Family/ Species	Common name	Habitat
Mugil cephalus Linnaeus		
Rhinomugil corsula (Hamilton-Buchanan)		
Valamugil buchanani ((Bleeker)		
Valamugil cunnesius (Valenciennes)		
Valamugil seheli (Forsskal)		
Valamugil spigleri (Bleeker)		
Family Sphyraenidae	**Barracudas**	**Mostly occurring in coastal waters, from the surface to about 100m depth**
Sphyraena jello Cuvier		
Sphyraena obtusata Cuvier		
Family Polynemidae	**Threadfins**	**Shallow coastal waters and in estuaties**
Polynemus paradiseus Linnaeus		
Eleotheronema tetradactylum (Shaw)		
Polydactylus indicus (Shaw)		
Polydactylus plebeius (Broussonet)		
Polydactylus sextarius (Bloch)		
Polynemus paradiseus Linnaeus		
Polynemus longipectoralis Weber and de Beaufort		
Family Uranoscopidae	**Stargazers**	**Demersal- typically lie buried in sand**
Uranoscopus cognatus Cantor		
Family Callionymidae	**Dragonets**	**Benthic**
Callionymus carebares Alcock		
Callionymus fluviatilis Day		
Callionymus recurvispinnis Li		
Callionymus sagitta Pallas		
Eleutherochir opercularis (Vallenciennes)		
Family Blennidae	**Blennies**	**Primarily in shallow marine habitats, and are especially common in the intertidal and subtidal zones.**
Petroscirtes breviceps Valenciennes		
Petroscirtes variabilis Cantor		

Family/ Species	Common name	Habitat
Family Eleotridae	**Sleepers**	**Brackish waters and estuaries**
Eleotris fusca (Bloch and Schneider)		
Eleotris melanosoma Bleeker		
Eleotris lutea Day		
Butis butis (Hamilton – Buchanan)		
Butis melanostigma (Bleeker)		
Ophiocara porocephala (Valenciennes)		
Ophieleotris aporos (Bleeker)		
Odonteleotries macrodon (Bleeker)		
Family Gobiidae	**Gobies**	**Mostly marine, bot-tom- dwelling, some inhabiting brackish or fresh waters**
Odontamblyopus rubicundus (Hamilton– Bu-chanan)		
Taenioides buchanani (Day)		
Taenioides anguillaris (Linnaeus)		
Taenioides cirratus (Blyth)		
Taenioides erruptionis (Bleeker)		
Caragobius urolepis (Bleeker)		
Pseudotrypauchen multiradiatus Hardenberg		
Trypauchen vagina (Bloch and Schneider)		
Amblyotrypauchen arctocephalus (Alcock)		
Ctenotrypauchen microcephalus (Bleeker)		
Trypauchenichthys sumatrensis Hardenberg		
Trypauchenichthys typus Bleeker		
Apocryptes bato (Hamilton – Buchanan)		
Apocryptodon madurensis (Bleeker)		
Oxuderces dentatus Eydoux and Souleyet		
Pseudapocryptes elongatus (Cuvier)		
Pseudapocryptes borneensis (Bleeker)		
Parapocryptes serperaster (Richardson)		
Boleophthalmus boddarti (Pallas)		
Boleophthalmus dussumieri Valenciennes		

Family/ Species	Common name	Habitat
Scartelaos histophorus (Valenciennes)		
Periophthalmus chrysospilos Bleeker		
Periophthalmus koelreuteri (Pallas)		
Periophthalmus malaccensis Eggert		
Periophthalmus pearsei Eggert		
Periophthalmus vulgaris Eggert		
Periophthalmus novemradiatus (Hamilton-Buchanan)		
Periophthalmus kalolo Lesson		
Periophthalmodon schlosseri (Pallas)		
Periophthalmodon septemradiatus (Hamilton – Buchanan)		
Gobiopterus chuno (Hamilton – Buchanan)		
Stigmatogobius sadanundio (Hamilton – Buchanan)		
Bathygobius fuscus (Ruppell)		
Gnatholepis cauerensis (Bleeker)		
Acentrogobius viridipunctatus (Valenciennes)		
Drombus globiceps (Hora)		
Istiogobius ornatus (Ruppell)		
Glossogobius giuris (Hamilton – Buchanan)		
Parachaeturichthys polynema (Bleeker)		
Hemigobius hoevenii (Bleeker)		
Gobiopsis macrostoma Steindachner		
Brachygobius nunus (Hamilton – Buchanan)		
*Amblyeleotris gymnoceph*ala (Bleeker)		
Oligolepis scutipennis (Valenciennes)		
Awaouichthys menoni Chatterjee		
Family Kurtidae	**Humpheads**	**Shallow coastal waters**
Kurtus indicus Bloch		
Family Siganidae	**Rabbit fishes**	**Shallow coastal waters, including estuaries**
Siganus canaliculatus (Park)		

Family/ Species	**Common name**	**Habitat**
Siganus javus (Linnaeus)		
Family Trichiuridae	**Ribbon fishes**	**Coastal waters to about 100m depth**
Eupleurogrammus glossodon (Bleeker)		
Eupleurogrammus muticus (Gray)		
Lepturacanthus pantului (Gupta)		
Lepturacanthus savala (Cuvier)		
Trichiurus gangetcus (Gupta)		
Trichiurus lepturus Linnaeus		
Family Scombridae	**Mackerals**	**Epipelagic**
Rastrelliger kanagurta (Cuvier)		
Scomberomorus commerson (Lacepede)		
Scomberomorus guttattus (Bloch and Schneider)		
Family Stromateidae	**Silvery pomfrets**	**Pelagic**
Pampus argenteus (Euphrasen)		
Pampus chinensis (Euphrasen)		
ORDER PLEURONECTIFORMES		
Family Psettodidae	**Indian Halibuts**	**Demersal**
Psettodes erumei (Schneider)		
Family Citharidae	**Flouders**	**Demersal**
Brachypleura novae-zeelandiae Gunther		
Family Bothidae	**Lefteye Flounders**	**Demersal**
Pseudorhombus arius (Hamilton-Buchanan)		
Pseudorhombus elevatus Ogilby		
Pseudorhombus javanicus (Bleeker)		
Pseudorhombus malayanus Bleeker		
Pseudorhombus triocellatus (Bloch)		
Family Cynoglossidae	**Tonguesoles**	**Demersal**
Cynoglossus arel (Schneider)		
Cynoglossus cynoglossus (Hamilton-Buchanan)		
Cynoglossus lida (Bleeker)		
Cynoglossus lingua Hamilton-Buchanan		
Cynoglossus macrostomus Norman		
Cynoglossus puncticeps (Richardson)		

Family/ Species	Common name	Habitat
Cynoglossus semifasciatus Day		
Paraplagusia bilineata (Bloch)		
Symphurus gilesii (Alcock)		
Family Soleidae	**Soles**	**Demersal**
Euryglossa pan (Hamilton-Buchanan)		
Hetermycteris oculus (Alcock)		
Synaptura albomaculata Kaup		
Synaptura commersoniana (Lacepede)		
Zebrias altipinnis (Alcock)		
Zebrias quagga (Kaup)		
ORDER TETRADONTIFORMES		
Family Triacanthidae	**Triplespines**	**Benthic**
Pseudotriacanthus strigilifer (Cantor)		
Triacanthus biaculeatus (Bloch)		
Triaxyphichthys weberi (Chaudhuri)		
Family Balistidae	**Trigger fishes**	**relatively shallow coastal habitats, some are pelagic**
Canthidermis rotundatus (Proce)		
Family Ostraciidae	**Box fishes**	**Benthic**
Rhynchostracion nasus (Bloch)		
Family Tetraodontidae	**Puffers**	**Estuaries and fresh-waters**
Arothrodon immaculatus (Bloch and Schneider)		
Arothrodon nigropunctatus (bloch and Schneider)		
Arothrodon stellatus (Bloch and Schneider)		
Chelonodon fluviatilis (Hamilton-Buchanan)		
Chelonodon patoca (Hamilton-Buchanan)		
Fugu oblongus (Bloch)		
Kanduka michiej Hora		
Lagocephalus inermis (Temminck and Schlegel)		
Lagocephalus lunaris (Bloch and Schneider)		
Lagocephalus sceleratus (Gmelin)		
Tetraodon cutcutia (Hamilton-Buchanan)		

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2.15 HERPETOFAUNA

Herpetofauna (amphibians and reptiles) have radiated extensively throughout terrestrial and freshwater habitats in the tropical and subtropical regions of the world.

KAUSHIK DEUTI
Herpetologist

Fuels detrital food chains in mangrove ecosystems

The transition from water to land is a very remarkable step in the phylogenetic history of the vertebrates. Among the vertebrates this conquest of land was first initiated by the primitive amphibians in the Devonian period and was completed by reptiles in the course of time. Although amphibians are credited as the first land dwellers, they are not fully adapted to the terrestrial environment. They constitute a transitional group, neither fully aquatic nor fully terrestrial, but they have made a compromise between two opposing environments. In fact, the emergence of reptiles as true land-dwelling heterogeneous vertebrates offers the greatest dramatic events in the course of organic evolution (Sinha et al. 1997).

The class Amphibia comprises three living orders: Gymnophiona (*Apoda*), Urodela (*Caudata*), and Salentia (*Anura*). Only four widely divergent orders of the class Reptilia are living today: Squamata (lizards and snakes); Rhynchocephalia (*Sphenodon*); Chelonia (Turtles and Tortoises); and Crocodilia (crocodiles, gharials, alligators, and caimans) (Marshall and Williams 1988).

Both reptiles and amphibians are often referred to as cold blooded although at certain times their body or blood temperature is actually hotter than that of most birds and mammals. It is therefore better to refer to them as poikilothermous (as their body temperature varies with that of the environment in which they live). Thermoregulation in reptiles is a behavior function and is achieved by a judicious use of available sunlight. By basking in the sun or absorbing heat through a hot substratum when heat is required and moving away from the sun when heat is not needed, reptiles are able to maintain the ideal temperature within their body, which is more or less the air temperature of their habitat. The hot summer is

Monocled Cobra (Naja kaouthia)

spent by aestivating in burrows and hiding among thick vegetation, while in winter, they need to bask in the sunshine for some time before they become active. In the Sundarbans, which hardly has a proper winter, they are therefore active throughout the year.

This activity is more in the case of reptiles as their body is covered by scales (in the case of lizards and snakes) and scutes or osteoderms (in the case of turtles and crocodiles). They can therefore move around easily on land, on trees, in freshwater, and even in the sea while the soft porous skin of amphibians restricts them to the moist habitats in or near freshwater or occasionally in brackish water. In the Sunderbans, amphibians are mostly seen in freshwater ponds, pools, and canals but rarely in brackish-water habitats. Turtles and crocodiles are found in freshwater as well as brackish water and marine habitats and lizards and snakes on land and trees as well as freshwater, brackish-water, and marine habitats.

However, no matter where the reptiles wander they must return to land to lay their eggs as these have a hard shell. The amphibians on the other hand lay their eggs in water or in frothy gelatinous foam as their eggs are semipermeable. In the Sundarbans too, the turtles (even the marine turtles and snakes) and crocodiles return to the sandy beaches or tidal creeks to dig a pit and deposit their eggs while the lizards and snakes deposit eggs in burrows on land. A few specialized arboreal snakes and lizards lay their eggs in tree holes.

High salinity is an especially difficult condition, given that amphibians are hypoosmotic, causing them to lose water and gain ions in marine environments. Due to these fluctuations in water equilibrium, most amphibians are unable to cross even narrow salty water barriers (Duellman and Tueb 1994). Additionally, amphibians lack salt glands, rendering them unable to eliminate high concentrations of salt. Marine reptiles have specialized glands for excreting excessive salt, mostly in the form of sodium chloride (Peaker and Linzell 1975; Zug 1993). Species of reptiles that tolerate saltwater would be more numerous; their impermeable skin is an effective mechanism for protection from desiccation.

Herpetofauna use mangrove habitats primarily because of their feeding pattern and secondarily because of their reproductive patterns. Amphibians are linked to water during their egg and larval stages and many reptiles are functionally tied to wetlands (Harris and Gosselink 1990). Herpetofauna also play a major role in the food chain of mangrove ecosystems by fuelling detrital food chains.

OVERVIEW OF THE GROUP

The Amphibia web database (September 20, 2010) lists 6,715 amphibian species in the world, of which 5,941 are Anura (frogs and toads); 588 are Caudata (newts and salamanders); and 186 are Gymnophiona (caecilians). Reptiles are an extraordinarily diverse group of animals that occupy a central position in the vertebrate phylogeny (Pough et al. 2009). With over 8,734 living species (Reptilian Database 2010), reptiles are more speciose than most other major chordate groups, including mammals, lissamphibians, chondrichthyans, sarcopterygians, and agnathans. The Zoological Survey of India database lists 311 amphibian (Dinesh et al. 2010) and 460 reptilian species (Ramakrishna and Alfred 2007) in India.

Herpetofaunal diversity has been found to be present in large numbers in Indian mangroves (table 1) when compared to the mangrove ecosystems of Indo-Malaysia and Australasia.

Species composition reflects continent-wide pattern of dominance of a few families. An analysis (Table 2) of six wetland ecosystems with mangrove habitat reveals that the amphibian diversity is lower than the reptiles in the Sundarbans.

Low species numbers are reported from Canadian peatlands because of the cold climate. The low species numbers reported for Tonle Sap is certainly the result of insufficient inventories. However, Tonle Sap in Cambodia is the only wetland that lists seven water snakes. Forty amphibians and 96 reptile species are reported from the Pantanal, Brazil. However, it is noteworthy that most reptile species benefit from terrestrial habitats inside the Pantanal. The same holds true for the Okavango Delta in Botswana that harbors 33 amphibians and 64 reptile species; 12 reptile species are considered aquatic. Both areas have 10 families in common, 5 of them belonging to the Serpentes. Most wetlands are refuges for endangered species such as the turtles *Batagur baska*, *Cuora amboinensis,* and *Hieremys annandalii* and the Siamese Crocodile (*Crocodylus siamensis*) in Tonle Sap, Cambodia. In the Sundarbans, the amphibian diversity is low whereas reptiles are quite numerous. In Kakadu National Park, Australia there are 26 anurans from a variety of habitats, with 1 introduced toad species, *Bufo marinus*. There are 127 reptile species, with around 30 inhabiting the wetlands, including the file snakes *Acrochordus arafurae* and *A. granulatus* and the crocodilians *Crocodylus porosus* and *C. johnstoni* (Junk et al. 2006).

Table 1: Number of Herpetofaunal species in mangrove ecosystem of different regions of the Indian Ocean region.

Sr. No.	Name of the region	Amphibia	Reptilia	Reference
1	Indo Malaysia	22	3	Spadling *et al.,* 1997
2	Australasia	2	0	Spadling *et al.,* 1997
3	India	13	85	Kathiresan *et al.,* 2005


River Terrapin (Batagur baska)

Table 2: Orders and number of species of Amphibians and reptiles reported for the different wetland ecosystems with mangrove habitat: Sauria and Serpentes are sub-orders.

Sr. No	Order	Everglades	Pantanal	Okavango	Tonle Sap	Kakadu	Sundarbans
1	Anura	-	40	33	2	26	11
2	Chelonia	1	3	7	5	4	14
3	Chelidae	1	-	-	-	5	-
4	Squamata	-	-	-	-	-	-
5	Sauria	-	26	31	-	5	15
6	+ Amphis-baenidae	2	2	5	-	-	-
7	Serpentes	-	63	43	17	10	41
8	Crocodilia	1	2	1	1	2	1

Note: Sauria and Serpentes are suborders

SYNOPTIC VIEW

Diversity

Herpetofauna in Sundarbans is represented by 82 species in 57 genera under 20 families (table 3 and annexure) of amphibians and reptiles. Maximum generic diversity was found in Colubridae (16), Hydrophidae (6), Geoemydidae (4), and Trionychidae (4). The Sundarbans unique ecosystem supports a specialized group of Herpetofauna, which includes at least 11 species of freshwater turtles (figure 2); 3 species of marine turtles; 1 species of estuarine crocodile (figure 3); 15 species of lizards (figure 4); 41 species of snakes (figure 5); and 11 species of amphibians (frogs and toads) (figure 6) that have adapted themselves suitably to live in this harsh and difficult environment. Figures 2–6 give a comparative analysis of herpetofaunal species (Frost 2010; Dinesh et al. 2010; Das 2010; Reptilian Database 2010) found in the world with respect to the families found in the Sundarbans.

Water Monitor Lizard (Varanus salvator)

Table 3: Total number of families, genera, species composition of Herpetofauna in Sundarbans.

Sr. no.	Herpetofaunal group	Family	Genera	Species
1	Turtles	Dermochelyidae	1	1
		Cheloniidae	2	2
		Geoemydidae	4	6
		Trionychidae	4	5
2	Crocodiles	Crocodylidae	1	1
3	Lizards	Agamidae	2	2
		Gekkonidae	2	5
		Scincidae	2	5
		Varanidae	1	3
4	Snakes	Typhlopidae	2	2
		Acrochordidae	1	1
		Colubridae	16	20
		Elapidae	3	4
		Hydrophidae	6	12
		Viperidae	2	2
5	Amphibians	Bufonidae	1	1
		Microhylidae	2	2
		Dicroglossidae	3	6
		Ranidae	1	1
		Rhacophoridae	1	1
		Total	57	82

Among the turtles, the River Terrapin (*Batagur baska*) is specialized to live in river mouths with extensive mangrove vegetation because it depends solely on the fruits and leaves of the *Sonneratia* plants for its food. Most feeding occurs at high tide when vegetation from low-hanging branches becomes more accessible from the water. River Terrapins in Malaysia and Myanmar travel upriver from foraging areas to nest on sandbanks and river islands. In contrast, this species in the Sundarbans of India and Bangladesh nest on the coast due to the absence of any sandy substrate upriver (Das 1995).The species nests on specific sandy beaches on the Bay of Bengal coast in the southern part of the STR, namely Kalash, Mechua, Kedo, and Chaimari (Ghosh and Mandal 1990).

The water monitor lizard (*Varanus salvator*) is another mangrove specialist as it searches for stranded crabs and molluscs among the pneumatophores of mangroves when the tide recedes and even frequents the sandy beaches for eggs in the nests of sea turtles and the estuarine crocodile. The File or Wart Snake (*Acrochordatus granulatus*) is capable of remaining submerged under brackish water for two hours (Das 2002). It feeds exclusively on estuarine fishes and crustaceans. The Dog-faced Water Snake (*Cerberus rynchops*) lives in crab holes near the shoreline, anchored by the tail with just the head peeping out, swaying in the flow, waiting for mudskippers and gobies. Similarly, the White-bellied Mangrove Snake (*Fordonia leucobalia*) and the Glassy Marsh Snake (*Gerardia prevostianus*) inhabit mangrove swamps and tidal rivers for soft-shelled crabs, shrimps, and small fishes.

Functional Guild Structure of Herpetofauna Distribution

Guild structure analysis for distribution of herpetofauna in the Indian Sundarbans reveals six guilds based on their respective habitat. The following are the species groups:

- **Pelagic species**. Spend most of their life in the open sea
- **Marine occasional species.** Mainly terrestrial or riparian but occasionally are found in marine waters
- **Littoral species.** Found in the littoral zone, including salt marshes and mangrove swamps
- **Supralittoral species.** Found in the supralittoral zone, including sandy beaches and rocky beaches
- **Terrestrial species**. Found in land and ponds and marshes on land
- **Arboreal species.** Tree dwelling

Terrestrial species, littoral species, and pelagic species were the dominant functional guilds representing 34 percent, 20 percent, and 18 percent, respectively, of the total herpetofauna found in the Sundarbans.

Local Community Dependencies and Traditional Use

Terrestrial species, littoral species and pelagic species are the dominant functional guilds

Majumder and Dey (2007) reported a drug prepared by the tribes (Santhal, Oraon, and Munda) from different species of herpetofauna in the Sundarbans for the remedy of various diseases. Eighty medicinal applications have been reported from the Sundarbans, made from 7 herpetofaunal species, namely *Crocodylus porosus* (5), *Aspideretes gangeticus* (18), *Varanus bengalensis* (27), *Varanus salvator* (11), *Calotes versicolor* (10), *Xenochrophis piscator* (4), and *Endydris enhydris* (5). The medicines are applied locally and mostly externally to cure diseases such as psoriasis, impotency, lumbago, opthalmia, oedema, epistaxis, piles, ringworm, leucoderma, scorpion bite, osteoarthritis, synovitis, and urticaria.

Ecological Importance and Need for Conservation

80 MEDICINAL APPLICATIONS FROM 7 HERPETOFAUNAL SPECIES

Terrestrial amphibians and reptiles are excellent indicators of the relative amounts of microhabitats in ecosystems (Jones 1986). Aquatic amphibians and snakes are good indicators of the health of aquatic systems. These animals are especially sensitive to pollution and loss of aquatic habitat (Hall 1980). Herpetofauna are important in food chains and they make up large proportions of vertebrates in certain ecosystems (Bury and Raphael 1983). Information on amphibian and reptile abundance and diversity helps determine the relative health of ecosystems. For example, frogs, toads, and salamander abundance and diversity fluctuate directly with changes in the composition and amount of microhabitats. It may be that amphibians signal environmental stress earlier than most other organisms. Amphibians, being good bioindicators of environmental health, rapidly absorb toxic substances (Blaustein and Wake 1990) because of their unprotected, permeable skin and lack long-range dispersal

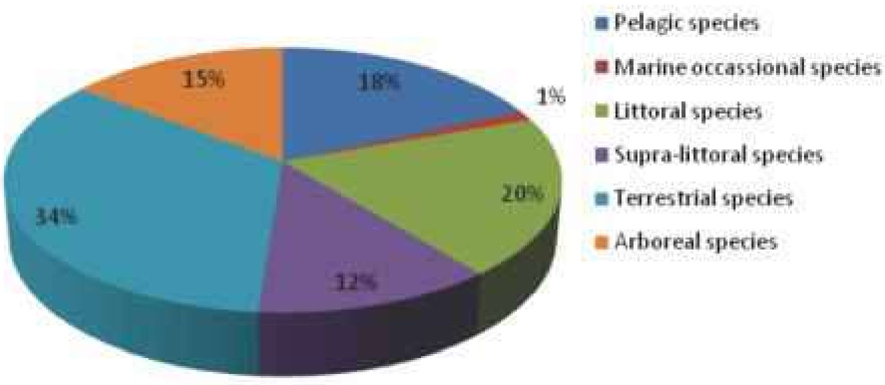


Fig 1: Functional Guild Structure of Herpetofauna Distribution

Information on herpetofaunal abundance and diversity helps in determining the relative health of ecosystems

capability (Lannoo 1998). They inhabit both aquatic and terrestrial habitats, which means that they are exposed to both aquatic and terrestrial pollutants. The egg stage is extremely susceptible to chemical pollutants, and exposure to high concentrations can result in developmental abnormalities. The growth rates of frogs and toads may be significantly affected by even short-term exposure to acidic conditions. Reports of declining amphibian populations in many parts of the world are numerous, but supporting long-term census data are generally unavailable (Pechmann et al. 1991).

A critical component of regional conservation strategies is to give conservation priority to highly diverse areas in terms of species richness, endangerment, rarity, and endemism (Ceballos 1995; Bonn et al. 2002; Brooks et al. 2001; Ortega-Huerta and Peterson 2004). Determining spatial patterns of diversity and hotspots have a valuable application for conservation but are of greater relevance when assessed in relation to the distribution of existing protected areas and undisturbed ecosystems (Ortega-Huerta and Peterson 2004). Selection of areas for protection may sometimes be made on an opportunistic basis for reasons other than their purely biological value (Pressey 1994; Ortega-Huerta and Peterson 2004), resulting in the probable scenario of highly diverse areas which are unprotected or not considered within future conservation plans.

Determining the status of species is often difficult because of limited knowledge of population dynamics and distribution (Hecnar and M'Closkey 1996), given the scenario of Sundarbans. Lack of consistent and up-to-date information on the type, location, size, and quality of natural habitats has been identified as a major constraint (Bojorquez-Tapia et al. 1995; Ceballos 1995; Ceballos et al. 1998; Dennis et al. 2002; Myers et al. 2000; MacNally and Fleishman 2003; Weiers et al. 2004).

Modelling has been used to determine spatial patterns of diversity, especially in regions with marked differences in inventory effort between areas due to short duration studies or time and financial constraints (Bojorquez-Tapia et al. 1995; Sanchez-Cordero and Martinez Meyer 2000; Midgley et al. 2002; Meggs et al. 2004; Peterson et al. 2002a, b; Peterson and Kluza 2003; Grand et al. 2004; Ortega-Huerta and Peterson 2004). Generic Algorithm for Rule Set Prediction (GARP) modelling has been satisfactorily applied to determine spatial patterns of diversity and identify hotspots to set conservation priorities (Lim et al. 2002; Midgley et al. 2003; Raxworthy et al. 2003; Illoldi-Rangel et al. 2004; Ortega-Huerta and Peterson 2004).

Reza (2010) performed ecological niche modelling to predict probability distribution using Maxent software for 40 herpetofaunal species from Bangladesh in 4 temporal scenarios (2010, 2020, 2050, and 2080). It was predicted that more than 30 percent species among the 40 selected amphibians and reptiles will lose up to 50 percent of their suitable climatic conditions in the next 70 years given the present association of species localities with climatic variables (Intergovernmental Panel on Climate Change's 3rd assessment data).

STATUS AND THREATS

The threats to the reptilian species, especially to the large estuarine crocodile, are predominant due to the loss of mangrove habitat and the skin trade. Among the lizards, all the three species of monitor lizards (Bengal land monitor, water monitor, and yellow monitor) are exploited for their skin. All the turtle species are caught and eaten, their eggs being considered delicacies. Their shells are also used for various curios. Many of the snakes, especially the cobras and vipers, are killed for their skin.

Given the conservation and protection regime prevalent in the world and India, 41 herpetofaunal species (table 4 and 5) have been given protected status.

The Crocodile Project and hatchery at Bhagabatpur, Sundarban set up about three decades ago helped immensely in increasing the population of the estuarine crocodile which had decreased considerably throughout the Sundarbans. Many crocodile eggs were collected from the wild, incubated in the Bhagabatpur hatchery, and the hatchlings reared to a size of 1 m for a few months and released into the mangrove creeks.

Estuarine Crocodile (Crocodylus porosus)

Reed Frog (Hylarana tytleri)

Table 4: Species of Turtles in the Sunderbans and their Protection Status

Sr No.	Common English Name	Scientific Name	IUCN Red List Status	Indian Wild-life (Ptotec-tion)Act, 1972 (Schedule)	Appen-dix of CITES
01.	Leatherback Sea Turtle	*Dermochelys coriacea*	CE	I	I
02.	Hawksbill Sea Turtle	*Eretmochelys imbricata*	CE	I	I
03.	Olive Ridley Sea Turtle	*Lepidochelys olivacea*	V	I	I
04.	River Ter-rapin	*Batagur baska*	CE	I	I
05.	Three-striped Roofed Turtle	*Batagur dhon-goka*	E	-	II
06.	Red-crowned Roofed Turtle	*Batagur ka-chuga*	CE	I	I
07.	Spotted Pond Turtle	*Geoclemys hamiltonii*	V	I	I
08.	Crowned River Turtle	*Hardella thurjii*	V	-	-
09.	Indian Roofed Turtle	*Pangshura tecta*	LC	I	I
10.	Narrow-headed Soft-shell Turtle	*Chitra indica*	E	IV	II
11.	Asian Giant Softshell Turtle	*Pelochelys cantorii*	E	I	-
12.	Indian Flap-shell Turtle	*Lissemys punc-tata*	LC	I	II
13.	Indian Soft-shell Turtle	*Nilssonia gangetica*	V	I	I
14.	Indian Pea-cock Softshell Turtle	*Nilssonia hu-rum*	V	I	I

Note: CE-Critically Endangered; E-Endangered; LC- Least Concern; V-Vulnerable

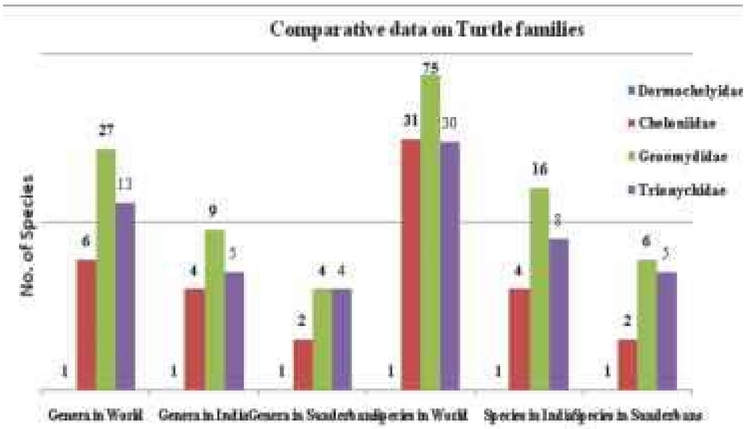
Table 5: Species of Snakes in the Sunderbans and their Protection Status

Sr No.	Common English Name	Scientific Name	IUCN Red List Status	Indian Wildlife Act (Schedule)	Appendix of CITES
01.	Common worm snake / Brahminy blind snake	*Ramphotyphlops braminus*	NT	IV	-
02.	Slender Worm Snake	*Typhlops porrectus*	NT	IV	-
03.	File / Wart snake	*Acrochordatus granulatus*	NT	IV	-
04.	Common Vine snake	*Ahaetulla nasuta*	NT	IV	-
05.	Buff-striped Keelback	*Amphiesma stolatum*	NT	IV	-
06.	Olive Keelback water snake	*Atretium schistosum*	NT	IV	-
07.	Common Indian Cat snake	*Boiga trigonata*	NT	IV	-
08.	Dog-faced Water Snake	*Cerberus rynchops*	NT	IV	-
09.	Ornamental Flying Snake	*Chrysopelea ornata*	NT	IV	-
10.	Copperheaded Trinket snake	*Coelognathus radiatus*	NT	IV	-
11.	Painted Bronze-back Tree Snake	*Dendrelaphis pictus*	NT	IV	-
12.	Common Bronze-back Tree Snake	*Dendrelaphis tristis*	NT	IV	-
13.	Common Smooth Water Snake	*Enhydris enhydris*	NT	IV	-
14.	Siebold's Smooth Water Snake	*Enhydris sieboldii*	NT	IV	-
15.	White-bellied Mangrove Snake	*Fordonia leucobalia*	NT	IV	-
16.	Glossy Marsh Snake	*Gerardia prevostianus*	NT	IV	-
17.	Common Wolf snake	*Lycodon aulicus*	NT	IV	-
18.	Yellow-speckled Wolf snake	*Lycodon jara*	NT	IV	-

Sr No.	Common English Name	Scientific Name	IUCN Red List Status	Indian Wildlife Act (Schedule)	Appendix of CITES
19.	Banded Kukri Snake	*Oligodon arnensis*	NT	IV	-
20.	Rat snake	*Ptyas mucosa*	NT	II	II
21.	Black-headed snake	*Sibynophis subpunctatus*	NT	IV	-
22.	Dark-bellied Marsh snake	*Xenochrophis cerasogaster*	NT	II	-
23.	Checkered Keelback	*Xenochrophis piscator*	NT	II	-
24.	Common Krait	*Bungarus caeruleus*	NT	IV	-
25.	Banded Krait	*Bungarus fasciatus*	NT	IV	-
26.	Monocellate Cobra	*Naja kaouthia*	NT	II	II
27.	King Cobra	*Ophiophagus hannah*	V	II	II
28.	Hook-nosed Sea snake	*Enhydrina schistosa*	NT	IV	-
29.	Malacca Sea snake	*Hydrophis caerulescens*	NT	IV	-
30.	Annulated Sea snake	*Hydrophis cyanocinctus*	NT	IV	-
31.	Fasciated Sea snake	*Hydrophis fasciatus*	NT	IV	-
32.	Black Annulated sea Snake	*Hydrophis nigrocinctus*	NT	IV	-
33.	Estuarine Sea snake	*Hydrophis obscura*	NT	IV	-
34.	Malabar Sea snake	*Lapemis curtus*	NT	IV	-
35.	Colubrine Amphibious Sea snake	*Laticauda colubrina*	NT	IV	-
36.	Common Amphibious Sea snake	*Laticauda laticauda*	NT	IV	-
37.	Cantor's narrow-headed Sea snake	*Microcephalophis cantoris*	NT	IV	-
38.	Common narrow-headed Sea Snake	*Microcephalophis gracilis*	NT	IV	-
39.	Black and Yellow Sea snake	*Pelamis platura*	NT	IV	-
40.	Russell's Viper	*Daboia russelii*	NT	IV	-
41.	Green Pit Viper	*Trimeresurus gramineus*	NT	IV	-

Note: NT-Not Threatenend; V-Vulnerable

Fig 2: Comparitive data on Turtle Families found in Sundarbans



Note: The bar diagram is to be read from left to right for the families Dermochelyidae (hardly discernable), Cheloniidae, Geomydidae & Triconyidae

Fig 3: Comparitive data on Crocodile Families found in Sundarbans

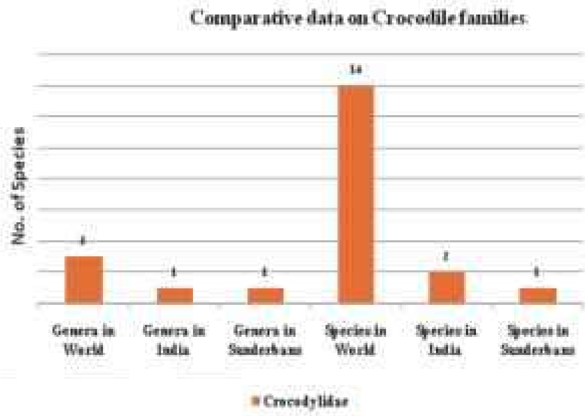


Fig 4: Comparitive data on Lizard Families found in Sundarbans

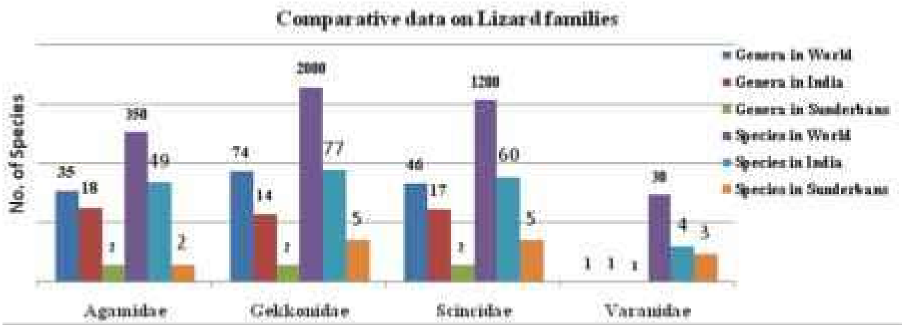


Fig 5: Comparitive data on Snake Families found in Sundarbans

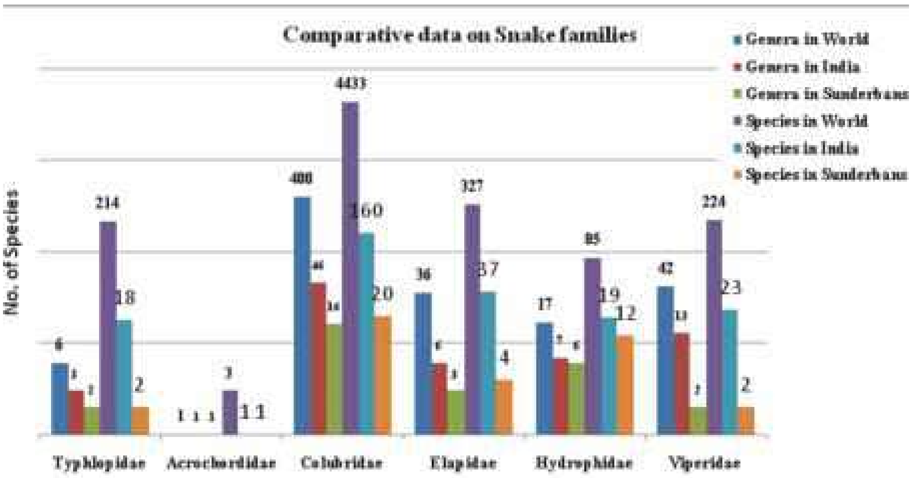
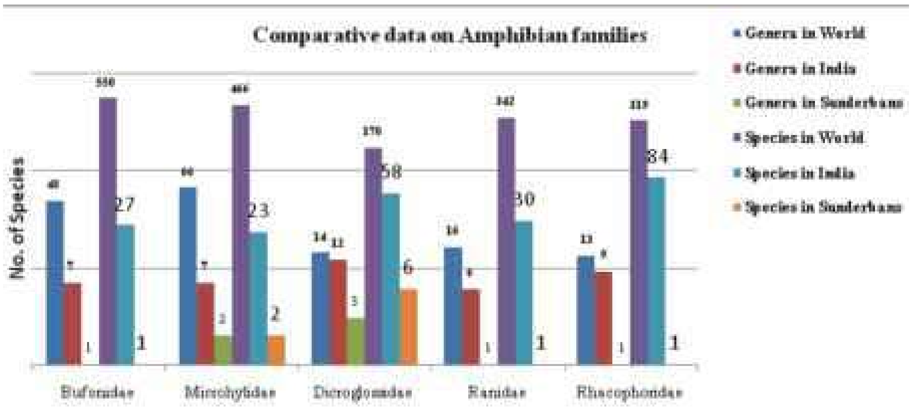


Fig 6: Comparitive data on Aphibian Families found in Sundarbans



ANNEXURE

Herpetofaunal Species in the Indian Sundarbans:

Sr No.	Class	Order	Family	Species	Common English Name	Local Name (if any)	Habitat
01	Reptilia	Chelonia	Dermochelyidae	*Dermochelys coriacea*	Leatherback Sea Turtle	Samudra kachim	Pelagic
02	Reptilia	Chelonia	Cheloniidae	*Eretmochelys imbricata*	Hawksbill Sea Turtle	Bada samudra kachim	Pelagic
03	Reptilia	Chelonia	Cheloniidae	*Lepidochelys olivacea*	Olive Ridley Sea Turtle	Gola kochchop / Jalpaironger kochchop / Pakhi kochchop / Samudrik katha	Pelagic
04	Reptilia	Chelonia	Geoemydidae	*Batagur baska*	River Terrapin	Bala katha / Boro ketho / Ram kachim / Pora katha / Bali katha	Supra Littoral
05	Reptilia	Chelonia	Geoemydidae	*Batagur dhongoka*	Three-striped Roofed Turtle	Sada katha	Littoral
06	Reptilia	Chelonia	Geoemydidae	*Batagur kachuga*	Red-crowned Roofed Turtle	Adi kori katha	Littoral
07	Reptilia	Chelonia	Geoemydidae	*Geoclemys hamiltonii*	Spotted Pond Turtle	Bagh kathua / Bhut katha / Kalo katha	Littoral
08	Reptilia	Chelonia	Geoemydidae	*Hardella thurjii*	Crowned River Turtle	Boro katha / Kali katha	Littoral
09	Reptilia	Chelonia	Geoemydidae	*Pangshura tectum*	Indian Roofed Turtle	Kori katha	Littoral
10	Reptilia	Chelonia	Trionychidae	*Chitra indica*	Narrow-headed Softshell Turtle	Chitra / Dhush kachim / Gotajil	Littoral
11	Reptilia	Chelonia	Trionychidae	*Pelochelys cantorii*	Asian Giant Softshell Turtle	Jata kachim	Littoral
12	Reptilia	Chelonia	Trionychidae	*Lissemys punctata*	Indian Flapshell Turtle	Chip kathua / Chiti kachim / Mete kachim / Til kachim	Littoral
13	Reptilia	Chelonia	Trionychidae	*Nilssonia gangetica*	Indian Softshell Turtle	Ganga kachim / Kholua / Kaucha kachim / Kachrong kachim	Littoral
14	Reptilia	Chelonia	Trionychidae	*Nilssonia hurum*	Indian Peacock Softshell Turtle	Dhalua kachim / Dhum kachim / Bukum	Littoral

Sr No.	Class	Order	Family	Species	Common English Name	Local Name (if any)	Habitat
15	Reptilia	Croco dylia	Crocodylidae	*Crocodylus porosus*	Estuarine or Salt-water Crocodile	Sunderbaner Kumir	Marine occasional
16	Reptilia	Squamata	Agamidae	*Calotes versicolor*	Indian Garden Lizard	Girgiti	Terrestrial
17	Reptilia	Squamata	Agamidae	*Sitana ponticeriana*	Fan-throated Lizard		Supra Littoral
18	Reptilia	Squamata	Gekkonidae	*Gekko gecko*	Tokay / Giant Gecko	Takhkhak	Arboreal
19	Reptilia	Squamata	Gekkonidae	*Hemidactylus frenatus*	Asian House Gecko	Tiktiki	Arboreal
20	Reptilia	Squamata	Gekkonidae	*Hemidactylus flaviviridis*	Yellow-Green House Gecko	Tiktiki	Arboreal
21	Reptilia	Squamata	Gekkonidae	*Hemidactylus brooki*	Brook's House Gecko	Tiktiki	Arboreal
22	Reptilia	Squamata	Gekkonidae	*Hemidactylus leschenaulti*	Bark Gecko	Gecho Tiktiki	Arboreal
23	Reptilia	Squamata	Scincidae	*Lygosoma punctata*	Spotted Supple Skink	Anjani	Terrestrial
24	Reptilia	Squamata	Scincidae	*Lygosoma albopunctata*	White-spotted Supple Skink	Anjani	Terrestrial
25	Reptilia	Squamata	Scincidae	*Eutropis carinata*	Keeled Grass Skink	Sadharan Anjani	Terrestrial
26	Reptilia	Squamata	Scincidae	*Eutropis macularia*	Bronze Grass Skink		Terrestrial
27	Reptilia	Squamata	Scincidae	*Eutropis multifasciata*	Many-lined Grass Skink		Terrestrial
28	Reptilia	Squamata	Varanidae	*Varanus bengalensis*	Bengal Land Monitor Lizard	Gosap	Supra Littoral
29	Reptilia	Squamata	Varanidae	*Varanus flavescens*	Yellow Monitor Lizard	Sonali Godhika	Supra Littoral
30	Reptilia	Squamata	Varanidae	*Varanus salvator*	Water Monitor Lizard	Jal Gosap	Supra Littoral
31	Reptilia	Squamata	Typhlopidae	*Ramphotyphlops braminus*	Common worm snake / Brahminy blind snake	Bamun dumokho sap	Terrestrial

Sr No.	Class	Order	Family	Species	Common English Name	Local Name (if any)	Habitat
32	Reptilia	Squamata	Typhlopidae	*Typhlops porrectus*	Slender Worm Snake	Soru dumokho sap	Terrestrial
33	Reptilia	Squamata	Acrochordidae	*Acrochordatus granulatus*	File / Wart snake	Ukha sap / Reti sap / Gurul sap / Achil sap	Littoral
34	Reptilia	Squamata	Colubridae	*Ahaetulla nasuta*	Common Vine snake	Laudaga sap / Sutanali	Arboreal
35	Reptilia	Squamata	Colubridae	*Amphiesma stolatum*	Buff-striped Keelback	Hele sap	Terrestrial
36	Reptilia	Squamata	Colubridae	*Atretium schistosum*	Olive Keelback water snake	Mete sap / Maitta sap	Supra Littoral
37	Reptilia	Squamata	Colubridae	*Boiga trigonata*	Common Indian Cat snake	Bonkhochur sap	Arboreal
38	Reptilia	Squamata	Colubridae	*Cerberus rynchops*	Dog-faced Water Snake	Jalbora / Gangmete sap	Littoral
39	Reptilia	Squamata	Colubridae	*Chrysopelea ornata*	Ornamental Flying Snake	Kalnagini sap	Arboreal
40	Reptilia	Squamata	Colubridae	*Coelognathus radiatus*	Copperheaded Trinket snake	Dudhraj / Arbali sap	Terrestrial
41	Reptilia	Squamata	Colubridae	*Dendrelaphis pictus*	Painted Bronzeback Tree Snake	Kharichur	Arboreal
42	Reptilia	Squamata	Colubridae	*Dendrelaphis tristis*	Common Bronze-back Tree Snake	Betachra	Arboreal
43	Reptilia	Squamata	Colubridae	*Enhydris enhydris*	Common Smooth Water Snake	Paina sap / Huria sap / Metuli sap	Littoral
44	Reptilia	Squamata	Colubridae	*Enhydris sieboldii*	Siebold's Smooth Water Snake		Littoral
45	Reptilia	Squamata	Colubridae	*Fordonia leucobalia*	White-bellied Mangrove Snake	Sundari sap	Littoral
46	Reptilia	Squamata	Colubridae	*Gerardia prevostianus*	Glossy Marsh Snake	Chakchaka / Mohonar sap	Littoral
47	Reptilia	Squamata	Colubridae	*Lycodon aulicus*	Common Wolf snake	Gharginni	Terrestrial
48	Reptilia	Squamata	Colubridae	*Lycodon jara*	Yellow-speckled Wolf snake		Terrestrial
49	Reptilia	Squamata	Colubridae	*Oligodon arnensis*	Banded Kukri Snake	Bonkhoraj	Terrestrial

Sr No.	Class	Order	Family	Species	Common English Name	Local Name (if any)	Habitat
50	Reptilia	Squamata	Colubridae	*Ptyas mucosa*	Rat snake	Danras	Terrestrial
51	Reptilia	Squamata	Colubridae	*Sibynophis subpunctatus*	Black-headed snake	Kalo matha dhora sap	Terrestrial
52	Reptilia	Squamata	Colubridae	*Xenochrophis cerasogaster*	Dark-bellied Marsh snake	Kalo mete dhora sap	Supra Littoral
53	Reptilia	Squamata	Colubridae	*Xenochrophis piscator*	Checkered Keelback	Jaldhora sap	Supra Littoral
54	Reptilia	Squamata	Elapidae	*Bungarus caeruleus*	Common Krait	Kalkeute / Kalaj / Chitti sap	Terrestrial
55	Reptilia	Squamata	Elapidae	*Bungarus fasciatus*	Banded Krait	Sankhamuthi / Sankni / Sankhini sap	Terrestrial
56	Reptilia	Squamata	Elapidae	*Naja kaouthia*	Monocellate Cobra	Keute / Keutiya	Terrestrial
57	Reptilia	Squamata	Elapidae	*Ophiophagus hannah*	King Cobra	Sonkhochur / Raj gokhro	Terrestrial
58	Reptilia	Squamata	Hydrophidae	*Enhydrina schistosa*	Hook-nosed Sea snake	Barsinak samudrik sap / Hooghly patee	Pelagic
59	Reptilia	Squamata	Hydrophidae	*Hydrophis caerulescens*	Malacca Sea snake		Pelagic
60	Reptilia	Squamata	Hydrophidae	*Hydrophis cyanocinctus*	Annulated Sea snake	Chittul / Kalo halud balayjukto lathi sap	Pelagic
61	Reptilia	Squamata	Hydrophidae	*Hydrophis fasciatus*	Fasciated Sea snake	Lathi sap	Pelagic
62	Reptilia	Squamata	Hydrophidae	*Hydrophis nigrocinctus*	Black Annulated sea Snake	Kalo balayjukto lathi sap	Pelagic
63	Reptilia	Squamata	Hydrophidae	*Hydrophis obscura*	Estuarine Sea snake	Mohonar sap	Pelagic
64	Reptilia	Squamata	Hydrophidae	*Lapemis curtus*	Malabar Sea snake	Baitha tebi sap	Pelagic
65	Reptilia	Squamata	Hydrophidae	*Laticauda colubrina*	Colubrine Amphibious Sea snake	Ubhochar sap	Pelagic
66	Reptilia	Squamata	Hydrophidae	*Laticauda laticauda*	Common Amphibious Sea snake	Ubhochar sap	Pelagic
67	Reptilia	Squamata	Hydrophidae	*Microcephalophis cantoris*	Cantor's narrow-headed Sea snake	Sarumatha samudrik sap	Pelagic
68	Reptilia	Squamata	Hydrophidae	*Microcephalophis gracilis*	Common narrow-headed Sea Snake	Sarumatha samudrik sap	Pelagic

Sr No.	Class	Order	Family	Species	Common English Name	Local Name (if any)	Habitat
69	Reptilia	Squamata	Hydrophidae	*Pelamis platura*	Black and Yellow Sea snake	Kalo halud samudrik sap	Pelagic
70	Reptilia	Squamata	Viperidae	*Daboia russelii*	Russell's Viper	Chandrabora / Sekalbora	Terrestrial
71	Reptilia	Squamata	Viperidae	*Trimeresurus gramineus*	Green Pit Viper		Arboreal
72	Amphibia	Anura	Bufonidae	*Duttaphrynus melanostictus*	Common Indian Toad	Kuno bang / Kat-kati bang	Terrestrial
73	Amphibia	Anura	Microhylidae	*Microhyla ornata*	Ornate Narrow-mouthed Frog	Cheena bang	Terrestrial
74	Amphibia	Anura	Microhylidae	*Kaloula taprobanica*	Indian Painted Frog	Vepu bang / Sundari bang	Terrestrial
75	Amphibia	Anura	Dicroglossidae	*Euphlyctis cyanophlyctis*	Skittering Frog	Jal bang	Supra Littoral
76	Amphibia	Anura	Dicroglossidae	*Euphlyctis hexadactylus*	Green Pond Frog	Sabuj bang	Supra Littoral
77	Amphibia	Anura	Dicroglossidae	*Fejervarya orissaensis*	Orissa Cricket Frog	Jhi-jhi bang	Terrestrial
78	Amphibia	Anura	Dicroglossidae	*Fejervarya syhadrensis*	Syhadra Cricket Frog	Jhi-jhi bang	Terrestrial
79	Amphibia	Anura	Dicroglossidae	*Hoplobatrachus crassus*	Jerdon's Bull Frog		Terrestrial
80	Amphibia	Anura	Dicroglossidae	*Hoplobatrachus tigerinus*	Indian Bull Frog	Kola bang / Sona bang	Terrestrial
81	Amphibia	Anura	Ranidae	*Hylarana tytleri*	Reed Frog	Pana bang	Terrestrial
82	Amphibia	Anura	Rhacophoridae	*Polypedates maculatus*	Indian Tree Frog	Gecho bang / Shepo bang / Kath bang	Arboreal

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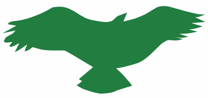
2.16 AVES

Aves have often been termed as glorified reptiles and the discovery of the fossil of Archaeptoteryx unequivocally speaks about the reptilian origin of birds (Sinha et al. 1997).

KUSHAL MOOKHERJEE
Wildlife consultant with specialization in Avifauna



Birds in the mangrove areas have developed special characteristics to their beaks and feet.

Birds are the most highly specialized craniate class, in which the epidermal exoskeleton takes the form of feathers over the greater part of the body, horny sheath to the beak, and claws on the digits of the foot and sometimes of the hand. Subsequent development of true flight, as distinct from the occasional gliding that is found among fishes, amphibians, reptiles, and mammals (excluding the true flight of bats), enabled birds to successfully exploit a new environ- ment and to evolve into one of the most successful groups of modern animals (Marshall et al. 1988).

The class Aves is subdivided into two subclasses, *Archaeornithes* and *Neornithes*. The subclass *Archaeo- rnithes* includes the fossil bird *Archaepteryx*. The subclass Neornithes consists of four superorders: *Odontognathae* (extinct cretaceous birds); *Palaeognathae* (running birds); *Impennae* (penguins); and *Neognathae* (flying birds). *Neognathae* includes 22 orders, of which the order Passeriformes has the largest number of species (Sinha et al. 1997).

Birds have very unique adaptations that allow them to live in a wide array of habitats. Some birds are specialized and may be susceptible to changes in environment. Because of the great variety of wetlands, bird adaptation to use of wetland environments differs widely from species to species.

Birds use mangrove wetlands during breeding cycles. Some birds depend on these wetlands almost totally for breeding, nesting, feeding, or shelter during their breeding cycles. Birds that need functional access to a wetland or wetland products during their life cycle, especially during the breeding season, can be called 'wetland dependent' (Stewart 2007). Birds living in the mangrove areas have developed special characteristics to their beaks and feet to help them adapt to this environment to live off certain prey. Pelicans and other seabirds live in the canopies of the mangrove swamps. During the breeding season, they form large nesting assemblages of adult birds and their offspring, called large 'rookeries' (Maikut 2004).

Mangroves consist of a succession of monospecific stands located along tropical and subtropical coasts. Their local distribution is not directly associated with terrestrial climatic factors such as rainfall, humidity, or air temperature (Elhaï 1968) but rather with hydrographic factors such as water temperature (Rodriguez 1975), wave intensity, marine currents, and water salinity (Blasco 1984; Chapman 1977; West 1977). Accordingly, mangroves are distributed in isolated forest patches of varying sizes. Despite their often similar plant composition and structure, these mangrove patches frequently experience different climatic conditions (Jiménez 1992; Oliver 1982). Botanical studies have shown that timing of flowering and leaf production (Duke 1990; López-Portillo and Ezcurra 1985), as well as intensity of vegetative growth (Lugo and Snedaker 1974), is influenced by flooding, seasonality, and underground salinity. Since these factors depend mostly on rainfall and tide (Por 1984), mangrove phenology is likely to vary geographically (Duke 1990). The extent to which these variations affect the invertebrate community and their prey, especially the bird fauna, is unknown.

Common Red Shank (Tringa totanus)

In the salt marshes of North Carolina, the length of the flooding period and tide level appeared to be major influences on invertebrate composition (Davis and Gray 1966). Because invertebrates are the only food resource available to birds in mangroves (Lefebvre et al. 1994), invertebrate composition is likely to affect the bird-feeding guild assemblage. However, Neotropical-Nearctic migrants and Neotropical residents could respond distinctly to such variations in food resources because of their differing physiological requirements (overwintering survival versus potential reproduction) and foraging plasticity (Poulin and Lefebvre 1996; Rappole 1995). Some of the resident bird species are highly dependent on mangroves for their survival. Because of this dependence, disturbances to the *mangal* may reverberate throughout the bird populations. This may be particularly true where the bird species show stray site fidelity (Warkentin and Hernandez 1996).

Little cormorants (Phalacrocorax niger)

Great egret (Ardea alba)

Little Tern
(Sterna albifrons)

Collared Kingfisher
(Todriamphus chloris)

Overview of the Group

Mangrove ecosystems provide an excellent habitat for birds. Gill and Donsker (2010) list 10,396 species of birds of the world. Members of the family Ardeidae, Charadriidae, Laridae, Ciconidae, Accipitridae, and Alcedinidae are the most common birds in the mangrove. Mangroves provide an important habitat for land birds, shorebirds, and waterfowl, and they are home to a number of threatened species, including spoonbills (*Ajala ajala*); large snowy egrets (*Cosmorodium albus*); scarlet ibis (*Eudocimus ruber*); fish hawks (*Pandion haliaetus*); royal terns (*Sterna hirundo*); West Indian whistling-ducks (*Dendrocygna arborea*); and Storm's Storks (Danielsen et al. 1997; Panitz 1997; Staus 1998).

Distributions and abundances of the feeding guild, which indicates species assemblages that exploit the same class of resources similarly (Root 1967), were found consistent with the abundance and distribution of their invertebrate prey (Lefebvre and Poulin 1997). In Singapore, sand pipers, plovers, herons, and egrets all regularly use the mangrove habitat (Murphy and Sigurdsson 1990). Resident bird species are also highly dependent on mangroves for their survival. The yellow warbler (*Dendroica petechia*) and the mangrove vireo (*Vireo pallens*) are nearly confined to mangroves (Parkes 1990; Buden 1992). The mangrove gerygone spends 80 percent of its time on *Avicennia marina* (Noske 1996) while *A. germinans* provides an important breeding habitat for Florida prairie warblers (*Dendroica discolour paludicola*) and Cuban Yellow Warblers (*D. petechia gundlachi*) (Prather and Cruz 1995).

Migratory birds visiting the mangroves may fly long distances to find food and nesting places. The structural diversity of the mangrove habitat enables a variety of passerines and non-passerines, which are uncommon in other wetland areas, to use mangrove swamps (Samant 1985).

Avifaunal diversity has been found to be significantly higher in Indian mangroves (table 1) when compared to the mangrove ecosystems of Indo-Malaysia and Australasia.

An analysis (table 2) of eight wetland ecosystems from different biogeographical regions with mangrove habitat reveals that the avifaunal diversity is comparatively low in the Sundarbans when compared to other wetland ecosystems with mangrove habitat. In the Pantanal, Brazil, 27 percent of the species are restricted to wetland habitats (17 percent aquatic and 10 percent terrestrial) and 73 percent are not restricted to wetlands. In the Okavango Delta, Botswana, the numbers are 38 percent (25 percent aquatic and 13 percent terrestrial) and 62 percent, respectively. Water birds are only listed for Kakadu National Park, Australia, with 50 percent being migratory shorebirds. (Junk et al. 2006). About 315 species of birds are known from the Sundarbans of Bangladesh. The most common ones are white-bellied sea eagles (*Haliaetus leucogaster*) and Pallas's fish eagles (*Haliaetus leucorhyphus*; Hussain and Acharya 1994). Mangroves at Bhitarkanika, Orissa harbor 174 species of birds and is one of the few protected areas in India which has 6 species of kingfishers: Common (*Alcedo atthis);* Brown-winged (*Halcyon amauroptera);* White-throated (*H. smyrnesis);* Black-caped *(H. pileata);* Collared (*Todriamphus chloris);* and Pied *(Ceryle rudis)* (Pandav 1996). Alves et al. (1997) counted 32 bird species (2 marine species, 18 terrestrial species, and 12 waterfowl) in the mangroves of Jequiaman, Brazil. Seventy-seven bird species have been recorded in the Pacific mangroves of Colombia. Forty-three percent of these are permanent residents, 22 percent are regular visitors, and 18 percent are temporary winter residents (Naranjo 1997).

Table 1: Number of Avifaunal species in mangrove ecosystem of different regions of the Indian Ocean region

Sr. No.	Name of the region	Birds	Reference
1	Indo Malaysia	177	Spadling *et al.*, 1997
2	Australasia	244	Spadling *et al.*, 1997
3	India	433	Kathiresan *et al.*, 2005

SYNOPTIC VIEW

Diversity

Avifauna in the SBR is represented by 234 species[1] (annexure 1, table 3, and figure 1) under 46 families (*Status of Avifauna* 2006). Maximum species diversity was found in Passeriformes (92), Ciconiiformes (80), Cuculiformes (11), Coraciiformes (11), Piciformes (11), and Anseriformes (10). Ninety-two species of birds of the order Passeriformes are found from the Sundarbans, which strongly ratifies the Medway and Nisbet (1965) reports that passerine birds are not common in the *mangal* although their existences are very common in the Nypa zones.

234
SPECIES
UNDER 46 FAMILIES
OF AVIFAUNA IS FOUND
IN THE SUNDARBAN
BIOSPHERE RESERVE

The SBR is one of the few protected areas in India which harbors sympatric species. Eight species of kingfishers are sympatric here: Common Kingfisher (*Alcedo atthis*); Brown-winged Kingfisher (*Halcyon amauroptera*); Stork-billed Kingfisher (*Halcyon capensis*); Ruddy Kingfisher (*Halcyon coromanda*); White-throated Kingfisher (*Halcyon smyrnensis*); Black-capped Kingfisher (*Halcyon- pileata*); Collared Kingfisher (*Todiramphus chloris*); and Pied Kingfisher (*Ceryle- rudis*) and eight species of cuckoo: Pied Cuckoo (*Clam- ator jacobinus*); Chestnut-winged Cuckoo (*Clamator coromandus*); Common Hawk Cuckoo (*Hierococcyx varius*); Indian Cuckoo (*Cuculus micropterus*); Oriental Cuckoo (*Cuculus saturates*); Lesser Cuckoo (*Cuculus poliocephalus*); Grey-bellied Cuckoo

(*Cacomantis passerines*); and Plaintive Cuckoo (*Cacomantis merulinus*).

A total of 149 species of resident and 85 species of migrant visitors (table 3) have been recorded from the area; 42 species of the order Ciconiiformes are the most abundant migrants in the Sundarbans. Four bird species found here are mainly restricted to the mangrove forests of India: Brown winged and Collared kingfisher, Mangrove pitta, and Mangrove whistler (*Pachycephala grisola*). In the Indian subcontinent, the Mangrove whistler is otherwise found only in Bhitarkanika and in a narrow zone fringing the shore in the Andaman and Nicobar Islands (Ali and Ripley 1987).

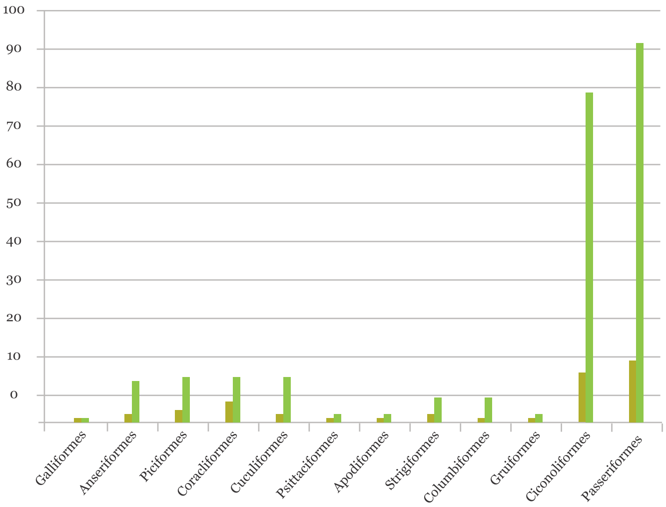
The Red Jungle Fowl (*Gallus gallus*) is common on the forest floor. Rufous Woodpecker *(Celeus brachyurus)*; Fulvous-breasted Woodpecker *(Dendrocopos macei)*; and Streak-throated Woodpecker *(Picusxanthopy- gaeus)* seek insect larvae in the older trees of the landward fringes. The Rose-ringed Parakeet (*Psittacula krameri*) is one of the most commonly encountered birds in the Sundarban mangrove; large numbers may be seen flying in from outside to feed or roost in the forest. The Eurasian Collared Dove (*Streptopelia decaocto*) is also very common and huge numbers fly in to the forest to feed or roost. The Orange-breasted Green Pigeon (*Treron bicincta*) is also common seasonally.

Table 2: Total number of birds and number of migrating species in the different wetlands with mangrove habitat

Sr. No	Name of Region	Total Number	Palaearctic migrants
1	Everglades, Florida	349	294
2	Pantanal, Brazil	390	20
3	Okavango Delta, Botswana	444	58
4	Kakadu National Park, Australia	107*	54
5	Sundarbans, Bangladesh	315	84
6	Bhitarkanika, India	174	-
7	Jequiaman, Brazil	32	-
8	Pacific mangroves, Columbia	77	-

Note: *- Water-birds only are listed for Kakadu National Park

Fig 1: Family and Species composition of Avifauna in Sundarbans



[1] Status of Avifauna within the Sunderban Reserved Forests and non-forest areas of the SBR carried out by Prakriti Samsad, Kolkata in collaboration with the Forest Department, Government of West Bengal—aided by the United Nations Development Programme.

The Mangrove Pitta (*Pitta brachyura*), though common all over the forest area throughout the year as evident from its call, is seldom seen. The Bronzed Drongo (*Dicrurus aeneus*) is very common throughout the forest area. The Jungle Myna (*Acridotheres fuscus*) is the most common myna of the forest and breeds and roosts in huge numbers. The Common Tailorbird (*Orthotomus sutorius*) is common all over the forest. The Greenish Warbler (*Phylloscopus trochiloides*) is possibly the most common wintering warbler. The Indian Scimitar Babbler (*Pomatorhinus horsfieldii*), though common all over the forest area as evident from its call, is very difficult to see. Loten's Sunbird (*Nectarinia lotenia*), whose known distribution had been southern India up to coastal Orissa, has been recorded from the Sundarban forests.

The White-bellied Sea Eagle (*Haliaeetus leucogaster*) and the Brahminy Kite (*Haliastur indus*) are the most commonly seen raptors. The Whiskered Tern (*Chlidonias hybridus*) is probably the most common among the terns and gulls encountered in the Sundarbans forest. The Great Cormorant (*Phalacrocorax carbo)* and Little Cormorant (*Phalacrocorax niger*) found here are characteristic of rivers and estuaries. The Darter *(Anhinga melanogaster)* is rare (Macnae 1968). Herons use the channel banks as fishing grounds and often nest communally with cormorants and darters in the taller trees in the more isolated parts of the *mangals*. Noted heron species are Black-crowned Night Heron (*Nycticorax nycticorax*) and Little Heron (*Butorides striatus*), which may be found on the banks of the mangrove channels of the Sundarbans. Whimbrel (*Numenius phaeopus*) and Common Sandpiper (*Actitis hypoleucos*) are perhaps the most commonly encountered waders in the forest area. Waders like Whimbrel (*Numenius phaeopus*); Common Redshank (*Tringa tetanus)*; and Terek Sandpiper (*Xenus cinereus*) may be found perching on the branches of the mangroves in the seaward fringes during the high tide. They scatter over the mud flats as soon as the tide has fallen sufficiently. Among the ducks, the most common in the large rivers are perhaps the Gadwall (*Anas strepera*) and the Tufted Duck (*Aythya fuligula*). Among interesting species commonly seen are Common Shelduck (*Tadorna tadorna*).

Distribution

Root (1967) introduced the concept of 'guild' to collect information of exploitation patterns of birds. A guild is defined as a group of species that exploit the same class of environmental resources in a similar way. This term groups together species, without regard to taxonomic position, that overlap significantly in their niche requirements. The guild has a position comparable in the classification of exploitation patterns to the genus in phylogenetic schemes. Guild structure analysis for distribution of avifauna in the Indian Sundarbans reveals 15 guilds (table 3 and figure 2) based on their feeding habitat. Table 3 contains the species groups:

Brown-winged kingfisher (Halcyon amauroptera)

White bellied sea eagle (Haliaeetus leucogaster)

Table 3: Status and feeding guilds of Avifauna in Sundarbans.

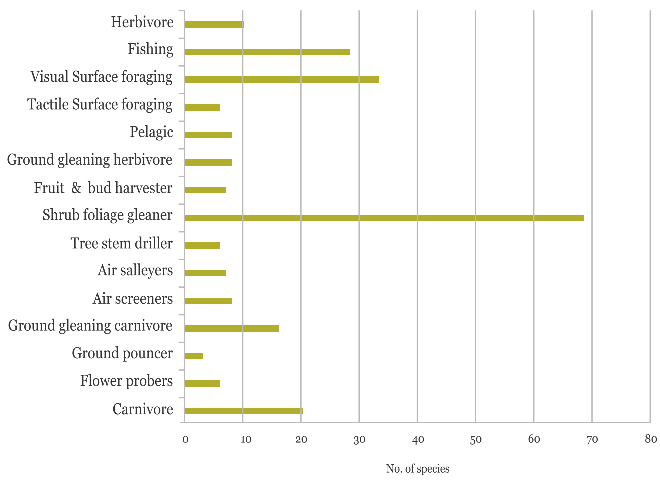
Order	Status		Total	Feeding Guilds														
	R	M		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Galliformes	1		1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Anseriformes	3	7	10	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Piciformes	9	2	11	-	-	-	-	-	-	3	-	6	-	-	2	-	-	-
Coraciiformes	11		11	-	8	-	-	-	-	-	-	-	2	-	-	1	-	-
Cuculiformes	7	4	11	-	-	-	-	-	-	-	10	-	-	-	1	-	-	-
Psittaciformes	2		2	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-
Apodiformes	2		2	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Strigiformes	6		6	-	-	-	-	-	-	-	-	-	-	1	-	-	-	5
Columbiformes	6		6	-	-	-	-	-	4	2	-	-	-	-		-	-	-
Gruiformes	2		2	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
Ciconiiformes	38	42	80	-	20	31	6	8	-	-	-	-	-	-	-	-	-	15
Passeriformes	62	30	92	-	-	-	-	-	3	-	58	-	5	5	13	2	6	-
Total	**149**	**85**	**234**	**10**	**28**	**33**	**6**	**8**	**8**	**7**	**68**	**6**	**7**	**8**	**16**	**3**	**6**	**20**

Note: (A) Herbivore (B) Fishing (C) Visual surface foraging (D) Tactile surface foraging (E) Pelagic (F) Ground gleaning herbivore (G) Fruit & bud harvester (H) Shrub foliage gleaner (I) Tree stem driller (J) Air sallyers (K) Air screeners (L) Ground gleaning carnivore (M) Ground pouncer (N) Flower probers (O) Carnivore.

Various studies in Africa, Asia, and the Neotropics show that the mangrove avifauna is partially composed of migrant species from the temperate zone. For tropical habitats in general, various authors consider that the winter assemblages of migrants and residents represent fully integrated ecological communities, while resident species do not fill the available niche space after the migrants leave. In contrast, others suggest that the lack of competition between migrants and residents results from the exploitation by migrants of food resources unexploited by residents due to their irregular temporal or spatial distributions. Lefebvre et al. (1994) reported that migrants compete with residents by limiting their breeding season or by promoting population movements.

The open beaches of Jambu Island off the coast of Fraserganj are good for water birds, mainly waterfowl. Small congregations of waders, gulls, and terns are seen along the beaches of Bakkhali, especially near the estuary where the small creek flows out into the sea. The extensive beaches on the southern face of Sagar Island, Sundarbans has assorted wader congregations in winter though not in large numbers. Halliday Island Wildlife Sanctuary is a small island in the middle of the Matla River and is one of the most important staging grounds for wintering waders. Thousands of small waders, mainly Lesser Sand Plovers, use the sand flats on the southern parts of the island. The beaches to the south of the Lothian Island Wildlife Sanctuary, Sundarbans attract large congregations of gulls, mainly Pallas's Gull in winter. The beach to the south of Kalash Island and the adjoining waters also attract large congregations of gulls, mainly Pallas's Gull, in winter. The riverine stretch south of the Bidya Forest Range Office in the Sundarbans often attracts large congregations of waterfowl, mainly ducks and gulls, in winter. There are a few locations on the Matla River in the Sundarbans which attract congregations of waterfowl like ducks. The stretch of the river east of Basanti Island is one of them. One location near Canning Block, called Dabur Char, which used to have an extensive open mud flat during the low tide, used to be an excellent habitat for waterfowl.

Fig 2: Functional guild structure of Avifauna in Sundarbans



Local Community Dependencies and Traditional Use

100
MEDICINAL APPLICATIONS HAVE BEEN REPORTED FROM SUNDARBANS.

Majumder and Dey (2007) reported drugs prepared by the tribes (Santhal, Oraon, and Munda) from different species of avifauna in the Sundarbans for the remedy of various diseases. A total of 100 medicinal applications made from 7 avifaunal species have been reported from the Sundarbans, namely *Bubulcus ibis* (18); *Milvus migrans* (6); *Gallus* (28); *Columba livia* (18); *Acridotheres tristis* (5); *Corvus splendens* (10); and *Corvus macrorhynchos* (21). The medicines are applied locally and mostly externally to cure diseases such as otorrhoea, muscular pain, headache, leprosy, scorpion bite, alopecia, leucorrhea, carditis, sciatica, osteoarthritis, opthalmia, and obesity.


Red Jungle fowl (Gallus gallus)

Ecological Importance and Need for Conservation

Wading birds serve important ecosystem functions such as accelerating nutrient cycling at feeding grounds (Morales and Pacheco 1986) and regulating fish populations (Kushlan 1976; Lopez et al. 1988; Miranda 1995). Our understanding of these functions is facilitated by information on the species' food habits and the extent of their dietary similarities (Kushlan 1978). Birds, as consumers, act as accelerators of nutrient cycling through food consumption and faeces deposition within the ecosystem. Mukherjee (1971) reported that the Little Green Heron, which was known to feed only on aquatic animals, feeds instead on terrestrial insects such as grasshoppers, mantids, and toads. Crustaceans form the bulk of its food, constituting 31.8 percent, and consist mostly of commercial species. Next to the crustaceans are fishes (29 percent) and insects (14.5 percent). Stomach content analysis of 26 Little Green Heron from the Sundarbans revealed 108 examples of fishes, mostly mudskippers. Tadpoles form 13.8 percent of the total bulk. Annelids (3.62 percent), both freshwater as well as brackish-water forms, are consumed in very small proportions.

Provide information on the major changes in the pattern of the flow of energy and nutrients of the entire ecosystem

Owing to their great mobility, birds are also especially important in nutrient transport to or from the ecosystem (Morales and Pacheco 1986). Gonzalez-Jimenez and Escobar (1977) reported that top carnivores are nutrient accumulators by themselves. Their nutrient levels exceed those of water, soil (Bulla et al. 1980), and plant tissues. Morales and Pacheco (1986) reported that nutrient flow through birds may mobilize large amounts of nutrients, primarily nitrogen, phosphorus, and calcium and might be viewed as biological indicators of the aquatic productivity. The enrichment of a red mangrove stand by bird guano stimulates plant growth and results in higher


Lesser Adjutant, (Leptoptilos javanicus)

nitrogen concentrations of some parts in comparison to a nearby stand with no enrichment (Onuf et al. 1977). As top consumers, they can provide information on the major changes in the pattern of the flow of energy and nutrients of the entire system.

Many plants depend on pollination by animals for successful seed set. Over 920 species of birds pollinate plants; typically 5 percent of a region's flora and up to 10 percent of the islands' flora is being pollinated by birds (Stiles 1981, 1985; Kato and Kawakita 2004; Anderson et al. 2006; Bernardello et al. 2006). *Bruguiera gymnorrhiza* is one of the most important and widespread large-leafed mangrove species. In *B. gymnorrhiza*, the flowering and fruiting occur continuously throughout the year. The flowers with red sepals and brown petals are quite conspicuous against the foliage. The mature buds which are ready for opening require external tripping by birds, and in the absence of bird visits, the buds remain as they are and fall subsequently. This flower-bird relationship is well developed and coevolved to cause an explosion of flowers following tripping by birds. At the Coringa mangrove forest, the birds involved in floral tripping are sunbirds (*Nectarinia asiatica and N. zeylonica*) and white-eyes (*Zosterops palpebrosa).* This indicates that *B. gymnorrhiza* disperses pollen to its neighboring or distantly spaced trees through floral explosion by using bird species. This type of flower-bird relationship in this tree species is not a local adaptation but a universal adaptation throughout the distribution range of mangrove forests (Subba Rao and Raju 2005).

STATUS AND THREATS

Estuarine mud flats like in the Sundarbans are very important for many shore -bird populations during winter and migration, many species of which feed exclusively on intertidal benthic invertebrates at low tide (Barnes et al. 1997). In tropical regions, the biodiversity of benthic macro fauna on intertidal mud flats is


Congregation of gulls (Chroicocephalus brunnicephalus)

much higher (Alongi 1990). An equivalent biomass of macrofauna on mudflats in the tropics produces a biomass turnover (productivity) that is ten times faster than in temperate intertidal habitats (Ansell et al. 1978; Alongi 1990). Restriction of feeding opportunity because of land claims on the upper parts of feeding grounds can jeopardize the ability of the birds to take sufficient reserves to breeding grounds to breed successfully or even jeopardize their own survival (Davidson and Evans 1988).

Some of the resident birds are totally dependent on mangrove trees for their survival and show strong site fidelity when disturbed. Habitat disturbance may be natural, for example, the frequent cyclonic storms that strongly affect myna populations in the Pichavaram mangrove of South India (Nagarajan and Thiayagesan 1995). Habitat disturbances are more frequently caused by human activity (Karthiresan and Bingham 2001).

The climate change effects on birds has major implications for the population dynamics of birds. These effects include earlier breeding; changes in timing of migration; changes in breeding performance (egg size, nesting success); changes in population sizes; changes in population distributions; and changes in selection differentials between components of a population (Walther et al. 2002; Parmesan and Yohe 2003; Root et al. 2003). Some species may find it difficult to adapt to climate change because, for example, of the use of inappropriate environmental cues as phenological triggers or because different parts of a food chain may respond differentially to climate change (Harrington et al. 1999).

A major consequence of future sea-level rise for coastal birds seems likely to be changes to habitat structure and quality (Austin and Rehfisch 2003). The extent to which the invertebrate populations of coastal mud flats will be influenced by sea-level rise is likely to depend on whether rates of sedimentation can compensate for sea-level rise (Beukema 1992). Similarly, the structure of habitats such as salt marshes and beaches may change significantly as a result of sea-level rise, which is likely to influence the important breeding and wintering populations of wildfowl (Vickery et al. 1995); waders (Liley 1999; Norris et al. 2004); and passerines (Brown and Atkinson 1996) which use these habitats. Many brackish-water and coastal freshwater sites also hold internationally important bird populations and sea-level rise may threaten these sites through tidal inundation following breaches of any sea defenses.

The abundance of intertidal invertebrates, the major prey of many internationally important populations of wintering waders, is significantly reduced in years following mild winters (Beukema et al. 2001). A successful tree plantation programme carried out on the mud flats at *Dabur Char* (Block Canning in Sundarbans) has resulted in a miniature forest patch, but the waterfowl, mostly waders which used to visit the area, is not seen nowadays (*Status of Avifauna* 2006).

> 14 species fall under Schedule I; 207 species are under Schedule IV; 1 species under Schedule V and 13 species does not find place in the Wild Life (Protection) Act, 1972

Large-scale collection of prawn seeds in intertidal zones, mudflats, and mud banks is affecting the biodiversity of the microhabitats. The continuous movement of prawn seed collectors along the mud banks and mudflats has a compacting effect on the soil, thus affecting the micro-habitat for many wading birds. This in turn is responsible for the decline of bird records and mostly the waders from these zones. Trapping and killing of waterfowl is also prevalent in many localities. Fishermen resent the presence of fish-eating birds like cormorants and actively drive them away or kill them.

Analyses of the past records and present data show that the population of birds which depend on fish and other aquatic fauna in the Sundarbans has declined to 36 percent during the last three decades. Among them, noted species are Swamp Francolin (*Francolinus gularis*); White-headed Duck (*Oxyura leucocephala*); Falcated Duck (*Anas falcate*); Red-crested Pochard (*Rhodonessa rufina*); Speckled Piculet (*Picumnus innominatus*); Water Rail (*Rallus aquaticus*); Baillon's Crake (*Porzana pusilla*); Purple Swamphen (*Porphyrio porphyrio*); Jack Snipe (*Lymnocryptes minimus*); Temminck's Stint (*Calidris temminckii*); Oriental Pratincole (*Glareola maldivarum*); Caspian Tern (*Sterna caspia*); and Bonelli's Eagle (*Hieraaetus fasciatus*), which are not sighted nowadays. Given the conservation and protection regime of the Wild Life (Protection) Act, 1972 in India, avifaunal species (see annexure) found in the Sundarbans has been categorized under schedules. Analysis of the data shows that 14 species fall under Schedule I; 207 species are under Schedule IV; 1 species under Schedule V; and 13 species do not find a place in the Act.

Stenseth et al. (2002) point out that climate variability can affect populations in a density-independent manner but may also affect the strength of density dependence regulating a population. Population modelling, similar in scope to work undertaken by Rodenhouse (1992), is urgently needed so that we can go beyond single parameter studies and begin to understand the complexities of the interactions between different components of a species' demography.

ANNEXURE

List of Avifauna reported from Indian Sundarban and their Functional guild.

Order	Family	Species	Common English Name	Associated Guild	Status	Schedules*
Galliformes	Phasianidae	*Gallus gallus*	Red Junglefowl	F	R	IV
Anseriformes	Dendrocygnidiae	*Dendrocygna javanica*	Lesser Whistling-duck	A	R	IV
Anseriformes	Anatidae	*Tadorna ferruginea*	Ruddy Shelduck	A	M	IV
Anseriformes	Anatidae	*Tadorna tadorna*	Common Shelduck	A	M	IV
Anseriformes	Anatidae	*Sarkidiornis melanotos*	Comb Duck	A	R	IV
Anseriformes	Anatidae	*Nettapus coromandelianus*	Cotton Pygmy-goose	A	R	IV
Anseriformes	Anatidae	*Anas strepera*	Gadwall	A	M	IV
Anseriformes	Anatidae	*Anas penelope*	Eurasian Wigeon	A	M	IV
Anseriformes	Anatidae	*Anas acuta*	Northern Pintail	A	M	IV
Anseriformes	Anatidae	*Anas clypeata*	Northern Shoveler	A	M	IV
Anseriformes	Anatidae	*Aythya fuligula*	Tufted Duck	A	M	IV
Piciformes	Picidae	*Jynx torquilla*	Eurasian Wryneck	M	M	IV
Piciformes	Picidae	*Celeus brachyurus*	Rufous Woodpecker	I	R	IV
Piciformes	Picidae	*Dendrocopos macei*	Fulvous-breasted Woodpecker	I	R	IV
Piciformes	Picidae	*Picus xanthopygaeus*	Streak-throated Woodpecker	I	R	IV
Piciformes	Picidae	*Dinopium javanense*	Common Flameback	I	R	IV
Piciformes	Picidae	*Dinopium benghalense*	Black-rumped Flameback	I	R	IV
Piciformes	Picidae	*Chrysocolaptes lucidus*	Greater Flameback	I	R	IV
Piciformes	Megalaimidae	*Megalaima lineata*	Lineated Barbet	G	R	IV
Piciformes	Megalaimidae	*Megalaima asiatica*	Blue-throated Barbet	G	R	IV
Piciformes	Megalaimidae	*Megalaima haemacephala*	Coppersmith Barbet	G	R	IV

Order	Family	Species	Common English Name	Associated Guild	Status	Schedules*
Piciformes	Upupidae	*Upupa epops*	Common Hoopoe	M	M	-
Coraciiformes	Coraciidae	*Coracias benghalensis*	Indian Roller	N	R	IV
Coraciiformes	Alcedinidae	*Alcedo atthis*	Common Kingfisher	B	R	IV
Coraciiformes	Halcyonidae	*Halcyon amauroptera*	Brown-winged Kingfisher	B	R	IV
Coraciiformes	Halcyonidae	*Halcyon capensis*	Stork-billed Kingfisher	B	R	IV
Coraciiformes	Halcyonidae	*Halcyon coromanda*	Ruddy Kingfisher	B	R	IV
Coraciiformes	Halcyonidae	*Halcyon smyrnensis*	White-throated Kingfisher	B	R	IV
Coraciiformes	Halcyonidae	*Halcyon pileata*	Black-capped Kingfisher	B	R	IV
Coraciiformes	Halcyonidae	*Todiramphus chloris*	Collared Kingfisher	B	R	IV
Coraciiformes	Cerylidae	*Ceryle rudis*	Pied Kingfisher	B	R	IV
Coraciiformes	Meropidae	*Merops orientalis*	Green Bee-eater	K	R	-
Coraciiformes	Meropidae	*Merops philippinus*	Blue-tailed Bee-eater	K	R	-
Cuculiformes	Cuculidae	*Clamator jacobinus*	Pied Cuckoo	H	M	IV
Cuculiformes	Cuculidae	*Clamator coromandus*	Chestnut-winged Cuckoo	H	M	IV
Cuculiformes	Cuculidae	*Hierococcyx varius*	Common Hawk Cuckoo	H	R	IV
Cuculiformes	Cuculidae	*Cuculus micropterus*	Indian Cuckoo	H	R	IV
Cuculiformes	Cuculidae	*Cuculus saturatus*	Oriental Cuckoo	H	M	IV
Cuculiformes	Cuculidae	*Cuculus poliocephalus*	Lesser Cuckoo	H	M	IV
Cuculiformes	Cuculidae	*Cacomantis passerinus*	Grey-bellied Cuckoo	H	R	IV
Cuculiformes	Cuculidae	*Cacomantis merulinus*	Plaintive Cuckoo	H	R	IV
Cuculiformes	Cuculidae	*Eudynamys scolopacea*	Asian Koel	H	R	IV
Cuculiformes	Cuculidae	*Phaenicophaeus tristis*	Green-billed Malkoha	H	R	IV
Cuculiformes	Centropodidae	*Centropus sinensis*	Greater Coucal	M	R	IV

Order	Family	Species	Common English Name	Associated Guild	Status	Schedules*
Psittaciformes	Psittacidae	*Psittacula krameri*	Rose-ringed Parakeet	G	R	IV
Psittaciformes	Psittacidae	*Psittacula eupatria*	Alexandrine Parakeet	G	R	IV
Apodiformes	Apodidae	*Cypsiurus balasiensis*	Asian Palm Swift	L	R	-
Apodiformes	Apodidae	*Apus affinis*	House Swift	L	R	-
Strigiformes	Strigidae	*Otus scops*	Scops Owl	P	R	IV
Strigiformes	Strigidae	*Otus sunia*	Oriental Scops Owl	P	R	IV
Strigiformes	Strigidae	*Otus bakkamoena*	Indian Scops Owl	P	R	IV
Strigiformes	Strigidae	*Ketupa zeylonensis*	Brown Fish Owl	P	R	IV
Strigiformes	Strigidae	*Athene brama*	Spotted Owlet	P	R	IV
Strigiformes	Caprimulgidae	*Caprimulgus macrurus*	Large-tailed Nightjar	L	R	IV
Columbiformes	Columbidae	*Streptopelia chinensis*	Spotted Dove	F	R	IV
Columbiformes	Columbidae	*Streptopelia tranquebarica*	Red Collared Dove	F	R	IV
Columbiformes	Columbidae	*Streptopelia decaocto*	Eurasian Collared Dove	F	R	IV
Columbiformes	Columbidae	*Chalcophaps indica*	Emerald Dove	F	R	IV
Columbiformes	Columbidae	*Treron bicincta*	Orange-breasted Green Pigeon	G	R	IV
Columbiformes	Columbidae	*Treron phoenicoptera*	Yellow-footed Green Pigeon	G	R	IV
Gruiformes	Rallidae	*Rallina eurizonoides*	Slaty-legged Crake	C	R	IV
Gruiformes	Rallidae	*Amaurornis phoenicurus*	White-breasted Waterhen	C	R	IV
Ciconiiformes	Scolopacidae	*Gallinago stenura*	Pintail Snipe	D	M	IV
Ciconiiformes	Scolopacidae	*Limosa limosa*	Black-tailed Godwit	D	M	IV
Ciconiiformes	Scolopacidae	*Limosa lapponica*	Bar-tailed Godwit	D	M	IV
Ciconiiformes	Scolopacidae	*Numenius phaeopus*	Whimbrel	D	M	IV
Ciconiiformes	Scolopacidae	*Numenius arquata*	Eurasian Curlew	D	M	IV
Ciconiiformes	Scolopacidae	*Tringa erythropus*	Spotted Redshank	C	M	IV

Order	Family	Species	Common English Name	Associated Guild	Status	Schedules*
Ciconiiformes	Scolopacidae	*Tringa totanus*	Common Redshank	C	M	IV
Ciconiiformes	Scolopacidae	*Tringa nebularia*	Common Greenshank	C	M	IV
Ciconiiformes	Scolopacidae	*Tringa ochropus*	Green Sandpiper	C	M	IV
Ciconiiformes	Scolopacidae	*Tringa glareola*	Wood Sandpiper	C	M	IV
Ciconiiformes	Scolopacidae	*Xenus cinereus*	Terek Sandpiper	C	M	IV
Ciconiiformes	Scolopacidae	*Actitis hypoleucos*	Common Sandpiper	C	M	IV
Ciconiiformes	Scolopacidae	*Arenaria interpres*	Ruddy Turnstone	C	M	IV
Ciconiiformes	Scolopacidae	*Calidris tenuirostris*	Great Knot	C	M	IV
Ciconiiformes	Scolopacidae	*Calidris alba*	Sanderling	C	M	IV
Ciconiiformes	Scolopacidae	*Calidris minuta*	Little Stint	C	M	IV
Ciconiiformes	Scolopacidae	*Calidris temminckii*	Temminck's Stint	C	M	IV
Ciconiiformes	Scolopacidae	*Calidris alpina*	Dunlin	C	M	IV
Ciconiiformes	Scolopacidae	*Calidris ferruginea*	Curlew Sandpiper	C	M	IV
Ciconiiformes	Burhinidae	*Burhinus oedicnemus*	Eurasian Thick-knee	C	R	IV
Ciconiiformes	Burhinidae	*Esacus recurvirostris*	Great Thick-knee	C	R	IV
Ciconiiformes	Charadriidae	*Haematopus ostralegus*	Eurasian Oystercatcher	C	M	IV
Ciconiiformes	Charadriidae	*Himantopus himantopus*	Black-winged Stilt	C	R	IV
Ciconiiformes	Charadriidae	*Pluvialis apricaria*	European Golden Plover	C	M	IV
Ciconiiformes	Charadriidae	*Pluvialis fulva*	Pacific Golden Plover	C	M	IV
Ciconiiformes	Charadriidae	*Pluvialis squatarola*	Grey Plover	C	M	IV
Ciconiiformes	Charadriidae	*Charadrius dubius*	Little Ringed Plover	C	R	IV
Ciconiiformes	Charadriidae	*Charadrius alexandrinus*	Kentish Plover	C	M	IV
Ciconiiformes	Charadriidae	*Charadrius mongolus*	Lesser Sand Plover	C	M	IV
Ciconiiformes	Charadriidae	*Charadrius leschenaultii*	Greater Sand Plover	C	M	IV

Order	Family	Species	Common English Name	Associated Guild	Status	Schedules*
Ciconiiformes	Charadriidae	*Charadrius asiaticus*	Caspian Sand plover	C	M	IV
Ciconiiformes	Charadriidae	*Charadrius asiaticus*	Caspian Sand plover	C	M	IV
Ciconiiformes	Charadriidae	*Vanellus cinereus*	Grey-headed Lapwing	C	M	IV
Ciconiiformes	Charadriidae	*Vanellus indicus*	Red-wattled Lapwing	C	R	IV
Ciconiiformes	Laridae	*Larus ichthyaetus*	Pallas's Gull	E	M	IV
Ciconiiformes	Laridae	*Larus brunnicephalus*	Brown-headed Gull	E	M	IV
Ciconiiformes	Laridae	*Larus ridibundus*	Black-headed Gull	E	M	IV
Ciconiiformes	Laridae	*Gelochelidon nilotica*	Gull-billed Tern	E	M	IV
Ciconiiformes	Laridae	*Sterna caspia*	Caspian Tern	E	M	IV
Ciconiiformes	Laridae	*Sterna bergii*	Great Crested Tern	E	M	IV
Ciconiiformes	Laridae	*Sterna hirundo*	Common Tern	E	M	IV
Ciconiiformes	Laridae	*Sterna albifrons*	Little Tern	E	M	IV
Ciconiiformes	Laridae	*Chlidonias hybridus*	Whiskered Tern	B	R	IV
Ciconiiformes	Accipitridae	*Pandion haliaetus*	Osprey	B	M	I
Ciconiiformes	Accipitridae	*Milvus migrans*	Black Kite	P	R	I
Ciconiiformes	Accipitridae	*Haliastur indus*	Brahminy Kite	P	R	I
Ciconiiformes	Accipitridae	*Haliaeetus leucogaster*	White-bellied Sea Eagle	P	R	I
Ciconiiformes	Accipitridae	*Gyps bengalensis*	White-rumped Vulture	P	R	I
Ciconiiformes	Accipitridae	*Circaetus gallicus*	Short-toed Eagle	P	R	I
Ciconiiformes	Accipitridae	*Spilornis cheela*	Crested Serpent Eagle	P	R	I
Ciconiiformes	Accipitridae	*Circus melanoleucos*	Pied Harrier	P	M	I
Ciconiiformes	Accipitridae	*Accipiter badius*	Shikra	P	R	I
Ciconiiformes	Accipitridae	*Pernis ptilorhyncus*	Oriental Honey-Buzzard	P	R	I
Ciconiiformes	Accipitridae	*Aquila clanga*	Greater Spotted Eagle	P	R	I

Order	Family	Species	Common English Name	Associated Guild	Status	Schedules*
Ciconiiformes	Accipitridae	*Spizaetus cirrhatus*	Changeable Hawk Eagle	P	R	I
Ciconiiformes	Falconidae	*Falco tinnunculus*	Common Kestrel	P	M	IV
Ciconiiformes	Falconidae	*Falco chicquera*	Red-necked Falcon	P	R	I
Ciconiiformes	Falconidae	*Falco severus*	Oriental Hobby	P	M	IV
Ciconiiformes	Falconidae	*Falco peregrinus*	Peregrine Falcon	P	M	I
Ciconiiformes	Podicipedidae	*Tachybaptus ruficollis*	Little Grebe	B	R	IV
Ciconiiformes	Anhingidae	*Anhinga melanogaster*	Darter	B	R	IV
Ciconiiformes	Phalacrocoracidae	*Phalacrocorax niger*	Little Cormorant	B	R	IV
Ciconiiformes	Phalacrocoracidae	*Phalacrocorax fuscicollis*	Indian Cormorant	B	R	IV
Ciconiiformes	Phalacrocoracidae	*Phalacrocorax carbo*	Great Cormorant	B	R	IV
Ciconiiformes	Ardeidae	*Egretta garzetta*	Little Egret	B	R	IV
Ciconiiformes	Ardeidae	*Casmerodius albus*	Great Egret	B	R	IV
Ciconiiformes	Ardeidae	*Mesophoyx intermedia*	Intermediate Egret	B	R	IV
Ciconiiformes	Ardeidae	*Bubulcus ibis*	Cattle Egret	B	R	IV
Ciconiiformes	Ardeidae	*Ardeola grayii*	Indian Pond Heron	B	R	IV
Ciconiiformes	Ardeidae	*Ardea cinerea*	Grey Heron	B	R	IV
Ciconiiformes	Ardeidae	*Ardea goliath*	Goliath Heron	B	R	IV
Ciconiiformes	Ardeidae	*Ardea purpurea*	Purple Heron	B	R	IV
Ciconiiformes	Ardeidae	*Butorides striatus*	Little Heron	B	R	IV
Ciconiiformes	Ardeidae	*Nycticorax nycticorax*	Black-crowned Night Heron	B	R	IV
Ciconiiformes	Ardeidae	*Ixobrychus sinensis*	Yellow Bittern	B	R	IV
Ciconiiformes	Ardeidae	*Ixobrychus cinnamomeus*	Cinnamon Bittern	B	R	IV
Ciconiiformes	Ardeidae	*Dupetor flavicollis*	Black Bittern	B	R	IV
Ciconiiformes	Threskiornithidae	*Threskiornis melanocephalus*	Black-headed Ibis	D	R	IV
Ciconiiformes	Ciconiidae	*Anastomus oscitans*	Asian Openbill	C	R	IV

Order	Family	Species	Common English Name	Associated Guild	Status	Schedules*
Ciconiiformes	Ciconiidae	*Leptoptilos javanicus*	Lesser Adjutant	C	R	IV
Passeriformes	Pittidae	*Pitta brachyura*	Indian Pitta	M	M	IV
Passeriformes	Pittidae	*Pitta megarhyncha*	Mangrove Pitta	M	R	IV
Passeriformes	Irenidae	*Chloropsis aurifrons*	Golden-fronted Leafbird	H	R	IV
Passeriformes	Laniidae	*Lanius cristatus*	Brown Shrike	N	M	-
Passeriformes	Laniidae	*Lanius schach tricolor*	Long-tailed Shrike	N	R	-
Passeriformes	Corvidae	*Pachycephala grisola*	Mangrove Whistler	H	R	IV
Passeriformes	Corvidae	*Dendrocitta vagabunda*	Rufous Treepie	H	R	IV
Passeriformes	Corvidae	*Corvus splendens*	House Crow	H	R	V
Passeriformes	Corvidae	*Corvus macrorhynchos*	Large-billed Crow	H	R	-
Passeriformes	Corvidae	*Artamus fuscus*	Ashy Woodswallow	L	R	-
Passeriformes	Corvidae	*Oriolus oriolus*	Eurasian Golden Oriole	H	M	IV
Passeriformes	Corvidae	*Oriolus chinensis*	Black-naped Oriole	H	M	IV
Passeriformes	Corvidae	*Oriolus xanthornus*	Black-hooded Oriole	H	R	IV
Passeriformes	Corvidae	*Coracina macei*	Large Cuckooshrike	H	R	IV
Passeriformes	Corvidae	*Coracina melaschistos*	Black-winged Cuckooshrike	H	M	IV
Passeriformes	Corvidae	*Coracina melanoptera*	Black-headed Cuckooshrike	H	R	IV
Passeriformes	Corvidae	*Pericrocotus cinnamomeus*	Small Minivet	H	R	IV
Passeriformes	Corvidae	*Rhipidura albicollis*	White-throated Fantail	H	R	IV
Passeriformes	Corvidae	*Dicrurus macrocercus*	Black Drongo	H	R	IV
Passeriformes	Corvidae	*Dicrurus leucocephalus*	Ashy Drongo	H	M	IV
Passeriformes	Corvidae	*Dicrurus aeneus*	Bronzed Drongo	H	R	IV
Passeriformes	Corvidae	*Dicrurus hottentottus*	Spangled Drongo	H	R	IV

Order	Family	Species	Common English Name	Associated Guild	Status	Schedules*
Passeriformes	Corvidae	*Hypothymis azurea*	Black-naped Monarch	K	R	IV
Passeriformes	Corvidae	*Terpsiphone paradisi*	Asian Paradise-flycatcher	K	R	IV
Passeriformes	Corvidae	*Aegithina tiphia*	Common Iora	H	R	IV
Passeriformes	Corvidae	*Tephrodornis pondicerianusd*	Common Woodshrike	H	R	IV
Passeriformes	Muscicapidae	*Monticola solitarius*	Blue Rock Thrush	M	M	IV
Passeriformes	Muscicapidae	*Zoothera citrina*	Orange-headed Thrush	M	R	IV
Passeriformes	Muscicapidae	*Turdus unicolor*	Tickell's Thrush	M	M	IV
Passeriformes	Muscicapidae	*Ficedula parva*	Red-throated Flycatcher	K	M	IV
Passeriformes	Muscicapidae	*Eumyias thalassina*	Verditer Flycatcher	K	M	IV
Passeriformes	Muscicapidae	*Cyornis rubeculoides*	Blue-throated Flycatcher	K	M	IV
Passeriformes	Muscicapidae	*Copsychus saularis*	Oriental Magpie Robin	H	R	IV
Passeriformes	Muscicapidae	*Copsychus malabaricus*	White-rumpd Shama	H	R	IV
Passeriformes	Muscicapidae	*Saxicoloides fulicata*	Indian Robin	H	R	IV
Passeriformes	Muscicapidae	*Phoenicurus ochruros*	Black Redstart	H	M	IV
Passeriformes	Sturnidae	*Sturnus malabaricus*	Chestnut-tailed Starling	H	R	IV
Passeriformes	Sturnidae	*Sturnus vulgaris*	Common Starling	H	R	IV
Passeriformes	Sturnidae	*Sturnus contra*	Asian Pied Starling	H	R	IV
Passeriformes	Sturnidae	*Acridotheres tristis*	Common Myna	H	R	IV
Passeriformes	Sturnidae	*Acridotheres fuscus*	Jungle Myna	H	R	IV
Passeriformes	Paridae	*Parus major*	Great Tit	H	R	IV
Passeriformes	Hirundinidae	*Riparia riparia*	Sand Martin	L	R	-
Passeriformes	Hirundinidae	*Hirundo rustica*	Barn Swallow	L	M	-
Passeriformes	Hirundinidae	*Hirundo daurica*	Red-rumped Swallow	L	M	-

Order	Family	Species	Common English Name	Associated Guild	Status	Schedules*
Passeriformes	Hirundinidae	*Hirundo fluvicola*	Streak-throated Swallow	L	M	-
Passeriformes	Pycnonotidae	*Pycnonotus jocosus*	Red-whiskered Bulbul	H	R	IV
Passeriformes	Pycnonotidae	*Pycnonotus cafer*	Red-vented Bulbul	H	R	IV
Passeriformes	Cisticolidae	*Cisticola juncidis*	Zitting Cisticola	H	R	IV
Passeriformes	Cisticolidae	*Prinia flaviventris*	Yellow-bellied Prinia	H	R	IV
Passeriformes	Cisticolidae	*Prinia socialis*	Ashy Prinia	H	R	IV
Passeriformes	Cisticolidae	*Prinia inornata*	Plain Prinia	H	R	IV
Passeriformes	Zosteropidae	*Zosterops palpebrosus*	Oriental White-eye	H	R	IV
Passeriformes	Sylviidae	*Acrocephalus dumetorum*	Blyth's Reed Warbler	H	M	IV
Passeriformes	Sylviidae	*Acrocephalus stentoreus*	Clamorous Reed Warbler	H	R	IV
Passeriformes	Sylviidae	*Orthotomus sutorius*	Common Tailorbird	H	R	IV
Passeriformes	Sylviidae	*Phylloscopus collybita*	Common Chiffchaff	H	M	IV
Passeriformes	Sylviidae	*Phylloscopus fuscatus*	Dusky Warbler	H	M	IV
Passeriformes	Sylviidae	*Phylloscopus chloronotus*	Lemon-rumped Warbler	H	M	IV
Passeriformes	Sylviidae	*Phylloscopus inornatus*	Yellow-browed Warbler	H	M	IV
Passeriformes	Sylviidae	*Phylloscopus humei*	Hume's Warbler	H	M	IV
Passeriformes	Sylviidae	*Phylloscopus trochiloides*	Greenish Warbler	H	M	IV
Passeriformes	Sylviidae	*Phylloscopus magnirostris*	Large-billed Leaf Warbler	H	M	IV
Passeriformes	Sylviidae	*Pellorneum ruficeps*	Puff-throated Babbler	H	R	IV
Passeriformes	Sylviidae	*Pomatorhinus horsfieldii*	Indian Scimitar Babbler	H	R	IV
Passeriformes	Sylviidae	*Macronous gularis*	Striped Tit-Babbler	H	R	IV
Passeriformes	Sylviidae	*Timalia pileata*	Chestnut-capped Babbler	H	R	IV

Order	Family	Species	Common English Name	Associated Guild	Status	Schedules*
Passeriformes	Sylviidae	*Chrysomma sinense*	Yellow-eyed Babbler	H	R	IV
Passeriformes	Sylviidae	*Turdoides earlei*	Striated Babbler	H	R	IV
Passeriformes	Sylviidae	*Turdoides striatus*	Jungle Babbler	H	R	IV
Passeriformes	Alaudidae	*Eremopterix nigriceps*	Ashy-crowned Sparrow Lark	F	R	IV
Passeriformes	Alaudidae	*Alauda gulgula*	Oriental Skylark	F	R	IV
Passeriformes	Nectariniidae	*Dicaeum trigonostigma*	Orange-bellied Flowerpecker	O	R	IV
Passeriformes	Nectariniidae	*Dicaeum erythrorynchos*	Pale-billed Flowerpecker	O	R	IV
Passeriformes	Nectariniidae	*Dicaeum cruentatum*	Scarlet-backed Flowerpecker	O	R	IV
Passeriformes	Nectariniidae	*Nectarinia zeylonica*	Purple-rumped Sunbird	O	R	IV
Passeriformes	Nectariniidae	*Nectarinia asiatica*	Purple Sunbird	O	R	IV
Passeriformes	Nectariniidae	*Nectarinia lotenia*	Loten's Sunbird	O	R	IV
Passeriformes	Passeridae	*Passer domesticus*	House Sparrow	F	R	IV
Passeriformes	Passeridae	*Dendronanthus indicus*	Forest Wagtail	M	M	IV
Passeriformes	Passeridae	*Motacilla alba*	White Wagtail	M	M	IV
Passeriformes	Passeridae	*Motacilla citreola*	Citrine Wagtail	M	M	IV
Passeriformes	Passeridae	*Motacilla flava*	Yellow Wagtail	M	M	IV
Passeriformes	Passeridae	*Motacilla cinerea*	Grey Wagtail	M	M	IV
Passeriformes	Passeridae	*Anthus richardi*	Richard's Pipit	M	M	IV
Passeriformes	Passeridae	*Anthus rufulus*	Paddyfield Pipit	M	R	IV
Passeriformes	Passeridae	*Anthus hodgsoni*	Olive-backed Pipit	M	M	IV
Passeriformes	Passeridae	*Ploceus philippinus*	Baya Weaver	H	R	IV
Passeriformes	Passeridae	*Lonchura malabarica*	Indian Silverbill	H	R	IV
Passeriformes	Passeridae	*Lonchura striata*	White-rumped Munia	H	R	IV
Passeriformes	Passeridae	*Lonchura punctulata*	Scaly-breasted Munia	H	R	IV
Passeriformes	Passeridae	*Lonchura malacca*	Black-headed Munia	H	R	IV

Associated Guild : (A) Herbivore (B) Fishing (C) Visual surface foraging (D) Tactile surface foraging (E) Pelagic (F) Ground gleaning herbivore (G) Fruit & bud harvester (H) Shrub foliage gleaner (I) Tree stem driller (J) Air sallyers (K) Air screeners (L) Ground gleaning carnivore (M) Ground pouncer (N) Flower probers (O) Carnivore

Status : (R) Resident (M) Migrant

* The Wild Life (Protection) Act, 1972 as amended by S.O. 2293(E), dt 4th September, 2009

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2.17 MEGA-FAUNA

The group among the animals that is positioned at the topmost level in the evolutionary hierarchy is the mammals. Mammals are primarily divided into three main categories depending on how they are born: monotremes, marsupials, and placentals.

SUBRAT MUKHERJEE
Protected Area Manager with specialization in mangrove conservation

Except for the monotremes (which lay eggs), all mammal species give birth to young ones. There is tremendous variation within the group with regard to size and behavior although mammals are unified by the characteristic mammary glands, three middle ear bones, presence of hair on the body at some point in their lifetime, and a single lower jaw bone on each side of the jaw. Most mammals also possess specialized teeth, and the largest groups of mammals, the placentals, use a placenta during gestation. Also, the mammalian brain regulates endothermic and circulatory systems, including a four-chambered heart.

The first complete appraisal of all mammals of the world was produced by Trouessart (1898–99 and 1904–05). McKenna and Bell (1997) provided a complete phylogeny of mammals above the species level, including fossil and recent forms. After this publication, an explosion of literature based on new techniques of molecular systematics has resulted in a paradigm shift in global thinking about mammalian phylogeny.

It is estimated that the first mammals may have appeared slightly more than 250 million years ago, they evolved quickly and many different groups arose therefrom. Though the first mammal is yet to be known, the Genus *Morganucodon* and, in particular, *Morganucodon watsoni* (Kühne 1949), a 2–3 cm (1 inch) long weasel-like animal whose fossils were first found inside caves in Wales and around Bristol, is believed to have lived between 200 Million years ago and 210 MYA and may be a possible contender for the first known mammal described (Kermack and Kermack 1984). Later claims also exist for unearthing the first known mammal in China, India, North America, South Africa, and Western Europe. However, *Gondwanadon tapani* that Datta and Das (1996) reported from India on the basis of a single tooth in 1994 may be an earlier contender for the title, with a claimed date of 225 MYA.

The mammals are in fact the most 'seen' animals and to most people, animals are mammals. The Encyclopedia Britannica, in its article on the importance of mammals to humans, has fittingly ascribed that 'wild and domesticated mammals are so interlocked with our political and social history that it is impractical to attempt to assess the relationship in precise economic terms'. The mammals are entities that we as humans either love or abhor, get fascinated or horrified with, use for great many number of human needs, use as substitutes in science particularly in biomedical research, and nurture an expectation of getting them to entertain us.

5,416 SPECIES
OF LIVING MAMMALS, BELONGING TO 29 ORDERS AND 153 FAMILIES

OVERVIEW OF THE GROUP

Worldwide, there are about 5,416 species of living mammals, belonging to 29 orders and 153 families (Wilson and Reeder 2005). The maximum number of described global mammalian species belong to the order Rodentia, characterized by two continuously growing incisors in the upper and lower jaws which must be kept short by gnawing (2,277 species under 481 genera). This is followed by Chiroptera consisting of flying mammals—the bats (1,116 species under 202 genera)—and Soricomorpha—the group of shrews and moles (428 species under 45 genera). With regard to the number of genera there are other orders that outnumber the order Soricomorpha: order Carnivora, the flesh-eating placental mammals (286 species under 126 genera); order Artiodactyla comprising the even-toed ungulates (240 species under 89 genera); and order Primates, the group consisting of the prosimians and the simians, including humans (376 species under 69 genera).

401 SPECIES
UNDER 45 FAMILIES INCLUDING 45 SPECIES ENDEMIC TO INDIA

Mammals inhabiting the geographical boundaries of India represent an admixture of Oriental, Palaearctic, Ethiopian, and 'true Indian' elements, attributable to the location at the confluence of the first three major biogeographical realms (Alfred et al. 2006). India has a representation of about 8.6 percent of the total global mammal species described. Interestingly, till recently, that is, before the bumble bee bat (*Craseonycteris thonglongyai*)—also called Kitti's hognose bat—was described from Thailand as the smallest described mammal, both the largest and the smallest described mammals on this earth were found in India, the smallest being the Pygmy white-toothed Shrew (*Suncus etruscus*) and the largest being the Blue Whale (*Balaenoptera musculus*). The Indian mammals are represented by 180 genera, 401 species under 45 families and 13 orders and include 45 species endemic to the country (table 1) (Alfred et al. 2006). Interestingly, as opposed to the global position, Chiroptera or the bat group occupy first place in species diversity, followed by rodents.

Royal Bengal Tiger (Panthera tigris)

Table – 1: Diversity & Endemicity of Indian Mammals

Sl. No.	Name of the Order	Number of			
		Family	Genera	Species	Endemic Species
1	Insectivora	3	11	30	7
2	Scandentia	1	2	3	2
3	Chiroptera	8	35	113	11
4	Primates	3	6	15	3
5	Carnivora	7	34	59	4
6	Cetacea	7	21	28	-
7	Sirenia	1	1	1	-
8	Proboscidea	1	1	1	-
9	Perissodactyla	2	2	3	-
10	Artiodactyla	5	20	31	1
11	Pholidota	1	1	2	-
12	Rodentia	4	43	104	17
13	Lagomorpha	2	3	11	-
	Total	**45**	**180**	**401**	**45**

Source: Alfred *et. al*., (2006)

A discussion pertaining to the fauna inhabiting mangroves of the world need to mention the works of MacNae (1968), which is a general account of the fauna of mangroves in the Indo-West Pacific Region, and Saenger et al. (1983), who have discussed the global status of mangrove ecosystems, including their fauna. Rao (1987), in a comprehensive document, detailed that mangrove ecosystems of the world are home to, among others, more than 250 species of mammals. A number of good publications on the wildlife of the Sundarbans exist, both in India and Bangladesh (Sanyal 1983; Chaudhury and Choudhury 1994; Gittin 1981; Hendrichs 1975; Islam 2000; Khan 1986; Rashid et al. 1994; Reza et al. 2002) though not much can be found published on the megafauna inhabiting other mangrove areas of the world, more so because most of the present day faunal species inhabiting mangrove forests belong to invertebrates and among the vertebrates, the avian fauna, fish fauna, and reptiles dominate the scenario.

Mangroves, by and large, do not have significant mammalian population, and only a limited variety of mammals are found to exist in the mangrove ecosystems of the world though not much can be referred to regarding their ecology and association with the mangroves also. Some of the species worth mentioning include dolphins (*Platanista gangetica*); Andaman masked civets (*Lavata tylen*); mangrove monkeys [*Macaca mulatta* and *Macaca fascicularis umbrosa*] and otters (*Lutra perspicillata*) (Gopal and Krishnamurthy 1993); flying fox (*Pteropus conspicialltus* Gould 1850 and *Pteropus alecto* Temminck 1837) in northern Australia (Richards 1990; Loughland 1998); and capuchin (*Cebus apella* Linnaeus 1758) in Brazil (Fernandes 1991). In southeastern Brazil, distributions of some cetacean species can also be related to the distribution of mangroves (Martuscelli et al. 1996). Small clawed otters (Lutrinae) are reported to take shelter among *Acrostichum ferns* during dry seasons in the mangroves of Singapore and Malay Peninsula' (Sivasothi and Burhanuddin 1994).

A search on the faunal composition of Indian mangrove areas other than the Sundarbans and Bhitarkanika reveal only a few publications that deal with the mammalian megafauna of the mangrove regions in India. This may be because these areas are bereft of any so-called megafauna. Evidence of Indian mangrove areas being home to mega-herbivores (order Artiodactyla) and major carnivores (order Carnivora) in the distant past emerge on and off, but over time it is being observed that most of these grassland species are disappearing from such environments. In fact, a global observation reveals that the dominant larger animal species of the mangrove regions of the world are more of the aquatic types. Within the Indian subcontinent too, lack of mega-herbivores and major carnivores along the coastal tracts is evident and is attributable to rapid industrialization and habitat fragmentation.

An appraisal of the publications on the mangrove fauna of the Indian maritime states does not give much information on megafauna. GEER (2000, 2004) gives an account of the faunal components of Gujarat. Though Gujarat is endowed with high faunal diversity, the publications reveal that this diversity does not include mammals. With regard to Andhra Pradesh, Kumar (2010), in his communication on conservation and restoration on mangroves, gives an account of the faunal components inhabiting the mangrove areas of the state, which include the mammalian species of smooth-skinned otter, fishing cat, common fox, rhesus monkey, and jackal; dolphins and sea turtles are found in the sea. In Orissa, the Bhitarkanika mangroves are home to diverse groups of megafauna and harbor one of India's largest populations of saltwater crocodiles (*Crocodylus porosus*). Patnaik et al. (1995) have reported that mammals of Bhitarkanika are represented by 31 species belonging to 25 genera and 14 families, including the leopard (*Panthera pardus* Linnaeus 1758), striped hyaena (*Hyaena hyaena* Linnaeus 1758), lesser cats, spotted deer (*Axis axis* Erxleben 1777), sambar (*Cervus unicolor* Kerr 1792), wild boar (*Sus scrofa* Linnaeus 1758), Rhesus monkey [*Macaca mulatta* (Zimmerman 1780)], and Palm civet [*Paradoxurus hermaphroditus* (Pallas 1777)].

SYNOPTIC VIEW

Diversity

The megafauna of the Sundarbans, particularly the species within the mammal group find territory in the forest, in the abundant aquatic perimeters or within the reclaimed areas with human habitation. These fauna not only exhibit extraordinary adaptability to the stressed areas that they inhabit but also changed behavior patterns, significantly different from their counterparts inhabiting other ecosystems. The adversities include difficult terrains, variable salinity regimes, periodic high tides and tidal inundations, occasional tidal surges, and frequent flooding, among others. Almost all the resident terrestrial species of mammals are powerful swimmers and also habituated to meet their food requirements from aquatic sources, which gives an interesting turn to the food and feeding habits of these species.

The Sundarbans presents a slightly different scenario as it is home to one of the larger carnivores, the tiger, along with one small ungulate as its prey base and a few more of its prey base species that can be classified as megafauna. The fauna of the Sundarbans have attracted much attention owing to the unique adaptability of the resident and migratory species. A treatise on the mammalian megafauna of Sundarbans is bound to focus, among others, on the Royal Bengal Tiger—the only tiger on the face of this earth that inhabits a mangrove ecosystem—the Spotted Deer, Wild Boar, Rhesus Monkey, and Dolphins, Porpoises, and Otters as prey base. Each of these faunal components demand separate treatment because of their uniqueness in more than one perspective. Though a single tract of continuous ecosystem exists in India and Bangladesh, of significant interest is the fact that the mammalian diversity exhibits stark differences between the Indian and Bangladesh sides of the Sundarbans. The Indian Sundarbans has only 31 species of mammals (Chaudhury and Choudhury 1994; Sanyal 1999) against 49 species reported in Bangladesh (Hussain and Acharya 1994), though in the same perspective, Mandal and Nandi (1989) have reported 47 mammals from the Indian Sundarbans. Out of these 47 mammals, 15 are megafauna, taking into consideration the theory by Bourlière (1975) that a large mammal's weight exceeds 5 kg when adult.

At least six mega-herbivore species, namely the Javan rhinoceros (*Rhinoceros sondaicus*); water buffalo [*Bubalus bubalis*; swamp deer (*Cervus duvauceli* Cuvier); gaur (*Bos frontalis* Lambert); and the hog deer [*Axis porcinus* (Zimmerman 1780)], have disappeared locally during the past century (Seidensticker and Hai 1983). Another mammal belonging to the Artiodactyla that has disappeared from the Indian Sundarbans but is present, albeit in a threatened condition, in the Sundarbans of Bangladesh is the barking deer [*Muntiacus muntjak* (Zimmerman 1780)] (IUCN 2000). The one-horned rhino [*Rhinoceros unicornis* (Linnaeus 1758)]; Indian bison (*Bos gaurus* Smith 1827); and Sambhar (*Cervus unicolor* Kerr 1792), which were once common here, are also now locally extinct. The only primate is the rhesus macaque [*Macaca mulatta* (Zimmerman 1780)] which still occurs in good numbers, but its population is declining gradually (Blower 1985; Gittins 1981).

Indo-Pacific Humpbacked Dolphin (Sotalia plumbea)

The Sundarbans of Bangladesh and India together support one of the largest populations of tiger, *Panthera tigris* (Linnaeus 1758). Spotted deer (*Cervus axis* Erxleben 1777) and wild boar (*Sus scrofa* Linnaeus 1758) occur in large numbers and form the principal prey of the tiger. Mandal and Nandi (1989) have given a concise account of megafauna of the Sundarbans, including their habitat, as shown in table 2.

Ecological Importance and Need for Conservation

Influence ecosystem function and biodiversity as ecological landscapers

The mammals contribute to some very important ecolo- gical roles in the ecosystems that they occupy. These include modification of vegetation structure and alteration of nutrient pathways, thereby changing species composition and as pollination mediators. These large-scale structuring effects go on to designate many large mammals as 'ecological landscapers'. These roles also make the mammals influence ecosystem function and biodiversity. These structuring roles of mammals in maintaining species diversity is not only evident in the case of vegetation but also reflects in birds, other mammals, and invertebrate populations and species composition.

The extent of such roles in the mangroves of the Sundarbans are subject to investigation and it is obvious that mammals like the tigers, lesser cats, other canines, major ungulates, and the marine forms in the ecosystem, even at their most abundant estimates, are numerically insignificant in comparison to such groups as birds, fishes, reptiles, insects, and protozoans among the faunal components. Nevertheless, mammals affect plant structure and function to a greater extent, relative to their abundance, than any other animal group. These roles reflect in the obvious choice of these species as prime candidates for conservation as 'umbrella species'. As such, protection of these mammal species and their habitats also conserves a large part of the other occupant communities. It also implies that such mammals are but obviously selected and studied as 'indicator species' for assessing the health of the ecosystem.

The mammal species influence the distribution of trees in the mangrove forests through three of their important activities: as pollinators (primarily bats and shrews), as mediators of seed dispersal and determinants of propagule fall and anchoring, and negatively by trampling young seedlings, thus affecting the species diversity of mangroves. The other obvious noted relationships in existence involving the mammalian species include the liking of tigers for the leaves and fruits of *Phoenix paludosa*, the preference of the rhesus monkey and the deer for fruits of *Sonneratia sp.*, and dispersal of the fruits as a consequence of this liking. The mammals also influence the rates of nutrient cycling in addition to altering the physical structure of the substratum. It is also reported that high soil nutrients lead to high ungulate densities, rapid grazing or browsing, and high fecal deposition. Nutrients in the faeces are then returned rapidly to the soil. In essence, ungulates fertilize their own food, thereby creating a positive feedback and increasing their population density.

Much remains to be learned about the ecological roles of marine mammals in the Sundarbans, but evidence elsewhere implies that the abundance and distribution of marine mammals can have important effects on the structure and function of ecosystems. Dedicated studies involving conservation biology, single-species and multi-species resource management, and ecosystem management in the Sundarbans will promote better understanding of the mangroves of the Sundarbans.

Table – 2. Account of mega fauna in Indian Sundarbans

Orders	Families	Species	Habitat
1. Primate	1. Cercopithecidae	**Rhesus Monkey**: *Macaca mulatta* (Zimmermann)	On trees
2. Pholidota	1. Manidae	**Indian Pangolin**: *Manis crassicaudata* (É. Geoffroy)	In Burrows
3. Rodentia	1. Hystricidae	**Indian Crested Porcu-pine**: *Hystrix indica* (Keer)	Fossorial
4. Cetacea	1. Platinistidae	**Gangetic Dolphin**: *Platanista gangetica* (Roxburgh)	Riverine
	2. Delphinidae	**Little Porpoise/ Black Finless Porpoise** : *Neophocaena phocaenoides* (Cuvier)	Marine
		Irrawady Dolphin: *Orcaella brevirostris* (Owen)	Marine
		Plumbeus Dolphin/ Indo-Pacific Humpbacked Dolphin: *Sotalia plumbea* (Cuvier)/*Sousa chinensis* (Osbeck)	Marine
		Malay Dolphin: *Stanella malayana* (Lesson)	Marine
5. Carnivora	1. Canidae	**Jackal**: *Canis aureus* (Linnaeus)	Terrestrial
	2. Felidae	**Fishing cat**: *Prionailurus viverrinus* (Bennett)	Terrestrial
		Jungle cat: *Felis chaus* (Schreber)	Terrestrial
		Tiger: *Panthera tigris* (Linnaeus)	Terrestrial
	3. Musttelidae	**Common otter:** *Lutra lutra* (Linnaeus)	Aquatic
6. Artiodactyla	1. Suidae	**Wild Boar**: *Sus scrofa* Linn.	Terrestrial
	2. Cervidae	**Spotted Deer**: *Axis axis* (Erxleben)	Terrestrial

Source: Mandal & Nandi, (1989)

STATUS AND THREATS

Javan rhino and the buffalo had become rare by 1908 and the barking deer and hog deer was declared as uncommon by 1914

In the recent past, that is, not even a century back, the Sundarbans had under its jurisdiction a much larger area, undivided by political barriers and unblemished by anthropogenic pressures and as such, supported a much richer and more diverse fauna. In the northern limits, extensive swamp areas existed, which used to be inhabited by mega-herbivores like the Great Indian one-horned rhino (*Rhinoceros unicornis*), the one-horned Javan rhino (*Rhinoceros sondaicus*), and other large herbivores such as the water buffalo (*Bubalus bubalis*), gaur or Indian Bison (*Bos gaurus*), swamp deer (*Cervus duvauceli*), Sambar (*Cervus unicolor*), and the Hog deer (*Cervus porcinus*) all of which have become extinct (Das and Nandi 1999; Reza et al. 2002). According to the Bengal District Gazetteer, by 1908, both the Javan rhino and the buffalo had become rare. By 1914, the barking deer and hog deer were listed as uncommon and then subsequently, were declared to be extinct in the Indian Sundarbans. According to Gupta (1964), the last reports proving the presence of Wild Buffalo in the Sundarbans *mangals* dates back to 1890 and that of the Javan rhino in 1888, after which both the species were exterminated from these habitats.

During 2000 and 2001, past evidences of the presence of the

Javan rhinoceros and the Wild Buffalo in the Indian STR were collected and further confirmed by the reports of Zoological Survey of India, Kolkata (Mukherjee 2004). Interestingly, most of the following samples were recovered from a depth of about 3.04–4.57 m below the ground level, except for one sample which was found at a depth of 6.09 m. This confirms very recent extinction of these fauna from the Sundarbans. The evidences include the recovery of some bones of an unknown animal from Mollakhali village of Sundarban, during excavation of a pond, from a depth of 3.04–3.65 m. The bone pieces were of the skull, ribs, and legs. These were confirmed by the scientists of the Zoological Survey of India (ZSI), Kolkata, to be of the Javan rhino (*Rhinoceros sondaicus* Desmarest). Recovery of similar bones belonging to *Rhinoceros sondaicus* Desmarest from a pond in Tentulia village near Pathankhali from a depth of about 20 feet confirmed the presence and subsequent extinction of the Javan rhinoceros from the Indian Sundarbans. Two more sets of recovered bones from the Netidhopani and Pirkhali Blocks of the STR were identified to be of the Wild Buffalo by the scientists of ZSI, who went on to confirm the presence and subsequent extinction of this large ungulate from the Sundarbans as well.

Regarding the mammals of the Sundarbans, the first and foremost hindrance in coming to a conclusion about the status of any particular species, including the tiger, is the fact that there is an absolute dearth of a proper baseline data, which can be used to effect in assessing the present status. The first tiger census during 1973 was an endeavor limited to the Sajnekhali Wild Life Sanctuary, which on obvious grounds made the results seem aberrated when translated to the total Sundarbans forests. Subsequent tiger censuses that have been undertaken in the Sundarbans using the pug mark method have had limitations, albeit having been time- and labor-intensive studies. Subsequently, with the National Tiger Conservation Authority (NTCA) having laid down the unitary tiger estimation method that is applicable for the whole country, post the Sariska episode[2] in 2004, different ways and means are being attempted to meet the standards.

Tiger censuses throughout India held every two years, and the NTCA method has not yet given any population density ranges in the case of the Sundarbans. The Forest Department also relies on the regular monitoring method which is done by direct sighting and indirect evidences like roars, scratches, and so on collected during patrolling and watchtower duties. These records are routinely maintained on a daily basis when the protected area manager collects the results every evening. The records are also send to the NTCA and analyzed. The primary condition that proves the existence of large animals is by and large 'seeing is believing'. As such, the most important method that the Forest Department has resorted to confirming tiger signs is 'sighting'. The basic units for sighting are the watchtowers within the forest. Since the time the author has had the opportunity of closely studying and monitoring the Sundarbans, the number of these enumeration units has risen by nearly 60 percent within a span of 10 years. As the enumeration units increase, so does the sampling intensity, which obviously reduces aberrations in results. The Sundarbans has also seen a significant rise in patrolling intensity. Patrolling units are also equipped with sighting registers as are all the beat offices or camps. So, an activity which was earlier limited to certain seasons of the year has become a regular and intensive exercise over a larger temporal and spatial scale. Sightings are in fact registered for not only the tiger but also other large animals, including lesser cats, crocodiles, deer, wild boar, water monitors, civets, otters, and dolphins. Over the years, there has been a significant rise in tiger and water monitor sighting but sighting of deer, wild boar, lesser cats, and dolphins shows a decreased trend. However, it will not be wise to draw conclusions based on simple sighting data because the total sighted area is very small, attributable to the small size of animals, density of the forest cover which makes visibility very poor, and the limitation of restricted movement within and outside the forests.

Coastal habitats across the world including the Sundarbans are under heavy population pressures, leading to pollution problems. Moreover, upstream problems are also found to percolate to the coastal areas, in the form of pollutants, sewage discharges, and oil spills which remain in the system as they have no other outlet. Among these habitats, the mangroves have been particularly vulnerable to exploitation because they contain valuable wood and fishery resources and occupy coastal land that can be easily converted to other uses, including human settlements. The scale of human impact on mangroves has increased dramatically over the past few decades or so, with many countries showing losses of 60 percent or more of the mangrove forest cover that existed even in the late 60s. This has had its bearing on the faunal populations which inhabit these increasingly saline stressed areas. The vulnerability results in many of these species becoming threatened, on the verge of extinction, and even extinct in many cases.

The mammals of the Indian Sundarbans are assigned a national status along with their existing global status, as designated by the IUCN (table 3).

The survival of the Sundarbans tiger depends on the cumulative effect of many causes, primary negative factors among them being poaching pressure on the tiger as well as its prey base, loss of habitat due to natural causes and man-made causes, and loss of genetic variability resulting from insularization of the population. It is difficult to evaluate and estimate the relative contribution of each of these and other factors. An analysis leads one to believe that protecting the Sundarbans tiger is more of a crime control issue rather than a habitat management endeavor. This is so because habitat degradation is not much of a problem in the Sundarbans as is the case with other tiger reserve areas of India. No enclave village exists within the protected area and encroachment problems too are nonexistent. Moreover, the approach to the forest is not so easy and there are limits of approaching within the hostile forests. The problem that plagues the Sundarbans as well as the Sundarbans tiger is presently related to the crimes that take place transborder as well as within the country's jurisdiction.

Earlier studies by Schaller (1967), Sunquist (1981), and Seidensticker and McDougal (1993) had qualitatively described a positive correlation between the tiger and the prey base. Although Karanth and Stith (1999) have identified prey depletion as a major factor driving the current decline of wild tigers, in the case of the Sundarbans tiger, the prey base population alone is not a decisive factor in the decline of the tiger population. This is because the Sundarbans tiger has adapted its feeding habits to the aquatic, arboreal, and terrestrial prey base. Even then, more intensive studies are necessary to assess the current prey base of the Sundarbans tiger in view of the frequent straying of tigers to human habitation areas in search of cattle.

[2] Inadequate protection and conservation strategies at the Sariska Wildlife Sanctuary located in Rajasthan, India, led to the number of tigers dwindling in the mid-1990s. Somewhere in the latter half of 2004, the tiger disappeared from Sariska.

Table - 3. Status of the mammals of Indian Sundarbans.

Mammalian species	Indian Wildlife (Protection) Act, 1972: Schedules	Global Status (IUCN)[1]
Rhesus Monkey: *Macaca mulatta* (Zimmermann)	II	Least Concern
Indian Pangolin: *Manis crassicaudata* (É. Geoffroy)	I	Near Threatened
Indian Crested Porcupine: *Hystrix indica* (Keer)	IV	Least Concern
Gangetic Dolphin: *Platanista gangetica* (Roxburgh)	I	Endangered
Little Porpoise/ Black Finless Porpoise : *Neophocaena phocaenoides* (Cuvier)	I	Vulnerable
Irrawady Dolphin: *Orcaella brevirostris* (Owen)	I	Vulnerable
Indo-Pacific Humpbacked Dolphin: *Sousa chinensis* (Osbeck)	I	Near Threatened
Malay Dolphin: *Stanella malayana* (Lesson)	I	Least Concern
Jackal: *Canis aureus* (Linnaeus)	II	Least Concern
Fishing cat: *Prionailurus viverrinus* (Bennett)	I	Endangered
Jungle cat: *Felis chaus* (Schreber)	II	Least Concern
Tiger: *Panthera tigris* (Linnaeus)	I	Endangered
Common otter: *Lutra lutra* (Linnaeus)	II	Near Threatened
Wild Boar: *Sus scrofa* Linn.	III	Least Concern
Spotted Deer: *Axis axis* (Erxleben)	III	Least Concern

1. Indian wild boar (*Sus scrofa*) **2.** Rhesus macaque (*Macaca mulatta*) **3.** Golden Jackal (*Canis aureus*)

4. Chital (*Axis axis*) **5.** Fishing cat (*Prionailurus viverrinus*) **6.** Jungle cat (*Felis chaus*)

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2.18 SMALL MAMMALS

Mammals, included under the class Mammalia, refer to animals having mammaries or teats for suckling the young. Another unique feature of the group is the possession of hair, at least during some period of life.

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In mammals, the mode of attachment of the lower jaw is very distinctive from other vertebrates. It is directly hinged to the skull whereas other vertebrates have a loosely hung bone which links the lower jaw to the cranium. Finally, the higher development of brain in mammals places them above all other animals. Though not enormous in number of species, mammalian fauna is one of the most fascinating features of global biodiversity. It encompasses species as large as whales, rhinoceros, and tigers and as small as shrews, mice, and bats. The modes of life which mammals have adopted are associated with great diversity of structures that they display as a class. In mammals, one can find diverse modifications with respect to the body shape, limb, skin, ear, tail, nail, claws, teeth, and many other anatomical and physiological features. Bewildering diversities in form and structure make them fit for most varied modes of existence such as volant, arboreal, aquatic, fossorial, and ground, dwelling in all types of habitats from deep sea to snow-clad mountains, from desert to dense forest.

Nearly 50 percent of the Sundarbans islands have been reclaimed for human settlement by deforestation and construction of embankments along the river banks. The rest of the islands support mangrove forests and a greater part of them become submerged during high tides. As a result of human intervention, the present habitat diversity of the Sundarbans include agricultural fields, tidal rivers, freshwater ponds, orchards, creeks, estuaries, mud flats, riverine islands, offshore islands, rich mangrove vegetation, and muddy and sandy coastlines, providing food and shelter for diverse faunal components.

Faunal exploration of the Sundarbans can be traced to the mid-19th century (Stoliczka 1869). However, except for Mandal and Nandi (1989), Chaudhuri and Choudhury (1994), and Management Plan, Sundarbans Tiger Reserve (2006), not much information regarding the small mammalian species diversity is available. Though only 27 species of mammals have been recorded from the area of the STR in the Management Plan, Mitra and Pal (2002) reported 40 species from the Indian Sundarbans. Further, at least five mammalian species, namely the Indian one-horned rhino (*Rhinoceros unicornis*), wild buffalo (*Bubalis bubalis*), barking deer (*Muntiacus muntjak*), swamp deer (*Rucervus duvaucelii*), and Javan one-horned rhino (*Rhinoceros sondaicus*) have become extinct from the area for the last 200 years. The skull of the one-horned rhino has been reported from the Baruipur areas of 24-Parganas South; this area was an extension of the mangrove forest zone of the Sundarbans (Ghosh et al. 1992).

Leopard cat (Prionailurus bengalensis)

OVERVIEW

The term 'small mammal' is so widely used that one might think that it is a clearly defined taxonomic entity. However, the phrase is somewhat arbitrary and an ill-defined grouping, based primarily on customary usage and stemming from the fact that many small insectivores and rodents have been the subject of much population research. The reason for the latter is the commonness and wide occurrence of these groups coupled with the desirability of obtaining large sample sizes and the practicality of handling these small animals (Snyder 1976). In fact, Delany (1974) appeared to limit the term to insectivore and rodent species not heavier than 120 grams. However, Bourlière (1975) considered small mammals as those whose individual live weight does not exceed 5 kg[1] when adult. Obviously, this will include the majority of or all species belonging to the orders Rodentia, Scandentia, Chiroptera, Lagomorpha, Erinaceomorpha, Soricomorpha, a few species of Primates, Pholidota, Artiodactyla, and Carnivora. By far, small mammals make up the greater number of mammalian species on earth.

A review of the literature has shown certain differences with regard to the number of mammalian species at the global as well as the Indian level (Ellerman and Morrison-Scott 1966; Honacki et al. 1982; Jairajpuri 1991; 2005; Agrawal 1998; Alfred et al. 2002; Pal 2006). Because of the inherent fluidity of mammalian taxonomy and especially with the advent and refinement of additional molecular techniques, dramatic changes occurred in short periods with respect to new data, interpretations, and discoveries of new species. The number of mammalian species at the global level has increased from 4,629 in 1993 to 5,416 in 2005 due to various revisionary works and the addition of 260 new species (Wilson and Reeder 2005). The number of recorded mammalian species from India has also increased from 372 (Jairajpuri 1991) to 397 (Alfred et al. 2002). As far as the state of West Bengal is concerned, Agrawal et al. (1992) listed 177 species.

Based on Prater (1998), Alfred et al. (2002), and Wilson and Reeder (2005), it may be stated that 293 species, that is, nearly 74 percent of the mammalian species of India, come under the small mammal category. Small mammalian species of India belong to 111 genera, 26 families, and 10 orders (table 1). The highest number of small mammals belong to the order Chiroptera followed by the order Rodentia. However, the greatest species diversity could be observed under the family Muridae of the order Rodentia.

[1] This figure has been decided by the International Biological Program (IBP) Small Mammals working group in March 1974.

Table 1. The number of genera and species of small mammals of India under the different orders and families

Order	Family	Common name	No. of genera	No. of species
Eranaceomor-pha	Erinaceidae	Hedgehogs	1	3
Soricomorpha	Soricidae	Shrews	8	23
	Talpidae	Moles	2	2
Scandentia	Tupaiidae	Tree shrews	2	3
Chiroptera	Pteropodidae	Flying fox, fruit bat	8	12
	Rhinopomati-dae	Mouse-tailed bat	1	2
	Emballonuridae	Tomb bat	2	6
	Megadermati-dae	False Vampire	1	2
	Rhinolophidae	Horse-shoe bat	3	28
	Vespertilionidae	Pipistrelle, Serotines, Bar-bastella, Yellow bats	16	58
	Molossidae	Free-tailed bat	3	4
Primates	Loridae	Loris	2	2
Carnivora	Canidae	Jackals, Foxes, Wolves, Dogs	1	1
	Felidae	Cats	3	4
	Herpestidae	Mongoose	1	7
	Mustelidae	Otters, Badg-ers, Weasels	4	11
	Ursidae	Bears, Pandas	1	1
	Viverridae	Civet, Bintu-rong	5	6
Artiodactyla	Suidae	Pigs	1	1
Pholidota	Manidae	Pangolin	1	2
Rodentia	Sciuridae	Squirrel, Mar-mot	12	30
	Dipodidae	Birch Mice	1	1
	Muridae	Rats. Mice, Vole, Gerbil	28	70
	Hystricidae	Porcupine	1	1
Lagomorpha	Ochotonidae	Pikas	1	9
	Leporidae	Hare	2	4
Total: 10	**26**		**111**	**293**

According to Molur et al. (2005), a rough estimate shows that rodents, bats, and insectivores contain 43 percent, 19 percent, and 9 percent, respectively, of the total mammalian species while all other orders jointly contribute to the remaining 29 percent.

Das (2001) made a comparison of the total number of mammalian species of mangrove ecosystems occurring in the Andaman and Nicobar Islands and the east coast of India. The highest number of species was revealed from Sundarbans, followed by Bhitarkanika. Based on the analysis of the species lists provided by Das and Dev Roy (1989), Mandal and Nandi (1989), Chaudhuri and Choudhury (1994), Chakraborty et al. (2004), and DFO (2010) and observations made by the present authors in the Sundarbans, Bhitarkanika, and the Andaman and Nicobar Islands, a comparative account of the number of small mammalian species and genera of four mangrove areas of the country is provided in tables 2 and 3. The number of small mammalian species as well as the genera are highest in the Sundarbans. However, it is worth mentioning that the number of species and genera in different mangroves, as shown in tables 2 and 3, are far from complete. In fact, no exclusive study has so far been made for inventorizing the small mammalian species in the mangrove ecosystems of the country.

Table 2. Number of mammalian species in four mangrove areas of India

Mangrove area	Total no. of mammalian species	No. of genera of small mammals	No. of small mammal species	No. of species not recorded in other three areas
Sundarbans	47	21	32	10
Bhitarkanika	35	19	21	1
Krishna	23	16	17	1
Andaman and Nicobars	11	8	8	4

Table 3. Distribution of genera of small mammals among the four mangrove areas of India

Genera	Sundarbans	Bhitarkanika	Krishna	Andaman and Nicobar
Suncus	+	+	+	-
Crocidura	-	-	-	+
Tupaia	-	-	-	+
Pteropus	+	+	+	+
Rousettus	+	+	+	-
Cynopterus	+	+	+	+
Rhonopoma	+	-	-	-
Taphozous	+	+	-	-
Megaderma	+	+	+	-
Rhinolophus	+	+	-	-
Hipposideros	+	+	-	-
Pipistrellus	+	+	+	+
Scotophilus	+	+	+	-
Vulpes	+	+	+	-
Prionailurus	+	+	-	-
Herpestes	+	+	+	-
Paradoxurus	+	+	+	-
Viverricula	+	+	+	-
Paguma	-	-	-	+
Amblonyx	+	-	-	-
Funumbulus	+	+	+	-
Bandicota	+	+	+	-
Mus	+	+	+	+
Rattus	+	+	+	+
Golunda	-	-	+	-
Total	21	19	16	8

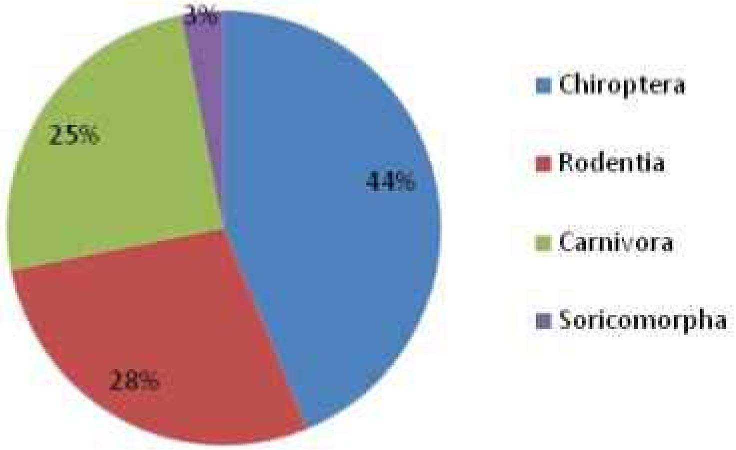
SYNOPTIC VIEW

Diversity

Greater parts of the uninhabited islands of the Sundarbans remain submerged during extreme high tides. Thus, little area for refuge and foraging remain available for small terrestrial or fossorial forms. No specific survey has so far been conducted for inventorizing small mammals in the uninhabited islands.

A review of existing literature lists 40 species of mammals from the Indian Sundarbans. From their fieldwork, present study could find the occurrence of seven more species from these islands, namely *Rousettus leschenaulti, Scotophilus heathi, Pipistrellus dormeri, Amblonyx cinereus, Mus cervicolor, Mus saxicola,* and *Rattus norvegicus*. Out of these 47 species, 32 (that is, 70 percent) may be considered under the category of small mammals. A list of small mammals from the Sundarbans is provided in the annexure. An analysis of the list reveals that small mammals of the Sundarbans belong to 4 orders, 14 families, and 21 genera. Order Chiroptera is represented by the highest number of families (6), genera (10), and species (14). With respect to the number of species, the order Chiroptera is followed by the order Rodentia (9) and order Carnivora (8). However, with respect to the number of families and genera, the order Carnivora is ahead of Rodentia, with 5 and 6, respectively, as opposed to 2 and 4, respectively, of the latter. The highest number of species diversity could be found in the family Muridae of the order Rodentia. It is interesting to note that globally the number of species and genera under the order Rodentia are the highest followed by the order Chiroptera (Wilson and Reeder 2005). However, in India as well as in West Bengal, species diversity is highest for the order Chiroptera followed by the order Rodentia (Alfred et al 2002). The same trend is reflected in the Sundarbans. Diversities of species in the Sundarbans are depicted in figure 1. Here, it is worth mentioning that a total of 68 mammalian species have been recorded from the mangroves of India (Pandey and Pandey 2010), out of which 47 occur in the Sundarbans.

Fig. 1. Diversity in species of small mammals



The mammalian species include the Microchiropteran bat species, *Mus* sp., *Herpestes* sp., and otters. Among the bats, the Flying Fox, *Pteropus giganteus*, could be found in the islands; it visits orchards regularly, particularly during the summer months. Roosts of the other two fruit bats, *Cynopterus sphinx* and *Rousettus leschenaultia*, can be observed in cowsheds, under wooden or concrete bridges, ceilings of rooms with relatively less disturbance, and under the surface of the fronds of palm trees. Microchiropteran bats roost in all sorts of relatively dark and undisturbed places, such as crevices, ceilings, ventilators, behind signboards, and rainwater pipes. Roosts of two specimens of the Indian Pygmy Pipistrelle, *Pipistrellus tenuis*, have also been observed in an upturned, deserted country boat.

Suncus murinus, the only species of shrew which occurs in the Sundarbans, is found close to human habitation. It makes burrows near kitchens, food stalls, drains, dumping grounds, or in some nearby bushes. It frequently visits houses from dusk to dawn in search of food. The Indian Field Mouse, *Mus booduga*, lives in simple burrows made a little away from human habitation in dry crop fields and wasteland. The other two species of *Mus* live in the vicinity of human habitation.

Both white- and dark-bellied forms of the house rat, *Rattus rattus*, have been found building nests in trees and also in roofs of houses. The Large Bandicoot Rat, *Bandicota indica*, is primarily restricted to the slopes of water bodies, living in fairly simple burrows. It occasionally visits houses, godowns, or crop fields and mainly feeds on molluscs, crabs, and fish, frequently visiting the water in search of them. Though the populations of *B. indica* have declined to a great extent in many parts of West Bengal due to ecological changes and aggression of the Lesser Bandicoot Rat, *Bandicota bengalensis,* it is fairly dominant in the marshy areas of these islands (Spillett 1966; Chakraborty 1988).

The Lesser Bandicoot Rat, *B. bengalensis*, is found in very complicated burrow systems of dry crop fields. When the fields are flooded, it exhibits a sort of local migration, moving to the higher side of the embankments, granaries, or godowns. The Norway Rat, *R. norvegicus*, is mainly confined to godowns or groceries of some densely populated islands like Sagar, Basanti, Gosaba, and Kakdwip. All three species of Mongooses, *Herpestes* sp., live in burrows made inside bushes, particularly along canals, *nullahs*, or water bodies. They rummage crop fields, bushes, in the vicinity of human habitation, and water bodies, seeking prey among a large and varied assemblage of creatures, including livestock. The Marsh Mongoose, *H. palustris*, is endemic to southern West Bengal. Both species of civets spend the day in the holes or crevices in scrub jungle, trees, and any other suitable places, even in and around human habitation. The clawless otter, *Amblonyx cinereus*, prefers bushes, burrows, or cavities at the base of trees not far from water bodies for shelter.

The Leopard Cat, *Prionailurus bengalensis*, is mainly confined to the mangroves of uninhabited islands, taking shelter in the hollows of trees. However, it frequently visits villages in search of poultry and often spends the day in bushes or on trees. The Indian Fox, *Vulpes bengalensis*, makes a complicated burrow system in barren lands having some scrub or green cover. After the harvesting of paddy during winter months, a section of its population settles in the paddy fields. It frequently visits the surroundings of houses in search of livestock, domestic refuse, fruits, and vegetables.

Richness of genetic diversity in some of the small mammalian species which occur in the Sundarbans can be visualized from the large number of recognized subspecies. Each of these subspecies is distinguished from the other by at least some morphological characters. Table 4 shows a number of recognized Indian subspecies of some of the species occurring in the Sundarbans. In the Sundarbans itself two distinct morphological varieties of *Rattus rattus* could be observed, *Mus musculus* and *Suncus murinus*.

Ecological Importance

In the island ecosystem of the Sundarbans, small carnivores, rodents, shrews, bats, birds, snakes, fishes, amphibians, insects, crabs, and molluscs play a crucial controlling role on the populations of one another and thereby maintain a balance. By destroying flowers and fruits, fruit bats become a factor in the control of plant life, but they also function as agents of seed dispersal and fertilization (Prater 1998).

The importance of mammalian species remains in their role in the various ecosystems as well as in human civilization. They serve as primary, secondary, and tertiary consumers, thereby exerting a controlling influence against the over-population of species whose unchecked increase would adversely affect the ecosystem. Their role in creating new growth and spread of vegetation, preventing congestion of crucial areas such as waterways, and also as scavengers is significant. Since the dawn of human civilization, mammalian species have been used as beasts of burden; friends of agriculture; sources of milk, protein, and clothing; and valuable economic assets. Further, they are widely used as experimental animals for anatomical, physiological, and medicinal researches. They are associated with the folklore and legendary beliefs of all civilizations.

Vanitharani (2007) showed the role of *Cynopterus sphinx* and other fruit bats in the forest restoration of the Kalakad Mundanthurai Tiger Reserve in Tamil Nadu. Further, it has been established that seeds passing through the different secretions of the bat's alimentary canal germinate faster than normal seeds (Douglas 1979; Thomas 1991). The role of microchiropteran bats in the control of insect populations and sustenance and shelter of many insects and small creatures is also well known (Prater 1998). However, apart from some stray reports on the positive role of small mammals, their significance has long lurked in the wild shadows of large beasts. However, recently, the world's little creatures pattered quietly into the biology limelight. The indirect values of small mammals are clearly explained by Blois et al. (2010). It was stated that small mammals are crucial members of local food webs and they play an important role in the ecosystems. They mix up the soil and recycle nutrients, disperse seeds and mycorrhizae that help many trees grow, and also serve as an important food source for larger carnivores belonging to the classes Reptilia, Aves, and Mammalia. The small mammal community serves as a useful, measureable indicator. A drop in the species diversity may indicate that similar changes are happening in many other communities. In summary, losses in small mammal diversity can also potentially affect the ecosystem services such as nutrient cycling and biomass production that benefit the biological communities of the Sundarbans.

Indian Flying Fox (Pteropus giganteus)

STATUS AND THREATS

Many of the small mammals are totally or partly dependent on agricultural, horticultural products or livestock. All these are available only in inhabited islands, and thus, the populations of rats, bats, shrew, mongooses, and civets grow on these islands. Further, a large number of vessels carrying goods and passengers regularly ply from the mainland as well as from one inhabited island to others. Thus, populations of small mammalian species, particularly rats, mice, bandicoots, and shrews, may get replenished by fresh arrivals on such vessels.

The annexure contains the protection or conservation status of the small mammals of the Sundarbans according to the Indian Wildlife (Protection) Act, 1972, the IUCN Red List, Convention on International Trade in Endangered Species(CITES), and Conservation Assessment and Management Plan Workshops (Molur et al. 2005). A total of 20 species have been placed under the schedules of the Indian Wildlife (Protection) Act, 1972, out of which only 9 species are under various degrees of threats, and the rest are considered as vermin, being treated as Schedule IV animals. It is clear that many of the species listed in the annexure are considered globally as of 'Least Concern' but are protected in India. This clearly indicates that population of those species are threatened in the national scenario. The Marsh Mongoose, *Herpestes palustris*, has been treated as endangered by the IUCN on the basis of its limited extent of occurrence and area of occupancy. In fact, there is also reduction in population of this species due to a decline in area and quality of habitat combined with a certain level of exploitation. However, this endemic species has been kept in Schedule II of the Indian Wildlife (Protection) Act, 1972 along with other species of the genus *Herpestes*. The Marsh Mongoose undoubtedly demands the highest degree of protection under the national law and should be placed in Schedule I of the Act. *Vulpes bengalensis* (Bengal Fox), *Prionailurus bengalensis* (Leopard Cat), *Paradoxurus hermaphrodites* (Common Palm Civet), *Viverricula indica* (Small Indian Civet), and *Amblonyx cinereus* (Asian Small-clawed Otter) find a place in the appendices of CITES, indicating their commercial significance.

Foxes, mongooses, civets, and otters impart a certain amount of damages to poultry, domestic stock, and, occasionally, fishery. This has resulted in some apathy toward them among the locals. The destructive role of rodents and fruit bats is also well known. However, the people of the Sundarbans consider such damages as part of nature. Killing of small carnivores or use of rodenticides are not very evident in the area.

Thus, except for the increase of human settlement area, gradual urbanization, and, to some extent, changes in the crop pattern, there are no specific man-made threats to the small mammalian species. However, natural disasters, such as cyclonic storms and frequent floods due to breaches in the embankments along riverbanks often take a huge toll on the population of small

Table 4. Number of recognised subspecies of some of the small mammal species occurring in Sudarbans (After Alfred et al. 2002 and Pradhan and Talmale 2009)

Name of the species	No. of Indian sub species
Rattus rattus	10
Mus musculus	3
Funambulus pennanti	4
Suncus murinus	8
Herpestes edwardsii	3
Paradoxurus hermaphrodites	7
Viverricula indica	5
Prionailurus bengalensis	3

Source: Alfred et al. 2002 and Pradhan and Talmale 2009

mammalian species. The entire Sundarbans is located at the land-sea interface. It is expected that these deltaic islands are likely to be the first affected by global warming. The World Wildlife Fund has warned that the days are numbered for much of the sensitive Sundarban ecosystem and in 60 years, vast tracts of rare mangrove forest will be inundated by the rising sea.

There are enormous gaps in our knowledge concerning the small mammalian species of the Sundarbans. No attempt has yet been made to take an inventory of species, particularly in the uninhabited islands. Data on the block-wise distribution of the species and population status are not available even for the inhabited blocks. A lot of information with regard to the species composition, relative abundance, ecological distribution, how the various pieces fit together, population dynamics of the species, economic significance, and the attitude of locals and others is unavailable. This information is crucial for planning a specific conservation programme. As such, no specific effort for the conservation of small mammalian species has been initiated in the area. However, the creation of the SBR in 1989 ushered in a new era of conservation of biodiversity in the intertidal zone of the Sundarbans. About 5,367 km^2 of the reserve comprises lands outside the forest. This manipulation zone of the reserve supports the majority of small mammalian species. The government as well as a large number of NGOs are working in the area for ecologically compatible economic development. The development of fishery—particularly ecofriendly prawn culture—apiary, oyster culture, mushroom culture, pearl culture, poultry, piggery, and agriculture have been initiated apart from providing basic needs of life, that is, improvement of transport through water, construction of bridges, removing illiteracy, providing drinking water and sanitation, strengthening the embankments, and conducting awareness programmes for conservation and afforestation.

ANNEXURE

Small mammals of Sundarbans and their Protection/ Conservation Status

Sr. No.	Species and their systematic position	Common Name	Indian Wildlife (Protection) Act, 1972, Schedules	IUCN Red List Category (2010)	CITES Appendices	National Status (Molur et. al (2005) and Anon (2002)
	Order: Soricomorpha					
	Family: Soricidae					
1	*Suncus murinus*	House Shrew	-	LC	-	-
	Order: Chiroptera					
	Family: Pteropodidae					
2	*Pteropus giganteus*	Indian Flying Fox	V	LC	II	LC
3	*Rousettus leschenaultii*	Leschenault's Rousette	V	LC	-	LC
4	*Cynopterus sphinx*	Greater Shortnosed Fruit Bat	V	LC	-	LC
	Family: Rhinopomatidae					
5	*Rhinopoma hardwickii*	Lesser Mouse-tailed Bat	-	LC	-	LC

Small mammals of Sundarbans and their Protection/ Conservation Status

Sr. No.	Species and their systematic position	Common Name	Indian Wildlife (Protection) Act, 1972, Schedules	IUCN Red List Category (2010)	CITES Appendices	National Status (Molur et. al (2005) and Anon (2002)
	Family: Emballonuridae					
6	*Taphozous longimanus*	Longed-winged Tomb Bat	-	LC	-	LC
	Family: Megadermatidae					
7	*Megaderma lyra*	Greater False Vampire	-	LC	-	LC
8	*M. spasma*	Lesser False Vampire	-	LC	-	LC
	Family: Rhinolopidae					
9	*Rhinolophus lepidus*	Blyth's Horse-shoe Bat	-	LC	-	LC
10	*Hipposideros pomona*	Andersen's Leaf-nosed Bat	-	LC	-	LC
11	*H. lankadiva*	Indian Leaf-nosed Bat	-	LC	-	LC
	Family: Vespertilionidae					
12	*Pipistrellus tenuis*	Least Pipistrelle	-	LC	-	LC
13	*P. dormeri*	Dormer's Pipistrelle	-	LC	-	LC
14	*Scotophilus heathi*	Greater Asiatic Yellow House Bat	-	LC	-	LC
15	*S. kuhlii*	Lesser Asiatic Yellow House Bat	-	LC	-	LC
	Order: Carnivora					
	Family: Canidae					
16	*Vulpes bengalensis*	Bengal Fox	II	LC	III	-
	Family: Felidae					
17	*Prionailurus bengalensis*	Leopard Cat	I	LC	II	-
	Family : Herpestidae					
18	*Herpestes edwardsii*	Indian Grey Mongoose	II	LC	-	-
19	*H. javanicus*	Small Asian Mongoose	II	LC	-	-
20	*H. palustris*	Marsh Mongoose	II	LC	-	-

Sr. No.	Species and their systematic position	Common Name	Indian Wildlife (Protection) Act, 1972, Schedules	IUCN Red List Category (2010)	CITES Appendices	National Status (Molur et. al (2005) and Anon (2002)
	Family: Viverridae					
21	*Paradoxurus hermaphroditus*	Common Palm Civet	II	LC	III	-
22	*Viverricula indica*	Small Indian Civet	II	LC	III	-
	Family: Mustelidae					
23	*Amblonyx cinereus*	Asian Small-clawed Otter	I	VU	II	-
	Order: Rodentia					
	Family: Sciuridae					
24	*Funambulus pennantii*	Five-striped Palm Squirrel	IV	LC	-	LC
	Family: Muridae					
25	*Bandicota bengalensis*	Lesser Bandicoot Rat	V	LC	-	LC
26	*B. indica*	Greater Bandicoot Rat	V	LC	-	LC
27	*Mus booduga*	Common Indian Field Mouse	V	LC	-	LC
28	*M. cervicolor*	Fawn-colored Mouse	V	LC	-	LC
29	*M. musculus*	House Mouse	V	LC	-	LC
30	*M. saxicola*	Brown Spiny Mouse	V	LC	-	LC
31	*Rattus norvegicus*	Brown Rat	V	LC	-	LC
32	*Rattus rattus*	Black Rat	V	LC	-	LC

LC = Least Concern; VU= Vulnerable

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3 ONGOING AND PREDICTED IMPACTS ON BIODIVERSITY

Biodiversity of the Sundarban delta is very sensitive and governed by a large variety of factors which include the current biophysical and anthropogenic factors. In recognition of its fragility and possible irrecoverable damage due to intense anthropogenic pressure, the British colonial administration kept the forested areas clear of settled population.

Currently, the protected forest areas of the Indian Sundarbans contain no settled population. However, the reclaimed portion is home to a large population variedly estimated between 4.2 and 4.6 million (ADB 2003; Danda 2007; School of Oceanographic Studies - Jadavpur University 2010, pers. comm.).

Biodiversity is the mainstay of all socioeconomic activities in the Sundarbans, with strong linkages across various livelihood sectors such as fisheries, agriculture, and forestry. Any depletion of bio-resources from the Sundarbans will have an adverse impact on these. Despite efforts to protect these rich biodiversity resources, they are threatened by a number of factors, including (a) increasing population and grinding poverty leading to excessive resource extraction to meet the demand for fish, including prawn seed, small timber, and fuel wood for local consumption; (b) relative sea-level rise; (c) salinization due to reduced flow of freshwater into the mangrove system; and (d) climate change manifested through higher ambient and sea surface temperature and increased frequency of severe cyclonic storms.

In the conservation context, a threat matrix (table 1) has been applied to the ecological region of the Sundarbans to allow decisions about conservation to be made with the best available information.

Table 1: Sundarbans Threat Matrix

Threat Category	Ecosystems	Large Fauna	Small Fauna (including aquatic)	Vegetation	Microbes
Population & poverty					
Resource extraction	--	Disturbance	Population decline	Partial damage to vegetated habitats	--
Wildlife harvesting	--	Endangered populations	Local extinctions	--	--
Encroachment/ land use change	Loss of ecosystems	Impact on breeding	Restricted distribution; local extinctions	Loss of carbon sequestration potential	Local extinc-tions
Sea level rise					
Sea Level Rise	Loss of Coastal mangroves	Inward/Upland Migration	Local Extinctions	Loss of veg-etated habitats	Local Extinc-tions
Salinisation					
Reduced freshwater inflow	Alteration of ecological patterns and processes	Aquatic fauna may change its range	Local Extinctions	Changes in mangrove com-position and distribution	--
Climate Change					
High intensity weather event	Damage to ecosys-tems	Migration	Migration	Partial loss to vegetation	Population decline
Increased Atmos-pheric CO_2	Fertilization effect	--	Depletion in fish stocks	Changes in community structure and composition; reduced pri-mary produc-tivity	Life cycle changes/ local extinc-tions
Key	(red)	Severe Impact			
	(orange)	Moderate Impact			
	(yellow)	Low Impact			

3.1 INCREASING POPULATION AND GRINDING POVERTY

The vast majority of livelihoods in the Indian Sundarbans are dependent on rain-fed agriculture, and over half the area's population is composed of landless laborers.

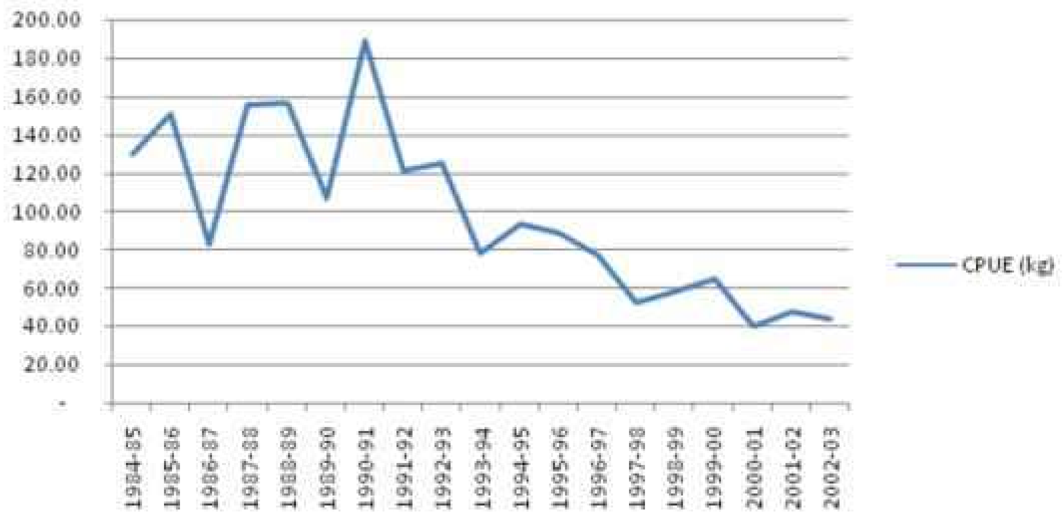
Although land is scarce and per capita holding is meagre, more than 60 percent of the population depends on land resource for agriculture with one staple crop of paddy. To increase production, agriculture of this eco-region relied on chemical fertilizers and pesticides and some reclamation of low-lying areas. The pesticides damage the non-target species and often enter the aquatic environment through runoff. Sarkar et al. (2008) present a comprehensive report of the organochlorine pesticide residues (OCs) such as hexachlorocyclohexane isomers (HCHs), dichlorodiphenyltrichloroethane (DDT) and its six metabolites, and hexachlorobenzene (HCB). Due to a diversity of inputs such as agricultural runoffs, wastewater and sewage discharges, and agricultural wastes, maximum concentrations of OCs were recorded at sites located along the main stream of the Hugli (Ganges) estuary. Among the HCHs and DDTs, β-HCH and DDE predominate. From an eco-toxicological point of view, the impacts of DDT and HCH are pronounced.

For a large number of people with little or no land assets and without other livelihood options, collection of prawn larvae belonging to the tiger prawn species (*Panaeus monodon*) to supply the aquaculture industry is a major livelihood activity. Prawn farming in the Sundarbans[1] can be classified as traditional or extensive, with stocking density of about 30,000 per ha or less but very high mortality. Commonly cultured species are *Panaeus monodon*, *Panaeus indicus*, *Metapanaeus dobsonii*, and *Metapanaeus monoceros*. Other forms of aquaculture include homestead pond culture and paddy-cum-shrimp culture. In this form of mixed livelihood strategy, paddy fields are flooded and used for seasonal brackish-water aquaculture of fish and prawn after the *kharif* farming period. Danda (2007) highlights the high proportion of recent migrants involved in prawn seed collection and underscores the connection between increased landlessness and the economic safety net that prawn seed collection provides, estimating that over a third of families who have lost their land to river erosion have chosen to turn to this as a means of livelihood.

Prawn seed collection is a highly destructive practice that results in the capture and discards of non-target species and exerts a heavy toll on the sustainability of marine, estuarine, and freshwater fish species (Chaudhuri and Chowdhury 1994; Dasgupta and Hazra 2005). For every tiger prawn seed, 161 juveniles of other prawns, 7 fishes, 30 crabs, 1 mollusc, and 8 unidentified meroplanktons get killed.

Aquaculture is generally believed to induce increased methane production from increased substrates like fertilizers, decomposition products of fish and shrimp, or sewage waters. Mukhopadhay et al. (2002) report high methane levels in the Sundarbans. Increased methane production in these soils has a negative impact on the initial development of mangrove propagules (Strangmann et al. 2008).

Figure 1: CPUE of Winter Migratory Bagnet Fisheries between 1984 and2003



[1] Spurt in prawn farming in the Indian Sundarbans since the late 1980s is almost entirely in response to market demand from industrialized countries although the domestic demand for prawn is also robust. This demand has also resulted in land use change and mangrove clearance in the northeastern part of the Indian Sundarbans. During the last decade, aquaculture farms expanded by about 4,600 ha (Hazra 2010).

The fishery sector is the next major contributor to the economy of the Sundarbans after agriculture but the Fisheries Department (2008) reports an alarming decline in capture fishery resources which are believed to have been over-exploited. Although catch data from estuarine fisheries show an increase in yield, catch per unit effort (CPUE) for winter migratory bag net fisheries has declined (figure 1), possibly indicating that maximum sustainable yield for estuarine ecosystems has already been exceeded (Dasgupta and Hazra 2005). Riverine fisheries are also thought to be adversely affected by a number of factors, including high pollution levels as well as reduced flows and obstructions due to dams (Chaudhuri and Chowdhury 1994)

The natural resources are the only capital available to a vast marginalized population and the proportion of such population is increasing over the decades, as can be seen in table 2. The table shows the change in employment in different sectors since 1971. While the proportion of cultivators has almost halved due to increased population although the absolute number of landowners might have remained the same, the proportion of wild harvesters has risen almost threefold. This is captured under the category 'other', comprising *Bowalis* or woodcutters, *Golpatta* collectors, crab[2] and shell collectors, *Moules* or honey collectors, and prawn seed collectors[3]. This group[4] often resorts to unauthorized resource extraction amounting to poaching, which goes unrecognized due to technical difficulties in observing and measuring the changes induced as well as difficulties with administrative reporting procedures. In pockets, such unchecked poaching reduces wildlife populations to the extent that they can only be recovered through scientific wildlife management interventions. Small fauna, including small aquatic species, are perhaps the most vulnerable.

Table 2: Percentage of population of Sundarban engaged in different sectors from 1971-2001. Source: adapted from Census of India (1971, 1981, 1991, 2001) data presented in Dasgupta (2008)

Year	Cultivators (Agr)	Labourers (Agr)	Household Industries	Other
1971	45.91	43.46	1	10.99
1981	42.3	38.78	1.48	16.53
1991	41	36.71	2.48	21.06
2001	24.37	36.35	4.86	31.84

[2] According to some estimates, 1,000–1,400 tons of mud crabs are landed annually, legally or otherwise, and about 10,000 families are dependent on this trade alone. Fortunately, as of now, parathelphusid crabs, *Sartoriana spinigera* and *Spiralothelphusa hydrodromus*, are available in appreciable numbers and are mainly available during the monsoon, thus restricting the harvesting window.

[3] Often these resource extractors become victims of human-wildlife conflict. Human-tiger conflict resulting in human fatality in the Sundarbans is perhaps the highest among all tiger-bearing areas. In the Sundarbans, the scale of the issue is so large that the editor of the volume has included a separate chapter on the subject by Chandan Surabhi Das as an annexure.

[4] Within the STR, 900 boat licenses are issued for prescribed resource extraction and over 2,000 such licenses are issued in the reserve forest areas.

3.2 SEA LEVEL RISE

Hazra et al. (2002) report a relative mean sea level rise of 3.14 mm per year in Sagar Island and the adjoining areas of the Bay of Bengal.

Analyses of 50 years of data from the Permanent Service for Mean Sea Level (PSMSL) show sea-level increase of between +0.76mm per year and +5.22 mm per year at different locations in the Hugli estuary (Nandy and Bandyopadhyay 2008). By 2050, there may be a sea-level rise of approximately 50 cm, which could accelerate coastal erosion of forested islands (Hazra et al. 2008). Coastal erosion is constantly reshaping the islands of the Sundarbans. During 2001–2009, the rate of coastal erosion in the Indian Sundarbans was found to be about 5.50 km^2 per year, mostly in the southwestern edges of individual islands. Erosion has affected sandy beaches as well as mud flats. Even islands with dense mangrove in the east (like Bhangaduani/Mayadwip, Dalhousi, or Bulcherry) have been substantially eroded. The entire island system of the Indian Sundarbans has suffered a net land loss of about 44 km^2 during 2001–2009 (figure 2).

Besides thermal expansion of water due to increased ambient temperature, subsidence of the Bengal Basin also contributes to sea-level rise in the Sundarbans. The subsidence of the Bengal Basin is largely the result of tectonic forces and can be attributed to two major factors. One is related to the isostatic adjustment of the crust (sediment load and the rise of the Himalayas) while the other is related to dewatering and compaction of the sediments of the Bengal deep-sea Fan.

Mangroves can adapt to sea-level rise if it occurs slowly enough (Ellison and Stoddart 1991), if adequate expansion space exists, and if other environmental conditions are met. Given the prevailing settlements and rising trend of sea-surface temperature of the Sundarbans, the ability of mangroves to migrate landward seems improbable unless space is made available for such migration. Eventually, mangroves will become progressively smaller with each successive generation and may perish if inland migration or growth cannot occur fast enough to account for the rise in sea level (UNEP 1994).

Due to accelerated erosion and inundation of mudflats, breeding and wintering populations of wildfowl, waders, and passerines may be adversely affected. The implication for birds also include earlier breeding; changes in timing of migration; changes in breeding performance (egg size and nesting success); changes in population sizes and distributions; as well as changes in selection differentials between components of a population. The extent to which the invertebrate populations of coastal mudflats will be influenced by sea-level rise is likely to depend on whether rates of sedimentation can compensate for sea-level rise (Beukema 1992).

Fig 2: Eroded and vulnerable islands

3.3 SALINISATION AND REDUCED FRESH WATER FLOW

The productivity of the mangrove ecosystem depends on a dynamic balance among freshwater flow, sedimentation, erosion, and species composition.

A significant change in any of these factors can create conditions resulting in changes in the vegetation and landform (Mirza 2004). Salinity is a key ecological parameter that could induce ecosystem level changes. The saline seawater being heavier allows the lighter freshwater coming from upstream to accumulate like a 'lens'. In a tide dominated delta like the Sundarbans, entrenchment takes place; as a result, a saline layer extends upstream like a wedge. Comparison of past data (of 1984) with more recent data (of 2001) reveals a drastic increase in salinity of the outer estuary (26 ppt to 36.2 ppt) and mid estuary (20 ppt to 26 ppt) for the summer data of the Eastern Sector.

Salinity trends, as observed, for both surface waters and groundwater with respect to estuary location are given in table 3.

An analysis of salinity trends indicate that communities in the following regions will suffer for increasing salinity trends: (a) Western sector outer estuary and inner estuary (Sagar and Mathurapur Block); (b) Central Sector mid estuary (Kultali Block); and (c) Eastern Sector mid and inner estuary (Gosaba and part of Basanti Blocks and Sandeshkhali Block).

Increasing salinity alters species composition of plant and animal communities and can trigger gradual extinction of species intolerant to high salinity levels, including some mangrove species. The composition of the mangrove ecosystem is quite sensitive to salinity levels. Studies on the impact of salinity on mangroves in Bangladesh have found that inadequate freshwater is responsible for the extensive top dying disease of the Sundari (*Heritiera fomes*) tree (Iftekar et al. 2004). Increasing salinity can lead to decreased productivity and seedling survival and may also cause a net loss of mangrove as anaerobic decomposition increases (Snedaker 1995).

Table 3: Salinity Trends in the Sundarbans

Estuary position		**Seasonal Trend (Increasing / Decreasing)**		**Pearson Correlation**	
Sector	Out /Mid /In	Pre-monsoon (N=)	Monsoon (N=)	‘ r ‘ value	P =
Pattern of Changes in Surface Water Salinity Trends during last three decades (1980-2010)					
Western	Outer	Insignificant (16)	Insignificant (16)	0.1/ 0.28	--
	Middle	Insignificant (5)	Insignificant (7)	0.07/ 0.45	--
	Inner	Increasing (7)	Insignificant (9)	0.97/ 0.06	0.001
Central	Outer	Increasing (7)	Increasing (6)	0.69/ 0.83	0.08/0.04
	Middle	Decreasing (3)	Insignificant (5)	-1.804878	P = 0.47
	Inner	Increasing (7)	Insignificant (4)	0.87/ 0.64	0.02/0.34
Eastern	Outer	Insignificant (6)	Increasing (7)	0.64/ 0.70	0.04
	Middle	Insignificant (11)	Increasing (5)	0.43/ 0.93	/0.01
	Inner	Increasing (26)	Insignificant (16)	0.58/ 0.23	0.002
Pattern of Changes in Ground water Salinity Trends during last three decades (1980-2010)					
Western	Outer	Increasing (7)	Increasing (11)	0.83/0.75	0.022/0.009
	Middle	Insignificant (7)	Insignificant (9)	0.5/0.13	0.253
	Inner	Insignificant (4)	Increasing (4)	0.76/ 0.95	0.237/0.046
Central	Outer	Data lacking	Data lacking		
	Middle	Increasing (5)	Insignificant (5)	0.993	0.001
	Inner	Increasing(4)	Increasing (4)	0.75/0.79	0.024/ 0.021
Eastern	Outer	Data lacking	Data lacking		
	Middle	Insignificant(3)	Increasing(4)	0.91/0.996	0.004
	Inner	Increasing(8)	Increasing(9)	0.86/0.75	0.008

3.4 CLIMATE CHANGE

Beaumont et al. (2011) assessed the likelihood that by 2070, 'Global 200' iconic eco-regions will regularly experience monthly climatic conditions that were extreme in 1961–1990.

Using more than 600 realizations from climate model ensembles, it has been shown that up to 86 percent of terrestrial and 83 percent of freshwater eco-regions will be exposed to average monthly temperature patterns >2 SDs (2σ) of the 1961–1990 baseline, including 82 percent of critically endangered eco-regions. Tropical and subtropical eco-regions and mangroves face extreme conditions the earliest, some with <1°C warming.

Mishra (2002) has reported an increasing trend in the mean maximum ambient temperature in the Sundarbans. During periods of high atmospheric evaporative demand, mangroves need to conserve water because of the limited capacity to extract freshwater from saline soils. As a result, water use efficiencies in mangroves are among the highest of all C3-plant species (Ball 1986). These high water use efficiencies presumably come at the expense of reduced rates of carbon assimilation (Ball et al. 1988). Added to this, leaves of mangroves need to cope with exceedingly high (1,000 W per m^2 around noontime) radiational loadings as they conserve water by reducing transpiration when the atmospheric evaporative demand is high. The modulation of energy loading on the foliage is accomplished through inclining leaf angles to reduce light interception, decreased leaf size to augment boundary layer sensible heat transport, or increasing leaf succulence to dampen fluctuations in foliage temperatures (Ball et al. 1988).

Elevated CO_2 concentrations also result in decreased nitrogen investment in leaves and a concomitant increase in the carbon-nitrogen ratio of plant tissues, which have flow-on effects to consumers (Stiling et al. 1999) and on decomposition processes; nutritious leaf material with low carbon-nitrogen ratios have higher decay rates (Bosire et al. 2005). Decreased precipitation results in a decrease in mangrove productivity, growth, and seedling survival and may change species composition favoring more salt-tolerant species and loss of the landward zone to unvegetated hyper-saline flats (Snedaker 1995). An increased CO_2 concentration in the atmosphere could lead to the decoupling of the phenology of flowering plants and their pollinators (Harrington et al. 1999). Climate change would also affect insect interaction with other species (competition, predation, and parasitism) or between herbivorous insects and host plants such as in herbivory (Menéndez 2007).

Several aspects of the insect life cycle and ecology, especially those directly controlled by energy availability variables such as degree day (accumulative temperature needed for development), are predicted to be affected due to warming. Consequently, potential responses would include changes in phenological patterns and habitat selection. Parmesan (2007) catalogued differing phenological responses to climate change over the last decade in nine taxonomic groups from the northern hemisphere. Shifts in timing of breeding responses by amphibians were more than twice those of trees, birds, and butterflies. Butterfly emergence or migratory arrival has advanced three times faster than the first flowering of herbs and may forecast increasing decoupling of insect-plant interactions.

Ecosystem response varies depending on the interaction of the species within the physical and chemical characteristic of the environment (Shaver et al. 2000), making significant errors in the stability of the ecosystem. The effects of increased CO_2 concentration and temperature on ecosystem depend, to a large extent, on a web of indirect effects on process interaction and feedbacks. Shaver et. al. (2000) use the example of net primary production (NPP) and heterotrophic respiration (Rh), which are both directly affected by temperature. Temperature also has an impact on factors such as nitrogen mineralization, species composition, moisture, litter quantity and quality, and soil organic matter quality, which in turn feed back to the NPP and Rh.

Sea surface temperature over the Bay of Bengal has been found to be rising at a rate of 0.019°C per year and a similar trend has been observed in data collected from the Indian Sundarbans. Current projections estimate that the temperature in the Indian Sundarbans will rise by 1°C by 2050 (Hazra et al. 2002). Subsequently, the ocean is absorbing excess CO_2 from the atmosphere at a rate of 49 Gigatons per year. The change in atmospheric pCO_2 will directly affect the carbonate system of the ocean. CO_2 can influence the physiology of marine organisms as well through acid-base imbalance and reduced oxygen transport capacity. The particular change in carbonate chemistry and 'ocean acidification' would involve change in biological food webs of aquatic organisms (for example, phytoplankton, zooplankton, and algae) and organisms like bivalves which need carbonate in their development and for forming shells and skeletons.

Such alteration could seriously affect the rich fishery resources in the Sundarban region which are dependent on planktons and may lead to large-scale ecological disaster in decades to follow. Subsequently, this change would have a direct economic bearing on fisherman who inhabit the eco-region, through decreased fishery and crab harvests.

Hazra (2010) reports that the sea surface temperature observed for the period 2003–2009 showed a rising trend at the rate of 0.0453°C per year and reached the highest level in 2009, but until 2005, there was a downward trend in sea surface temperature. During this period, from several depressions over the Bay of Bengal, only three materialized into severe and super-cyclonic storms. Over the next four years, with sharp rise in sea surface temperature, depressions over northern Bay of Bengal resulted in seven severe cyclonic storms, which includes Mala, Sidr, Bijli, and Aila that affected vast areas of the Sundarbans. Intense storm impacts on soil subsidence and accretion affect local calculations of relative sea-level rise (Cahoon 2006).

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4 THE WAY FORWARD

The Sundarbans, straddling India and Bangladesh, are part of the great mangrove-dominated delta facing the Bay of Bengal.

The Indian portion is home to more than 4 million poor and climate-vulnerable people. Their average per capita annual income is below the poverty line and 70 percent lack access to safe water. Many live at or below sea level and are at constant risk from floods and cyclones. They endure creeping salinization as the sea rises; about a third of the farmland already has high salinity. Productive landholdings average just 0.36 ha and are likely to shrink as the population grows.

In India, the Sundarbans ecosystem directly supports 1.3 million people through subsistence activities like fishing, crab hunting, and collection of non-timber forest products. A significant number of the people depend on forests and use the Sundarbans resources. (Intensity of forest dependence). The Sundarbans provide sanctuaries for threatened and endangered wildlife, contributing to maintenance of fish diversity by acting as nursery, breeding, and feeding grounds and are a repository of medicinal plants and non-timber forest produce. The benefits of ecosystem services provided by the mangrove forests include protection from cyclones and erosion, carbon sequestration, production of honey and other forest products, and marine and inland fishery.

Due to the information gaps, making decisions about the future of the Sundarbans is a matter of chance. However, despite the analytical work that remains to be done, it is clear that the Sundarbans are in a precarious situation and that action could be taken in the short term to prevent the permanent loss of critical ecosystem diversity.

The purpose of this chapter is to summarize the findings of the analytical work on Sundarbans biodiversity and suggest a way forward. The work undertaken under the World Bank non-lending technical assistance in West Bengal, India and Bangladesh by the WWF and IUCN, respectively, provides a basis for integrating biodiversity considerations into development planning. The analytical work illustrates the need to think now about how to shape long-term spatial and human development patterns to create a more sustainable and resilient future and strengthen biodiversity conservation.

4.1 THE STATE OF BIODIVERSITY IN THE SUNDARBANS

As discussed in previous chapters, internationally recognized specialists on each of the Sundarbans' biodiversity subgroups were asked to conduct an assessment of the state of the biodiversity as it related to their expertise.

The result was some of the most up-to-date and detailed work that has ever been conducted on the Sundarbans and the end result will, hopefully, be an expansion of the view that the public and policymakers have of the benefits and unique resources of the Sundarbans ecosystem.

For instance, the Sundarbans' coastal fisheries exist at an intersection of rich species biodiversity, endangered habitats, and economic necessity. The Sundarbans are home to 14.56 percent of India's fish species and are the nursery ground for roughly 90 percent of the aquatic species of the east coast. Thus, all the fisheries on the east coast of India are dependent on the continued health of the ecosystem, and millions of people, from poor tribal people to large commercial fishing vessels, are dependent on revenue from fishing. However, eight of the Sundarbans' fish species are currently under threat, and most of them are vulnerable to continued loss of mangrove acreage, water pollution, and unsustainable fishing practices.

The Sundarbans are the most unique among mangrove forests as there is a significant mammalian population. The forest is home to 47 mammal species, of which 15 are megafauna (species whose adult members weigh more than 5 kg). It is these species which are under the greatest threat. Important megafauna include the rhesus monkey, spotted deer, wild boar, five species of dolphin, and four species of wild cat (including the Royal Bengal Tiger). These species not only provide an important ordering function in the ecosystem, by modifying vegetation structure and keeping species' populations in check, but also an important indicator of overall species health. Since megafauna require vast quantities of food, their population is very sensitive to overall ecosystem health. Tigers and dolphins and spotted deer can only be healthy and numerous when their food sources are healthy and numerous. A number of megafauna have undergone local extinction in the last century. Out of the 15 remaining species of megafauna in the Indian Sundarbans, 7 have some kind of endangered status. The prime threats faced by these species are poaching, water pollution, and loss of mangrove forest cover.

The Sundarbans are home to 329 crustacean species (61.1 percent of West Bengal's inventory of crustacean species and roughly 10 percent of the total species known to be present in India). These crustaceans not only have commercial value (indeed, they form the Sundarbans' prime export and growth industry), they also have a valuable ecological function by breaking down decaying plant matter, aerating the soil, and recycling mineral and organic matter. However, crustacean habitats are increasingly under threat due to destruction of mangrove forests, unsustainable prawn larvae collection practices, and pollution of waterways.

The xiphosuran arthropods, or horseshoe crabs, are some of the world's oldest creatures; these have remained unchanged for over 350 million years. Only four species of xiphosurans remain in the world; three of these are endemic to the Indo-Pacific region and two are present in the Sundarbans. These species are used in traditional medicine and, in recent years, biomedical companies have begun harvesting their blood for use in western medical contexts. These species have an ecological role that is similar to that of crustaceans and are subject to similar threats. These are particularly threatened by loss of access to the beaches that they use as spawning grounds.

Mangrove ecosystems are an excellent habitat for birds, and India's mangrove ecosystems have even more biodiversity than other similar ecosystems in Malaysia and Australasia. The Sundarbans are home to at least 234 bird species, of which 85 are migrant visitors. Wading birds serve important ecosystem functions; they accelerate nutrient cycling at feeding grounds and regulate fish populations. Birds also assist in transporting nutrients to and from ecosystems. Enrichment of mangrove stands through bird guano stimulates higher plant growth and results in higher nitrogen concentrations. Many plants also depend on birds for pollination. According to present data, the populations of birds that depend on fish and other aquatic fauna have declined 36 percent in the last three decades; these impacts are largely due to human claims on traditional feeding areas and on loss of mangrove forest cover.

4.2 CHALLENGES FACED BY THE SUNDARBANS

The analytical work identified the need to deal with today's urgent poverty challenges but concluded that business-as usual development is not sustainable in the long run.

The combination of sea-level rise and greater variance in weather events, including more intense cyclonic events, will increase salinity, threaten biodiversity, and make lower-lying portions of the delta increasingly uninhabitable.

Sea-level rise and greater variance in extreme weather events will have an impact on the mangrove forests. Impacts include a rise in salinity decrease in mangrove productivity, growth, and seedling survival and may change species composition favoring more salt-tolerant species and loss of the landward zone to unvegetated hyper-saline areas. The mangroves will only have limited ability to migrate landward. The forest will become progressively smaller with each successive generation and may perish if land migration or growth cannot occur fast enough to offset the area lost.

The vast majority of livelihoods in the Indian Sundarbans are dependent on rain-fed agriculture. Although land is scarce and per capita holding is minimal, a large percentage of the population depends on land resource for agriculture, with staple crop of paddy. The agriculture of this eco-region relied on chemical fertilizers and pesticides to ensure high crop yields. The pesticides damage the non-target species apart from those they are intended to kill, for example, depriving insect-eating birds of food. The chemical fertilizers often get into the aquatic environment through runoff and into the local food chain and may then build up at even higher levels until they become toxic to much larger organisms.

Prawn seed collection—or the collection of prawn larvae belonging to the tiger prawn species to supply the aquaculture industry—remains a primary livelihood activity for a large number of people for whom other livelihood options are limited and with little or no land assets. Prawn seed collection represents a highly destructive practice with a high bycatch rate (between 95 to 93 percent) that results in the capture and discard of non-target species and exerts a heavy toll on the sustainability of marine, estuarine, and freshwater fish species. For every tiger prawn seed, several juveniles of other prawns, fishes, crabs, molluscs, and meroplanktons get killed. The fisheries sector feeds into a wider economy of commerce and job creation through associated processing and marketing activities. However, catch data from estuarine fisheries reveal an increase in yield but a decrease in catch per unit effort.

There are a range of traditional livelihoods-based occupations in the Sundarbans, including *Bowalis* or wood cutters, *Golpatta* collectors, crab and shell collectors, *Moules* or honey collectors, and prawn seed collectors. Threats related to poaching often go unrecognized due to technical difficulties in observing and measuring the changes induced and difficulties with administrative reporting procedures. Such unchecked poaching reduces wildlife populations to the extent that they can only be recovered through scientifically oriented wildlife management interventions. Small fauna, including small aquatic species, are perhaps the most vulnerable, and losses of microbes are the least studied.

4.3 KNOWLEDGE GAPS

Ecosystem resilience (Holling 1973) provides insurance to societies through ecological stability for sustaining a flow of ecological goods and services (Costanza et al. 2000).

Ecological stability is generated more by a diversity of functional groups than by species richness (Tilman 1996). Knowledge of these factors and functional groups are important in predicting mangrove resilience and ecological stability.

Knowledge of the factors that maintain ecosystem integrity in the Sundarbans is incomplete mainly because of the intrinsic complexity of natural systems. There is relatively little knowledge on the status of the Sundarbans ecosystem resilience and biodiversity groups contributing to it. In fact, there is no time series data with respect to threats identified and their impact on each biodiversity group. However, the loss of diversity within functional groups may weaken the ability of the system to adapt to catastrophic changes on longer time scales. Therefore, the task of preserving ecosystem integrity through management is challenging and would have been so even without being influenced by human activities. Nevertheless, in the light of global biodiversity loss due to human activity, the pressing question that needs to be answered for ecosystems of value, including the Sundarbans, is not how much but how little of functional redundancy of species can be compromised without pushing the system to the edge of irreversible change.

Given that the information base is so poor, how is it to be decided which biodiversity groups or species within the groups need to be conserved? In the absence of objective information, it would depend on the perspective of the decision maker. If the perspective is that of an economist, possibly the species of economic value will make it to the list, while a deep ecologist would possibly want all the species to be conserved for their intrinsic rather than their instrumental value. Such decisions, then, are essentially value judgments unless a cost-effectiveness methodology is used which results in a formula that can be used as a criterion for ranking. This ranking has to be sufficiently operational to be useful in suggesting what to look at when determining actual conservation priorities among endangered species under limited budget constraints.

Information from earlier chapters pertaining to limitations and gaps in knowledge of individual biodiversity groups are presented in the following matrix (table 4), as are the possible ways to address the same.

Table 4: Possible research and management interventions

Sr. No.	Biodiversity Group	Knowledge gaps and Limitations	Research/Management interventions
1	Microbes	(i) Current state of knowledge indicates that Sundarbans have the potential to host microbes of economic importance; yet the methods needed to culture is unknown (ii) In-situ conservation techniques	(i) Research particularly on the integration of phenotypic, genetic and ecological information (ii) Examine pathogenic microbes (iii) Identification of the genus and species of the producing actinobacteria (iv) Collection of actinobacteria through sector wise field sampling of the entire Indian *Sundarbans* (v) Promote bio-prospecting efforts with share to local Biodiversity Management Committee on existing The World Federation for Culture Collections (WFCC) guidelines (vi) More Involvement of Biotechnology industries
2	Algae	(i) Diversity studies to determine the present status of algal resources (ii) Detail taxonomic study needs to be done	(i) Critical evaluation of the species inhabiting the Sundarban areas (ii) Extensive monitoring in spatial and temporal scale (iii) Address industrial pollution and knowledge gaps
3	Phytoplankton	(i) Little information on sensitivity of cyanobacteria to more realistic CO_2 scenario.	(i) Impact of climate change in particular changing carbonate chemistry and ocean acidification on phytoplankton's

Sr. No.	Biodiversity Group	Knowledge gaps and Limitations	Research/Management interventions
		(ii) Few studies on potential effect of CO_2 release on planktonic life	(ii) A digital image repository should be made. (iii) Address knowledge gaps.
4	Lichens	(i) Lack of information on ecological role like community dynamics & succession patterns and trends due to the said threats	(i) Set up Lichen Reserves (ii) Multiculture forestry practice- lichen rich mangrove phorophytes (iii) Address knowledge gaps.
5	Mangrove	(i) Inaccessibility of the terrain and exorbitant costs involved in detailed manual surveys (ii) Extremely long duration in carrying out manual surveys in the hostile terrain (iii) Lack of infrastructure and manpower in the Forest Department	(i) Space for natural regeneration to cope with sea level rise (ii) Remote Sensing and GIS technology coupled with Ground Truth Verification to prepare detailed stock maps (iii) Massive mangrove plantation in degraded areas with local community participation (iv) Address industrial source pollution (v) Address shore stabilization along the sea-facing forested islands.
6	Non-mangroves	(i) Reason behind the depletion of 12 orchid species is not known.	(i) Non-mangroves which are distributed towards the inland areas and human inhabited regions may be considered for conservation (ii) Intensive studies on the causes of depletion of orchids and their restoration measures (iii) Non-mangrove adaptation from Sundarbans
7	Protozoa	(i) No studies to ascertain the status or predict the change in community with reference to climate change and pollution.	(i) Address knowledge gaps.
8	Mollusca	(i) Impact of habitat disturbance on population of mollusc.	(i) Regulation of catches (ii) Demarcation of no collection zones (iii) Improved collection methods (iv) Control on export (v) Mariculture practice.

Sr. No.	Biodiversity Group	Knowledge gaps and Limitations	Research/Management interventions
9	Polychaetes	(i) No cosmopolitan positive or negative indicator species to identify a community as healthy.	(i) Periodic environment monitoring to assess the population availability, density and diversity.
10	Xiphosurans	(i) No success in captive rearing (for medical research etc.)	(i) Monitoring of population in identified breeding ground.
11	Crustacea	(i) No baseline data for sustainable utilization	(i) Assessment of the present stock and studies related to the impact of salinity on the population. (ii) Permissible limit for annual catch
12	Spiders	(i) No systematic time-series data	(i) Monitoring population diversity patterns in mangrove ecosystem given the impacts of climate change.
13	Mites	(i) No systematic study of ecology and impact on trophic cascade.	(i) Need to identify potential mite species and address the gap areas.
14	Insects	(i) No comprehensive work on Insect ecology and inputs to the dynamics of ecosystem (ii) No comprehensive list of pollinators of mangrove forest in the Sundarbans.	(i) Identification of potential indicator taxa and monitoring. (ii) Future research on pollinators may be conducted based on the flowering time.
15	Fish	(i) No baseline data for the present stock.	Research needs: (i) Present stock assessment (ii) Permissible limit for annual catch (iii) Appropriate fishing techniques (iv) Possible impact – on the fishery resources due to closed and open season.
16	Herpetofauna	(i) Determining the status of species population and spatial pattern of diversity	(i) Ecological niche modelling to predict probability distribution; (ii) Awareness of people to differentiate between venomous and non-venomous snakes.
17	Aves	(i) Complexities of the interactions of species, given the climate change threats	(i) Population modelling; (ii) Monitoring of bird population at certain locations.
18	Mammals	(i) Species composition in the forested tracts & relative abundance (ii) Ecological distribution and study of population dynamics	(i) Monitoring of the population trends & introduction/invasive/migration of mainland species (ii) Assessment & follow up conservation program of the following species: dolphins, lesser cats, ungulates, wild boar, (iii) Habitat study. (iv) Reintroduction of lost species viz. barking deer.

4.4 POLICY OPTIONS FOR MANAGEMENT OF THE SUNDARBANS

Although regulatory instruments for conservation are already in place, new economic mechanisms could consolidate regulatory efficiency and help realize positive biodiversity conservation outcomes.

Illegal poaching of tigers, clearing of mangroves, and settlement in protected areas are all being tackled through traditional enforcement approaches. For the core area, the main goal centers on eliminating the illegal harvesting that is currently taking place in the forest. The Forest Department is also implementing a permit allocation system to control entry into the forest.

In recent years and in part due to this ongoing analytical work, increased governmental and civil society attention has been paid to the unique value and the special challenges of the Sundarbans. During 2011, the Sundarbans became a topic of particular discussion between the governments of India and Bangladesh. It was seen as an area where increased cooperation between the countries could be very fruitful. In the end, during Prime Minister Mammohan Singh's highly touted September 2011 visit to Bangladesh, the governments of India and Bangladesh signed a memorandum of understanding to cooperate on efforts to protect the Sundarbans.

In this five-year non-binding memorandum of understanding, the two governments agreed to explore the possibility of joint resource management, coordinated conservation, mangrove regeneration, habitat rehabilitation programs, and the development of synergistic ecotourism opportunities. They also agreed to explore the possibility of information-sharing, joint security patrols, joint tiger population censuses, and joint anti-poaching efforts[1]. Conservation efforts in the Sundarbans could be strengthened by research and development. The studies conducted under this document can serve as baselines for biodiversity conservation.

In response to the pressures on the Sundarbans, a plausible alternative includes embarking on a multigenerational plan to strengthen biodiversity conservation, reengineer estuary management, and encourage voluntary out-migration from the most-threatened areas. Flood-threatened farmland would give way to river and mangrove, requiring a managed retreat that would be difficult but would prevent future catastrophes. Increased attention to education and human development would equip new generations with the skills to seek better livelihoods in centers characterized by agglomeration economies. Policy-driven incentives that keep people in the region would be dismantled, and infrastructure and development would be targeted toward the less-threatened parts of the Sundarbans. The most-threatened parts of the area would eventually be allowed to revert to mangrove, expanding the rich and threatened ecosystem and boosting prospects for sustainable, profitable ecotourism.

The Sundarbans face a mix of climate- and population-related impacts. The climate-related changes are occurring on a global level and cannot be reduced by local planners, but going forward, planners could work to increase the resilience of the Sundarbans ecosystem. On the other hand, the population-related changes *can* be managed by local planners. West Bengal is considering interventions that will increase forest resilience and provide financial incentives to local populations to preserve biodiversity.

The use of economic incentives funded by revenues from climate change mitigation programs can play an important role in enhancing the effectiveness of regulatory enforcement in the near term. Sustainable forestry practices provide a basis for accessing these funds because of their ability to conserve biodiversity and prevent deforestation, thereby retaining forests for sequestering atmospheric carbon. By preserving the forest, it will be possible to take advantage of funding opportunities that have been created in the context of global carbon reduction efforts. Carbon financing schemes can be used to support a number of initiatives aimed at enhancing biodiversity by reducing the pressure that residents near the Sundarbans Reserve Forest are placing on forest resources.

The Sundarbans region could also possibly benefit from establishing mechanisms through which landowners and municipalities can receive financial compensation by adopting sound management practices for the conservation of wetland forests in the Sundarbans. Potential revenues associated with nonextractive uses (for example tiger viewing and carbon sequestration) could be shared with local communities. The use of innovative property rights would create benefit-sharing incentives for residents of communities near the forest to become custodians and co-managers of the forest, thereby decreasing direct pressures on the forest. Livelihood opportunities created to serve stable zone residents who continue living near the forest could be consistent with efforts to conserve the forest.

Mangrove restoration is an integral part of the adaptation strategy for the Sundarbans. The government of West Bengal is retreating embankments to protect coastal communities from erosion and climatic events. The areas between old (abandoned) and new (retreated) embankments are naturally regenerating mangrove to create a bioshield to attenuate wave energy. Mangrove restoration offers livelihood opportunities and also allows for local communities to become involved in conservation, sustainable management, and ecosystem restoration operations. As new mangroves are regenerated, these areas might be designated as 'community reserves' or 'conservation reserves' to shift the focus from exploitation of forest resources to management based on sustainability considerations.

[1] "Memorandum of Understanding Between the Government of the Republic of India and the Government of the People's Republic of Bangladesh on Conservation of the Sundarban." Office of the Prime Minister of India. September 2011.

[2] Under the amended Indian Wildlife (Protection) Act, 2002, "the State Government may, where the community or an individual has volunteered to conserve wild life and its habitat, declare any private or community land not comprised within a National Park, sanctuary or a conservation reserve, as a community reserve, for protecting fauna, flora and traditional or cultural conservation values and practices." Once such a reserve is declared, its land use cannot be changed except in accordance with a resolution passed by the management committee and approval of the same by the state government. A community reserve management committee is constituted by the state government, which shall be the authority responsible for conserving, maintaining, and managing the community reserve. This committee has five representatives nominated by the village panchayat (institution of local self-governance) or, where such a panchayat does not exist, by the members of the gram sabha (village assembly) and one representative of the state Forest or Wildlife Department under whose jurisdiction the community reserve is located. This committee is the competent authority to prepare and implement the management plan for the community reserve and to take steps to ensure the protection of wildlife and its habitat in the reserve. Source:Indian Wildlife (Protection) Act, 1972, as amended in 2002.

[3] According to the Indian Wildlife (Protection) Act, 1972, as amended in 2002: "The State Government may, after having consultations with the local communities, declare any area owned by the Government, particularly the areas adjacent to National Parks and sanctuaries and those areas which link one protected area with another, as a conservation reserve for protecting landscapes, seascapes, flora and fauna and their habitat. Provided that where the conservation reserve includes any land owned by the Central Government, its prior concurrence shall be obtained before making such declaration."A conservation reserve management committee is constituted by the state government to advise the chief wildlife warden to conserve, manage, and maintain the conservation reserve. This committee consists of a representative of the Forest or Wildlife Department, who shall be the member secretary of the committee, one representative of each village panchayat in whose jurisdiction the reserve is located, three representatives of nongovernmental organizations working in the field of wildlife conservation, and one representative each from the Department of Agriculture and Animal Husbandry.

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The conflict between predatoryanimals and their human neighbors is as old as the history of the human race.

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3.76 million with an average density of 845 persons per sq km (Census 2001) and about 100 tigers

Now, when an increasing number of people are crowding into a limited amount of land, human-wildlife conflicts are set to increase all over the world. In one generalization, the prey-predator ratio by weight has been estimated as 1:111, that is, 10,000 kg of prey is required to sustain just 90 kg of predators (Carbon and Gittelman 2002). Therefore, the predators require a disproportionately huge amount of space than their prey. With the growing human popu -lation, especially in developing countries, space has become scarce and is increasingly being competed for with their animal neighbors, for livestock rearing and agriculture. Indeed, conflict between people and felids has been termed as one of the most urgent wildcat conservation issues of the world (Inskip and Zimmermann 2009).

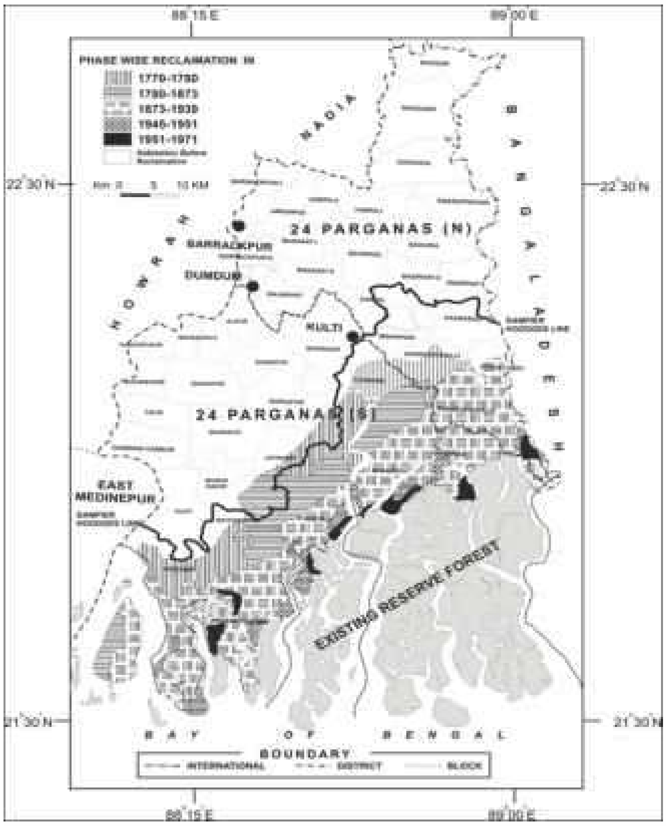
Reclamation of the Sundarban mangrove wetlands in the lower Ganga Brahmaputra delta was started from 1770 (Pargiter 1934). During the next two centuries, some 5,364 km^2 of the former tidal forests were converted to farmlands in 19 police station areas in the North and South 24-Parganas Districts of West Bengal (figure 1). The present area of the Indian Sundarbans wetlands amounts to 4,262 km^2. The reclaimed portion now supports a rapidly growing population of 3.76 million, with an average density of 845 persons per km^2 according to the 2001 census. People live in the reclaimed area of the Sundarbans, which was initially under mangrove forests till 1833. In the northern part, the morasses have been converted into fertile rice fields. The jungles were steadily pushed back and human habitation extended southwards into the interior. The southeastern part is a network of tidal waters covered with dense mangrove jungles. Majority of the population (approximately 95 percent) depends on agriculture, supported by other occupations like fishery, forestry, and handicraft making.

These people, because of their proximity to the mangroves and underdevelopment, are exposed to a unique set of biotic hazards—ranging from snakebites to tiger attacks—that has greatly influenced their mental makeup and sociocultural setup. Conflict of interests between the authorities protecting the mangrove wildlife and the people using its resources has also become apparent since 1960.

The common types of vertebrate-induced hazards seen in these areas are inflicted by snakes, tigers, crocodiles, and sharks. Animal attacks on humans are common in the Sundarbans. Attacks from snakes and tigers often prove fatal. Straying of tigers from reserve forests into human habitations also poses a major problem for the residents living along the forest boundary. Snakes are not restricted to forests and incidents of attack from these creatures outnumber any other category.

A single crop of paddy cannot cater to the needs of the people residing in the Sundarbans, and to eke out a living, they take to fishing, crab collection, honey collection, and woodcutting inside the mangrove forests. Increasing population pressure and dire poverty urge the people to take the risk of facing natural hazards as well as attacks from wild animals as they venture into the jungle. Trespassers take undue advantage of this human presence in the zone for pilferage of forest produce and poaching of wild animals. It is also not uncommon for the animals to stray into human habitations and cause dep - redations. All these lead to conflict between humans and animals—the root cause of which is socioeconomic.

Fig 1: Phase wise reclamation in Sundarban and loss of forest



Human survival and economic well-being are fully dependent upon biological diversity that includes all life forms, ecosystems, and ecological processes, acknowledging the hierarchy at genetic, taxa, and ecosystem levels. The more the biodiversity the greater is the access to available resources along with increased net primary production and decreased nutrient loss (Mandal et al. 2010).

Conflicts between wildlife and humans in the Sundarbans are evident owing to the increase in human population, extensive loss of natural habitats, and increase in dependency on forest resources. Conflicts are most acute when a species involved is critically imperiled while its presence in an area poses a significant threat to human welfare (Saberwal et al. 1994). Human-wildlife conflict is potentially any situation where (a) the behavior of people negatively affects wildlife (this includes human impacts on habitat); (b) the behavior of wildlife creates a negative impact

Conflict is evident owing to increase in human population, extensive loss of natural habitats and increase in dependency of forest resources.

for some stakeholders or is perceived by some stakeholders to affect themselves or others adversely; or (c) the wildlife-focused behavior of some people creates a negative interaction with other people, often in the form of a clash of values. Thus, a people-wildlife problem can involve a people-wildlife interaction or a people-people interaction (that is, disagreements among people regarding wildlife interaction) or both (Decker and Chase 1997).

HUMAN-TIGER CONFLICT

The Sundarbans have an age-old history of hazards related to man-tiger conflicts. Tigers in the Sundarbans mangrove are widely known for frequently straying into the villages on the fringe areas of the Sundarbans. Therefore, human-tiger conflict arises in two different ways: first, by people entering into tiger territory and second, by the tiger straying into human habitation.

Habits and Habitat

The Sundarban tiger or Royal Bengal Tiger (*Panthera tigris tigris*) is different from any other tiger in the country and the world because of its adaptability to the unique mangrove habitat. Its behavior is largely specific to the individual and cannot be generalized and is also not replicable from the studies made on other tigers of the world, the country, or even the Sundarbans. The much-used word 'aberrations' indicates its adaptation to a hostile land due to which it is perpetually under stress. Tigers in Sundarbans eat fish and crabs, can swim very fast in the big rivers even up to the speed of 16 km/hr, climb trees, drink salty water, catch their prey in broad daylight, prey upon human beings, and do not have any common preying behavior. The tiger pugmarks are seen everywhere in the forest though the tiger itself is not so visible. These, added to the hostile habitat, make the Sundarbans not an ideal place to study

Royal Bengal Tiger-(Panthera tigris)

tigers. The role that tigers play as a top predator is vital to regulating and perpetuating ecological processes and systems (Sunquist et al. 1999). The Sundarban tiger is clearly seen to be an adaptable species because of its ability to tolerate a wide range of physical conditions and habitat types.

Tigers need extensive areas to hunt and breed; thus, protecting wild populations and sustaining their habitats impose a set of complex and difficult tasks upon the protected area managers. For instance, tigers are large-bodied, obligate carnivores and readily come into conflict with humans by killing people in the fringe areas of the Sundarbans and their livestock. Predatory behavior differs according to the prey species, prey size, and hunting environment and also depends on the changing prey behavior. These wide ranges of tactics in capture and killing behavior allows tiger to have a wide range of prey types and sizes, from a few hundred grams of fish and crabs to a wild boar or deer weighing about 50 kg.

Study on Attack on Humans

A large number of poor people of the Sundarban fringe areas enter into the forests every year for their livelihood (table 1). Between 1985 and 2009, 789 persons (figure 2) were attacked by tigers, out of which 666 succumbed to their injuries, with an average of 27.75 events per year. Nearly 14 percent of the victims were honey collectors, 5 percent were woodcutters, and as much as 80 percent were fishermen, including crab collectors. About 1 percent of the victims were forest staff.

In the STR area, there are 15 forest blocks comprising about 2,584.89 km^2 of forest and water bodies. These are uninhabited and differ from the administrative blocks. The tiger victim data of the period 1986–2009 denoted that Jhilla (21.1 percent), followed by Pirkhali (19.72 percent), Chandkhali (11.72 percent), and Arbesi (9.35 percent), were the four most vulnerable forest blocks, accounting for more than 60 percent of the persons attacked and killed by tigers. All these forest blocks, except Chandkhali, border the fringe villages of Gosaba and Hingalganja Blocks, from where a large number of people regularly venture into the forest for their livelihood. Intensity of tiger attacks is comparatively low in the forest blocks of Gona, Bagmara, Mayadwip, Gosaba, and Matla because of their location away from the inhabited areas.

Around 59 percent of the tiger attack victims were residents of Gosaba Block. Hingalganja (14.96) was the second most vulnerable block, followed by Basanti, (9.99 percent), Hasnabad (3.8 percent), Canning II (2.54 percent), Pathar Pratima (2.54 percent), and Kultali (2.03 percent). The blocks of Canning I, Sandeshkhali I and Sandeshkhali II, Namkhana, and Kakdwip were the least affected in this respect because of minimum involvement of their residents in forest-related activities. On the other hand, Satjalia, Jamespur, Dayapur, Lahiripur, and Rajat Jubilee Villages of Gosaba Block and Samsernagar, Chargheri, and Hingalganj Villages of Hingalganj Block constitute the most-affected villages.

The available data indicate that intensity of tiger attacks fluctuated like a sine curve (figure 5). Between 1985 and 1989,

Biodiversity Based Livelihood

the incidents decreased with the introduction of measures like prohibition of entering into *hental* (*Phoenix paludosa*) forests that are frequented by tigers and establishment of electrified dummies and rear face masks. Both electrified dummies and masks were discontinued from 1989 and the frequency of attacks rose from an all-time low of 10 in 1989 to 49 in 1993. A sharp decrease in frequency was again recorded from 1994 to 1996 due to reintroduction of the measures. In recent times, after 2005, an upward trend has been observed, probably due to lack of monitoring of the protective measures as well as an increase in illegal entry into the forests. It is also revealed by the data that an overwhelming majority—87 percent—of the attacks were fatal; only 13 percent of the tiger attack victims could escape with their lives.

Tiger attacks on humans are characteristically distributed throughout the year. The attacks peak pre-monsoon, especially in April, during which 20 percent (n = 789) of the attacks took place. October, on the other hand, is the month recording the least number of attacks, at 5.96 percent (figure 4). This pattern seems to corroborate the observations made by Hendrichs

(1975), who related increase in salinity in the estuarine waters of the Sundarbans during April with increase in the frequency of attacks. April is also the peak honey collection season when both the frequency and number of *moulis* are maximum and the converse is true from October to December. Although November–January is the main fishing season in the Sundarbans, some fishing activity is also carried out during March–June, which accounts for the fact that more than 80 percent of all tiger victims were fishermen, including tiger prawn and crab collectors, and only 14 percent were *moulis*.

A team of mouli (honey collectors)processing honey in their boat after colleting it from tiger territory

Table1: Humans killed by tigers in Sundarban: 1975–2008

Year	Number	Average	Measures taken
1975	63	48.0	Digging of freshwater ponds started
1976	40		—
1977	37		—
1978	48		—
1979	52		—
1980	50	40.0	*Phoenix* permit discontinued
1981	29		—
1982	41		—
1983	21	23.5	Electrified dummies introduced
1984	16		—
1985	31		—
1986	26		—
1987	19	15.3	Human face masks introduced
1988	21		—
1989	6		—
1990	53	45.3	Dummies and face masks discontinued
1991	41		—
1992	40		—
1993	47		—
1994	16	12.3	Introduction of fibreglass headgear. Dummies and face masks reintroduced
1995	15		—
1996	6		—
1997	12		—
1998	21	32.0	Lack of monitoring of the measures
1999	35		—
2000	40		—
2001	24	24.5	Nylon fencing at selected entry points and intensive patrol - ling introduced
2002	28		—
2003	23		—
2004	23		—
2005	30	34.8	Lack of patrolling leading to gradual increase in illegal forest entrants
2006	33		—
2007	36		—
2008	40		—
1975-2008	1,063	31.3	

Source: Modified after Sanyal, 1999 (data up to 1995), Village survey, STR, Death Registry Office and RCHP

Probable Reasons for Attacks on Humans

The probable reasons for tiger attacks on humans are hostile environmental conditions and human use pattern of the habitat. The various groups of human intruders include honey collectors; fishermen, including tiger prawn seed collectors; crab collectors; and even Forest Department staff (figure 2).

These users have to stay in the forest in small *dingies* (country boats) and need to set foot on land as their profession demands. They also need to go ashore for bathing and toilet without any safety measures, except for a wooden log in most cases. Many times, because of rough weather, these small *dingies* are anchored in small creeks which remain unaffected by rough weather. These small rivers and creeks keep changing their direction and dimensions because of tidal actions. Since the *dingies* do not have proper anchoring provisions, during late night, they usually get into positions which make them more vulnerable to tiger attacks because of their proximity to the land. The tigers stealthily climb onto the small boats at night and sometimes into sleeping shelters built illegally on trees and seize one of the inmates.

It is evident from figure 2 that tigers are found to attack the honey collectors, crab collectors, and fishermen who enter the deep forest in the early mornings and afternoons, mostly because they intrude into the tigers' habitat and disturb the animal by their activities, which typically is lighting fires and/or creating smoke for honey collection. During these periods of the day, these groups of workers are caught unaware by the tiger, which makes them more prone to tiger attack. The tigers are not known to attack groups of more than 4 people and when the groups are well connected. In a span of 24 years (1985–2009), a total of 789 victims (666 dead and 123 injured) have been reported from the Sundarbans (Das 2009). The honey collectors are more vulnerable to tiger attack than the fishermen community as the honey season lasts only for two months in a year. A total of 108 cases (92 dead and 16 injured) have been reported for the period 1986–2009.

Crab collectors

Human face masks as a protective device against tiger attacks

Measures to Reduce Conflict in the Tiger Territor

Over the years, several management interventions have been undertaken by the concerned authorities of the Sundarbans to mitigate the human-tiger conflict in the Sundarban forest, for example, stopping the permit for collection of *Phoenix* and *Nypa* from the STR, digging of freshwater ponds, introduction of human face masks, introduction of clay models which were wrapped with energizers charged to 230 volts by a 12-volt battery source, and introduction of tiger guards for the staff (Sanyal 1987).

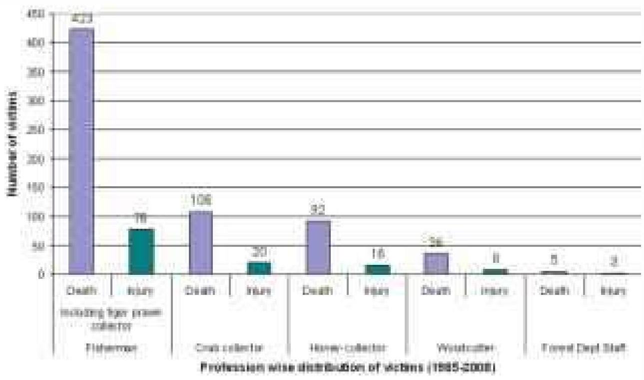
The clay models represented fishermen, woodcutters, and honey collectors. In all, six models were made, two for each profession, irrespective of the profession-wise pattern of tiger attacks (Sanyal 1987). These six models were set up in the Netidhopani, Pirkhali Panchamukhani, and Jhilla forest blocks. Maintenance of these proved very difficult and were therefore discontinued after 1990 (Das 2009).

Fishermen were supplied with rubber face masks which they put on the back of the head so that the tiger, which presumably attacks from the rear, is confused. The method was low cost and gained popularity among the people venturing into the Sundarbans. However, recent statistics show that this cannot prevent tiger attacks. Digging of freshwater ponds started from 1975 onwards to mend tiger tempers, but statistics reveal that there was minimal reduction in officially recorded attacks. Therefore, none of these methods could conclusively be proved as effective.

Patterns of Tiger Straying

On the other hand, during the period 1986–2009, a total of 279 incidents of straying occurred in the fringe villages of the Sundarbans, with an average of 12 incidents per year (figure 3). Incidents of straying have increased sharply since 2000 mainly due to increased human intrusion into the tigers' territories as well as destruction of their habitats. The incidents of straying generally damage the paddy crops as well as the livestock of the poor villagers. In addition, tigers are killed in retaliation by arrogant villagers, ignoring the poor administration by the forest officials.

Fig: 2 : Profession wise distribution of victims (1985-2008)



Most of the incidents occurred during the monsoon and winter months in the fringe villages of the Sundarbans. Out of the 279 reported incidents, 232 cases were from 16 villages of the Bagna and Sajnekhali ranges of the STR. The remaining incidents were reported from 24-Parganas (South) division. The most-affected villages include Samsernagar, Kalitala, and Kumirmari in Bagna and Rajat Jubilee, Jamespur, and Dayapur in Sajnekhali Block. Male tigers were involved in 85 of the cases. In most cases, tigers resorted to cattle lifting or feeding on poultry. Only in seven cases were humans attacked.

The blocks of Gosaba, Hingalganja, and Kultali are the most vulnerable to tiger straying. The heavily affected villages of Hingalganja Block are Samsernagar, Kalitala, Hemnagar, and Pargunti; in Gosaba they include Rajat Jubilee, Jamespur, Dayapur, Kumirmari, and Lahiripur while in Kultali Block they include Kultali, Sunkijan, Dealbari, Bhasa, Maipeet East, Gurgaria, Nagenabad, and Katamari. Sitarampur, Dashpur, K Plot, and Keshorimohonpur in Pathar Pratima Block and Jharkhali in Basanti Block are other villages affected by tiger straying. In the last few years of the period 1986–2009, the incidents in Basanti Block are negligible but sharply increased in Kultali Block since 2007. Overall, the most-affected village is Samsernagar (29.9 percent), followed by Rajat Jubilee (17.8 percent), Kalitala (9.3 percent), and Jamespur (6.5 percent).

One of the important characteristics of the Sundarban tigers is their ability to swim long distances and at a maximum speed of 16 km/hr. Records show that the tigers need to cross 50–150 m wide creeks to enter into the villages in the Bagna forest range. To enter the villages bordering the Sajnekhali range, the creeks that need to be crossed are between 300 m and 900 m in width.

The Kurekhali or Sakunkhali River in Hingalganja Block is the most vulnerable as far as tiger crossing is concerned (36.3 percent), followed by the Pirkhali (33.6 percent), Gumdi (7.5 percent), and Rangabeliya (6.5 percent) Rivers (table 2). In some areas, creeks play a crucial role in tiger straying. For example, the Kamalakhali creek, at places only 15 m wide, separates the Samsernagar Village of Hingalganja from the Arbesi Block. This is one of the villages that is most affected by tiger straying.

As soon as a straying tiger is detected, on most occasions, the villagers try to inform the STR authorities. At the same time, they also take the initiative to drive the tiger away. The general attitude of the people living in the fringe areas of the Sundarban forest toward the tigers is extremely hostile. Killing of a straying tiger is not unheard of in villages like Dayapur, Jamespur, and Rajat Jubilee in Gosaba and Samsernagar in Hingalganja.

A narrow creek dividing protected area and Samsernagar village of Sundarban

Fig 3: Tiger straying incidents in villages of Sundarbans (1986-2005)

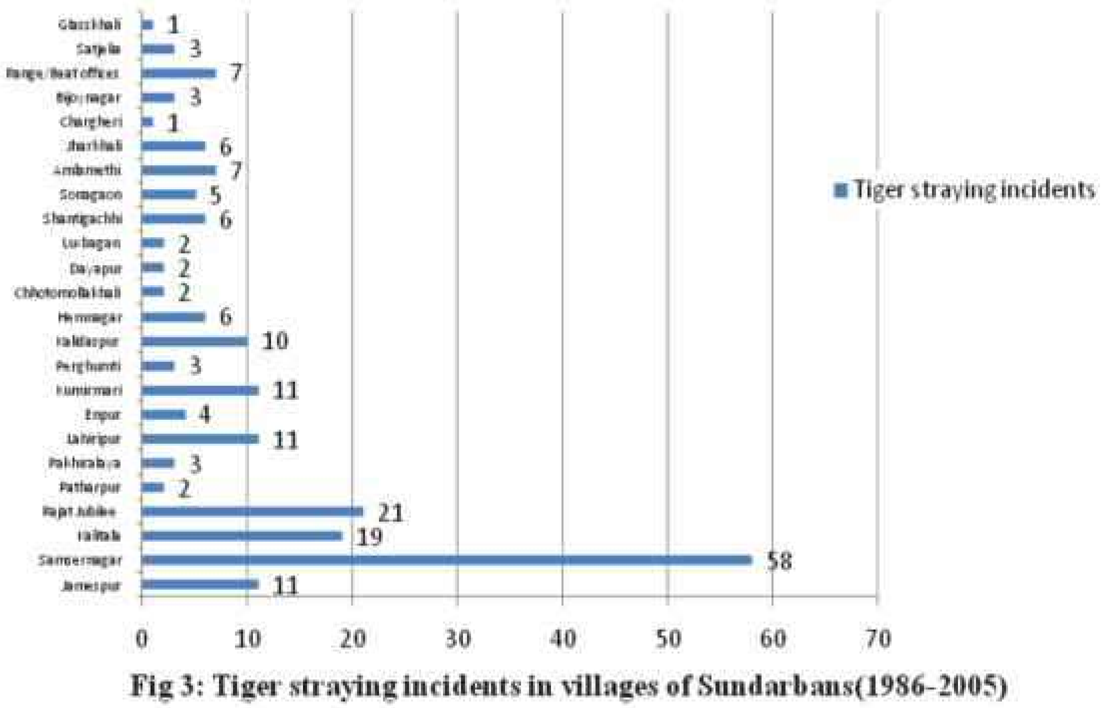


Table 2 Most vulnerable rivers related to tiger straying incidents: 1986-2009

River/Creek	CD Block	Width in metres	Percentage of crossing by tigers (n=279)
Kurekhali or sakunkhali	Hingalganj	25	36.3
Pirkhali	Gosaba	150	33.6
Gumdi	Gosaba	150	7.5
Korankhali	Gosaba	100	6.5
Rangabeliya	Gosaba	600	6.5
Raymangal	Hingalganj	800	2.2
Kapura	Hingalganj	50	1.8
Mokri	Kultali	40	1.7
Thakuran	Kultali	75	1.0
Others	-	-	2.9

SOURCE: Village survey, STR, Sundarban Biosphere Reserve (SBR), Divisional forest office (S -24 Pgs) and RCHP

Table 3: Tigers killed presumably by villagers: 1990-2009

Date	Village	Block	Remarks
08/12/1990	Dayapur	Gosaba	Strayed animal, killed by villagers.
23/01/1993	Sajnekhali	Gosaba	Strayed animal, electrocuted by the vil - lagers.
05/01/1994	Sudhan-yakali	Gosaba	Corpse detected by a private launch. Probably killed by villagers.
26/09/1994	Hemnagar	Hingal-ganj	Strayed animal found in a paddy field, killed by poisoning.
12/05/1994	Jamespur	Gosaba	Strayed animal, killed by villagers in self defence
08/03/1995	Luxbagan	Gosaba	Strayed animal, killed by villagers.
29/07/1998	Rajat Ju-bilee	Gosaba	Strayed animal, found in a paddy field, poisoned in retaliation of cattle lifting.
19/07/2001	Pakhiralaya	Gosaba	Strayed animal, killed by villagers.
02/10/2001	Kishorimo-hanpur	Kultali	Strayed animal, killed by villagers
15/12/2001	Kumirmari	Gosaba	Strayed animal, killed by villagers.

Source: Wildlife Protection Society of India (WPSI), STR, SBR & Field Study

Sometimes, thousands of people from the surrounding villages gather to kill or drive away a straying tiger. Although the Forest Department staff try to persuade the agitated villagers, the situation often goes beyond their control. In such cases, the *panchāyats*—the lowest tier of democratically elected bodies of the Indian union comprising one village to a few villages—usually come forward to assist the Forest Department in controlling the mob and to save the life of the straying tiger.

The Forest Department as well as local sources reveal that the tigers 'found dead' in various areas of reclaimed Sundarban are often poisoned, presumably by the villagers. Between 1990 and 2001, at least ten tigers were reported to have been killed by the villagers (table 3).

The population density in the villages surrounding the forests is high. The economic condition of the residents is also very poor. As straying tigers commonly kill cattle and tigers, in general, attack men when they venture into the forest for their livelihood, the villagers become habitually revengeful toward the tigers. This attitude is even more intensified by peoples' resentment to strict enforcement of laws concerning entry into the jungles by the Forest Department. In isolated cases, straying tigers are killed by villagers in self-defense, although it is observed that most of these tigers are not man-eaters. It, of course, is not easy to change this attitude toward the straying animals unless there is some incentive for the villagers for not treating the tigers shabbily.

Measures to Reduce Conflict from Tiger Straying

Fencing the boundaries of the vulnerable forest areas with vegetation, that is, *Garan-gewa* fencing (*Ceriops* spp.-*Excoecaria* spp.), and mechanical methods, such as nylon net fencings which are erected along the boundary of the forest areas, are found to have not been very effective. Eight cases of straying incidents (table 4) have been reported from Deulbari Village adjoining Heronbhanga-9 forest block of the STR over a span of 3 years although the edges of Heronbhanga-9 are lined with nylon net fencings. *Ceriops* and *Excoecaria* fencing is not encouraged nowadays because it requires cutting of *Ceriops* and *Excoecaria* trees in large numbers. It is not possible to erect fencing in small creeks and rivulets. Sometimes, fencing, which costs up to INR 120,000.00 (US$2,400 approximately) per km for both nylon net with *Ceriops* and *Excoecaria* fencing, is damaged by the local people as they enter into the forest areas for collection of fish, crab, and honey. Solar lights have also been installed on the boundary of the villages to lower tiger-straying incidents. However, solar power units and batteries require component replacements at regular intervals and are therefore very expensive.

In 2004, the Forest Department decided to use satellite-linked radio collars for monitoring the movement of tigers in the fringe areas of the Sundarbans. This effort, although carried out with some success on elephants, had never been tried on tigers in West Bengal. Till date only 4 tigers have been collared with satellite-linked radio collars. It is, however, doubtful whether the scheme would be able to bring into account the greater part of the 274 non-territorial tigers (2004 tiger census) present in the Sundarbans in the near future.

Nylon fencing along the creek in Samshernagar village in Hingalganja block separates nearby households.

Table 4: Tiger straying incidents in fringe villages of Heronbhanga-9, Forest Block of STR

Sr. No.	Year	Village	Adjoining forest	Number of Tiger Straying incidents
1	2007-08	Deulbari	Heronbhanga-9	1
2	2008-09	Kantamari (Betalpara)	Heronbhanga-9	1
		Deulbari	Heronbhanga-9	2
3	2009-2010	Deulbari	Heronbhanga-9	5
		Petculchand	Heronbhanga-9	1
		Jharkhali-3	Heronbhanga-9	1

Source: STR & SBR

Fig 4: Month wise distribution incidents of tiger straying & tiger attack (1986-2008)

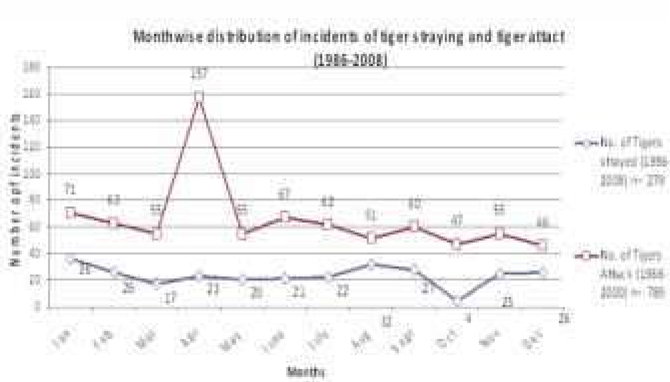
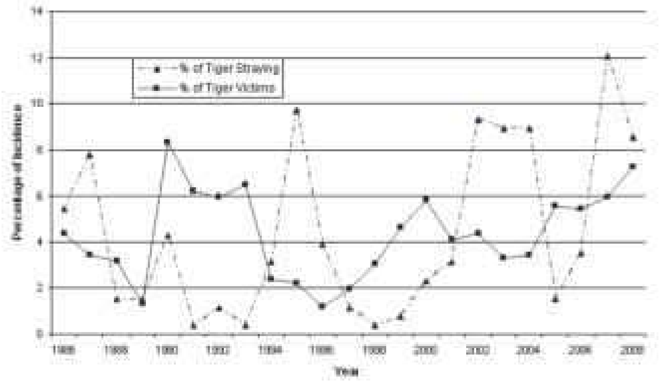


Fig 5: Percentage Distribution of Tiger Attacks and Tiger Straying by Years Which Shows a Weak Negative Correlation between Them



HUMAN-SNAKE CONFLICT

Habit and Habitat

In India, snakes are represented by over 200 species distributed under 11 families (Mahendra 1983; Smith 1943; Minton 1966), of which 52 are venomous in nature (Deoraj 1981). The common varieties of poisonous snakes found in India are cobras, vipers, coral snakes, and sea snakes. Interestingly, almost all these types are found in the Sundarbans. Snakes in the Sundarbans include Indian cobra, king cobra, Indian krait, banded krait, and Russell's viper. Among the nonpoisonous types, 17 species are common in the Sundarbans (De 1994). Common varieties include common blind snake, beaked blind snake, common wolf snake, green whip snake, rat snake, chequered keelback, striped keelback, olive keelback, trinket snake, painted brownback, Indian bronzeback, and dog-faced water snake.

This higher diversity of reptiles is due to the fact that the Sundarbans houses a wide variety of habitats, ranging from mud flats to sandy beaches and extremely saline zones to almost freshwater zones—each exhibiting seasonal oscillations of physico-chemical variables like salinity, pH, and dilution. Snakes offer a wide array of species in diversified habitats, for example, terrestrial, intertidal, and aquatic environments.

According to a study of snakebite cases and sighting of snakes between 1993 and 2005 in the Sundarbans, it appears that snake density is higher in the southern Sundarban blocks compared to the northern ones. Ranking of the poisonous snakes according to frequency of sightings by the resident population may be (a) common krait (*Bukgaras cueruleus),* (b) common cobra (*Naja naja)*, (c) banded krait (*Bungarus fusciatus)*, (d) Russell's viper (*Vipera russellic)*, and (e) king cobra (*Ophiophagus harirah*).

Pattern of Snakebite

Snakebite is a serious public health hazard in the reclaimed Sundarbans, causing the death of a large number of people every year. Basanti, Canning I, Canning II, and Gosaba are the four blocks where the magnitude and intensity of snakebite and deaths due to snakebite are very high compared to the rest of the region (Das 1996).

In these four blocks, 527 persons died from snakebites during the period 1993–2005, an average of 40 persons per year (table 5 and figure 6). This can be ascribed to poor communication facilities in these areas and nonavailability of proper medical treatment. As far as seasonal incidence of snakebite is concerned, most of the cases coincided with the monsoons (71 percent: July–September), when the burrows of the snakes usually get flooded. Records were nearly nonexistent during the winter (December–February) because this is the period of hibernation for snakes.

The common krait caused the maximum number of deaths (57 percent), followed by the common cobra (39 percent) and Russell's viper (4 percent). About 70 percent of the deaths occurred at night, which corresponds to the period of maximum activity of the common krait, and about 30 percent occurred during daytime, which can be attributed to common cobras and Russell's viper. The female-male ratio of the bite victims was 1:2.5. Although bite incidents were observed in all age groups, majority of the victims (70.41 percent) were found to be between 11 and 40 years of age. This group is most active outdoors and that increases the risk of cobra bites. Seventy-five percent of the bites occurred indoors and were caused by common kraits. It was found that most of the patients (76.12 percent) went to the village shamans, called *ojhās*, instead of visiting hospitals. Only 10 percent preferred to go to a hospital or health center.

Another survey on snakebite incidents, based on admission register records of the BPHCs of 19 adjacent blocks of the

Russell's Viper (Vipera russellic)

Figure 6: Percentage distribution of fatal snakebites by months: 1993-2005. n=527. (Source: Village survey and BPHC registered data)

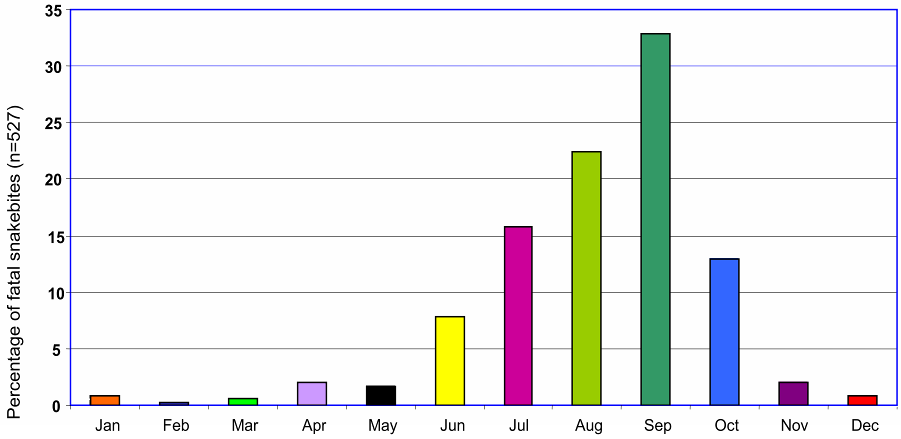


Table 5: Distribution of mortality from snakebites by blocks: 1993–2005

Block	Number of fatal snake-bites	Average number of fatal snakebites per year	Yearly mortality rate per 10,000 popula-tion
Gosaba	195	15.00	0.67
Basanti	146	11.23	0.40
Canning II	85	06.53	0.33
Canning I	101	07.76	0.32
All blocks	527	50.86	0.54

SOURCE: Village survey and BPHC-registered data

Table 6: Distribution of vulnerability to snakebites by blocks : 1993–2005

Block	Number of snakebites	Average number of snakebites per year	Yearly vulnerability to snakebites per 10,000 population
Namkhana	272	20.92	1.30
Sand-eshkhali II	189	14.53	1.07
Sand-eshkhali I	188	14.46	1.03
Gosaba	296	22.76	1.02
Hingal-ganja	182	14.00	0.90
Patharpra-tima	206	15.84	0.55
Canning I	102	7.84	0.32
Kultali	186	14.30	0.76
Canning II	104	8.00	0.41
Kakdwip	123	9.46	0.40
Basanti	185	14.23	0.51
Ma-thurapur I	57	4.38	0.27
Ma-thurapur II	94	7.23	0.36
Jaynagar I	44	3.38	0.15
Jaynagar II	36	2.76	0.13
Sagar	55	4.32	0.23
Hasnabad	40	3.07	0.17
Minakhan	34	2.61	0.15
Horah	48	3.69	0.20
All blocks	**2441**	**185.08**	**0.49**

SOURCE: BPHCs of Sundarban and Basirhat, Bangur Hospital (Tollyganj), Nilratan Sarkar Medical College and Hospital, Calcutta and field observation

Sundarbans, was conducted between 1993 and 2005 (table 6) to assess the nature and intensity of the problem in the area under review.

The study revealed that snakebite incidence is very high in Patharpratima, Namkhana, and Gosaba Blocks (>10 percent of recorded cases). High intensity (8–10 percent) is seen in Basanti, Canning I, Sandeshkhali I, and Sandeshkhali II Blocks; moderate intensity (6–8 percent) is observed in Canning II, Hingalganja, Kakdwip, and Kultali Blocks; and Mathurapur (I and II), Jaynagar (I and II), Sagar, Hasnabad, Minakhan, and Horoa show low intensity (<6 percent) (figure 7).

Measures to Mitigate Conflict with Snakes

The moist, warm climate and the presence of vast stretches of wetlands tend to increase the activity of snakes in the Sundarbans. Snakes remain active throughout the year except for the short hibernation period from November to the middle of February (Das 1998). Availability of prompt aid with antivenom serum (AVS) (available at the BPHCs) after occurrence of a venomous snakebite largely determines the chances of survival of a victim. A mosquito net provides protection from snakebites during sleep. Establishment of health centers to cover every two or three villages, with round-the-clock facilities for snakebite treatment and regular supply and storage of AVS, will minimize the problem. The location of the health center is crucial and may be decided based on the population size of the villages it would serve. To facilitate swift transfer of snakebite victims to health centers, especially during the monsoons, the interior roads should be paved with bricks. Lack of conveyance and poor infrastructure facilities at health centers determine the survivability of snakebite victims.

ATTACK BY CROCODILES AND SHARKS

Crocodile victims are generally of two types—fishermen and tiger prawn seed collectors. In the Sundarbans, hundreds of people, mostly women and young children, are engaged in prawn seed collection every day. Wading through waist-deep or even neck-deep water, they use fine nylon nets to filter out the spawn of shrimps. In an area where the scope for alternative employment is limited, this activity has become popular in the Sundarbans since 2000 as it yields very high returns (Ray 2000). It is also done on a commercial scale using nets spread across almost the entire width of the river with the help of boats and buoys.

According to a survey, around 103 people were attacked by crocodiles during 1997–2008; out of these, 61.16 percent did not survive—an average of 7.9 persons every year (table 7). Almost 80 percent of the victims were prawn seed collectors and belonged to the age group of 11 to 50 years. They were mostly children and women. Male victims are slightly lower in number (46.60 percent) than females (53.40 percent). This is probably because more females are engaged in the collection of tiger prawn and crabs in the Sundarbans. Most of the cases were recorded from Gosaba (34 percent), followed by Patharpratima (25.24 percent) and Namkhana (18.45 percent).

Apart from crocodiles, the persons exposed to the creeks of the Sundarbans are also vulnerable to attack from sharks—locally called *kāmots*. Shark attack is a relatively recent phenomenon in the Sundarbans and started since 1985 (Kanjilal 2000).

Prawn seed collection

Table 7 Distribution of Crocodile victims by Block: 1997-2008

Block	Gosaba	Nam-khana	Pathar Pratima	Kultali	Rest of Sundar-ban	Total
Number of incidents	35	19	26	15	8	103
Number of death	28	10	14	7	4	63
Percent-age of all incidents (n=103)	33.98	18.45	25.24	14.56	7.77	100
Yearly average of incidents	2.69	1.46	2.00	1.15	0.62	7.92
Yearly aver-age of death	2.23	0.83	1.17	0.58	0.33	5.25
Vulner-ability per 10,000 Population	0.12	0.9	0.07	0.06	-	0.09
Mortality per 10,000 population	0.10	0.05	0.04	0.03	-	0.06

SOURCE: Village survey, STR and RCHP, Forest Offices of 24 Pgs (South & North) Division

This was the time when prawn seed collection was introduced in the Sundarbans. Indeed, the majority of shark attacks are on the prawn seed collectors. About four species of sharks of the Sundarbans (*Scoliodon sorrakowah*, *Scoliodon dumerilii*, *Scoliodon palasorrah*, and *Scoliodon walbeehmi*) are known to attack humans (Sinha et al. 2000).

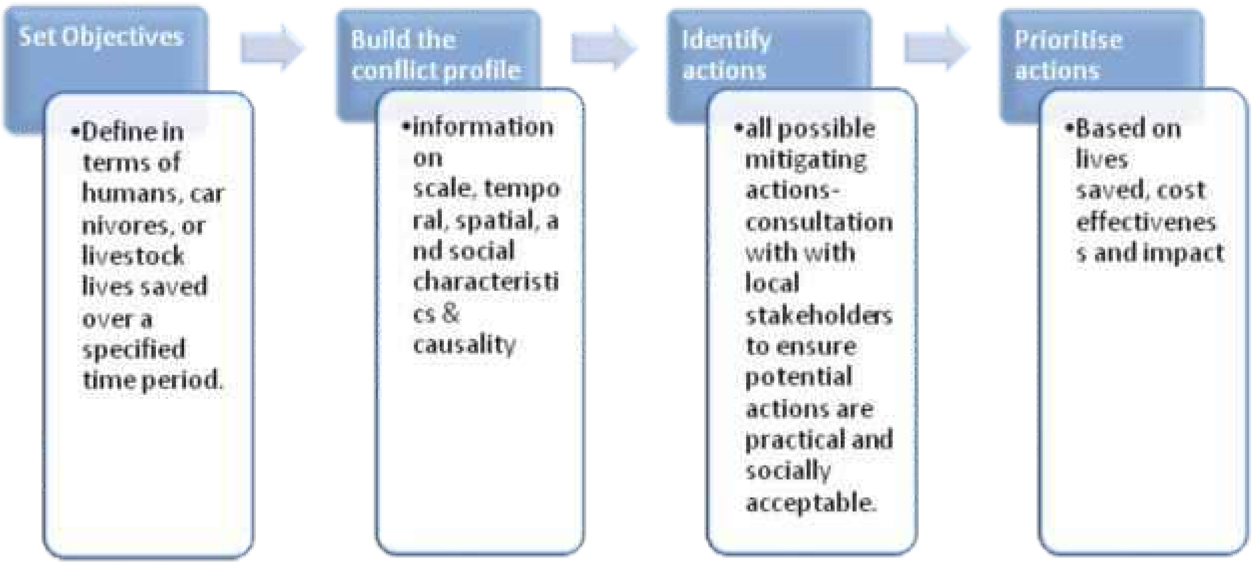
The attacks, however, are mostly accidental as the shark mistakes a person standing or floating in water as its natural prey. The victim of the attack often does not realize that she or he is being bitten although a chunk of flesh or even a limb may get severed. However, the risk of injury from shark attacks is negligible compared to the threats posed by snakes and tigers.

CONFLICT RESOLUTION FRAMEWORK

Decision makers are often forced to opt for instant conflict resolution options and are biased. The bias is often due to lack of data and being unaware of the root causes. The failure of the interventions, discussed in former sections, to reduce human conflict necessitates opting for a framework which sets objectives to rank actions in terms of number of lives, ensuring that selection of an action focuses on reducing the conflict rather than on addressing additional objectives the decision makers may have. Objectives should be specific, measurable, achievable, relevant, and time bound (SMART) (Tucker et al. 2005). The true test of a management framework is its applicability in the Sundarbans landscape.

The present review builds the conflict profiles using the Action-Selection Framework (Barlow et al. 2010) (figure 8) of the three most important fauna inhabiting the supra-littoral forests, intertidal mud flats, and estuaries of the Sundarbans, namely the Royal Bengal Tiger (*Panthera tigris tigris*) and venomous snakes. The profiles contain a general description of the circumstances in which the conflict takes place and specific information on the severity of the conflict and its spatial, temporal, and social characteristics. The severity of the conflict would reveal the relative size of each aspect of the conflict and help the concerned administrative bodies estimate the potential impact and costs of actions (Graham et al. 2005). Spatial information on the conflict would help in focusing actions in areas where they can be most effective. Information on temporal characteristics may help in identifying the seasonal variations and ideal time to implement the actions. Understanding social characteristics would help identify target groups (Barlow et al. 2010). The conflict profile would also highlight the gaps that require further research to identify and prioritize the actions for conflict resolution.

Fig 8: Steps of framework for selecting actions to mitigate human-carnivore conflict (Barlow et. al., 2010)



OUTLOOK

The conflict profiles (tables 8 to 10) prepared in view of the framework proposed (figure 8) is a first step toward the development of a comprehensive, yet structured approach to better understand and manage biodiversity conflict. As a guiding instrument for conflict analysis, it provides a more holistic picture of the actual reasons attributed to the conflict situation and improves our understanding of factors that trigger or worsen conflictive situations. On analyzing the framework, the concerned authorities would be in a better position to make interventions that are ecologically, economically, and socially viable.

The framework, if implemented, would also open the way for a future research program that aims to explore, in detail, relevant factors of the conflict, relations between factors and indicators, and their usefulness as conflict indicators. Exploring the links between factors and indicators of biodiversity conflicts provides fundamental insights and, at the same time, supports the development of management options that aim to influence social, ecological, or economic parameters (White et al. 2010).

Table 8: Profile of human–tiger conflict in the Indian Sundarban

A: Tiger attack in tiger territory (1985-2009).

Item		
Severity	On an average 33 people encounter with tiger each year of which 28 died due to confrontation. Vulnerability rate per 10,000 persons is 0.32 among the people of Gosaba, Hingalganj, Canning II & Basanti Blocks.	- 13677 (6277 Legal entrants & 7400 Illegal entrants) Forest entrants in STR between 1992-2001. -higher chance of human encounters with tigers in the forest
Spatial Characteristics	Some 59 per cent of the tiger attack victims were residents of Gosaba block. Hingalganj (14.96) was the second most vulnerable block followed by Basanti, (9.99%), Hasnabad (3.8%) and Canning II (2.54%), Pathar Pratima (2.54), Kultali (2.03). - Most humans killed by tigers in North-east Sundarbans	- Forest users spread throughout region; Crab collection is higher in eastern Sundarban while fishing is in western part. - Honey collection concentrated is also seen in the North Eastern side.
Temporal Characteristics	-High number of human victims in April & January. -Low numbers of victims in almost all the months of monsoon & post monsoon period.	-Human activity peaks in December and January coinciding with collection of wood and thatching material; -Honey collection mostly carried out in April; -Overall human activity less in monsoon (June–September)
Social characteristics	Majority of fatal victims are fisherman (63.51%), followed by crab collector (16.22%), honey gatherers (13.81%) & woodcutters (5.41%);	- Forest user groups vulnerable to attack when they get onto land; - Honey collectors vulnerable because they spread out in the forest as they search for honey combs

B: Tiger straying into the human habitation (1986-2009)

Item		
Severity	-279 incidents of straying occurred with an average of 12 incidents per year. In 126 cases (45.8 percent), approximately 326 livestock were killed i.e. 2.6 per straying. -During last 20 years (1990- 2009) at least twelve tigers have been reported to be killed by the villagers of Sundarban	-Tiger swim across the rivers or creaks to reach the villages in the fringe zone mainly in darkness. -Sharp increased over the last two decades mainly due to the increased human intervention into the tiger's territories as well as destruction of their habitats.
Spatial Characteristics	-The major affected villages include Samsernagar (29.9 %), Kalitala (9.3 %), Hemnagar in Hingalganj Block, Rajat Jubilee (17.8 %), Jamespur Kalitala (9.3 %), Dayapur Kumirmari in Gosaba Block, Jhorkhali in Basanti Block, Kultali, Sunkijan, Dealbari, Nagenabad in Kultali Block and Sitarampur, Dashpur, K Plot and Keshorimohonpur in Pathar Pratima Block.	-Sundarban tigers cross creeks or rivers between 50 and 150 m in width to enter into the villages in Bagna range (Hingalganj block) but 300- 900 m in width to enter into the villages of Sajnekhali range (Gosaba block) and cross more than km width rivers of Raimongal rivers of Kultali block.
Temporal Characteristics	-Peak season is the winter (Dec-Feb) when 42% tiger straying incidents occurred with January is the top of the list (16.8 per cent). Post monsoon period (Sept-Nov) is the least affected season accounting only 14% of straying. Most incidents occur at night. Only in 3.95 percent in daytime.	-Tiger's movement increases in the winter season as winter months are the peak season for tourists. -Tigers are nocturnal in nature and, therefore, they loss their direction or path during nigh.
Social characteristics	-Straying tigers commonly kill livestock. and tigers in general attack men as they venture into the forest in search of livelihood, the villagers become habitually revengeful to the tigers.	-This attitude is even more intensified by peoples' resentment towards strict enforcement of laws concerning entry into the jungles by the Forest Department.

Table 9 : Profile of snakebite victims in the Indian Sundarban (1993-2005)

Item		
Severity	40 human deaths each year on an average. Vulnerability rate per 10,000 persons is 0.57. Mortality rate per 10,000 persons is 0.54 in four most affected blocks (Gosaba, Basanti, Canning I & Canning II)	Higher probability of human encounters with snakes in & around habitation. Higher mortality is related to lack of good transport as well as poor infrastructure of health centres..
Spatial Characteristics	High incidence in the Patharpratima, Namkhana and Gosaba (>10% of recorded cases) blocks & low in Joynagar, Mathurapur blocks	Loss of snake habitat due to Increased human habitation
Temporal Characteristics	Coincide with monsoon rainfall (71%: July–September). Low incidents during the post- and pre-monsoons (November–March) and recorded peak values during the last phase of the monsoons (August–September).	Cold-blooded animals and hibernate during the winter. On the other hand, forced to come out for search of alternative shelter and food when water starts to flood their resting-places with the onset of the monsoons.
Social characteristics	Most of the fatal snakebite victims (76.12%) received treatment from shamans (locally called *ojhās*) instead of receiving treatments in hospitals	Unavailability of AVS & doctors in the nearby health centre. Superstition and lack of knowledge of poisonous snake.

Table 10 : Profile of Crocodile victims in the Indian Sundarban (1997–2009)

Item		
Severity	103 people were attacked by crocodiles out of this 61 per cent succumbed to death, at an average rate of 5.25 person yr^{-1}. Average yearly vulnerability and mortality rates per 10,000 persons are 0.09 and 0.06 respectively.	Victims are generally of two types—fishermen and tiger prawn seed (*P. Monodon*) collectors
Spatial Characteristics	Dominating in western Sundarban. Gosaba (34%), followed by Patharpratima (25%), Namkhana (18%) and Kultali (15%) blocks.	Collection of tiger prawn seed is the important secondary occupation among female & children. Forest creek or *Khari* with low mud flat is ideal place for crocodile.
Temporal Characteristics	Winter (November–January) is the peak period of attack corresponding to the main fishing season.	crocodile attacks during crab collection and the collection of tiger prawn seed

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