Situation Analysis on
Biodiversity Conservation
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M D Behera
Mohammad Solaiman Haider

Ecosystems for Life: A Bangladesh-India Initiative
Preface

Bangladesh and India share three major river systems: the Ganga, the Brahmaputra and the Meghna. Along with their tributaries, these rivers drain about 1.75 million sq km of land, with an average runoff of 1,200 cu km. The GBM system also supports over 620 million people. Thus, the need for cooperation on trans-boundary waters is crucial to the future well-being of these millions.

That is precisely the motivation for the Ecosystems for Life: A Bangladesh- India Initiative (Dialogue for Sustainable Management of Trans-boundary Water Regimes in South Asia) project. IUCN wishes to promote a better understanding of trans-boundary ecosystems between Bangladesh and India, by involving civil society in both countries and by providing a platform to discuss issues common and germane to the region. The overall goal is an improved, integrated management of trans-boundary water regimes in South Asia. The Ecosystems for Life is guided by a Project Advisory Committee (PAC) of eminent persons from Bangladesh and India. This four-and-a-half year initiative is supported by the Minister for European Affairs and International Cooperation, the Netherlands.

Ecosystems for Life will develop, through dialogue and research, longer-term relationships between various stakeholder groups within and between the countries. It will develop a common understanding to generate policy options on how to develop and manage natural resources sustainably such that livelihoods and water and food security improve. Inter-disciplinary research studies will be conducted by bringing together experts from various fields from both countries so that relevant issues are holistically grasped.

The initiative centres around five broad thematic areas:
- food security, water productivity and poverty;
- impacts of climate change;
- inland navigation;
- environmental security; and
- biodiversity conservation.

The first phase of the project concentrated on creating 'situation analyses' on each thematic area. Each analysis set identified core issues vis-a-vis a thematic area, their significance within the India-Bangladesh geographic focus, research gaps and needs and, ultimately, priority areas for joint research.

Studies were taken up in the later part of 2010 and early 2011. Authors discussed their points-of-view at a joint exercise; they shared their research. After due PAC review, the ensuing material was further circulated among multiple stakeholders in both countries. All outcomes of this dialogic process are incorporated in the final papers. 16 situation analyses related to the five thematic areas are now complete and ready for publication. We will also subsequently publish summary briefs, based on these studies. The initiative, thus, has taken a big step; now, the agenda for meaningful joint research is clear.

IUCN hopes these publications will be useful to academics, researchers and practitioners in the GBM region.
The Ganga-Brahmaputra-Meghna (GBM) region

<table>
<thead>
<tr>
<th>River</th>
<th>Ganga</th>
<th>Brahmaputra</th>
<th>Meghna</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length(^1) (km)</td>
<td>2,510</td>
<td>2,900</td>
<td>210</td>
</tr>
<tr>
<td>Catchment(^2) (sq km)</td>
<td>10,87,300</td>
<td>5,52,000</td>
<td>82,000</td>
</tr>
</tbody>
</table>

Total area of GBM region: 17,21,300 sq km

Source: 1. Average, based on various data; 2. Joint River Commission figures
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Conservation challenges in the Sundarban

M D Behera

The Sundarban delta region, the area under analysis, experiences a tropical to sub-tropical monsoonal climate. Rivers carrying an enormous amount of sediments contribute to its ecological dynamism. Salinity and the hydrological gradient vary from west to east and from north to south respectively. Regulated river flow by a series of dams, barrages and embankments that divert water upstream for various human needs and for flood control has reduced freshwater inflow, increasing salinity and changing the sedimentation load, so seriously affecting biodiversity downstream. Human population increase adds to the pressure.

Since the study site comprises distinct ecosystems that intersect and overlap, it would be best to dis-aggregate their biophysical characteristics. We begin with the river Hooghly estuary. The Hooghly estuary is shallow, depth averaging 6 m. The river Hooghly is a part of the Ganga system and serves as a navigable waterway to Haldia and Kolkata ports. The tidal effect is noticeable in the river up to nearly 200 km from the mouth at Sagar Island. Shallow depth and intense tidal mixing ensure the Hooghly estuary is a well-mixed type and vertically homogeneous throughout the year, except for a short period during the southwest monsoon season (June-September), when the estuary is partially stratified due to high freshwater discharge (Cole and Vaidyaraman, 1966). The large tidal variations, irregular coastal geometry, the presence of islands and navigational channels separated by shallow zones make the flow quite complicated.

Salinity intrusion is confined to 70 km from the mouth even during the dry season. The tidal variation at the mouth is from 6.1 m at springs to 0.22 m at neaps. Freshwater discharge ranges from a peak value of 4,250 cubic metres per second to almost zero in the dry season. Average freshwater discharge is 3,000 cu m/sec during the monsoon and 1,000 cu m/sec in the dry season (November-May). Normally, freshwater discharges are regulated by the Farakka barrage, to maintain water levels at Kolkata (Hussain and Acharya, 1994).

The plankton density of the freshwater zone of the Hooghly estuary ranges 34-1,204 units per litre. Of this, phytoplankton form 70.9-89.2%; the rest are zooplankton. Total plankton production here varies from 26-935 u/l. In the lower stretch of the Ganga, Bacillariophyceae followed by
Cyanophyceae and Chlorophyceae are the dominant forms. In the estuarine stretch, the population of periphyton is lower than in the freshwater stretch. *Rana* is widely distributed: *R. limnocharis*, *R. tigrina* and *R. cyanophlyctes* are recorded in the river’s lower stretch (Gopal and Chauhan 2006).

The study site falls in the Ganga-Brahmaputra system, which has the third highest average discharge of the world’s rivers, at about 1,086,500 cu ft/sec or 30,770 cu m/sec. The rivers’ combined suspended sediment load of about 1.84 billion tons per year is the world’s highest (Islam and Gnauck, 2008). The rivers are crucial to the socio-economy of the co-basin countries and possess vast economic potential for irrigation, power generation, industrial development, fisheries and navigation. The direct linkage between the dry season flows in the rivers and salinity ingress is a matter of concern in the lower Ganga basin.

A large chunk of the study site also forms part of a riparian ecosystem: long strips of vegetation adjacent to streams, rivers, lakes, reservoirs and other inland aquatic systems that affect or are affected by the presence of water. There are continuous interactions between aquatic and upland terrestrial ecosystems characterized by their high diversity, density and productivity. They serve as important natural bio-filters, protect aquatic environments from excessive sedimentation, polluted surface runoff and erosion and supply shelter and food for many aquatic species. The riparian zones also provide wildlife habitat, enabling aquatic and riparian organisms to move along river systems, so avoiding isolation. Salination of soils in lower riparian areas due to reduced flows by upstream diversion is an issue not yet fully appreciated in discussions about water-sharing.

Co-evally, the region accommodates many wetlands, of which east Kolkata and the Sundarban are noteworthy. It is bracketed by the river Hooghly on the west and the Kulti Gong on the east. There are 30 genera of phytoplankton; of these, Myxophyceae, Chlorophyceae and Bacillariophyceae contain 11, 12, and 7 genera respectively. Several economically important wetland plant resources are in use as medicine, paper pulp, vegetables, food for water fowl, green manure and compost.

The Sundarban, some 10,000 sq km of land and water, is part of the world’s largest delta—80,000 sq km—formed from sediments deposited by the Ganga, the Brahmaputra and the Meghna, all converging on the Bengal basin (Seidensticker and Hai, 1983). The Sundarban is classified as a wetland of international importance under the Ramsar convention. The land is moulded by tidal action, resulting in a distinctive physiography. Rivers tend to be long and straight as a consequence of the strong tidal forces as well as the clay and silt deposits that resist erosion.

Several species in the Indian Sundarban do not occur in the Bangladesh part, whereas many other species have been reported from Bangladesh alone (Choudhury, 1968; Ismail, 1990). Interestingly, some species listed earlier from Bangladesh (Prain, 1903; Choudhury, 1968), such as *Bruguiera sexangula*, *Rhizophora apiculata* and *Sonneratia alba*, were not recorded later (Chaffey et al., 1985), indicating these species may have disappeared from the eastern part of the Sundarban. *Heritiera fomes*, locally known as Sundari, the most important timber species from which the Sundarban derives its name, is abundant on the Bangladesh side but is not common on the Indian side, where it is considered endangered. The mammalian diversity exhibits significant differences between the Indian and Bangladesh sides of the Sundarban: the former has only 31 species of mammals (Chaudhuri and Choudhury, 1994; Sanyal, 1999); the latter, 49 species (Hussain and Acharya, 1994). At least five species, namely the Javan rhinoceros (*Rhinoceros sondaicus*), water buffalo (*Bubalus bubalis*), swamp deer (*Cervus duvauceli*), gaur (*Bos frontalis*) and probably the hog deer (*Axis porcinus*) have disappeared locally in the past century (Seidensticker and Hai, 1983). The one-horned rhino (*Rhinoceros unicornis*), Indian bison (*Bos gaurus*) and Sambhar (*Cervus unicolor*), once common, are also now locally extinct.
A floodplain ecosystem also exists here, serving as a good linkage between forests and the region's people. The land adjacent to a stream or river gets flooded during periods of high discharge; wetting of the floodplain soil releases an immediate surge of nutrients. They entail greater value to society and that value will rise immensely in the coming decades, as water will become the most critical natural resource in the trans-boundary region. Here, the coastal floodplains are especially significant. They represent the last place for substantial sediment trapping and biogeochemical amelioration of contaminants before water enters the critical estuarine habitats. The coastal ecosystem accommodates a greater number of species. The high degree of connectivity in marine and coastal communities is responsible for generally lower levels of endemism; however, knowledge relating to marine species distribution in this region is still insufficient for a detailed analysis of patterns for most groups. Therefore, a functioning coastal floodplain ecosystem is critical to water quality and quantity in the future, as well as to biodiversity and other ecological-economic values.

Physiography apart, there are socio-economic dimensions to the study site critical to any biodiversity conservation initiative. The area outside the reserve forest—54 islands, home to about 4 million people—is the human face of the Sundarban (Gopal and Chauhan, 2006). Habitation in the Sundarban started even before the islands fully emerged through the siltation of rivers. Historically, the islands were occupied by migrants/refugees from several parts of India and Bangladesh. The human face of the Sundarban epitomises abject poverty, deprivation and acute suffering. Due to harsh geographical challenges, the islanders struggle to survive on subsistence-level returns from diminishing natural endowments. Almost all of them depend on rain-fed/mono-crop agriculture, the forest for forest products and the rivers/estuaries for fishing; these hardly provide adequate support to households in terms of income and employment. A significant proportion of the women living adjacent to the rivers and rivulets of the Sundarban engages in spawn fishing, primarily to meet demand for spawn in neighbouring fisheries. This has a high occupational risk; women may and do fall prey to crocodiles and small sharks while collecting the spawn. Symptoms of serious ecological damage are (1) extinction of many indigenous varieties of fish, abundant a few decades ago: in collecting the seeds, the women (unknowingly) destroy many other aquatic lives; (2) dwindling catch of shrimp spawn over the years, due to indiscriminate collection; and (3) damaging the mangrove vegetation while fishing and the consequent erosion of the embankments.

The extent of poverty can also be gauged by the fact that a little less than half of the population, 47%, belongs to historically marginalised groups such as Scheduled Castes and Scheduled Tribes; about 55% of the farming community are landless labourers. About 21% of the Sundarban population in the working age group of 15-59 years earn from agriculture and about 2% are involved in fishing, honey collection and wood-cutting. Around 57% of people have attained only primary level of education and 5% have secondary or above level of education. A large portion of the population, 22%, is still illiterate (Gopal and Chauhan, 2006).

*The Sundarban is a mesh of ecosystems. It is important to know its physiography. But that is not enough. Conservation here has socio-economic dimensions: about 4 million people, very poor, also live here.*
The suffering face of the Sundarban is perpetuated by poor physical infrastructure. There are only 42 km of railway lines and about 300 km of metal roads in the entire area of about 4,500 sq km, almost half of which are inaccessible in the monsoons. Due to inaccessibility, most of the inhabited areas still do not have conventional electric supply. Ironically, the area which is surrounded only by water chronically suffers from lack of safe drinking water, since the river water is salty and of no use for drinking. The system of earthen embankments, which covers 3,500 km and was built mostly by the settlers to protect themselves from floods, is conspicuously fragile against the tidal actions which undercut the banks and often cause them to collapse (Hussain and Acharya, 1994).

The people of the Sundarban, particularly children below five years, are three times more vulnerable to respiratory ailments than the rest. All types of communicable diseases, primarily related to respiratory and gastrointestinal systems, are highly prevalent here. Arsenic is found in many of the blocks where the groundwater is highly contaminated. About 30 persons fall prey to animal attacks every year during fishing, collecting wood or honey and wax. About half (52%) of the children below five years suffer from malnutrition, directly attributable to chronic poverty and food insecurity (FHS, 2010).

Current state of knowledge

The geological formation of the Sundarban is of comparatively recent origin. Tectonic movements in the northwestern Punjab and the south-eastern flow of the river Ganga, along with other geomorphological changes since the tertiary period, resulted in the deposition of sediments in the Bengal basin and the development of the Sundarban delta (Wadia, 1961). Alluvial deposits are geologically very recent and deep. The monsoon rains, flooding, delta formation and tidal influence combine in the Sundarban to form a dynamic landscape. It harbours biodiversity and that can be attributed to spatial and temporal variability in hydrological regimes, topography and texture of the substratum, salinity and their interactions.

It is estimated that the whole of the Sundarban originally covered more than 40,000 sq km in coastal Bengal, nearly four times that of the present. The then Turk sultan rulers of Bengal first started clearing of the forest for rice farming, followed by the British administration. Today, about 4 million people live in hundreds of small villages very close to or within parts of the Sundarban, on which a very large number of people depend for their livelihood at certain times of the year.

The key to biodiversity conservation in the Sundarban region, therefore, hinges upon how efficiently the limited freshwater resources can be managed to meet both human and environmental needs, along with effective adaptive responses to the added threats from climate change.

Faunal diversity

The faunal diversity of the Sundarban is very rich, having higher economic importance. Crustaceans that include fiddler crabs, mud crabs, shrimps, prawns and lobsters are a major part of the animal biomass. In the Indian Sundarban, arthropods are the most abundant invertebrates (476 species), comprised almost entirely of crustaceans (240 species) and insects (201 species). Molluscs (143 species), annelids (78 species) and nematodes (68 species) are the next most common groups of invertebrates, other than 104 species of protozoans (Chaudhuri and Choudhury, 1994). The Indian Sundarban supports 165 species of fish (Sanyal, 1999); the fish diversity mainly depends on the salinity gradients in its different parts. The dominant fish in brackish water zones, of moderate salinity, are *Hilsa* (*Tenualosa*,or *illish*), *Pomadasys hasta*, *Polynemus* sp. and *Coilia* sp.
Among 14 turtle and tortoise species, six are nearly extinct or threatened (see Table 1). Of the four marine turtle species, the olive ridley turtle (*Lepidochelys olivacea*), though endangered, is the most abundant. The green turtle (*Chelonia mydas*) is rare due to excessive fishing, while the loggerhead (*Caretta caretta*) and hawksbill (*Eretmochelys imbricata*) are not common (Hussain and Acharya, 1994). Overall, 8 and 7 species of amphibians and 53 and 59 species of reptiles have been found in Bangladesh and India, respectively (Hussain and Acharya, 1994; Sanyal, 1999; Naskar *et al.*, 2004). The avifauna of the Sundarban is highly varied and very rich: more than 300 species exist of which about 100 are migratory (Chaudhuri and Choudhury, 1994). Several species of kingfishers, herons, waders, fish eagles and storks are abundant.

The hunting of tigers was banned completely in 1970, after the IUCN listed the Bengal tiger (*Panthera tigris tigris*) as an endangered species. Later, under Project Tiger, the government of India established a Tiger Reserve in the Sundarban covering 2,585 sq km in 1973. A wildlife sanctuary was established in 1976 on Haliday Island (595 ha) to protect the spotted deer (*Axis axis*), wild boar (*Sus scrofa*) and rhesus macaque (*Macaca mulatta*), which are dominant animals in a forest type consisting mainly of *Ceriops decandra*. The only primate here is the rhesus macaque (*Macaca mulatta*) which still occurs in good numbers, but its population is declining gradually (Blower, 1985; Gittins, 1981).

**Table 1: Threatened fauna of Sundarbans**

<table>
<thead>
<tr>
<th>Family</th>
<th>Scientific Name</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mammalia</td>
<td><em>Muntjanus muntjack</em></td>
<td>Barking Deer</td>
</tr>
<tr>
<td></td>
<td><em>Panthera tigris tigris</em></td>
<td>Royal Bengal Tiger</td>
</tr>
<tr>
<td></td>
<td><em>Felis bengalensis</em></td>
<td>Leopard Cat</td>
</tr>
<tr>
<td></td>
<td><em>Felis viverrina</em></td>
<td>Fishing Cat</td>
</tr>
<tr>
<td></td>
<td><em>Platinista gangetica</em></td>
<td>Gangetic Dolphin</td>
</tr>
<tr>
<td></td>
<td><em>Orcaela brevirostris</em></td>
<td>Irrawady Dolphin</td>
</tr>
<tr>
<td></td>
<td><em>Neophocaena phocaenoides</em></td>
<td>Little Indian Porpoise</td>
</tr>
<tr>
<td></td>
<td><em>Manis pentadactyla</em></td>
<td>Chinese Pangolin</td>
</tr>
<tr>
<td>Reptilia</td>
<td><em>Crocodylus porosus</em></td>
<td>Estuarine Crocodile</td>
</tr>
<tr>
<td></td>
<td><em>Lepidochelys olivacea</em></td>
<td>Olive Ridley Turtle</td>
</tr>
<tr>
<td></td>
<td><em>Batagur baska</em></td>
<td>Batagur Turtle</td>
</tr>
<tr>
<td></td>
<td><em>Lissemys punctata</em></td>
<td>Indian Flapshelled Turtle</td>
</tr>
<tr>
<td></td>
<td><em>Trionyx gangeticus</em></td>
<td>Indian Softshelled Turtle</td>
</tr>
<tr>
<td></td>
<td><em>Kachuga tecta</em></td>
<td>Indian Tent Turtle</td>
</tr>
<tr>
<td></td>
<td><em>Varanus bengalensis</em></td>
<td>Common Indian Monitor</td>
</tr>
<tr>
<td></td>
<td><em>Varanus fl avescens</em></td>
<td>Yellow Monitor</td>
</tr>
<tr>
<td></td>
<td><em>Varanus salvator</em></td>
<td>Water Monitor</td>
</tr>
<tr>
<td></td>
<td><em>Python morulus</em></td>
<td>Indian Rock Python</td>
</tr>
<tr>
<td>Aves</td>
<td><em>Ardea goliath</em></td>
<td>Great Goliath Heron</td>
</tr>
<tr>
<td></td>
<td><em>Pelecanus philippensis</em></td>
<td>Dalmatian Pelican</td>
</tr>
<tr>
<td></td>
<td><em>Leptotilos duius</em></td>
<td>Lesser Adjutant Stork</td>
</tr>
</tbody>
</table>

Source: Gopal and Chauhan, 2006
Besides three species of otters, there are wild cats (*Felis bengalensis*, *F. chaus* and *F. viverrina*). The Gangetic dolphin (*Platanista gangetica gangetica*), too, is found in the GBM river system in India. In the 19th century, these dolphins were abundant in the entire distributitional range, but its range and abundance has sharply declined. IUCN has marked it as endangered because its population has declined 50% and because the factors causing the decline (entanglement in fishing gear, diversion of water, pollution and fragmentation of habitat) are still present.

**Floral diversity**

In the Indian side, the total vascular flora (including mangrove associates) is estimated at 100 species, representing 34 families and 57 genera which comprise 30 species of trees, 32 shrubs, the rest being herbs, grasses, sedges and two species of fern. 36 species have been identified as true mangroves (Debnath and Naskar, 1999). Based on their present status, *Aegiceras corniculatum*, *Kandelia candel*, *Rhizophora sp.*, *Sonneratia acida*, *Sonneratia apetala* and *Sonneratia caseolaris* also require conservation measures (see Table 2).

The members of Rhizophoraceae and Avicenniaceae generally dominate in the Indian part, whereas the greatest abundance of Sterculiaceae (*Heritiera*) and Euphorbiaceae (*Excoecaria*) is found in the Bangladesh part. The Sundarban has a highly diverse algal flora comprised of both benthic and planktonic forms ranging from the freshwater to marine environments. Eighty species of algae (32 Cyanophyceae and 27 Chlorophyceae) have been recorded from different parts of the Indian Sundarban including seven species of diatoms (Sen et al., 1999). The diversity of bacteria and

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhizophoraceae</td>
<td><em>Rhizophora apiculata</em></td>
<td>Occasional</td>
</tr>
<tr>
<td></td>
<td><em>Bruguiera parviflora</em></td>
<td>Occasional</td>
</tr>
<tr>
<td></td>
<td><em>Ceriops decandra</em></td>
<td>Occasional</td>
</tr>
<tr>
<td></td>
<td><em>Kandelia candel</em></td>
<td>Occasional</td>
</tr>
<tr>
<td>Meliaceae</td>
<td><em>Aglaia cucullata</em></td>
<td>Rare</td>
</tr>
<tr>
<td></td>
<td><em>Xylocarpus mekongensis</em></td>
<td>Threatened</td>
</tr>
<tr>
<td></td>
<td><em>Xylocarpus granatum</em></td>
<td>Threatened</td>
</tr>
<tr>
<td>Sterculiaceae</td>
<td><em>Heritiera fomes</em></td>
<td>Threatened</td>
</tr>
<tr>
<td>Rubiaceae</td>
<td><em>Scyphiphora hydroidphyllacea</em></td>
<td>Very Rare</td>
</tr>
<tr>
<td></td>
<td><em>Hydrophyllax maritime</em></td>
<td>Very Rare</td>
</tr>
<tr>
<td>Tiliaceae</td>
<td><em>Brownlowia lanceolata</em></td>
<td>Occasional</td>
</tr>
<tr>
<td>Arecaceae</td>
<td><em>Nypa fruticans</em></td>
<td>Occasional</td>
</tr>
<tr>
<td>Acanthaceae</td>
<td><em>Acanthus volubilis</em></td>
<td>Very Rare</td>
</tr>
<tr>
<td>Papilionaceae</td>
<td><em>Cynometra ramiflora</em></td>
<td>Rare</td>
</tr>
<tr>
<td></td>
<td><em>Dalbergia spinosa</em></td>
<td>Rare</td>
</tr>
<tr>
<td>Sapotaceae</td>
<td><em>Manilkara hexandra</em></td>
<td>Rare</td>
</tr>
<tr>
<td>Rutaceae</td>
<td><em>Atalantia correa</em></td>
<td>Very Rare</td>
</tr>
</tbody>
</table>

Source: Gopal and Chauhan, 2006
fungi in the Sundarban has not been examined in detail, although some reports mention various microorganisms in the soils and on decomposing litter, besides pathogens. Furthermore, 32 species of lichens have also been recorded from the Indian Sundarban (Santra, 1998).

Both under threat
A number of species like the Javan rhinoceros (*Rhinoceros sondaicus*), water buffalo (*Bubalus bubalis*), swamp deer (*Cervus duvauceli*), Guar (*Bos gaurus*), hog deer (*Axix porcinus*) and marsh crocodile (*Crocodiles palustric*) became extinct during the last 100 years in the Sundarban. Oil spills are another recent potential threat and could cause immense damage, especially to aquatic fauna and seabirds and also to the mangrove forest biodiversity.

Conservation of the Sundarban mangrove is supposed to have started with its declaration as a reserve forest, under the Indian Forest Act in 1878, after Schlich in 1875 raised concern over its conservation (Presler, 1991). But today, the yearly natural calamity, global warming and its impacts are new challenging threats for coastal food security and biodiversity. Siltation has increased and sediment trapping has been aided by pneumatophores and dense roots of mangroves. The dominant species of Sundari (*Heritiera fomes*) and Goran (*Cariops decandra*) are affected by top-dying disease. Almost 265 km of *Heritiera*-type forest are moderately affected and 210 km severely affected; this is one of the main threats for a sustainable mangrove wetland management and the protection of its ecosystems (Islam and Gnauck, 2009). According to fish landing data, the *Hilsa* catch in the river Ganga has been reduced by more than 50% within 15 years. Local people have also started catching juvenile *Hilsa* which are hardly 3-4 inches in length.

Connecting biodiversity conservation to development trajectories

The strategy for biodiversity conservation involves setting aside areas where the entire life cycle needs of a community can be met and the ecological needs of wildlife can be linked into the overall management of the system for the Sunderban. The ecological processes upon which wildlife depend become integral values in the management matrix.

Downstream flow and its impact
After the construction of the Farakka barrage on the Ganga river in India and water withdrawal at Farakka barrage as well as other places for irrigation purposes in the lean season, a low quantity of water is received downstream. There is massive devastation in Malda on its upstream and Murshidabad on its downstream in West Bengal in India (Banerjee, 1999). Huge sedimentation, increasing flood intensity, bank failure and avulsion of the river are some of its impacts. These have resulted in population displacement, impoverisation and marginalization of rural people living by the river side. A comparison of salinity intrusion in 1967-68 showed increase in riverwater salinity downstream. Considering the value of water salinity of the Sundarban, the eastern zone still offers suitable conditions for mangrove ecosystems; the middle area is rapidly turning from middle saline zone to high saline zone and the south-western region, carrying the highest rate of water salinity, can be more harmful for sensitive mangrove plants and animals. Therefore, increased salinity and alkalinity has damaged vegetation and agricultural cropping systems and changed the cultural landscape. The impact on soil starts with the destruction of surface organic matter and of soil fertility for mangrove plant production. The changes alter basic soil characteristics related to aeration, temperature, moisture and the organisms that live in the soil (Islam and Gnauck, 2009).
The lower Ganga basin contains an active delta and a moribund delta; both are affected by enormous flood flows in the Ganga, relentless tidal pressures from the sea and occasional severe cyclonic storms capable of disrupting environmental systems. The major environmental issues associated with population factors include (1) increasing demands on natural resources from developmental activities; (2) inward penetration of higher salinity levels; (3) spread of waterborne diseases due to extensive embankment of former waterbodies; (4) water and soil pollution; (4) decline in fisheries; and (6) the excessive felling of the Sundarban forest.

Problems related to the trans-boundary water regime
Current trends show that the occurrence of floods over the last century has increased dramatically and experts predict the trend will continue in part due to the increasing hydrological variability associated with climate change. The problems associated with water-related disaster exacerbate human suffering through increased risk of water-borne disease epidemics, contaminated water supplies, as well as destruction of agricultural crops and homes.

Conserving H Fomes
The palynological evidence clearly shows that *Heritiera fomes* was very abundant in the western parts of the Sundarban 5,000 years ago, and has declined relatively recently as the salinity has increased (Blasco, 1975; Rahman, 1990). As a long-term consequence *Heritiera* is being replaced by *Excoecaria* (Christensen, 1984). In general, the forest structure is becoming simpler and the average height of the trees is decreasing. This also causes a decline in the habitat for birds, monkeys and other tree-dwelling species. Therefore, The Sundari trees need to be conserved as 'keystone species': with their conservation numerous other organisms can be conserved simultaneously.

The climate change problem
The large spatial and temporal variability in hydrological regimes (freshwater inflows and tides), topography and texture of the substratum, salinity and interactions between these result in very high habitat heterogeneity in the mangrove ecosystems, thereby ensuring an equally diverse biodiversity. The links between biodiversity and climate change run both ways: biodiversity is threatened by climate change, but proper management of biodiversity can reduce the impacts of climate change. The millennium ecosystem assessment ranks climate change among the main direct drivers affecting ecosystems. Consequences of climate change on the species component of biodiversity include changes in distribution, increased extinction rates, changes in reproduction timings and changes in length of growing seasons for plants. Some species that are already threatened are particularly vulnerable to climate change. Potential impacts of climate change and sea level rise on coastal ecosystems include increased coastal erosion, more extensive coastal flooding, higher storm surge

*Sea level rise will affect mangroves by changing or destroying their habitat and creating new areas to which some species may shift. If sea level rise is 1 metre, the Sundarban will be completely lost*
flooding, landward intrusion of seawater in estuaries and aquifers, higher sea-surface temperatures and reduced sea-ice cover. These changes are likely to affect species’ composition and distribution.

Sea level rise will affect mangroves by eliminating or modifying their present habitats and creating new tidally inundated areas to which some mangrove species may shift (IPCC 2001). Hardy species like *Avicennia sp* can recolonise the area fast but this is not true in case of the species of genus *Rhizophora, Ceriops, Sonneratia* and *Aegiceras* and *Heretia* sp., for they are unable to recover from the effect in a short period of time. Based on evidence and study of mangroves in other parts of the world, the likely impact on mangroves at different rate of sea level rise may vary as follows:

- **Low rate of sea level rise:** Existing mangroves can keep pace with a relative sea level rise of 8-9 cm per 100 years. A few species will be highly vulnerable in deltaic mangroves but many species will be threatened on islands. Mangroves in high latitude may gain in some areas.

- **Medium rate of sea level rise:** Mangroves would be under stress, especially islands with a relative sea level rise of 9-12 cm per 100 years. Substantial number of species will be vulnerable and majority of the species on island may face high risk of extinction. Impact may be less in the subtropical region.

- **High rate of sea level rise:** Mangroves cannot persist as expansive areas with a relative sea level rise of above 12 cm per 100 years. Loss of species would be very high in a short period in the tropical region, especially on islands. Total devastation may take place in the mangrove areas.

The Sundarban will be completely lost with 1 m sea level rise (World Bank, 2000).

The loss will mean a great loss of heritage, biodiversity, fish resources, livelihoods and—overall—the loss of a very high productive ecosystem. The resilience of ecosystems can be enhanced and the risk of damage to human and natural ecosystems reduced through the adoption of biodiversity-based adaptive and mitigative strategies. These include (1) maintaining and restoring native ecosystems (2) protecting and enhancing ecosystem services, (3) managing habitats for endangered species (4) creating refuges and buffer zones and (5) establishing networks of terrestrial, freshwater and marine protected areas that take into account projected changes in climate.

**Land use, land cover change and population growth**

It is estimated the Sundarban originally covered about 40,000 sq km. Clearing the forest for rice agriculture was first actively promoted by the Turk sultan rulers of Bengal. After the British colonised Bengal, the Sundarban still included 14,627 sq km of land and 4,881 sq km of waterways in 1793 (Richard, 1990). The British administration also actively promoted deliberate conversion to agriculture. At the end of the 18th century, the then governor of Bengal imposed a rule bringing the forest outside permanent settlements under government control (Hunter, 1875). The commissioner for the Sundarban was charged with the task of regulating and managing the waterlogged forests and swamps of the lower delta and to ensure that private land owners cleared, settled and reclaimed the Sundarban forests and swamps for rice cultivation (Richards, 1990). By 1870, 2,790 sq km of mangroves had been cleared. Another 2,750 sq km forests had been reclaimed within the next sixty years even though about 10,000 sq km of mangroves were declared a protected or reserve forest. The protected forests were available for clearance on leasing, while timber extraction was allowed in the reserve forests. It is estimated that 1,570 sq km mangroves were reclaimed in the three decades since independence in 1947 (Richards, 1990).

Thus major threats to biodiversity have come mainly from the growing human population, and consequently, over-exploitation of both timber and fauna, and conversion of the cleared land to agriculture and aquaculture.
Great threat to a great forest

Mangrove forests are one of the most productive and bio-diverse wetlands on earth. Yet, these unique coastal tropical forests are among the most threatened habitats in the world as experts fear they may disappear more quickly than inland tropical rainforests because of lack of public notice. The Sundarbans, too, is no exception. Threats to the Sundarban mangrove eco-system are rising partly due to biotic pressure from the surrounding environment and partly due to human-induced or natural changes in the upper catchments.

They can be summarised as below:

- Anthropogenic impacts like reclamation, human encroachment and influence;
- Recurrent coastal flooding due to climate change (global warming), changes in sea level (rise in sea level);
- Huge silt deposition, biodiversity loss and regeneration problems of obligate mangrove plants;
- High salinity, low water table and acidity problem, loss of soil fertility, coastal erosion and a steep fall in fishery resources;
- Reduction in the periodicity and quantity of freshwater reaching the mangrove environment due to diversion of freshwater in the upstream areas;
- Conversion of mangrove tracts for aquaculture and agriculture, and extension of other non-forestry land use into mangrove forests;
- Increasing demand for timber and fuel wood for consumption;
- Poaching of tiger, spotted deer, wild boar, marine turtles, horse shoe crab and other species;
- Uncontrolled collection of prawn seedlings and fishing in the water of reserve forests;
- Continuous trampling of river/creek banks by fishermen and prawn seed collectors;
- Organizational and infrastructure deficiencies and lack of public awareness.

Further threats to biodiversity because of pollution have arisen on both the landward and seaward sides of the mangrove. Agrochemicals (fertilizers and pesticides) used extensively in the catchments of the Ganga and Brahmaputra rivers and their numerous tributaries, as well in the fields close to the mangroves, pollute both the waterways and the landmass, affecting the aquatic vegetation and fauna directly.

Moreover, toxic products and urban wastes enter the system due to upstream pollution in the huge Ganga catchment. Pollution may not be a direct cause of mortality, but it does reduce the health of the forests, increasing the mortality rate of flora and fauna in the long term. Growing industrialization of areas contribute significantly to the pollution load and, hence, to the degradation of the Sundarbans mangroves. From the seaward side, major pollution occurs through oil spills that cause great damage, especially to the aquatic fauna and sea birds.

At present, trials with all the commercially important plant species are being carried out with the objective of accelerating the process of siltation and stabilization of soil, creating forest shelterbelts to protect life and property inland from tidal bores, creating an urgently needed resource to add to the national wealth, creating job opportunities for the rural communities and creating an environment for wildlife, fishes and other estuarine and marine fauna.

Ultimately, the future of the Sundarban mangroves hinges upon the efficiency of managing the limited freshwater resources for meeting both human and environmental needs, coupled with effective adaptive responses to the added threats from climate change. However, the future sustainability of the Sundarban will be contingent upon the political will of the governments of India and Bangladesh and continued support from the International agencies in respect to protect this unique wildlife feature of the world.
Priority areas for joint research

Assessment and Modelling of land use and land cover change (LULCC) in the Ganga river basin with respect to climatic and socio-economic drivers using geospatial tools

As evident from the above discussion, the conversion of forest for agriculture has occurred at a large scale, though efforts have been made and are also being made for restoration of forests. The shrinkage of riverine and floodplain space, as a result of conversion for agricultural purposes, needs to be reversed on the basis of sustainable ecological principle. Satellite derived LULC mapping and analysis at periodic interval since 1970s would provide a clear picture of the drivers responsible; and thereby would be helpful in providing restoration measures.

Study on pattern and (habitat) distribution of H. fomes and its top-dying disease

H. fomes (Sundari) trees show symptoms from the top of the main stem of the affected plant and gradual progression of the symptoms downward. Unlike the dieback symptoms of other trees, top-dying Sundari trees do not show epichromic branches and formation of new leaves from the immediate lower part of the affected areas of the main stem. The affected plant looks like a leafless bald-headed one, distinguishable from the other healthy ones. This symptom is often associated with one or more swellings on the diseased stem in the form of knots. Almost all parts of the Sundarbans are affected by the disease in various degrees. Different investigators consider the following factors to be responsible for the incidence of the top-dying disease:

- Increase in salinity of soil and water and decrease in flow of freshwater from the upstream;
- Increase in siltation in the banks of the rivers and channels;
- Decrease in mineral nutrients in the forest floor; and
- Attack by insect pests at the top of the plant or fungal/microbial infection at the root region. It has been reported that the frequency of top-dying affected trees are greater at the bank of rivers, canals and creeks.

Satellite image-based monitoring should be done to study the distribution pattern of the keystone species and its associates. Attempt should also be made to map the area of disease-infested species distribution and study the trend at regular intervals, as it should be possible using very higher resolution data with limited ground visit.

Study on pattern and (habitat) distribution of Hilsa fish

The migratory routes of Hilsa between the estuary and the river are believed to have been disrupted by the Farakka barrage. A special study (Sinha et al., 1996) found that observations are consistent with the fish moving into coastal waters in March and progressing into the lower estuary of the river.

We must map how much the Sundari tree, a flagship, is affected by top-dying disease. Also, how can we go on disrupting the migration of Hilsa fish, another flagship species? The key to conservation here is managing limited freshwater resources.
Padma in July to November. Further movement towards upstream appear to occur from October to May. However *Hilsa* contributes to 1% and 0.6% of the fish catch at Patna and Allahabad respectively. Thus habitat suitability, including water quality monitoring, study is proposed to understand the details regarding this flagship species.

**Modelling biodiversity vis-à-vis climate change/extreme weather events**

There is significant interest and research focus on the phenomenon of recent anthropogenic climate changes. Focus is on identifying the current impacts of climate change on biodiversity and predicting these effects into the future. Changes in long-term environmental conditions that can be collectively coined climate change are known to have had enormous impacts on plant diversity patterns in the past and are seen as having significant current impacts. It is predicted that climate change will remain one of the major drivers of biodiversity patterns in the future.

It is proposed that long-term observation and monitoring study be taken up in this region to understand the critical relationship between biodiversity *vis-à-vis* climate change and/or extreme climate events and vice versa.

**Biodiversity inventory, information and communication using geospatial tools**

There have been numerous studies in bits and parts on various aspects of biodiversity and environment in this region by various researchers/organizations. However, the results of the investigations are available here and there, thereby defeating the very purpose of further utilization and decision-making. The need of the hour is to make the information available in a single platform that is easily accessible. A web-based information system supported by geospatial platform helps in easy access, retrieval, query and modification of both spatial and non-spatial data.

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Core issues of joint research in conserving biodiversity

Mohammad Solaiman Haider

Bangladesh is situated between the Indo-Himalayas and Indo-Chinese sub-regions. The country has a total area of 147,570 sq km. About 80% area comprises one of the largest active deltas of the world, with a flat topography of very low elevations (> 10 metres from mean sea level). This deltaic floodplain is criss-crossed by about 230 rivers, including 57 trans-boundary rivers of which 54 are shared with India and three with Myanmar. The river system that flows through Bangladesh is the third largest source of freshwater discharge to the world’s oceans. The catchments area of the three major rivers system of the Ganga-Brahmaputra-Meghna (GBM) region is about 1.75 million sq km, 92% of which lies outside the country.

Distinct physiographic characteristics, variations in hydrological and climatological conditions and difference in soil properties in Bangladesh as well as in India support a rich diversity of plants and animals. To conserve this huge biological diversity, various international organizations are working with the governments of Bangladesh and India.

Our food and energy security strongly depend on biodiversity and so does our vulnerability to climatic hazards such as cyclonic storms and flooding. Biodiversity loss has negative effects on our health, material wealth and largely limits our freedom of choice. As all cultures gain inspiration from or attach spiritual and religious values to ecosystems or their components—landscapes, trees, hills, rivers or particular species—biodiversity loss also strongly influences our social relations. Increased diversity of genes within species, as represented by livestock breeds or strains of plants for instance, reduces risk from diseases and increases potential to adapt to changing climates. Since Bangladesh and India contain huge biological diversity, both must undertake collective efforts towards its conservation.

The case for conservation is strong in both countries. India possesses most diverse types of habitats for terrestrial, freshwater and marine animals. Among various wildlife found in India, WWF India is working to conserve the gharial (Gavialis gangeticus), the Ganges river dolphin (Platanista gangetica), Great Asian one-horned rhino (Rhinoceros unicornis), smooth-coated otter (Lutra perspicillata), red panda (Ailurus fulgens), snow leopard and whale shark (Rhincodon typus). India has 661 Protected Areas including 100 national parks, 514 wildlife sanctuaries, 43 conservation reserves, 38 tiger reserves and four community reserves.
Bangladesh has 34 nationally designated protected areas comprising 2,70,479 ha, which is 10.72% of the total forest land of the country. These include 15 national parks and 13 wildlife sanctuaries. Moreover, UNESCO designates three wildlife sanctuaries in the Sundarban as World Heritage sites. Sundarban, along with Tanguar Haor, are also designated Ramsar wetland sites of international importance. The objective of such protection is to preserve breeding places and habitats of flora and fauna and to protect communities and ecosystems. The aim is also to maintain natural processes as well as to provide facilities for research, education and recreation.

To begin with, it is difficult to understand the core issues related to biodiversity conservation unless we look at the threats that exist to the integrity of ecosystems here. We will first test the case with mangrove ecosystems.

**Conserving the mangrove ecosystem**

Bangladesh and India together possess the largest chunk of mangrove ecosystems in the world. This common patch of mangrove forest extends from southern West Bengal to the south-eastern part of Bangladesh. These forests contain diverse varieties of plants and animals including viviparous plant

### Map 1: The Sundarban

Source: http://www.preventionweb.net/files/8203_SalinityandMangrove.pdf
species and the Bengal tiger. The Sundarban, which covers about one million ha in the delta of the rivers Ganga, Brahmaputra and Meghna, is shared between Bangladesh (60%) and India (40%), and is the world’s largest coastal wetland. The forest is rich in biodiversity with about 334 species of plants, 270 species of birds, 42 species of mammals and 210 species of fishes, including 32 species of prawns. It is also famous for the natural habitat of a variety of wild animals, the important among them are tigers, deers, wild boars, wild fowls, monkeys, otters, crocodiles, birds, pythons, lizards, amphibians, molluscs, crabs and different varieties of snakes.

Alongside the recorded 42 species of mammals, waders and seabirds find the Sundarban as their suitable habitats and also both marine turtles and the endangered estuarine terrapin, Batagur baska, find it as their suitable nesting site.

The forest is equally rich in epiphytic ferns, parasitic plants and orchids; among the 66 species of orchids found in the forest about 13 are epiphytic. But above all, the Sundarban is home to the Royal Bengal tiger, Panthera tigris, whose population is estimated at 350-600, one of the largest surviving populations in the world.

The Sundarban consists of three wildlife sanctuaries (Sundarban West, East and South) lying on disjunct deltaic islands in the Sundarban Forest Division of Khulna district, close to the border with India and just west of the main outflow of the Ganga, Brahmaputra and Meghna rivers. All three wildlife sanctuaries were established in 1977 under the Bangladesh Wildlife (Preservation) (Amendment) Act, 1974. The Bengal tiger is the magnificent animal of the Sundarban. Four cetacean species have been identified in the mangrove channels, including the endangered Ganges river dolphin and Irrawaddy dolphin (see Map 1).

Research indicates a network of coastal defences, especially a belt of mangroves, is capable of absorbing 30-40% of the total force of a tsunami or typhoon and ensuing waves before they swirl over inhabited areas by the shore. Healthy mangroves not only protect coastal communities from the sea, but they are also profitable ecosystems in themselves. Mangroves act as nurseries for a wide range of species, such as fish and shrimp spawn, which mature in mangrove ecosystems before moving into deep and open water. As such, mangroves play an important role in the ecology that supports artisan fisheries of coastal communities.

**But there are threats**

It would be foolish, indeed fatal, to consider the Sundarban as a pristine set of ecosystems that are unchanging. Beyond the picture created above, the following are considered as the major threats to the mangrove ecosystems:

- Habitat destruction;
- Overexploitation;
- Indiscriminate use of agro-chemicals;
- Oil spills;
- Encroachment into the natural forests;
- Change in land use pattern and land use conflict;
- Indiscriminate hunting;
- Poaching of animals;
- Lack of people’s awareness;
- Poor management of protected areas;
- Inefficient implementation of law for wildlife conservation; and
- Natural calamities (flooding, storm surge).
Another real threat
And now, climate change is a real threat to the mangrove ecosystem and its biodiversity. The rise in sea level and availability of less freshwater, particularly during winter when rainfall will be less, will cause inland intrusion of saline water. As a result many mangrove species, intolerant of increased salinity, may be threatened. In addition, the highly dense human settlements just outside the mangrove area will restrict the migration of the mangroves to less saline area. The shrinking of mangrove areas will affect the economy. Many industries which depend on raw materials from the Sundarbans will be threatened with closure and create large unemployment.

The Sundarbans may be completely inundated by a 1 m rise in sea level. Increase in temperature, too, will seriously affect the Sundarbans’ ecosystem and biodiversity. The area may shrink and many flora and fauna species may face extinction. Water stress during winter and excess water during summer will have effects on the ecosystem and biodiversity. A wide range of mammals, birds, amphibians, reptiles, crustaceans, and above all the Royal Bengal tiger, will face extinction. The ecosystem of the only coral island, St. Martin’s island, may also be affected. The coastal length covered by mangrove forests will be exposed to cyclones and storm surges.

Top-dying of the Sundari tree (Heritiera fomes) and salinity increase due to lack of freshwater flush during the dry months are causing negative effects. Dying originates from excessive salinity in the rivers, together with chemicals foreign ships discharge. The trees have been facing attacks by a virulent disease but nothing effective has been done yet to combat the disease on either side. Due to high evapo-transpiration and low flow in winter, the salinity of the soil will increase. As a result the growth of freshwater-loving species would be severely affected. Eventually the species that offer dense canopy cover will be replaced by non-woody shrubs and bushes, while overall forest productivity will decline significantly. The degradation of forest quality might cause a gradual depletion of the rich diversity of the forest flora and fauna of the Sundarban ecosystem.

In sum, then, the world’s largest stretch of mangrove ecosystems is facing serious threats of loss of biodiversity due to man-made interventions and climate change. The existence of the Bengal tiger, a flagship species of the Sundarbans, is critically endangered. The major threats to the Bengal tiger comprise poaching and habitat destruction. For over thousand years, tigers have been hunted as status symbol, decorative items such as wall and floor covering, as souvenirs and curios and for use in traditional Asian medicines. As tigers continue to lose their habitat and prey species, they are increasingly coming into conflict with humans as they attack domestic animals—and, sometimes, people. In retaliation, tigers are often killed by angry villagers.

Sundarban is home to 300 species of birds and 250 species of fish. The Gangetic River Dolphin (Platanista gangeticus) is common in the rivers. No less than 50 species of reptiles and eight species of amphibians are known to occur. The Sundarban now supports the only population of the estuarine, or salt-water crocodile (Crocodylus parasus) in Bangladesh, and that population is estimated at less than two hundred individuals. The dominant plant of the Sundarban is the Sundari tree which alone constitutes 73% of the total plants and trees. Top-dying of the Sundari tree is seriously degrading the health of mangrove ecosystem. The ecosystem services of the mangrove will be jeopardized if the
present trend continues. If appropriate steps are not taken on time to address the problem of top-dying, the largest mangrove forest of the world might wither away in future.

**Therefore, joint research on the Bengal tiger and top-dying of the Sundari tree are imperatives towards conserving globally precious mangrove ecosystem in this part of the world.**

To this end, the conservation and management planning of the mangrove ecosystem should be based on proper understanding, analysis and assessment of the complex geomorphological, fluvial, oceanic and natural climatic characteristics of the whole area, including the impact of the unnatural influence of human interventions.

Thus the following areas of joint research or study should vigorously be taken into account:

- Monitoring fresh water recharge, river morphology and river flow;
- Monitoring the trend of salinity intrusion;
- Study the threats on the brackish water and intertidal fish species;
- Study towards tiger conservation;
- Monitoring the trends of top-dying of Sundari trees;
- Periodic mapping of Sundarbans mangrove forests has to be carried out using Remote Sensing and GIS technology to monitor the changes or degradation in the ecosystem;
- Research on integrated conservation and management systems of mangroves and aquaculture;
- Public education campaign to make local communities, the tourism industry and other sectors aware of the importance of mangroves.

Now let’s turn to the Bengal tiger, or Royal Bengal tiger (*Panthera tigris tigris*), a subspecies of tiger that really needs our attention. The Bengal tiger is now strictly protected and is the national animal of both India and Bangladesh. But habitat destruction and poaching decrease the numbers of these animals in the wild. As tigers continue to lose their habitat and prey species, they are increasingly coming into conflict with humans as they attack domestic animals and, sometimes, people. In retaliation, tigers are often killed by angry villagers.

Fact is the tiger is the king of the jungle. As top carnivore the tiger sits atop the food pyramid and therefore has large land requirements. In this way it represents thousands of other animals and plants which live in its forest home. If we can save the tiger, we can also save the rest of these creatures and our last surviving forests. To facilitate the best use of limited conservation resources, ecology-based method for identifying priority areas for conservation that incorporates both habitat representation and landscape-level features is very vital. Protected areas cover only small areas of tiger conservation units. If the long-term prospects for tiger conservation are to improve, poaching must be stopped and the conservation effort of the protected areas should be further strengthened.

To enhance landscape integrity, the priority tiger conservation units that straddle international borders should be managed as trans-boundary reserves, giving tiger conservation a stronger regional structure.

### Conserving riverine ecosystems

The Ganga-Brahmaputra-Meghna (GBM) region is made up of the catchment areas of three major river systems that flow through India, Nepal, Bhutan, the Tibet region of China and Bangladesh. This huge system is second only to the Amazon, with an annual discharge of 1,350 billion cubic metres (bcm) and total drainage area of 1.75 million sq km. The Ganga river flows southwest from Gangotri,
turns southeast joining with many major tributaries. After flowing into Bangladesh, the Ganga joins with the Brahmaputra and Meghna rivers to flow into the Bay of Bengal as the Meghna (Padma) river. The GBM river system is a lifeline for a large area of the two countries.

Discharging waste into the river and water flow controlled by various barrages and dams have had severe adverse impacts on the habitat of aquatic animals like the Gangetic dolphin, the gharial and fish biodiversity in general.

**Conserving the Gangetic dolphin’s habitat**
The Ganges river dolphin, or susu, is threatened by removal of river water and siltation arising from deforestation, pollution and entanglement in fishing nets. In addition, alterations to the river due to barrages are also separating populations. A recent survey conducted by WWF-India and its partners in the entire distribution range in the Ganga and Brahmaputra river system—around 6,000 km—identified fewer than 2,000 individuals in India.¹⁹

In Bangladesh and India, individuals live in rivers that flow slowly through the plains. The Ganges river dolphin favours deep pools, eddy counter-currents located downstream of the convergence of rivers and of sharp meanders and upstream and downstream of mid-channel islands. The susu shares its habitat with crocodiles, freshwater turtles and wetland birds, many of which are fish eaters and are potential competitors with dolphins.

**Conserving the Gangetic gharial’s habitat**
The gharial is listed as a critically endangered species by IUCN.²⁰ Gharials were once widely distributed in the large rivers that flow in the northern part of the Indian subcontinent. These include the Indus, Ganges, Brahmaputra and the Mahanadi-Brahmani-Baitrani river systems of Bhutan, Bangladesh, India, Nepal and Pakistan.²¹ Gharials reside exclusively in river habitats with deep, clear, fast-flowing waters and steep, sandy banks. Adult gharials prefer still, deep pools, formed at sharp river-bends and river confluences and use sandy banks for basking and breeding. Young gharials are found in much shallower, rapidly flowing stretches in the water.

One of the largest of crocodilian species—it can grow to 7 m in length—the gharial has a thick skin covered with smooth epidermal scales that do not overlap. The snout of the gharial is, uniquely, the thinnest and most elongated among all the crocodylians. In addition, the adult males sport a large bulb at the tip of their snout called the ‘ghara’. It is also the most aquatic of all crocodylians, never moving far from water. Females lay their eggs in steep, sandy river banks. Unlike other crocodiles, the gharials feed on warm-blooded species and even the largest gharial adults feed exclusively on fish, which they catch between the pointed, interlocking teeth of their long jaws.²²

Less than 400 adults of the critically endangered gharial survive in the world today.²³ Gharials, which once almost became extinct because of hunting for their valuable skins, are today threatened by destruction or intense human pressure on their habitat. In some places their eggs are stolen for eating while many young gharials die every year by accidentally getting trapped in fishermen’s nets.

**Discharge of waste into the rivers that are a lifeline to the Sundarban, and water flow controlled by various dams and barrages, are adversely impacting aquatic habitats**
Look to the Hilsa’s spawning and migratory routes

_Hilsa_ signifies any of the members of the genus *Tenualosa* of the family Clupeidae, order Clupeiformes. Locally known as *Ilish*, and much valued culturally as well as gastronomically, the fish has been designated as the national fish of Bangladesh. It is evident that today hilsa fishery is experiencing recruitment over-fishing and growth over-fishing.\(^24\)

Indiscriminate catching of mature fish and jatka has become a threat to the natural *Hilsa* production. In this way, their natural breeding is interrupted. *Hilsa* spawning and migratory routes are being affected through upstream pollution and decrease of water flow due to deposition of silt in the river beds. Environmental degradation in the water quality of the river causes hindrance and change in the natural route of migration of the *Hilsa*.

Being a favorite fish of Bangladesh and West Bengal, the _Hilsa_ and its habitat and migratory routes should be conserved for our security of protein supply and economic growth.

Conserve the migratory routes and habitats of waterfowls

Habitats of the animals once thriving in the riverine ecosystem of the Ganga river upstream to downstream of the Padma and the Meghna rivers are severely affected by over-exploitation, poaching and unscrupulous use of fisheries resources and added-up pollution in both countries. The migratory routes and habitats of waterfowls have also been affected. The issues, very common to both the countries, call for joint research for conserving the riverine ecosystem and associated habitats for the very survival of these flagship species.

Bangladesh has 244 migratory bird species of which 96 are waterbirds.\(^25\) Considering the present threat to waterbird conservation in the country, 31 migratory waterbird species are of high priority for future action for conservation. Bangladesh is also important for resident waterbirds. These waterbirds needs attention for immediate conservation effort and 32 resident waterbirds are of high priority for conservation. The key breeding areas of these waterbirds are the _Haor_ areas of the North-East region, new accretion in river systems and mangroves of offshore islands.

The joint research on waterfowls should, therefore, be focussed on:
- Extensive survey of migratory as well as resident waterbirds;
- Inventory and assessment of waterbird habitats;
- Establishment of bird sanctuary;
- Awareness related to conservation of waterbirds and their habitats;
- Support for capacity building in terms of technical and management aspect; and
- Resource mobilization for waterbird conservation.

Marine ecosystems

Bangladesh, India, Indonesia, Malaysia, Maldives, Myanmar, Sri Lanka, and Thailand are the countries bordering the the BoBLME, or Bay of Bengal Large Marine Ecosystem.\(^26\) A number of forces\(^27\) at work in the BoBLME contribute to (1) over-exploitation of marine living resources; (2) degradation of critical habitats; and (3) pollution. These forces present a range of challenges to actions designed and implemented to address these problems, and can be grouped into:
- Socio-economic drivers;
- Institutional, legal and administrative drivers; and
- Climate change.

Major rivers such as the Brahmaputra and the Ganga discharge large quantities of freshwater...
into the Bay of Bengal. This input of freshwater and silt impacts the salinity of the coastal and estuarine waters as well as coastal circulation patterns. Wetlands, marshes and mangroves play an important role in the overall productivity of LME. The BoBLME is considered a Class II, moderately productive—150-300 grams of carbon per sq m per year—ecosystem based on Sea-viewing Wide Field-of-view Sensor (SeaWiFS) global primary productivity estimates.

Changing environmental conditions are influencing currents, productivity and coastal pollution. Some coastal areas, serving as nursery grounds for commercially valuable species of prawns, are polluted. Two areas of critical biological diversity between Bangladesh and India are: the Sundarban and the Marine (Wandur) National Park in the Andaman and Nicobar islands. This tropical region has a relatively great marine biodiversity, reflected in the catch composition. There is a high catch percentage for miscellaneous coastal fishes and pelagic fishes (tuna, yellowfin, big eye and skipjack). Herrings, sardines and anchovies represent more than 15% of the catch. The crustacean catch—shrimp is the major export earner—is just below 15% of the total catch (FAO, 2003). Catch trends are quite diverse and it is difficult to identify a pattern: information on the status of fisheries resources and their exploitation is inadequate.

Heavy fishing through open access and unauthorized incursions of foreign fleets are a comparatively recent phenomenon. There is an increase of competition and conflicts between artisanal and large-scale fisherman. There is an alarming increase in cyanide fishing in this LME’s coral reefs for the lucrative live food fish markets in Hong Kong and Singapore. Mangroves and estuaries—critical fish spawning and nursery areas—are also under stress or threatened by pollution, sedimentation, dams for flood control and intensive coastal aquaculture.

Both countries surround the Bay of Bengal; in both countries clear policies, appropriate strategies and measures for the sustainable management of fishery resources are weak. There is a need to establish systematic data collection system in order to prepare a regional strategy.

The ecosystem stresses experienced are connected to the size of the coastal populations bordering the LME (Aziz Ahmad et al, 1998). Issues of ecosystem health that are common throughout the region are: environmental stresses on the Bay of Bengal’s water quality; the degradation of many of the coral, mangrove, wetland and seagrass bed habitats that support fisheries; and the use of fishing gear that may affect the long-term sustainability of the fisheries resource.

Climate change, especially sea level rise, also compromises the ecological stability of the coastal zone and the marine ecosystems. The major rivers bring in large concentrations of pollutants from agricultural pesticides and industrial waste that damage fish spawning and nursery areas, cause fish kills and lead to possible changes in trophic structure. High levels of pesticides can be found along the coast, especially near cities and ports (Dwivedi, 1993). A major part of Bangladesh consists of a delta plain positioned below the GBM confluence. Sediment loading in the system due to accelerated soil erosion in the Himalayas is considered to be one of the main factors contributing to downstream flooding. In some regions of the Bay of Bengal, a change in composition of plankton species has been observed (The Bay of Bengal Programme, 1994). There is heavy oil tanker traffic between Japan and the Middle East, with the main shipping route passing outh of Sri Lanka before entering the Straits of Malacca via a passage below the Nicobar Islands. For this reason, oil spills are a major concern.

There is inadequate information on pollution and sedimentation loads entering the Bay of Bengal, on coastal habitats and endangered species. This information is necessary in order to understand how the ecosystem functions and its reaction to stress over time. Also, there is an urgent need for long term planning for the conservation and management of the marine ecosystem stretched over the territory of India and Bangladesh. Moreover, conflicts between large and small fishermen—
The rationale for joint research related to the complex of crises the Sundarban faces is simple: India and Bangladesh share this immense ecosystem

poverty, unsustainable fishing practices and a decline in income from fisheries—are contributing to a crisis. Addressing this crisis requires the co-ordinated effort of the two countries bordering the Bay of Bengal. The initiative is mobilizing national and regional efforts to improve the food and livelihood security of the region’s coastal populations.

Conserving marine turtles, whales and sharks
Fishermen normally use drift, gill and fixed gill nets for fishing which entangle sea turtles, trapping and eventually causing them to drown. Villagers consider turtle sightings during fishing to be bad luck. No laws currently exist for enforcing the use of Turtle Excluder Devices (TEDs) in shrimp trawl nets to allow turtles to escape.

Flagship species of LME like the marine turtle, whales, sharks and dolphins are reported to be threatened due to over-exploitation of fisheries resources in the Bay of Bengal marine ecosystems. Joint research on these species, particularly on their present status, trend and migratory routes may lead to adoption of appropriate initiatives towards conserving these species in a scientifically informed way.

India and Bangladesh should undertake joint research towards conserving marine turtle, whales, sharks and dolphins for maintaining healthy populations. The following activities are very important in this regard:
- Assessing the status, ecology, and exploitation of the flagship species;
- Involving the local community in conservation;
- Conserving habitats are fundamental for marine species;
- Initiating the use of TEDs in shrimp trawl nets;
- Initiating conservation education programs; and
- Raising awareness to conserve marine ecosystem from grassroots to the international level.

Conservation issues not specific to an ecosystem

Asian wild elephants are very hard to count, but fewer than 50,000 are thought to survive in total. The Asian elephant is still a critical ecological driver opening up forests, creating highways for animals and encouraging grasslands, so important for the diversity of the habitat.

As human populations grow and people settle in areas that were once the sole domain of elephants, human-elephant conflicts are becoming increasingly common leading to retaliatory killings of elephants. At present, this is amongst the biggest threats to the survival of Asian elephants in the wild. As forest cover becomes fragmented, elephants raid plantations and crop fields in their quest for food or for operating between forest patches. They uproot and scatter other plants, trees, and groundcover as they forage. This puts them in direct conflict with farmers settling in elephant habitat. A single elephant can devastate a small farmer’s crop holding in one feeding raid. This makes elephants the target of retaliatory killings, especially when people are injured or killed.
Even where suitable habitat exists, poaching remains a threat to elephants. In 1989, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) banned the international trade in ivory. However, there are still some thriving but unmonitored domestic ivory markets in a number of Asian and other countries which fuel an illegal international trade.\(^{33}\)

Infrastructure development, human encroachment and the logging industry have combined to fragment the forest lands that were home to the Asian elephant, squeezing them into ever smaller areas. This loss of habitat has led to increasing human-elephant conflict, mostly in the form of crop-raiding. One nocturnal raid by elephants can deprive a human family of its staple food (rice) or cash crop (maize, mangos, or sugar cane), as well as the occasional death.

The loss of habitat is the primary threat to Asian elephants. Approximately 20% of the world’s population lives in or near the range of Asian elephants.\(^{34}\) Asian elephants are less prone to poaching (killing elephants for ivory tusks) because few males (and no females) grow tusks.

Asian Elephants are very unique species for all of Asia. To undertake joint research and conservation activities will enable the flagship species in this part of the world.

Owning to destruction of habitat, elephants and wild cats migrate from one part of border to another and this kind of migration sometimes lead to revenge killing of the animals by the local inhabitants. So, collaborative research and conservation initiatives on these species may pave the way towards ensuring their very existence on this earth.

**Competition for resources:** Competition for various common property resources like fisheries and forest products or non-timber forest products are going on at such a scale that it should be halted to prevent further degradation of the ecosystems in both Bangladesh and India. Joint research and collaboration on understanding of the issues and solutions to the problems is very crucial to curve the situation.

**Climate change challenge:** Climate change has already produced numerous shifts in the distribution and abundance of species such as amphibians, grasses, migratory birds and butterflies. Coral reefs are threatened by the bleaching that occurs with changes in ocean temperature and chemistry. Forests and agricultural systems are vulnerable to increased incidents of disease and pest outbreaks as a result of changing climate. Long term research to monitor impacts of climate change, on the behaviour and survival of various life forms and ecosystems and collaborative development activities on adaptation in the face of climate change, variability and extreme events will be very useful for conserving precious biological resources and ecosystems of both countries.

**Wildlife trafficking:** Wildlife trafficking for trading of hides and skins, teeth and other bones, bushmeat and the like is being taking place in both sides of the border. Illegal trading of wildlife or products of wildlife should be stopped for the sake of conservation of the endangered species of wildlife. Both India and Bangladesh could facilitate dialogue and enforcement measures to stop wildlife trafficking.

*Conservation challenges exist beyond the Sundarban, too. As does the need for joint research: information today on important issues is inadequate, or not shared. This paradigm needs change*
Conversing germplasm: Diversity of agricultural species is dramatically eroded due to intensive agriculture, monoculture, introduction of high yielding verities and in the absence of protective mechanism of traditional knowledge to conserve agro-biodiversity. Therefore, collaborative research and development activities to conserve rich agro-biodiversity are very important for long term prosperity of both the countries.

Transboundary air pollution: Transboundary air pollution is not only impacting on the quality of global environment but it is also telling upon the health of ecosystems in both the countries. Sources of air pollution should be identified through collaborative research towards controlling such kind of long-distance air pollutants.

Watershed management in the border areas: Water shortage in the dry season affects all water-using sectors in both the countries, with tremendous adverse impacts on the ecosystems and species diversity. Due to inadequate surface water, groundwater is extensively used for irrigation and its over-extraction is causing deterioration of its quality. Flash flood occurs in Bangladesh every year due to runoff during heavy rainfall in the neighboring upland areas, mostly outside Bangladesh. Flash floods cannot be managed as both the countries are lacking a comprehensive and planned watershed management. Joint research in this area on identification of important watersheds and conservation initiatives will save various biodiversity from risk of extinction.

Strategy for joint research and cooperation

Joint research and co-operation strategy towards conserving biodiversity should be based on transboundary river basin management. A shared vision which would encompass the common sustainable development approach and the emphasis would focus on:

- Enhancing bilateral co-operation for implementing joint research;
- Designing cost-effective river basin management;
- Strengthening water-saving initiatives;
- Utilization of regional potential hydro-power resources;
- Reinforcing water resources protection;
- Ensuring compliance of international conventions/treaties on biodiversity conservation;
- Ensuring water security and water rights;
- Strengthening advocacy on conserving biodiversity;
- Polluter pays principle;
- Capacity building through learning-by-doing;
- Strong political commitments and good governance;
- Ensuring green growth in any development initiative;

Basin-wide development and management would be very important. Indo-Bangla has long contained huge biological resources of the globe. These varied habitats are facing problems due to the indiscriminate development spree of human societies throughout the region. Conservation of biological resources here needs collective efforts of both the countries which can foster better outcome than the individual initiatives. Joint research and development on biodiversity of this region will not only contribute to global well-being but regional development as well.

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