Chapter 12
Mangroves of Sundarban

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Abstract The Sundarbans are the largest delta of mangroves in the world comprising 10,277 km^2 at the meeting of two Himalayan rivers, the Ganges and Brahmaputra. The Sundarbans span India's state of West Bengal (4260 km^2) to Bangladesh (6017 km^2). The Sundarban mangroves are important in respect of species diversity, richness in mangrove flora and fauna, mangrove abundance and unique succession features. The Sundarbans provide 'home' for globally threatened species like Royal Bengal tiger, fishing cat, Gangetic dolphin, estuarine crocodile, horse shoe crabs, water monitor lizard and river terrapins. Mangrove forests provide a large amount of fish catch (up to 80%), thereby supporting the livelihood and ensuring the food security of coastal people. The mangroves of Sundarbans are endangered and are in an alarming state due to present trends of over- exploitation and large-scale dependency of an enormous rural population of the Lower Gangetic Delta. Sundarbans mangrove ecosystems, ecological and socio-economic services have also not been considered in the past and the mangroves have been developed for prawn and fish farms. However, these problems are now being addressed through the Joint Forest Management (JFM) system for better management of mangroves in Sundarbans.

Keywords Mangroves · Delta · Dependence · Species diversity · JFM · Exploitation

12.1 Introduction

Sundarbans, the largest delta of the world, is the much talked about natural resources site and it is a privilege for India and Bangladesh to have such a wonderful place of natural wildlife habitat. It spans from the Hoogli River in India's state of West Bengal in the western side to the Baleswar River of Bangladesh in the eastern site. Sundarban Mangrove is a unique ecosystem. This delta is formed in the inter-tidal areas at the confluence of two mighty Himalayan rivers, viz. the Ganges and the Brahmaputra with Bay of Bengal. Area of Sundarban region is 10,277 km^2 of which

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6017 km^2 in Bangladesh and 4260 km^2 in India. It is criss-crossed by riverine streams, canals and creeks and lies just south of the Tropic of Cancer between latitudes 21°32′N and 22°40′N and longitude 88°10′E and 89°51′E. It is considered as a self-maintaining coastal, inter-tidal estuarine component, which thrives due to constant interaction with the terrestrial and marine ecosystem. The pristine deltas of the Sundarbans are located at the southernmost fringe of Bangladesh and West Bengal, a state of eastern India. Since time immemorial, Sundarbans are considered to be a topic of immense ecological significance by scholars and researchers. This was brought under 'Project Tiger' in 1973. The immense biodiversity and ongoing geological processes led to further accolades as the reserve was declared a World Heritage Site by UNESCO in 1987 for Indian part and in 1997 for Bangladesh part. The Sundarbans are the treasure-trove for naturalists and scientists, a paradise for nature and wildlife photographers and a wonderland for tourists from all over the world.

Sundarbans is one of the largest deltaic zones which has attracted the interest of world-renowned botanists and ecologists since the later part of the eighteenth century. On the basis of his own work and the collections of others, William Roxburgh documented the first authentic work on this Lower Ganga Delta which was published in Roxburgh 1814 under the title 'Hortus Bengalensis'. The pioneer workers on Sundarbans were Voigt (1845), Anderson (1862), Schlichs (1875) and Clarke (1895). Based on these collections, Prain (1903a), Prain 1903b and Prain 1905 also published the monumental works on the 'Flora of Bengal' in general and the Flora of Sundarbans in particular. Over the course of time, the overall landscape of the Bengal basin in general and Sundarbans in particular has changed due to geological and geographical changes and the rapid growing human interaction and population pressure on these Sundarbans (Naskar and Guha Bakshi 1987). The current assessment by the Forest Survey of India (2019) through analysis of satellite imagery shows very dense mangrove comprises 29.66% of the mangrove cover, moderately dense mangrove is 29.73% while open mangroves constitute 40.61% of mangrove cover. Sundarbans also provides shelter to a wide variety of faunal species both terrestrial and aquatic. It provides excellent habitat to the Royal Bengal Tiger, estuarine crocodile and their prey-base.

12.2 Physical Attributes

12.2.1 Geology, Rock and Soil

The Sundarbans delta is the largest prograding delta of the globe. The formations of different lithologic units of deltaic deposition in this system took place at major shifts of strand lines. The high strand shoreline was far west 215,000 years back, a strandline change took place 82,000 years back and the present deposition of detritus formed since the last 6000 years of stable phase. There is general slope towards south

as well as west to east. The upper 100 m layer is composed of thick clay with occasional clay balls. There occurs unconsolidated sediment at 137 to 152 m depth composed of sand, silt and clay and gravels of varying colours. This serves as a boundary for the upper aquifer. At about 350 m depth, there lies a second aquifer of potable water. The whole sediment is composed mainly of montmorillonite, which is very sticky. They are derived from the basic and semi-acidic rocks like Dolerite, Gneiss and Mica schists lying within the course of Ganga flow. Soil salinity reaches up to 3%. The older the sediments the higher the salinity in the Sundarbans area.

The Sundarbans saline soils are considered to cause higher plant mortality and the white salt encrustations are very often visible on the soil surface. The salinity rises to the maximum in the middle of May and decreases on the onset of monsoon. The salt contents are mostly chlorides and sulphates of sodium, magnesium and calcium, though bicarbonates are also present in traces. The subsoil layer remains under reduced condition along with mottles of different sized dark coloured horizons. The soil pH ranges between 5.4 and 8.5 in reaction. In submerged condition and with higher salinity, the decomposition rate of the organic matter is less as the bacterial population in those areas is generally poor (Qureshi 1957). The organic matter decomposition in these tidal zones is carried out by some facultative and obligate anaerobic bacteria. Mangroves usually have a low decomposition rate of root biomass relative to root production, which results in the accumulation of organic matter in the soil.

12.2.2 Hydrology and Water Sources

12.2.2.1 River Systems

A close network of rivers, channels and creeks intersects the whole area, which has resulted in formation of innumerable flat islands. These are submerged completely during high spring tides and partially during ordinary high tides. The main rivers in the Indian part of the Sundarbans are Hoogli, Thakuran, Matla, Bidyadhari, Goasaba, Jhilla, Harinbhanga, Kalindi and Raimangal. In Bangladesh, the Ganges delta is formed by the confluence of the Ganges (locally called Podda), Brahmaputra (locally called Jamuna) and Meghna rivers and their tributaries (Fig. 12.1). The Ganges unites with the Jamuna and later joins the Meghna, finally flowing into the Bay of Bengal. Bangladesh has 57 trans-boundary rivers. The existing large rivers running north to south are the remnants of the old courses of the Ganga. During the sixteenth to eighteenth century, the Bengal basin was affected by a neo-tectonic movement by way of which an easterly tilt came along a hinge zone, i.e. from Sagar to north of the district of Malda, West Bengal, and then gradually curving towards Dhaka, Bangladesh. As a result of the trend of surface elevation contours ENE-WSW, the present course of Ganges, which used to flow along the course of Tamralipta till twelfth century A.D., started flowing along the river Padma within Bangladesh leaving Hooghly as a mere tidal channel. Even till the early eighties, the

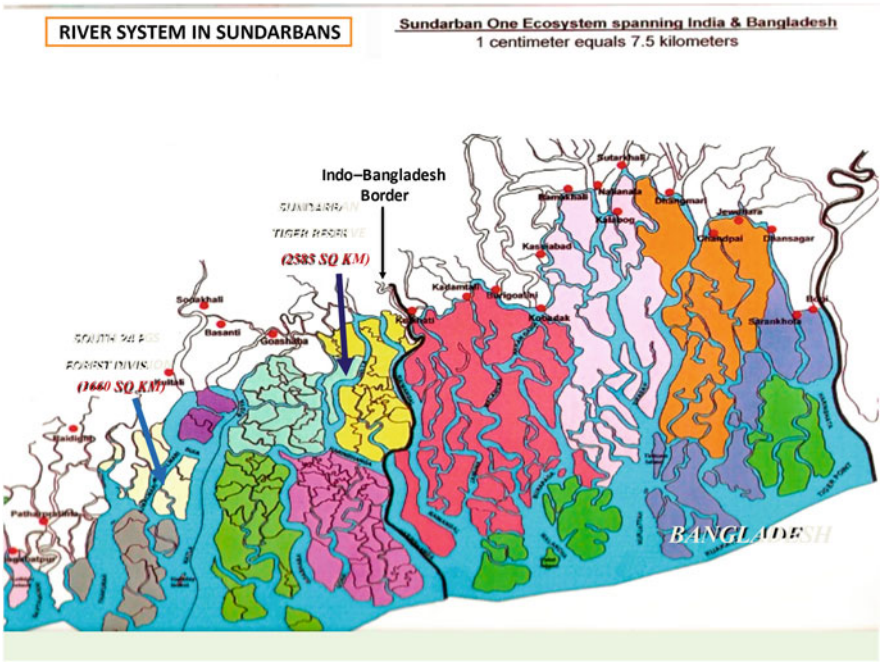

Fig. 12.1 River system in Sundarbans (both India and Bangladesh)

tidal effect of Hooghly could be felt up to 281 km upstream up to Nabadwip in the district of Nadia, West Bengal. During this period, the Matla and Bidyadhari river system formed an innumerable network of creeks between Ganges and Padma; however, these river systems got completely cut off from sweet-water source and are presently fed by the backwaters of sea.

During the rains, the Raimangal receives an overflow of the Ganga through the Ichhamati, which connects them. The rivers Matla, Saptamukhi and Thakuran lying on the Western side have practically no connection with their original parent stream and are now creeks of the sea. These are highly brackish all the year round in comparison with the Hooghly and the Raimangal. The Hooghly is fed mainly by the Rupnarayan and is also connected with the Ganga through the Jalangi and the Bhagirathi. However, the estuary of the Hooghly remains brackish even during the rains on account of its great width. With the coming up of Farakka Barrage, sweet-water flow in Hooghly has increased and is now brackish below Diamond Harbour. The sources of all the rivers in the western Sundarbans are being progressively silted up leaving hardly any passage for freshwater, with the result that the rivers are getting more brackish and shallow year after year.

12.2.2.2 Climate

The climate is tropical, moist, warm and equable. The humidity is uniformly high and temperature is equable due to its proximity to the sea. It receives good amounts of rainfall and is humid for most parts of the year. The temperature varies little throughout the year, mean annual temperature is close to 27 °C, maximum is 32 °C and minimum is 22 °C. The mean annual rainfall of the Sundarbans is 1920 mm. The west coast and Andaman get a high rainfall of over 3000 mm. The atmospheric humidity is 73% to 80% and is more or less uniform throughout the year. During the months of January and February, dense ground mists occur in the early morning. The summer extends from the middle of March to the middle of June and the winter extends from December to February. The climate is more equable in the areas covered by forest than in the neighbouring cleared areas. The monsoon starts usually between the middle of June and lasts up to the middle of September. Overall, the rough weather lasts from 15th March to 15th September and the fair weather prevails between middle of September to middle of March.

The prevailing wind is from north to north-east from the beginning of October to middle of March. January to February is calm. The wind commences to blow violently from south-west from middle of March to end of September. Storms are common; some of these often develop into cyclones of varying intensity accompanied by tidal waves and cause much damage to forests. The vast block of forest acts as a barrier and reduces the severity of the gales. Apart from damage to standing trees, there is intensification of flow tides and retardation of ebb tides caused by such winds. Every year, 4–5 cyclonic storms are common. These are of common occurrence in the lower Ganga delta during mid-March to mid-June and occasionally during October to November. During cyclones and storms, the sea or the river water rises up much more than what it normally rises. The accompanying winds impart it with much force with which the waves dash against the surrounding areas. The funnel shape of the Bay of Bengal in the lower part of the Gangetic delta, poses the most serious threat, from the surges, driven by storm waves (Fosberg and Chapman 1971).

12.2.2.3 Tidal Amplitude

In the Sundarbans, high-tides and ebb-tides occur twice daily and the current changes its direction every 6 h. The spring tides, which occur at the vernal equinox (March–April), produce the maximum rise and fall, as there is very little current in the rivers during this time. The tidal current passes from west to east, so the change of tide is earlier in the west than in the east. The velocity of the tidal current increases in the northern part of the tract where the rivers are narrow and the maximum rise and fall occur where the speed is the highest. Near the sea coast, the average rise and fall is about 2.15 m. While a south wind prolongs the period of the flow, a north wind

shortens the same. The maximum and minimum tides recorded at Sagar Island (west part of Sundarbans) are 5.68 m and 0.96 m, respectively.

However, as a rule, the flood tide in the estuarine system lasts more than the ebb-tides. The resulting effect, unless there is excess river energy from upstream flush, the decantation of traction load sediments takes place. Thus, these backwater channels are getting silted up day by day. With the change in seasons, tidal interactions in the estuarine system in and around the Indian Sundarbans also change (Pillay 1954). During the monsoon months, the effect of flood tide is more or less countered and nullified by freshets and there is a strong predominance of ebb-tide. The strength of flood tide over ebb-tide is at a minimum during the post-monsoon season. Conversely, during the pre-monsoon season, the effect of flood tide is considerably stronger than that of the ebb-tide.

12.2.2.4 Water Supply

Cultivation in Sundarbans is solely dependent on rainwater. The fishermen, honey collectors and woodcutters carry large earthen pots for carrying their ration of sweet waters whenever they go to the field. There is acute scarcity of sweet water in the islands. A deep tube-well (nearly 300 m deep) has been sunk at Bidya station and is the primary source of water for all touring launches and few camps where there is no source of drinking water. To date, deep tube-well boring has been unsuccessful in most of the islands. Most of these field camps have freshwater ponds and recently, rainwater harvesting has been carried out, where rain water is collected and stored in large aboveground and underground tanks. This has given encouraging results and shall be replicated in other camps as well. Tanks are generally dug down to the layer of impervious sodic clay. Rainwater stored therein is subsequently bailed out. By such repeated washing with rain water in about 3 years, a tank becomes sweet.

12.3 Floral Biodiversity

The mangrove forest of Sundarbans is a very dynamic ecosystem. It is in a continuous state of erosion and accretion leading to subsidence or erosion of existing banks and appearance of new lands and mud flats. Flora is very rich in the Sundarban forests in comparison to other mangrove areas in the world. There are 61 species of true mangrove and 69 species of mangrove associates (Fig. 12.2).

12.3.1 Vegetation Type

Mangroves and mangrove associates constitute the dominant vegetation type of the area. Champion and Seth (1968) made one of the most comprehensive assessments

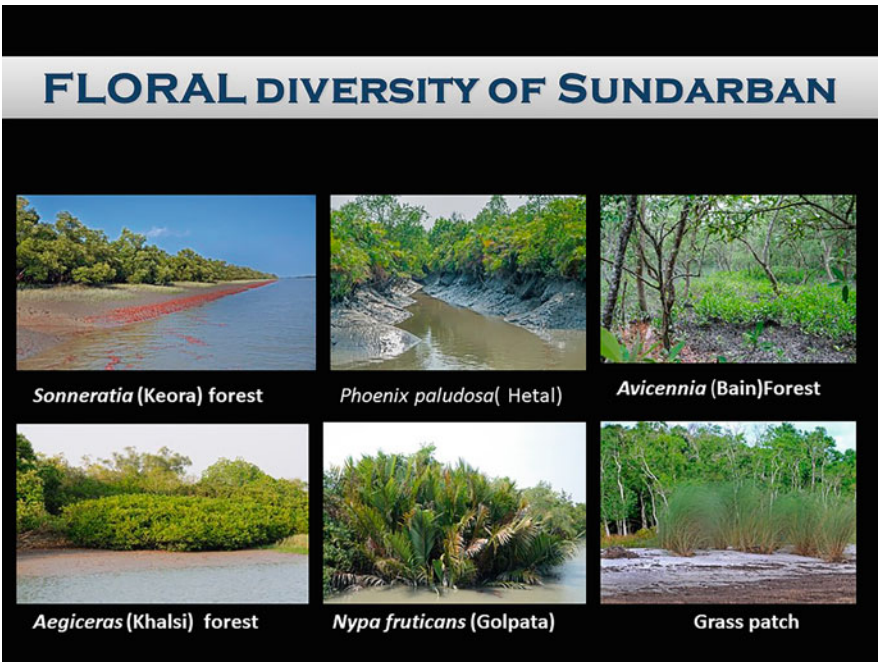

Fig. 12.2 Glimpses of floral diversity in Sundarbans

of the vegetation communities of the Indian Sundarbans. They divided the forest into categories based on broad characteristics of physiognomy and structure. These communities were defined irrespective of physiographic, edaphic or biotic factors. They were of the opinion that some communities were clearly associated with a definite site factor, which differed appreciably from the surrounding areas. According to Champion and Seth's (1968), Tidal Swamp forests are classified under sub-group 4B with following sub-divisions.

12.3.1.1 Mangrove Scrub: Sub-Type 4B/TS_1

It is known as low mangrove forest or salt-water forest occurs on soft tidal mud submerged by salt water by every tide. It is a dense forest of low average height of 3–6 m. In the upper canopy, the promising species are *Ceriops decandra, Avicennia alba, Aegialitis rotundifolia, Excoecaria agalllocha, Phoenix paludosa* (drier ground). *Acanthus ilicifolius* often forms the undergrowth. Local patches of grass may also be seen. Few species are markedly gregarious, all evergreen with leathery leaves. Vivipary is seen, common in Western Sundarban.

12.3.1.2 Mangrove Forest: Sub-Type 4B/TS_2

It is known as tree mangrove forest. It is typically an evergreen forest of moderate height composed of trees specially adapted to survive on tidal mud which is permanently submerged with salt water and is submerged by every tide. It is found on mud banks of delta streams and near sea-face where accretion is in progress. Stilt roots are very typical in *Rhizophora,* leaves are leathery and vivipary is seen. The upper and lower storeys are composed of *Rhizophora mucronata, Kandelia candel, Avicennia alba, Excoecaria agallocha, Ceriops decandra, C. tagal, Bruguiera gymnorhiza, Xylocarpus granatum, Sonneratia apetala* in West Sundarbans. In Krishna, Godavari and Mahanadi deltas, *Avicennia officinalis* is the principal species, the associates consist of *Rhizophora mucronata, Ceriops decandra, Sonneratia apetala, Bruguiera gymnorhiza* and *Acanthus ilicifolius*.

12.3.1.3 Salt-Water Mixed Forest (*Heritiera*): Sub-Type 4B/TS_3

It is known as moderately salt-water forest, occurs behind and above the previous two types. This type of forest occurs where ground is flooded by every type with definitely brackish water. The forest is fairly dense with trees up to 20 m height and the trees never attain large girth. Pneumatophores are typical. There is less silt deposition and the soil has less humus. The upper and lower storeys are composed of *Heritiera fomes*, *Excoecaria agallocha*, *Ceriops decandra*, *Xylocarpus mekongenesis*, *Avicennia officinalis*, *Aegialitis rotundifolia* (near sea-face). A light ground cover of *Nipa fruticans* is sometimes found.

12.3.1.4 Brackish-Water Mixed Forest (*Heritiera*): Sub-Type 4B/TS_4

It is known as freshwater forest occurs primarily in the deltaic region of the Ganges. This type represents the finest and the most valuable form of the tidal forest and it is poorly represented in the western part of Sundarbans. The major portion of this type represents in the eastern part, i.e. in Bangladesh. Height of the trees may reach up to 33 m. The ground is flooded for some portion of each day by water which is either quite fresh or slightly brackish. There is good deposit of silt every year. The upper canopy is composed of *Heritiera fomes*, *Sonneratia apetala*, *Xylocarpus mekongenesis*, *Bruguiera* sp., *Sonneratia caseolaris*, *Excoecaria agallocha*, *Ceriops decandra*, *Phoenix paludosa* (high land), *Acanthus ilicifolius*, *Nypa fruticans* (fringing banks).

12.3.1.5 Palm Swamp Type: Sub-Type 4B/E_1

It is mainly represented by *Phoenix paludosa.* It is seen on drier areas within salt-water mangrove scrub or mangrove forest. Forest area is partly flooded for some part of the day.

12.3.2 Vegetation Succession

Naskar and Guha Bakshi (1987) worked extensively on the succession of mangrove flora. They identified five ecological successions of the Sundarbans swamp based mainly on tidal magnitude, viz.

- Phase I: Swampy Mangrove or Intertidal Mangrove Zones.
- Phase II: Tidal Mangrove.
- Phase III: True Mangrove Decline.
- Phase IV: Colonisation of non-littoral species.
- Phase V: Xerophytic non-mangrove and dry evergreen forest.

The mangrove forest is a very dynamic ecosystem. It is in continuous state of erosion and accretion leading to subsidence or erosion of existing banks and appearance of new lands and mud flats. Mangrove succession starts with the appearance of the pioneer species locally known as dhani ghas (*Porteresia coarctata*) (Fig. 12.3) on the newly arisen mud flats. With the passage of time, this grass species traps the propagules of *Avicennia* and *Sonneratia* sp., which come up well in freshly silted and firm mudflats. Once the land gets consolidated, *Ceriops* sp. and *Excoecaria agallocha* come and colonise the area. *Phoenix paludosa*

Fig. 12.3 Mangrove succession starts with *Porteresia coarctata* followed by *Avicennia* sp.

considered as the climax species which comes upon high lands and forms gregarious growth.

In general, the northern boundary and new depositions are characterised by Bain (*Avicennia marina, A. alba, A. officinalis*) flanked by foreshore grassland of *Porteresia coarctata.* Bain is gradually replaced by Gnewa (*Excoecaria agallocha*) and then Goran (*Ceriops decandra*). About 70% of the area is covered with Gnewa-Goran association. There are, however, southern and eastern associations of Garjan (*Rhizophora apiculata*, *R. mucronata*), Kankra (*Bruguiera sexangula*, *B. gymnorhiza*, *B. cylindrica* and *B. parviflora*) and patches of Sundari (*Heritiera fomes*)–Gnewa–Goran. Pure Hental (*Phoenix paludosa*) forests exist on relatively high lands. These Hental forests are considered as the climax vegetation. *Xylocarpus granatum* and *X. mekongensis* are distributed throughout the forests. *Nypa fruticans* palm swamp is common on central, eastern and southern portions, alongside creeks and rivers having soft mud deposition. The sea-facing areas have *Excoecaria* sp., *Lumnitzera racemosa*, *Saccharum*, *Derris indica*, *Thespesia populnea*, *Ipomea pes-caprae*, etc.

Heritiera fomes, which was once found throughout the area, has over the years become confined to the eastern and southern sector. This shift in distribution has been attributed to the gradual reduction of sweet water into the system as the river sources have been cut off from their origin owing to siltation and are purely arms of the sea, thereby leading to an overall increase in the salinity regime.

12.3.3 Mangrove Species Preferred by Wildlife

The species most favoured by the herbivores is Keora (*Sonneretia* spp.) whose fruits and leaves are preferred by Spotted Deer (*Axis axis*) and *Rhesus macaque*. Pangas fish (*Pangasius pangasius*) has been found to eat Keora (*Sonneretia* spp.) fruits. Apart from this, fresh shoots of Hental (*Phoenix paludosa*) are browsed by Spotted Deer (*Axis axis*) and *Phoenix* fruits are preferred by birds and macaques. *Avicennia* and *Excoecaria* are also browsed quite often by the herbivores. Succulent tips of dhani grass (*Porteresia coarctata*) growing on newly colonised mud flats have also been seen to attract Spotted Deer (*Axis axis*) herds. The flowers of *Bruguera gymnorhiza,* when shed and float in water are a good source of food for river Terrapin (*Batagur baska).*

12.4 Faunal Biodiversity

12.4.1 Historical Perspective

A detailed account of the wildlife, which was once present in the area, is given in the Hunter's Statistical Account of Sundarbans (Hunter 1878). Some excerpts of which are reproduced below:

'Tigers, leopards, rhinoceros, wild buffaloes, wild hogs, wild cats, barasinga or large deer, spotted deer, hog deer, barking deer, porcupines, otters and monkeys are the principal varieties of wild animals found in the Sundarbans. Tigers are very numerous, and their ravages form one of the obstacles to the extension of cultivation.

The serpents found in the Sundarbans are the boa constrictor, cobra-di-capello or gokhura, kuriat, sankhachur or salt-water snake, gosap and green viper.

The birds of Sundarbans comprise the following: Adjutants of two kinds, viz. *Ardea gigantia* and the Marabout adjutant–vultures, kites, hawks, owls, mynas, doves, green pigeons, parrots, parroquets, jungle-fowl, woodpeckers, sandpipers, egrets, waders, large and small spoonbills, pelicans, storks, paddy birds of several kinds, herons, snipe, crows, several varieties of kingfishers, divers, hornbills, jays, orioles, teal, seagulls, curlew, Indian pheasants, waterfowl, reedbirds, plovers, partridges and a great variety of wild geese and ducks.

The fishes abound in nearly all the rivers. Porpoises and crocodiles (commonly called alligators) abound but the latter are less numerous than they were 20 years ago.

The Sharks also are by no means uncommon in the larger streams and estuaries. No trade is carried on in wild beast skins, with the exception of the skins and horns of the spotted deer, which are sold for a trifle and to a very small extent'.

However, over a period of time we have lost a number of animals due to ecological changes, habitat degradation and related anthropogenic activities. Some of the animals, which were once present but have been lost, include Javan Rhinoceros, Wild Buffalo, Swamp Deer, Barking Deer and Hog Deer.

A total of 1434 faunal species have been reported so far from Sundarbans (Nandi et al. 1993) from terrestrial, intertidal and aquatic environments. These animals comprise 989 species of invertebrates, one species of hemichordate and 445 species of vertebrates. It is also reported that 486 species from supralittoral zone, 499 species from tidal flats and 449 species from estuarine waters. Phylum-wise major contributors are

1. 476 species of Arthropoda of which 240 species are Crustacea, 201 species of Insecta and 33 species of Arachnida.
2. 445 species of Chordata of which 154 species are Osteichthyes, 22 species of Chondrichthyes, eight species of Amphibia, 58 species of Reptilia, 163 species of Aves (110 resident and 53 migratory) and 40 species of Mammalia (five species of Dolphin and Porpoises are aquatic and rests are terrestrial).
3. 142 species belong to Phylum Mollusca.

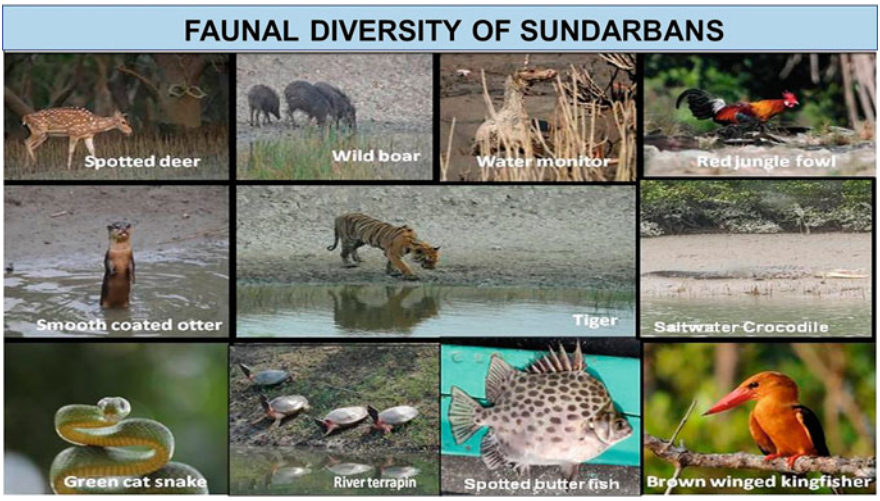

Fig. 12.4 Glimpses of fauna diversity in Sundarbans

The terrestrial mangrove ecosystem in Sundarbans is the domain of the Royal Bengal Tiger, *Panthera tigris tigris,* which is at the apex of the food chain. It is the only mangrove-tiger kingdom in the world and presently harbours 95 tigers in Indian Territory and 105 tigers in Bangladesh. The estuarine crocodile (*Crocodylus porosus*) is the top-most predator in the aquatic ecosystem. Apart from the estuarine crocodile, the water monitor lizard (*Varanus salvator*) which reaching up to 2.4 m in length can be frequently found within the reserve. About 11 species of crabs found within the creek waters. The Gangetic shark (*Glyphus gangeticus*) is also found in Sundarbans. Current observations of fauna in the Sundarbans (Fig. 12.4).

12.4.2 The Current Status

Mangrove fauna is found to occur in both the terrestrial and the aquatic ecosystems. These areas can be differentiated as:

The littoral or supra-littoral (i.e. areas beyond the high tide) forest biome is typically a terrestrial environment, which includes both aerial and arboreal forms and the soil inhabitants. The inter-tidal (region between high- and low-tide) mudflats are essentially semi-terrestrial or semi-aquatic habitat supporting mainly the soil forms and the benthos. While the other faunal components in the mudflat and estuary can broadly be divided into zoo-plankton, nekton and benthos. Several species of crustaceans and larvae of fishes form the main component of the zoo-plankton in this region. The pattern of distribution of animals in mangrove ecosystem is influenced by the substratum, salinity, tidal amplitude, vegetation, light and temperature.

12.4.2.1 The Arboreal Community

Animals under this community include both aerial and arboreal forms. The upper canopy of mangrove trees is the home of birds, bats, monkeys and insects. For example, the Pigmy pipistrella, *Pipistrellus mimes* can be found flying on the onset of evening inside the Tiger Reserve areas. The Rhesus macaque (*Macaca mulatta*), the only species of primate occurring in the Sundarban is well-distributed in the entire forest. They are often found feeding on Keora trees (*Sonneratia apetala*) but are also well adapted to crab eating. It is interesting to note that herds of deer follow the troops or Rhesus Monkey from one Keora tree to another in search of leaves that the monkeys drop from the trees tops in course of their feeding; the deer also get advance information about the movement of the tiger from the monkey's call.

Many species of birds build their nests in the mangrove trees. Herons, Egrets, Cormorants and Darters enjoy roosting in colonies on the tall trees of Bain, Sundari and Genwa. The *Sonneratia* tree is especially preferred by parakeets and woodpeckers, several species of birds use trunk, branches and aerial roots of mangrove as observation posts for feeding.

Honey bee, i.e. *Apis dorsata* is responsible for pollination in about 80% of the mangrove species, thereby plays a very important ecological role in the mangrove forests. These bees are known to build their honeycomb inside the forest in large numbers. Yearly more than 20 tonnes of honey is produced by the bees in the entire Sundarbans area. About 39% of honey is produced from *Excoecaria agallocha* (Genwa), 16% from *Avicennia* species (Bain), 11% from *Ceriops* species (Goran), 10% from *Rhizophora* species (Garjan) and only 24% from the rest of the plants. *Phoenix-Excoearia* (Hental-Genwa) association is thought to be the ideal sites for honey comb formation.

12.4.2.2 Terrestrial and Aquatic Community

12.4.2.2.1 Mammals

The terrestrial mangrove ecosystem in Sundarbans is the domain of the Royal Bengal Tiger, *Panthera tigris tigris,* (Fig. 12.5) which is at the apex of the food chain. It is the only mangrove-tiger kingdom in the world and presently harbours 95 tigers in Indian Territory and 105 tigers in Bangladesh. The tiger leads an almost amphibious life and is an excellent swimmer. It has been seen to cross rivers as wide as 2 km at a stretch. It has adapted itself nicely to this difficult terrain which is characterised by sharp pneumatophores, muddy substratum, innumerable rivers and creeks with tidal rhythm, variable salinity and lack of freshwater source. The principal prey species of the tiger are spotted deer, wild boar and *Rhesus macaque* that also swim across the streams and water channels. In addition, it also feeds on fish, crab and water monitor. In one instance, a post-mortem of a dead animal revealed the presence of a Monocellate cobra and a King cobra from the stomach

Fig. 12.5 Royal Bengal Tiger (*Panthera tigris tigris*) of Sundarbans

of the animal. This is only one of the very few recorded instances of tigers eating King cobras. The man-eating traits of Sundarban tigers have become almost a legend in Bengal and elsewhere. It is considered that man-eating propensity of tiger in this area is an acquired trait over a period of generations given the harsh surrounding conditions. It has been noticed that in the last 10 years apart from one case where the tiger had accidently killed a girl, all the deaths have occurred inside the forest. This peculiarity in the tiger behaviour has been explained by various experts that within the forest area, i.e. their habitat, they consider all moving objects as their prey. It is generally believed that the tigers in this mangrove forest do not have territories due to the obliteration of urination marks by the tidal waters. However, this is yet to be borne out by scientific facts. Recent data from radio-collared tigers reveal that the animals are using specific areas possibly indicating territoriality.

Though the tigers may breed at any time of the year but in Sundarban it has been observed that the mating season starts in winter and continue up to March to April. During this period, males often fight with each other but there has never been any report of fatal fights in the Sundarbans. General gestation period of tiger is 95 to 110 days. In Sundarban, the litter size of 1 to 2 is very common and rarely three or more cubs have been sighted. Usually, cubs stay with their mother up to 2–3 years but in Sundarban it is seen that they are separated by the time they are two-years old approximately. Generally, inter-cub interval of tigress is approximately 3 years but not much observation has been made regarding Sundarban tigers due to difficult terrain and their man-eating propensity. Occasionally, up to five tigers have been

sighted together in Sundarbans. This could be a case of the sub-adults with the male and female.

Based on the preliminary results of the radio telemetry studies in Bangladesh, Sundarban (Barlow et al. 2008) documented home range sizes for two adult females of between 12 and 15 sq. km. They also studied on the skulls of Bangladesh Sundarbans tigers and found that it is significantly different craniometrically from all other currently defined subspecies, both in terms of size and shape. This distinction was most notable for male tigers, which tend to have more variable morphology than females. These findings add to previous work on tiger craniometrics that found substantial differences between the mainland and Sundarban Island.

Apart from the tiger, the secondary predators are mainly the fishing cats (*Felis viverrina*) and to small extent the jungle cat. They feed on small birds, snakes, fish, etc. Among other ground dwelling fauna are Spotted Deer (*Axis axis*) and wild boar (*Sus scrofa*). The wild boars feed on underground tubers but also relish dead fishes, prawns, crabs, molluscs and sea turtle eggs. The Spotted Deer preferably browse on leaves, twigs and fruits of Keora (*Sonneratia apetala*), 'Bain' (*Avicennia officinalis*) and Genwa (*Excoecaria agallocha*).

The cetaceans like Gangetic Dolphin (*Platinista gangetica*) and the Irrawady Dolphin (*Orcellabre virostris*) are frequently found in the eastern side particularly in rivers like the Raimongal, Goasaba, Matla and the sea-facing areas. The Black Finless Porpoise (*Necmeris phoceanoides*) is also found in rivers near the estuary.

12.4.2.2.2 Reptiles

The estuarine crocodile (*Crocodylus porosus*) (Fig. 12.6) is the top-most predator in the aquatic ecosystem. Apart from the estuarine crocodile, the water monitor lizard (*Varanus salvator*) which reaching up to 2.4 m in length can be frequently found within the reserve. The sea-facing beach of the reserve forms a nesting ground for

Fig. 12.6 Estuarine crocodile (*Crocodylus porosus*) in Sundarbans

olive ridley sea turtle (*Lepidochelys olivacea*), which come to lay eggs on the sandy beaches of the Tiger Reserve. The egg laying is sporadic and takes place mainly during December to March. The water monitors are the greatest predators of their eggs and hatchlings along with wild boars, terns and sea gulls. The endangered River Terrapin (*Batagur baska*) also uses the beaches as their nesting ground. The Mechua beach in Bagmara block is an important nesting ground. Dr. A.K. Mukherjee of Zoological Survey of India (ZSI) has recorded other coastal soft-shell turtle (*Pelochels bibroni)*, Bengal eyed terrapin (*Morenia ocellata*) and three keeled terrapin (*Geomydatrica rinata*) from the area. Occasional reports of presence of green sea turtle (*Chelonia mydas*) and Hawksbill turtle (*Eritmochelys imbricata*) have also been received.

Since the 1980s, ex-situ conservation program was started and eggs of the turtles were collected from turtle pits and incubated at Sajnekhali. The hatchlings were subsequently released in the sea. This practice has been subsequently discontinued and now in-situ conservation of the turtle is carried out on the beaches. The egg pits are surrounded by wire meshes to prevent the eggs from being destroyed by the wild boars and water monitor lizards. After hatching, the wire mesh is removed and the hatchlings move out into the sea. Similarly, an ex-situ conservation program for the estuarine crocodiles is going on at Bhagbatpur. The crocodiles reared here are released into the tidal waters. This is an ongoing program.

Around 53 species of snakes are found in the area. Prominent among the poisonous are the king cobra, monocellate cobra, banded krait, Russell's viper, common krait. The python, chequered keelback, dhaman, green whip snake, ornamental snake and several other species constitute the non-venomous snakes. The tidal creeks also harbour Homalopsid snakes adapted to living in water, the most common being the *Cerberus rhynchops* or dog-faced water snake. Snake bite cases are very common in the fringe villages between July and October, especially due to cobra and krait.

12.4.2.2.3 Avifauna

There are over 200 species of birds, which have been recorded from the area. These include a large number of migrants from the higher latitudes that visit the area in winter. Heronries are developed during monsoons in Arbesi and Jhilla blocks. Common birds found in the area include herons, egrets, darters, spoonbills, cormorants, storks, etc., which come out and nest in the area. Earlier there was a heronry around Sajnekhali covering 1.5 sq. km area, which used to develop from June to end of September. However, this nesting ground suffered intense damage during the cyclone of 1988 and is no more active.

The bird species, which are most abundant in the Sundarbans Tiger Reserve, include the Purple Heron (Fig. 12.7), Adjutant Stork, Common Sandpiper, Indian Ringed Dove, Whimbrel, Tailorbird, Black-capped Kingfisher, Jungle Myna, Rose-ringed Parakeet, Large Egret, Bronzed Drongo, White-collared Kingfisher, Magpie Robin, Pond Heron, Common Iora and Red-vented bulbul. The mangrove is also

Fig. 12.7 Huge Purple Heron in Sundarban (photographed in April, 2020)

known as the kingfisher's paradise with 8 out of 12 species of kingfishers found throughout the country found here. Other birds found in the area are median egret, brahminy kite, white-bellied sea eagle, lesser adjutant stork, osprey, Goliath heron, whiskered tern, brown-winged gull, common sandpaper, jungle myna and rose-ringed parakeet.

12.4.2.3 Aquatic Community

The aquatic habitat has not yet been studied in full. However, some works have been done by Zoological Survey of India. The most interesting is the formation of Phytoplankton in the shallow clear water of the tidal creeks receiving enough sunlight for a luxuriant growth. The phytoplanktons are the sources of augmentation of oxygen content in the water. This influx, however, is checked by the zoo-plankton particularly by the shrimp population, which invades mangrove estuary during the semi-larval stage to adult stage. The zoo-plankton consumes the phytoplankton and diminishes the oxygen content and the whole equilibrium is also controlled by the seasonal salinity of the creeks. The total catch fish diminishes to a minimum during the highest salinity as has been recorded by Chaudhuri and Choudhury 1994. The micro-organisms, like *Noctuluca*, dinoflagellates produce bioluminescence during winter night particularly near the sea-face and entire atmosphere turns into a fairy land.

12.4.2.3.1 Fishes and Crabs

A wide and varied assortment of fishes, molluscs, crabs and prawns inhabits the estuaries. The mangrove leaves, which decompose slowly, offer food and shelter for the larval shrimps and they migrate from the sea to the mangrove estuary for attaining maturity. Even the snappers or mullets depend very much on the mangroves. Mullets like Bhetki and Bhangor constitute the main form, the edible fishes in the area. The studies of fish made by Chakraborty (1984) also reveal that *Pangasius pangasius* fiddler, i.e. Pangas fish is the primary heterotrophy, which often swallows full keora fruit. The amphibious crab mud skipper fish such as *Periophthalmus* and *Boleophthalmus* arouse considerable interest. The former creeps up the trees with the rising water level. Among the crustaceans, the one-armed (*Uca* species) often shows off to his mate with the colourful arm. They have diurnal clock inside which regulates their colour change along with tides. Another interesting crab is the *Clibanarius padavensis* (deman), i.e. Hermit crabs occupying gastropod shells of genus *Telescopium, Nerita, Cerithidea* or *Semifusus.* The edible crab *Scylla serrata,* is important as well as the ghost crab and patalchingri (*Thalassina anomala*). Marine borer like *Teredo* often causes concern to the watercrafts.

There are two species of trilobite, viz. *Tachypleus gigas* and *Carcinoscorpius rotundicauda* commonly known as Horse shoe crab or king crab. King crabs are now protected owing to its ability or high sensitivity to bacterial endotoxins. The cell lysates obtained from the blue blood of the species are widely used for estimation of bacterial endotoxin. They have hardly changed in 400 million years are also called living fossils. They visit Sundarbans during pre-monsoon season (March to June) when the salinity reaches its peak. During this season, they are found mating in mangrove creeks and mudflats. They are often killed by people owing to the belief that they can cure arthritis.

The fish fauna of the estuarine waters in and around the Sundarbans have been classified into residents and transients (migrants). The residents include *Mugil parsia*, *M. tade*, *Polynemus paradiseus*, *Polydactylus indicus*, *Otolithoides biauritus*, *Lates calcarifer*, *Hilsa toil*, *Arius jella*, *Harpodon nehereus*, *Ilisha elongata*, *Pama pama*, *Sillaginopsis panijus*, etc. The transient or migratory fish which enter the estuary for a short time mainly to spawn include *Tenualosa ilisha, Pangasius pangasius*, *Polydactylus indicus,* etc.

12.4.2.3.2 Sharks and Rays

The sharks and rays found in Sundarban include the Ganges shark (*Glyphus gangeticus*), Small-toothed saw fish (*Pristis microdon*), Pointed saw fish (*Anoxypristis cuspidata*) and white-spotted shovel-nosed guitar fish (*Rhynchobatus djiddensis*) all of which are Schedule-I species in the Wildlife (Protection) Act, 1972. In addition to these, the following are also found— *Rhinobatus granulatus, Himantura alcockii, Rhinoptera javanica, Sphryna zygaena,* etc.

12.5 Phytoplankton, Zooplankton and Microbial Diversity

12.5.1 Phytoplankton

Phytoplankton diversity is huge in mangrove areas. Diatoms form the predominant group in the mangrove habitat. The common diatoms identified are *Navicula* sp., *Pleurosigma* sp., *Gyrosigma* sp., *Cymbella* sp., *Cyclotella* sp., *Fragillaria* sp. and *Amphipleura* sp. The Cyanophyceae or Myxophyceae floras are *Oscillatoria* sp., *Lyngbya* sp., *Spirulina* sp., *Anabaena* sp., *Microcoleus* sp., *Nodularia* sp. and the Chlorophycean planktons are *Protococcus* sp., *Pediastrum* sp., *Hydrodictyon* sp. and *Ankistrodesmus* sp., while the common desmid is *Cosmarium* sp. The common benthic algal floras from this brackish water area of Sundarbans are *Oscillatoria* sp., *Gleocappa* sp., *Symploca* sp., *Protococcus* sp., *Enteromorpha* sp., *Polysiphonia* sp. and *Gyrosigma* sp. (Guha Bakshi et al. 1999).

The pneumatophores, knee roots, stilt roots, areal roots and the lower trunk regions of *Avicennia* sp., *Xylocarpus* sp., *Sonneratia* sp. and the members of Rhizophoraceae hold the dense cover of *Bostrychelium* like *Bostrychium* sp., *Caloglossa* sp. and *Catenella* sp. These periphytons have also much value as fish food in these mangrove swamps. Molluscs, crabs and other crustaceans are also dependent on these algal species in mangrove habitat as their natural food.

12.5.2 Zooplankton

Sundarbans mangrove ecosystem harbour heterogenous assemblage of innumerable invertebrates which are collectively called zooplankton. Zooplankton comprises diverse taxonomic groups mainly consisting of copepods, amphipods, ostracods, chaetognaths, mysids and hydromedusae. Pillay (1954), Chakraborty (1984) and others have pointed out that in Sundarban estuarine water, copepods are dominant representing usually more than 60% of the total zooplankton population. The important copepod species are *Diatomus* sp., *Pseudodiatomus* sp., *Acartia* sp., *Cyclops* sp. and *Cyclopsis* sp. Zoea and megalopa larvae, mysids are reported by Pillay (1954). Benthic animals produce millions of planktonic larvae which constitute staple food of mangrove associated fishes. Ciliates, Flagellates, Helminthes and Rotifers are found in this brackish water during the monsoon months which have much value for these euryhaline fish and prawn species. This way a definite ecological cycle having dependence between autotrophs and heterotrophs exists.

The heterogeneous communities of Zooplanktons play a significant role in trophic structure and energy transfer. Taxonomically, diverse benthic animals which mostly occupy littoral and sub-littoral zones of this ecosystem are also ecologically and economically very significant. Some of these benthic communities belonging to Mollusca and Crustacea comprise shellfishes which are having direct

economic importance. Benthic animals produce millions of planktonic larvae to support fish population (Chaudhuri and Choudhury 1994).

12.5.3 Microbial Activity

Cyanophyceae group of algae normally grow and flourish well on the ill-consolidated saline- sedimented humus soil in the mangrove areas which are hydrophilic and biologically very active and able to bind the soil particles together in consolidated form. These blue-green-algae (BGA) accelerate the growth and wide coverage of Chlorophyceae. Chlorophyceae group of algae prefer mostly consolidated soils, rich in nitrate and phosphate. By the oxidation process of these Cyanophyceae algae, inorganic phosphate and ammonical radicals are released which later on converted to nitrates. On the other hand, the excreta and exuviae of the mangal biota enrich the silty clay soils on its upper layer with the gradual decomposition and deposition of inorganic nitrate, phosphate and other substances. All these nitrate molecules accelerate the active growth of the autotrophs. These surface soil layers within the depth of 5.0 cm are well oxygenated. The mangrove soils are also sticky and black coloured for the reduced state of ferric compounds to ferrous sulphides. This reduction process is initiated by the abundant hydrogen sulphides.

Numerous pores and burrows are formed on these consolidated tidal river flat soils and forest floors due to the activity of certain crustaceans, molluscs, nematodes and some fishes like *Boleopthalamus* spp., *Periopthalamus* spp., etc. Several biotic and abiotic factors of these tidal mangrove soil phases assist the microbial activities. In these highly saline river basin soils, the molluscan and crustacean shells and other organic detritus fertilise the soil for the effective growth of the mangrove herbs, shrubs and trees (Naskar and Guha Bakshi 1987). Higher percent of calcium ion (Ca^{2+}) in these tidal mangrove soils reduces the adverse effect of sodium ion (Na^{+}) taken in by the mangrove flora. *Porteresia coarctata* thrives well both in the less-consolidated and in consolidated sedimented soils on the river flats. This halophytic grass can stand higher soil and water salinity and send its pseudo-tap roots to the deeper soil layers and afterwards its wide spreading fibrous roots anchor firmly on these loosely sedimented soils. Schuster (1952) stated that bacteria, blue-green-algae, green algae and diatoms act as nitrogen-fixing and sulphur-reducing agents in these alluvial tidal mangrove soils.

12.6 Mangrove Dependence and Livelihoods

12.6.1 Socio-Economic Profile of the Villages

The fringe villages have a high percentage of socially disadvantaged groups like Scheduled Castes 32% and Scheduled Tribes 12%. The level of literacy as well as per capita income is much lower in Sundarbans than in other parts of West Bengal. The tribal population here is the descendent of the group of tribes of Chottanagpur, who were brought here for clearing the areas for human settlement during the nineteenth century. In the absence of any major industry in the area, the vocation can be divided as cultivators 26.5%, agricultural labour 47%, household worker 1.5% and others 25% which include fishermen, crab collectors, honey collectors, etc. The majority of the farmers fall under the category of small and marginal farmers.

The village-rich mainly invests in agricultural land and commercial fishing, by engaging the poor fishermen to earn high profits. Moneylenders also abound in the villages. They give advances to fishermen and honey collectors in return of which they take all the fish catch and honey collected from the fishermen/honey collectors for a pittance. Most of the villagers also have cattle population, which are reared not for milk supply but to fulfil their protein requirements. Most of the cattle are stall fed or are left out in the local fields and the Tiger Reserve does not have grazing problems due to village cattle as is seen in other parts of the country. Prawn fishery has become a very popular trade by regulating the tidal water flow inside low-lying fields and farm land outside the reserve.

The infrastructure in the villages is poorly developed with hardly any metalled roads. The kutcha roads become very slippery during the rains making it very difficult to walk there. There is no electricity in the area. The wood gassifier plant at Gosaba having capacity of 500 kW was established in 1996–1997 by the West Bengal Renewable Energy Development Authority (WBREDA) and supplies electricity to some parts of the Gosaba Island. Though, the demand for the raw material is met from the wood growing in the local areas, still it faces a perpetual shortfall in supply of wood. The rest of the area is steeped in darkness. Individually some of the families have availed of subsidy by WBREDA to get solar lights installed in the village. Mode of communication in this area is mainly country boats and mechanised boats and the speed of which is regulated by the movement of the tidal currents. Concrete jetties which are boarding and disembarking points for people boarding watercraft are few and far between and at many places still brick block jetties are used to board boats. Primary health centres and schools are also not adequate. The local markets are called ‘haats’ and are organised once a week where the villagers come from far off places to buy and sell agricultural and other produce.

12.6.2 Resource Dependence of the Villagers

The lack of industries coupled with high population density have led to a high level of resource dependency (Ellison 2008). Dire poverty is the primary reason for people venturing into the forests braving risks like man-eating tigers and other fierce animals, frequent cyclones and storms. Every year some of these people who enter the forest fall prey to the tiger. They enter the mangrove forests for fishing, honey and fuel-wood collection. However, many miscreants often take the guise of fishermen and enter the forests with the intention of poaching and felling of timber species. Though in the past people would enter the forest for collection of *Nypa fruticans* (golpata) and *Phoenix paludosa* (hental) leaves which are used for thatching. These practices have since been discontinued.

12.6.2.1 Fuelwood and Timber Collection

The people in many border areas especially the eastern sector used to enter the Tiger Reserve to collect fuelwood and at times timber species also. The main species collected were *Ceriops decandra* locally called as Goran. The sticks from these trees were used for fencing purpose and thicker ones for posts of houses. In addition to these, *Avicennia* sp. which also have high calorific value were also cut. Most of the mangroves have little timber value except *Xylocarpus* and *Heritiera* sp. Presently these activities have been totally stopped inside the tiger reserve. In Arbesi Block under Jhingakhali beat of Basirhat Range, due to the silting up of the demarcating khal called the Shakunkhali and during low tide, the forest and village side are separated by a distance of only 2–3 m at some places. Although, a nylon net fencing separates the forest from the village area all along Arbesi 1, there is a tendency of the people to cut the net to gain entry into the forest. This often leads to man-animal conflict scenarios.

12.6.2.2 Fishing

Fishermen enter into the STR area for fishing after getting permits from the office of Sundarban Tiger Reserve. These permits are given for a specific time and area as mentioned in the permit. These permits are issued against registered Boat Licence Certificates or BLC's. Presently in Sundarban Tiger Reserve, there are about 923 Boat Licence Certificates or Fishing Permits, out of which three quarters are active and one quarter are lying inactive due to various administrative and technical reasons. However, some irregularities have been noticed like the fishermen usually extend their period of stay in the forest area and try to enter non-permitted areas.

12.6.2.3 Tiger Prawn Seed Collection

It is a much profitable livelihood activity. This livelihood has been heavily discouraged due to its negative impact on the ecosystem. Presently after formation of Joint Forest Management Committees (JFMCs), only a handful of people are involved in this activity.

12.6.2.4 Honey Collection

Rock bees (*Apis dorsata*) from the Himalayas visit the Sundarbans Forest every year. Most of the mangrove flowers are highly nectar bearing. This attracts the rock bee to visit Sundarbans during summer months which is the main flowering season. Flowering starts with the bloom of *Aegiceras corniculatum* at the end of March and is followed by the flowering of *Acanthus ilicifolius, Avicennia* spp., *Sonneratia apetala, Rhizophora* spp. This continues for 2 months from April to May. The density of honey depends on the number of salt-excretory glands available on the tree. Khalsi (*Aegiceras corniculatum*) having 19 glands per sq. mm. gives the best honey. As rock-bees are migratory, so the experiment of setting up apiaries has failed. The honey from Khalsi is considered to be the best in quality. The Goran produces the maximum and the minimum is obtained by Gnewa (*Exoecaria* spp.). It has been found that Gnewa bears about 39% of honey comb and Bain (*Avicennia* spp.) 16%, Goran (Ceriops spp.) 11%, Garjan (*Rhizophora* spp.) 10% and others bear only 24%. The ideal site for construction of hive would be Hental-Gnewa combination forests. Honey Collection is a very important activity in Sundarbans. A lot of people are involved in honey collection which is facilitated by the Forest Department. The collection of honey begins from the month of March to April and continues for about two to three months. This is the time when most of Sundarban flora is in full blossom. Permits are issued to the honey collectors after the minimum support price is decided by a joint meeting of the Sundarban Tiger Reserve management and West Bengal Forest Development Corporation. Each permit allows 6–10 people enter the forest areas. During this period, fishing is stopped. Floating camps are put up with armed staff equipped with RT sets, speed boats, etc. are placed in different places to keep a watch and ward over the entire activity and to attend to the emergencies like tiger attack, snake bite, etc.

12.6.2.5 Ecotourism

Sundarbans are rich in flora and fauna. Ecotourism is catching up rapidly in Sundarban areas. Main tourist season is from October to February though tourists visit Sundarbans throughout the year. Some people are engaged in hotel/resort business, some are engaged in supply boat/launch to tourists and some are engaged as tourist guide. They earn a good amount during tourist season.

12.7 Threats and Conservation

The mangroves of the Sundarbans are endangered and are in alarming state due to present trends of over exploitation and the large–scale dependence of huge rural population of the Lower Gangetic Delta. Besides this, the recently changed geological events, viz., neotectonic movement of the Earth and change of upstream fresh water flow towards east of the river Hugli (The Ganga) have changed the Sundarban mangroves to a great extent. These mangrove ecosystems are used for developing prawn and fish farm. Indiscriminate shrimp seed collection has led to damage to other indigenous shrimp, fish juveniles and planktonic population. The uncontrolled harvesting of exportable mud-crab and alarming trend of wood cutting also possess threat to mangroves of Sundarban. There are also threats to many species like spotted deer, wild boar, water monitor lizard, Olive Ridley turtles and sometimes tiger for poaching. Poachers in Sundarbans use many techniques like nylon rope traps, steel wire traps, gun shots, poisoning, etc. to poach the target animals. There are clandestine local markets for deer and boar meat. Olive Ridley turtles are also poached by fishermen because of their meat. The drainage of hydrocarbons from ships and other marine vessels leads to development of pathogenic microbes which infect the free living and cultivable aquatic life forms. This causes serious setback to cultivation and production of dollar earning species. With the adoption of Joint Forest Management with People's participation, the protection and management of mangrove flora and fauna of Sundarbans have improved a lot. This has been possible due to involvement of local people in Forest Reserve management, decision making, conducting entry point activities and ecodevelopment activities, study tour to the successful JFM areas.

12.8 Conclusion

Sundarbans is one of the biodiversity rich sites in the world and it is the privilege of this region to have such a wonderful wildlife habitat. Now it is felt necessary to conserve the Sundarban ecosystem in its natural state so that several natural calamities can be averted and can be helped to check the atmospheric pollution. The wild lives of the mangrove forests also help to maintain the ecological balance as the plants and animals are directly interdependent on each other. The tigers in land and the crocodiles in the water in Sundarbans are the two top consumers in a closed ecosystem. Hence, their presence is very much necessary to keep in control the ecological flow by the sustained growth of another biota. The rivers and creeks of Sundarbans are the nursery ground of numerous fishes including economically important tiger prawns (*Penaeus monodon*). With the increasing population pressure, the ecosystem of the Sundarbans is losing its balance slowly. As a result of our inordinate hunger and personal greed and owing to our laziness, the present-day environmental degeneration has come into being and repair of the same can be

possible by our efforts only. Environment and ecology cannot be preserved unless the need-based planning for maintenance of life and living of the inhabitants of the Sundarbans is taken up together.

References

Anderson R (1862) Catalogue of Plants indigenous in the Neighbourhood of Calcutta with Directions for Examination and Preservation of Plants, Calcutta, India

Barlow ACD, Ahmed MIU, Rahman MM, Howlader A, Smith AC, Smith JLD (2008) Linking monitoring and intervention for improved management of tigers in the Sundarbans of Bangladesh. Biol Conserv 141:2031–2040

Chakraborty K (1984) Dynamics of flora and fauna diversity in the mangroves of Sundarbans in comparison to laterite forests of South Bengal and North Bengal forests – a bio-ecological study. Indian J Forestry 7(8):220–232

Champion HG, Seth SK (1968) A revised survey of the forest types of India. Manager of Publications, Delhi

Chaudhuri AB, Choudhury A (1994) Mangroves of the Sundarbans Volume I: India, IUCN, Bangkok, Thailand, pp 1–247

Clarke CB (1895) Presidential address to the Linnean society on the Sundarbans of Bengal. Proc Linn Soc London 32:14–29

Ellison AM (2008) Managing mangroves with benthic biodiversity in mind: moving beyond roving banditry. J Sea Res 59:2–15

Fosberg FR, Chapman VJ (1971) Mangroves v. tidal waves. Biol Conserv 4(1):38–39

FSI (2019) India state of Forest report 2019. Published by Forest Survey of India, Ministry of Environment, Forest and Climate Change, Government of India, pp 53–55

Guha Bakshi DN, Sanyal P, Naskar KR (eds) (1999) Sundarbans Mangal. Naya Prokash, Calcutta, India

Hunter WW (1878) Hunter's statistical account of Sundarbans (1878) director- general of statistics to the government of India; volume I. districts of the 24 Parganas and Sundarbans. Published by TRÜBNER & CO., London

Nandi NC, Das AK, Sarkar NC (1993) Protozoa fauna of Sundarban mangrove ecosystem. Rec Zool Surv India 93(1–2):83–101

Naskar KR, Guha Bakshi DN (1987) Mangrove swamps of Sundarbans: an ecological perspectives. Naya Prakash, Calcutta, pp 1–264

Pillay TVR (1954) The ecology of brackish water bheries with special reference to fish culture practices and biotic interactions. Proc Nat Inst Sci India 20:899–927

Prain D (1903a) Flora of Sundarbans. Rec Bot Surv India 2:231–370

Prain D (1903b) Bengal Plants, Vol 2 (Rep. Ed. 1963). Botanical Survey of India, Calcutta

Prain D (1905) The vegetation of the district of Hugli, Howrah and 24 Parganas. Rec Bot Surv India 3:143–329

Qureshi IM (1957) Results of some studies on the forest soils of India and their practical importance. Van Vigyan, 5(1 &2), Dehra Dun

Roxburgh W (1814) Hortus Bengalensis. Serampur Mission Press, India

Schlichs W (1875) Remarks on Sundarbans. India For 1:6–11

Schuster WH (1952) Fish culture in salt water in Java. Indo-Pacific Fisheries Council, Bangkok

Voigt JO (1845) Hortus Sundarbonus Calcuttensis, Calcutta, India