World Heritage Sites

Protected Areas and World Heritage

SUNDARBANS NATIONAL PARK
INDIA

The Sundarbans lie across the outer deltas of the Ganges, Brahmaputra and Meghna rivers. At 10,000 sq.km, it forms the largest estuarine mangrove forest in the world, 40% in India, 60% in Bangladesh. The adjacent World Heritage sites in India and Bangladesh cover just over a quarter of its area. The forest is composed of small forested islands and mudflats intersected by an intricate network of tidal waterways. It exemplifies the ecological processes of monsoon rain flooding, delta formation, tidal influence and plant colonisation.The area has a wide range of rare fauna, including the Bengal tiger, estuarine crocodile, Indian python and many reptiles and birds. The devastation caused by Cyclone Sidr emphasised how important mangrove forests, flood refuges and an early warning system are to protection of the coastal population.

COUNTRY
India

NAME
Sundarbans National Park

NATURAL WORLD HERITAGE SITE
1987: Sundarbans National Park inscribed on the World Heritage List under Natural Criteria ix and x.

STATEMENT OF OUTSTANDING UNIVERSAL VALUE [pending]

INTERNATIONAL DESIGNATION
2001: Sundarbans National Park designated a Biosphere Reserve under the UNESCO Man and Biosphere Programme (963,000 ha).

IUCN MANAGEMENT CATEGORY
Ia Strict Nature Reserve

BIOGEOGRAPHICAL PROVINCE
Bengalian Rainforest (4.3.1)

GEOGRAPHICAL LOCATION
The Sundarbans mangrove forest lies among the creeks and distributaries of the Ganges and Meghna (Bramaputra) river deltas. The Indian site in the west lies about 130 km southeast of Calcutta between the Matla and Raimangal rivers, between 21°31' to 22°53'N and 88°37 to 89°09'E. It adjoins the South Sanctuary of the Bangladesh site.

DATES AND HISTORY OF ESTABLISHMENT
1875: The entire forest in the Twenty-four Paraganas, Khulna and Backergunje districts made a Reserve Forest under the Indian Forest Act VIII of 1865, under Forest Department control. Much of the area was later leased out by the government for cultivation;

1926: The boundaries of the remaining protected forests were fixed by Notification 4457-for those in the Basirhat Division of the district were declared reserved forests in 1928 under Notification.15340, and those in Namkhana Division in 1943 under Notification 7737-For;

1973: The Sundarbans Tiger Reserve designated (258,500ha);

1976: Sajnakhali Wildlife Sanctuary established in the north (36,234ha);

1984: The Tiger Reserve established a National Park by Notification 2867-For.

LAND TENURE
Owned by the Government of India. Management is by the Project Tiger Program, overseen by the. Directorate of Forests of the Government of West Bengal under the national Ministry of Environment and Forests.

AREA
133,010ha. The total area of both Sundarbans World Heritage sites is 272,510ha.

The site is the core area of the Sundarbans Tiger Reserve (258,500 ha). Sajnakhali Wildlife Sanctuary (36,234ha) lies in its buffer zone to the north. Two Wildlife Sanctuaries are nearby to the southwest: Halliday Island (583ha) and Lothian Island (3,885ha), but they are not part of the Reserve. The South Wildlife Sanctuary of the Bangladesh site is contiguous on the southeast.

ALTITUDE
Sea level to 7m.

PHYSICAL FEATURES
The Sundarbans are part of the world's largest delta, formed from the sediments brought down by three great rivers, the Ganges, Brahmaputra and Meghna, which converge on the Bengal Basin. The forest extends over some 200 islands, separated by 15 major distributary rivers flowing north-south, and 400 interconnected tidal estuaries, creeks and canals. It forms an impenetrable saltwater swamp reaching 100-130km inland, which supports the largest tidal mangrove forest in the world, covering 10,200 sq. km. Of this, 426,200ha (42.5%) are in India, 232,000ha (54.5%) of which is land; and 595,500 ha (59.3%) in Bangladesh. The landscape is one of low-lying forested alluvial islands, 56 on the Indian side, mudbanks with sandy beaches, and dunes along the coast. The area is approximately three-fifths of the 16,700 sq.km that existed 200 years ago, having been cleared and converted to agriculture, especially in the northwest (Hussain & Archarya, 1994). The forest swamp, extensively embanked and empoldered, is an essential buffer for inland areas against the ravages of frequent cyclones from the Bay of Bengal. The nutrient-rich waters also provide the most important nursery for shrimps and spawning grounds for crustaceans and fish along the whole coast of eastern India.

The land has constantly been moulded and altered by tidal action, with erosion along estuaries and deposition along the banks of inner creeks augmented by the discharge of silt from seawater (Sanyal & Bal, 1986). The wider rivers of this intricate network of waterways are over two kilometres wide, run north-south and tend to be long and straight. They are maintained largely by the two diurnal flow tides and ebb tides over a tidal range of 3m up to 8m, together with the erosion-resistance of the clay and silt of their banks (Ghosh & Mandal, 1989). Innumerable small channels drain the land at each ebb but major coastal deposition occurs primarily in Bangladesh. There is a deep submarine canyon-head depression in the eastern Bengal shelf which forms a sediment trap where sedimentation increases. The way that waves diverge over the delta undersea, especially during monsoon gales, largely depends on the accompanying changing deep wave fields which are affected by this trough. Flood currents deflect waves more to the east, ebb currents deflect them more to the west, and are important in the redistribution of river-borne sediments along the coast (Ghosh & Mandal, 1989; Michels *et al*., 1998). On the coast, easily eroded sands collect at the river mouths forming banks which are blown into dunes above high-water level by strong south-west monsoon winds. Finer silts are washed out into the Bay of Bengal and where they are protected from wave action, form mud flats in the lee of the dunes. These become overlain with sand from the dunes, and develop into grassy flats. This island-building process 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 & Hai, 1983).

The National Park is dissected by seven main north-south-flowing rivers from the Hooghly to the Harinbhanga. These waterways now carry little fresh water as they are mostly cut off from the Ganges, the freshwater outflow of which over 400 years has shifted progressively eastwards from the Bhagirathi-Hooghly channels (Seidensticker & Hai, 1983). This shift is due to tectonic subsidence of the Bengal Basin during the 10th-12th centuries, and the continuing gradual eastward tilting of the underlying crust, while the western side in India remains relatively stable. The Tiger Reserve on the Indian side being

essentially land-locked, its rivers are almost completely cut off from the main freshwater sources and are now salt (Sanyal & Bal, 1986). The average salinity of water and soils therefore decreases markedly from west to east (Islam, 1973). The area has three main hydrological zones: brackish, moderately saline and saline, which influence the types of vegetation which dominate each. As with the rest of the Bengal Plain, the alluvial deposits are geologically very recent but deep, sediments of just the last few million years being as much as 1,000m thick (Seidensticker & Hai, 1983). The subsoil consists of alternate layers of sand and silty clay loam down to a depth of 1.1-1.4m and thereafter stiff black clay, gradually changing into shales and sandstone. The soils are saline, chiefly an alkaline clay with an excess of salt except on the seaward side of islands at the coastal limits, where sandy beaches occur (Lahiri, 1973). The pH ranges from 5.6 to 8.0 (Christensen, 1984). By comparison with the eastern Sundarbans the surface soil in the west is drier, harder, highly saline and less suitable for tree growth (Choudhury, 1968).

CLIMATE

The climate is humid sub-tropical, tempered by the sea. Temperatures rise from daily minima of 2-4°C in winter to over 32°C during the monsoon and a maximum around 43°C in March. The mean annual maxima and minima recorded at the Jhingakhali meteorological station were 34°C and 20°C respectively. Rainfall is heavy and the humidity averages 70-80% due to the nearness of the Bay of Bengal. The mean annual rainfall varies from about 1,800mm at Khulna, and 1,920mm at Jhingakali north of the Sundarbans, to 2002mm recorded at the observatory on the western coastal island of Sagar and 2,790mm on the Bangladesh coast. 80% of the rain falls during the monsoon between mid-June and October, cleansing saline soils of their salt. From then to mid March the weather is dry until mid-March, a period when evapotranspiration exceeds precipitation. During the monsoon over half the Sundarbans can be submerged under water. Conditions are most saline in February to April, when the depletion of soil moisture occurs at the same time as freshwater flows from upstream are reduced. From 1983 to 2003 the annual sea level rise was 3.14cm compared with the world average of 2cm and the outer islands began to erode away. A 25cm rise in sea level would destroy 40% of the Sundarbans, and a 45cm rise by the end of the 21st century would destroy 75% (Colette, 2007). Rising sea levels also increase saltwater intrusion into aquifers.

The prevailing wind is from the north and northeast from October to mid-March, although January and February are calm. However, violent southwesterlies prevail from mid-March to September. Storms, funnelled up the shallow upper Bay of Bengal, are common in May and from October to November, sometimes developing into cyclones which can be accompanied by storm surges up to 7.5m high, causing enormous loss of life, damage to property and forests, as in 1970 and 1991. The effects in the India of the 2004 tsunami were very bad, and of the mid-year monsoon floods and cyclone Sidr in November 2007 though less drastic than in Bangladesh, were disastrous. Cyclonic winds reached 220 kph with a 6.5m storm surge which took over 5,000 lives, affected up to twelve million people in the area, and damaged or destroyed some one million homes, livestock, rice fields, forests and the fishing industry (Bangladesh Forest Department, 2008; Indian Water Portal Blog, 2007). Such storms vividly emphasise the protective function of the coastal forest but also the vulnerability of the Sundarbans to the effects of climate change.

VEGETATION

Mangrove swamp forest extends over half of the Sundarbans, the rest being largely brackish and salt water. The name comes from the dominant *sundari* tree *Heritiera fomes*, so called because of its elegance, and from *ban*, forest (Jain & Sastry, 1983). The vegetation consists of Malayan Peninsular and Polynesian elements, with some Indo-Chinese and Ethiopian elements, even a few from the New World. It is found nowhere else except in small parts of the Mahanadi and Godaveri deltas to the southwest and in the Bay Islands (Mukherjee, 1975). The mangrove flora of the Sundarbans, which contains 27 species, is unique in comparison with non-deltaic coastal mangrove forests. Unlike these, the Rhizophoraceae and Avicenneaceae are of only minor importance: most of the genera are from the Sterculiaceae and Euphorbiaceae (Hussain & Acharya, 1994). The dominant species are *sundari Heritiera fomes*, *gewa Excoecaria agallocha*, *goran Ceriops decandra* and *keora Sonneratia apetala*. The *sundari* dominate where the soil water is relatively fresh, especially in the northeast, and on higher ground, and forms 60% of the commercially useful timber. The reason for the difference is the strong influence of freshwater. *Excoecaria agallocha* dominates the zone of moderately saline soils; and *Ceriops decandra*, the saline soils. Other mangrove species include *garjan* or red mangrove *Rhizophora mangle*, *R. mucronata* and *R. apiculata*, *kankra Bruguiera gymnorhiza*, and *baen* or Indian mangrove *Avicennia officinalis*.

The Sundarbans are classified as moist tropical seral forest, comprised of a mosaic succession of four types of tidal forest communities: low mangrove forest, tree mangrove forest, salt-water *Heritiera* forest and freshwater *Heritiera* swamp forest, now largely cleared for settlement. The pioneer vegetation on newly accreted sites progresses from herbaceous swamp to thickets, later forests of *Sonneratia apetala* followed by *Avicennia officinalis*. The *golpata* or nypa palm *Nypa fruticans* grows on well established levee banks. As the ground rises with soil deposition, *Exoecaria agallocha*, comes to dominate, and when the land is only occasionally flooded, *Heritiera.* Beach forest occurs on coastal islands of low very xerophytic sand-dunes due to the lime from disintegrating shells and salt. The sand dunes are partially covered with spear-grass *Imperata cylindrica*, with behind them, creepers and shrubs or trees such as *jhao Tamarix troupii*, *palita Erythrina variegata* and *kulsi Aegiceras corniculatus*. Wild rice *Oryza coarctata*, *Nypa* and speargrass *Imperata cylindrica* are prevalent on mud flats (Khan, 1986). The large stands of *Sonneratia*, which colonises new mudbanks, provide important wildlife habitat (R.Salter, pers. comm., 1987). Though mangrove forests are not very diverse, there are many climbers, creepers, algal and fungal species on the forest floor. Prain (1903) described the flora of the mangrove forest of the Ganges-Brahmaputra delta, recording 245 genera and 334 species of plant as did Seidensticker & Hai in 1983 in the Bangladesh part of the delta, listing the principal woody and herbaceous species. A recent examination of the composition and structure of the mangrove vegetation on the Indian side, identified 64 species: 36 true mangroves, 28 associated species and seven obligate mangrove species, in 29 families and 49 genera (Calcutta University, 1987). This report includes inventories of algae, phytoplankton and fungi. Islam (1973) also gives an account of the mangrove algal flora.

Because of their salinity the soils of the western Sundarbans support a less diverse flora than the east. Only low mangrove forest and salt-water *Heritiera* forests occur within the Indian section (Champion, 1936). The salt-water *Heritiera* forest, 6-11m high, occurs between the Raimangal and Matla rivers, where fresh water flows from the Ichhamati river into the Raimangal river. Characteristic species include *Rhizophora*, *Bruguiera gymnorhiza*, *Ceriops decandra* and *Avicennia officinalis*. Sundari forest is scattered over areas of higher elevation, along with *Sonneratia apetala*, *Excoecaria agallocha*, *dhundul Carapa obovata* and the hental palm *Phoenix paludosa*. The *Nypa fruticans* palm growing along the creeks on wet mud-banks is relatively uncommon. Low mangrove forest, 3-6m high, occurs between the Matla and Muriganga rivers, to the west of the National Park and in the Tiger Reserve, which has no fresh water. In the low mangrove forests soft mud, which is submerged by the tides supports a dense forest, very similar in composition to salt-water *Heritiera* forest except that sundari and are virtually absent. *Ceriops* and *Avicennia* are the commonest trees, occupying extensive areas but only growing up to 2m. Clusters of *Phoenix paludosa* are very common. The northwest margin of the mangroves and some forest tracts on low-lying islands were cleared for agriculture two hundred years ago and various exotics introduced (Mukherji, 1975; Jain & Sastry, 1983). Some variety has been lost to the higher salinity partly due to large-scale irrigation schemes on the Ganges upstream.

FAUNA

The Sundarbans is the only remaining habitat in the lower Bengal Basin with a great variety of fauna. 49 mammal species have been documented. The Sundarbans support one of the subcontinent's largest populations of tiger, the Bengal tiger *Panthera tigris tigris* (EN), known for its swimming and man-eating. According to the WWF Tiger Programme in 2007 the area may now shelter about 350 tigers in the Bangladeshi section and an estimated 250 on the Indian side, though an IUCN Species Survival Commission study suggested that the latter may be fewer than 100 (UNESCO, 2002), and a report in 2011 from the National Tiger Conservation Authority cited a total of 70 in the Indian Tiger Reserve (Anon, 2011). Its high density relative to the availability of prey, and the number of encounters with local people in the Tiger Reserve are probably the reasons for its habit of man-eating (Hendrichs, 1975; Chakrabarti, 1986a). The only primate is rhesus macaque *Macaca mulatta*, considered to number about 68,200, based on a survey by Khan (1986). The smooth-coated otter *Lutrogale perspicillata* (VU) which may number 20,000 (Hendrichs, 1975), is domesticated by fishermen to drive fish into their nets (Seidensticker & Hai, 1983). Other mammals include leopard cat *Prionailurus bengalensis* and jungle cat *Felis chaus*. Chital or Indian spotted deer *Cervus axis*, estimates of which vary between 52,600 (Khan, 1986) and 80,000 (Rahman, n.d.), and wild boar *Sus scrofa*, estimated at 20,000 (Hendrichs, 1975), are the principal prey of the tiger, together with macaques, crabs and fish. Aquatic mammals include the Indo-Pacific hump-backed dolphin *Sousa chinensis*, Irrawaddy dolphin *Orcaella brevirostris* (VU) and finless porpoise *Neophocaena phocaenoides* (VU) (Mukherjee, 1975). Species accounts and a check-list are given by Salter (1984).

Several of the large species are now locally extinct due to agricultural reclamation and the increase in soil salinity during the 20th century. They include Javan rhinoceros *Rhinoceros sondaicus* (CR), Indian

rhinoceros *Rhinoceros unicornis* (VU), Indian water buffalo *Bubalus arnee* (EN) last recorded in 1885, swamp deer *Rucervus duvaucelii* (VU), plentiful until the early 20th century, and Indian muntjac *Muntiacus muntjak*, last seen on Haliday Island in the late 1970s (Sanyal, 1983), gaur *Bos gaurus* (VU), and hog deer *Axis porcinus* (EN). Gharial *Gavialis gangeticus* (CR), mugger *Crocodylus palustris* (VU) and narrow-headed softshell turtle *Chitra indica* (EN) also became locally extinct last century (Salter, 1984; Sanyal,n.d.). Mukherjee (1975) gives an extensive account of the vertebrate and invertebrate fauna. Later inventories have been compiled by Sanyal (n.d.) and Calcutta University (1987).

The bird-life of the Sundarbans waterways is varied and colourful. A total of 315 species (39.5% of the national total) has been recorded, of which 84 are migratory (Hussain & Acharya, 1994), including about 95 species of waterfowl (Scott, 1989), 38 species of raptors and two pheasants (Sarker, 1985). Four of the rarer species are the greater and lesser adjutant storks *Leptoptilos dubius* (EN) and *L. javanicus* (VU), band-tailed fish-eagle *Haliaeetus leucoryphus* (VU) and masked finfoot *Heliopais personata* (EN). There are many other water birds, including Asian open-bill stork *Anastomus oscitans*, black-necked stork *Ephippiorhynchus asiaticus*, white ibis *Threskiornis melanocephalus*, swamp francolin *Francolinus gularis* (VU), collared and black-capped kingfishers *Todiramphus chloris* and *Halcyon pileata*, brown-winged and stork-billed kingfishers *Pelargopsis amauroptera* and *P. capensis*. Waders include the Asian dowitcher *Limnodromus semipalmatus*, a rare winter migrant, sandpipers, whimbrel, curlew and numerous others are seen on the muddy banks and sandbanks exposed during the dry season. Marsh birds in the reclaimed areas include great, little and intermediate egrets *Casmerodius albus*, *Egretta garzetta* and *Mesophoyx intermedia*, purple heron *Ardea purpurea*, a rare vagrant from Africa, and green-backed heron *Butorides striata*. Raptors include osprey *Pandion haliaetus*, white-bellied sea-eagle *H. leucogaster* (131 breeding pairs), the rarer grey-headed fishing eagle *Ichthyophaga ichthyaetus*, short-toed snake-eagle *Circaetus gallicus,* peregrine falcon *Falco peregrinus*, oriential hobby *F. severus*, northern eagle owl *Bubo bubo* and brown fish owl *Ketupa zeylonensis* (Sarker & Sarker,1985,1986). There are many species of gulls and terns along the coast and larger waterways. There is also a considerable variety of forest birds such as woodpeckers, barbets, shrikes, drongos, mynahs, minivets and babblers (Salter, 1984). Further details of the avifauna are given in Scott (1989).

Some 53 reptile species (53% of the national total) and 8 amphibians are recorded (Hussain & Acharya, 1994). The eighteen recorded species of snake include king cobra *Ophiophagus hannah* (VU), spectacled cobra *Naja naja*, Asiatic rock python *Python molurus*, three vipers and six sea-snakes (Salter,1984). Estuarine crocodile *Crocodylus porosus* (100 individuals) still survives, its numbers greatly depleted by hunting and trapping for skins. There are also three species of monitor lizards, Bengal, yellow and water *Varanus bengalensis*, *V. flavescens* and *V. salvator*, River terrapin *Batagur baska* (CR), Indian flap-shelled turtle *Lissemys punctata* and Indian peacock soft-shelled turtle *Nilssonia hurum* (VU) are present. Four species of marine turtle have been seen, olive ridley *Lepidochelys olivacea* (VU) being the most abundant. Green turtle *Chelonia mydas* (EN) is rare due to excessive fishing. Hawksbill *Eretmochelys imbricata* (CR) are caught by fishermen, and loggerhead *Caretta caretta* (EN) have been reported on the beaches (Hussain & Acharya, 1994).

Over 120 species of fish are said to be commonly caught by commercial fishermen (Seidensticker & Hai, 1983) and 400 species are said to exist in all, with 20 shrimp, 8 lobster and 7 crab species regularly fished (Pasha & Siddiqui, 2003). Brackish water and marine species are dominant, freshwater species being found only in the Baleswar River on the eastern edge (Mukherjee, 1975). A rare species of shark, the Ganges shark *Glyphis gangeticus* (CR), has been found in the Hooghly River, and mud-skippers or gobys, the walking and even tree-climbing fish characteristic of mangrove swamps occur in large numbers. There are 48 species of crabs and a large variety of molluscs. The crustacea form by far the largest proportion of the animal biomass, with an estimated 40 million kilograms of fiddler crabs and 100 million kilograms of mud crabs (Hendrichs, 1975). The area supports a varied insect population including 300 species of spider (Pasha & Siddiqui, 2003) and large numbers of honey-bees, but other insect life has been little studied. Note that figures quoted above before 1987 may refer to the Indian side only and that references may not distinguish between that section and the whole area.

CONSERVATION VALUE

The Sundarbans contain the world's largest halophytic mangrove forests and one of the most biologically productive of all natural ecosystems. In the 1860s they were the first mangrove forests to be scientifically managed. They contain a rich biota which includes the Bengal tiger and many threatened reptiles. They are also of great economic importance as a storm barrier, shore stabiliser, nutrient and sediment trap, a source of timber and natural resources, and before cyclone Sidr were the most important source of fish and shrimps on the east Indian coast, They are an excellent example of the

ecological processes of monsoon rain flooding, delta formation, tidal influence and plant colonisation. They lie within a WWF Global 200 Eco-region, and are contained by both a Ramsar Wetland and a UNESCO Biosphere Reserve which contains the Tiger Reserve, National Park and three wildlife sanctuaries.

CULTURAL HERITAGE

In India the Baghmara Forest Block near the coast contains the ruins of a city said to have been built by the Chand Saudagar merchant community in approximately 200-300 AD. During the Moghul Empire, Raja Basand Rai and his nephew took refuge in the Sundarbans from the armies of Emperor Akbar. The buildings they erected at Netidhopani on the east bank of the Matla river where the ruins are still evident subsequently fell to Portuguese pirates, salt smugglers and dacoits in the 17th century. The widespread reclamation of the Sundarbans for agriculture started in 1770. Banobobi, incarnation of the Goddess Durga, is the area's reigning deity, among many other gods. Her blessings are sought for protection from the tiger (Rishi, 1988). In the early 20th century Gosaba became the centre for Sir David Hamilton's cooperative self-help movement. The area features in Bengali literature, for example, Bankim Chandra Chatterjee's novel *Kapal Kundla,* Amitav Ghosh's 2004 novel, *The Hungry Tide* and part of Salman Rushdi's *Midnight's Children*.

LOCAL HUMAN POPULATION

Approximately 2.5 million people lived in small villages surrounding the Sundarbans in 1981 which by 1991 had increased to 3 million (Ministry of Environment & Forests, pers. comm., 1995). At nomination, some 35,330 people worked in the forest, 4,580 of whom collected timber and firewood, 1,350 collected honey and beeswax and 4,500 harvested the natural resources and hunted mainly deer, and 24,900 were fisherman and shrimp farmers (Chakrabarti, 1986a). Today, the area provides a livelihood at some seasons of the year for an estimated 300,000 people. Local people are also dependent on the forests and waterways for charcoal, timber for boats and furniture, poles for house-posts and rafters, nypa palm thatch for roofing, grass for matting reeds for fencing, shells and reptile skins, with deer, fish, crabs and shrimps taken for food. The season for collecting honey and wax is limited to ten weeks from April 1st. Thousands of people, with permits from the Forest Department, enter the forest for nests. Honey production is discussed by Chakrabarti (1987c). Before Cyclone Sidr, which destroyed the fishing industry, more than 10,000 local people fished year-round (Hussain, 1997). In 1986 the average annual catch was 2,500 tonnes (Chakrabarty, 1986). No-one lives in the Tiger Reserve but several activities encroach on tiger habitat, and throughout the Sundarbans some 300 people are killed by tigers or crocodiles each year. Transport is only by boat. Because of the annual flooding, only one crop can be taken each year. The people are therefore poor.

VISITORS AND VISITOR FACILITIES

Visitors are not allowed to visit the National Park without a permit. But the buffer zone averaged 34,390 visitors a year between 1992 and 1997 (Project Tiger, 2001) and about 40,000 were reported by UNESCO in 2002. In the Tiger Reserve, visitors have to stay within limits and most travel is by boat so there is little conventional wildlife watching except from the water, but there are watchtowers at the Sajnakhali Bird Sanctuary, Sudhanyakhali, Haldi and Netidhopani. There are lodges at Sajnakhali and entry points, Bakkali and Piyali. Visitors often overnight on board the sightseeing boats. The Sundar Cheetal Sajnekhali Tourist Lodge is very basic but has a Mangrove Interpretation Centre. Nearby is a heronry which can be visited by boat. The Sundarban Tiger Camp at Dayapur, Gosaba, is some distance from the Park but runs conducted tours from Kolkata. The Jungle Camp arranges ex-Kolkata round trips and travel within the delta including places such as the Baghatpur Project. Rail access is via Canning Town, then by boat and/or bus to Basanti, Gosaba and Sajnakhali. Launches can be hired from the Tourist Bureau or Sundarbans Launch Association in Calcutta.

SCIENTIFIC RESEARCH AND FACILITIES

Considerable research has been carried out on the Sundarbans ecosystem and its wildlife. Early contributions to the flora and avifauna were made by Prain (1903) and Law (1954, 1956). Mukherjee (1975) gives a fairly comprehensive account of both flora and fauna, based largely on his visits to the Sundarbans in 1955-1960. Mukherjee & Gupta (1965) studied the rhesus macaque and Mukherjee (1969, 1971, 1972) examined the water birds. Hendrichs (1975) undertook a three-month field study of tiger in 1971, concentrating on the problem of man-eating, and of other animals. Chakrabarti (1986a) analysed factors associated with man-eating by tigers. He also showed that species diversity is greater below the tidal level than above it and that in general floral diversity is lower than in the forests of North and South Bengal (Chakrabarti, 1986b, 1987b). A long-term monitoring program has been followed since 1980 by the Marine Science Department of Calcutta University (1987). The Tiger Reserve with the

Botanical Survey of India made a preliminary floral survey and with the Zoological Survey of India from its research station at Canning Town has surveyed the fauna and takes a biennial census of the tiger population. In 1996-7 the negative impacts of intensive prawn culture on the aquatic ecosystem were investigated. There are the Indian Central Inland Fisheries Research Station at Kakdwip, Sagar Marine Biological Institute on the westernmost island and Central Soil Saline Research Institute at Canning Town. Meteorological stations at Haldi, Jhingakhali and Sajnakhali monitor the climate.

MANAGEMENT

The part of the Sundarbans lying in India is managed by Project Tiger under the aegis of the Ministry of Environment and Forests and the direction of the West Bengal Chief Conservator of Forests, Wildlife & Bio-Diversity who is the Chief Wildlife Warden. The core area nearest the coast, now a National Park, is designated a wilderness zone under the West Bengal Amendment of the Indian Forest Act (1988); the Fisheries Act of the West Bengal Government; and the Coastal and Regulatory Zone Rules. Transboundary cooperation is being encouraged by the World Heritage Committee and financed by the United Nations Fund. This is particularly important in relation to the effects of climate change and of upstream diversions of the Ganges (Agrawala, S., *et al.*, 2003). Within the area 12,440 ha is a strictly reserved Primitive Area where no forestry operations or other interference are allowed. Elsewhere in the Tiger Reserve in the northwest, forests are subject to 'selection-cum-improvement' felling. Exploitation of the hental date palm and nypa palm, and seasonal collection of honey are allowed by permit. Local people may also fish in the tidal waters but require a permit for firewood used during such trips (Lahiri, 1973). The remaining area, mainly in the northeast, east and centre, comprises a buffer zone of nine forest blocks.

There has been a marked improvement in the biota, shown in the steady rise of the tiger population, considered an indicator of the health of the ecostystem. Based on censuses of tracks, data suggest that this increased by 7% annually from 181 in 1976 to 264 in 1983 (Chowdhury & Sanyal, 1985). Predation on man has declined. Freshwater ponds have been constructed in several localities for the benefit of the wildlife. 24 captive-bred estuarine crocodiles were re-introduced to the area from the Bhagabatpur hatchery and olive ridley turtles are reared in captivity at Sajnakhali for subsequent release into the National Park. The original management plan for the Tiger Reserve has been updated for the period 2001-2010. Participatory management is practiced with 10 Forest Protection and 14 Eco-Development Committees from fringing communities. Eco-development projects have provided them with help with irrigation channels, ponds, wells, jetties and advice on fish and crab culture; also medical clinics, training and employment on tourist boats and as guides (UNESCO, 2002; Milne, 1997).

MANAGEMENT CONSTRAINTS

A long-term ecological change is taking place in the Sundarbans, due to the eastward migration of the Ganges, the abandonment of some distributaries, and past diversion of water and withdrawals for irrigation. Up to 40% of the dry season flow of the Ganges was diverted in 1974 by the Farraka Barrage upstream in India. Diminished fresh water flushing of the Sundarbans has resulted in increased saline intrusion, particularly in the dry season. Reclamation has also led to salinisation and soil acidification. Siltation is another increasing problem necessitating dredging to improve river flow: local fishermen expect that the Matla River will soon no longer be navigable up to Canning Town. Some deterioration in the flora, including localised die-back of *sundari,* commercially the most valuable tree species has been noticed. Its top-dying is probably due to the decrease in freshwater flow, either through increasing salinity or related edaphic changes. Its gradual replacement by *Excoecaria* is a likely long-term effect (Christensen, 1984). This deterioration is well-documented and is under continuing study but its possible effects on the fauna are unknown. However, the stocking of spotted deer appears lower in western areas, where salinity is highest, than in the east where salinity is lowest.

The Sundarbans has been notorious for its man-eating tigers since the 17th century but predation by tigers is diminishing. From 1975 to 1982, on average, 45 people were killed by tigers each year. In 1988, 65 deaths in four months were reported in *The Guardian* (28 Dec.1988). Noting that tigers which hunted man like any other prey occurred only in the south and west, Hendrichs (1975) hypothesised a link between high salinity levels due to the absence of freshwater and man-killing. More recent analyses suggest that the killing may partly relate to the availability of easy human prey and the frequency of their interactions with tigers (Salter, 1984; Siddiqi & Choudhury, 1987). Immobilisation for capture and release elsewhere, and nylon fencing, have been used to deal with the problem (UNESCO, 2002). The casualty rate fell after the introduction of countermeasures such as electrified human dummies and face masks worn on the back of the head (Chowdhury & Sanyal, 1985). Between 1994 and 1995, the number of victims fell to less than 12 (Rishi, 1988) and in 1997 had fallen to 2-4 per year though 18 people were

killed during 2000-2001 (UNESCO, 2002). Villagers now tend to drive straying tigers back into the forest rather than kill them (Milne, 1997). Illegal fishing and poaching remain a main management constraint and very destructive of prawn larvae used to supply the intensive and often illegal prawn farms which are encroaching into the Reserve (UNESCO, 2002; Ministry of Environment & Forests, pers. comm., 1995). Smuggling and piracy are also used to augment very low incomes.

There are potential sources of pollution from industry. There were plans for a fertiliser plant at Mathurapur, 5 km from the Satpukur sluice gate at the edge of the Sundarbans from which armful effluents such as sulphur dioxide, sulphates and fluorine would enter the waterways (Gupta, 1987). And oil spills from a proposed system of national waterways through the Tiger Reserve are a potential threat which could cause immense damage to aquatic fauna, seabirds and to riverine forests (Blower, 1985). Mangroves have been illegally used to fuel a gas plant at Gosabi Island. The main threat to the system has been from cyclones and excessive flooding. Storm surges can be up to 7.5m high, causing loss of life and damage to both property and forests.

Cyclones and tidal waves normally cause some damage to the forest along the sea-face, and result in considerable occasional mortality among spotted deer. However, the effects of the 2004 tsunami were bad, but those of the July and September monsoon floods and cyclone Sidr in 2007 were totally disastrous. Cyclonic winds and a 6.5m storm surge along 100km of coast took over 3,500 lives, affected up to four million people, damaged or destroyed some one million homes, livestock, rice fields and the region's entire fishing industry (Indian Water Portal Blog, 2007). A UNESCO Mission found that 40% of the site had been seriously damaged, most of it World Heritage site. Regeneration of the Sundarbans ecosystem, should normally take 10 to 15 years, if poaching and other intrusions do not jeopardize this. The field stations, boats, jetties and equipment of the Bangladeshi Forest Department in the area were washed out to sea by the storm, severely limiting the authority's capacity to manage the site and to prevent poaching of marine and terrestrial fauna and flora for commercial and subsistence purposes (UNESCOPRESS, 2007). The early warning system and concrete cyclone shelters limited the damage, but such storms emphasise the important protective function of the coastal forests, flood refuges and prompt evacuation. Recovery will take time and much help to restore the infrastructure, field stations and equipment sufficiently to prevent uncontrolled exploitation before order returns. Over US$100,000 was granted by the international community towards recovery though this could restore little of the destroyed infrastructure. Two years later many field stations remained unusable, particularly in the east, and radio-communications towers remained out of service. However, a 5-year rehabilitation project was being developed (UNESCO, 2009).

STAFF

The National Park is administered by a Deputy Field Director with an Assistant Field Director. The park area is divided into two ranges, each overseen by Range Forest Officer. The ranges are subdivided into beats. There are field stations, anti-poaching camps and floating watch stations to protect the property from poachers. The sanctioned staff strength in 2001 was 268, with 63 posts lying vacant (Project Tiger, 2001). At least 100 more guards were considered necessary by IUCN in 2002.

BUDGET

Funding is by the State Government and the national Ministry of Environment and Forests. In 1995 this totalled Rs70,000,000 (US$2,000,000) of which Rs 18.500,000 was from the State Government and the rest from the Central Government (1994/95) (Ministry of Environment & Forests, pers. comm., 1995). Funding is also received for Project Tiger from the Central Government. Both funding and infrastructure were stated to be inadequate for the size and complexity of the Reserve (Project Tiger, 2001). In 2001 the UNF granted US$105,000 towards transboundary cooperation with Bangladesh. After cyclone Sidr in 2007 international sources granted US$75,000 emergency assistance and Switzerland granted US$32,590, which helped the acquisition of 12 patrol vessels and the restoration of 6 field station staff lodges, repair 11 boats, 2 field stations and a wildlife sanctuary shed (UNESCO, 2009).

LOCAL ADDRESSES

The Field Director, Sundarbans Tiger Reserve, Government of West Bengal, Directorate of Forests, Canning Town, District 24-Parganas, West Bengal.

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Jan. 1987. Updated 11-1987, 5-1990, 8-1995, 4-1997, 6-2008, 6-2009, May 2011.