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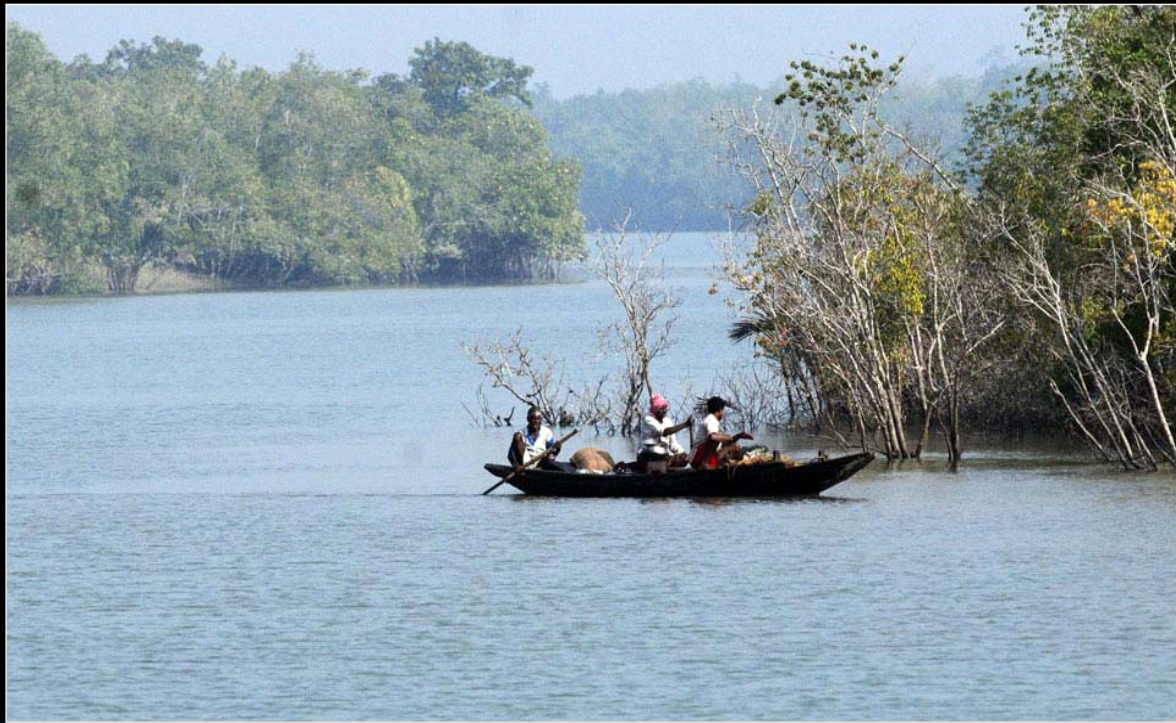
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Front cover: Spotted deer (*Axis axis*) in Indian Sundarbans
Back cover: Goliath heron (*Ardea goliath*) in Indian Sundarbans
(Photos courtesy of P.K. Pandit)

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BIODIVERSITY OF MANGROVE FORESTS OF INDIAN SUNDARBANS AND ITS CONSERVATION

by P.K. Pandit



PHOTOGRAPHY: P K PANDIT, IFS

Mangrove forests of Sundarbans (Photo: P.K. Pandit)

Introduction

Living along the interface between land and sea, the mangrove forests support genetically diverse groups of aquatic as well as terrestrial organisms. Mangrove habitats constitute a diverse group of habitats such as core forests, water bodies (rivers, bays, intertidal creeks, channels and back waters), mudflats, litter-forest floors and sea grass ecosystem (wherever these occur). Mangroves can exist and flourish under a wide range of salinity conditions, tidal aptitudes, winds, temperatures and in muddy and anaerobic soil conditions. The highly variable conditions make mangrove forests profusely rich in biodiversity and they support huge numbers of plant and animal communities, including many rare, endangered and threatened species. Mangroves are biodiversity hot spots because of the high species

richness. The biodiversity of mangroves has also been gaining greater importance because of the conservation of biological biodiversity and also because the mangrove ecosystems are one of the most threatened by global climate changes, especially the rise in sea level. These highly productive and dynamic ecosystems are subjected to different types of threats such as anthropogenic pressure, which includes excessive natural-based resource dependency of fringe villages for the collection of fuel wood and small timbers; over-exploitation of aquatic fauna (e.g., collection of crabs, fishes, tiger prawn seeds); collection of honey and wax; hydrological factors, including an increase of salinity due to reduced flow of fresh water from upstream; the construction of embankment protection bundhs along fringe villages; climate change and global warming; increased levels of

pollution; changing species composition; etc. Many efforts have been made to save the world famous Sundarbans mangrove ecosystem, at both international and national levels.

Study area

The Sundarban mangrove forest is the largest single track of mangrove forest in the world, covering an area of approximately 10,260 km² in the delta of the rivers Ganga, Brahmaputra and Meghna. It is shared by Bangladesh (6,000 km².) and India (4,260 km²). The Indian part of Sundarbans is situated in the southernmost part of West Bengal State, in the district of South & North 24-Parganas, lying a little south of the Tropic of Cancer between latitudes 21°31'2" & 22°31'2" North and longitudes 88°10'2" & 89°51'2" East. A close network of rivers, channels and creeks intersects the whole Sundarbans, which has resulted in the formation of 102 islands, out of which 54 have human inhabitants. The main rivers which flow in and around Sundarbans are Matla, Bidya, Gosaba, Gona, Kalindi, Harinbhanga, Raimangal, Jhilla, Kapura, Thakuran, Muriganga, Hatania and Doania. Raimangal, Harinbhanga and Kalindi rivers separate India and Bangladesh on the eastern side. Sundarbans is bounded by Bangladesh in the east, fringe villages in the north and west and the Bay of Bengal to the South. The enormous amount of sediments carried by the rivers has contributed to its expansion and dynamics; salinity gradients change over a wide range of spatial and temporal states. The area has a sub-tropical monsoonal climate with high humidity and the average annual rainfall is approximately 1,900 mm. High tides and ebb tides occur twice daily and the current changes its direction at six hour intervals. The average elevation varies from 5.8 m to 6.1 m above mean sea level, with several low line depressions. The maximum and minimum tides recorded at Sagar Island are 5.68 m and 0.96 m respectively. Biotic factors at Sundarban play a significant role in physical coastal evolution and a variety of habitats have developed for wildlife, which includes estuaries, beaches, permanent and semi-permanent swamps, tidal flats and tidal creeks. The mangrove vegetation itself assists in the formation of new landmasses and the inter-tidal vegetation plays a significant role in Sundarbans.

Every year around 250,000 tourists visit Sundarbans for entertainment, education, interpretation and to provide direct and indirect support to the fringe people.

Floristic diversity

Mangrove and mangrove associates constitute the dominant vegetation type of the area. These salt-loving plants, which are found throughout the tropical and sub-tropical regions of the world, have been variously categorized by different authors. According to Champion and Seth's revised classification, the mangrove forests of Indian Sundarban fall under mangrove scrub (4B/TS1), mangrove forests (4B/TS2), salt-water mixed forests (4B/TS3), brackish water mixed forest (4B/TS4) and palm swamp type (4B/E1). Naskar and Guha Bakshi (1982) grouped these forests into five major zones: i) sea-face of beach forest; ii) formative island flora; iii) flora of reclaimed land and low-lying areas; iv) flora of river banks; and v) swamp forests. The first category is dominated by xerophytic plants due to the dryness of the soil and numerous sand dunes. The formative island flora consists of mainly *Porteresia coarctata*, *Salicornia brachiata*, *Suaeda martima*, *S. nudiflora*, *Acanthus illicifolius* and a few tree species like *Avicennia*, *Sonneratia* and *Excoecaria*. The reclaimed land and low-lying areas are dominated by mesophytic flora, while the last two zones are dominated by halophytic mangrove forests.

There are 140 flowering plant species under 101 genera and 59 families, comprising true mangroves, mangrove associates, back mangrove trees and shrubs, non-halophytic non-mangrove associates, halophytic herbs, shrubs, weeds, epiphytes and parasitic plants (Naskar, 2007).

Mangrove forest is a special type of vegetation community comprising a variety of salt-resistant species having some special adaptations and characteristics for growing in intertidal areas and the estuary mouth between land and sea. The mangrove forest of Sundarbans is one of the most dynamic ecosystems on the earth (Alongi, 1996). It provides habitat for diverse flora and fauna, including some that are endangered. However, this unique ecosystem is threatened in many places in

the world. Some of the characteristics and adaptations of mangrove species are: i) formation of a lateral root system for secure anchorage against diurnal tidal inundation (e.g., *Excoecaria* sp.); ii) supporting roots such as stilt roots or prop roots, root buttresses, etc. are formed in *Rhizophora* sp. and *Xylocarpus* sp.; iii) vertical knee roots spring from horizontal lateral roots in *Lumnitzera* sp., *Bruguiera gymnorrhiza*, *Kandelia candel*, etc.; iv) formation of pneumatophores or breathing roots; v) viviparous germination (germination on the tree) in *Rhizophora* sp., *Bruguiera* sp., etc.; vi) sunken stomata to prevent water loss; and vii) thick wax-coated leaves.

Some important mangrove families found in the Sundarbans are Rhizophoraceae, Avicenniaceae, Meliaceae, Sonneratiaceae, Sterculiaceae, Myrtiniaceae, etc.

In India, species of mangrove ecosystems are generally in a vulnerable condition. Only two mangrove species, namely *Avicennia marina* and *Excoecaria agallocha* are at lesser risk according to their IUCN category. *Xylocarpus* sp. is becoming rare in Sundarbans due to past over-exploitation (Naskar and Mandal, 1999). A few important mangrove species and their status are given in Table-1.

Table-1: Some mangrove species and their IUCN status

Serial No	Family	Species	IUCN status of species	Occurrence
1	Rhizophoraceae	<i>Rhizophora apiculata</i>	LR	C
2	Rhizophoraceae	<i>Rhizophora mucronata</i>	LR	C
3	Rhizophoraceae	<i>Bruguiera parviflora</i>	VU	C
4	Rhizophoraceae	<i>Bruguiera cylindrica</i>	LR	C
5	Rhizophoraceae	<i>Bruguiera gymnorrhiza</i>	LR	C
6	Rhizophoraceae	<i>Bruguiera sexangula</i>	VU	F
7	Rhizophoraceae	<i>Ceriops tagal</i>	VU	R
8	Rhizophoraceae	<i>Ceriops decandra</i>	VU	R
9	Rhizophoraceae	<i>Kandelia candel</i>	LR	F
10	Meliaceae	<i>Xylocarpus mekongensis</i>	VU	C
11	Meliaceae	<i>Xylocarpus granatum</i>	VU	F
12	Sterculiaceae	<i>Heritiera fomes</i>	VU	R
13	Arecaceae	<i>Nypa fruticans</i>	EN	R
14	Acanthaceae	<i>Acanthus ilicifolius</i>	LR	C
15	Sonneratiaceae	<i>Sonneratia alba</i>	VU	-
16	Sonneratiaceae	<i>Sonneratia apetala</i>	VU	F
17	Sonneratiaceae	<i>Sonneratia caseolaris</i>	VU	F
18	Avicenniaceae	<i>Avicennia marina</i>	LR	C
19	Avicenniaceae	<i>Avicennia alba</i>	LR	C
20	Avicenniaceae	<i>Avicennia officinalis</i>	LR	C
21	Myrtiniaceae	<i>Aegiceras corniculatum</i>	LR	A

EN = Endangered, VU = Vulnerable, LR = Lower Risk, - = Not recorded, A = Abundance, C = Common, R = Rare, F = Frequent

Source: Kathiresan (2000) and Kathiresan and Qasim (2005)

Non-flowering plants: Limited studies have been done on algal flora in Sundarbans, but recently Naskar *et al.* (2004) reported 150 species of algae. According to Santra (1998), 32 species of lichens are found in Sundarbans. The diversity of fungi and bacteria in Indian Sundarbans has not been studied in detail, although bacteria play a significant role in the mangrove ecosystem for the decomposition of litter in the soil.

Faunal diversity

Mangrove fauna, in general, is found to occur in both terrestrial and aquatic ecosystems. These areas can be differentiated into littoral or supra-littoral forests, inter-tidal mudflats and estuaries (Anon, 2011). The faunal diversity of Sundarbans has attracted much attention because of the huge economic importance of many species, as well as the presence of the Royal Bengal tiger. It supports a huge number of coastal and marine fishes, crustacea, honey bees, mammalian species, reptilia, avi-fauna, mollusks, insects and annelids in addition to other mega-fauna.

Mammals: In Indian Sundarbans 31 species of mammals are found (Chowdhuri and Chowdhury, 1994; Sanyal, 1999). Among them, the most important is the Royal Bengal tiger (*Panthera tigris tigris*), which is one of the endangered species. Other important mammalian species existing in Sundarban mangrove forests are fishing cat (*Felis viverrina*), jungle cat (*Felis chaus*), leopard cat (*Prionailurus bengalensis*), spotted deer (*Axis axis*), gangetic dolphin (*Platanista gangetica*), Irrawady dolphin (*Orcaella brevirostris*), Rhesus macaque (*Macaca mulatta*), Wild boar (*Sus scrofa*), smooth-coated otter (*Lutrogale perspicillata*), etc.

Reptilia and Amphibia: The species richness among reptiles and amphibians in Sundarbans is very high; about 59 species of Reptilia and 7 species of Amphibians have been recorded in Indian Sundarbans (Sanyal, 1999; Naskar *et al.*, 2004). Estuarine crocodile (*Crocodylus porosus*), another endangered species, is the top predator and largest reptile in the aquatic ecosystem. Water monitor lizard (*Varanus salvator*) is another large reptile found in abundance. Among 14 turtle and tortoise species, six are nearly extinct or

threatened. Out of 4 marine turtles, the olive ridley turtle (*Lepidochelys olivacea*), though endangered, is found in Sundarbans. There is a significant population of the river terrapin (*Batagur baska*), which was once believed to be extinct. The green sea turtle (*Chelonia mydas*), Hawksbill turtle (*Eretmochelys imbricata*) and flap-shell turtle (*Lissemys punctata*) are very common here. Around 53 species of snakes (Anon, 2011) are found in this area. Prominent among the poisonous snakes are the king cobra (*Ophiophagus hannah*), monocellate cobra (*Naja naja*), branded krait (*Bungarus fasciatus*), Russel's viper (*Daboia russelli*) and common krait (*Bungarus caeruleus*). Among the non-venomous snakes present are python (*Python molurus*), chequered keelback (*Xenochrophis piscator*), dhaman (*Ptyas mucosa*), trinket snake (*Elaphe helena*), green whip snake, common wolf snake, bronzeback snake, ornamental snake, common vine snake and several other species. The tidal creeks also harbor Homalopsid snakes adapted to living in water, the most common being *Cerberus rhynchops* (dog-faced water snake).

Avi-fauna: Indian Sundarbans is very rich in avi-fauna with 217 recorded species. Moreover, during winter, 52 species of migratory birds visit the Sundarbans. It is called the kingfishers paradise as out of 12 species found in India, 8 are found here, namely common kingfisher (*Alcedo atthis*), black-capped kingfisher (*Halcyon pileata*), collared kingfisher (*Todiramphus chloris*), brown-winged kingfisher (*Halcyon amauroptera*), ruddy kingfisher (*Halcyon coromanda*), white-throated kingfisher (*Halcyon smyrnensis*), stork-billed kingfisher (*Halcyon capensis*) and pied kingfisher (*Ceryle rudis*). During the monsoon, heronries develop in Arbesi block near Samshernagar. Common birds found in the area include herons, darters, spoonbills, cormorants and storks. The most abundant bird species are common sand piper, Indian ringed dove, whimbrel, tailorbird, jungle myna, rose-ringed parakeet, large egret, bronze-winged drongo, magpie robin, pond heron, common iora, red-vented bulbul and brahminy kite. Goliath heron (*Ardea goliath*), an African visitor and the largest heron in the world, is also found in this area. Other birds which are frequently found in this area include large and median egret, white-bellied sea eagle, lesser adjutant stork, osprey, whiskered tern,

Some important fauna of Indian Sundarbans (Photos: P.K. Pandit)



Salt-water crocodile (*Crocodylus porosus*)



Mudskipper (*Periophthalmus nonembradiatus*)



PHOTOGRAPHY: P K PANDIT, IFS

Royal Bengal Tiger (*Panthera tigris tigris*)



Brahminy kite (*Heliastur indus*)



PHOTOGRAPHY: P K PANDIT, IFS

Water monitor lizard (*Varanus salvator*)

brown-winged gull and changeable hawk eagle, among others.

Fishes: Mangrove forests serve as nurseries for shell fish and fin fishes and sustain the coastal fisheries of the entire coast. More than 200 species of fishes are found in the Indian Sundarbans, out of which some are transient (migrant) and some are residents. The residents include *Mugil parsia*, *M. tade*, *Polynemous paradiseus*, *Polydactylus indicus*, *Otolithoides biauritus*, *Lates calcarifer*, *Hilsa toil*, *Arius jella*, *Pama pama*, *Sillaginopsis panijus*, etc. Among the migratory species *Tenualosa ilisha*, *Pangasius panjasius* and *Polydactylus indicus* are common.

The sharks and rays found in Sundarbans, include Ganges shark (*Glyphus gangeticus*), small-toothed saw fish (*Pristis microdon*), pointed saw fish (*Anoxypristis cuspidate*) and white-spotted shovel-nosed guitar fish (*Rhynchobatus djiddensis*); all are Schedule-I species in the Wildlife (Protection) Act, 1972 of India. In addition to these, *Rhinobatus granulatus*, *Himantura*

alcockii, *Rhinoptera juanica* and *Sphyrna zygaena* are also found.

Invertebrate species: Among the invertebrates, 143 species of mollusks, 201 species of insects, 240 species of crustaceans, 78 species of annelids, 68 species of protozoa and 104 species of nematods are found in the Indian Sundarbans (Chowdhuri and Chowdhury, 1994). Moreover, numerous species of phytoplanktons and zooplanktons are also present. Two species of horseshoe crabs found in the Sundarbans are *Tachypleus gigas* and *Carcinoscorpius rotundicaudata*. They are considered to be living fossils thought to be more than 400 million years old.

Threatened and extinct animals

In Indian mangroves, faunal species are also at threat. It was recorded by Chaudhuri and Chaudhury (1994) that 2 reptile, 3 bird and 5 mammal species are extinct, and 10 reptile, 3 bird, and 2 mammal species are at threat (See Table-2).

Table-2: Threatened species of Indian Sundarbans

Serial No	Category	Family	Animal species	IUCN status
1	Mammal	Felidae	<i>Panthera tigris tigris</i>	T
2		Platinistidae	<i>Platanista gangetica</i>	T
3	Reptile	Crocodylidae	<i>Crocodylus porosus</i> ,	T
4		Varanidae	<i>Varanus salvator</i>	T
5		Chelonidae	<i>Chelonia mydas</i>	T
6		Pelomedusidae	<i>Eretmochelys imbricata</i>	T
7		Chelonidae	<i>Lepidochelys olivacea</i>	T
8		Chelonidae	<i>Caretta caretta</i>	E
9		Dermochelyidae	<i>Dermochelys coriacea</i>	E
10		Emydidae	<i>Batagur baska</i>	T
11		Tryonychidae	<i>Lissemys punctata</i>	T
12		Tryonychidae	<i>Trionix gangeticus</i>	T
13		Tryonychidae	<i>T. hurun</i>	T
14		Boidae	<i>Python molurus</i>	T
15	Avifauna	Pelecanidae	<i>Pelecanus philippensis</i>	T
16		Ardeidae	<i>Ardea goliath</i>	T
17		Cyconidae	<i>Leptoptilos javanicus</i>	E
18		Theskiornithidae	<i>Theskiornis melanocephalus</i>	T
19		Anatidae	<i>Sarkiodornis melanotus</i>	E
20		Anatidae	<i>Cairina scutulata</i>	E

T = Threatened, E = Extinct

Mammals that have disappeared: Mammalian species that once existed in Sundarbans and have disappeared (Seidensticker and Hai, 1983) over a period of time are:

- Javan rhinoceros (*Rhinoceros sondaicus*) – Last reports of evidence proving the presence of this rhinoceros dates back to the year 1888. In April 2000, skeletal remains of *Rhinoceros sondaicus* were found 2.7 m below the surface in Mollakhali Island under Gosaba P.S.
- Wild buffalo (*Bubalis arnee*) – The wild buffalo roamed in Sundarbans until 1885 and died out at the end of the 19th Century. In March 2001, some bones were recovered from Netidhopani Compartment–I. The bones were sent to ZSI for identification and were identified as wild buffalo.
- Swamp deer (*Cervus duvaucelli*) – This animal was reported to exist in good numbers until the earlier part of the 20th century and were probably extinct by 1930.
- Barking deer (*Muntiacus muntjac*) – This animal was found to exist in the southern part of the Sundarbans even up to 1976. It was also found on Halliday Island.
- Hog deer (*Axis porcinus*) – It was reported to found in the Sundarbans up till 1945.

In the recent past, fossils of *Rhinoceros unicornis* have been discovered from Bakkhali. Fossils of freshwater tortoise (*Chitra indica*) and jaws of gharial (*Gravialis gangeticus*) were found in the excavations of Dum Dum near Kolkata along with stumps of Sundari (*Heritiera* sp.) and fruits of *Derris* and *Cerriops* species.

Threats to biodiversity

The rich biodiversity of the Sundarbans is threatened continuously by many factors ranging from the evolutionary history and paleoclimate to the current biophysical and anthropogenic factors, plus the nature and intensity of interactions with adjacent systems (Gopal and Chauhan, 2006). Mangroves differ from fresh-water wetlands in their hydrology, as they interact daily with both sea and inland areas.

The major threat to biodiversity is the growing human population, who are dependent on the forest-based natural resources for their livelihood.

The population situated around the Sundarbans are economically very backward and have few alternative livelihood choices except rain-fed single cultivation. The main occupations of the villagers are agricultural laborers or household workers, other than cultivating their own land. After cyclone AILA hit in 2009, salt water infiltrated the agricultural land, resulting in big drops in crop production, so the majority of eligible male members had to look for work in construction and other labors in major cities of India. Infrastructure as well as basic amenities in the villages is very limited. There are no good road networks, markets, schools, colleges and or health care facilities. All these factors lead to a high level of resource dependency. Villagers are mostly dependent on mangrove forests for the collection of fuelwood, fodder, small timbers, fishes, tiger prawn seeds, honey, crabs, etc. Out of these activities, fishing, tiger prawn seeds and honey collection are done for commercial purposes. Officially, every day approximately 10,000 fishermen enter the Sundarbans for fishing throughout the year, except for 3 months (April to June). However, unauthorized entry for fishing is very common and it is a major challenge for the Sundarbans management authority, along with the killing of wild animals.

Among the hydrological factors, the inflow of fresh-water is the major factor which influences the salinity as well as the geomorphology of the area. The tidal frequency is a constant factor, but the tidal height is an important matter for inundation, erosion and accretion of soil. The salinity regimes are also affected by tidal heights. Human settlements and their associated activities such as clearing of forests, establishment of a 3,500 km long earthen bund to protect villages from tidal effects and floods, and conservation of land for other uses, directly influences the fresh-water flow and sediment accretion on water-bodies. The nature of the sediment directly influences the flora and fauna of the mangrove ecosystem. Most of the tributaries of the River Ganges on the Indian side have been silted up and do not carry fresh water, which leads to increased salinity and as well as directly affecting the biodiversity. Salt-tolerant species are gradually predominating due to the increased salinity level. Recent studies (Hoq *et al.*, 2006) in Bangladesh have clearly

demonstrated the strong influence of salinity, temperature and conductivity on the seasonal abundance and distribution of shell fishes and fin fishes.

Heritiera fomes, *Nypa fruticans*, *Phoenix paludosa*, etc. are species that are declining rapidly in the Sundarbans (Blasco, 1975; Rahman, 1990) and *Heritiera* sp. is being replaced by *Excoecaria* sp. (Christensen, 1984). The forest structure in general is becoming simpler and the average height of the trees is decreasing. In Bangladesh Sundarbans it is estimated that 0.4% of the forest area is replaced by dwarf species every year, which consequently decreases the habitat of arboreal species like birds, monkeys and others. Reports indicate that the changes in herbaceous species are affecting the spotted deer population; however, an increase in *Sonneratia* sp. and *Avicennia* sp. favors the deer because the leaves of mangrove trees constitute the staple diet of spotted deer.

The effect of salinity levels and their seasonal variation is a significant factor in the recruitment and growth of different animals and the effect on their predators (Hussain and Acharya, 1994). Fresh-water inflows upstream have been diverted for irrigation, flood control and hydropower. Farakka barrage in India, on the border with Bangladesh, has been constructed to divert more water to Hooghly river with the aim to keep the river open for navigation from the Bay of Bengal to Kolkata Port. As no detailed study on biodiversity was carried out before the construction of this barrage it is very difficult to assess the extent of qualitative or quantitative changes of flora and fauna since then. But some studies (Sinha and Khan, 2001; Payne *et al.*, 2004) clearly indicated that the hilsa (*Hilsa ilisha*) fisheries have declined considerably in the Indian part of Sundarbans, mostly because the barrage acts as a barrier to upstream migration to breeding sites.

The 3,500 km long embankment protection works have altered the flooding regime, increased salinity intrusion, enhanced siltation in the riverbed and reduced the nutrient exchange, which directly affects the biodiversity as a whole (Rahman *et al.*, 1992; Bhattacharya, 1999).

Pollution is another threat to the biodiversity of mangrove forests as agrochemicals such as pesticides, fungicides and fertilizers used extensively in the catchment of the river Ganga and its tributaries as well as in fringe villages of Sundarbans has polluted both the water-bodies and the landmass, which directly or indirectly affect the aquatic fauna and flora. Growing industrialization upstream and at Kolkata, particularly the Haldia Industrial Complex, contribute significant amounts of pollutants, which are gradually causing degradation of the Sundarban mangroves. Oil spills from the seaward side cause great damage to aquatic fauna and sea birds (Blower, 1985). The future of the Sundarbans will depend upon the management of the fresh water supply, as well as conservation of biological resources.

Conservation

The first management plan for the Sundarbans was formulated in 1871, designed to regulate harvesting of Sundari. Part of the Sundarbans was declared as Reserve Forest in 1878 (Bhattacharya, 1990). The most comprehensive plan, in the early 1990s, delineated the Sundarbans into management units called “compartments.”

In the Indian part, the whole area in 24-Parganas District was declared first as protected forests following a Notification dated 7 December 1878, and the boundaries of the remaining protected forests were fixed by Notification No. 4457-For. – dated 9 April 1926. The protected forests in the Basirhat subdivision of the district, presently Basirhat Range in Sundarban Tiger Reserve, were constituted as Reserve forests as per Government Notification No. 15340-For., dated 9 August 1928. The Indian Forest Act 1927 prohibits or otherwise restricts the carrying of guns, cattle grazing, tree cutting, and removal of forest produces or land clearance. The protected forests of Namkhana Range (except Mahisani and Patibania Islands) were also finally declared as Reserve Forests under Notification No. 7737-For, dated 29 May 1943. After independence, Lothian Island (38 km²) was declared a Wildlife Sanctuary. The hunting of tiger was banned completely in 1970 after the IUCN listed the Bengal tiger (*Panthera tigris*

tigris) as an endangered species. To protect the tiger, the Government of India initially declared 9 tiger reserves covering a total area of 9,115 km², of which the Sundarbans is one (2,585 km²). In 1976, Sajnekhali Wildlife Sanctuary was declared, covering an area of 362.33 km² within the Tiger Reserve. Halliday Island with an area 5.95 km² was declared a sanctuary in 1976. An area of 1,330.10 km² within the Sundarbans Tiger Reserve (STR) was declared as Sundarbans National Park in 1984. Considering the importance of this biogeographic region, the national park area of STR was added to the list of World Heritage Sites in 1985 by UNESCO. The whole Sundarbans region south of the Dampier Hodges Line, including the protected areas of STR, was declared a Biosphere Reserve in May 1989.

To involve local communities in the protection of the biodiversity of Indian Sundarbans, 65 Joint Forest Management Committees (JFMCs) have been formed. In this process, 51,092 people from 72 nearby fringe villages are deeply involved in protecting 67,728 ha of mangrove biodiversity. To improve their socio-economic condition and provide alternate livelihood activities, several individual input or community development-oriented activities have been undertaken, including necessary training by the State Forest Department. Some of these activities involve making irrigation channels for irrigation; sinking deep tube-wells to provide drinking water; construction of brick-paved paths; construction of a flood centre for easy communication; digging ponds; and making earthen bunds as protection measures. Moreover, saline-resistant paddy seeds, pump machines, spray machines, cycle van rickshaws, etc. have been distributed. For the health of the fringe villages, both human beings as well as livestock, regular medical camps and veterinary camps are being organized. To increase protection measures, especially in Protected Areas (PAs), the number of protection camps has increased two-fold, and to combat poachers the number of firearms also increased three-fold during the last decade. Moreover, there are protection measures in collaboration with the Border Security Force (BSF) and State Arm Police (SAP) and to strengthen them one BSF camp at Khatuajhuri and one SAP camp at Jhilla have been established. Frequent joint patrolling is being organized in border areas

as well as in vulnerable areas as and when necessary. For conservation of biodiversity, plantation of mangrove species in degraded mangrove forests and raised char land is done regularly. To meet the need for fuelwood and small timber, as well as to reduce the biotic pressure on the forest, plantation of non-mangrove species is done regularly along roadsides, canal banks, unused village land and other areas. To encourage the local people in protection efforts, a 25% share of the revenue earned from tourism is distributed equally to all JFMC members in the PAs. Human-tiger conflicts are a major issue in the Sundarbans, so to reduce it net fencing approximately 90 km long and 8-10 feet high has been erected inside the forest along the village boundary; needless to say, it is giving good dividends. Moreover, to further reduce man-animal conflicts, 6 tiger combat forces equipped with all possible facilities have been established at strategic locations.

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Garjan (*Rhizophora mucronata*) (Photo: P.K. Pandit)



Genwa (*Excoecaria agallocha*) (Photo: P.K. Pandit)