Biodiversity of the Sundarbans

Ethics of Conservation Ecology (1770-2022)

By

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This book is dedicated to my late wife Krishna

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PREFACE

The Sundarban mangrove wetlands, lying a little south to the Tropic of Cancer, occupy the western part of the lower Ganga-Brahmaputra delta. The area was evolved during 5,000 to 1,800 years. This changing landscape consists of 251 (disjunct) islands over 11, 455 km^2 in 2015-2016 as against 253 (11,903 km^2) in 1904-1924, 250 (11,663 km^2) in 1967 and 244 in 2001 (11,506 km^2), where the trend of reduction was 2.55-times higher in the western (Indian) segment of the region compared to that of the eastern (Bangladesh) section (Bandyopadhya *et al.,* 2022). The region is separated by about 400 interconnected tidal rivers, creeks and canals. Thus, the Sundarban ecosystem has become an isolated and dynamic wildlife refuge, boxed in by humans, inland waterbodies and outer sea in the districts of Satkhira, Khulna and Bagerhat (99%) and partly in Patuakhali and Barguna (1%), in Bangladesh (6,017 km^2) and India (4,220 km^2) in South and North 24-Parganas districts.

Earlier, a geoinformatics-based study has explored changes in the Indian and Bangladesh Sundarbans over two and half century (1773-2016) (Hussain *et al.,* 2017), where the area coverage has been decreased in different time-scales. The total area was 22,354 km^2 in 1773, including 12,290 km^2 and 10,064 km^2 in Bangladesh and India respectively. In 1873, the area was reduced to 16,431 km^2 (8,537 km^2 and 7,894 km^2 respectively in Bangladesh and India) whereas in 1973, the reduced figure was 10,802 km^2 (6,525 km^2 and 4,277 km^2 in Bangladesh and India respectively) and in 2016 was estimated as 9728 km^2 (6,152 km^2 and 3,576 km^2 in Bangladesh and India respectively). Thus, the total mangrove forest has decreased by 12,626 km^2 (56.48%) including 10,695 km^2 of forest land and 1,931 km^2 of river bodies. The spatial change took place on all sides. The southern part was lost due to erosion and the other three sides for land reclamation. The decreasing trend is more in the Indian Sundarban compared to the Bangladesh Sundarbans. The average rate of decreasing in India 2.68% more than Bangladesh per decade. During 46 years, yearly average loss in Bangladeshi part is 0.35% as against 1.02% in Indian part. This decreasing trend has disrupted the mangrove forest and its ecosystem considerably.

The Sundarban delta has undergone rapid changes caused by neotectonic activity over the past millennium, and geomorphic processes of sediment accretion and erosion have influenced its extent.

Here, the landforms are classified into two broad morphotypes (including sub-types)-

I. Coastal area (5%)

(i) Beach in the outer (seaward) strand of the southern islands,
(ii) Dune (Aeolian) behind the beaches,
(iii) Beach-bank transitional (tidal/fluviotidal)
(iv) Estuary bank (tidal/fluviotidal) along the sides of the estuaries and tidal channels; and

II. Interior island area (95%)

(v) Inter-distributary estuarine swamp (biotidal), where mangroves or marshes are present;
(vi) Inter-creek reclaimed deltaic plains (bio-tidal/anthropogenic modifications) including almost whole of the supratidal interior areas.

Although erosion of the estuary margins and sea face is continuing for many decades, interior channels, especially in the west, are getting silted up due to sediment reworking in a flood-tide dominated environment that is greatly intervened by reclamation efforts initiated in 1770. In 1920-21, when the island was under forests, there were hardly any water bodies in the island. During its subsequent reclamation, a number of tidal creeks were blocked at their entrances and a marginal embankment was constructed all around the island and along the major channels. This transformed the free-flowing water courses to stagnant water bodies. With time, these water bodies were subjected to eutrophication and/or land-filling for expansion of farmlands or for habitation use. In contrast, none of the creeks in the adjacent non-reclaimed areas lost their original density (Nishat *et al.*, 2019).

Coastal retreat in the Sundarbans is highest between the Saptamukhi and the Hariabhanga estuaries and gradually reduces eastward, almost to reach zero on the west bank of the Baleswar. Here, the Bulchery Island has shown relentless erosion through different years. Like other sea-facing islands in the region, its area was reduced by 50% within last 100 years and is estimated to get obliterated within the next 100 years or so. A

number of interior creeks and estuaries are also getting silted, mostly (partly) in the western (northern) section.

Analysis of the noninvasively-collected tiger samples from the Sundarbans for mitochondrial and microsatellite markers in comparison to the mainland (northern and peninsular) Bengal tiger populations in India, the Sundarban tigers were found to be genetically distinct and had lower genetic variation in comparison to other mainland tiger populations (Singh, 2017). Demographic analysis indicated recent historical isolation (600–2000 years ago) of the Sundarbans tiger from the mainland. Both historical and genetic evidences supported that the Sundarbans tiger was genetically connected to other mainland tigers until recently. Conclusively, the genetic isolation from the mainland tiger population and unique ability and skill (not inherent but learnt with the passage of time), adapting to the changing factors, conditions or environments of the mangrove ecosystem, might have jointly shaped the genetic architecture of the Sundarbans tiger. Since the Sundarban is totally cut off from the northern and south-western tiger populations and gene pool, the Sundarban tiger may be managed efficiently as an evolutionary significant unit (ESU) under the adaptive evolutionary conservation (AEC) criteria and the largest single transboundary keystone population along with its associates in the changing natural habitat through trans-boundary (India-Bangladesh) collaboration.

The ecological history of Sundarbans dates back to late 17th century, when Kolkata was its northern boundary. The reclamation process started during 1770s to establish settlements in this fertile area considered 'wasteland'. During the early colonial period, the estimated area of Sunderbans was around 43,252 km^2 (Sharma, 2013), but reduced to 25,000 km^2 (14,600 km^2 freshwater swamp forest and 20,400 km^2 Mangroves) due to rapid reclamation. The present study has revealed that 10,119 km^2 or 49.60 percent of this ecosystem is impact area or locality covering about 20,400 km^2 and the remaining 10,281 km^2 or 50.40 percent is forest land.

During the initial two hundred years of imperial and post-colonial forest management, the primary focus was large-scale clearing of forests and promotion of ruthless hunting for huge revenue and production forestry, violating the traditional ethical issues of living by the 'rules of nature'. Mukherjee (1975: 14) has described some of the consequences of such deforestation:

"The reclamation of the land which rose from the mud and clay by deforestation and human settlement has upset the ecology, resulting in the disappearance of a major part of the wildlife. What exists today in these cultivated tracts are some common forms of birds and aquatic fauna of the tidal creeks, common to both the reclaimed and the forest areas. From the northern part of the district some animals have immigrated and have established themselves in the reclaimed area, for example the jackal, fox, civet cat, mongoose and rats. Freshwater fishes have been introduced in the freshwater (sweet-water) tanks, and various insect pests have appeared on cultivated crops which were not known when these areas were covered with virgin forest."

With the conversion of the swamp grassland to cultivation and human settlements, loss and degradation of the habitats during the intervening period has caused historical species extinction of the herbivorous lesser one-horned rhinoceros, wild buffalo, swamp deer, sambar and hog deer and population decline of the other species. The barking deer has also become extinct in the western Sundarbans and critically endangered in the eastern Sundarbans. Extirpation of multiple prey species has affected the tiger population. In addition to the absence of large herbivores, the tiger population continued to decline because of surreptitious poaching for sports, safety and illegal trade in tiger bones, meat, pelt, eyeballs, teeth, whiskers, tongue, brain, fat, genital organ, paw or nails. Five groups were identified who are involved in tiger killing: villagers, poachers, local hunters, trappers and pirates. The villagers kill straying tigers in the village predominantly for safety, while other groups kill inside the forest professionally or opportunistically. The poachers kill tigers just for money, but other groups hunt for excitement, profit or social status. The pirates, on the other hand, not only kill tigers for profit and but also for personal safety in the forests. There are many streams and rivers, which are used by the offenders as their entry and exit ways, particularly during the high tide because of easy navigability.

In the Bangladesh Sundarbans, the tiger killers locally tan the skin using local ingredients and bury the rest of the body to collect the bones later. The price range of a skin varies between BDT 40,000-90,000 (USD520-1,169); for bones BDT 1,500-3,000/kg (USD20-39) and for a canine BDT 1,000-7,000 (USD13-91) and the outsiders buy the bones from the tiger killers (Saif, 2016).

According to Seidensticker and Hai (1983), the problems for conservation and management arise not only from the physical alteration of the vegetation type but also invasion by alien species and these animals, through competition for food or competitive exclusion in a number of forms, threaten the survival of the forest animals. In the past, the animals living in the forest were buffered by a broad transitional belt of habitat that man destroyed in the process of reclamation. In the process of transforming this belt, a considerable segment of the fauna of the basin was lost, including the more spectacular forms and the animals left with can survive in the southern portion of the forest if conserved well, a number of threats must be contained.

After independence in 1947, the need for wildlife conservation made a shift in the government policy. Here, 'wildlife' refers to the mammals, birds, fishes, frogs, lizards and snakes, flies and beetles, crabs and lobsters, sponges and jellyfish, and all the little bacteria and microbes. All of the wildlife on our planet needs plants and other wildlife to survive. They depend on each other for food and habitats. These inter-dependent wildlife and plants may be termed 'biodiversity', which is the spice of all life-forms and has three levels- genetic diversity, species diversity and ecosystem diversity. The Sundarban is an ideal cradle of such diversity.

The 1970's bought with it two landmark events of utmost ethical importance that were to influence the wildlife conservation in India. The first was introduction of the stringent Wildlife (Protection) Act in 1972 banning hunting and establishment of PAs. The other event was launching of the Project Tiger, the largest wildlife conservation initiative in 1973, including the Sundarbans. Biodiversity conservation within and beyond the PAs is the 1990s manifestation based on the ethical issues. In all, 15 PAs have been set up in the Sundarbans- five in India and 10 in Bangladesh. But in spite of creation of a PA Network, the Indian Sundarbans were considered endangered in the 2020 assessment under the IUCN Red List of Ecosystems framework.

There is no substitute for the Sundarbans to protect the environment and biodiversity as well as human life in coastal areas. Therefore, SNP (1,330.10 km^2) in India was declared as a 'World Heritage Site' on the basis of two criteria (ix)(x) as follows:

Criterion (ix): The Sundarbans is the largest area of mangrove forest in the world and the only one that is inhabited by the tiger. The land area in the Sundarbans is constantly being changed, moulded and shaped by the action of the tides, with erosion processes more prominent along estuaries and deposition processes along the banks of inner estuarine waterways influenced by the accelerated discharge of silt from sea water. Its role as a wetland nursery for marine organisms and as a climatic buffer against cyclones is a unique natural process.

Criterion (x): The mangrove ecosystem of the Sundarbans is considered to be unique because of its immensely rich mangrove flora and mangrove-associated fauna. Some 78 species of mangroves have been recorded in the area making it the richest mangrove forest in the world. It is also unique as the mangroves are not only dominant as fringing mangroves along the creeks and backwaters, but also grow along the sides of rivers in muddy as well as in flat, sandy areas.

1,395 km^2 in Bangladesh Sundarbans was so declared in 1997 on the basis of same criteria mentioned above.

The Sundarban is also one of the most important wetlands under the World Wetlands (Ramsar) certificate in the UNESCO list of the United Nations Educational and Cultural Organization. 10,247 km^2 (6,017 km^2 in Bangladesh and 4,230 km^2 in India was declared in 1992 and 2019 respectively). The Sundarban met four of the nine criteria required for the status of 'Wetland of International Importance'- presence of rare species and threatened ecological communities, biological diversity, significant and representative fish and fish spawning ground and migration path.

According to the Ramsar authorities,

"The mangrove forests protect the hinterland from storms, cyclones, tidal surges, and the seepage and intrusion of saltwater inland and into waterways. They serve as nurseries to shellfish and finfish and sustain the fisheries of the entire eastern coast. The STR is situated within the Site and part of it has been declared a 'critical tiger habitat' under national law and also a 'Tiger Conservation Landscape' (39) of global importance. The Sundarban is the only mangrove habitat which supports a significant population of tigers and they have unique aquatic hunting skills. The Site is also home to a large number of rare and globally threatened species

such as the critically endangered northern river terrapin *(Batagur baska),* the endangered Irrawaddy dolphin *(Orcaella brevirostris),* and the vulnerable fishing cat *(Prionailurus viverrinus).* Two of the world's four horseshoe crab species and eight of India's 12 species of kingfisher are also found here. The uniqueness of the habitat and its biodiversity and the many tangible and intangible, local, regional and global services they provide, makes the Site's protection and management a conservation priority".

The supra-tidal area of Bangladesh Sundarbans was bigger than the Indian counterpart [1914: 3,693.5 (+30.36%), i.e. 92.1 km^2 (2.55%); 2016: 3,601.4 km^2 (+28.54%)]. Now, India holds 34.82% and Bangladesh 65.18% of the total area. During the initial two hundred years of imperial and post-colonial forest management, the primary focus was revenue and production forestry, whereas biodiversity conservation within and beyond the protected areas is the 1990s manifestation based on the ethical issues- "biodiversity, aesthetic values and integrity" and management of ecological balances challenged by development works and anthropogenic activities.

Involvement of local people/community in the forest and wildlife management in the form of co-management is now obvious for the protection, conservation and management of the Sundarbans.

A published book highlighting the ethical, ecological and historical (250 years) perspectives on the Great Sundarbans is not readily available. In this context, this book is a novel one. This book contains well-researched (literature/field surveys) and 47 years' experience-oriented information on the species (micro-macro) diversity, first-ever reported from the world's largest mangrove ecosystem and quarter-millennial reclaimed hinterland, struggling against the natural and anthropogenic threats.

This monograph is ideal for the researchers, postgraduate and graduate students in zoology, botany, ecology and conservation. This comprehensive treatise will serve the professionals, such as foresters, environmentalists, conservationists, resource managers, planners, government agencies, academic institutions, NGOs and naturalists.

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CHAPTER 1
INTRODUCTION

Study area

During the British rule, the entire Sundarban was administered as a single unit in India. After partition in 1947, the eastern Sundarban eco-region is in Bangladesh, located from the Harinbhanga (West Bengal, India) to the western bank of the Meghna, and is composed of SRF and ECA as well as SIZ surrounding SRF. In India, SBR, i.e. the western Sundarban eco-region, extends from the river Hooghly on the west to the river Matla (South 24-Parganas Forest Division) and from the Matla to the Raimangal-Harinbhanga on the east (STR) as well as the inhabited areas south of the Dampier-Hodges (imaginary) line, passing through South and North 24-Parganas districts. Geographically, the undivided Sundarban tract was extended approximately 260 km west-east along BoB from the Hooghly estuary to the western segment of the Meghna estuary. This region has a coastal stretch of 289.682 km and reaches inland (upstream) for about 112.654 km at its broadest point, comprising the major portions of the 24-Parganas, Khulna and Barisal districts (Curtis, 1933).

Indian Sundarbans

A large part of the South 24-Parganas district falls under this western region (proposed Sundarbans District). 2,788.71 km^2 (27.99 per cent of the geographical area) as per 2019 estimates, including very dense forest (983.10 km^2), medium dense forest (745.03 km^2) and open forest (1,060.58 km^2). This forest land is spread over five community blocks:

(1) Basanti: Herobhanga RF: J.L.No. (Jurisdiction List Number)- 114-116 (between Matla and Bidya rivers);
(2) Gosaba: Sundarbans RF (between Matla and Raimangal-Harinbhanga rivers);
(3) Kakdwip: Sundarbans RF: Small portion south of J.L. Nos. 231 and 232;
(4) Namkhana: Sundarbans RF: Two river (Saptamukhi) banks east of J.L. No. 286 and 290; J.L. Nos. 318 (Lothian Islands); 319 (Henry Island); 320 (Frederick Island); 321 (Susni Island) and 322 (Jambu Island); and

(5) Patharpratima: Sundarbans RF: J.L. Nos. 361, 372, 411 and 414.

A small part of North 24-Parganas district is included in the Sundarbans (proposed Basirhat and Ichamati districts):

(1) Arbesi RF (1-5)= 142.84 (Land 98.35+ Water 44.49) km^2 and (2) Hingalganj Community Block (238.80 km^2) between the two branches of the River Ichamati and SRF.

SBR (1989) - Total area 9,630 km^2 (Deforested Settlement Area 5,366 km^2 + SRF and PAs: 4,264 km^2) (Govt. of India's Notification No. 16/6/84-CSC dated 19.03.1989).

I. STR (21'51'-22'31'N, 88'10'-89'51'E) (Proclamation 23.12.1973)- Field Management System:

Four Forest Ranges:

1. Basirhat: 5 Beats – Bagna, Burirdabri, Jhingakhali, Khatuajhuri and Harinbhanga;
2. Sajnekhali WLS: 3 Beats – Sajnekhali, Dobanki and Dattar;
3. Sundarban NP (East): 3 Beats – Chamta, Bagmari and Chandkhali;
4. Sundarban NP (West) 3 Beats – Haldibari, Netidhopani and Kendo.

Official records: Area changed over 30 years [2,584.89 (forest 1,680.13+ water 904.76) or 2,585 km^2 as per 1973's estimate, but has increased to 2,626.36 km^2 as per 2003 satellite data (forest 1,624.18+water 1,002.18)] with 9 Blocks (9 x 5 = 45 Compartments):

PA 1. Sajnekhali WLS- 376.34 km^2 (as per Government Notification No. 5396-Forest, dated 24.6.1976)

Boundary: North: Bara Herobhanga Khal, Gomdi Khal and Pitch Khal; East: Duttar Gang; South: Part of Gosaba river and Netidhopani Khal; West : Bidya river

Forest Block: (i) Panchmukhani (1-5)- 176.90 (142.82+34.08) km^2; (ii) Pirkhali (1-5)- 199.44 (148.88+50.56) km^2;

PA 2. Sundarbans NP (1,330.12 km^2 as per Government Notification No. 2867-Forest, dated 4.5.1984; increased to 1,520.78 km^2 by including additional area in 2003)

Boundary: North : Reserve forest blocks and compartments, namely, Netidhopani1, 2 and 3; Chamta-3 and 2; Chandkhali-2 and 4; and Baghmara-1; East: Harinbhanga river adjoining the international boundary with Bangladesh; South : Bay of Bengal; West: Matla river.

(i) Matla (1-5) 189.74 (123.50+66.24) km^2;
(ii) Chamta (1-5) 228.36 (169.43+58.93) km^2;
(iii) Chotohardi (1-5) 166.11 (78.50+87.61) km^2;
(iv) Gosaba (1-5) 173.11 (103.79+69.32) km^2;
(v) Gona (1-5) 149.02 (79.20+69.82) km^2;
(vi) Bagmara (1-5) 307.23 (155.00+152.23) km^2;
(vii) Mayadip (1-5) 307.21 (82.25+224.96) km^2;

PA 3. Buffer Zone [Reserved Forest] (6 Blocks 885.27 km^2)(6 x 5= 30 Compartments) (as per Government Notification No. 615-Forest, dated 17.2.2009)

(i) Arbesi (1-5) 142.84 (98.35+44.49) km^2;
(ii) Jheela (1-5) 120.13 (89.30+30.83) km^2;
(iii) Khatuajhuri (1-5) 119.43 (100.00+19.43) km^2;
(iv) Harinbhanga (1-5) 116.76 (83.50+33.26) km^2;
(v) Netidhopani (1-5) 77.04 (54.74+22.30) km^2;
(vi) Chandkhali (1-5) 153.04 (114.92+38.12) km^2.

As per the 21st century's satellite imagery, the forest cover has decreased by 55.95 km^2 in STR during last 30 years due to extensive land erosion, while the water area has increased by 97.42 km^2. Therefore, the total area has increased to 41.47 km^2.

PA 4. Core or Critical Tiger Habitat- 1,699.62 km^2 (re-distributed or newly constituted core area as per Government Notification No. 6028-Forest, dated 18.12.2007)

(i) Matla (1-4) [NP] 176.30 km^2;
(ii) Chamta (1-3) [RF] 96.32 km^2;
(iii) Chamta (4-8) [NP] 124.37 km^2;

(iv) Chhotahardi (1-3) [NP] 175.67 km²;
(v) Gosaba (1-4) [NP] 171.73 km²;
(vi) Gona (1-3) [NP] 139.03 km²;
(vii) Bagmara (1) [RF] 24.30 km²;
(viii) Bagmara (2-8) [NP] 269.63 km²;
(ix) Mayadip (1-5) [NP] 273.36 km²;
(x) Netidhopani (1-3) [RF] 93.00 km²;
(xi) Chandkhali (1-4) [RF] 155.91km².

II(A). South 24-Parganas Forest Division: Reserved Forest Area 1,679 km² (4 WLS: 600.40 km² + Other Forests: 1,078.60 sq. km):

1. Halliday Island WLS: Dulivasani- 7 (Part) - 5.95 or about 6 km² (Notification No.5388-Forest dated 24.06.1976)

2. Lothian Island WLS: Saptamukhi 1 (Part) - 38 km² (Notification No.5392-Forest dated 28.06.1976)

3. West Sundarbans WLS: 556.45 km² (Notification no. 1828-Forest dated 11.09.2013) composed of 2 forest blocks

(i) Dulivasani 307.49 km² [Dulivasani 1= 48.85, Dulivasani 2= 48.39, Dulivasani 3= 19.02, Dulivasani 4= 34.24, Dulivasani 5= 35.80, Dulivasani 6= 20.88, Dulivasani 7 (partial)= 42.20, Dulivasani 8= 58.11] and (ii) Chulkati 248.96 km² [Chulkati 1= 23.46, Chulkati 2= 25.14, Chulkati 3= 50.66, Chulkati 4 = 14.96, Chulkati 5 = 60.11, Chulkati 6 = 36.10, Chulkati 7 = 19.96 and Chulkati 8 = 18.57]
Boundaries: In the north, the Ajmalmari river joins the Thakuran river and the Suiya Ganges; BoB to the south; on the east the Matla River; Thakuran river in the west.

4. Chintamani Kar (Formerly Narendrapur) WLS (0.06956 km²) (Notification no.4300-For dt. 21.10.2005)

Boundaries: Adiganga canal flows to the west, roads to the south and east and villages to the north.

II(B). North 24-Parganas Forest Division:

5. Bibhuti Bhushan WLS (formerly Parmadan) 0.64 km² (Block Parmadan-1)(Notification no. 2776-For dt. 19.8.98)

Boundaries: North, South and West by Ichamati river and village to the east.

III. East Calcutta (Kolkata) Ramser Wetlands (No. 1208) Calcutta, North 24 Parganas and South Twenty Four Parganas District: Total area 125 km² (2003) - Fish farming 5,852.14 ha, Agriculture 4,718.56 ha, Waste area 602.78 ha and human habitations 1,326 ha.

IV. CRZ (1991 amended in 2011)- 545.191 km²

The region has ecologically sensitive conservation areas like Sand Dune-Fraserganj, Gangasagar Island, etc., located between HTL and LTL and affected by the tidal action, which includes most of the localities with tidally influenced rivers/creeks and roadside vegetation. Out of the total 2,227.19 km² coastal controlled zone area (mostly in the Sundarbans), mud flats occupy 223.94 km², wetland vegetation occupies 22.59 km² and islands occupy 1,303.60 km². The deforested areas are mainly converted to settlement and agriculture. Of this, about 347.46 km² of brackish water is used for fish farming in the *bheri* (shallow pond).

However, the natural landscape has changed considerably since 1991. Some islands have completely sunk and some new islands have formed. This L-shaped coastal zone of the Sundarbans controls two distinct geographies-

(1) along the Hooghly River (Central Zone) and
(2) east of the Hooghly River (Eastern Zone).

Bangladesh Sundarbans

The protected areas consist of 10 sanctuaries –

1. Sundarbans East WLS (Notified on 29.6.2017)- District Bagerhat (1,22,920.90 ha), Compartment Nos. 1,2,3,4,5,6,7, 8 (Part), 9, 11, 45 (Part) (excluding 170 ha Dudhmukhi Dolphin WLS)

Boundary north from Baga Canal, Miter Bharani, Bara Shiala Canal, Shela Gang, Harintana Camp downstream of Latimara Canal via Betmore Gang to Dudhmukhi Camp and Daburi Bharani Canal to junction of Bhola River; Baleshwar River on the east; west from the Passur River to the Namur River; BoB (except Dublar Char) to the south.

2. Sundarbans South WLS (Notified on 29.6.2017)- District Khulna (75,310.30 ha), Compartment Nos. 18, 19, 43, 44

Boundary on the north via Pataksta Canal upstream of Hansraj River to Pathakatha Bharani, on the east via Morjat River to Numud River, on the west BoB from Arpangasiya River and Bara Panga River to Malancha River, south with Putni Island.

3. Sundarbans West WLS (Notified on 29.6.2017)- District Satkhira (1,19,718.88 ha), Compartment Nos. 49, 51A, 51B, 52, 53, 54, 55

Boundary: On the north by Jamuna River or Mahmuda River to Firingi Gang, on the northwest by Kachikata Canal, from Arpangasiya River and Bara Panga River to Malancha River in the east, Harinbhanga River to Rayamangal River in the west, BoB including Talpatti in the south.

4. Dudhmukhi WLS (Notified on 29.1.2012) Compartment no. 2 and 3, District Bagerhat (170 ha) for dolphins

It is 5 km long, opposite to the Dudhmukhi patrol post, from the junction of Boro Sheola canal to the Bhola River and the junction of the Boro Sheola canal.

Boundary: North: Land area of 2 no. compartment and West bank of Betmore River from 22^{0}06′082″ Latitude and 89^{0}46′325″ Longitude to East bank of Betmore River, 2 no. compartment 22^{0}06′082″ Latitude and 89^{0}46′512″ Longitude, also from the adjoining East bank of Bhola River 22^{0}04′631″ Latitude and 89^{0}48′464″ Longitude to 1 no. compartment adjoining east bank of Betmore River 22^{0}02′631″ Latitude and 89^{0}48′510″ Longitude; South: Land area of 3 no. Compartment and from the estuary of Betmore River and Boro Shawla khal to the estuary of Bhola River and Boro Shawlakhal on the opposite of Dudhmukhi Patrol Camp; East: Across the Bhola River and Boro Shawla khal and the land area of 1 and 2

no. compartment; West: Betmore River adjoining land area of East part of 12 no. compartment.

5. Chandpai WLS (Notified on 29.1.2012)- 560 ha, Compartment no: 27 and 28. District Bagerhat for dolphins

It is 15 km long, covering Jongra patrol outpost, Nandabala, Chandpai, Mrigmari and Andharmanik patrol outpost.

Boundary: North: Chandpai Range adjoining Joymonirgul and Chandpai check station; south of Mrigmarikhal adjoining land and Passur River adjoining south reserve forest of 31 compartments; South: Adjoining land of Mrigmari Khal and in front of Mrigmari Patrol Post the estuary of Mrigmari and Andharmanik channel of 26 and 28 Compartment; From Jongra Patrol Post west part of Pashur River to Nandabala Patrol Post; East: Mrigmari Khal adjoining 27 Compartment, on the west of Pashur River Joymonirgul adjoining forest area and Mrigmari Khal adjoining west land of 27 compartments; West: Passur River adjoining land of 30 no. compartment.

6. Dhangmari WLS (Notified on 29.1.2012)- 340 ha, Compartment no: 31, District Bagerhat for dolphins

It is 12 km long, stretching from Ghagramari station to Ghagramari patrol camp and covering the entire Dhangmari canal, extending up to the west bank of river Passur in the Karamjal wildlife breeding centre.

Boundary: North: Dhangmari village, latitude $22^{0}26'807''$ to $89^{0}36'00''$ between Dhangmari and Mongla; South: From the Jongra patrol post to the middle of Passur River on the East; East: Across the middle of Passur River; West: The whole channel from Dhangmari Station to Ghagramari Patrol Camp and covering Dhangmari and Bhedonkhali village, Karamjal breeding centre adjoining 31 no Compartment and west bank of Passur River.

7. Marine protected area: Ganga Khat or Swatch of No Ground (Swatch of No Ground or SoNG) WLS (Notified on 27.10. 2014) to conserve marine biodiversity (cetacean and other aquatic resources)= 1,738 km^2; depth 900+ m.

Boundary : North: up to Sundarbans (BoB); Latitudes 21°37'35"N and longitudes 89°30'22"E; North-west: Latitudes 21°37'35"N and longitudes 89°21'13"E; North-east: Latitudes 21°37'35"N and longitudes 89°40'30"E; South-west: BoB up to Indian jurisdiction; Latitudes 21°19'57"N and longitudes 89°21'13"E; South-east: BoB; Latitudes 21°20'28"N and longitudes 89°40'30"E; South: Latitudes 21°06'25"N and longitudes 89°31'14"E; East: BoB; West: BoB up to Indian jurisdiction.

In 2020, three more dolphin sanctuaries were declared by MoEFCC in Pankhali, Sibsha and Bhodra, inside the Sundarbans.

8. Pankhali WLS (Dolphin)- 140 ha.

Boundary: North: The boundary of the border of Pankhali Ferry Ghat, from the edge of the Gas cylinder plant to the middle of the Passur River; South: The margin of the border of Pankhali Ferry Ghat, the adjacent waterway of the Pankhali Bazar border and the middle of the River of Pashur from the adjacent land area of the village; East: The boundary of the village of Pankhali and Kamarkhola along the border between Pashur River; West: The boundary between the banks of the Pankhali River, the Pankhali and Kamarkhola village.

9. Shibsa WLS (Dolphin)- 1,650 ha, Compartment no: 33 and 35

Boundary: North: Kalabogi village and adjoining floating settlement; Kalabogi khal adjoining the land of south-west of 32 no. compartment; Reserve forest and Shibsa River adjoining south part of Nalian Bazar; South: Northern part of 34 and 40 no. compartment, Shibsa River adjacent land and reserve forest; East: Floating populations of Kalabogi village, water bodies and reserve forests near Kalabogi canal, Kalabogi Forest Station, waterbody and reserved forest areas adjacent to 33 no. compartments, water body adjacent to Shibsa Forest Camp and reserved forest areas; West: Waterbody and reserve forest adjacent to 35 no. compartment, Sasanangla canal and Arua Shibsa canal adjacent water body and reserve forest.

10. Vodra WLS (Dolphin)- 410 ha. Compartment no: 39

Boundary: North: From Bhadra Forest Camp to Harbaria Forest Camp, the waterbodies of the Passur River and adjacent waterbodies and reserve

forest areas, 22nd and 29th compartment of the waterbody and reserve forest; South: 39 and 21 no. compartments adjacent waterbody and reserve forest, waterbody of Passur River and Charaputia Forest Camp adjacent reserve forest; East: 21 and 22 no. compartments, adjacent waterbodies and reserve forest; West: Bhadra forest camp adjacent water body and reserve forest, 39 no. compartment, adjacent reserve forest.

Total Dolphin Sanctuary= 3,270 ha (Present: 1,070 and new: 2,200); Core area 2,200 ha and extended Buffer area 1,227 ha - 3,427 ha.

Range-wise jurisdiction- 6,087 km^2
1. Satkhira range = 1,826 km^2
2. Khulna range = 1,613 km^2
3. Sharankhola range = 1,332 km^2
4. Chandpai range = 1,316 km^2

Buffer areas

1. ECA

Sundarbans in Bangladesh refers to forest area only, but under the Environmental Conservation Act of 1995 the government of Bangladesh had declared a 10-km (ECA over about 17.5 km^2) to the north and east of the forest boundary on 30 August, 1999 (ref no. pa ba ma/4/7/87/99/263) covering five districts (Bagerhat, Khulna, Satkhira, Pirojpur and Barguna), ten upazilas (Bagerhat Sadar, Mongla, Morrelganj, Sarankhola, Dacope, Koyra, Paikgacha, Shymnagar, Mathbaria and Patharghata), 47 unions (27 full and 20 partial) and 1,302 villages with the main objective of providing protection to the SRF and conservation of its biodiversity. This 10 km band is designated as the interface landscape zone in the context of climate change adaptation through value chain and livelihood enterprises and support for environmental and biodiversity conservation. There has been a great deal of change in the land use patterns of the ECA and agricultural lands have been transferred to *ghērī* that are developed for fish and shrimp culture. This interface landscape or sensitive area continues to suffer over-exploitation. Illegal urban development continues, including the use of bulldozers to extract sand at the confluence of Kalagachi and Chuna River at Burigoalini Range, within the Sundarban ECA.

2. SIZ

Another impact area within a 20 km wide radius surrounding the periphery of the Sundarban (SIZ) is often termed as an Ecologically Critical Area. The populations residing within this area are directly dependent on the Sundarban. Five districts of Bangladesh named Bagerhat, Satkhira, Khulna, Barguna and Pirojpur including 20 upa-zillas fall within the SIZ. The southern part of Satkhira, Khulna and Bagerhat and parts of Barguna and Patuakhali form the Bangladesh Sundarban.

ECOLOGICAL TRANSFORMATION AND MANAGEMENT

Ecological history

Although the geological history of 'Sundarban(s)' began probably during the early Pleistocene and the delta formation started from the tertiary period, extensive mangrove forests developed along the NE-SW zone of thickened Holocene. This estuarine land was gradually filled up by sediments brought down by the Himalayan drainage in phases over around 10,000 (BP) years.

Geo-morphologically, this landscape is an outcome of progressive tidal accretion vis-à-vis ecological adaptation starting from growth of the pioneer mangrove grasses like *Porteresia coarctata*, herbs and shrubs, thereby stabilising the intertidal shoals splashed by regular tides and successive changes in mangrove vegetation evolving the climax vegetation above the spring high tide line, but not submerged by bay-water except occasionally by tides augmented by episodic cyclones. It was observed that such accretion and development of an island (e.g. Nayachar formed in the Hooghly estuary; 22.03°N, 88.06°E) took approximately 60 years (1948-2008). The shoreline in between the rivers Saptamukhi and Gosaba has faced maximum erosion at the rate of 40 m per year (base 1914). Such erosion is rather slow beyond this stretch in Bangladesh. Along with accretion, there is evidence of simultaneous land subsidence in the geological sequence of the Sundarban delta, creating major ecological problems of instability. The estuary is still undergoing the dynamic process of formation and disappearance through the combined impact of-

(i) Deposition of silt-load by the freshwater rivers flowing into the estuary, including new island formation,
(ii) Erosion and submergence of a few sea-faced islands, and
(iii) Rise of sea-level and flooding due to global warming.

The history of Sundarbans can be traced back to 200-300 AD. During the reign of the Bengal sultanate (1206-1526), the Sundarban forest tracts were converted to wet-rice cultivation. By the mid-fifteenth century, the reclamation process had brought the southern extent of cultivation to the edges of South Jessore and northern Khulna. The process of bringing virgin forest under cultivation continued unabated in the Mughal era. The Mughal Emperors leased the forests of the Sundarbans to nearby residents. Historical records reveal that the northern boundary of the Sundarbans during the Mughal period (1203-1538) extended from Hariagarh, south of Dimond Harbour on the Hooghly, to Bagerhat in the southern part of Jessore and Haringhata, along the southern portions of Sirkars Satgaon and Khalifatabad. During this time the Ganges changed the course from the original Hooghly channel to combine upstream with the Brahmaputra. As a result, most parts of the 24-Parganas Sundarban faced increased salinity and this gradually affected the biodiversity of the area. The era also witnessed devastating cyclones.

The early management of the Sundarbans forests was confined to the realisation of revenue on the export of forest produce. The first recognition of this as a source of revenue was made by Sultan Shuja in 1658, when revising Todar Mal's original settlement of 1582. During the late 18th century up to early 20th century, there were small salt-farms in many parts of the southern and central Sundarbans. There was no comprehensive Mughal policy on problems of forestry including its preservation, propagation, protection or improvement.

The area was mapped first by the Surveyor General as early as 1769 when the uncleared Sundarban forest was a 'no man's land stretched uninterrupted over 19,200 km^2. First lease was granted by the East India Company to individuals for land reclamation for cultivation and timber supply in 1770-1773. The Sundarbans was taken to be the property of the state in 1817.

Over the next century the British had relentlessly pursued a policy of deforestation and extension of cultivation in the Sundarban. The forests of

Khulna district were reserved (completely government controlled and protected) in 1875 and 1876, and the remaining forests in the 24-Parganas district were declared protected (partly government controlled) in 1879.

The first working plan that of Mr. R.L. Heinig came into force during 1893-1894 followed by periodical revisions. Hunting and shooting were controlled by the rules in the notification no.839-For. dated the 23rd January 1915, and its various amendments. The close season for deer (1st May to 30th September) was not suitable for Cheetal in the Sundarbans. The stags are mostly in velvet from the middle of October to the end of March, and the rutting season is from about the middle of April to the end of June. Since a large number of tiger (604) had been killed during 1912-13 to 1929-30, the number of deer and wild pigs was increased, whereas the number of human killing by the tiger was 23.72 per year during the same period, but reduced during 1923-24 to 1929-30 varying from 1 to 7. As per local government's letter no.318-T.-R., dated the 27th May 1927, issuance of professional permits was stopped and the tiger population started increasing. During last eight years, 60 woodcutters also died due to crocodile attacks (Curtis, 1933). Fishing or collection of natural resources was allowed subject of permits and payment of revenue to the Forest Department. Entry without permit was prohibited from that time.

Post-independence status

The Sundarbans mangrove forest covers an area of about 12,164.1 km^2, of which forests in Bangladesh's Khulna Division, extend over Satkhira 1632.00 km^2, Khulna 1,668.14 km^2 and Bagerhat 1912.82 km^2 districts. The belt contains, in addition to the vast mangrove forest, the reclaimed and cultivated lands to the north of it. In West Bengal, the forests extend over 4,235.3 km^2, mostly across the South 24-Parganas and partly (eastern) North 24-Parganas districts. During 1948-2003, the Tiger Reserve area has been increased by 41.47 km^2 due to increase in water area by 97.42 km^2 and reduction of land area by 55.95 km^2 and the area under South 24-Parganas Forest Division increased by 64.74 km^2 (land: 169.82 km^2, water: 234.56 km^2). During the first decade of 21st century, forest area was reduced from 2,168.9 km^2 to 2,132 km^2 due to erosion and submergence and conversion of forest to saline blanks or salt pans were increased from 38.74 km^2 to 74.796 km^2 (Hazra *et al.* 2010). Water area is increased engulfing the forest, although some patches of recolonisation by salt-

tolerant mangrove species is evident in some islands as a result of continuous plantation.

SBR has lost 284 km^2 of land in the past 50 years, whereas accretion has been only 84 km^2. During the first decade of present century, the rate of land loss has been increased from 2.85 km^2 per year to 5.5 km^2. In case of Jambudwip Island, for example, the total area lost has been over 50%, while Sagar Island has shrunk by 15% and three other islands, Lohachahara, Suparibhanga and Bedford, completely disappeared, whereas Ghoramara Island has been eroded significantly.

In terms of area 272.9 km^2 (6.05%) was lost in India as against 180.8 km^2 (2.22%) in Bangladesh during the same period. In fact, during 1914 the supratidal area of Bangladesh Sundarbans was bigger than the Indian counterpart and the difference was 3,601.4 km^2 (+28.54%), whereas after about hundred years this difference comes to 3,693.5 (+30.36%), a difference of 92.1 km^2 (2.55%). Therefore, out of the total supratidal area shared by India and Bangladesh (2016), India holds 34.82% and the remaining 65.18% is managed by Bangladesh (contrary to the popular guess estimate of 40% and 60% respectively).

CHAPTER 2
MATERIALS AND METHODS

Secondary data were gathered by using an extensive literature (non-conventional, commercial or academic publishing, distribution channels and grey literature) review, including the official policies, practices and procedures in vogue on the biodiversity resources of the Sundarbans before field verification. Data were also collected from the FD, publications and unpublished documents and collated for preparing a database and facilitating field verification.

Both quantitative and qualitative methods were used for collection of data from time to time. Generally, data were gathered from multiple sources to strengthen reliability and consistency in results. The quantitative tools include surveys, questionnaires and statistical data. The qualitative method involves observation, one-on-one interviews, focus groups (stakeholders) either individually or in a community setting and recorded manually or electronically. All quantitative data is based on and interpreted by qualitative judgement. Intensive case studies also enabled in-depth exploration of intricate phenomena within some specific context at foundation, pre-field, field and finalisation phases.

The island habitat of the Sundarbans is totally different from the terrain found in the mainland. In practice, surveying inside the hostile mangrove habitat, which is approachable and traversed only by the watercrafts, is very difficult due to inaccessibility, absence of any forest road, natural obstacles and lack of logistic infrastructures. The stilt root/pneumatophore-infested and muddy forest floor prevents any transect survey. Hence, the field study was conducted with help of the stationed and mobile FD staff, who are engaged in regular patrolling and monitoring. Direct (sighting) observations with binoculars were made to identify the habitats with surviving species. In addition, the indirect methods (identifying the animal signs, roars, calls, nests, pellets and others) were also followed in the pre-selected accessible niches.

Both up- and down-stream surveys were carried out by using a mechanized boat at a speed of 1.5-3 km/h along the rivers and creeks from 5:30 h to 19:00 h with a break during mid-day. Observations were made

from both the front and back of this vessel with a binocular. The boat-survey was, however, suspended at night due to poor visibility and security-risk. At night, observations were made from the wire-caged watch towers by using a search light.

CHAPTER 3
ECOLOGICAL RESOURCES AND BIODIVERSITY CONSERVATION

Ecosystems

There are two types of ecosystems in the Sundarbans- terrestrial and aquatic. The coastal and estuarine forest ecosystem is different from the vegetation of mainland forests. Here, the soil is saline. As salinity increases coastward in the tidal and subtidal areas, there is a transition of dense mangrove vegetation. The soil of Sundarbans is also very muddy. So, it is not suitable for air circulation. So, the branch roots of the plants of this region grow erect and spread along the upper layer of the soil instead of inward penetration. Root tips of these plants bear numerous spores through which atmospheric oxygen enters into the plant body for respiration. They are the producers in this ecosystem. Insects, birds, deer, etc. are primary consumers. Jackals, turtles, cranes etc. are secondary consumers. Tiger, hogs, etc. are among the tertiary consumers. Among them, hogs are omnivorous and now the tigers are opportunistic omnivores (Mallick, 2015).

The aquatic (flowing or stagnant) ecosystem is an ecologically independent and self-regulating unit. The abiotic components like water, dissolved oxygen, carbon dioxide are used directly. Here, the producers are minute floating or suspended small plants, e.g. phytoplanktons. Water weeds, *Eichhornia* etc. are among floating macrophytes. Like minute floating plants, there are also some microscopic zooplanktons like aquatic insects, small fish, mussel snail, etc. which primarily consume the producers. Medium sized fishes, those that survive on eating the primary consumers, are the secondary consumers, whereas the big fish, stork etc. who eat secondary consumers are called tertiary consumers. Bacteria, fungi, etc. decompose the dead organisms. These decomposed substances are again used by the producers of this aquatic ecosystem.

Habitat and niche

In mangroves, the habitat has many niches, encompassing various physical and environmental conditions. The niche-preferences are broadly