tiger population is estimated at 3,176-4,556 animals (Seidensticker *et al.* 1999). The figures are largely 'guestimates' because naturally secretive tigers are difficult to count in their habitats (Jackson 1993). In most of the 14 range countries the tiger has adequate legal protection, but enforcement is deficient. These 14 range countries are Bangladesh, Bhutan, Cambodia, China, India, Indonesia (Sumatra), Korea (North), Laos, Malaysia, Myanmar, Nepal, Russia, Thailand, and Vietnam (Table 1.1). International commerce in tigers and their products is banned under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). However, only 6 of the 14 range countries are party to CITES (Jackson 1993).

In Bangladesh, the Sundarbans supports a healthy population of the Bengal tiger. Estimates vary. According to Mountfort (1969), the leader of WWF expedition to Bangladesh, tiger population was said to be between 50 to 100, an informal guestimate. Subsequent studies based largely on extrapolation of track counts from sampled areas have pointed to higher numbers.

Hendrichs (1975) estimated tiger population at 350 in the Sundarbans based on three months of detailed study in three areas: compartments 29, 30 and 31 in the

north; compartments 46, 47 and 50B in the northwest and compartments 3, 4 and 6 in the northeast. He suggested that the tigers were fairly evenly distributed throughout the forest at a density of about 1/10 km^2. The Bangladesh Forest Department estimated the tiger population at 450-600 (Salter 1984), whereas Gittins and Akonda (1982) mentioned the number to be 430-450 (they apparently used the Forest Dept. estimates). A more recent estimate by Jalil (1998) puts the number at 362. This is the result of a methodical investigation on tiger population, which was carried out in 1993. The estimation was made by studying pugmarks in 350 km^2 in the northeastern part of the Sundarbans. The density was determined at 1/10.9 km^2. Male-female ratio was 1:2-3 and juveniles and cubs were found to make up 40% of the population.

Table 1.2 Physical features and estimated population of the eight sub-species of tiger

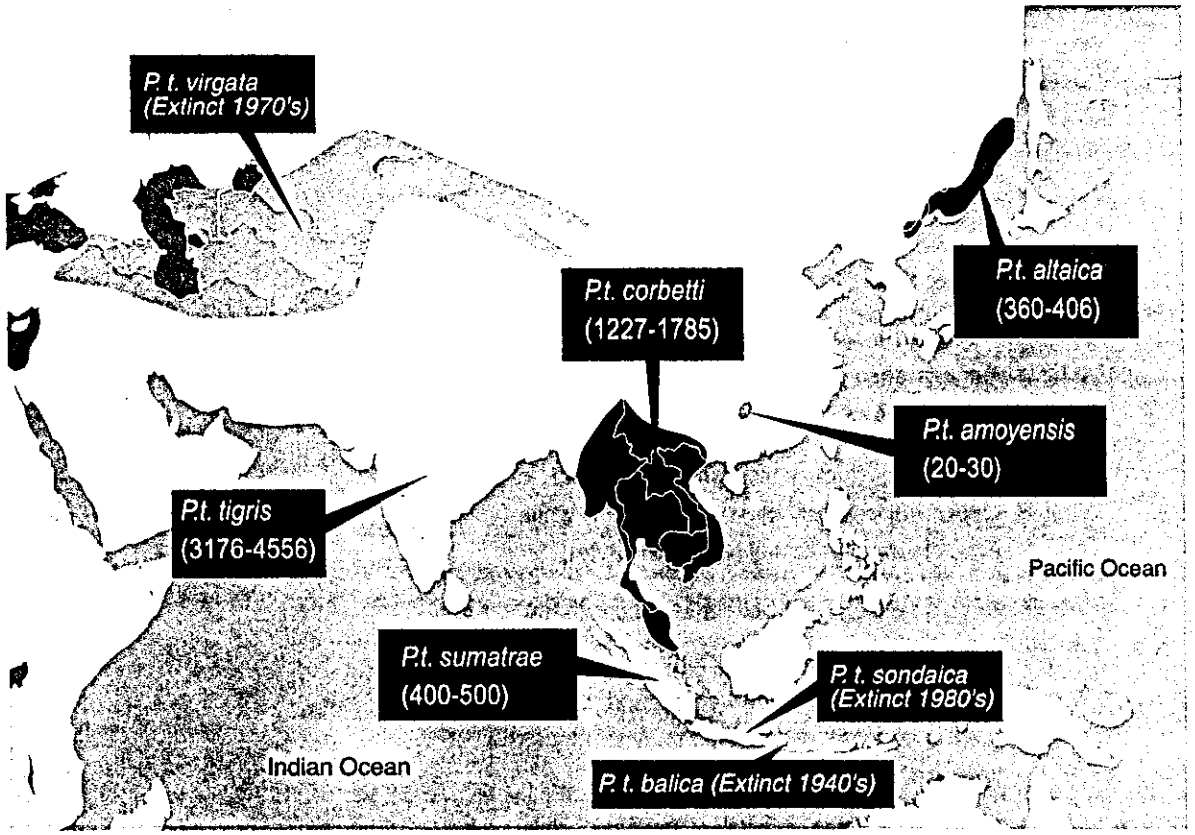
Sub-species	Physical features	Estimated population
Bengal tiger	Reddish-yellow to rust brown, underside whitish, stripes black, ears black with white spots on outside	3176-4556
Indo-Chinese tiger	Darker than Bengal tiger, lighter than South Chinese tiger	1227-1785
Sumatran tiger	Smaller than Bengal tiger, stripes closer, cheek hair long, short neck mane	400-500
Siberian tiger	Coat long, thick yellowish without red in winter but reddish in summer, belly white extends onto flanks, tail black and white	360-406
South Chinese tiger	Reddish-ocher, light belly mane long, mape, mane short	20-30
Javan tiger	Smaller body size, darker ground colour, greater number of flank strips and stripes narrower	Extinct in 1980s
Caspian tiger	Greater numbers of stripes but less wide, longer fur and broader occiput, more brownish on sides	Extinct in 1970s
Bali tiger	The smallest tiger	Extinct in 1940s

Source: Seidensticker *et al.* 1999

Distribution

The tiger is an endangered big cat, whose demographic status is uncertain across its entire distributional range, spanning 14 Asian countries (Table 1.1). The geographical distribution of this animal once spanned Asia, from eastern Turkey to the Sea of Okhotsk (Map 1.1). Over the last century its range has been greatly reduced, but tigers are still found in a broad variety of forest types, including dry deciduous, moist deciduous, semi-evergreen, wet evergreen, riverine, swamp, and mangrove forests (Sunquist *et al.* 1999). They are also found in diversified habitats, e.g. coniferous-deciduous forests of eastern Russia, in the tall-grass habitats south of the Himalaya, the tropical rainforests of Sumatra and Malaysia, and swampy mangrove forests of Bangladesh and India.

map: 1.1 Global atlas showing presence of eight tiger subspecies (Source: Seidensticker *et al.* 1999)



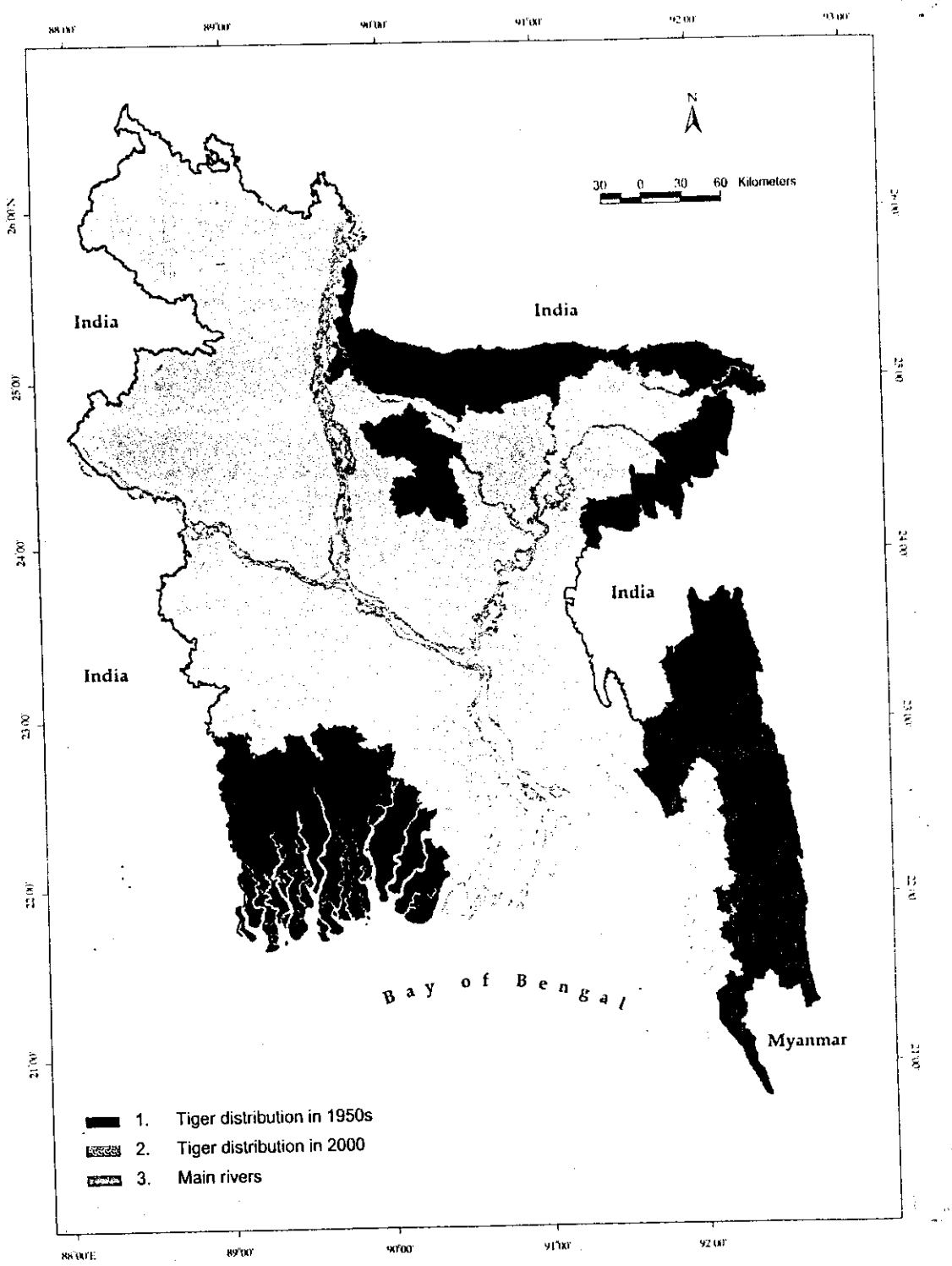
Among the Five existing sub species of tigers, the Bengal tiger is found only in the Indian subcontinent, i.e. in India, Bangladesh, Bhutan, Myanmar (western), Nepal and China (Table 1.1). It occurs in humid evergreen forests, dry open jungle, and grassy swamps of the terai, while in the Sundarbans, it leads an almost amphibious life in a saline terrain of trees, mud, and water. It is found even up to an altitude of 3,050 m in the Himalayas. Three things are essential for the tiger: i) large animals

to prey upon, ii) ample shade as shelter, and iii) water to quench the thirst (Prater 1971).

In Bangladesh, once the Bengal tiger was found all over the country, but is now confined to the Sundarbans mangrove forest in the southwest of Bangladesh (Map 1.2). The last tiger outside the Sundarbans, according to the Forest Department, was shot in the *sal* (*Shorea robusta*) forest of Thakurgaon district (northwestern Bangladesh) in 1956, in the Bhawal Madhupur tracts (central Bangladesh) in the

Sitakunda semi - evergreen forest: a former abode of the Bengal tiger

photo: Ali Reza



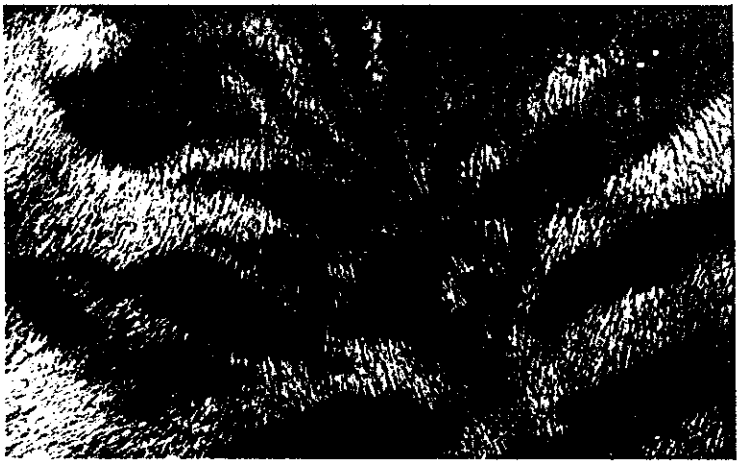
Map 1.2: Tiger habitat shrinking rapidly

70s, in the mixed evergreen forests of Kassalong of the Chittagong Hill Tracts (southeastern Bangladesh) in 1976, and in the mixed evergreen forest of Pathalia hills of Sylhet district (northeastern Bangladesh) in 1985 (Mawla 1996; Islam 2000). However, during the 21st century, the tigers in the wild survive only in the Sundarbans mangrove forest of Bangladesh, though there are some unconfirmed reports about its existence in the Chittagong Hill Tracts in the southeast of the country.

STUDIES ON THE BENGAL TIGER

Modern research on the Bengal tiger may be said to have begun in 1963-65, just slightly more than a generation ago, with Schaller's studies in Kanha National Park in India, which he later published in his book, *The Deer and the Tiger (1967)*. Schaller's base-line research convincingly established the ecosystem approach for analyzing of predator-prey relations. He reported on numerous aspects of the natural history of tigers, including population dynamics, home range, social organization, communication, reproduction, hunting and killing, and feeding ecology.

In the 1970s, Sunquist (1981) pioneered the technique of radio-telemetry and conducted his research in the Royal Chitwan National Park in Nepal and also Kanha National Park in India, in order to determine the movement patterns and associations of tigers in that area. An even more recent innovation appeared in the 1990s: the use of 'camera-traps' as an aid to the identification of individual tigers and to refine density estimates. Camera-trap analyses have been carried out in Nagarahole National Park in southern India, as well as in a number of other forests (Pench, Kanha, Kaziranga, Namdapha, Bhadra, Ranthambore, Bandipur, and even an effort was made in Indian Sundarbans) by a pioneer scientist of successful camera-trap technique, Karanth (1995).



A close view of stripes which differs for each individual

photo: Ali Reza

The other long-term ecological studies of the Bengal tiger were conducted by Seidensticker (1976), McDougal (1977), Panwar (1979a), Smith (1984, 1993), Tamang (1982), etc. But these long-term studies were conducted in evergreen or undulating hilly terrain forests, which differ from the swampy tidal mangrove forest of the Sundarbans.

So far, no systematic study on ecology of the Bengal tiger have been reported. Various other aspects, such as status, habitat insularization, and man-eating behaviour of Bengal tiger were studied by Hendrichs (1975), Seidensticker (1986), and Siddiqui and Choudhury (1987), respectively. Recently, some studies were conducted by Reza (2000), Islam (2001), Neamotullah (2001), and Reza *et al.* (2002, 2002a, 2001, 2001a and 2000) in the Bangladesh Sundarbans.

SUNDARBANS: THE MANGROVE TIGERLAND

SUNDARBANS:
THE MANGROVE TIGERLAND

It is not exactly known how the name 'Sundarbans' came about. According to ancient history, the name 'Sundarbans' is derived from the two Bangla words ***'Samudra Ban'*** which means 'Sea Forest', because this vast tract of mangrove forest is situated in a delta right off the sea - the Bay of Bengal. Another more rational and popular theory is that the word 'Sundarbans' is derived from another two vernacular words: ***sundri*** (*Heritiera fomes*) and ***ban*** (forest). Thus, Sundarbans is the forest of sundri trees. In the Mughal times, it was referred to as *Bhati* (meaning 'extreme south').

The *Sundri*, the predominant Sundarbans species

photo: Rubaiyet & Elisabeth Mansur

The Sundarbans mangroves grow on soil formations of recent origin consisting of alluvium washed down from the Himalayas at north (Karim 1994). This mangrove forest is the junction of fresh water ecosystems dominated by the melting snows of the Himalayan and Tibetan Plateau and the run-off of the monsoon rains flowing down in streams and rivers with the coastal and marine ecosystem influenced by tidal regime of the Bay of Bengal. The three mighty rivers, the Ganges, Brahmaputra and Meghna, meet here with the sea, to create an 80,000 sq. km delta fringed by the single largest tract of productive mangrove forest in the world (Chakrabarti 1992). Moreover, the Sundarbans is also the only mangrove tigerland in the world where the tiger occupies the top of both aquatic as well as terrestrial food webs (De 1999). The whole Sundarbans has been well known for its man-eating tigers since 17th century.

The Bengal basin experienced an easterly tilt on account of geotectonic movement from the 12th to the 16th century and the Ganges, which used to flow through the Sundarbans, ran along the Padma channel on the east into Bangladesh. Geological evidence accounts for the changing dynamics of the Ganges, and reveals that during and towards the end of the Pleistocene, the Ganges and its tributaries were building deltas to the west of Kolkata. The course of the Ganges gradually shifted eastward. The Ganges appears to have built a delta in the Jessore area, while extending it later into the present Sundarbans (Karim 1994).

Perhaps, no other plant community in the world has, attracted more scientific attention than the mangrove ecosystem, primarily on account of its growing in a highly stressed habitat due to high amount of dissolved salts in the substratum and the water. The Sundarbans is typical mangrove forest. So, the dissolved salt in the substratum and the water periodically cover the root system during high tides and

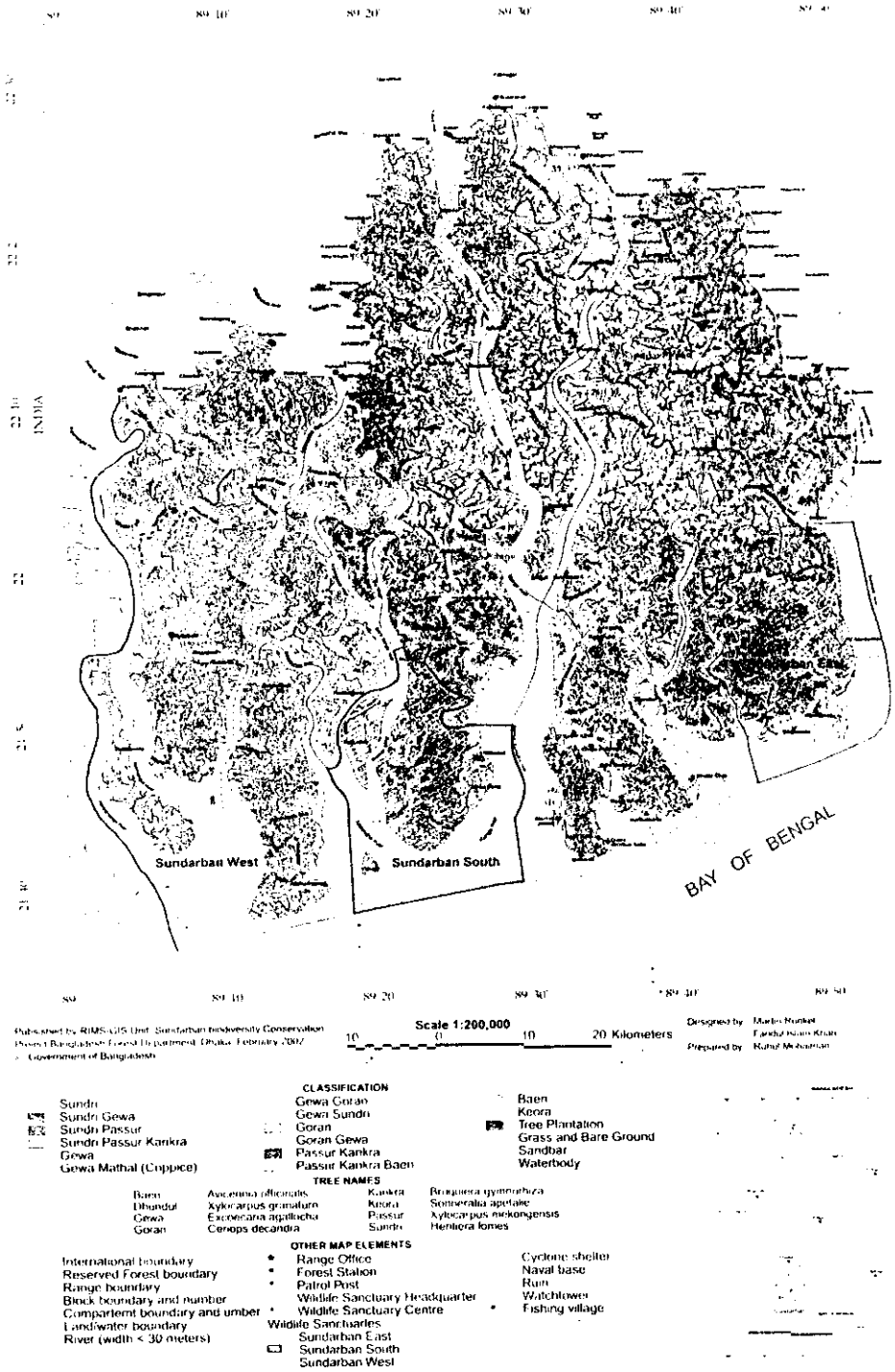
that is why a very limited amount of aeration is available. Also the presence of various types of aerial roots, primarily for aeration and viviparous seedlings hanging on most of the trees are characteristic features.

The Sundarbans has also a complex drainage pattern made up of inter-connected rivers, cross channels, and estuaries and is affected by heavy seasonal rainfall, inflow of water and sediments. Geological and tectonic activity, together with past and present drainage patterns have been instrumental in defining the present geomorphology of the Sundarbans. In places, the mangrove tract within Bangladesh now exhibits the special ecological effects of sea water undeterred by any flow of freshwater. Thus, the Sundarbans has a unique biogeographical characteristic.

The *Sundri* pneumatophore, a species identification tool

photo: Ali Reza

The Sundarbans is situated in the southwest of Bangladesh, and extends from the international boundary with India along the Harinbhanga-Raimangal-Kalindi river system in the west and Baleswar river in the east. At present only the Baleswar River is directly linked to the river Ganges and so, it is responsible for the flow of freshwater in the eastern part of the Sundarbans. About 150 years ago, the Sundarbans was twice its present size (Kabir 1999). At present the Bangladesh Sundarbans covers an area of about 5,770 km^2 of which 4,016 km^2 is land and the remaining 1,761 km^2 are under water, in the form of rivers, canals and creeks (Hussain and Karim 1994). About 62% of the forest lies between latitudes 89°00′ and 89°55′ E and 21°30′ and 22°30′ N longitudes in the administrative districts of Bagerhat, Khulna and Satkhira in Bangladesh. The rest, 38% of the mangrove forest, lies in India. The mangrove tract of Bangladesh constitutes 44% of the total forested area in Bangladesh and contributes about 50% of the revenue from the forestry sector (Tamang 1993).

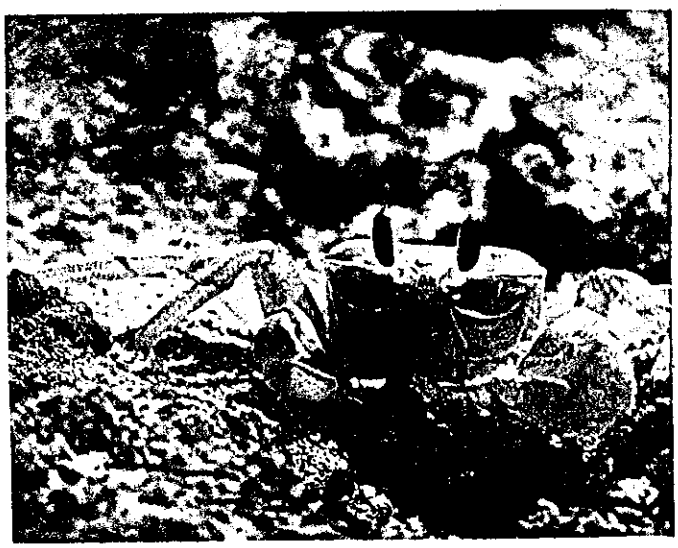


MAP 2.1: The Sundarban Reserved Forest

The whole Sundarbans remains under tidal influence with a tidal period of about 12 hours and 25 minutes. It takes approximately 2.5 hours for the tides to cover the whole of the forest from the south to the north. From the coast, tide starts flowing through the main estuaries such as Raimangal, Jamuna, Malancha, Passur, Sibsa, Baleswar, Kunga and Shela. The depth of water during high tide or flood tide inside the forest varies a little from the south to the north. Average height may vary from few centimeters in the north to 1.5 meters in the south.

Mangles are forests that grow below the high tide mark and comprise several species of trees and a few non-woody herbaceous plants which is popularly known as the 'mangrove forest'. In the Indian subcontinent, mangroves are found in very limited areas - Gangetic delta, mouths of Mahanadi, Godavari and Krishna, Cauvery delta, Bombay region, Saurashtra and Kutch coast, and Andaman and Nicobar Islands (Map 1). Nearly 85% of the mangals of this subcontinent are confined to Sundarbans (Bangladesh and India) and to the Islands of the Andaman and Nicobar groups (Singh *et al.* 1986). The Sundarbans is wealthy for its high biodiversity, and this ecosystem still remains relatively undisturbed. But this intact mangrove forest in Bangladesh is now declining due to clearfelling of trees, increase of water salinity and siltation due to diversion of waters of the Ganges at the Farakka barrage in India, and natural catastrophes, like cyclones.

The Sundarbans is of great economic importance. According to a Forest Department estimate in the late 1970s, about 45,000 people work in the forest on any given day during the main harvest season while, according to an unofficial estimate, the number of people entering the forest in a given year can be as high as one million (Hussain and Karim 1994). Most people working as woodcutters (*bowalis*), fishermen (*jailas*), honey gatherers (*mowalis*), nipa palm (*golpatta*) collectors, crab collectors (*moshai*), mollusk shell collectors (*jangrakhota*), and sungrass collectors. The people living in the vicinity of the forests depend on such renewable natural resources of the Sundarbans as timber, firewood, pulpwood, building materials, honey, wax, fish, and shrimp for their survival. But the most important value of the Sundarbans stems from the protection it affords to millions of people against the ravages of cyclonic storms and tidal waves, which are very frequent in the Bay of Bengal.



Like this colourful Ghost crab, several crab species are found in the forest

photo: M.S. Mayilvahanan/ Sanctuary

The Sundarbans acts as a physical buffer between the people in the north and the sea in the south. If not for the Sundarbans, millions of people would face the full fury of cyclones and tidal waves and perish. for example, in 1970, more than 300,000 people perished in one storm on the reclaimed areas at the mouth of the Meghna river (Seidensticker and Hai 1983).

The area, however, extremely vulnerable to global warming. At the present rate of global warming, by 2050, the sea level is estimated to rise by 0.05 to 0.32 m (IPCC 2002), sufficient to wipe out major portion of the mangrove forests. A more immediate threat to the biological integrity of the Sundarbans may arise from the planned exploration for oil and natural gas in the area. Although the oil companies concerned have pledged not to drill for oil and gas within the Sundarbans reserved forest, even the so called 'lateral drilling' may lead to environmental damage that would be detrimental to the wildlife of the area (Reza *et al.* 2000).

Any effort to conserve the tiger in the Sundarbans will directly benefit countless other species of wildlife that are sympatric with it, and thereby ensuring the maintenance of biological diversity across a wide geographic area. On the cusp of the 19th century, the Sundarbans included a much wider area than it does today, and supported a much richer and more diverse fauna. For example, Prain (1903) recorded 13 species

Sundarbans orchids, disappearing fast

photo: Rubaiyat & Elisabeth Mansur

of orchid during his survey in the Sundarbans, but during a recent survey to the Sundarbans, only 7 species were recorded (IUCN-2004). It is believed that orchids are very sensitive to salinity. Therefore, increase of salinity might have caused extinction of the other 6 species from the forest in course of the last century.

Samber, an extinct resident of the Sundarbans.

photo: Shihab Uddin

In the north of the present Sundarbans, there were extensive swamp lands inhabited by the megaherbivores, such as, the one-horned rhinoceros (*Rhinoceros unicornis*), the Javan rhinoceros (*Rhinoceros sondaicus*) and the other large herbivores such as the wild buffalo (*Bubalus bubalis*), gaur (Bos gaurus), swamp deer (*Cervus duvauceli*), sambar (*Cervus unicolor*), and the hog deer (*Cervus porcinus*) - all of which have become extinct today. By 1908, according to the Bengal District Gazetteer, both one-horned rhino and wild buffalo had become rare; while by 1914 even barking deer and hog deer were listed uncommon. The Bangladesh Sundarbans now supports populations of spotted deer (*Cervus axis*), barking deer (*Muntiacus muntjac*), wild boar (*Sus scrofa*), and rhesus macaque (*Macaca mulatta*) which form the principal prey species of the Bengal tiger (Reza *et al.* 2000).

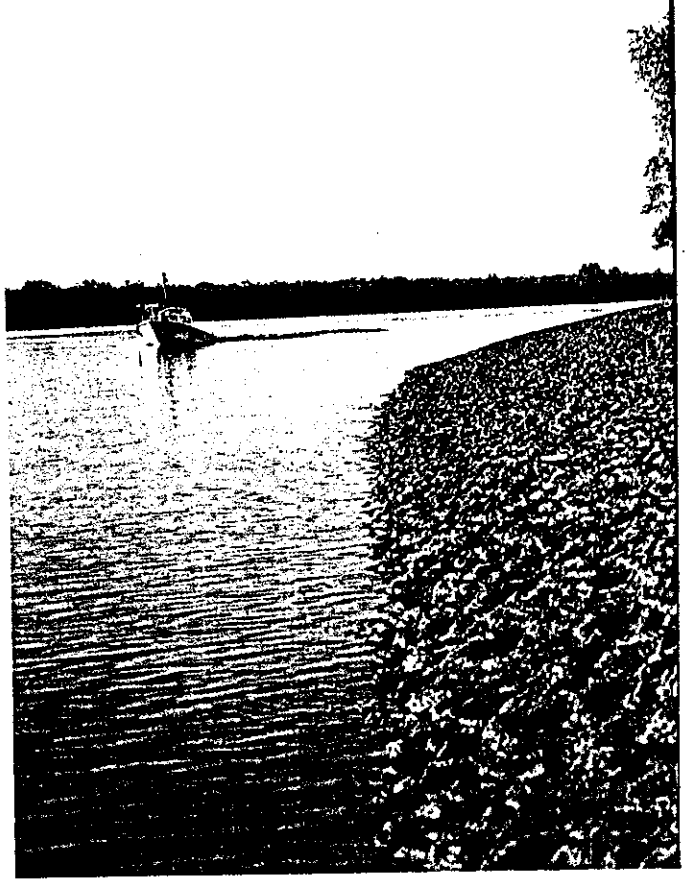
PHYSICAL FEATURES

The land of this mangrove forest is moulded by tidal action, resulting in a distinctive physiography. An intricate network of interconnecting waterways, of which the larger channels of about a mile or more in width run in a generally north-south direction, intersect the whole area. Innumerable small *khals* (small canals) drain the land at each ebb tide. Rivers tend to be long and straight, a consequence of the strong tidal forces and the clay and silt deposits, which resist erosion. Easily eroded sands collect at the river mouths and form banks and *chars* (islands), which are blown into dunes above the high-water mark by the strong south-west monsoon. Finer silts are washed out into the Bay of Bengal, but where protected from wave action, mud flats form in the lee of the dunes. These become overlain with sand from the dunes and develop into grassy middens. This process of island building

An autumnal Sundarbans afternoon

photo: Rubaiyat & Elisabeth Mansur

continues for as long as the area on the windward side is exposed to wave action. With the formation of the next island further out, silt begins to accumulate along the shore of the island and sand is blown or washed away (Seidensticker and Hai 1983). Apart from the Baleswar river, the waterways carry little freshwater as they are cut off from the Ganges, the out flow of which has shifted from the Hoogly-Bhagirathi channels in India progressively eastwards since the 17th century. They are kept open largely by the diurnal tidal flow (Seidensticker and Hai 1983).



Sundarbans madflats, water, vegetation: the whole atmosphere is salinity driven
photo: Ali Reza

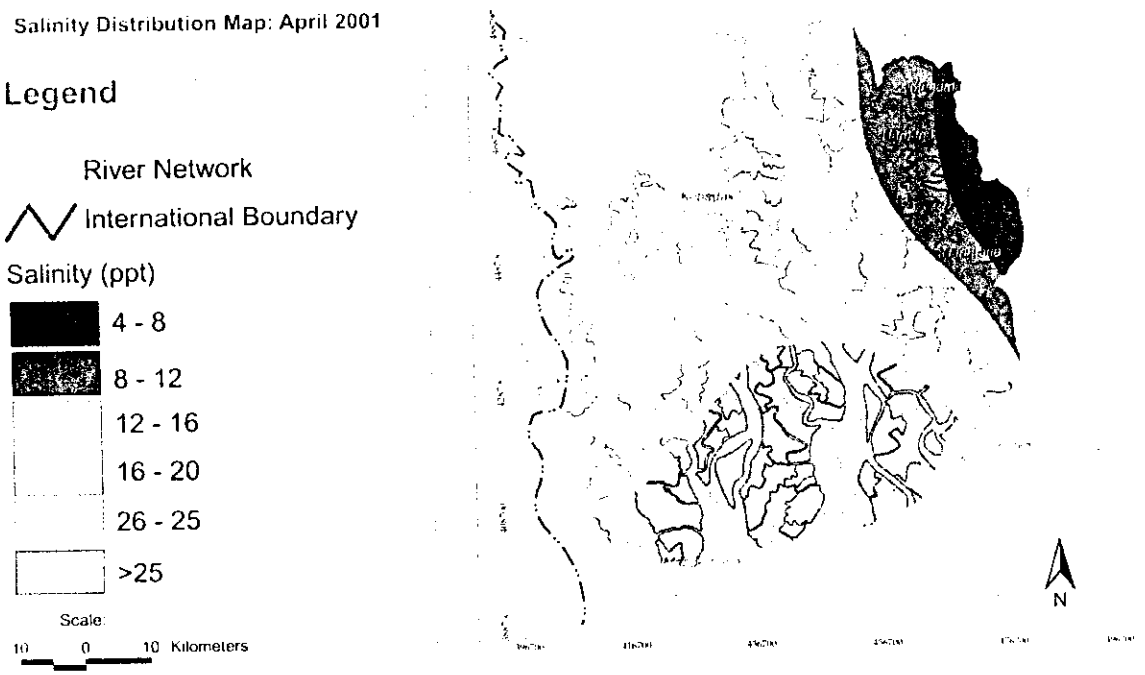
Alluvial deposits are geologically very recent and deep. The soil is silty clay loam with alternate layers of clay, silt, and sand. The surface soil is clay except on the seaward side of islands in the coastal limits, where sandy beaches occur. In the eastern part of the Sundarbans, the surface soil is soft and fertile, whereas it is harder and less suitable for tree growth in the west (Choudhury 1968).

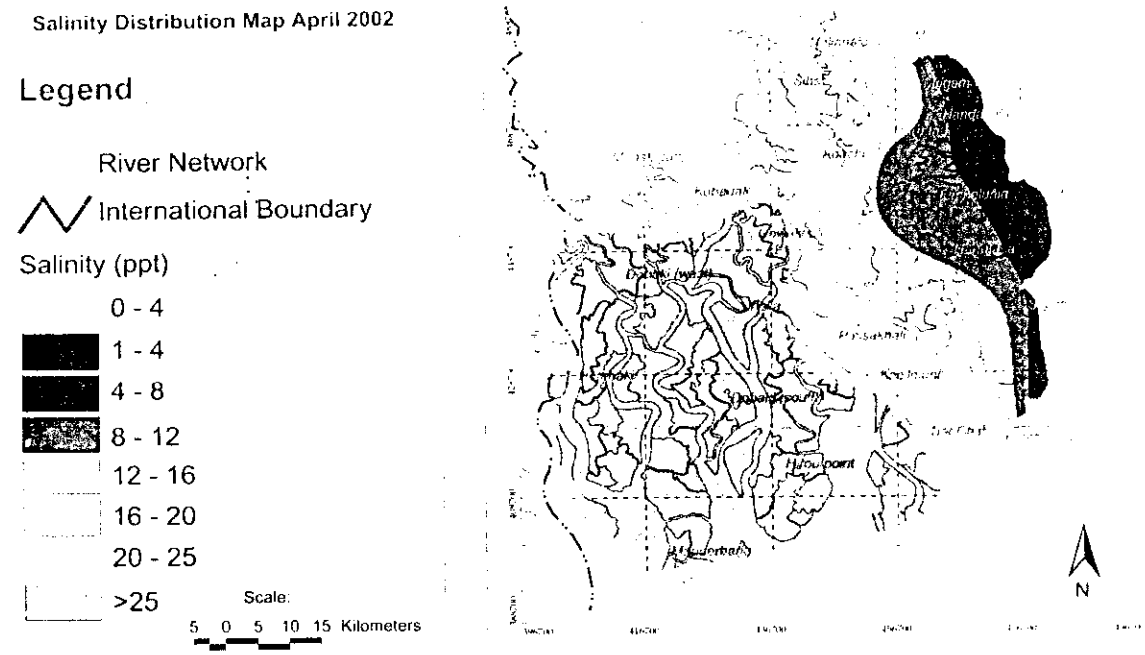
Salinity

Curtis (1933) divided the entire Sundarbans into three salinity zones. The slightly saline zone consists of Chandpai-Sarankhola range (21°50′ - 22°25′ N latitudes and 89°45′ - 89°25′ E longitudes), moderately saline zone consists of Khulna range (21°20′ -22°30′ N latitudes and 89°40′ -89°20′ E longitudes) and the rest strongly saline zone consists of Satkhira range (22°20′ -21°40′ N latitudes and 89°30′ -89°25′ E longitudes). The salinity zones are shifting over the time. Curtis (1933) salinity zones were located in the north-south direction, whereas according to a recent study conducted by the Institute of Water Modeling (IWM 2002) the salinity zones are being shifted to an east-west direction (map 2.2 & map 2.3).

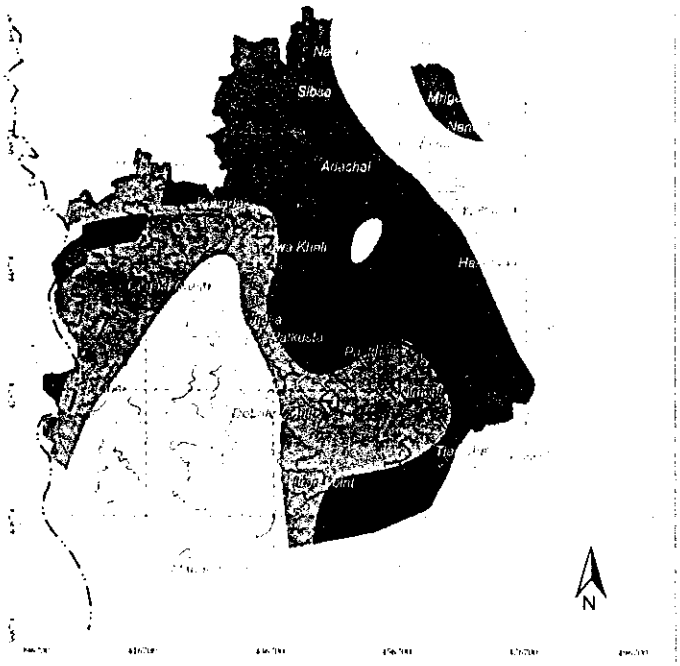
Soil

The soil of the Sundarbans are derived allochthonously from deltaic floodplain alluviums and allochthonously from tidal-marsh materials consisting mainly of organic matter (i.e. peat deposits), and to a lesser extent, from biocarbonates from shell-forming marine-estuarine organisms. The soils are deep, poorly drained, and have mineral compositions that are traceable to the bedrock parent material of the gneissic mountains of the Himalaya. The top soil horizon is a silty, clay loam overlying alternating horizons of clay and sand (Choudhury 1968), the pattern of which is indicative of a meandering river in an active delta. Surface soils are dominantly clay overlain with thin layers of fresh silt delivered annually by monsoon floods. In the more eastern Sundarbans, where the annual silting process provides fertile nutrients, the delta forests are more highly productive. In the western portions of the Sundarbans, however, flow velocities in the moribund distributary rivers are frequently so low that any suspended silts settle out in the stream beds, which further restricts their drainage ability. This encourages a build-up of soil salinity and the creation of a hard, compacted soil that support a productive forest. Furthermore, compacted, de-watered clays tend to selectively concentrate chlorides, which, at high levels, can affect forest growth, even that of the salt-tolerant mangroves. In general, soil fertility (including a suitable water balance) decreases from east to west and from north to south (Curtis 1933).





Map 2.2: Salinity distribution: pre-monsoon condition (souce: IWM 2002)



Salinity Distribution Map December 2001

Legend

River Network

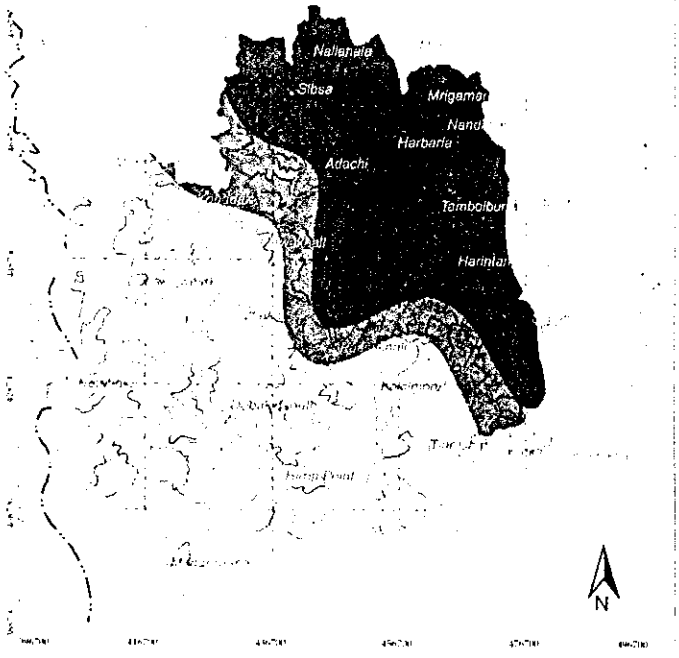
International Boundary

Salinity (ppt)

0 - 1
1 - 4
4 - 8
8 - 12
12 - 16
16 - 20
20 - 25

Scale:

5 0 5 10 15 Kilometers



Salinity Distribution Map December 2002

Legend

River Network

International Boundary

Salinity (ppt)

0 - 1
1 - 4
4 - 8
8 - 12
12 - 16
16 - 20
20 - 25

Scale:

5 0 5 10 15 Kilometers

Map 2.3: Salinity distribution: post-monsoon condition (souce: IWM 2002)

Climate

The Sundarbans is located at the south of the Tropic of Cancer and at the northern limits of the Bay of Bengal. Rainfall is heavy and humidity high (80%) due to the proximity of the Bay. About 80% of the rainfall occurs in the monsoon, which lasts from June to October. Mean annual rainfall varies from about 1,800 mm at Khulna (north of the Sundarbans), to 2,790 mm on the coast (extreme south of the forest). There is a six-month dry season during which evapotranspiration exceeds precipitation. Conditions are most saline in February-April, the depletion of soil moisture being coupled with reduced freshwater flow from upstream. Temperatures rise from daily minima of 2-4° C in winter to a maximum of about 43° C in March and may exceed 32° C in the monsoon. Storms are common in May-November and may develop into cyclones, usually accompanied by tidal action of up to 7.5 m high (Seidensticker and Hai 1983).

VEGETATION AND BIODIVERSITY

The mangrove of the Sundarbans is unique when compared to the non-deltic coastal mangrove forest. Unlike the latter, the Rhizophoraceae is of only minor importance, and the dominant species is *Heritiera fomes* (sundri), from which the Sundarbans takes its name, and the most widespread species is *Excoecaria agallocha* (gewa). Globally, the members of the Rhizophoraceae family dominate the mangrove forests. Hence, Sundarbans is an exception and unique in this regard. The above mentioned two plant species belong to the Sterculiaceae and Euphorbiaceae families respectively. In a broad sense, the Sundarbans mangrove forest categories is based on 8 dominant plants species namely, *Heritiera fomes*, *Exocoecaria agallocha*, *Xylocarpus mekongensis* (passur), *Xylocarpus granatum* (dhundul), *Bruguiera gymnorhiza* (kankra), *Sonneratia apetala* (keora), *Avicennia officinalis* (baen) and *Ceriops decandra* (goran). Ninty-nine percent of the total area of the forest is accounted for by 10 forest types. *H. fomes-E. agallocha* forest type covered the largest area (29%) followed by pure *H. fomes* (21%) and *E. agallocha-H. fomes* forest type (15%) and *C. decandra-E. agallocha* (14%) respectively (Chaffey *et al.* 1985). Recently, FD and RIMS (2002) categorized the whole mangrove forest into major 22 vegetation types, where the dominant vegetation types were shown in the maps produced by them. Prain (1903) gives an account of the flora of the

A mixed mangroves patch
photo: Ali Reza

mangrove forest of the Ganges-Brahmaputra delta, where he reported a total of 334 plant species, representing 245 genera, present in the delta, and listed principal woody and herbaceous species. However, it was not until 1985 that Chaffey *et al.* (1985) provided a detailed list of trees and shrubs in the Bangladesh portion.

This mangrove tract is also both diverse and complex in the terms of fauna. Of the 425 species of wildlife that have been recorded from the Sundarbans, 49 are mammals, 315 birds (this number may have declined considerably today; a more likely figure would be about 186 species), 53 reptiles, and 8 amphibians (Rashid *et al.* 1994 and Reza *et al.* 2000a). In addition, its waterways and canals have been recognized as one of the richest fish-nurseries in the region (Kabir 1999). Despite the combination of high tidal flow velocities, heavy silt load and low light penetration, remarkable finfish and shellfish biodiversity exists inside the Sundarbans forest and in the adjacent marine zone of the northern Bay of Bengal. The fish community is composed of at least 222 species of finfishes and 100 species of shellfishes (Bernacsek 2001a, 2001b). These are mainly of marine origin, but several freshwater species are able to take advantage of low salinity and freshwater conditions in the northern part of the forest.

The King Cobra, a prize species of the Sundarbans

photo: Ali Reza

WILDLIFE SANCTUARY AND WORLD HERITAGE SITE

At present, there are three wildlife sanctuaries within the Sundarbans, which covers an area of 323 km^2, which is only 5.59% of the total area of the Sundarbans reserved forest, acting as *'ecological islands'* within the mangrove forest. These are

The Katka sea beach (photo manipulated)

photo: Ali Reza

the East Wildlife Sanctuary (54 km^2) in Sarankhola Range, South Wildlife Sanctuary (179 km^2) in Khulna Range and the West Wildlife Sanctuary in Satkhira Range (90 km^2), established in 1977 under Bangladesh Wildlife (Preservation) (Amendment) Act, 1974. These areas ware first gazetted as forest reserves in 1878 under the Indian Forest Act, 1878. The total area of wildlife sanctuaries was extended in 1996. In order to draw global attention to this fragile ecosystem, the three existing wildlife sanctuaries were included as the part of the World Heritage Site of the Sundarbans, which came into effect in December, 1997. The total area of the World Heritage Site is 1,400 km^2 (24.26% of the total area of the Sundarbans reserved forest), of which 910 km^2 is land and 490 km^2 is under water. The entire Sundarbans is divided into two Forest Divisions (Sundarbans east and Sundarbans west), four Forest Ranges (Sarankhola, Chandpai, Khulna and Satkhira), 8 Forest Blocks, and 55 compartments for management. From the point of tiger conservation, the East and West Wildlife Sanctuaries are not large enough to support viable tiger populations.

STUDY SITES

Two sites from the two different physical and ecological habitats were selected for this study: a) one was Katka-Kochikhali area under Sharankhola range, which is within the slightly saline zone, and b) the Burigoalini area under the Satkhira range.

which is within the strongly saline zone (Nazrul-Islam 1995).

The Katka-Kochikhali study area is an island of about 20 km^2, as it is surrounded by the Bay of Bengal in the south, Kochikhali and Jamtala *khal* in the north, the Supoti river in the east, and the Katka river in the west. The coastline of this island is irregular, as a result, a number of tidal creeks are formed. This is an island that has diverse habitat types. There is a big meadow, an ideal habitat for the spotted deer and wild boar and also for the tigers due to the abundance of prey species. Because of the presence of large numbers of ungulate species to prey on, deep forests to take shelter in and waterholes to drink freshwater from this area can support a high density of tigers. It is supposed that the tiger density here is higher than that in any other place in the Sundarbans. The area was, therefore, chosen for the present study.

The Burigoalini area is situated beside some heavily populated villages in the northwestern periphery of the Sundarbans and there is no physical barrier between the forests and the villages except a tiny creek. Local people cross this creek while encroaching into the forest for their livelihood. The human-tiger conflict in this area is higher than in any other places in the Sundarbans. The area was chosen as a study site for man-tiger conflict study.

KATKA-KOCHIKHALI

The Katka-Kochikhali is located at the south-eastern extreme in the Sundarbans facing the south towards the Bay of Bengal. The area lies between 89°41′ and 89° 51′ E longitudes and 21°50′and 21°55′ N latitudes under the administrative district, Bagerhat. The area consists of forests, meadows (grasslands), sea beaches, rivers, canals, and creeks. There are three man-made waterholes and one natural waterhole for freshwater in this area. In the rainy season, most parts of the area become flooded. The soil is mainly composed of sand and silt. Unlike other places of the forest, most of the land surfaces are accessible on foot even inside the forests. There are no permanent settlers inside the forest. As the Katka-Kochikhali area is a part of Sundarbans East Wildlife Sanctuary, collection of forest resources is legally restricted. However, in winter (November to January), for the extraction of sungrass (*Imperata* sp.), the management authority allows sungrass collectors to reside in the area and establish temporary huts. Forest Department has dug three freshwater ponds and planted some date palm and coconut trees within the area. There is a wildlife observation tower to observe wildlife just beside the meadow. The tropical climate has three distinct seasons: summer, monsoon and winter. The hot summer is from March to June. The mean annual maximum temperature has been recorded as 32.4°C. This is followed by a rainy season or monsoon from July to October. The maximum annual rainfall within this area is about 2000 mm; 80 to 85 percent annual rainfall occurs during the monsoon season from July to September. The cold season (winter) lasts from November to February. The mean

Katka - Kochikhali habitat mosaic: a creek, a meadow, a Keora grove

photos: Ali Reza

annual maximum temperature in winter is 29.4°C. The mean annual relative humidity varies from 70% to 80% (Karim 1994).

Floral Study

Mangrove forests are edaphic evergreen communities, occurring chiefly on muddy sheltered shores of coastal areas subject to periodic submergence by tidal waters (Schimper 1903). The natural vegetation of Katka-Kochikhali is dominated by halophytic tree species. Herbaceous climbers are also common; undergrowth is mainly dominated by *Acrostichum aureum* (tiger fern); epiphytes and woody parasites are few. The average maximum height of the trees of this area is between 15.3 and 10.7 m and consists mainly of dense, well-stocked forests (Curtis 1933). Katka-Kochikhali area is an island, composed mainly of forests, grasslands and bushes. Forests cover about 50% of the area, grassland and openlands cover 20% and the remaining 30% consist of mudflats, canals, creeks and sea-beaches (Reza 2000). Due to the presence of sea on one side, the outstanding features of the forest plants of this area are adaptations to growing in seawater and establishing themselves in estuaries, creeks, and riverbank areas. The coastline of the island is irregular and has a number of tidal creeks, which are densely populated by species such as *Nypa-Sonneratia-Heritiera-Excoecaria*. The commonest tree species in the forest is *Excoecaria agallocha*, followed by *Sonneratia apetala* and *Heritiera fomes*. The other plant species are *Phoenix paludosa* (hental), *Nypa fruticans* (golpata), *Hibiscus tiliaceous* (bala), *Acanthus ilicifolis* (hargoza), *Pandanus foetidus* (kewa

Katka - Kochikhali habitat mosaic: a creek, a meadow, a Keora grove

photos: Ali Reza

kanta), *Amoora cucullata* (amur), *Avicennia officinalis* (baen), *Phragmites karka* (nol kagra), *Rhizophora mucronata* (garjan), *Xylocarpus mekongensis, Cynometra ramiflora* (shingra), etc. The grasslands or meadows and parts of the forest go under water during the monsoon.

Using available map and the extensive field survey during the study period, 18 quadrats (6 X 6 m) were selected randomly for the floral study in Katka-Kochikhali (Appendix 12). These quadrats covered almost all major habitat types proportionately. The total height, bole height, crown height, and diameter at breast height (dbh) were measured for all trees (dbh> 10 cm) in all those quadrats. The grass height in the grasslands was recorded in various seasons in the quadrates.

Forest structure

All trees (dbh> 10 cm) in 18 randomly selected quadrats were tagged and recorded for both forest structure and composition. A total of 276 trees was recorded in 11 quadrates. The other 7 quadrats were covered by grass (*Imperata* sp.). The average grass height throughout the year was 22 to 92 cm. Measuring 276 trees within 11 quadrates showed the total height of the recorded trees varied from 3.5 to 16.25 m.

Mean bole height of these trees was 1.0 to 7.0 m, and the dbh varied from 10.0 to 45.8 cm. Three distinct canopies were found in the forest of Katka-Kochikhali area. The upper canopy consisted of *Sonneratia apetala*, and its canopy height varied from 8.00 to 15.50 m. The second canopy consisted of *Heritiera fomes* where the height varied from 8.00 to 14.00 m. The lowest canopy consisted of *Excoecaria agallocha*, with the canopy height varying from 3.5 to 12.5 m.

The vegetation of Katka-Kochikhali is mixed type, so there is natural mangrove vegetation, savannah type grassland (meadow), along with planted palm or other types of fruiting trees (e.g. *Borassus flabellifer, Syzygium* sp., *Phoenix sylvestris*, etc.). *Excoecaria agallocha* was the most common species whereas *Sonneratia apetala* was the most dominant plant species in the area in terms of absolute density, relative density, absolute dominance, and relative dominance (Table 2.1).

Forest composition

All the tree species were recorded to calculate the density of the species. Diameter at breast height (dbh) was measured for all trees found in the 18 randomly selected quadrats for calculating the basal area. The basic formula (Mueller-Dombios and Ellenberg 1974) was followed to calculate the absolute density, relative density, absolute dominance, and relative dominance which were as follows:

Absolute Density = No. of individuals of a species or family/area

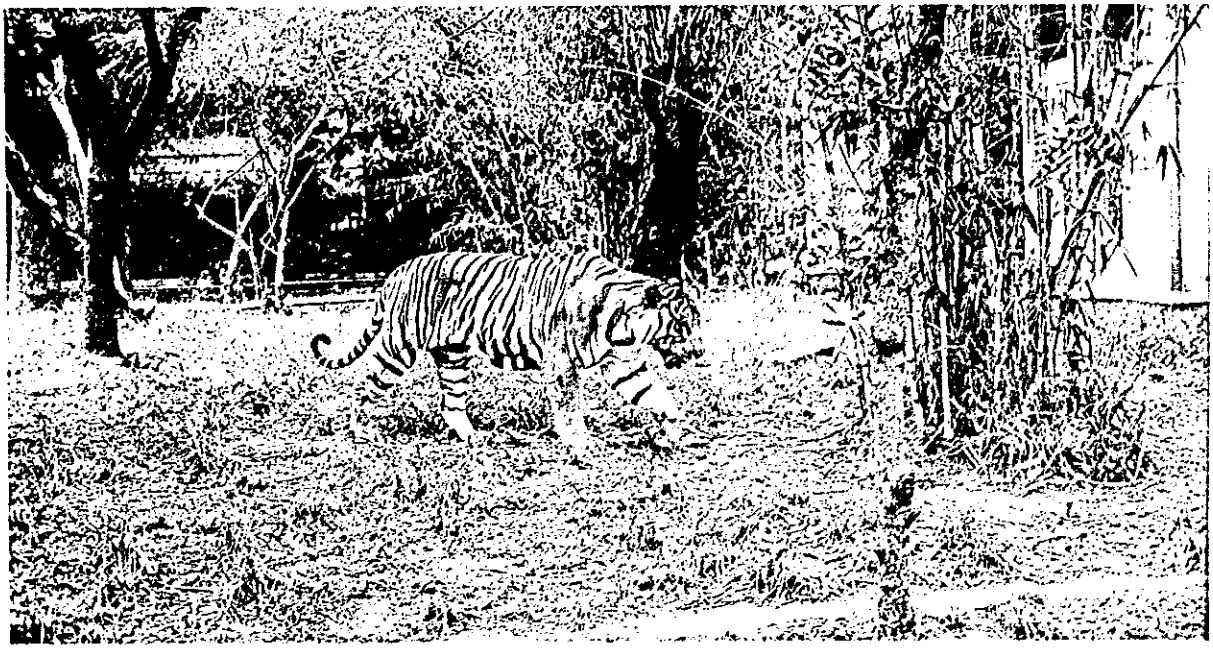
$$\text{Relative Density} = \frac{\text{No. of individuals of a species or families}}{\text{No. of individuals of all species or families}} \times 100$$

Absolute Dominance = Total basal area of a species or family/area

$$\text{Relative Dominance} = \frac{\text{Total basal area of a species or family}}{\text{Total basal area of all species or families}} \times 100$$

A total of 14 species of plants was identified in the 18 randomly selected quadrats (Appendix 12). The number of plant species varied from 1 to 7 species in these quadrats. The number of trees occurring in the quadrats varied from 20 to 32 trees/quadrats. A floristic composition of these quadrates is given in the Appendix 12. The most common tree species in Katka-Kochikhali was *Excoecaria agallocha* on the basis of absolute density and relative density whereas *Sonneratia apetala* was the most dominant plant species in the area on the basis of absolute dominance and relative dominance (Table 2.1). The second most common tree species in the area was *Sonneratia apetala*, and *Heritiera fomes* was the third most common. *Xylocarpus granatum* was the least common plant species in the area.

Tiger in territorial visit
photo: MM Feeroz



It was reported that *Heritiera fomes* is the most dominant plant species in that area (Nazrul-Islam 1996). But the present study indicated that *Excoecaria* was the most dominant, and *Heritiera* ranks as the third dominant plant species of the area. The coastline of the study area was observed irregular, which is why the number of tidal creeks was formed. These tidal creeks and riverbanks were densely populated by *Nypa*, *Xylocarpus*, *Excoecaria*, and *Bruguiera*.

Phenology

Nearly all plant communities of the temperate, subtropical, and tropical dry zones have more or less pronounced seasonal aspects. These seasonal aspects of a plant community, termed phenology, involve flowering, fruiting, leaf emergence, and leaf fall from trees, and forest floor perennials. The phenology of certain species can be assessed quantitatively by periodic observations in permanent quadrats and by marking individuals, or even individual branches and flowers on trees.

Gewa foloage
photo: Ali Reza

Table 2.1 Absolute density (DA), relative density (RD), absolute dominance (DoA) and relative dominance (DoR) of the dominant plant species in Katka-Kochikhali area

Family	Species	DA (plants/ hectare)	RD	DoA (m^2/ hectare)	DoR
Euphorbiaceae	*Excoecaria agallocha*	1929	45	6161	9.9
Sonneratiaceae	*Sonneratia apetala*	1079	26	7538	12.1
Sterculiaceae	*Heritiera fomes*	725	17	2707	4.4
Rhizophoraceae	*Ceriops decandra*	139	3	21	0.03
Meliaceae	*Amoora cucullata*	62	1	5	0.008
Meliaceae	*Xylocarpus mekongensis*	31	0.7	8	0.01
Meliaceae	*Xylocarpus granatum*	15	0.4	1	0.002
Avicenniaceae	*Avicennia officinalis*	31	0.7	2	0.004
Myrsinaceae	*Aegiceras corniculatum*	46	1	10	0.02
Myrtaceae	*Syzygium sp.*	170	4	219	0.4

The Sundarbans is subject to seasonal climatic pulses (Karim 1994). This seasonal climatic change and the seasonality in leaf, flower and fruit production of trees were observed to be directly related to various seasons in the study period, which has a direct relationship with the faunal activities. Most of the trees in the Sundarbans

show a flowering pulse, which occurs during the summer months, March and April. In the study area, most of the trees in January and February became faded due to continuous sunlight, but from March and onwards, they showed flowering pulse. Begening in May, all the trees started fresh flushing and flowering. In June/July *Heritiera, Sonneratia, Excoeria*, etc. started fruiting. At that time, fruits of *Sonneratia* become a good food for the spotted deer (*Cervus axis*) and rhesus macaques (*Macaque mulatta*). With the onset of monsoon in June, most of the forest areas became inundated.

The flowering and fruiting of *Sonneratia, Aegiecras*, etc. influenced the behaviour of the faunal assemblage, e.g. *Sonneratia* fruiting bring deer and macaques together to feed on the fruit. These two animals are potential prey species of tiger. The macaques not only drop the leaves and fruits on the forest ground, but also give an alarm call on seeing a predator, the tiger. Thus, the deer get chance to move to a safer place. Plants like *Aegiceras* starts flowering in June-July, which is a good honeybee foraging plant. This plant is the main source of honey in the Sundarbans.

BURIGOALINI

The another study site Burigoalini area lies between 89°15′ and

Tigers are dependent on prey animals very close to their habitat.

photo: Ali Reza

Kholisha in bloom: the best source of honey

photo: Ali Reza

89°20′ E longitudes and 22°15′ and 22°20′ N latitudes. This area is situated in the northeastern portion of the Sundarbans and under Satkhira district. The Burigoalini area is situated in the strongly saline zone and the highest salinity occurs in March, which is up to 27,000 micromhos/cm and the lowest in November 10,150 micromhos/cm (Nazrul-Islam 1995). Though the soil composition of the Sundarbans is rich in silt followed by the clay, the percentage of clay is higher in this area than in other areas (Nazrul-Islam 1996). The area consists of deep inaccessible forests and many creeks and small rivers. The forest is not so healthy and the canopy height is restricted within 6.1 to 10.7 metres. This strongly saline zone is jointly shared by the villagers and the forests. There are small patches of forest inside the villages. Tigers sometimes enter the villages and kill the domestic cattle. On the other hand, tigers are also killed by villagers.

The mean maximum temperature recorded to as 32.1° C in the hottest months of May-June. The temperature fluctuation between summer and winter is not very high. In winter, the mean maximum temperature is 29.4° C. The mean annual rainfall within the forest is about 1600 mm. Major portion of annual rainfall in this area occurs during May to September. The mean annual relative humidity varies from 75% to 80% (Karim 1994).

Vegetation

In Burigoalini, gently sloping mudflats consist of a sequence of species assemblages. Following a narrow belt of transition consisting of *Sonneratia*, *Aegiceras* and *Ceriops* species, the vegetation consists of sparsely distributed low trees of *Excoecaria* with *Ceriops decandra* in the understorey (Karim 1994). This area forms consociation of *Ceriops decandra*, *Aegiceras corniculatum*, *Sonneratia apetala*, *Phoenix paludosa*. In addition association of *Xylocarpus* and *Bruguiera* is also found occasionally (Nazrul-Islam 1996). *Avicennia marina* is the dominant species, although it is rare in other places in the Sundarbans, forming the upper strata of the forest in this area. This vegetation sequence is not repeated in all cases. Generally, *Ceriops decandra* occurs as an undergrowth. The vegetation canopy becomes sparse and plant height is reduced with an increase in land elevation, and the average canopy height remains between 6.1 and 10.7 meters.

Goran collection

photo: Rubaiyat & Elisabeth Mansur


TIGERS IN
KATKA-KOCHIKHALI

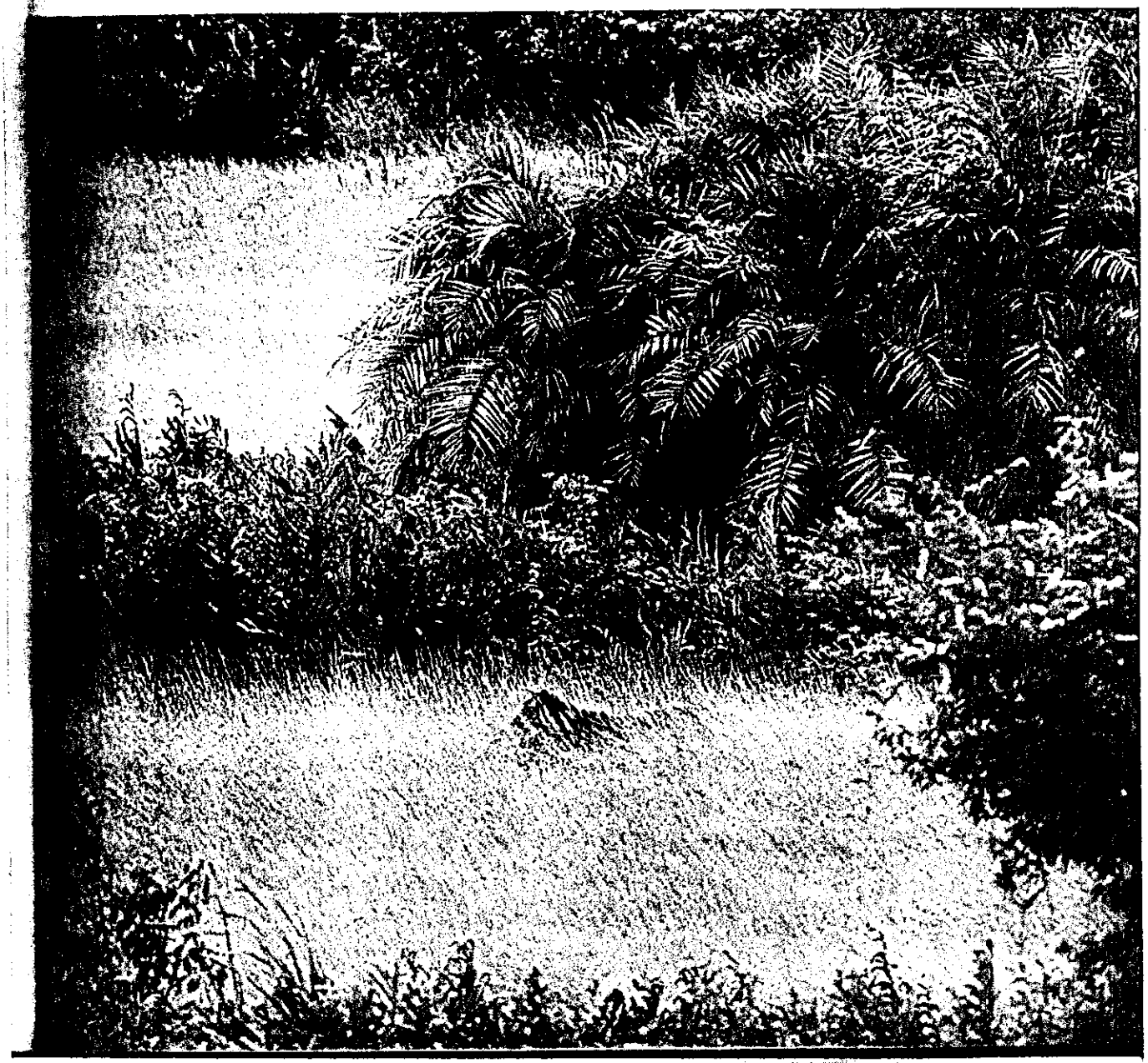
TIGERS IN KATKA-KOCHIKHALI

POPULATION

Most large predators are sparsely distributed, cryptic, nocturnal, and often solitary (Seidensticker *et al.* 1973, Beier *et al.* 1995). This makes it difficult to count all the individuals in a population simultaneously. In such cases, population estimates need to be precise and accurate, since a small decline in a population could prove disastrous (Taylor and Gerrodette 1993, Coughley 1994). Also methods for estimating population of this type of secretive carnivore need to be practical and cost effective with regard to the prevailing socio-economic conditions of the area (Jhala *et al.* 1999). The counting from footprints the 'Pugmark Tracing Technique' is the most cost effective (Singh 2000).

An elusive Bengal tiger stalking at Katka

photo: Rubaiyat & Elisabeth Mansur



An accurate assessment of tiger density by population estimation throughout any portion of its range is a difficult task (Rabinowitz 1993). Because tigers are secretive, nocturnal, and scarce, visually counting them is impossible (Karanth 1995a). Therefore, scientists have developed various indirect methods other than the visual or direct count by which it is possible to estimate tiger population in the wild. These include pugmarks tracing techniques (Das and Sanyal 1995; Gore *et al.* 1993; Panwar 1979; Smallwood and Fitzhugh 1993, 1995), track counts (Palomares *et al.* 1996; Van Sickle and Lindzey 1991), waterway, and sign surveys (Rabinowitz 1993), radiotelemetry and intensive study in small areas, densities of which are then extrapolated to estimate total population (Fuller 1989), mark-recapture by camera-trap (Garshelis 1992; Karanth 1995; Karanth and Nicholes 1998). The last two methods are high-tech and very expensive for a third world country like Bangladesh. Moreover, in an area like Sundarbans mangrove forest, where major portion of the forest is covered by deep halophytic trees making much of the forest inaccessible. Also the mangrove forest of the Sundarbans is a forest where a major part of the forest floor is subjected to periodic inundation by the seawater twice a day. In such difficult environment, these two methods are not easily applicable.

Estimating population size of the tiger in a given natural habitat must inevitably depend upon indirect evidence because of the difficulty in the actual sighting of individuals inhabiting that area. The technique described here for arriving at a reasonably reliable estimate (minimum number) of tiger population in a given area employs the recording of tiger pugmarks as the basis for identifying individuals. The technique, widely known as the 'Pugmark Tracing Technique'; is based on specific postulates or assumptions, the dependability of which have been established by testing through field applications. The method is indeed an extension of the ethnic methods used by tribals and *shikaris* in different parts of the Indian subcontinent. At the outset, credit for scientifically establishing these postulates or assumptions must be given to the late S.R. Choudhury, a forester from Orissa, India. A number of practicing wildlifers, e.g. Panwar (1979), Gore *et al.* (1993), Das and Sanyal (1995), and more recently Singh (2000) have further refined the technique. This presentation borrows from their research and from the year long experience of the present study.

In the future, other methodologies need to be refined and tried out, and if found to be practical, acceptable and reliable, they should also be considered for estimating tiger population in the Sundarbans. In future, there could be a combination of methods and to assess tiger numbers in the Sundarbans.

Population estimation

Panwar (1979) and McDougal (1999) argued that experienced persons could identify each individual tiger by its pugmark analysis. But Karanth (1987) did not quite applaud the pugmarks tracing technique and argued that the paw prints (pugmarks) of the same tiger may look very different due to variations in soil type, slope, movement and other factors, and so prints are not reliable. The pugmarks tracing technique of tiger population estimation has several weak points: i) if there are leopard pugmarks then it is very hard to identify whether it is made by a juvenile tiger or leopard, ii) soil formation and slope of the area may not be similar, iii) the movement of the animals may not be uniform, etc. These are the basic concerns, which can make the population estimation biased. However, the technique can generates reasonably unbiased and precise population estimations if the following underlying assumptions are satisfied:

- Tigers make all pugmarks, which are traced and analyzed.
- All the pugmark tracing data comes from the same soil type.
- The movement of the animals does not vary due to various activities of the animal.
- There is no significant variation of the slope of the substrata from where the tracing data is collected.

Water hole, a most frequented habitat type

photo: Ali Reza

Table 3.1 Comparison of tiger densities and biomass of 8 natural habitats in the Indian subcontinent

Reserve	Year	Area (km^2)	Total tiger	Tiger density (tiger/km^2)	Biomass (kg/km^2)		Source/methods used
					General	Metabolic	
Sundarbans WS	1999-00	20	4	1/5.00	30.0	22.60	Reza 2000 (Pugmark tracing & Year-round monitoring)
Kanha NP	1964-65	318	22	1/14.45	10.38	7.82	Schaller 1967 (Radio-tracking & Year-round monitoring)
Chitwan NP	1974-76	544	32	1/17.00	8.82	6.64	Sunquist 1981 (Radio-tracking & Year-round monitoring)
Chitwan NP	1980	1,024	90	1/11.37	13.18	9.93	Smith 1984 (Radio-tracking & Year-round monitoring)
Kanha NP	1995	900	26	1/8.55	17.54	13.16	Karanth 1998 (Camera-trap data analysis)
Pench NP	1995	290	5	1/24.39	6.15	4.61	Karanth 1998 (Camera-trap data analysis)
Nagarahole NP	1996	644	25	1/8.70	17.24	12.93	Karanth 1998 (Camera-trap data analysis)
Kaziranga NP	1996	488	22	1/5.95	25.21	18.91	Karanth 1998 (Camera-trap data analysis)

Note: WS - Wildlife Sanctuary, NP - National Park. The average body weight of tiger was considered as 150 kg.

ECOLOGICAL FACTS

Territory

The tiger is a territorial animal. Each territory is fairly well demarcated and the occupant of a territory is subjected to change when the occupants are ousted by a stronger rival or by death. Male occupants of territories change more often, and females tend to hold a territory for longer periods. It is also well accepted that the territory of a male overlaps with those of one or more females. The cubs are reared

exclusively by the mother who remains attached to them for up to two and a half years, the female cubs often occupying territories or home ranges adjacent to their mother's. Thus, within the short period of field operations for demarcation of tiger territories by the pugmark method, the occupants of different territories remained unchanged. This helps in eliminating duplication and arriving at a reasonable accurate minimum figure of the tiger population in the area (Singh 2000).

Camera-trapping technique
sketch: Shumon
photo: CWS/India

Food and feeding habit

Samples of available intact tiger scats (faeces) were collected from the study area during the study period. In order to collect the maximum number of scats, dense forests, meadow, forest edges, sea beach, riverbanks were thoroughly searched. While collecting the scats, data on weight, appearance, size, odour, and colour were noted. The seasonal variation of scat availability was also recorded. Samples were then hand picked and kept in airtight polythene bags, which were later transported to the laboratory for analysis. The method was largely based on that adopted by Ranawana *et al.* (1998) in Sri Lanka.

Only 52 tiger scats were collected during the 15 month study period (Appendix 3). Some scats had been washed by water either by rain in the monsoon or during high tide from the lowland area in winter and summer. However, all available scats were collected for this study.

While taking its food, tiger prefers drinking water nearby

photo: Debal Sen / Sanctuary

Before sieving, fresh and dried weights of the scats were noted down. In the laboratory, tiger scats were washed with water over a cloth sieve. Washing and boiling was done to soften the scats. The scats were then oven dried at 60-70°C for two days. Scat contents were carefully examined for the identification of the prey items, such as hair, teeth, claws, hooves, and skeletal remains. Hairs from all

portions of scats were examined in water under microscope to identify different types of hair on the basis of size, shape and colour. Hairs were further examined in temporary water mounts under a light microscope paying particular attention to circular scalation, medulla and pigmentation to compare with the permanent slides of various prey species hair (Kitsos *et al.* 1995) like spotted deer (*Cervus axis*), muntjac or barking deer (*Muntiacus muntjac*), wild boar (*Sus scrofa*), rhesus macaque (*Macaca mulatta*), jungle cat (*Felis chaus*), etc.

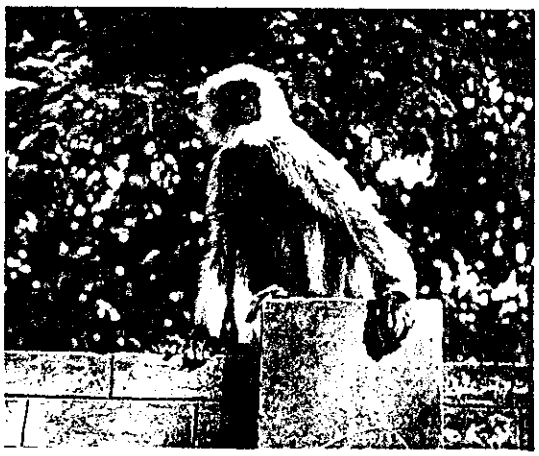
Among the 52 tiger scats, 12 were intact and fresh. Weights of scats varied from 75 to 200 g (mean=122±15.1). Hairs of three mammalian prey species were identified: spotted deer, wild boar and rhesus macaque. The proportion of different food items varied significantly (χ^2 = 53.1, df = 4; Fig. 3.1). The hair of spotted deer varied from 50-80 % of the total weight of the scats (Reza *et al.* 2001). Spotted deer and wild boar appeared to be the common prey animals of tiger in the study area. Unidentified animal parts consisted of scales of fishes, broken hard shells of crabs, fractions of bones, teeth, jaws, hooves, etc, which made up 4% of the total weight of the scats. The soluble material (6%) was soil; sometimes grasses were also found as soluble material. Feathers of a Green-billed Malkoha (*Rhopodytes tristis*) were recorded in one scat in April (Appendix 4).

Fig. 3.1 : Composition of tiger scats

Soluable materials
Monkey hair
Unidentified animal parts

Bengal tiger food habits were compared with those from other tiger habitats available in the literature and an effort was made to correlate them (Appendix 6). An attempt was also made to justify whether there was a significant variation in the prey selected by the tiger, which is determined by the density of prey species of the area. The food habits of the tiger vary depending on the habitat conditions and availability of prey species. In Katka-Kochikhali, tigers depend on larger prey like spotted deer, wild boar, and rhesus macaque (Reza *et al.* 2001). In other habitats of Asian countries tigers also depend on several other species as their prey, but the principal

Green-billed malkhoha
photo: Shihab Uddin



Common langur seems to be a common prey species other than the mangrove forest
photo: Ali Reza

prey species in any tiger habitat is the large-medium sized herbivores.

A review of tiger food habits from a few selected Asian parks shows that the prey species and mean body weight of prey killed by tigers are quite variable (Appendix 6). In Huai Kha Khaeng Wildlife Sanctuary in Thailand, the main prey species is barking deer or muntjac (34.8%). Common langur becomes the second prey in two national parks, Chitwan National Park in Nepal and Kanha National Park in India,

Monitor lizard : a rare prey species of tiger
photo: Ali Reza

whereas in Nagarahole National Park, it is the third prey species of tiger. Sambar is the second prey in Nagarahole, but in Chitwan it is the third prey of tiger. Porcupine is the second and third prey in Huai Kha Khaeng and Kanha respectively. Wild boar and rhesus macaque are included as second and third prey species respectively in the Sundarbans East Wildlife Sanctuary (Appendix 6).

PREY DEPENDENCY OF THE TIGER

The tiger is traditionally associated with such large mammalian herbivorous prey species around the world: wild buffalo (*Bubalus bubalis*), gaur (*Bos gaurus*), sambar (*Cervus unicolor*), nilgai (*Boselaphus tragocamelus*), swamp deer (*Cervus duvaucelli*), barking deer (*Muntacus muntijak*), spotted deer (*Cervus axis*), wild boar (*Sus scrofa*) etc. (Reza *et al.* 2001). Where these key prey species have been exterminated, the tiger does not survive (Seidensticker *et al.* 1999). In the Sundarbans, with the conversion of the swamp grasslands at the turn of the century to rice fields, the large herbivores prey of the tiger such as buffalo, gaur, samber, swamp and hog deer became extinct. More recently, even moderately large herbivores such as barking deer have been threatened.

To hunt a deer is not an easy task for the tiger

photo: Vivek Sinha / Sanctuary

Thus in absence of other large herbivore mammalian prey species, the tiger finds itself literally with its back against the wall in the Sundarbans. As its reproductive potential is high, however, the tiger under protection from poaching can bounce back, provided with adequate populations of its prey. In the Nagarhole National Park in India, according to Karanth *et al.* (1999), tiger numbers increased from 15 in 1970 to 52 in 1986 - a dramatic increase of 347% or at the rate of 8.3% per annum. This shows that not all small populations are *ipso faccto* 'doomed' and so should be conserved, and not abandoned on the hypothesis that inbreeding will automatically eliminate them (Reza *et al.* 2000b). In the Sundarbans, the tiger survival depends on the availability of adequate prey of the right size, and the reduction or eradication of poaching. Tiger numbers would increase if poaching were to stop, provided prey populations remain healthy and adequate. On the other hand, even with healthy prey populations, the tiger population will continue to decline if poaching goes out of control.

PREY SPECIES

The mammalian prey species of the Bengal tiger in the Sundarbans were identified as spotted deer (*Cervus axis*), wild boar (*Sus scrofa*) and rhesus macaque (*Macaca mulatta*) (Reza *et al.* 2001a). These three animals mainly constitute the large mammal community of the Sundarbans mangrove forest. The spotted deer is widely distributed throughout the Sundarbans. They are more abundant in the southern part of the Sundarbans in widespread meadows covered by grasses. A small population of the barking deer (*Muntiacus muntjac*) is reported in the Sundarbans mangrove forest. Barking deer is also found in the forested areas of northeast and southeast portions of the country. They would also be the prey of the Bengal tiger, but the recent studies have not proved this. The wild boar and rhesus macaque have wide distribution in most of the forested areas of Bangladesh.

Spotted deer

The spotted deer (*Cervus axis*) is perhaps the most beautiful of all deer in the world. Its bright reddish coat is marked with white spots which are usually arranged in rough longitudinal rows and which are retained throughout the animal's life. There is a dark dorsal stripe, and the under parts, inner legs, and under tail are snow white. The coloration of adult bucks differs from that of does in that bucks have darker coats and black facial markings. There is no seasonal difference in the color of the coat, except that during the cool season it is somewhat glossier, darker, and thicker than during the hot and wet seasons. They are medium sized deer standing about 35 to 38 inches high at the shoulders and weights about 85 kg (Prater 1971). The male bears antlers. The first set of antlers in yearlings consists

common in the Sundarbans, Chittagong Hill Tracts, and Cox's Bazar Forest Divisions. The domesticated wild boars are found in various districts of the country. Bangladesh, as a muslim country, pork is generally not eaten. But it is a popular food item for the non-muslims and is sold in some markets throughout the country. Its rang expand over nearly the whole of India, Myanmar, Thailand, and part of the Malay Peninsula. The wild boar is very common in Sri Lanka (Prater 1971).

Rhesus macaque

The Rhesus macaque (*Macaca mulatta*) is among the most common monkeys in the Indian subcontinent. It is highly intelligent and has learnt to adapt to almost of all habitat types. From near-desert habitats to thick jungles, even to mountains above the snowline at 2,500 m. The monkey has a brown body with lighter brown under parts. The monkey's face and rump are red. The average height for females is 18.5 to 20.9 inches, and 19 to 25 inches for males. The average weight for females is approximately 9 to 24 pounds, while males weigh between 12 and 24 (Neamotullah 2001). This monkey has the usual squat, thick build of a macaque. The hairs on its crown radiate backwards to form the forehead without the neat center-parting, so distinctive in its relative the macaque of southern India. The orange-red fur on its loins and rump distinguishes it from any other Indian monkey. Colour as well as length and texture of coat of the animal varies with season. Females are smaller and slighter in build. The largest and heaviest animals are found in the westerly ranges of the Himalayas. Rhesus macaques are being used in large number both for the pet trade and bio-medical research. Being one of the few natural homes of the monkeys, Bangladesh had been an important source for supply of wild rhesus monkey in the recent past, but this is strictly banned now.

Rhesus macaque: the most common primate in Bangladesh

photo: Rubaiyat & Elisabeth Mansur

The genus *Macaca*, the Asian representative of cercopithecine monkeys, is the most widely distributed of non-human primates. The rhesus macaque occurs from eastern Afghanistan to China, and has been most extensively studied in India, though data are also available from Afghanistan, Bangladesh, Bhutan, China, Laos, Myanmar, Nepal, Pakistan, Thailand, and Vietnam. The species is found in a variety of habitats throughout its range, including urban areas. In Bangladesh, it had a wide distribution and used to live in the cities, townships, villages and in all types of forests, *i.e.* Madhupur *sal* forest, semi evergreen forests of Sylhet and Chittagong region, and the Sundarbans mangrove forests, etc. The largest population lives in the Sundarbans. The species

has been wiped out from the sal forests of Dinajpur and Rangpur districts. Still, the urban monkeys are found in old Dhaka city, Narayangonj, Dhamrai, Bormibazar, Uzirpur Police Station under Barisal, Madaripur town, Matlab Police Station under Chandpur, and Chapai Nawabgonj districts (Feeroz, *et al.* 1995).

ECOLOGICAL STUDIES

Population dynamics

The population dynamics (e.g., group size, group density, individual density, biomass, metabolic biomass, etc.) of the three principle prey species of the Bengal tiger in the Sundarbans were studied based on line transect method (Johnsingh 1983). The prey animals were recorded by direct counts to assess and know their status and other biological facts. In the case of large mammals (e.g. spotted deer, wild boar, and rhesus macaques) in the Sundarbans, direct sightings are numerous enough to draw a population structure of them (Hendrichs 1975). In the study area, three 7 to 10 km long permanent transects were laid covering all habitat types proportionately. One transect was laid through the forest, one was through the meadow, and the other one through the sea beach from Katka to Kochikhali. These are the major habitat types in the study area.

Deer herd in Katka-Kochikhali
photo: Khasru Chowdhury

The fieldwork was carried out on foot twice a day between 0600 and 1000 hrs, and 1500 and 1800 hrs. Walking in the permanent transects in a zigzag route, the entire

terrain, especially, areas favoured for walking on foot (Nair *et al.* 1977) such as deep forest, forest edge, meadow, and sea beach were traversed. Sometimes it was difficult to walk inside the forest because of the presence of pneumatophores and submerged land due to high tide or heavy rain. At times, a country boat was also used to explore the difficult part of the transect. The narrow creeks of the study area were also explored by the boat at a speed of 3-5 km/hour. Whenever animals were sighted, the vehicle was stopped and animal group size, age, sex, etc. were recorded with the aid of binoculars (8 X 40). An SLR camera with 70-300 mm zoom lens was used to photograph the animals.

Classification and analysis of group size, age grouping, sex, etc. were largely based on the method used by Johnsingh (1983) and McCullough (1993). For calculating spotted deer density, the average effective strip width used was 100 metres, as a large part of the study was conducted in the open meadow (Appendix 7) where the visibility was reasonably good. In the case of wild boar, the average effective strip width was assumed as 40 metres. In the case of rhesus macaque, the distance was assumed to be 30 metres on account of its body size and agile activities. Because the study species were most active in the mornings and evenings, the census was done twice between 0600 and 1000 hrs, and 1500 and 1800 hrs. The biomass of the animals in the study area was calculated following the method of Karanth and Sunquist (1992).

Visibility is very high in a habitat like Katka-Kochikhali
photo: Ali Reza

Spotted deer was the most common prey species of tiger in Katka-Kochikhali (Reza *et al.* 2001). The density of the animal was 70.4 individuals/km^2. A total of 889 groups of spotted deer was recorded where the group size varied from 2 to 137 (mean 7.36) and group density was 9.56 groups/km^2. The biomass and metabolic biomass of this animal was 3870 kg/km^2 and 2903.2 kg/km^2 respectively (Table 4.1). Following the same method in the same study area, Islam (2001) and Neamotullah (2001) reported the density of the spotted deer as 77.58 individuals/km^2. The mean biomass of the

animals, by those two studies, was reported as 4281.75 kg/km^2 (Table 4.2). The mean group density of the deer in Katka-Kochikhali was calculated as 7.18 group/km^2 by Islam (2001) and Neamotullah (2001). The spotted deer density was found higher in the next two studies (Islam 2001 and Neamotullah 2001) than the earlier one (Reza 2000). These increase could be attributed that after the activity of the researcher in the area during the last of couple of years to which made it difficult for the poachers of these large mammals to invade those areas during this time. Moreover, Forest Department increased regular petrol activity due the advocacy of the researchers for the conservation of the prey species of the tiger during this time.

Table 4.1 Population status of the major three prey species of the Bengal tiger in Katka-Kochikhali

Species	No. of groups	No. of individuals	Group Size (individuals/ group)	Group Density (group/km^2)	Density (individuals/ km^2)	Biomass (kg/ km^2)	Metabolic Biomass (kg/ km^2)
Spotted deer	889	6545	7.36	9.56	70.4	3870	2903.2
Wild boar	133	294	2.21	3.58	7.9	300.2	225.2
Rhesus macaque	37	442	11.92	1.33	15.8	126.8	95.1

Source: Reza (2000)

According to Reza (2000), a total of 133 wild boar groups was recorded during the study period where the group size varied from 1 to 15 (mean 2.21). The group density was 3.58 groups/km^2. Density of this species was 7.9 individuals/km^2 and the biomass was 300 kg/km^2 (Table 4.1). Following the same technique in the same study area, Islam (2001) and Neamotullah (2001) reported the density of the wild boar as 8.69 individuals/km^2. The mean biomass and the metabolic biomass of the animal, by those two studies, were reported as 330.22 kg/km^2 and 247.67 kg/km^2 respectively. The mean group size of the animal was calculated as 3 individual/group and the group density was 2.89 group/ km^2 (Table 4.2). The reason for the increased density of the animals could be attributed the same reasons identified for the spotted deer.

The density of the rhesus macaque was 15.8 individuals/km^2 according to Reza (2000). A total of 37 groups of rhesus macaque was recorded (1.33 groups/km^2), the largest group consisting of 41 individuals whereas the smallest one had 3 members. The mean group size of rhesus macaque was 11.92 individuals/group. (range 3 to 41). The biomass of the animals was 126.7 kg/km^2 (Table 4.1). On the

other hand, Neamotullah (2001) calculated the group size and group density of the monkey was 7.71 individuals/group and 1.54 group/km^2 respectively. The density and biomass of the rhesus macaque was calculated as 23.88 individuals/km^2 and 191.04 kg/km^2 respectively (Table 4.2).

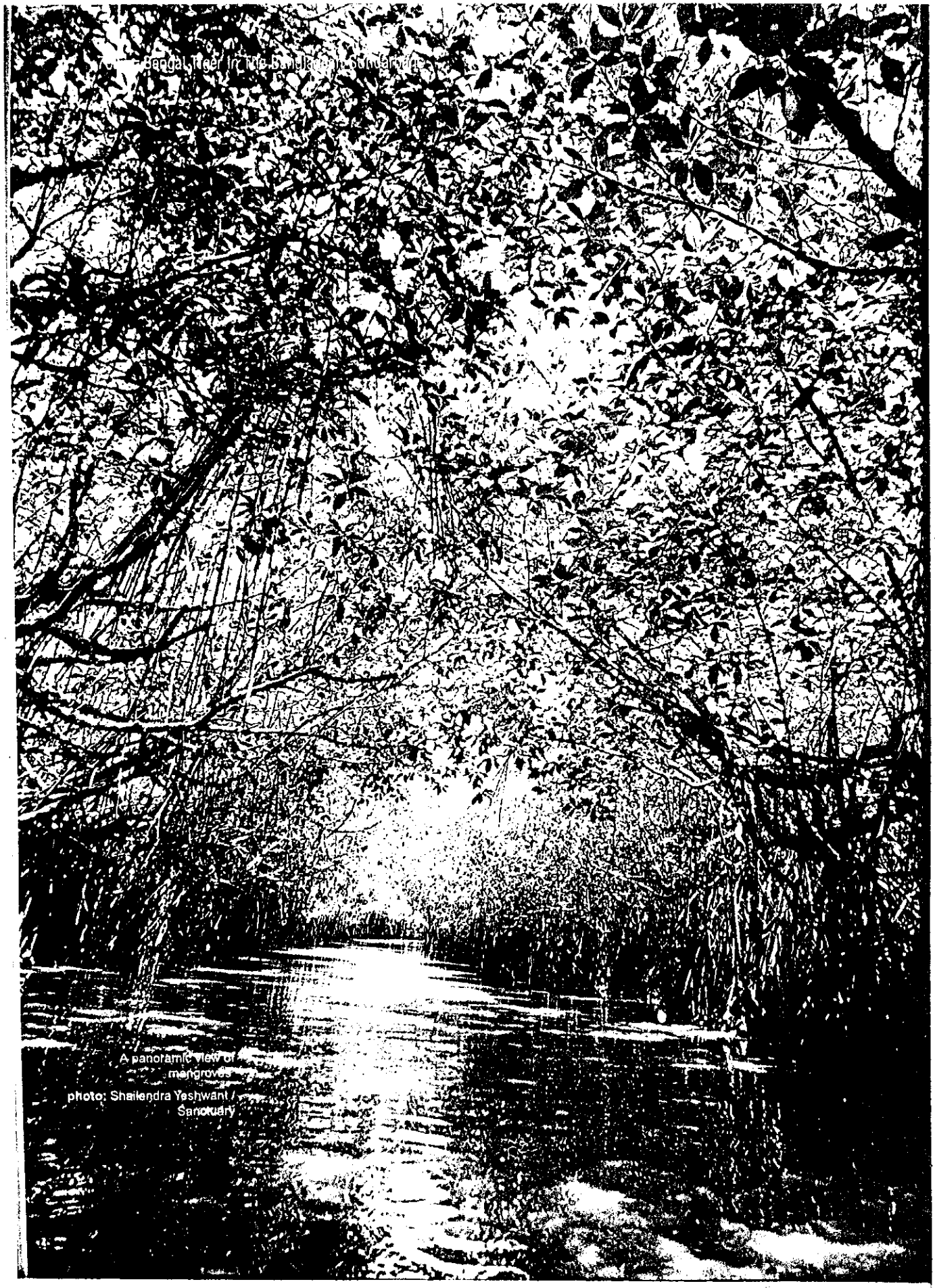
Table 4.2 The major three prey species in Katka-Kochikhali

Species	No. of groups	No. of individuals	Group Size (individuals/ group)	Group Density (group/km^2)	Density (individuals/ km^2)	Biomass (kg/ km^2)	Metabolic Biomass (kg/ km^2)
Spotted deer	181	1962	10.83	7.18	77.85	4281.75	3211.31
Wild boar	73	219	3.00	2.89	8.69	330.22	247.67
Rhesus macaque	39	301	7.71	1.54	23.88	191.04	143.28

Source: Neamotullah (2001)

The spotted deer was the most common and conspicuous mammal at Katka-Kochikhali while the wild boar was comparatively rare. Rhesus macaque was mostly recorded in the morning and afternoon, especially on the forest edges and riverbanks. Hendrichs (1975) estimated the density of spotted deer as 20 individuals/km^2 and Khan (1986) as 13.15 individuals/km^2. All these studies were conducted throughout the whole mangrove forest. Since the present study was exclusively conducted in the Katka-Kochikhali, an island situated in the Sundarbans East Wildlife Sanctuary and the habitat quality is better than any other parts of the forest, hence, spotted deer density was recorded reasonably very high. Rashid et al. (1994) referred to the status of the spotted deer of the area as 'the population of spotted deer may have increased beyond the carrying capacity of the area and the food supply for the animal may be insufficient'. Moreover, due to its location in the southern extreme of the Sundarbans reserved forest and inside a wildlife sanctuary, Katka-Kochikhali is away from human disturbances.

Hendrichs (1975), Gittins (1981), and Khan and Ahsan (1986) estimated the density of Rhesus macaque in the Sundarbans as 10/km^2, 52/km^2 and 17.05/km^2 respectively. During the present study, the estimated density of this primate species was 15.8/km^2. The density appears to be closer to the results of Khan and Ahsan's estimation. The group size of the Rhesus macaque was calculated as 11.9 individuals/group, which is smaller than that of any other forest in Bangladesh (Feeroz *et al.* 1995). The wild boar density was estimated as 8 individuals/km^2 whereas Hendrichs (1975) estimated the density as 5/km^2.



A panoramic view of mangroves

photo: Shailendra Yashwant / Sanctuary

Activity Pattern

Quantitative behavioural data were gathered through systematic scan sampling (Lehner 1998) during the study period. Every 15 minutes, all animals in a group in view for a period of 5 minutes were scanned to record their activities. The number of scans amounted to a total of 1,206 for the whole study. These recording rules were continuous recording (*ad libitum*) type, which means all behavioural occurrences during an individual scan was recorded. This method aims to provide an exact and faithful record of the behavior, measuring true frequencies and duration and the times at which behavior patterns stopped and started. In each month, three days were spent for quantitative behavioral data collection purposes. The observations of a group of populations were continued until they were invisible. Binoculars were generally used to collect the quantitative data. If a single species was found that also was included for observation. Sometimes a country boat was used to observe the creek and animal activity inside the forest.

The three following categories of activities of the deer herds were recorded during this study:

I. Movement: direct or non-direct movement from one place to other. It was sometimes difficult to decide whether a young (juvenile or infant) was moving or playing. In this study playing was recorded as movement.
II. Feeding: when an individual was actively manipulating a potential food source, ingesting food or masticating the same.
III. Resting: inactive periods when the individuals remain stationary or even when an individual was leaning against an object or lying down or was sleeping.

In Katka-Kochikhali, spotted deer generally fed in open areas or in meadows. Highest number of deer recorded, occured between 0730 and 0900 hours and also between 1500 and 1830 hours. The least number of deer was recorded between 0900 and 1200 hours and also between 1200 and 1500 hours. In the afternoon, they usually start coming out on the open meadows by 1600 to 1700 hours and remain active in the full night. The percentages of activity pattern were 62% grazing, 35% moving, and 3% resting (Table 4.3).

Though the wild boar is nocturnal animal, they were also observed in the open meadow areas in the morning and evening. The wild boar fed in the meadow areas from 0730 to 0800 hours. They entered into the forest at about 0830 hours and then took rest. They again came out by 1630 to 1700 hours and remained active until night. Some times they began to show up at the edge of the forest between 0900 hours and 1600 hours, but this was very rare. A total of 73% individuals of wild boar were found in moving 23% feeding, 4% resting (Table 4.3).

The rhesus macaque tends to be active whole day. The maximum activities of rhesus macaque were recorded in the forest edges and inside the forests. Usually, movements began at 0600 to 0630 hours daily for feeding. It was observed that movements and feeding occurred simultaneously. Rhesus macaque spent 46% time in moving, 41% feeding, and 13% resting at Katka-Kochikhali area (Table 4.3).

Table 4.3. Daily activity of three mammalian prey species of the Bengal tiger in Katka-kochikhali

Species	Feeding (%)	Moving (%)	Resting (%)
Spotted deer	62	35	3
Wild boar	19	77	4
Rhesus macaque	41	46	13

Source: Neamotullah (2001)

In the comparative study of the prey species, it was revealed that wild boar spent more time in moving, spotted deer in feeding. Resting was high in case of rhesus macaque (Table 4.3). Resting occured more in November and less on January. In case of wild boar and spotted deer maximum resting was found in January.

Habitat preferences

All three principal prey species of the Bengal tiger are found in the different habitat types in Katka-Kochikhali of the Sundarbans mangrove forest: forest, meadow, sea beach, forest edge, water hole area, and riverbank. A combination of both the pellet count method (Fuller 1991 and White 1992) and direct observation method (Sutherland 2000, Dittus and Dittus 1995) were used for the habitat preferences of the three prey species in the Sundarbans. Habitat uses and preferences were examined by determining proportions of time they spent within the specific habitat types. Following transect lines, the field data was collected on the behavioural and other aspects of ecology of the animals through direct observation. The overall occurrence of the three principal prey species according to the visual observations in different habitats varied significantly (Reza *et al.* 2002a). The overall prey species density in different types of habitats has been annexed in the Appendix 8. In general, the animals were found highest in the meadows (43%) and the lowest in the riverbank (4%) during most of their activity hours in the day time (Fig. 4.1).

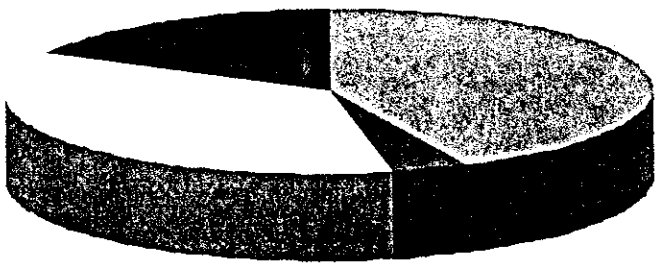
In case of visual observations, most of the spotted deer were found in the meadow (40%) followed by forest edge (35%) and water hole area (14%) (Islam 2001). They were found mostly within the meadow because grass was identified as their main

food item, which was only found in this habitat. But because the presence of humans and other predators, it generally prefers the forest edge as the second habitat. The other study technique, pellet count method indicated similar results for the spotted deer habitat preferences. The utilization of different habitats by spotted deer does not only depend on the vegetation type but is also influenced by various other factors. Deer prefer to use grassland that have Keora trees nearby. The distribution and density of spotted deer may be influenced by among others the availability of prefered food items such as grass and Keora (fruit and young twigs). A habitat that have a mix of preferred food species, open sady spaces, low salinity and an availability of drinking water (Feeroz 2003) are frequented by deers.

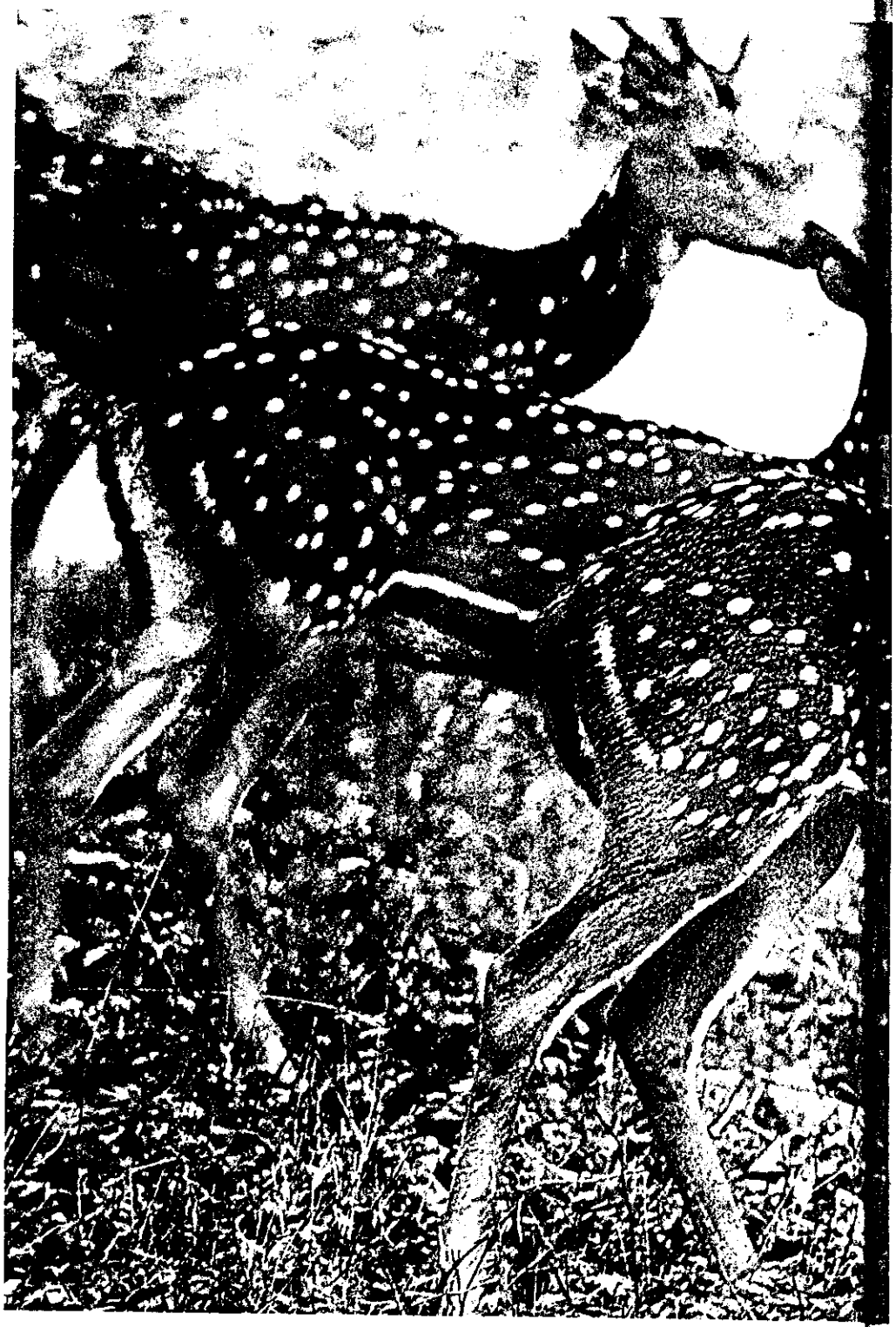
Similar results for the habitat preferences were observed in case of wild boar. They were also more active in the meadows (48%) and forest edges (42%) whereas they used the sea beach very occasionally (1 to 4%). These results are the outcomes of both the visual observations and the pellet count methods.

Habitat preference of the rhesus macaques was based on only the visual observation technique. Rhesus macaques mainly used the forested habitat (71%); they were not at all found to visit the sea beach area. A few macaques (12%) found in the meadows, specially, in the evening hours (Neamotullah 2001).

Fig. 4.1 Percentage occurrence of the animals in different habitat types (Reza *et al.* 2002b)

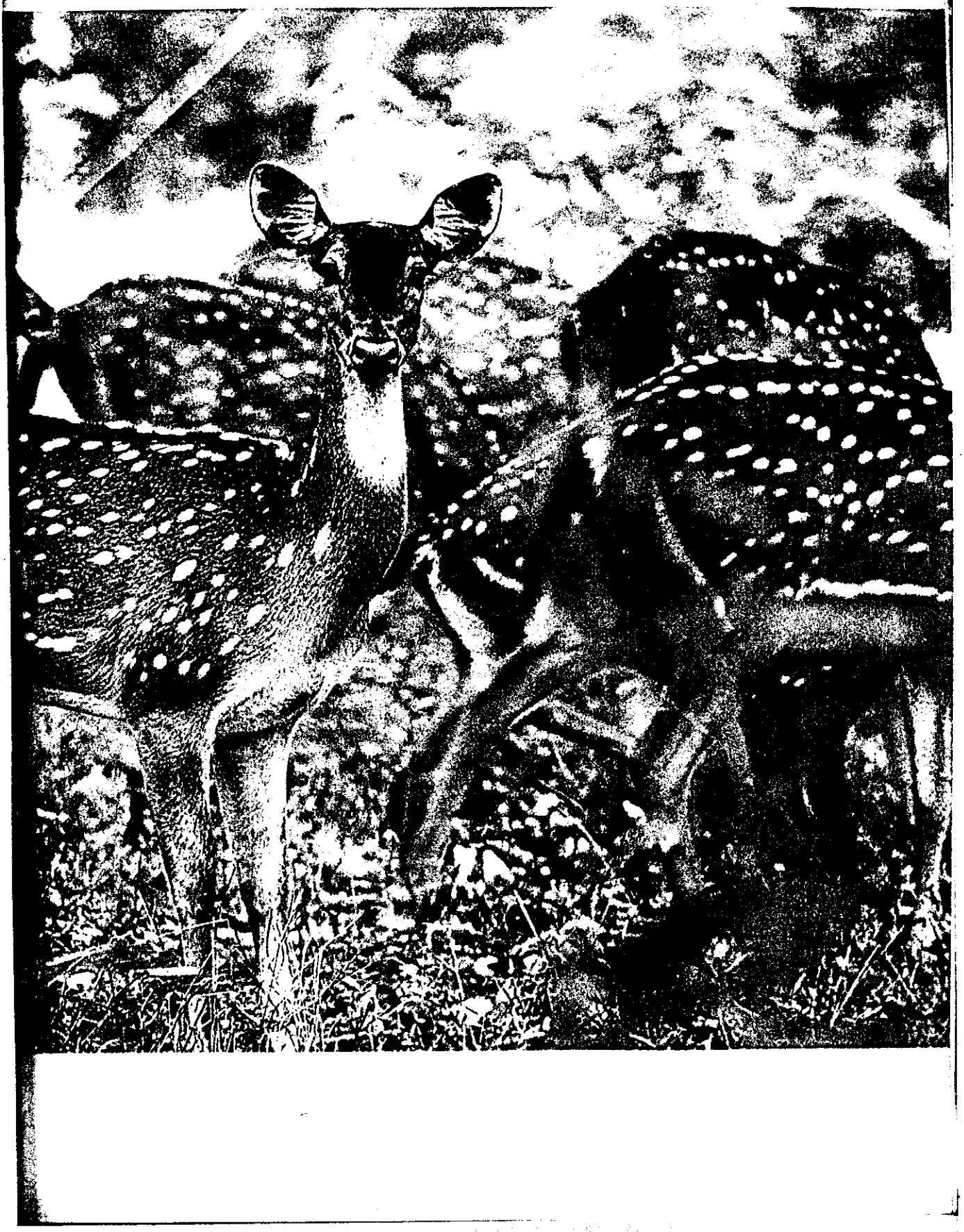


Riverbank
Sea beach
Forest edge
Forest
Meadow



A deer heard

photo: Anish Andheria / Sanctuary



The spotted deer are gregarious grazers and seem to attain their peak abundance in forested areas where grassy clearings are present (Karanth and Sunquist 1992). The density estimation of the spotted deer in Katka-Kochikhali of the Sundarbans was very high due to the presence of grassy clearings and healthy forest in the same habitat. In the present study area, the wild boars are also gregarious but seem to attain the peak numbers in the forest edge where grassy and forested bushes were present in a same patch. The rhesus macaque was mostly recorded from the forest edge while searching for food. Sometimes it was also recorded in the forest, and in the riverbanks during the low tide while feeding on the roots of dhanshi (*Myriostachya* sp.). The density estimation of the ungulate species of Katka-Kochikhali has been compared to those estimates, derived from elsewhere in Indian forests. The comparison indicates that the density estimates of the ungulates species in the mangrove forests of the Sundarbans are comparable to or higher than those from semi-evergreen, deciduous or semi-arid forests in India (Table 4.5).

Table 4.5 Ungulate densities in different tiger habitats in the Indian subcontinent

Species	Densities at different sites in Bangladesh and India (individuals per km^2)							
	SRF	RNP	GIR	PNC	KN	NHL	BDR	BNR
Spotted deer	70	38	25	51	50	38	3	80
Wild boar	8	4	2	1	3	3	2	3

Sources: SRF: Sundarbans Reserve Forest - Reza (2000); RNP: Ranthambore National Park- Kumar (2000); GIR: Gir National Park - Khan (1997); PNC: Pench National Park- Karanth and Nicholas (1998); KNH: Kanha National Park- Karanth and Nicholas (1998); NHL: Nagarahole National Park - Karanth and Nicholas (1998); BDR: Bhadra National Park - Ahrestani (1999); BNR: Bandipur National Park - Johnsingh (1983).

Prey selection

The prey selection study was based on analysis of remains of kills and scat data. All types of tiger habitat were extensively explored to collect maximum number of kills and scats. Tiger kills or carcasses were located using clues like odour, alarm calls of prey, calls and flight patterns of vultures and crows, and predator signs. Sometimes local people provided information of the location of the carcasses. A total of 26 tiger kills were recorded, of them 65% were spotted deer, 23% were wild boar, and remaining 11% were monitor lizards (Appendix 9). Five fresh spotted deer kills were recorded during the study period. All of these 5 kills were recorded

in the early morning. Of the 17 spotted deer kills, 13 were males and had antlers. Most of the wild boar kills were not fresh and only the bones and skulls were recorded. One fresh monitor lizard kill was recorded that was not eaten up by the predator.

The average prey selection tendency was calculated from the scat and kill data analysis. From these results, it appears that the spotted deer was the most preferred (67%) prey species of the tiger in Katka-Kochikhali (Appendix 10). The mean body weight (55 kg) of this animal is higher than the other two mammalian prey species. Tigers chose these animals as its prey because of effectiveness in efforts. The results indicated that the tiger liked to prey on spotted deer (67%), which was the largest ungulate in Katka-Kochikhali. In Nagarahole National Park in South India, tiger selected prey weighing more than 176 kg, whereas the other predators of the area, e.g. leopard and dhole, focused on prey in the 30-175 kg size class (Karanth and Sunquist 1995). In the Sundarbans, tiger selected prey weighing 8-55 kg. Tigers in this area also selected aquatic animals as its prey items.

Fresh tiger kill, not so easy to find out in the forest

photo: Ali Reza

Sex ratio and breeding season

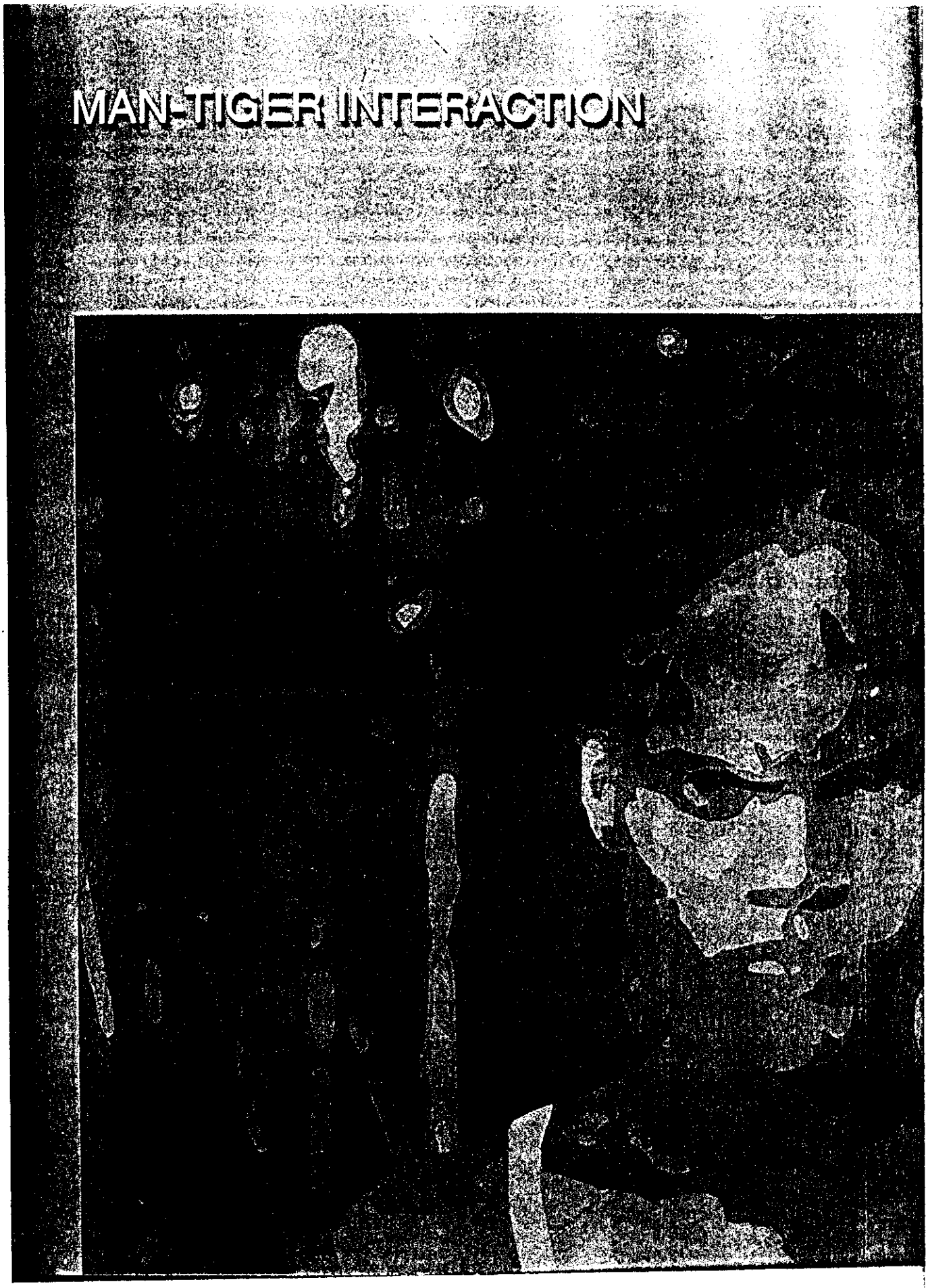
In case of spotted deer, the sex ratio is biased in favour of the females because of their mixing with the juvenile males, who did not grow antlers at young ages. The crude male to female ratio throughout the study period was 67:100. From this result, it appears that the females were more numerous than the males, and the population of this species is increasing. In Katka-Kochikhali, the spotted deer showed rutting behaviour throughout the year. The peak-rutting season was May-June, just in the middle of the rainy season. And after an 8 month gestation period (Schaller 1967) more fawns were seen in January-February, in the middle of the winter. Very young fawns remained hidden during their first few weeks. During April-May the fawns were seen abundantly. This was the time of heavy rainfall in the forest and the grasses started sprouting, which are the major food items of the spotted deer in Katka-Kochikhali. However, throughout the year, some fawns were

seen with the does, which indicated that the spotted deer could breed throughout the year at Katka-Kochikhali.

The peak breeding season of the wild boar in Katka-Kochikhali was from January to February. But the piglets were seen throughout the year. Most piglets with their mothers were recorded in the rainy season. This indicates that breeding takes place before the rainy season. A group of 15 piglets and adult females was sighted on June 7, 1999 at Kochikhali meadow and another group of 9 piglets was seen on July 27, 1999 at the Badamtoli area of Katka.

The rhesus macaque shows a definite breeding season, correlated with climatic conditions (Prater 1971). In the Sundarbans, it was also correlated with its climatic factors and phenology of plants. At Katka-Kochikhali, macaque mating was observed in all months of the year but the greatest frequency was seen in winter (September-November) and summer (March-May). Infants were common in late summer, especially in the month of June/July when the plants start leafing and fruiting.

MAN-TIGER INTERACTION



MAN-TIGER INTERACTION

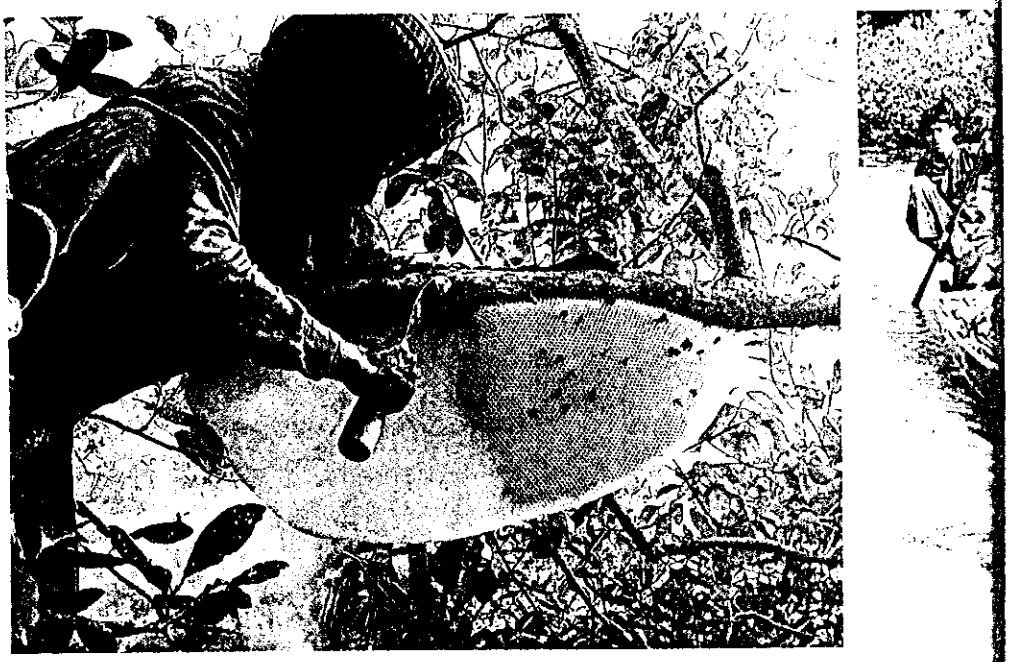
The Sundarbans has an age-old history of man-tiger conflict (Corbett 1946, Khan 1961, Mountford 1969, Chakrabarty 1992). There are far more opinions about the tigers in the Sundarbans than there are facts, especially from the Bangladesh portion. Records on man-eating tiger date from as far back as 1670. Curtis (1933) recorded 427 people killed between 1912 and 1921. According to him, 452 tigers were killed by hunters during the same period. Killing of tigers was not banned till the promulgation of the Bangladesh Wildlife (Preservation) (Amendment) Act, 1974.

Result of man-tiger interaction

photo: Rubaiyat & Elisabeth Mansur

Over the last fifty years, tigers in the Sundarbans have taken a toll of about 1,000 humans (Chaudhury and Choudhury 1994). These are only the reported cases and there are many that never get reported. The victims are almost invariably poor villagers from the adjacent areas. Sheer economic necessity compels them to brave the hazards of the terrain time and again. Supernatural qualities are attributed to man-eaters and tiger attacks are accepted as professional hazards, by the locals. In fact, there are elaborate rituals to ensure co-existence of man and tiger. A priest accompanies the workers to the forest and invokes the blessings of Dakshin Rai - the principal folk deity and lord of the forest - as well as blessings from Narauani Ma, Bonbibi, Kalukhan, Sa Jungli and Gazi Saheb to obtain immunity from tigers, crocodiles, snakes, and other creatures (Chaudhury and Choudhury 1994).

Past records do not indicate whether the forest or civil administrators were very concerned about protecting the forest workers from tiger attacks except that villagers were allowed to keep fire-arms to protect themselves at their homesteads. On the other hand, it was also reported that from the remote past, Sundarbans tiger was the main target of hunters, who at times had been rewarded by the forest authorities. Although strict prohibition on killing or hunting of tiger has been legislated by the Bangladesh Wildlife (Preservation) (Amendment) Act, 1974, tiger killing still goes on.



Collection of non-timber forest resources: i) honey; ii) crab; and iii) fish

photo: i) Rubaiyat & Elisabeth Mansur
ii) Ali Reza
iii) Shailendra Yeshwant / Sanctuary

COMPETITION FOR SURVIVAL

Man-eating propensity in the Sundarbans tigers is a subject of traditional debate amongst naturalists, ecologists and wildlife enthusiasts all over the world. The Sundarbans tigers are popularly branded as hereditary man-eaters (Chakrabarti 1992). The terrain has an age-old history of man-tiger conflict, which has turned the situation into a survival competition between man and tiger.

During the present research, a human-tiger conflict study was conducted mainly based on the records registered by the Forest Department. Available data were collected from the Forest Department and analyzed. Sometimes local people gave valuable information about the conflict. On hearing any news of tiger killed by man or vice versa, the area was visited and all available information was recorded. In the western part of the Sundarbans, due to scarcity of prey species, tigers sometimes enter the neighbouring villages and kill cattle and, occasionally, even human beings.

Today about one million people directly or indirectly depend on a variety of resources of the Sundarbans. Thus tiger often attacks man when encountered inside the forest. The human-tiger conflict study reveals that a total of 401 people were killed by tigers between 1984 and 2000. The average human causality rate by the tiger was about 24 people per year. This is based on the office records, but there is a tendency among the Forest Department staff to minimize the number of incidents. For example, in a publication of the Sundarbans Forest Division, it is claimed that 20 people are killed every year (Dey 2001). During the time period,

from 1984 to 2000, a total of 41 tigers were killed by humans (Fig. 5.1). On average, about 3 tigers were killed by humans annually. Again, this is an official figure; the actual figures for tiger poaching may be several times higher than this.

A very limited number of tigers in the Sundarbans are man-eaters, of which only a few are obligate man-eaters (Reza *et al.* 2000). Moreover, established man-killers are declared as man-eaters and killed by the Forest Department. The Forest Department declared 4 man-eating tigers from 1981 to 1992 in the Bangladesh Sundarbans, which were subsequently killed by them. From January 1999 to March 2000, a total of 6 tigers were killed, none of which were declared as man-eaters (Table 5.1).

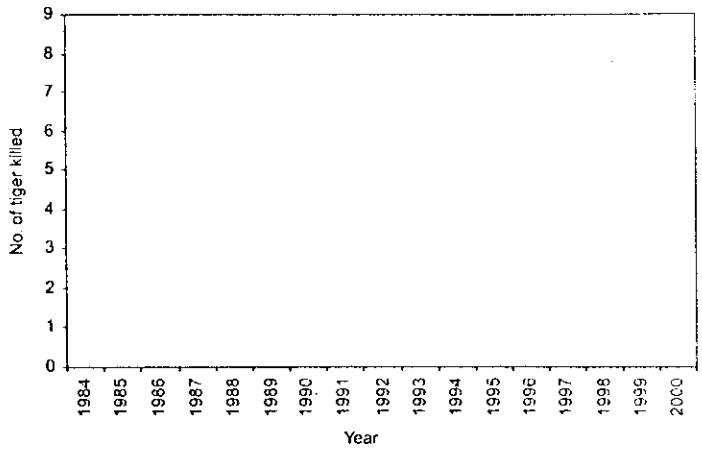


Fig. 5.1 Tigers killed by humans (only those were recorded) in and around the Sundarbans during 1984 and 2000 (Reza 2000)

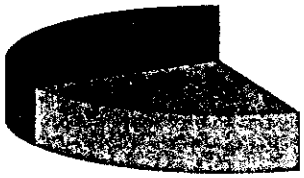
Among the four existing forest ranges of the Sundarbans Forest Division, the conflict between man and tiger was highest in the Burigoalini range (45%) and lowest in the Khulna range (9%) (Fig. 5.2). Burigoalini range is situated in the western corner of the Bangladesh Sundarbans. Here, the Sundarbans mangrove forest is the next-door neighbour of the villagers. Everyday the people from the adjacent villages enter the forest to collect the forest resources for their livelihood. Many of them enter into the reserve forest illegally. These people are not much aware of tiger attacks, which may be one of the major causes for such highest casualties. Chakrabarty (1992) claimed as much as 25% of tigers turning man-eaters as salinity of water is probably the most important factors. In this area, the vegetation of the forest is quite different from that in the eastern part of the Sundarbans. As a result, the main prey species of tiger, the spotted deer and the wild boar population are not so abundant as in the eastern part of the forest.

Table 5.1 Tigers killed (only those were reported) by humans between January 1999 and March 2000 (Reza *et al.* 2002a)

Tiger killed	Place of killing	Killer	Date/ Month	Punishment for poaching	Information source
1	Burigoalini under Satkhira Range	A Major in the Bangladesh Rifles	August, 1998	No punishment	Local people and the killer, also in newspaper (The Daily Star, July 2, 1999)
1	Bogi under Sarankhola Range	2 forest officials, Bangladesh Forest Dept.	November 6, 1998	Arrested by Bangladesh Police and suspended from the Dept.	TIGERLINK, News, Vol. 5, No. 1, January 1999, Ranthambhore Foundation, New Delhi, India. 31 p.
1	Khasiabad under Khulna Range	Unknown; wounded in a trap and found dead	May 19, 1999	Not known (possibly a case was filed by the Station Officer)	A.K.M. Mohiuddin, Station Officer, Khashiabad Forest Station, Khulna Range. Reported on 27.09.99
1	Datinakhali under Satkhira Range	Local poachers supported by a political leader	First week of June, 1999	No report of punishment	Newspaper (The Daily Star, July 2, 1999)
1	Katakhali under Chandpai Range	Villagers	July 22, 1999	No report of punishment	Local people and Newspaper (The Daily Observer, Ittefaq, Sangbad, Muktokantho, Janokantha, etc July 24, 1999)
1	Ashirsina under Chandpai Range	Local poachers	August 2, 1999	Law-suit was brought by the Station Officer of Chandpai Range	Local people and newspapers (The Daily Muktokantho, Prothom Aalo, August 4, 6; 1999)

Eight types of occupational people were identified who regularly enter the Sundarbans. It was concluded from the results that certain professions were at a

higher risk than others. From 1984 to 2000, of all the professions, fishermen (44%) were the main tiger victims, followed by woodcutters (36%) and honey collectors (18%) (Fig. 5.3). Fishermen, woodcutters and honey collectors constitute the bulk of the permit holders, who enter the forests in pursuit of forest products and resources. These people think that it is their professional fate and there is no alternative solution to avoid the conflict. Therefore, it is their fate to enter and collect the natural resources from the forest as they had inherited it from their parents or ancestors.



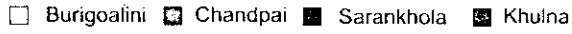


Fig. 5.2 People killed by the tigers in four forest ranges of the Sundarbans during 1984-2000 (Reza 2000)

Monu Mollah, a survivor of attack by a tiger

photo: Ali Reza

The tiger victims were divided into 7 age group classes. The most likely victims were people aged between 26-35 years (38%) followed by 36-45 years (30%) (Fig. 5.4), possibly because people in these age groups have become more daring about their safety. Supernatural qualities are attributed to man-eaters and tiger attacks are accepted as professional hazards among the local resource users. In fact, there are elaborate rituals to ensure co-existence.

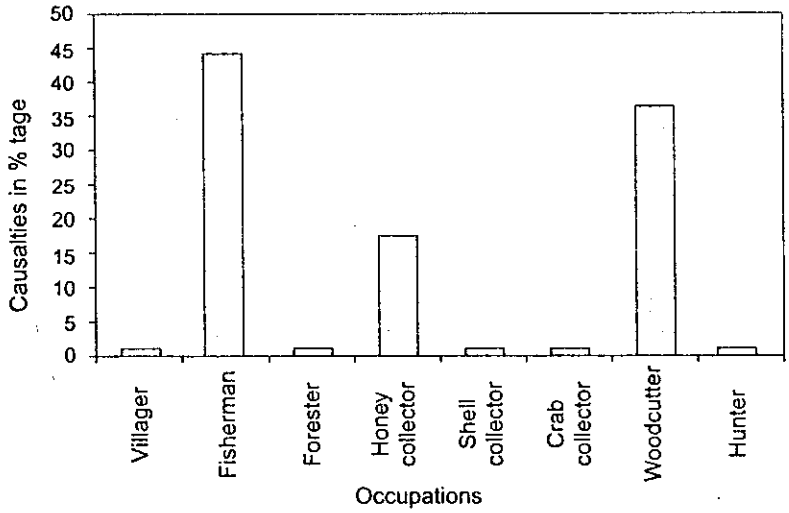


Fig. 5.3 People of different occupation killed by the tigers in the Sundarbans during 1984-2000 (Reza 2000)

It is necessary to identify the causes of tiger depredation if we are to develop appropriate measures for mitigation of such continued conflict between man and tiger. Tigers in general are shy animals that hunt in the night through mainly the sense of smell. Unlike the lion, they are not social animals (Krebs and Davies 1992). Therefore, hunting is an extremely energy-expending process, and the tiger uses its acute sense of smell plus its stealth in capturing its prey. The prey animals too are well equipped to escape the tiger predation. Therefore, any opportunity to attack sluggish/easy to capture prey is exploited by the tiger. Hence, humans can become this kind of easy prey for the tigers.

Furthermore, as a tiger gets older, it looses teeth, and so the animal finds capturing the fleet-footed prey extremely difficult. In such situations, a tiger may turn into a man-eater since attacking human beings especially those who are either absent-minded or fast asleep are relatively easy to capture. The problem is further

exacerbated by the fact that thousands of fishermen, woodcutters and honey collectors enter the mangrove forests inhabited by the tiger in the Sundarbans. It is this category of forest exploiters that fall victim to tiger attacks.

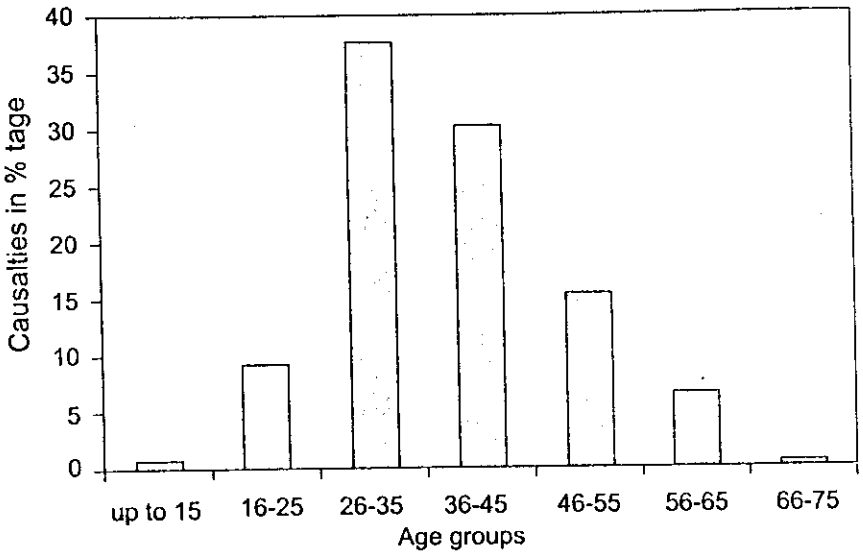


Fig. 5.4 People of different age group killed by the tigers in the Sundarbans during 1984-2000 (Reza 2000)

SOCIO-ECONOMIC CONDITIONS OF THE LOCALS

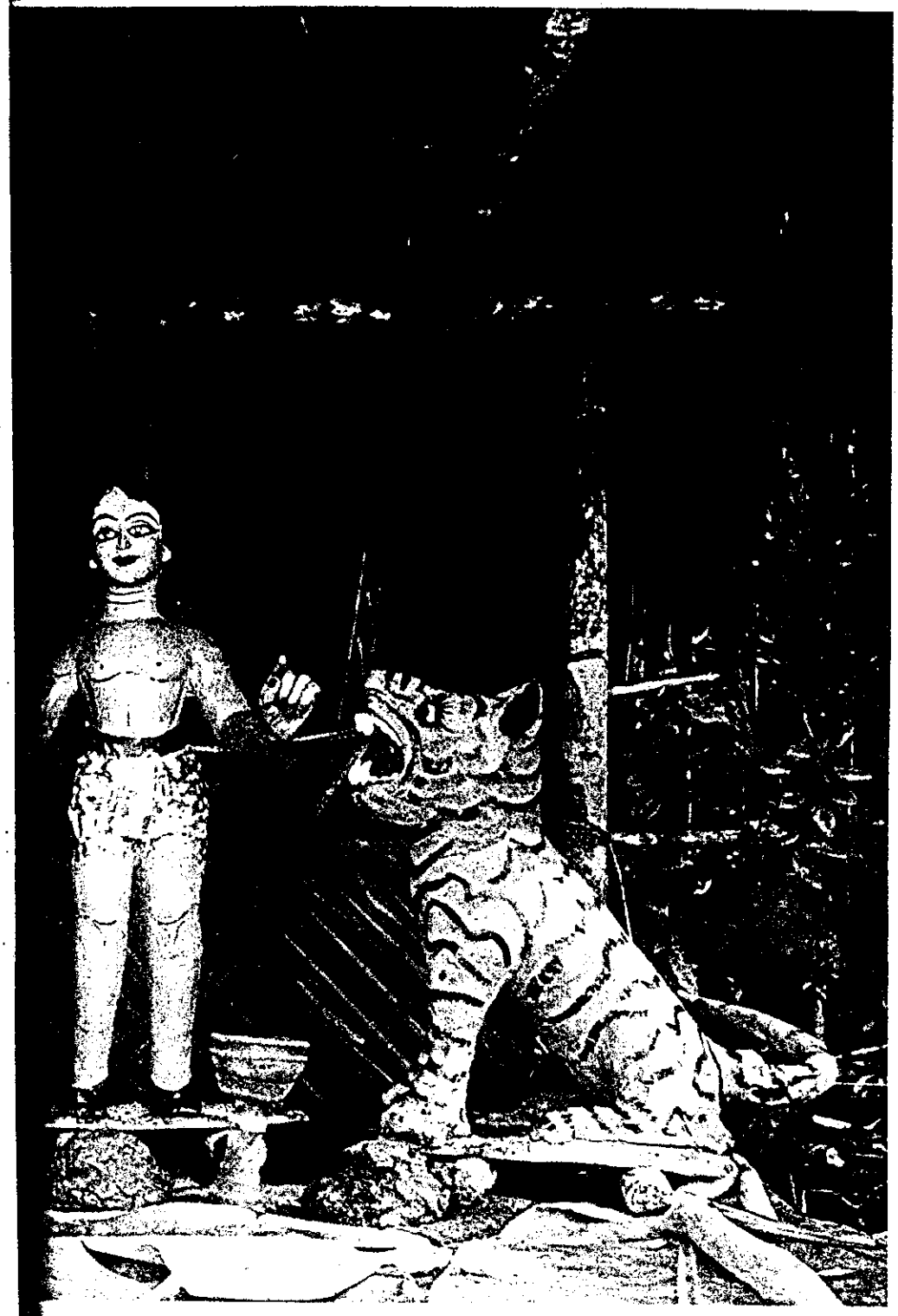
Questionnaire survey and Participatory Learning Appraisal (PLA) techniques were applied to investigate the local people's perception about tiger, its ecology, management, and conservation status in the Bangladesh Sundarbans. Local resource users and FD staff were asked to fill the questionnaires, which covered representatives from all communities (e.g. grasscutters, woodcutters, fishermen, honey collectors, shell collectors, businessman, tourists, farmers and FD staff) who enter the forest for various purposes. All the respondents were divided into six categories: grasscutters, woodcutters, businessman related to forest products, farm and day labours, tourists and FD staff (Appendix 11). The age groups of the respondents were also recorded. PLA was conducted during social discussions and casual conversations with their companions, during which general information was also collected on their perceptions about the traditional beliefs, myths, taboos related to the tiger in the Sundarbans. For this purpose, a questionnaire format was developed to conduct a survey among the local people on their perception about tiger and its prospects for conservation.

The main objective of this study was to investigate local people's perceptions about tiger, its ecology, conservation, and other wildlife. The Sundarbans is the only forest in Bangladesh where there is no permanent settlement. So, it was difficult to get many respondents. It is notable that this questionnaire survey was done only among males, because except for some very few fisherwomen and tourists, there were no females who were engaged in any job in the forest. Additional questions were included to gauge the respondents' general knowledge of wildlife, and attitude towards conservation of other wildlife. This was done during social discussions and casual conversations.

Stakeholders consultation on board

photo: Ali Reza

A total of 111 people from different occupations were interviewed. The survey was conducted at the two study sites - Katka-Kochikhali in the east (inside the Sundarbans East WS), Burigoalini in the west (outside the WS) - and at different other places of the Sundarbans mangrove forest (Appendix 11). A major part (51%) of the survey was conducted in Katka-Kochikhali, which is situated inside the Sundarbans east wildlife sanctuary, 30% was conducted in Burigoalini, and 19% was conducted in various other places of the Sundarbans. Among the respondents, the forest officials were the highest (32%) followed by the grasscutters (19%).



Banbibi Than: locals have been praying to these forest deities for centuries

photo: Rubaiyat & Elisabeth Mansur

INTERACTION OF TIGER WITH THE LOCALS

Tiger sightings and activity hours

It appeared from the study that the grasscutters encountered tigers (67%) most frequently followed by farmers and day labourers (47%). Although the tiger is the main attraction for tourists in the Sundarbans, none of those surveyed observed any tiger. Tiger sightings mainly occur in the mornings (between 0600 and 1000 hrs) (52%) and evenings (between 1400 and 1800 hrs) (31%). The study revealed that the tigers are more active either in the morning or in the evening.

Breeding season, habitat quality and medicinal value of tiger parts

The monsoon (45%) and winter (31%) are the breeding seasons for the tiger in the Bangladesh Sundarbans according to the respondents of the survey whereas 24% had no idea. More than 60% respondents mentioned that for hunting the prey and also the humans, the tigress was more active than the male tigers whereas 27% people believed that both male and female were equally active. Most of the respondents (95%) believed the Sundarbans as an ideal habitat for tiger. More than 55% respondents believed that tiger's body parts have some medicinal value or supernatural power.

Wildlife Act 1974, Forest Department and tiger conservation

About 50% local people and 17% forest officials had no idea about the Bangladesh Wildlife (Preservation) Act, 1974. Nearly 50% respondents thought that Bangladesh Forest Department should be well equipped and 20% respondents believed that the Forest Department was not so effective for the overall management of the forest. More than 75% respondents did not consider the tiger an enemy and wanted to conserve the species in the Sundarbans. About 23% respondents felt it is a threat to their lives and did not want to conserve it.

CONSERVATION AND MANAGEMENT OF TIGER

"Wildlife Management is the science and art of changing the characteristics and interactions of habitats, wild animal populations, and men in order to achieve specific human goals by means of wildlife resource" - this is how a pioneer scientist Giles (1971) defined 'wildlife management'. Whatever the ultimate human goals - control, harvest or preservation of a species or changing the characteristics of habitat - wildlife management usually involves manipulation of animal population or the habitat in a scientific manner. Therefore, animal populations or their habitat features, which determine the survival of that specific species or influence other animal populations, are of great interest to wildlife managers. The bottom line of this manipulation is to achieve specific human goals for sustainable development through improved management of the entire ecosystem. Two biologically important environmental components are the subject of the present discussion: the Sundarbans and the Bengal tiger, both of which are extremely important for the conservation and management of the world's largest chunk of productive mangrove forest, the Sundarbans.

Involvement of locals for the sustainable management is extremely important

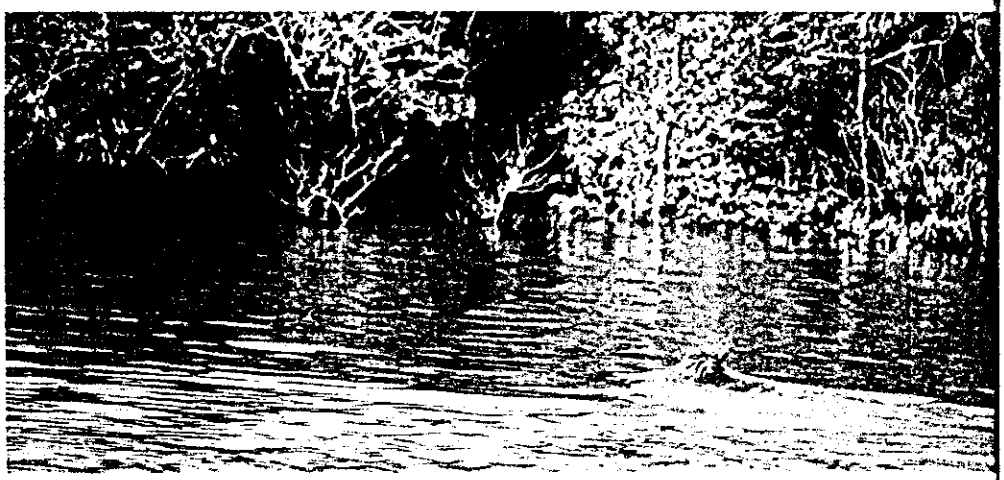
photo: Munir

Mangrove ecosystems are self-sustaining coastal landscape units that that have evolved through long-term geomorphological processes and continuous interactions of contiguous ecosystems in its regional mosaic. They are open systems with respect to both energy and matter, and thus can be considered 'interface' ecosystems coupling upland terrestrial and coastal estuarine ecosystems. The fact that mangrove ecosystems are open has presented people with a difficult problem in terms of management and conservation, particularly with respect to estuarine-dependent fisheries (Lugo and Snedaker 1974). The Sundarbans mangrove forest represents a major conservation area in Bangladesh, which is mostly exploited by the adjoining villagers. However, Bangladesh is one of the world's most densely populated country and the people are extremely poor and needy. So, people from the adjacent areas frequently enter and eventually explore every nook and corner of the forest including the protected areas, mainly to earn their livelihood. These people are among the poorest in Bangladesh.

There is no doubt that the Sundarbans is valuable and will become increasingly so with increasing demand. There are two major service functions provided by the Sundarbans: the forest is a major storm barrier and it is the nursery for major fisheries of the Bay of Bengal. The Sundarbans provides natural capital in terms of food and materials for Bangladesh, where tigers, deer, forest, and men are linked inseparably. Therefore, any attempt to separate the tiger from its prey, the deer from the forest, or people from their needs will surely jeopardize the whole system (Seidensticker and Hai 1983). However, the Sundarbans also has two other important distinctions: i) it has no permanent human settlements, though located in one of the world's most densely populated countries, and ii) it is one of the oldest managed mangrove forests in the world, an unique beneficial result of the British colonial rule.

A tiger crossing a river

photo: Bittu Sahgal / Sanctuary



As Schaller (1995) stated that, we know how to protect tigers, but do not know how to manage them. Of the twin evils of loss of prey species and poaching, the former is more serious for the Sundarbans, since most carnivore populations can withstand a certain amount of loss. These are possibly the reasons why across much of the tiger's present range is in danger: there are many potentially good tiger habitats without any tigers in them but in most of the prey species have nearly disappeared. Thus the message is clear: as far as the Sundarbans is concerned, protection of the forest alone will not ensure the long-term survival of the tiger. Much attention must be given to the maintenance of healthy populations of suitable prey species. Even in the presence of low level poaching, tigers can survive provided their prey base is maintained at adequate levels (Karanth and Stith 1999). Thus prey depletion remains the most potent threat to tiger survival in the Sundarbans. The forest has already lost its swamp deer, hog deer, and some other wild cervids, which were the prey species of the tiger. It is therefore of enormous importance that habitat conditions are managed and manipulated in such a way to ensure that spotted deer and wild boar populations remain abundant. It must be ensured that the tiger's principal prey species in the Sundarbans are enhanced and regularly monitored (Reza *et al.* 2000).

PRESENT MANAGEMENT STRATEGY

Sundarbans, being a reserved forest, tigers therein are protected under the Forest Act, 1927. Tiger conservation actually started in Bangladesh with the promulgation of the Bangladesh Wildlife (Preservation) Order, 1973 which was later enacted as Bangladesh Wildlife (Preservation) (Amendment) Act, 1974. According to this Act nobody can kill, hunt or capture tigers. Under the Act, to date, 15 protected areas have been established in Bangladesh, and 3 of these wildlife sanctuaries are located in the Sundarbans. From the wildlife conservation viewpoint, the total area

Hog deer: new extinct in the Sundarbans

photo: MM Feeroz

Sundarbans crabs

photo: Rubaiyat & Elisabeth Mansur

allocated for the sanctuaries is not enough, especially for large carnivores like tiger, since they need very large areas as their home ranges. It is to be noted that the present status of the Sundarbans south and west wildlife sanctuaries is much better than that of the east. Tourist pressure is one of the main causes of such degradation of the east wildlife sanctuary though it has the richest and most diverse ecosystems in the Sundarbans.

These three wildlife sanctuaries are also part of the World Heritage Site. These are not managed properly according to the criteria set by the World Commission on Protected Areas (WCPA). Bangladesh Forest Department is neither well equipped nor possess adequate manpower required for the purpose. The incentives of the FD personnel are not adequate, to ensure sincere performance under the tough environment of the Sundarbans. This is one of the major causes of the poor management of Sundarbans mangrove forest.

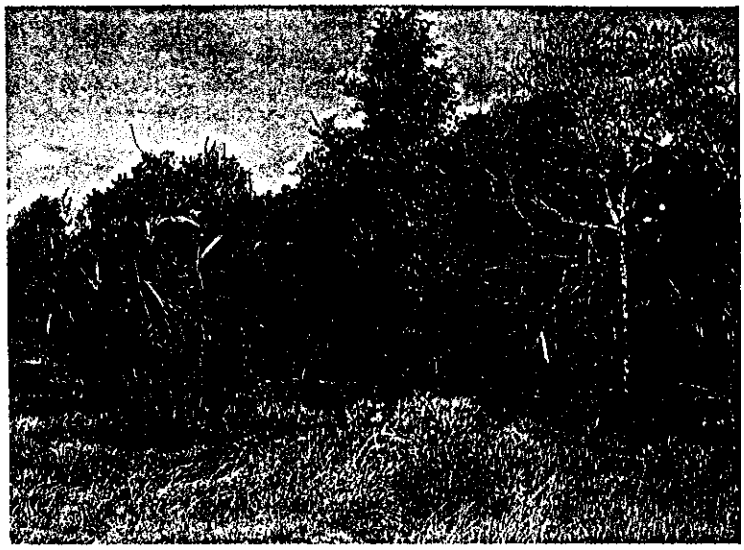
Currently, the two Sundarbans Forest Divisions, East and West, and the Environment Management Division (EMD), Khulna are responsible for the overall management and conservation of wildlife including tigers in the Sundarbans. The Divisional Forest Officer (DFO), EMD with its headquarters at Khulna is exclusively responsible for the conservation and management of the wildlife sanctuaries situated in the Sundarbans. There are 8 stations cum tiger center in the wildlife sanctuaries and every sanctuary is supposed to be headed by an Assistant Conservator of Forest (ACF). The total number of staff of the wildlife sanctuaries including the ACFs is 121. The wildlife sanctuary stations have basic facilities. A management Plan for the Sundarbans wildlife sanctuaries has been prepared under the Forest Resources Management Project (FRMP) in 1997. The plan includes protection, monitoring, research, investigation etc. but these are yet to be implemented properly.

For the purpose of management, the Sundarbans reserve forest has been divided into four zones. i) The marine zone, including the marine area of the extreme south of the forest; ii) The protection zone, including three wildlife sanctuaries (which are the parts of the World Heritage Site), where all types of resource collection is legally prohibited; iii) The production zone, subjected to sustainable harvest; and iv) A buffer zone, and approximately 20 km belt on the periphery of the reserved forest. The two DFOs, Sundarbans East and West Forest Divisions, headquarters at Bagerhat and Khulna respectively are responsible for overall management of the Sundarbans reserved forest. These Divisions have their subordinate offices such as Range Offices, Revenue Stations, Patrol Posts, Wildlife Centers, Camp Offices, etc. in and around the entire Sundarbans reserved forest. There are four Range Offices,

with headquarters along the northern boundaries of the reserved forest and adjoining the settlements. The Revenue Stations as well as most of the Patrol Posts are located along the boundaries of the Sundarbans. Besides these, there are special mobile protection units to combat poaching and illicit logging. The Forest Range Offices are normally headed by an ACF. The Stations are headed by a Forest Ranger or Deputy Ranger. Foresters, Forest Guards and Forest Boatmen work under their command.

MANAGEMENT CONSTRAINTS

There is no denial of the fact that the mangroves of the Sundarbans reserved forest are difficult to work in because of their unique geographic location, criss-crossed by networks of turbulent streams, rivers, canals and creeks. A long international border with India on its west is an added constraint. River routes are the only means of communication in the Sundarbans. Thousands of mechanised boats and trawlers move in the Sundarbans area. These make the world's most luxuriant mangrove forest vulnerable to threats such as pollution of the natural habitat, poaching of wildlife, and pilferage of timber and fuel wood. Bangladesh inherited the colonial legacy of a particular framework for resource management and control regarding forests and forest products. This legacy involved the gradual development of a colonial policy that appropriated the pre-existing rights and access of local resource user groups while dismantling what could be considered a system of common property arrangements for utilization and management of natural resources. Some of the major constraints, which might pose threats to the management of the tiger as well as the Sundarbans mangrove forest are listed below:



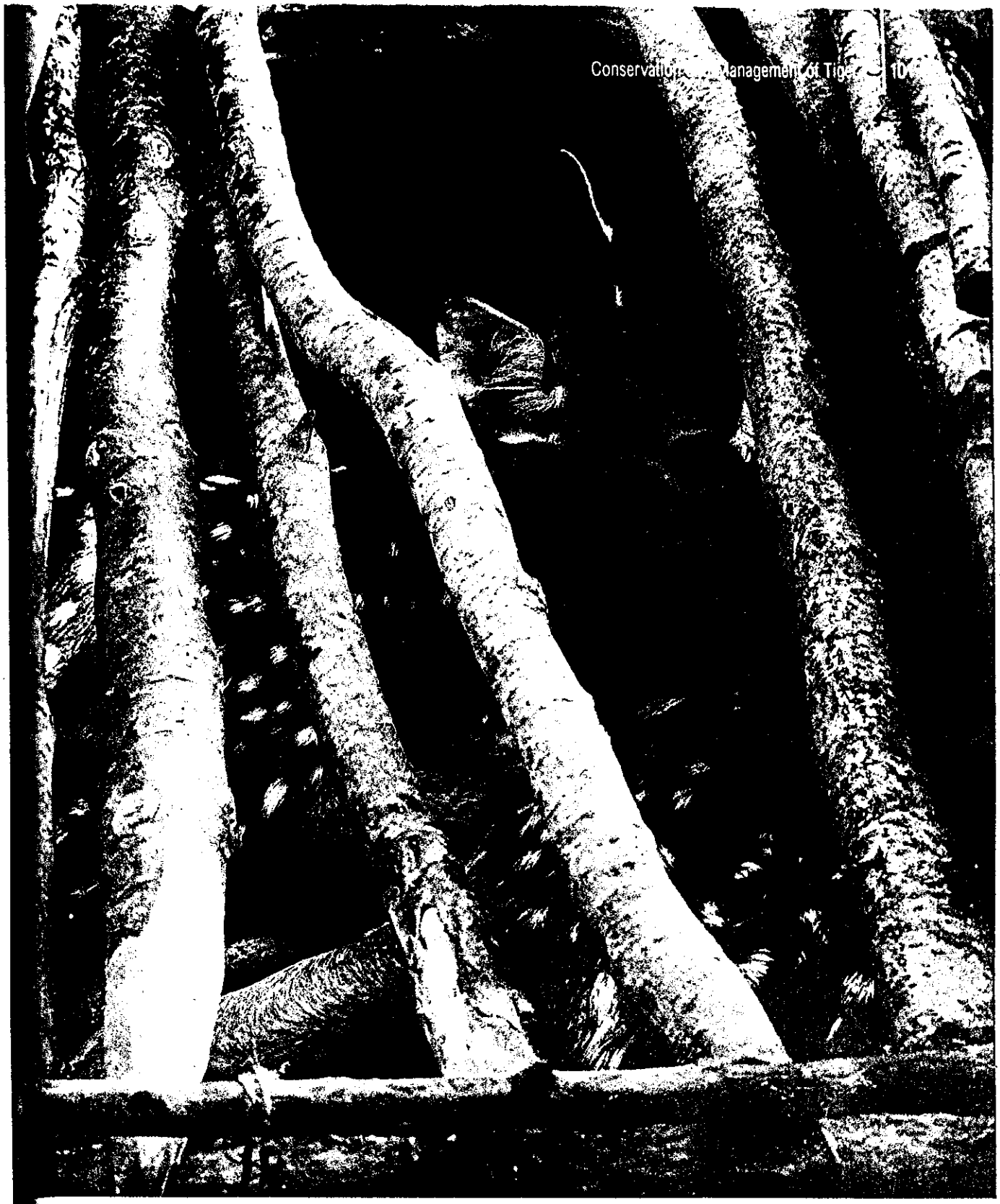
Lack of proper and sustainable management is the main constraint of tiger conservation

photo: Ali Reza

1. The area lacks proper and sustainable management endeavor or long-term management programme for the Sundarbans unique mangrove ecosystem and biodiversity. There is no specific long-term tiger conservation strategy and proper action plan even though the tiger is regarded as the national animal. Also, there is lack of reliable scientific data which is prerequisite for effective and sustainable management and conservation of Bengal tiger and its habitat,

Spotted deer in poacher's pen on board a country boat

photo: Ali Reza

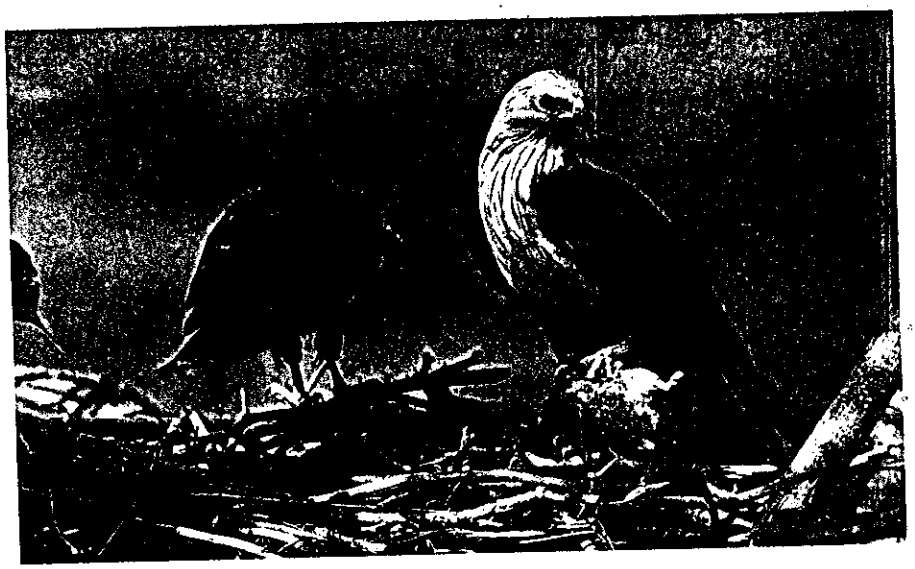


2. Law and order enforcement activities are not satisfactory to maintain a viable tiger population in the Sundarbans mangrove forest. Poaching of tigers and its prey species, and habitat destruction are the vital threats. These two activities are known as the *Twin Evils* for the survival of Bengal tiger in the Sundarbans,

3. The brackish water fishery, fishing and shrimp farming are contributing to environmental pollution of the Sundarbans, thus adversely affecting the mangrove ecosystems of the area. Large scale collection of shrimp fry causes the damage to the mullet population, which ultimately causes threats to many other varieties of fishes in the area. This is very likely to create a situation that may cause some of the species to be lost from this mangrove ecosystem,

4. The freshwater flow, especially in the southern parts of Sundarbans from the up streams has been alarmingly reduced due to the construction of dams and barrages. This in turn has caused choking and enhanced salinity and siltation of streams, rivers, canals, creeks, etc., especially east-west flowing ones. Soil erosion along numerous rivers, canals, creeks, etc. inside the Sundarbans mangrove forest has increased deposition of sand especially in the sea fronts.

5. 'Salt Pans' have been set up within the forest areas because of lesser tide inundation and thus the vegetation is getting destroyed and larger blanks are appearing. Oil spills from the international ships, mechanise trawlers, and water vessels passing through the Sundarbans are posing a potential threat to the natural mangrove ecosystem.



Brahminy kite in its nest
photo: T.R.A. Arunthavaselvan / Sanctuary

During the last 150 years, a large area has been reclaimed from Sundarbans mangals; this reclamation had been initiated by cutting and converting the mangrove forest areas and making high embankments along the riverbanks for protecting the entry of the saline water during the high tides. These activities were aimed at the development of agriculture, renovation of the brackish water fishery and human settlements but have affected the tiger and its ecosystem.

Endowed with a unique combination of beauty, strength and strategic abilities, secretiveness and capacity for spurts of speed and power, the tiger personifies the very ultimate in the evolation of a supreme predator given to a solitary mode of life. The versatility of the tiger is that it had adapted itself to different modes of life in a wide spectrum of environments. The tiger in its evolution, however, has all along been a threatened animal. The tiger is the national animal of India and Bangladesh and also it is on the national emblem of Malaysia. Therefore, it would be a national and international disaster if the Sundarbans becomes so degradated that it can no longer sustain the tiger.

CONSERVATION STRATEGIES

The management strategies for the tiger as a flagship species should be initiated in the Sundarbans with an aim to promote the natural ecosystem by mitigating human induced limiting factors in a participatory way. Further emphasis is needed to promote healthy welfare conditions for the naturally occurring association of fauna so as to bring them up to the level of sustainability carefully maintaing carrying capacity of the habitat. Reducing human impacts and maintaining biodiversity are absolutely necessary to preserve the biodiversity of both the flora and fauna remaining in the unique mangrove ecosystem of the Sundarbans. Some of the management objectives could be as follows:

1. **Long-term monitoring programme for tigers and its prey species:** A long-term monitoring programme for tiger and its prey species is extremely important for assessing the status of tigers and its prey species, and their conservation needs in order to prioritize immediate management and conservation efforts. Important management questions that long-term monitoring on tiger and its prey species could answer include: how are the tiger and its prey species population changing nationally? How are the populations changing on a specific area of the Sundarbans mangrove forest? Where are the most important or critical areas for the animals? What are the habitat requirements for the animals? How do populations respond to specific environmental changes in any management initiative? The monitoring

programme will also help in determining why the animal species, both the tiger and its prey, have declined during a specific period of time. For long-term monitoring purposes, traditional, easily replicable and comparatively less expensive (cost-effective) survey techniques, e.g. pugmarks tracing technique, waterhole survey, tract and sign survey should be given priority. These will help managers to formulate the conservation needs of the animals in order to prioritize immediate management and conservation efforts.

2. **Carry out comprehensive ecological studies on tigers and its prey species:** Comprehensive ecological studies on tiger and its prey species should employ standardized, objective methodologies for determining the present status and relative abundance of tiger and its prey species. It is particularly useful to be able to compare the current abundance and distribution of populations with the past. The Sundarbans reserve forest

Tracking a radio-collared tiger
sketch: Shumon

managers should base their habitat management on such data. However, in practice, long-term data is usually difficult to interpret. If long-term data is to be useful, it is essential that the methods are consistent or, if altered, that the consequences of changes are assessed carefully. At the very least, managers should use simple sampling techniques based on direct encounter rates, the pugmark tracing technique, and tract and sign survey techniques for tigers along with direct encounter rates, line transect surveys and relative abundance by pellet or dung counts for prey species which will indicate whether the animal populations are increasing or decreasing. Tiger population monitoring using rigorous scientific methodology is a long-term commitment that is necessary for evaluating management efforts, such as controlling poaching and habitat destruction over time. Prey density estimation techniques such as those derived from line transect surveys of prey and estimates of tiger abundance based on camera-trap data can be used.

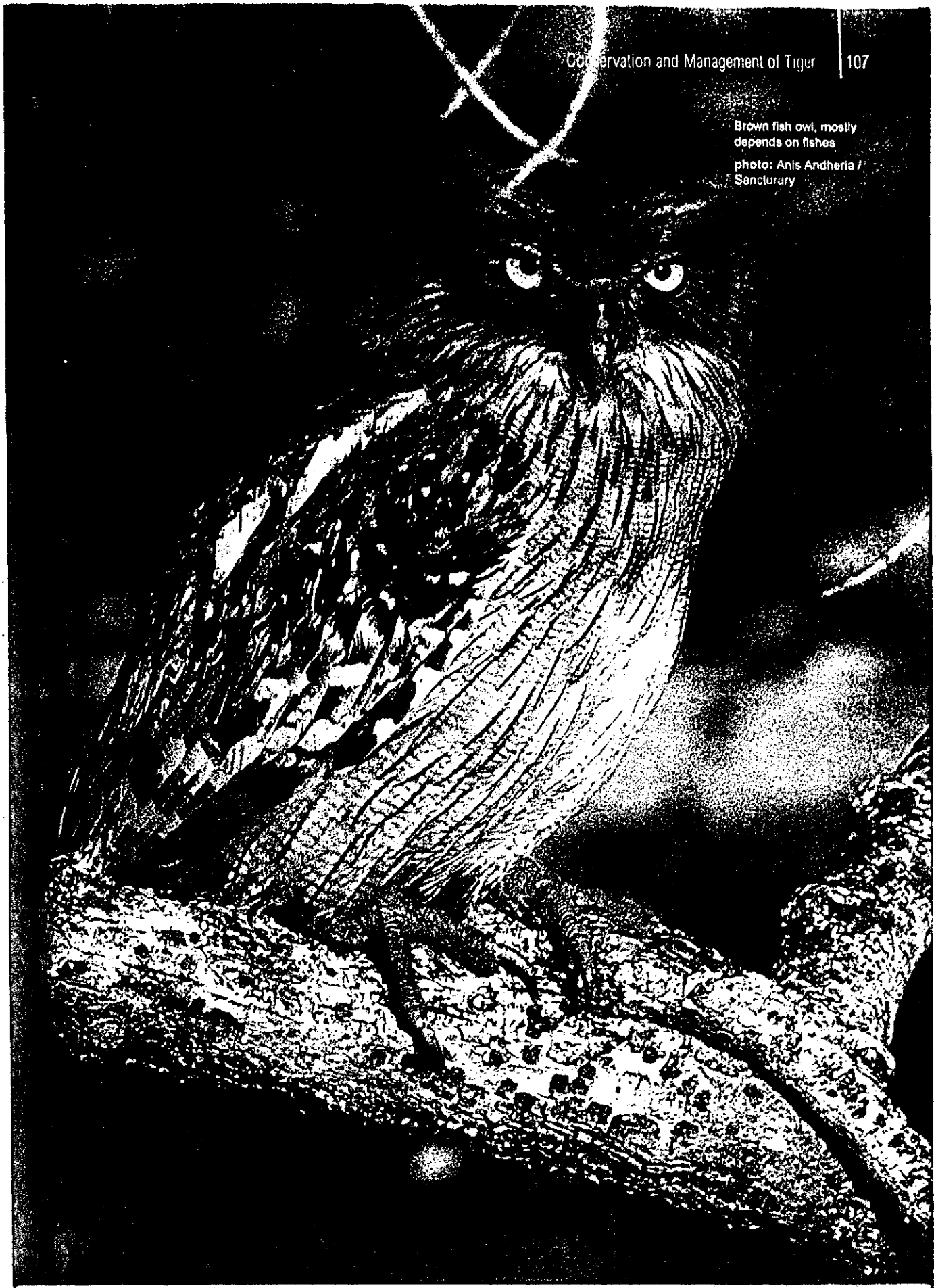
For ensuring comprehensive ecological studies on tiger and its prey species, we have to develop a research facility for biological and social sciences with the objectives to support effective management and conservation systems in the Sundarbans mangrove forest. Moreover, we have to provide support and collaboration from universities, voluntary or non-profit organisations in research, awareness building, and collaborative management system to evolve an effective conservation strategy for the unique floral and faunal association of the Sundarbans mangrove forest.

3. **Preservation and improvement of the habitat:** If the objective is to maintain natural habitats then why not just minimise human influences? The increasingly accepted philosophy is to do just this by allowing rivers to take their natural course, coastal erosion to proceed and forest to burn naturally. The justifications for this are partly ecological, in restoring natural processes, and partly aesthetic, in creating a feeling of naturalness and wilderness. Hence, the Sundarbans mangrove forest needs to be treated as one of the critical natural habitats for tigers in the world; therefore, forestry exploitation, from commercial operators to local extraction of timber, fuelwood, fodder, and non-timber forest products, must be prohibited at a certain level. To keep the natural process ongoing of the forest, we have to reduce large development projects such as dams, mining, and road-building in the periphery and upstream of the Sundarbans mangrove forest. Some area of the mangrove forest could be declared as a core area for the tiger and outside the area there should be a multiple-use area which should be managed for land use and resources production practices.

Aerial view of the forest

photo: C.H. Bassapanawar/ Sanctuary

4. **Preservation and protection of floral and faunal association:** It might be useful to think of the role of diversity of flora and fauna of an area as insurance against discontinuities. Diversity and equilibrium, within and between species, are keys to the survival of a specific ecosystem on the earth. When species exist in diversity, they are capable of meeting the trials of life whereas when diversity is eroded their survival is at risk. Put another way, the fate of the deer and the tiger are inextricably linked and not just because the former is



Brown fish owl, mostly depends on fishes

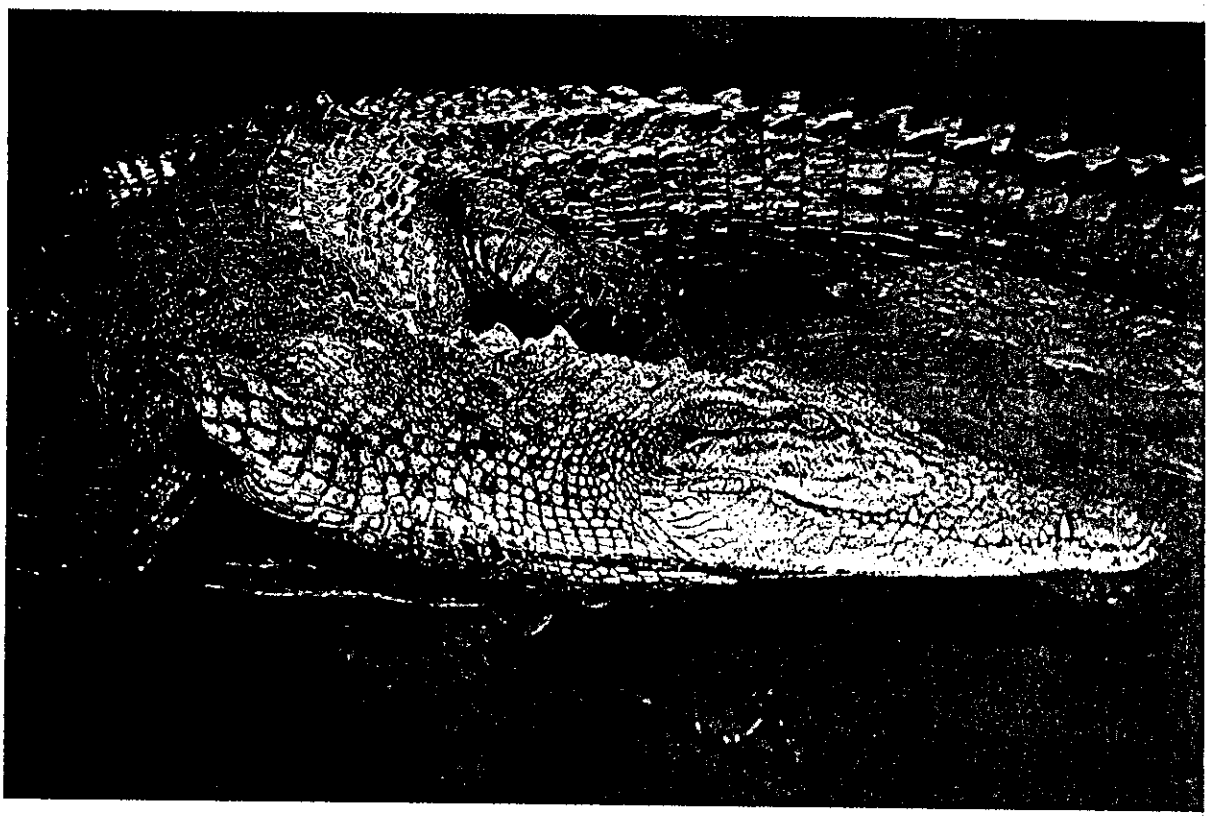
photo: Anis Andheria / Sanctuary

dependent on the later for food on a daily basis. When a tiger stalks the jungle it applies qualitative and quantitative pressure on its prey species. Thus, ensures that deer numbers do not exceed the carrying capacity of the ecosystem. Simultaneously, the predator helps ensure that only the fittest survive to pass on their genes. Removing the predator from a forest causes a sort of rot sets in. Deer numbers will initially swell and they could conceivably overgraze the landscape. This in turn, will affect countless insects that evolved to survive on the favoured plants that the deer exhausted. Without food, deer numbers could crash. And the tapestry unravels. Hence, we need to convince the populace the survival of this natural mangrove ecosystem depends on ensuring a stable association of flora and fauna.

5. **Collaborative management for tiger management in the Sundarbans:** People around the Sundarbans mangrove forests are integral part of the ecosystem, and compatable used of the natural resources is necessary for any management plan to succeed. The rational for promoting collaborative management is based on the assumption that effective management is more likely when stakeholders or local resource users have shared or exclusive rights to make decisions and benefit from resource use. This feature alone represents a major difference in relation to more conventional forms of management, where one party retains some responsibility for decision-making and other stakeholders remain at the periphery. Hence, for the collaborative management of Sundarbans mangrove forest, we have to ensure that the Government (FD as Government representative) and resource users agree about their tenure, thus providing a foundation of confidence and legitimacy for forest management. This management system offers regulations of people's behaviour in tiger habitats as well as analysis of conflicts and compensation programmes. Moreover, by introducing this collaborative management system, it could be possible to acquire the involvement of the local stakeholders in the protection and management of Bangladesh's only tiger habitat, the Sundarbans. This could be possible by offering them incentives and by involving them in the forest management.

6. **Management of stray tigers:** Stray tigers are a major problem in the Sundarbans mangrove forest, both in Bangladesh and India. Straying from the natural habitat to the adjoining villages is an abnormal behaviour observed in some of the tigers of the Sundarbans. Though definite reason could not be found for such abnormality, it could be concluded from various case studies that either the young tigers or the very old tigers are the usual strayers. Search of adequate shelter and food are perhaps the chief cause of such straying.

Young tigers strayed from its natural habitat to satisfy their adventurous mode of behaviour observed in this particular age of the tiger, while old age often incapacitates tigers and, therefore, they have to depend more on easily available domestic cattle in the nearby villages. The only solution of the straying tiger is to capture it and release it into its natural habitats. The task of capturing animal is not new; our ancestors and people around the world had survived by trapping animals. Present day wildlife managers have modified these trapping techniques so that the animals are caught alive and uninjured. It is necessary that the investigators should be thoroughly conversant with the habits of the particular wild animal to be captured. Before taking any action for restraining the wild animals, especially tigers, all the possible cause of it straying should be considered (Chakrabarti 1992).

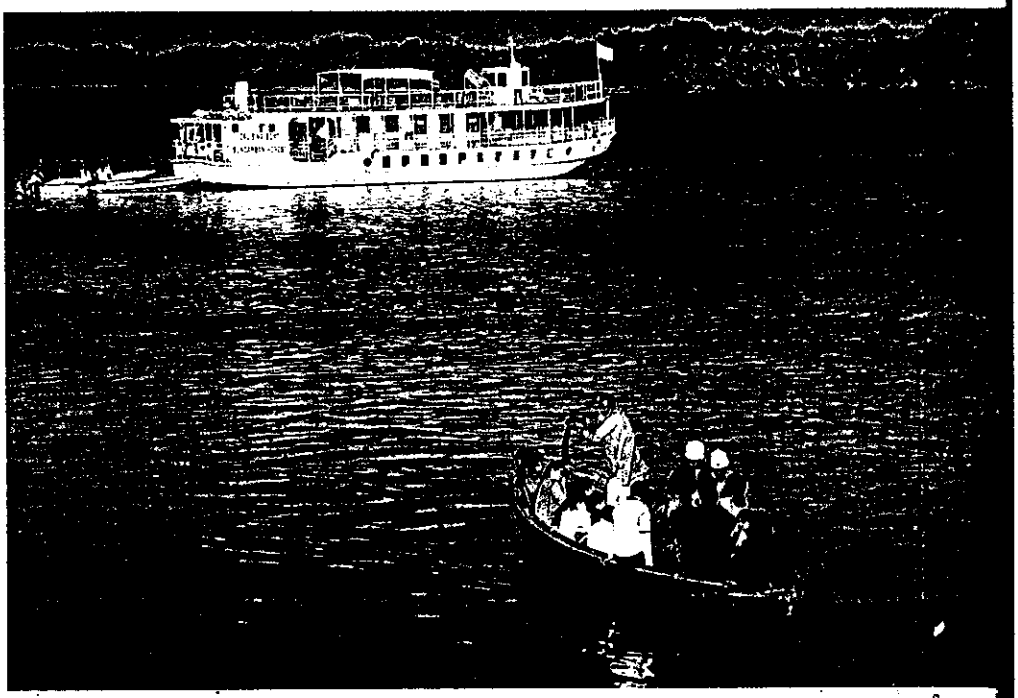


Saltwater crocodile, a flagship species of the aquatic environment

photo: Debal Sen / Sanctuary

7. **Anti-poaching activities:** Poaching and poachers are a grave threat to the survival of wildlife in the protected areas and reserve forests. Because tiger poaching and smuggling is both a local (national) and an international phenophenomenon, an anti-poaching programme must reach out to local and international communities. The anti-poaching programme ideally will develop this capability itself, and not rely exclusively on some other department in the

government. One important initiative could be to strengthen anti-poaching activities and crack down on illegal export of tiger skins and tiger parts abroad. It could be planned to increase the number of anti-poaching brigades, fully equipped with modern transportation, weapons, and radio communication. Another possible efforts could be to increase the ungulate populations that are the prey base to the tiger. This could be achieved by reducing hunting limits as well as time and area limitations.



Ecotourism could be an important source of revenue

photo: MM Feeroz

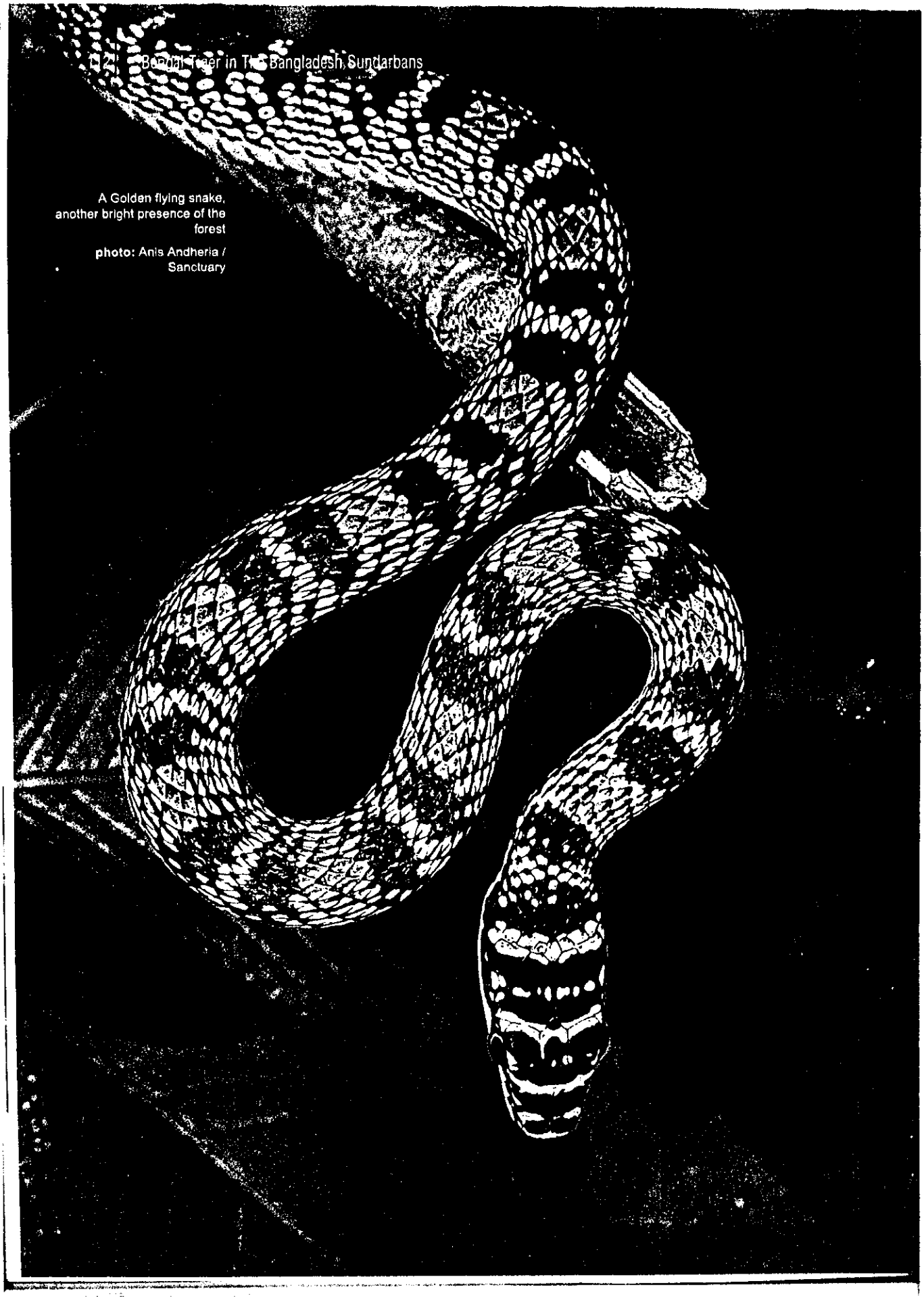
The several basic ways to secure local cooperation and support for the anti-poaching activities includes: i) The leader of the anti-poaching programme must meet with local community representatives (whether they are village elders or local leaders), get to know them, listen to their concerns, and find some common ground between their goals and the goals of the anti-poaching programme, ii) Managers need to incorporate these local concerns into the anti-poaching work, and if possible, involve some of the locals in the anti-poaching programme. iii) In some cases, academics could help in general on environmental education by developing brochures that explain the full scope of the anti-poaching programme and why its important for both nature and people. iv) Managers need to establish good relations with press to get the mission and the results of the work into the newspapers, and onto radio and television. This publicity will educate the local community and cultivates interest and support for the anti-poaching programmes.

8. **Promote ecotourism practices:** Ecotourism is a special kind of travel, usually involving a deliberate decision to make a long-distance journey into remote area to enjoy natural surroundings and to put up with a relatively high level of material inconvenience (for example, spartan amenities, indifferent food, early wake-up calls, and frequent power outages). Few tourists visit the Sundarbans mangrove forest due to the difficulty and cost of arranging transport and due to

Prantic: the Forest Department rest house at Katka

photo: Ali Reza

the lack of suitable accommodation and other facilities. This estuarine mangrove forest has no potential for mass tourism but it does offer obvious possibilities for limited special-interest tourism from October to April. The use of launches equipped with catering and sleeping facilities is more practicable than permanent land-based facilities and would provide greater flexibility. Now a days, some tourism agencies with these kind of equipped launches offer seasonal trips to the Sundarbans and this kind of tourism is becoming more popular during the last few years. Moreover, there is, however, a large well-equipped rest house belonging to the Port Authority at Hiron Point, Sundarbans South Wildlife Sanctuary, and some smaller ones belonging to the Forest Department at Katka and Kochikhali in the Sundarbans East Wildlife Sanctuary. However, it is extremely important to promote ecotourism within the Sundarbans with a view to gaining support for conservation providing facilities for nature education, interpretation and embarking on publicity campaign for conservation using the tiger as a flagship species.



A Golden flying snake, another bright presence of the forest

photo: Anis Andheria / Sanctuary

Integrated management of the Sundarbans mangrove forest with its contiguous counterpart of India may be a good strategy for managing one of the viable units of tiger populations in the world. This is also an ideal site to catalyze international co-operation in actual management of a tigerland. These initiatives are expected to lead to more focused attention of the world community towards the conservation of tiger and its habitat giving it a greater chance of sustainability.

It is unfortunate that at the national level we have no specific conservation strategy or any long-term conservation programme for the Bengal tiger though it is our national animal. According to the Red Book of Threatened Animals of Bangladesh (IUCN Bangladesh 2000), it is categorised as a *Critically Endangered*. Therefore, special emphasis should be given on the better management of the animal for its sustainability in future.

In Bangladesh, sustainability of the Bengal tiger depends on the following factors:

- Local involvement and support is a key issue,
- Skills and equipment must be adequate to meet the challenge posed by the poachers and the environment,
- High level political commitments and back up is essential,
- Effective communication across international boundaries is essential, and
- Good public awareness to generate local support for the programme and future funding required.

Following the above steps, we can secure a future for the tiger in Bangladesh. However, the fact remains that the Sundarbans has acted as a tiger landscape despite human activities for more than a century and the tiger has survived.

Our best tiger science reveals that for the Sundarbans to continue to sustain a tiger population, we need to link core areas that provide adequate prey and refuge and conditions where about 80 reproductively capable female tigers can be accommodated. As Seidensticker (pers. comm.) hypothesized from his working experience, the female tigers consistently require larger areas than that for the male tigers for at least three months during the initial nursing stage of their infant cubs. Those are rather precise requirements. We don't know if these conditions are met in the Sundarbans. It is very difficult to identify the exact location and home range of these key 'female cubbing refuges'. Therefore, we need to identify these 'zones' first and then try to manage them sustainably. From our present knowledge on the guestimates number of tiger in the Bangladesh Sundarbans, 50% area of the total reserve forests could accommodate at least 100

reproductively capable female tigers. The existence prey species population will be able to supply the required amount of food for the said number of tiger (100 reproductively capable tiger).

So, it is strongly recommended that 50% of the Sundarbans reserved forest should be exclusively allotted for the Bengal tiger and its prey species, and in this area all types of resource exploitation and other activities (e.g. tourism, nature camping, recreation, etc.) should be controlled. The rest 50% area of the Sundarbans reviewed forest could be declared as 'buffer zone' where a certain amount of resource exploitation and other activities may be permitted. The Sundarbans thus may become in an ideal Tiger Land, where the tiger can live, hunt, and reproduce safely. Hence, the tiger will be feared but not hated, and here the tiger can be revered irrespective of all castes and religions but probably, not loved. For the Sundarbans, the tiger is a sacred creature who rules this enchanted mysterious land, and human need to protect this unique ecosystem to ensure the tiger's survival.

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APPÉNDICES

Appendix 1. English common name, scientific name, distribution, and protection status of the wild cats of the world Family: Felidae

Common name	Scientific name	Distribution and protection status
Subfamily: Acinonychinae		
Cheetah	*Acinonyx jubatus*	Throughout the drier parts of sub-Saharan Africa. Vulnerable. CITES Appendix I
Subfamily: Felinae		
Caracal	*Caracal caracal*	Drier savannah and woodland regions of sub-Saharan Africa. Not listed. CITES Appendix II
Bornean bay cat	*Catopuma badia*	Island of Borneo. Insufficiently known. CITES Appendix I
Asiatic golden cat	*Catopuma temmincki*	Tropical and sub-tropical moist evergreen and dry deciduous forests. Indeterminate. CITES Appendix I
Chinese mountain (desert) cat	*Felis bieti*	North-eastern edge of the Tibetan Plateau. Insufficiently known. CITES Appendix II
Jungle cat	*Felis chaus*	Variety of habitats across a wide geographic area. Not listed. CITES Appendix II
Sand cat	*Felis margarita*	Sandy and stony desert of the world. Insufficiently known. CITES Appendix II
Black-footed cat	*Felis nigripes*	Arid lands of southern Africa. Not listed. CITES Appendix I
Wildcat of Africa and Eurasia	*Felis silvestris*	African wildcat has a very broad habitat tolerance, whereas Asiatic wildcats are typically associated with scrub desert. Not listed. CITES Appendix II

Common name	Scientific name	Distribution and protection status
Jaguarundi	*Herpailurus yaguarondi*	Distributed in United States but occupies a broad range of both open and closed habitats - from dry scrub, swamp, and savannah woodland to primary forest. Not listed. CITES Appendix II
Ocelot	*Leopardus pardalis*	Every country south of the United Status, except Chile. Not listed CITES Appendix I
Oncilla, Little tiger cat	*Leopardus tigrinus*	Montane cloud forest of the United States. Insufficiently known. CITES Appendix I
Margay	*Leopardus wiedi*	Evergreen and deciduous forest of the United States. Insufficiently known. CITES Appendix I
Serval	*Leptailurus serval*	Sub-Saharan Africa. Not listed. CITES Appendix II
Canada lynx	*Lynx canadensis*	Boreal forest belt of North America and south into the American Rocky Mountains. Not listed. CITES Appendix II
Eurasian lynx	*Lynx lynx*	Throughout Europe and Siberia. Not listed. CITES Appendix II
Iberian lynx	*Lynx pardinus*	Restricted to the Iberian peninsula. Endangered. CITES Appendix I
Bobcat	*Lynx rufus*	United States. Not listed. CITES Appendix II
Pampus cat	*Oncifelis colocolo*	Associated with grass and shrub habitats of the United States. Indeterminate. CITES Appendix II

Common name	Scientific name	Distribution and protection status
Geoffroy's cat	*Oncifelis geoffroyi*	Pampas grasslands and arid Chaco shrub and woodlands, and up around the Salinas. Not listed. CITES Appendix II
Kodkod	*Oncifelis guigna*	Only in Argentina and Chile. Indeterminate. CITES Appendix II
Andean mountain cat	*Oreailurus jacobitus*	Rocky arid and semi-arid zones of the high Andes above the timberline. Insufficiently known. CITES Appendix II
Pallas's cat or Manul	*Otocolobus manul*	Stony alpine desert and grassland habitats of central Asia. Insufficiently known. CITES Appendix II
Leopard cat	*Prionailurus bengalensis*	Wide distribution in Asia. Not listed. CITES Appendix II
Flat-headed cat	*Prionailurus planiceps*	Swampy areas, oxbow lakes and riverine forest of Asia. Insufficiently known. CITES Appendix I
Rusty-spotted cat	*Prionailurus rubiginosus*	Only in India and Sri Lanka. Insufficiently known. CITES Appendix I
Fishing cat	*Prionailurus viverrinus*	Wetland habitats of Tropical Asia. Insufficiently known. CITES Appendix II
African golden cat	*Profelis aurata*	Moist forest zone of equatorial Africa. Insufficiently known. CITES Appendix II
Puma, Cougar or Mountain lion	*Puma concolor*	Andes mountain range. Endangered. CITES Appendix II
Subfamily: Pantherinae		
Clouded leopard	*Neofelis nebulosa*	Primary evergreen tropical rain forest of Asia. Vulnerable. CITES Appendix I
Lion	*Panthera loe*	North Africa and southwest Asia. Endangered. CITES Appendix II

Common name	Scientific name	Distribution and protection status
Jaguar	*Panthera onca*	Seasonally flooded swamp areas, pampas grassland, thorn scrub woodland and dry deciduous forest of the United States. Not listed. CITES Appendix II
Leopard	*Panthera pardus*	Throughout the Indian sub-continent, absent in deserts, the Sundarbans and densely settled areas. Endangered. CITES Appendix I
Tiger	*Panthera tigris*	Tropical evergreen and deciduous forests of southern Asia to the coniferous, scrub oak, and birch woodlands of Siberia including the Sundarbans. Endangered. CITES Appendix I
Marbled cat	*Pardofelis marmorata*	Moist tropical forest of Asia. Insufficiently known. CITES Appendix I
Snow leopard	*Uncia uncia*	Mix of long narrow mountain systems and islands of montane habitat scattered throughout the central Asian deserts and plateaus. Endangered. CITES Appendix I

Source: Wozencraft 1993, and Nowell and Jackson 1996

Appendix 2. Identification toolkit for individual tiger on the basis of hind pugmarks measurement

Identification	Maximum Total Length (cm)	Maximum Pad Width (cm)	
		Male	Female
Tiger cub	6.6-6.9	5.5	5.1
	7.0-7.4	5.6	5.2
	7.5-7.9	5.7	5.3
	8.0-8.5	5.8	5.4
	8.6-8.8	6.8	5.9
	8.9-9.1	6.9	6.0
	9.2-9.4	7.0	6.1
Juvenile tiger	9.5-9.7	7.1	6.2
	9.9-10.1	7.2	6.3
	10.2-10.4	7.3	6.4
	10.5-10.7	7.4	6.5
	10.8-11.0	7.5	6.7
	11.1-11.3	8.4	7.6
	11.4-11.6	8.5	7.7
	11.7-11.9	8.6	7.8
Adult tiger	12.0-12.2	8.7	7.9
	12.3-12.5	8.8	8.0
	12.6-12.7	8.9	8.1
	12.8-13.0	9.0	8.2
	>13.1	>9.1	8.3

Modified from: Chaudhuri and Choudhury.1994, and Singh 2000

Appendix 3. Weight of tiger scats collected from the study area

Month	No. of scats	Ave. wt. (gm) when collected ± sd	Ave. wt. (gm) after drying
Jan 99	4	125 ± 16.14	100 ± 13.26
Feb 99	5	110 ± 10.67	90 ± 11.50
Mar 99	3	075 ± 19.23	60 ± 9.45
Apr 99	2	200 ± 13.81	175 ± 15.25
May 99	-	-	-
Jun 99	6	085 ± 16.49	65 ± 8.75
Jul 99	6	122 ± 12.62	95 ± 10.65
Aug 99	5	098 ± 16.21	70 ± 9.15
Sep 99	6	116 ± 13.50	100 ± 12.25
Oct 99	7	109 ± 11.22	85 ± 8.30
Nov 99	4	186 ± 19.65	150 ± 14.50
Feb 00	1	150 ± 10.25	120 ± 11.35
Mar 00	3	085 ± 21.33	68 ± 8.20
Average	**4 (n=52)**	**122 ± 15.09**	**98 ± 10.20**

Appendix 4. Composition of tiger scats collected from the study area

Month	No. of scats	Ave. wt. when collected (g)	Ave. wt. After sheaving (g)	Percentage (%) of the total weight				
				Deer hair	Boar hair	Monkey hair	Other materials	
							Unidentified Animal parts	Soluble material
Jan 99	4	125±16.14	75±11.35	70	00	10	15	05
Feb 99	5	110±10.67	60±9.23	80	10	00	00	10
Mar 99	3	075±19.23	40±7.91	75	15	05	00	05
Apr 99	2*	200±13.81	130±13.25	50	15	10	10	15
May 99	-	-	-	-	-	-	-	-
Jun 99	6	085±16.49	50±6.20	65	25	05	05	05
Jul 99	6	122±12.62	65±9.35	68	22	05	00	05
Aug 99	5	098±16.21	54±6.55	62	20	10	05	03
Sep 99	6	116±13.50	72±8.75	73	13	05	05	04
Oct 99	7	109±11.22	65±8.66	65	25	05	02	03
Nov 99	4	186±19.65	110±11.45	80	08	00	05	07
Feb 00	1	150±10.25	100±8.25	74	20	00	00	06
Mar 00	3	085±21.33	45±5.85	70	15	05	05	05
Average	4 (n=52)	**122±15.09**	**72±8.83**	**69**	**15**	**5**	**4**	**6**

*N.B. *Feather of large green billed malkoha was found in one scat*

Appendix 5. Height and location of trees of the tiger claw markings in Katka-Kochikhali

Marking code	Tree species	Height of the markings (cm from the ground)	Location
CM 01	*Sonneratia apetala*	170	Riverbank
CM 02	*Excoecaria agallocha*	97	Forest edge
CM 03	*Excoecaria agallocha*	78	Forest
CM 04	*Amoora cucullata*	55	Seabeach
CM 05	*Excoecaria agallocha*	129	Forest
CM 06	*Sonneratia apetala*	133	Forest edge
CM 07	*Excoecaria agallocha*	105	Forest edge
	Average height	**109 (Sd±38.15)**	

Appendix 6. Comparative food habits of tigers in four Asian parks with Katka-Kochikhali based on frequency of major three mammalian species in the scats

Site	Prey species		Ave. body wt. (kg)	Relative % tage
	English name	Scientific name		
Sundarbans East WS Bangladesh (n=52)	Spotted deer	*Cervus axis*	55	69.3
	Wild boar	*Sus scrofa*	38	15.1
	Rhesus macaque	*Macaca mulatta*	8	05.0
Chitwan National Park, Nepal (n=123)	Spotted deer	*Cervus axis*	55	27.8
	Common langur	*Semnopithecus entellus*	8	16.9
	Samber	*Cervus unicolor*	212	15.3
Kanha National Park, India (n=300)	Spotted deer	*Cervus axis*	55	50.3
	Common langur	*Semnopithecus entellus*	8	21.6
	Indian porcupine	*Hystrix indica*	8	10.3
Huai Kha Khaeng WS, Thailand (n=38)	Muntjac	*Muntiacus.muntjak*	20	34.8
	Porcupine	*Hystrix brachyura*	8	27.1
	Hog-Badger	*Arctonyx collaris*	10	17.9
Nagarahole National Park, India (n=455)	Spotted deer	*Cervus axis*	55	22.8
	Samber	*Cervus unicolor*	212	11.4
	Common langur	*Semnopithecus entellus*	8	11.3

Sources: Sundarbans - (Reza 2000) Chitwan - McDougal 1977; Kanha - Schaller 1967; Huai Kha Khaeng - Rabinowitz 1989, and Nagarahole - Karanth and Sunquist 1995.

Appendix 7. Proportion of various habitat types and distance covered during the study period

Habitat		Distance covered	
Types	**% of the total area (approx.)**	**Kilometres**	**% of the total distance**
Forest	50	201	20
Meadow	30	379	41
Sea beach	9	197	22
Forest edge	6	81	9
Riverbank	5	72	8
Total	**100**	**930**	**100**

Appendix 8. Prey species density in different habitats of Katka-Kochikhali

Habitat type	Area surveyed (km^2)	Spotted deer	Wild boar	Rhesus macaque
Forest	20.1	48.8	2.2	9.7
Meadow	37.9	79.9	2.3	0.8
Sea beach	19.7	100.4	0.6	0.2
Forest edge	8.1	41.0	15.8	21.1
River bank	7.2	31.5	3.3	6.1

Appendix 9. Status of recorded tiger kills from the study area during the study period

Month	Total kills	Spotted deer kills			Wild boar kills			Monitor lizard kills		
		A	B	C	A	B	C	A	B	C
Jan 99	4	1	1*	1	-	-	-	1	-	-
Feb 99	3	2	-	-	-	1	-	-	-	-
Mar 99	5	1*	2	-	-	-	1	-	1	-
Apr 99	2	-	1	-	-	-	1	-	-	-
May 99	-	-	-	-	-	-	-	-	-	-
Jun 99	4	-	1	2	1	-	-	-	-	-
Jul 99	2	-	1*	-	-	-	1	-	-	-
Aug 99	-	-	-	-	-	-	-	-	-	-
Sep 99	1	-	-	-	-	-	1	-	-	-
Oct 99	4	1*	2	-	-	-	-	-	1	-
Nov 99	-	-	-	-	-	-	-	-	-	-
Feb 00	-	-	-	-	-	-	-	-	-	-
Mar 00	1	-	-	1	-	-	-	-	-	-
Total	**26**	**5**	**8**	**4**	**0**	**2**	**4**	**1**	**2**	**0**

Note: *A - Very fresh kills and recorded within 12 hours after killing,*
B - Moderately fresh kills and recorded within 48 hours after killing,
C - Old kills and recorded only the bones and other hard body parts;
** Deer doe.*

Appendix 10. Proportion of different prey species in tiger diets, as derived from scat analysis and kill data

Prey species	Ave. body wt. (kg)	Scat (%)	Kill (%)	Average (%)
Spotted deer	55	69.23	65.38	67.30
Wild boar	38	15.66	23.07	19.36
Rhesus macaque	8	05.00	-	2.50
Monitor lizard	6	-	11.53	5.76
Unidentified	-	10.18	-	5.09
Total	**-**	**100**	**100**	**100**

Appendix 11. People of different occupations interviewed during the study period

Category	Age rang (years)	Place of interview			Total
		Katka-Kochikhali	Burigoalini	Other places in the Sundarbans	
Woodcutter	32-65	9	9	3	21
Grasscutter	42-62	18	0	0	18
Businessman Farmer and	35-70	3	6	3	12
Day labourer	25-68	3	9	3	15
Tourist	25-34	9	0	0	9
Forest official	26-57	15	9	12	36
Total	**25-70**	**57**	**33**	**21**	**111**

Appendix 12. Floristic composition of the randomly selected 18 quadrats (6 X 6 m) in Katka-Kochikhali

Species	Family	Quadrats																		%
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Excoecaria agallocha	Euphorbiaceae	+	+	+	+	+	+	-	-	-	-	-	-	-	+	+	+	+	+	61
Sonneratia apetala	Sonneratiaceae	+	+	+	+	+	+	-	-	-	-	-	-	-	+	+	+	+	+	61
Heritiera fomes	Sterculiaceae	-	+	+	+	+	+	-	-	-	-	-	-	-	+	+	+	+	+	50
Imperata sp	Gramineae	-	-	-	-	-	+	+	+	+	+	+	+	+	+	-	-	-	-	50
Borassus flabellifer	Palmae	-	-	-	-	-	-	-	-	-	+	+	-	-	+	+	-	-	-	28
Ceriops decandra	Rhizophoraceae	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	+	+	22
Aegiceras corniculatum	Myrsinaceae	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	22
Hibiscus tiliaceous	Malvaceae	-	-	+	+	+	-	-	-	-	-	-	-	-	+	-	-	-	-	22
Amoora cucullata	Meliaceae	-	-	+	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	22
Syzygium sp.	Myrtaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	17
Avicennia officinalis	Avicenniaceae	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	17
Phoenix paludosa	Palmae	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	17
Xylocarpus mekongensis	Meliaceae	-	-	+	+	+	-	-	-	-	-	-	-	-	-	+	+	-	-	11
Xylocarpus granatum	Meliaceae	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	06
Number of species		3	7	7	7	6	5	1	1	1	2	2	1	1	7	7	6	5	5	

Note: '+' indicates the presence of plant species in the quadrats; '-' indicates no tree species in the quadrate