Status of the Mangroves and Mangrove Ecosystem of Sundarbans in West Bengal : Its Impact on Estuarine Wetland Fisheries

Central Inland Fisheries Research Institute
(Indian Council of Agricultural Research)
Barrackpore, Kolkata - 700 120, West Bengal

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Foreword

Mangroves of the Indian Sundarbans are the immensely important, threatened, fragile and vulnerable ecosystems. These ecosystems with their direct and indirect impacts on the human population are in need of a lot of protection and conservation efforts. For undertaking such efforts it is important to have a thorough knowledge about the present status of the Mangroves of Sundarbans. In this regard, the study conducted by the National Fellow, ICAR and the Project Personnel is very timely.

The publication entitled 'Status of the Mangroves and Mangrove Ecosystem of Sundarbans in West Bengal : Its Impact on Estuarine Wetland Fisheries' is a concerted effort to highlight the state of the mangroves in the Indian Sundarbans. It also highlights the ecology of the algal flora of Sundarbans. The microbiological aspects dealing with nutrient release have been dealt with. The edaphic factors and water chemistry has been highlighted and correlated with mangrove abundance in the Mangals. Also highlighted are the fauna of Sundarbans with up to date lists of the mammals, reptiles, amphibians, shell fish and fin fish, birds and threatened, extinct and rare fauna.

I am hopeful that this document will greatly help in formulating guidelines for scientific management of the mangroves of Indian Sundarbans in particular and elsewhere in India in general.

D. Nath
Director, CIFRI

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1.1. Introduction

Mangrove plants and the mangals find immense ecological importance in having unique and efficient roles in maintaining the sustainability of the coastal ecosystem. They are also well known for their potential economic resources, which cater to the needs of the coastal zone inhabiting people of the tropical and sub-tropical countries of the Globe. Mangrove vegetation enrich the adjoining terrestrial and aquatic phases and also protect the shallow sheltered bays and wide beach areas in particular and the total coastal ecosystem at large. This ecosystem provides ideal habitats for good number of economic and important species of estuarine and off-shore fish, shrimps, prawns, crabs and good number of other threatened, rare, endemic but very important species of the aquatic, semi-aquatic, terrestrial and arboreal habitats. Coastal and estuarine mangrove vegetation with its dense growth and wide spreading habitats provide physical support and play protective roles in these fragile zones. Mangrove biomass continuously supplies nutrients to coastal, estuarine and offshore ecosystem, resulting in a healthy environment for estuarine and offshore species of fauna and also contribute towards the productivity. Besides these, mangrove wood has immense value in carpentry works, hut or cottage making and also as fuel wood to the rural people.

These interesting physiognomic status, productive potentials and protective roles of the mangrove ecosystem have naturally attracted the attention of the coastal inhabiting people, scientists, planners, policy makers, nature lovers and conservationists. During the recent past, mangrove research, in all it's facets has assumed significant and relevant status not only in India, but also throughout the world.

Sundarbans, in the coastal West Bengal of India and Bangladesh is well known for having interesting and extensive mangrove flora and mangrove dwelling fauna. Adaptations and successions of these mangrove plants and mangrove dwelling fauna in the delta lands and estuarine mouths of the rivers, Ganga - Brahmaputra is unique and important. These mangrove plants grow in inter-tidal delta lands having higher salinity regimes because of a number of salt contributing factors from the bay, these salts are present in the soil, as well as, water phases. As such, mangrove plants and mangrove dwelling fauna have developed unique saline resistance mechanisms. The Sundarbans mangrove forest area have been included in the list of '*World Heritage Site*' and very recently it has also been considered in the list of '*Ramsar Site*'. Any conservation or restoration programme of this vulnerable ecosystem relates to proper identification and investigations on the biotic components, their ecological status and economic potentialities in a holistic way.

1.2. What are mangroves?

Mangroves are the coastal, inter-tidal vegetation or groups of plants showing tolerance to salinity. These plant species can grow, survive and regenerate within the frequently tidal inundated salt dominated areas in the tropical and sub-tropical zones of the world. The term '*mangrove*' is derived from two Portuguese and English words, *viz.*, '*mangue*' and '*grove*', respectively. A mangrove tree or bush is called '*mangue*' in Portuguese, where as the community of trees and the bushes are known as '*grove*' in English. The words '*Mangrove*' and '*Mangrowe*' were used in the Oxford English Dictionary, since 1613. These terms were also derived from the Haitian Sawara language for the trees and shrubs under the Genus – *Rhizophora* L.. Mangroves may be defined as the '*typical tropical coastal forest formation, encircled or spread over within the tidal rivers and / or the sea water flooded zones or plants bathed frequently during tidal water ingress*'.

Since the middle of 18th century, the wide spread meaning of the term '*mangrove*' referred to the arborescent species that grow in the tidal zones of the tropics; but during the colonial administration of the British in India and in the South - East Asian countries, the term mangrove was much used to define the tidal forests, as well as, the individual plants of the tidal forest and sometimes it meant both the '*mangrove plants*' and the '*mangrove ecosystem*'. Other than these mangroves, few other plants can normally grow in these inter - tidal coastal, estuarine and delta regions. Most of these mangrove species can survive and grow in these saline soil and frequent salt water inundated zones, where other non-halophytic and non-mangrove plants cannot survive or grow due to absence of selective salt screening or salt excretion mechanism. Normally, these plants form aerophores or air-breathing roots, these are known as pneumatophores, blind root suckers, plank roots, root knees and pneumatothods (in *Phoenix paludosa* Roxb.) along with conventional, characteristic taproots, adventitious fiber roots, *etc.* These aerial roots perform effective root zone respiration in this anoxic water logged compact inter-tidal saline soil and also provide mechanical support to these plants. Besides these air breathing roots, supporting stilt roots or prop roots, root buttresses, knee roots, plank roots are the characteristic features of these major mangrove species. Dominant mangrove species mostly have unique viviparous, crypto-viviparous or pseudo - viviparous germination mechanism, by which these plants can get better chance of seedling germination in these inter-tidal silted up saline soil. Mangrove plants have special salt tolerance mechanisms, *i.e.*, *salt-extrusion*, *salt-exclusion* and *salt-accumulation*. By these unique salt tolerance abilities, mangrove species can adapt best in saline habitat, within the inter-tidal zones in coastal areas and estuarine mouths. *Mangroves are in a broad sense the tropical and sub-tropical coastal inter-tidal vegetation and also the ecosystem.* These coastal mangroves and halophytic plants may also supply considerable volume of bio-mass and provide nutrients to these coastal soil and water and enrich the soil and water phases considerably and increase the productivity of these interesting inter-tidal ecosystem. For having these characters mangrove forests are identified as the *'highest productive zone'* in comparison to the other ecosystem in tropical zones of the Globe. Deltas, sheltered bays, inter-tidal coastal areas and muddy estuarine mouths are the ideal habitats for these mangrove plants, where large group of marine and the terrestrial fauna are also abundant. As such, mangrove zones may be considered as *'sea-land interface'* zone. The dominant mangrove zones of the world are spread over in the Old and New World tropics and sub- tropics (Map-1).

1.3. The terms and definitions of the mangroves

Several world reputed mangrove experts and workers have recognised and defined the term '*mangrove*' differently; few of these are as follows:

1. Davies (1910) defined, '*plants which live in muddy loose wet soils in tropical tide water are* mangroves'.
2. Mac Nae (1968) defined, '*trees or bushes growing between the level of high water of spring tide and level close to but above mean sea level are* the mangroves'. Mac Nae (1968) has also referred the term *'mangal'* for the mangrove forest community, while the term '*mangrove*' as individual kind of trees. This inter-tidal flora or plant association and the faunal assemblages are commonly described as '*mangrove ecosystem*'.
3. Aubreville (1970) defined, '*coastal tropical formations, found along the border of the sea and lagoons, reaching up to the edges of the river to the point where the water is saline and grow in swampy soils covered by sea water during high tides are* the mangrove '.
4. Geriech (1973) reported that 'm*angroves are trees of various species under several families, which grow only where they come into permanent contact with sea water*'.
5. UNESCO (1973) defined, ' the *mangroves are the evergreen sclerophyllous, broad leafed trees with aerial roots, like pneumatophores or stilt roots and viviparous germinated seedlings'.*
6. Blasco (1975 & 1977) defined –'*the mangrove is a type of coastal woody vegetation that fringes muddy saline shores and estuaries in tropical and sub-tropical regions*'.
7. Arroyo (1977) defined, 'mangroves are *small group of flowering plants and associated species belonging to systematically unrelated families, possessing similar physiological characteristics and structural adaptations with common preference to the inter-tidal habitat'.* The term 'mangroves' was further used by Arroyo (1977) for the (a) forest ecosystem, (b) the component vegetation and (c) both forest ecosystem and the component vegetation.
8. Clough (1982) defined, 'these are the only trees amongst relatively small group of higher plants that have been remarkably successful in colonizing in the inter-tidal zone at the interface between land and the sea'.
9. Hamilton & Snedaker (1984) defined, 'the mangroves are salt tolerant forest ecosystems of the tropical and sub-tropical inter-tidal regions of the world'.
10. Naskar & Guha Bakshi (1987) defined, 'mangroves are tropical coastal forest formation encircled or spread by the tidal rivers and or sea water, flooded frequently by the tidal water.

1.4. Factors governing the ideal mangrove ecosystem and habitat

The mangroves or the mangals are dependent on the following inter-related environmental and geological factors, *viz.*, edaphic, geomorphologic, geographical, physical and biological;

(a) Edaphic factors – these are the physical, chemical and biological properties of the soil and water that influence the living organisms of the areas;

(b) Geomorphologic factors – these are the factors governing the origin, formation and development of the land in the intertidal zone where successively the living organisms grow and adapt;

(c) Geographical factors – these are the position of the areas and relationship with the ambient water supply, quality of water, nature and properties of soil, water and the climatic factors;

(d) Physical factors - these are nature and properties of the soil, mode of formation of the substratum and also the overall climatic conditions of the environment.

(e) Biological factors – these factors play vital and significant roles in any ecosystem, as each and every individual plant and animal species have intimate linkage, adaptation and relationship with each other.

The typical and best mangrove flora require frequent tidal inundation, typical tropical climate, within the temperature ranges between 20°C and 35°C along with torrential annual rainfall between 150.00 cm to 300.00 cm and coastal aridity, high humidity, silt-clay sediment soil and protected shallow sheltered bays, wide beach areas. The long armed rivers with wide mouths or estuaries are the ideal sites or potential areas for healthy growth of these diverse mangrove flora and also form ideal habitats for large group of mangrove dwelling fauna including most economic species of brackish - water fish, shrimp, prawns and crabs. These mangrove dwelling fauna are chief source of protein for the coastal inhabiting people of the tropical countries of the world and also provide important articles of commerce.

On the contrary, the mangroves cannot tolerate frost with little exception of high frost areas at S. E. Australia at 38°S latitude and 150° E longitude. The humid climate is better for the physiological functions of mangroves than the arid climate. Temperature condition controls the limit of spreading the mangroves; while rainfall determines the sequence of mangrove zones in the tidal region. Among these climatic factors, the atmospheric and water temperature, atmospheric humidity, seasonal monsoon precipitation, wind velocity, solar radiation or day length, average number of rainy days/ annum and the volume of upstream freshwater supply are the other important and dominating factors for better growth and development of the mangroves. It has been observed that the mangroves develop best in the tropical estuaries and occasionally in the sub-tropical wetlands and grows very rarely in the sub-tropical dry zones. Mangrove spread within the latitudes between 32°N and 38°S. The tropical estuaries receive heavy rainfall, which is evenly distributed throughout the year, this is preferable for the effective growth and development of mangroves. Aridity may act as the limiting factor for the effective growth, regeneration and development of mangroves.

Besides these climatic factors, the wide estuarine mouths with year long upstream flow and silted up delta lands or sheltered coastal silt dominated bays or areas in the tropical and sub-tropical zones are the ideal site for the natural growth and regeneration of these mangroves.The world's most dominant mangrove forest and characteristic true mangrove species are present in and around the sheltered shallow bays or coast lines of the Indo-West Pacific regions of the Old World Tropics, between the longitude 30°E-178°E and latitude between 38°45'S-36°N; while, the New World mangroves are restricted within the west coast of Tropical Africa (Eastern Atlantic) and both the East and West coasts of Tropical America (West Atlantic and East Pacific), between the longitude 15°E- 120° W and latitude 25°S - 38°N (Map –1). Clayey sediment soil, protected shallow shelter bays or wide beach areas are also good as mangrove habitats.

1.4.1. Environmental and climatic factors for ideal mangrove habitat

Mangrove ecosystems are restricted in very limited areas or zones for its specific requirement of environmental, physical and climatic conditions. These mangrove plants grow in much stressed condition in physiologically dry soil. As such, they require enough freshwater supply along with moderate temperature of air and water and protected coastal zones or estuarine mouths serve as their most suitable atmosphere. All these specific and desirable environmental and climatic conditions are presented in Tables 1 and 2.

Table - 1. Factors governing the ideal mangrove habitat conditions

Climatic factors for the effective growth of mangroves				
Remarks	**Optimum Growth**	**Minimum Growth**	**Maximum growth**	**Factors**
Well drained silt clay soil of tropics & sub-tropical zones	Silt-clay loamy of the intertidal zone	Sandy/ coralloid and water logged soil	Well-drained soil in the frequent tidal inundated zone	Nature of soil for effective growth of the mangroves
Silt-clay loam soil frequently flooded	Silt-clay loam soil frequently flooded	Sandy and rocky zone	Step by step silt deposited soil	Soil media
Within tropical & sub-tropical zone	Tropical & sub-tropical coast	Beyond tropics	Tropical zones	Position of the area
Periodical & frequent	Moderate inundation	Less inundation	Maximum	Tidal fluctuation
Moderate salinity	Moderate saline soil	High saline zone	Less saline zone	Salinity condition
Availability of good mother plant	Moderately presence of mother plant	Minimum number of mother plant	Presence of good mother plant	Availability of mother plant
Maximum rain water flow	High rain-fall, 200 – 300 cm /yr.	Less and irregular seasonal rain-fall	Maximum rain-fall beyond 120 cm	Nature of rainwater
Maximum supply of rain water	Moderate duration	Short duration	Prolonged duration	Year round water supply
Minimum biotic interference	Minimum biotic interaction	With heavy biotic interaction	Without any human interaction	Other factors, biotic/ human pressure
High rain-fall with high run-off	2000 mm	< 700 mm.	> 3000 mm.	Rainfall (mm/year)
20°C- 35°C is good	35°C	10°C	30°C	Temperature (0°C)
High humidity is good	80	40	95	Humidity (%)
Frost free zone is good	Minimum frost	High frost zone	Frost free zone	Frost
High coastal aridity is good	Moderate aridity	No aridity	High aridity	Other factor/ coastal aridity

Table - 2. Environmental or climatic factors serving as ideal mangrove habitat

Environmental / Climatic Factor	Ideal Condition
Nature of soil for effective growth of the mangroves	Silt-clay loamy of the intertidal zones
Nature of soil media for effective growth of mangroves	Silt-clay loam soil frequently flooded
Position of the area for effective growth of the mangroves	Tropical & sub-tropical coast
Tidal fluctuation for effective growth of the mangroves	Moderate inundation
Salinity condition for effective growth of the mangroves	Moderate saline soil
Availability of mother plant for better growth of mangroves	Moderate presence of mother plant
Nature of rain water for effective growth of mangroves	High rainfall, 200 – 300 cm / yr.
Year round water supply for effective growth of the mangroves	Moderate duration
Biotic/ human pressures for effective growth of the mangroves	Minimum biotic interaction
Rainfall (cm / year) for better growth of mangroves	200 cm /year
Temperature (0°C) for better growth of mangroves	35°C
Humidity (%) for better growth of mangroves	80%
Effect of Frost on growth of mangroves	Minimum frost
Other factor/ coastal aridity for better growth of mangroves	Moderate aridity

1.4.2. Physical and chemical factors for the ideal mangrove habitat

Mangrove species prefer and flourish well in frequent tidal inundated and tidal influenced well-consolidated silt-clay soil; for their effective growth and regeneration the moist land along with well drained perforated soil is ideal for mangrove habitat. Nutrient status of the mangrove habitat soil may be initially less enriched but on well grown mangrove areas the soil become impregnated gradually with the organic matter and enriched with minerals; all these nutrients are received from the marine sources, upland nutrient flow and mangrove bio-mass decomposition.

Table - 3. Ideal soil physical properties in the well grown mangrove habitat at Indian Sundarbans

Nature of Soil	Sand (%)	Silt (%)	Clay (%)	Soil Type
A. Eastern Part of Sundarbans				
South Coast Facing	**50.5** (34.7 - 55.4)	**27.2** (21.7 - 36.6)	**27.6** (4.7 - 42.5)	**Sandy Clay Loam**
Central Estuarine part	**47.1** (15.0 - 80.6)	**29.1** (8.2 - 49.2)	**26.7** (1.5 - 75.7)	**Loam**
Northern Part	**44.4** (35.1 - 58.5)	**28.1** (21.1 33.5)	**25.2** (7.9 - 43.7)	**Loam**
B. Central Part of Sundarbans				
South Coast Facing	**35.0** (28.1 - 43.5)	**25.0** (21.4 - 30.5)	**39.9** (26.0 - 48.8)	**Clay Loam**
Central Estuarine part	**33.8** (25.8 - 61.0)	**22.9** ((0.96 - 33.0)	**34.2** (6.0 - 53.2)	**Clay Loam**
Northern Part	**42.8** (34.8 - 48.1)	**26.6** (22.9 - 30.1)	**30.3** (21.7 - 42.2)	**Clay Loam**
C. Western Part of Sundarbans				
South Coast Facing	**41.4** (38.6 - 44.2)	**24.1** (21.6 - 27.2)	**27.4** (25.8 - 30.6)	**Clay Loam**
Central Estuarine part	**26.4** (22.6 - 30.1)	**40.2** (38.1 - 42.6)	**30.2** (28.4 - 31.6)	**Clay Loam**
Northern Part	**18.1** (16.4 - 20.1)	**60.6** (58.8 - 62.4)	**40.1** (38.6 - 42.4)	**Silty Clay**

1.4.3. Salinity tolerance of the different mangrove plant species

Mangrove species have wide range of salinity tolerance; as such, mangroves grow or rather survive in the frequently tidal inundated saline coastal zones and estuarine mouths. This salinity gradient interact with the overall distribution of different mangrove species in different places. The soil and water salinity in these coastal and estuarine zones may interact with the mangrove species by three different ways, *viz.*,

a) by osmotic inhibition of salt water absorption;
b) by specification effects on nutrition and
c) by causing toxicity.

These mangrove species have specific adaptations and effect of salinity on these different mangroves have been identified as:

(1) *Avicennia* spp., *Aegiceras* sp., *Acanthus* spp., *Aegialitis* sp. have salt glands on leaves, which actively secrete the accumulated salt from the leaf surface;
(2) *Rhizophora* spp. also exclude excess salt from the leaves;
(3) The deciduous species, *viz.*, *Xylocarpus* spp. and *Excoecaria* sp. exclude salt during senescence of the old leaves and by this mechanism excess accumulated salt is excluded out prior to onset of new growing stage or flowering and fruiting time and foliage formation;
(4) The gall like tumors or outgrowth on the trunk bases of *Excoecaria* sp. perform the removal of excess salt through perforated areas of the gall;
(5) High salinity in the habitats may affect the distribution of mangroves and other halophytic species, which also affect the productivity of the zone;
(6) Increase of the environmental salinity considerably retards the growth of the mangroves;
(7) Gross primary productivity of the mangroves increases along with the availability of fresh water ;
(8) The plants growing in high saline environment tend to transpire less water than those growing in less saline condition; growth and height of the plants is more in less saline environment than the higher saline zones;
(9) But, *Avicennia* spp. can grow best in higher saline soils and regular tidal inundated areas than in less saline zone; these species can accumulate Na^+ ion in its leaf tissue ten times higher than K^+ ion;
(10) *Heritiera fomes* can also grow best in slightly saline soils and are found to accumulate more of K^+ ion than Na^+ ion;
(11) The presence of salt gland, viviparous germination and succulent nature of the leaves may control salt resistance of mangroves;
(12) *Lumnitzera racemosa* and *Sonneratia* spp. accumulate extra salt in their salt glands on both sides of the leaves; as such, their leaves are succulent or thick;
(13) The flow of important organic matter from the land to the mangrove environment and the export of organic matter from the mangroves to the sea water are the important roles played by these mangroves; as such, the mangrove forests serve as a link between terrestrial and aquatic ecosystem, as these plants grow in the sea-land interface.

For all these reasons, these mangrove habitat zones are important as grazing grounds or as nursery areas for fish, shrimp and crabs along with other aquatic or coastal fauna.

Generally, the saline water and soil are not utilised or conducive for normal agricultural practices, as such the development and utilisation of these areas for fish farm or as natural fishing harbours can be considered to be economically more viable. Moreover, in the present perspective of heavy population pressure, this can be considered to be an important thrust area and utilisation of these productive zones is definitely more desirable.

Table – 4. Salinity tolerance of different major and minor mangrove species

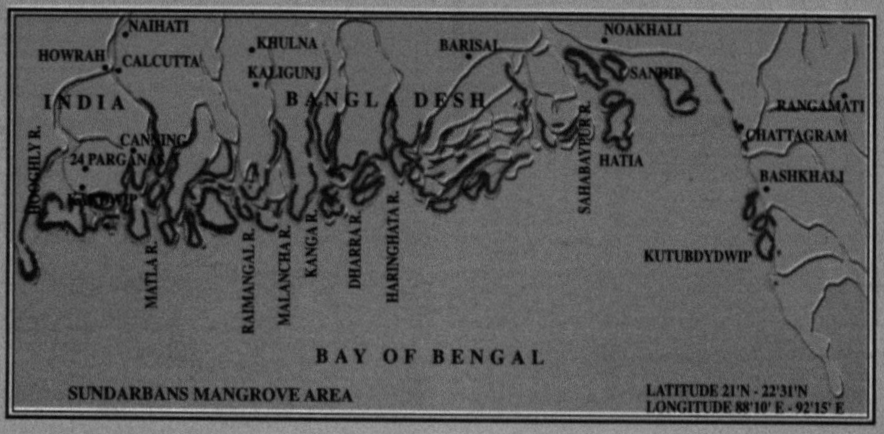
Name of the Family	Name of the Species	Average	Range
1. Rhizophoraceae	1. *Rhizophora mucronata* Lamk.	17.7	7.1 - 28.7
	2. *Rhizophora apiculata* Blume	14.9	9.7 - 21.3
	3. *Bruguiera gymnorhiza* (L.) Lamk.	17.2	11.5 - 30.0
	4. *Bruguiera sexangula* (L.) Poir	26.3	10.4 - 28.4
	5. *Bruguiera cylindrica* (L.) Blume	16.1	9.7 - 25.8
	6. *Bruguiera parviflora* W. & A.	15.9	12.6 - 23.8
	7. *Ceriops tagal* (Perr.) Robin.	16.3	7.2 - 25.4
	8. *Ceriops decandra* (Griff.) Ding Hou	14.6	7.9 - 23.8
	9. *Kandelia candel* (L.) Druce	13.0	7.2 - 18.1
2. Avicenniaceae	10. *Avicennia officinalis* L.	11.5	7.6 - 17.8
	11. *Avicennia alba* Blume	14.1	7.2 - 21.3
	12. *Avicennia marina* (Forsk.) Vierh.	12.8	7.2 - 23.4
3. Sonneratiaceae	13. *Sonneratia apetala* Buch. Ham.	15.4	7.9 - 25.7
	14. *Sonneratia caseolaris* (L.) Engler	9.4	7.8 – 13.4
	15. *Sonneratia griffithii* Kurz.	15.8	7.9 - 25.8
4. Meliaceae	16. *Xylocarpus granatum* Koen.	13.2	7.0 - 18.3
	17. *Xylocarpus mekongensis* Pierre	15.3	7.4 - 20.9
	18. *Aglaia cucullata* (Roxb.) Pellegrin.	12.3	9.8 – 15.6
5. Myrsinaceae	19. *Aegiceras corniculatum* (L.) Blanco	13.0	7.4 - 18.9
6. Aegialitidaceae	20. *Aegialitis rotundifolia* Roxb.	13.1	9.5 - 17.8
7. Arecaceae	21. *Nypa fruticans* (Thunb.) Wurmb.	12.5	9.7 - 17.4
	22. *Phoenix paludosa* Roxb.	15.6	13.4 - 21.3
8. Sterculiaceae	23. *Heritiera fomes* Buch.- Ham.	15.0	9.2 - 20.4
9. Combretaceae	24. *Lumnitzera racemosa* Willd.	16.3	10.8 – 24.4
10. Euphorbiaceae	25. *Exoecaria agallocha* L.	16.9	7.2 – 28.5
11. Rubiaceae	26. *Scyphiphora hydrophyllacea* Gaertn.f.	16.4	9.2 – 22.4
12. Tiliaceae	27. *Brownlowia lanceolata* Kost.	17.2	10.3 – 23.2
13. Acanthaceae	28. *Acanthus ilicifolius* L.	16.8	7.3 – 27.2
	29. *Acanthus volubilis* Wall.	12.4	8.9 – 25.3
14. Fabaceae	30. *Cynometra ramiflora* L.	16.8	12.4 – 25.7
	31. *Derris indica* Bennet	7.2	5.3 - 11.4
	32. *Derris scandens* Benth.	6.4	5.2 – 10.9
	33. *Derris trifoliata* L.	7.8	5.4 – 12.7
	34. *Dalbergia spinosa* Roxb.	6.9	6.8 – 9.3
15. Caesalpiniaceae	35. *Caesalpinia crista* L.	7.4	5.7 – 9.3
	36. *Caesalpinia bonduc* Roxb.	7.7	5.2 – 8.9
16. Asclepiadaceae	37. *Sarcolobus globosus* Wall.	18.3	11.5 – 21.7
	38. *Sarcolobus carinatus* Wall.	14.3	7.4 – 17.6
	39. *Pentatropis capensis* Bull.	8.6	5.7 – 11.3
17. Tamaricaceae	40. *Tamarix dioica* Roxb.	19.6	16.9 – 23.5
	41. *Tamarix gallica* L.	19.7	16.9 – 25.7
18. Verbenaceae	42. *Clerodendrum inerme* Gaertn.	10.8	7.9 – 13.5
	43. *Clerodendrum nerlifolium* var. *macrocarpa* L.	16.8	8.6 – 17.5
19.Chenopodiaceae	44. *Suaeda nudiflora* Roxb.	15.6	12.3 – 18.1
	45. *Suaeda maritima* Dum..	16.2	13.2 – 17.8
	46. *Salicornia brachiata* Roxb.	15.4	13.7 – 18.2
20. Aizoaceae	47. *Sesuvium portulacastrum* Linn.	16.3	14.2 – 17.6
21. Boraginaceae	48. *Heliotrophium curassavicum* L.	19.3	15.3 – 22.8
22. Ruppiaceae	49. *Ruppia maritima* L.	7.8	5.6 – 12.7
23. Araceae	50. *Cryptocoryne ciliata* Fish. ex Wydler	8.9	7.8 – 13.2
24. Amaryllidaceae	51. *Crinum defixum* Ker. Gawlar	7.5	6.4 – 12.4
25. Rutaceae	52. *Atalantia correa* M. Roem.	17.6	15.9 – 20.5
26. Poaceae	53. *Porteresia coarctata* Taka	13.9	11.2 – 14.3
	54. *Myriostachya wightiana* Hk. f.	8.3	7.6 – 11.7
27. Pandanaceae	55. *Pandanus tectorius* Parkin.	14.3	10.7 – 18.3
28. Apocynaceae	56. *Cerbera odollam* Gaertn. Fruct.	9.3	7.2 – 11.3
29. Sapindaceae	57. *Dodonaea viscosa* (L.) Jacq.	12.3	9.2 – 15.4
30. Pteridaceae	58. *Acrostichum aureum* L.	18.4	15.3 – 19.8

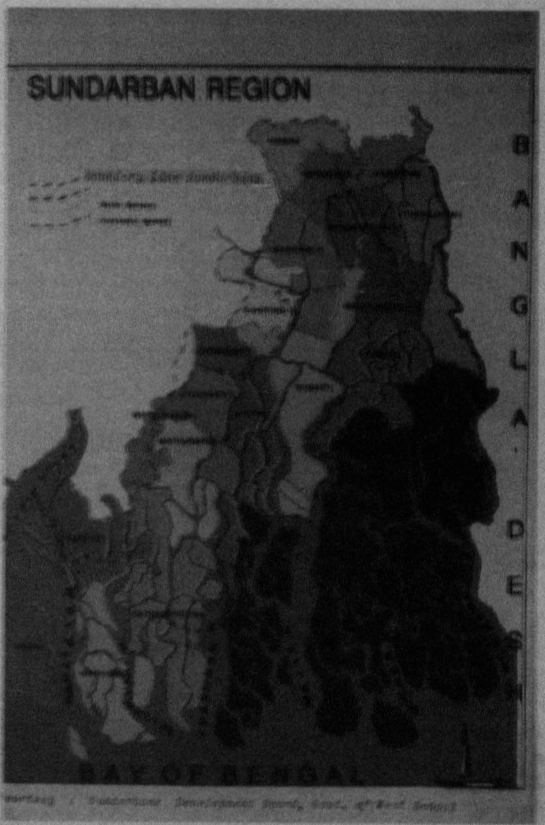
1.5. Productive potentials of the mangrove ecosystem

Mangrove ecosystem is in no way exception to other typical tropical ecosystems. Here in the aquatic system, the basic producer group of organisms are plankton,benthic and periphytic algae and the inter - tidal mangrove plants. The primary consumers are zooplankters, zoobenthos, large group of microbes, molluscs, crabs and crustaceans. These entire micro - fauna graze on alga and the decomposed mangrove detritus. Furthermore, the alga, mangrove detritus, smaller groups of micro - fauna, molluscs and crustaceans act as natural food for the secondary group of consumers; these are particularly the small fish, amphibians, reptiles and others. Predator fish, cat fish, different species of snakes, sharks, dolphins, birds are the secondary and tertiary consumers and the crocodile, *Crocodilus porosus* in the estuarine water of Sundarbans is the top consumer.

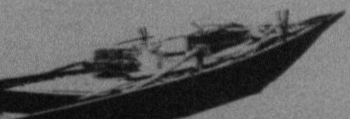
While, in the forest land, the herbivorous deer, wild boar and monkey graze on these mangrove seedlings and tender leaves or grasses (*Porteresia coarctata*); all these herbivorous primary consumer groups are the important food for the secondary, tertiary and top consumers, *viz.*, different species of wild cats, including tiger, *Panthera tigris tigris*. The tiger, *Panthera tigris tigris* of Sundarbans is the top consumer and they practically protect this virgin but vulnerable forests from human interferences, who are responsible for indiscrminate exploitation on one hand and also from wild animals, *viz.*, deer, wild boar, etc. on the other hand who are responsible for destruction of the forests by grazing.

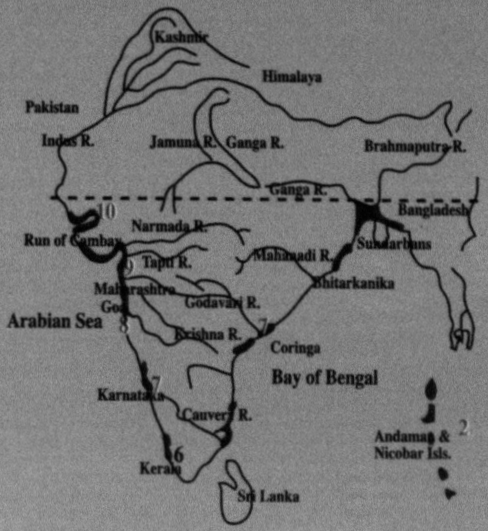
All chlorophyll bearing organisms, *viz.*, phytoplankton, periphyton, benthic algae and other macrophytic forms, *viz.*, the major mangroves, minor mangroves, mangrove associate, other terrestrial forms of green plants and the sea grass in the aquatic food web serve as primary producers, through photosynthesis resulting in the formation of a wide range of organic compounds, depletion of carbon - di - oxide, *vis - a - vis*, oxygenation of the surrounding waters in the estuarine and deltaic regions of Indian Sundarbans. Out of the average sunlight impinging upon the producers about half is absorbed and about 1 to 5 percent is converted into food energy by the productive vegetation. The total assimilation rate of the producers in an ecosystem is designated as primary production or primary productivity. It is the total amount of organic matter fixed, including that used up by plant respiration during the measurement period. Net primary productivity is the organic matter stored in plant tissues in excess of respiration during the period of measurement. Net production represents the potential food material available to the organisms of the next trophic level. The optimum factors for healthy primary production from any area depends on adequate availability of sun light as radiant energy, its optimum transmission and availability of nutrients. As such, Sundarbans is definitely a zone of high primary production due to availability of solar radiation and adequate supply of nutrients from the dense mangrove forest zones.





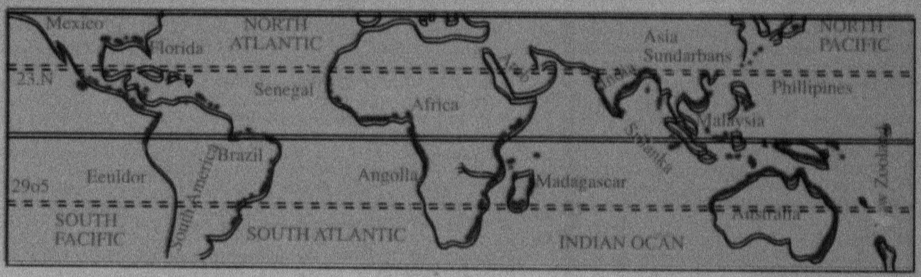
The Indian Sundarbans - showing both reclaimed area and existing mangrove forest area.



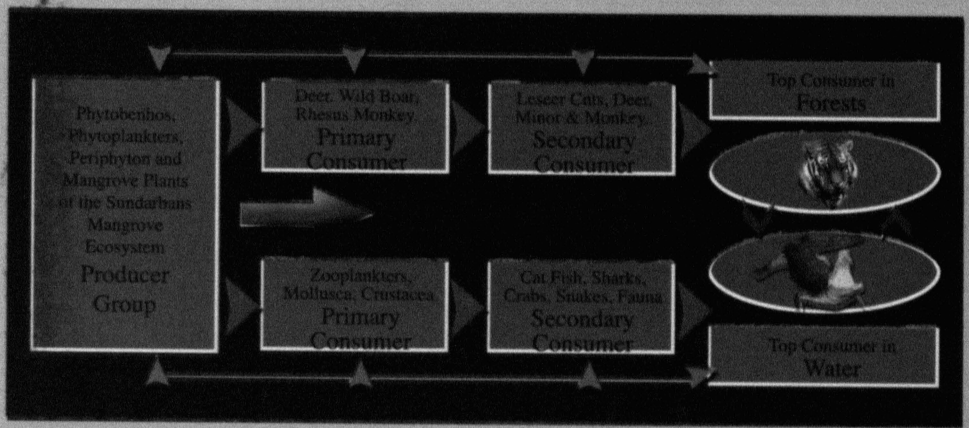


INDIAN SUNDARBANS, WEST-BENGAL

Showing 19 Rural Blocks &
Sundarbans Mangrove Forest



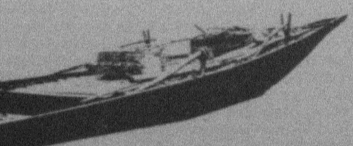
Green Areas show the mangrove areas of the tropical and sub-tropical zones of the World


Phytobenhos, Phytoplankters, Periphyton and Mangrove Plants of the Sundarbans Mangrove Ecosystem
Producer Group
Deer, Wild Boar, Rhesus Monkey,
Primary Consumer
Leseer Cats, Deer, Minor & Monkey,
Secondary Consumer
Top Consumer in Forests
Zooplankters, Mollusca, Crustacea
Primary Consumer
Cat Fish, Sharks, Crabs, Snakes, Fauna
Secondary Consumer
Top Consumer in Water

Succession of mangroves in Sundarbans -
Porteresia coarctata
followed by *Avicennia alba.*

Mature forest of Sundarbans -
Longview of stilt roots of *Rhizopho*
mucronata.

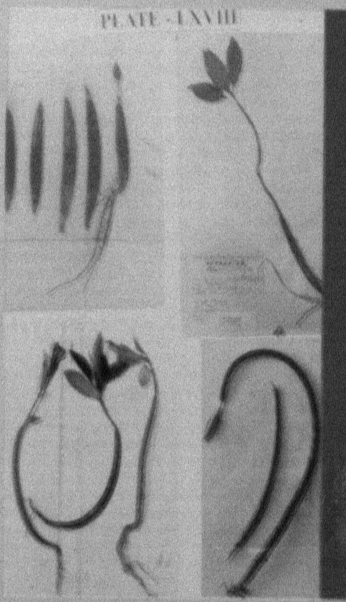
Tidal inundated
forest floo in Sundarbans



izophora apiculata in the Indian Sundarbans.

Viviparous germinated hypocotyl of *Bruguiera gymnorhiza.*

Viviparous germinated hypocotyles of *Rhizophora mucronata.*



Viviparous germination of some true mangrove species.

Scyphiphora hydrophyllacea - reported for the first time during the present studies.

Acanthus volubilis - the rare plant species of Sundarbans.

Sundari - *Heritiera fomes* the common plant of Sundarbans slowly becoming rare.

Aerial root systems of different true mangrove species.

The aerial pneumatophores of *Xylocarpus* sp.

Spreading horizontal roots of *Excoecaria agallocha* check soil erosion.

Mangrove area converted to paddy fields.

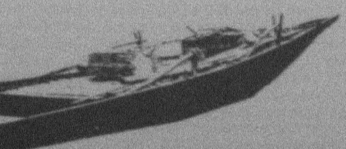
Mangrove reclaimed area converted to brackish water fisheries.

Marginal Fishermen of Sundarbans area.

Poor women exploit mangrove wood for their livelihood.

Prawn seed collection *vis- a -vis* erosion of river dyke.

Reclaimed mangrove areas in degraded condition.



Silted up Matla river being crossed on foot.

Mangrove reclaimed area converted paddy-field, fisheries and brick field Ghushighata in Sundarbans.

Salt crust area of Sundarbans in the denuded zones.

Fishermen fishing in tidal creek of Sundarbans.

Tide receded forest floor dominated b
Excoecaria agallocha.

Coastal zone with *Excoecaria* - forest
and grazing
by different crab species.

1.6. General physiognomy of the total Indian mangrove ecosystem

In the Indian Territory, the mangroves are distributed or present in the inter - tidal coastal areas, estuarine mouths and other frequently tidal inundated zones (Map - 2, Table - 5). Most of these mangrove ecosystems along with the important mangrove plants are very much threatened and in rapid degrading conditions throughout India. As such, the habitat conditions of these mangals need to be protected for the existence of these important and most productive ecosystems in India. The general physiognomy of these common mangrove ecosystems are of the following six major types, *viz.*,

(i) The Estuarine and / or Delta Mangroves, which are abundant on the river mouths of the Ganga (Hugli river), the Mahanadi, the Krishna, the Godavari, the Cauveri, the Mandovi and the Zuary rivers. Mostly, these dominant delta or estuarine mangroves exist in the East Coast of the Indian Territory, except the Mandovi and the Zuary river mouths which are on the West Coast;

(ii) The Island Mangroves of the Andaman & Nicobar Islands are scatteredly distributed on the inter tidal fringe areas of the Bay Islands, which are the second dominant and best mangrove zones in the Indian Territory due to comparitively less human interactions;

(iii) Sea-shore or Coastal Mangroves are present in Karnataka, Goa, Maharashtra and Gujarat States in the West Coast;

(iv) Mangroves of Marshy Back Waters of Kerala coastal areas were dominant previously but now they are scarce;

(v) Mangroves of the Gulfs, *i.e.*, Gulf of Cambay, Gulf of Kachchha are present in the state of Gujarat;

(vi) The Mangroves of the Coral Reef, *i.e.*, Lakshadweep Atolls and Mangroves of the Arabian Sea are scatteredly distibuted.

Among these, the estuarine mouths and delta zones of the East Coast of India have about 70% of the total Indian mangals. The Indian Sundarbans comprise of about 66% of the total Indian mangroves, presently covering an area of 4,267 km² and about 90% of the total Indian mangrove species have been collected, identified and reported from this lower Ganga delta of Indian Sundarbans. About 18% mangrove areas (1,152 km²) and 90% mangrove species are distributed in the Andaman and Nicobar Islands. But, most of these Indian mangrove ecosystems are in very much degraded and threatened condition, due to anthropogenic pressure. The mangrove areas of India (percentage) are highlighted in Pie Chart - 1.

Two centuries back, forest and river areas in this undivided Sundarbans of present day's India and Bangladesh was more than 20,000 km² and restricted within the latitudes 21°N and 22°31'N and longitude 88°10'E and 92°15'E. This extended from the mouth of the Hugli River to the Chittagong coast, which covered four coastal districts of Bangladesh and two coastal districts of West Bengal. Most of these mangrove forest areas were reclaimed for human settlement, renovation of agricultural fields, fish culture farms and salt pans and also for the development of ports or harbours. Within the last two centuries, this mangrove forest zone including its surrounding rivers was reduced to half, *i.e.*, to about 10,000 km²; and behind it remained the mangrove reclaimed areas (Map - 3). After the partition of Bengal more than 66% of the total mangrove areas of Sundarbans had fallen within the jurisdiction of Bangladesh and only 34% mangrove forest of Sundarbans remained within India, between the latitude 21°31'N and 22°30'N, and longitude between 88°10'E and 89°51'E. Till date, the total area of Sundarbans in India is only 9,630 km²; out of these the mangrove forest area including six major estuarine rivers, other rivers, creeks and canals is about 4,266.7 km². During the last two centuries, more than 50% of these mangrove areas in Indian Sundarbans alone have been reclaimed for other land use purposes. All these reclaimed human habitat areas of the Indian Sundarbans is now under 19 rural blocks; 13 blocks under South 24 Parganas and 6 blocks under North 24 Parganas (Map - 4, Table – 6).

Table – 5. Total Indian Mangrove Areas in the Eleven Maritime States of India

(Based on the Government of India Publication: Anonymous, 1987)

	Indian Mangrove Zones and Mangrove Areas	Areas (Sq. Km.)	Nature of the Mangrove Areas	Salient Features
1	Sundarbans in West Bengal	4267*	Estuarine or Delta mangroves	Most Threatened
2	Andaman & Nicobar Islands of the Bay of Bengal	1152	Island mangroves	Less Disturbed
3	Mahanadi Delta and Bhitarkanika in Orissa	120	Estuarine or Delta mangroves	Scattered
4	Krishna and Godavari Delta – the Coringa Mangroves of Andhra Pradesh	184	Estuarine or Delta mangroves	Most Disturbed
5	Cauvery Delta – Pichavaram, Muthupet and Chhatram in Tamil Nadu	26	Estuarine or Delta mangroves	Most Disturbed
6	Coastal Kerala and Cochin Estuary	Negligible	Backwater mangroves	Most Disturbed
7	Coondapur and other mangroves of Karnataka	60	Coastal mangroves	Most Disturbed
8	Mandovi, Zuary and minor mangroves of Goa	20	Estuarine or Delta mangroves	Most Disturbed
9	Ratnagiri and coastal mangroves of Maharashtra	330	Coastal mangroves	Most Disturbed
10	Gulf of Cambay, Gulf of Kachchh and other mangroves of Gujarat	260	Gulf mangroves	Most Disturbed
11	Lakshadeep and Minicoy Attols in the Arabian Sea	Negligible	Coral Reef mangroves	Narrow Fringes
	Total Indian Mangrove Area	**6419**		

** Based on Naskar & Guha Bakshi (1987) and Naskar & Mandal (1999).*

Table - 6. Mangrove Areas in the Indian Sundarbans Biosphere Reserve

Identity of the Geographical Area	Covered Area
Total area under the Sundarbans Biosphere Reserve, West Bengal	**9,630.0 sq. km.**
Sundarbans Mangrove Ecosystem, Lower Ganga Delta, India	4,266.6 sq. km.
Total Forest Land in Indian Sundarbans (55% of total)	2,347.0 sq. km.
Total Water area in Indian Sundarbans (45% of total)	1,920.0 sq. km.
Sundarbans Tiger Reserve area in India	2,585.1 sq. km.
Buffer Area (Zone) within S. T. R.	1,225.0 sq. km.
Core Area	1,330.12 sq. km.
Primitive Area	124.40 sq. km.
Mangrove Forest Area outside the S. T. R.	1,681.5 sq. km.
Mangrove Reclaimed Human Habitat Zones at S & N 24 Parganas	5,363.8 sq. km.

1.6.1. Importance of mangroves in estuarine, coastal and off-shore areas of Indian Sundarbans

1. Mangrove plant species and the particular ecosystem protect the coastal and offshore areas from frequent tidal thrusts, surges, cyclones and other natural calamities.

2. Many mangrove plant species have several economic importance, *e.g.*, *Xylocarpus granatum*, *Xylocarpus mekongensis*, *Heritieria fomes*, *etc.* are the major timber yielding tree species. *Ceriops decandra*, *Ceriops tagal*, *Rhizophora mucronata*, *etc.* contain high percentage of tannin besides their use as hard, durable, minor wood and /or timber. Nector of *Aegiceras corniculatum* and other mangrove flowers are the major sources of honey. Besides these, bark of *Bruguiera gymnorhiza* is useful in diarrhoea, bark of *Rhizophora mucronata* is said to be useful in haemorrhage and diabetes; seeds of *Heritiera fomes* and *Xylocarpus* spp. are also useful in relief from diarrhoea. Paste of the rhizome of *Acrostichum aureum* is useful in the treatment of boils; leaf paste of *Premna corymbosa*, a back mangrove species is also useful for the remedy of piles, tumor and skin diseases, while *Cerbera odollum* is said to be used in hydrophobia. The in-depth inventory on medicinal values of different mangrove species need to be assessed critically (Naskar & Mandal, 1999).

3. Mangrove plant species are the major source of food (in the form of organic nutrients) in the detritus as well as, grazing food chain operating in the coastal and offshore ecosystems.

4. Coastal and offshore ecosystem act as sink for the sewage pollutants discharged from the industrial belt of Kolkata Metropolis. Mangrove plant species are known to prevent water pollution to some extent by it's chelating action.

5. Decline of the major plant species, *viz.*, *Heritiera fomes* and *Nypa fruticans* act as an indicator of the threatened condition of this ecosystem; decrease in the number and distribution of these above said two species indicate the increase of salinity of the coastal and off-shore ecosystem.

6. Tidal influenced forest area is the subject to simultaneous rise and fall of the water level during the tidal current. This cause maximum amount of soil erosion, which is identified as a major problem in this ecosystem. When mangrove plants occupy the river bank area erosion may be prevented. The species, *Porteresia coarctata* protect the newly silted up soil from erosion; *Excoecaria agallocha* prevent soil erosion in much consolidated soil and *Ipomoea pes-caprae* act as sand binders in the coastal above tidal sandy areas.

7. Mangrove community or mangrove complex are the nursery of most economic fin-fish and shell-fish species of the coastal and offshore ecosystem.

8. Being the ecotonal region, coastal and offshore ecosystem is dominated with very interesting types of diversified plant and animal species, which makes this ecosystem very rich in bio - diversity.

Flow Chart – 1. Roles played by the mangrove flora and mangrove inhabiting fauna

Mangroves Serve	***Coastal Stability** ***Raised Productivity** ***Aesthetic Values** ***Maintenance of Bio-diversity** ***Habitat for Variety of Flora & Fauna** ***Check Adverse Climatic Conditions** ***Protect the Coastal Areas from Calamities**	**Future Sustainability of the Ecosystem**

1.6.2. Protective roles played by these mangroves and mangrove ecosystem of Sundarbans

The coastal, estuarine or delta areas are very much fragile and prone to several severe natural calamities, particularly in the Sundarbans. During cyclones and storms, the sea or river water rises up far beyond its normal reach and the wind force hits the surrounding and neighboring areas. During these times of natural calamities, large scale damage to the coastal areas or the estuarine mouths have been noted or reported throughout the globe. Since the year 1582, there are records of about 90 such devastating natural calamities from the coastal areas of Bengal in general and Sundarbans in particular. These natural calamities have damaged enormous lives and property in Sundarbans. As such, prior to undertaking any developmental activities in these cyclone prone areas, proper planning with regards to Environmental Impact Assessment (EIA) require to be undertaken carefully before planning any construction works or clearing the natural mangrove habitats for such purposes.

This lower Ganga delta land was silted up or accreted by gradual silt deposition on the sea board and still these delta formation activities are in progress, this renders the ecosystem very much prone to natural calamities. These delta areas and the estuarine mouths are low-lying tidal inundated zones and the ground layer was built up with fine grained silt, clay and fine sand particles. The funnel shaped Bay has to face cyclone and tidal thrust very frequently. As such, several severe problems have prevailed in these areas due to natural calamities. Few of such natural calamities are mentioned in Table – 7; these natural calamities are one of the main causes of suffering of the rural people inhabiting these coastal areas. During the last 100 years 44 such natural calamities or severe cyclones were recorded from this Lower Ganga Delta Region alone.

In an estimate it was observed that during the last four centuries more than ninety severe cyclones, sea surges, earth quakes were responsible for partially or fully destroying these coastal zones of Sundarbans. Among these, most severe cyclones/ storms were reported during the year 1737, at the rate of 250 km/ hour wind speed, tidal thrust or surges at the height of about 41 ft. along with the severe earth quake; all these incidents completely destroyed the entire human habitats in Sundarbans and the mangrove forests, as well. Furthermore, during the recent past on 29th November 1988, the reported cyclone/ wind speed was at the rate of 250 km/hour. Fosberg (1971) had observed, 'the situation of the Ganga delta, at the head of the funnel shaped Bay of Bengal poses perhaps the most serious threat from the surges, driven by storm waves....'.

In the year 1688, a huge surge in the Bay of Bengal took a toll of more than 60 thousand in the Sagar Island of Sundarbans alone; again in the year 1707, the cyclone and storm devastated the entire Sundarbans. In the year, 1833, hurricanes and cyclones forced to cease all the developmental works in the Sundarbans; the cyclones in 1884 took 4,137 lives from the Sagar Island alone. During the year 1867, cyclones damaged the entire Sundarbans from Sagar Island to the Pabna district of the Bangladesh. The earthquake of 1895 also adversely affected a lot in the Sundarbans. In the year 1942, there was a terrible and devastating hurricane over the Sundarbans, due to which several houses, cottages, cattles and lives collapsed. During the recent time, most disastrous one in the history of this region probably occurred on 13th November, 1970, which took a toll of several thousands from the Sundarbans. Again devastation occurred during 1973; on 10th and 11th December of 1981, during 1991 and few others.

Several signs of human settlements are still noticed inside the Sundarbans mangrove forests, which may have been destroyed during early times due to these severe natural calamities. During the recent times, on the last week of October, 1999 the super cyclones and tidal thrusts devastated the entire Orissa coast at Paradip, Jagatsinghapur and Erasama and part of the Midnapore districts. After the Super Cyclone on the Orissa coast, scientists and other experienced experts from the country and abroad again had pointed out that if the natural mangrove forest on the Orissa coast had existed like the earlier times, the effect of this Super Cyclone could have been minimised.

Table - 7. Severe natural calamities, *viz.*, cyclones, floods, earth quakes recorded from Sundarbans

Year	Means of Natural Calamities	Year	Means of Natural Calamities	Year	Means of Natural Calamities
1582	One severe cyclone	1883	Three severe cyclones	1936	One severe cyclone
1688	One severe cyclone	1884	One severe cyclone	1937	One severe cyclone
1707	One severe cyclone	1885	Flood	1940	One severe cyclone
1737	Cyclone & earth quake	1887	Two severe cyclones	1941	One severe cyclone
1742	One severe cyclone	1888	Three severe cyclones	1942	One severe hurricane
1762	Earth quake	1889	Two severe cyclones	1943	One severe cyclone
1823	Flood	1890	Severe flood	1945	One severe cyclone
1830	One severe cyclone	1893	Two severe cyclones	1946	One severe cyclone
1832	Three severe cyclones	1894	One severe cyclone	1948	One severe cyclone
1833	One severe cyclone	1895	Earth quake	1950	One severe cyclone
1834	Once flood	1896	Five severe cyclones	1952	One severe cyclone
1839	One severe cyclone	1897	Earth quake	1956	One severe cyclone
1840	One severe cyclone	1898	Four severe cyclones	1960	One severe cyclone
1842	Once earth quake	1899	One severe cyclone	1961	One severe cyclone
1844	One severe cyclone	1900	One severe cyclone & flood	1962	One severe cyclone
1848	One severe cyclone	1901	Four severe cyclones	1965	One severe cyclone
1850	One severe cyclone	1904	Two severe cyclones	1966	One severe flood
1852	One severe cyclone	1907	Two severe cyclones	1968	One severe cyclone
1856	Severe flood	1909	One severe cyclone	1970	One severe cyclone
1858	One severe cyclone	1912	One severe cyclone	1973	One cyclone & flood
1859	Two severe cyclones	1913	Two severe cyclones	1976	Severe flood
1862	One severe cyclone	1916	Two severe cyclones	1978	Severe flood
1864	Severe cyclone & flood	1917	Two severe cyclones	1981	One severe cyclone
1867	One severe cyclone	1919	One severe cyclone	1982	One severe cyclone
1868	Severe flood	1920	One severe cyclone	1985	One severe cyclone
1869	Severe flood	1922	One severe cyclone	1988	One severe cyclone
1871	Severe flood	1927	One severe cyclone	1991	One severe cyclone
1877	Three severe cyclones	1928	Severe cyclone	1994	One severe cyclone
1878	One severe cyclone	1932	One severe cyclone	1997	Two severe cyclones
1880	One severe cyclone	1934	One severe cyclone	1999	One severe cyclone
1882	Two severe cyclones	1935	One severe cyclone	2001	One severe cyclone

1.7. Sundarbans Tiger Reserve in West Bengal : it's area and bio-diversity

General Information :

India's globally renowned conservation scheme Project Tiger was initiated on 23.12.1973 and thus Sundarbans also has the distinction of being one of the largest Tiger Reserves amongst the initially declared 9 Tiger Reserves in India. Presently, Sundarbans is one of the most important Tiger Reserves within India's nation wide network of 27 Tiger Reserves. Sundarbans Tiger Reserve is situated in the coastal districts of West Bengal, *viz.*, 24 - Parganas (South) and 24 - Parganas (North) covering the southern most extremity of the lower Ganga delta bordering the Bay of Bengal. The Sundarbans can best be described as a tangled region of estuaries, rivers, canals and creeks enclosing a vast number of islands of various shapes and sizes. The Sundarbans Tiger Reserve is bounded within 21° 32' N to 22° 40' N latitudes and 88° 05' E to 89° 10' E longitudes. This littoral forest under the Project Tiger covers an area of 2,585.10 sq. km and is an unique ecological habitat of the tiger not only in India but also in the world except Bangladesh which is a continuous tract of the Indian Sundarbans (Table - 6).

The 'Tiger Reserve Project' initiated in 1973 is functioning towards biotic conservation in the area (Map - 5). Within the 2,585.10 sq. km., Tiger Reserve area, about 1,330.10 sq. km tidal mangrove forest is demarcated as 'Core Area' and declared as 'National Park' since 1984, which is under strict management practices and kept free from all types of human interference. An area of 124.40 sq. km. within the Core Area is preserved as Primitive Zone (Chamta forest block of STR) to act as gene pool. About 1,255 sq. km of this mangrove forest area serves as the buffer zone, where limited forestry and fishing activities are permitted with prior permission of the Forest Department. Inception of the Tiger Reserve Project in the Sundarbans is an effort towards protection of the Royal Bengal Tiger. Within this area is located the Wild Life Sanctuary at Sajnekhali, conserved within an area of 362.33 sq. km., a subsidiary wilderness zone comprising of 241.06 sq. km. and the rest 651.77 sq. km. is the multiple use zone for regulated harvest of resources for meeting local needs. In this Sundarbans Tiger Reserve there are 15 forest blocks and under these forest blocks there are 71 compartments; all these forest blocks and compartments are silt and clay accreted small to medium islands encircled by narrow to wide tidal rivers, impregnated with saline sea water. The land area of the STR in India remain within an average altitude of 5.8m - 6.1m above MSL; within this STR area the average annual rainfall was recorded within 160 cm and 192 cm and temperature fluctuated within 22° C and 34° C. This mangrove forest area is unique for having natural and dense mangroves and mangrove associated plants spread over on the island sides and vast groups of wild animals including land dwelling tigers, deer, wild boar and the water inhabiting crocodiles, water monitors, snakes, sharks, dolphins and about 200 species of fin-fish and several shell - fish and other fauna are recorded from Sundarbans.

Considering the importance of this region the National Park area of Sundarbans Tiger Reserve has been included in the list of World Natural Heritage Sites in 1985. Since 1989, the entire Sundarbans (total area = 9,630 sq. km) has been declared as '*Man.& Biosphere Reserve*' and was taken under the Sundarbans Biosphere Reserve Project. The broad objectives of this project include -

(1) Conservation of its ecosystem and the genetic diversities,
(2) Promotion of basic and applied research works and its monitoring and
(3) Dissemination of the experiences for education and training.

The Sundarbans Tiger Reserve is bounded in the east by the international boundary with Bangladesh formed by the rivers Harinbhanga, Raimangal and Kalindi. On the south lies the Bay of Bengal. The western border is along the Matla river forming the boundary with the territorial Forest Division of 24 - Parganas and north west is bounded by river Bidya, Gomdi, Kapura, Korankhali, Raimangal, Kamalakhali and Kalindi. The core area is bounded in the east by river Harinbhanga, the west by the river Matla, the south by Bay of Bengal and the north by the buffer zone and Sajnekhali Wildlife Sanctuary.

Ecological units of mangrove vegetation

1. The eastern patch lying east of river Harinbhanga where sweet water flow is plenty in Bangladesh.
2. The western patch lying west of river Thakuran where a trickle of sweet water reaches from the river Hugli in 24 Parganas Division.
3. The central true mangrove patch which is practically completely cut off from upstream flow and is fed by backwaters of Bay of Bengal lying between rivers Harinbhanga and Thakuran mostly in the Sundarbans Tiger Reserve.

Main Flora

There are about 80 plant species in Sundarbans Tiger Reserve with the capacity to withstand estuarine conditions and saline inundation as a result of tidal effects. All these plant species are important for having their unique succession pattern in this saline hostile environment. For this unique saline dominant /salt dominant habitat and continuous tidal action adaptation of these mangroves and mangrove associated or back mangrove plant species are not only interesting but unique and also provide unique habitat for vast group of fauna both in the aquatic and the terrestrial ecosystem. Besides these, the mangrove forest biomass enrich the deltaic soil and estuarine water along with organic matter and turn these entire forest area nutrient rich for dense growth of mangroves and associated plants.

Main Fauna

Tiger, Fishing Cat, Spotted Deer, Wild Boar, Gangetic Dolphin, Water Monitor, Estuarine Crocodile, River Terrapin (*Batagur baska*), Olive Ridley Turtle, Green Turtle, Hawks Bill Turtle, Poisonous and non-poisonous snakes, King Crab (Horse shoe), more than 200 species of Birds, more than 200 species of both Fin fish and Shell fish species, *etc* are the common inhabitants and adapt in the hostile ecosystem and water ways. The Sundarbans mangrove forest and mangrove surrounding water areas are also unique habitats for vast groups of both macro and micro fauna; all these flora and fauna depend on each other for their food, shelter, grazing and breeding place or nursery. The fauna on the other hand protect the forest areas from several other biotic and abiotic factors.

1.7.1. Eco-Tourism and Infrastructure facilities

Tourism in Sundarbans is principally nature - based but also attracts tourists by its rich tradition and culture which is intertwined with the forest practices of the local people. Tourism elsewhere has had its toll on the local resources, natural environment and social values of the locals but the situation is not so severe in the Sundarbans. The basic problems created by prevailing tourism practices in the Sundarbans include environmental degradation due to the left - over of the visitors and picnickers in the forest and water areas in the form of plastics and non degradable articles; sound pollution created by blaring microphones used by the tourists on the forest fringes; use of blinking decorative lights disturbs the movement of nocturnal animals. Eco-tourism is being perceived as a ray of hope. This can provide a revenue stream that can help offset the cost of conservation, and turn a pristine natural environment into a sustainable commercial resource. An enlightened nature tourist can be looked up to as an aide in the cause of bio-diversity conservation. Regulated and well-managed tourism in the form of nature education tours helps the tourists to appreciate the need of conservation and preserving wilderness values.

Keeping in mind these values, the steps undertaken by the National Fellow Project were to initiate eco-tourism with students, teachers, interested visitors and stakeholders who matter the most for the well being and conservation of this ecosystem. As such, regular visits of such groups were encouraged and also undertaken, specially in the Mangrove Ecological Park developed by the National Fellow Project personnel and Calcutta Wildlife Society. The attempt of developing such a Park in the heart of Sundarbans has been highly acclaimed from various sectors.

1.7.2. Tiger Population Estimation (Census) in the Sundarbans Tiger Reserve

The Census in Sundarbans is conducted biennially and the technique used is the Pug Mark Counting which was first developed by Chaudhari (1970 & 1971) and applied for counting tigers in the State of Orissa at Simplipal Tiger Reserve in 1969. Later the first all India Tiger Census was carried out in 1972, which used this technique and named it 'Co-operation Census'. This involved large number of people of the Forest Department, Scientists and also local people. This methodology is based on recording several distinguishable morphological features of tiger's foot prints or pug marks because studies have shown that each tiger has an unique pug mark which makes it possible to distinguish individual tigers in the forests.

The principle requirement of the Census is the detection and record of tiger pug marks. Great care is taken to select a representative pugmark, so that the best plaster cast can be obtained from it. In case of Sundarbans Plaster of paris is used for conducting Census operation. There are a lot of difficulties and situations in the Sundarbans Tiger Reserve area which render a lot of aberrations in ultimate results. Casts are three dimensional, made under varied soil depth situations and so they are much difficult to use for precise comparison and analysis. Forest situations of Sundarbans create serious problems related to soil conditions. Muddy surfaces and deep fine soil are common and easily detectable but have to be avoided. Best prints are obtained in Sundarbans on comparatively hard soil with even surface and which has a film of moist fine soil about 5 mm thick or a compact fine sandy surface near the sea shore. Abberral figures are also obtained due to the natural slopes on the mud flats. Determination of pugmark print age is very subjective so it is better not to be judgemental. Obliteration on the edges of pugmarks due to wind in the coastal areas is fairly common.

1.8. Evaluation of bio-diversity of the mangroves in Indian Sundarbans

Sundarbans mangrove forest and ecosystem have the uniqueness for having good number of mangrove plant species, mangrove inhabitant fauna including world renowned 'Royal Bengal Tiger', *Panthera tigris tigris*. This area was also potential for having large group of fish species, prawns, crabs and with unique tropical climate for good production of agricultural crops, *etc.*

Table - 10. Biodiversity weealth of the Indian Sundarbans Mangals

Group/ Class of Organisms	Order/ Class/Family	Reported/	Reported by
1. Higher Plants	Major Mangrove Species	40	Source : Naskar, K. R. & R. N. Mandal (1999).Ecology & Biodiversity of Indian Mangroves, Delhi., 755.
	Minor Mangrove Species	32	
	Back Mangrove & Associates	30	
	Mangrove Habitat Fern	3	
Total Number of Macrophytes in Sundarbans Mangals =		105	
1. Lower Group of Plants	Algae	150	Source : Sen, Neera & K.R.Naskar (2000). Algal Flora of Sunderbans Mangals, Delhi-
	Fungus	Not assessed	
	Lichen	32	
			Santra, S.C., *et al.* (1999).
1. Higher Group of Fauna/Animal	Phylum -1.Chordata	445	Source :
II.Kingdom-ANIMALIA	Class- Chondrichthyes	22	1.Das, A.K. & N.C.Nandi (1999). *In*: Sundarbans Mangal. (Edt. D.N. Guha Bakshi, P. Sanyal & K.R. Naskar) pp.. 417-427.
	Class- Osteichthyes	154	
	Class- Amphibia	8	
	Class- Reptilia	58	
	Class- Aves	163	
	Class- Mammalia	40	----Based on other Publications--
2. Lower Group of Fauna	Phylum-		Source :
I. Kingdom- PROSTISTA	1.Sarcomastigophora	45	1.Das, A.K. & N.C.Nandi (1999). *In*: Sundarbans Mangal. (Edt. D.N. Guha Bakshi, P. Sanyal & K.R. Naskar) pp.. 417-427.
Subkingdom - PROTOZOA	2.Apicomplexa	24	
	3.Myxozoa	4	
	4.Ciliophora	31	
II.Kingdom –ANIMALIA	Phylum-		
	1.Porifera	1	2.Mukherjee, A.K. (1975). Bombay nat. Hist. Soc. 73 : 2- 20
	2.Cnidaria	33	
	Class- Hydrozoa	20	
	Class- Anthozoa	13	3.Mandal, A.K.& N.C. Nandi (1969). Fauana of Conservation Area. ZSI, 3: 9-116.
	3.Ctenophora	2	
	4.Platyhelminthes	41	
	Class- Turbellaria	1	
	Class-Monogenea	21	4.Nandi, et. al.(1993). Rec. Z.S.I.93: 83-101.
	Class-Trematoda	13	
	Class-Cestoda	6	
	5. Namatheminthes	68	5.Chaudhuri, A.B. & A. Chaudhury (1994).Sundarbans, Part - 1. IUCN. 1-247.
	6. Acanthocephala	3	
	7. Nemertinea	2	
	8. Rotifera	4	
	9. Mollusca	143	6.Anon (1998). West Bengal Estuarine Ecosystem Series, ZSI. Part-2: 1 - 542.
	10. Sipuncula	2	
	11. Echiura	3	
	12. Annelida	78	
	Class - Polychaeya	69	
	Class - Oligochaeta	6	
	Class - Hirudinea	3	
	13. Arthropoda	476	
	Class - Crustacea	240	
	Class - Insecta	201	
	Class - Arachnida	33	
	Class - Merostomata	2	
	14. Entoprocta	1	
	15. Bryozoa	3	
	16. Brachiopoda	1	
	17. Chaetognatha	4	
	18. Echinodermata	20	
	19. Hemichordata	1	
Total Fauna / Animal Species Reported from Indian Sundarbans		1434	

1.8.1. The Mangrove Plant Species in the Indian Sundarbans

The naturally growing higher groups of plants reported till date in the Indian Sundarbans mangals are about 140 species (Table - 9), including trees, shrubs and herbs. The published report of 110 species includes about 25 species of true mangroves (Ghosh,*et al*, 2003). Most of these plants are endemic in this inter-tidal high saline deltaic areas, for having their special adaptation in these physiologically dry soil. Besides these, about 40 number of mangrove associates and back mangrove species are also present in Sundarbans mangals. All these collected and identified mangroves plants and the mangrove associates are mentioned in the book Naskar & Mandal (1999) and highlighted in the recent publication Naskar (2004).

The major and minor mangroves or the true mangrove plants of the Indian Sundarbans are about 41 species under 16 families and 26 genera. These true mangrove plant families are Rhizophoraceae, Avicenniaceae, Sonneratiaceae, Meliaceae, Myrsinaceae, Aegialitidaceae, Sterculiaceae, Combretaceae, Rubiaceae, Tiliaceae, Arecaceae, Euphorbiaceae, Asclepiadaceae, Acanthaceae, Papilionaceae and Rutaceae. Apart from these, 1,100 non mangrove flowering plants under 154 families were collected and reported from mangrove reclaimed areas of Indian Sundarbans by Naskar (1981 & 1993). Ten very dominant and distinct families are - Fabaceae, Poaceae, Asteraceae, Cyperaceae, Euphorbiaceae, Malvaceae, Acanthaceae, Rubiaceae, Convolvulaceae and Scrophulariaceae.

The major form of vegetation, which imparts richness to the bio-diversity of Sundarbans, is the mangroves. Although there exist relatively few species, which can be designated as true mangroves or major and minor components of the mangroves; these mangrove ecosystems are nevertheless unique because they include structural niches and refuge for numerous non-mangrove species. Plant diversity in the Indian Sundarbans refers to diversity in the form of mangroves, mangrove associates, back mangroves, coastal flora, beach flora, swamp and marsh inhabiting flora, *etc.* The uniqueness of the Sundarbans mangroves lies not only in terms of numerical diversity but also in the kind of distribution of these floristic component into different tidal niches and saline regimes.

On the survey of different areas in the Indian Sundarbans both inside and outside the Sundarban Tiger Reserve, patches of diverse plant groups were revealed (Naskar, *et. al.*, 2002) . Each of these groups have their characteristic flora and physiognomy; these groups are referred to as communities. Till date, 110 plant species have been collected and identified from the Indian Sundarbans belonging to 50 families. The true mangrove species are 25 in number out of which 18 species are major elements of mangroves and 7 species are minor element of mangroves, 30 species belong to mangrove associates, 38 species are back mangrove, 7 species are beach flora and 10 species are parasite or epiphytes on mangrove plants (Ghosh, *et al* 2002; Naskar & Mandal, 1999).

The total 140 plants being reported in this Bulletin are basically of six categories, *viz.*, (A) Major Elements of Mangroves or True Mangrove species which mostly grow in the intertidal areas of Sundarbans, (B) Minor Elements of the Mangroves and Mangrove Associated plants of the Indian Sundarbans, (C) Back Mangrove trees and shrubs in the Indian Sundarbans (D) Non Halophytic and Not Mangrove Associates but present in the mangrove habitats, (E) Halophytic herbs, shrubs, Weed flora of the Indian Sundarbans Mangals and (F) Mostly epiphytes, parasites or mistletoes growing in the Sundarbans Mangals.

All these mangrove plants are presently in very much threatened condition for two reasons; first of all due to the changing nature of soil and water salinity and reduced flow of upstream fresh water due to abstraction of the river flow of the Ganga from this part of Lower Bengal delta, secondly, the population pressure in this part of Bengal are enhancing day by day and pressure on the forest has resulted in direct destruction of forest resources

Table – 9. Flora of Indian Sundarbans

Sl.No	Family Names & Scientific Names	Habit	Habitat / Zones	Sundarban of L. Ganga Delta, W.B.	% of Mangrove Characteristics Present
A. Major Elements of Mangroves or True Mangroves species (Mostly in the inter-tidal areas of Sundarbans)					
I.	**Family – Rhizophoraceae (Under 4 genera there are 9 species collected from the Indian Sundarbnans mangal)**				
1	*Rhizophora mucronata* Lamk.	Tree	IRS & TIRF	B	100 %
2	*Rhizophora apiculata* Blume	Tree	IRS & TIRF	D	100 %
3	*Bruguiera gymnorhiza* (L.) Lamk.	Tree	IRS & TIRF	B	100 %
4	*Bruguiera sexangula* (L.) Poir, Lamk.	Tree	IRS & TIRF	D	100 %
5	*Bruguiera cylindrica* (L.) Blume Ency.	Tree	IRS & TIRF	E	100 %
6	*Bruguiera parviflora* W. & A. ex Griffith	Tree	IRS & TIRF	E	100 %
7	*Ceriops tagal* (Perr.) Robinson	Tree	IRS & TIRF	C	100 %
8	*Ceriops decandra* (Griff.) Ding Hou,	Shrub	IRS & TIRF	A	100 %
9	*Kandelia candel* (L.) Druce	Tree	IRS & TIRF	D	100 %
II.	**Family- Avicenniaceae (Single genus with 3 species & one variety grow throughout in Indian Sundarbans.**				
10	*Avicennia officinalis* L.	Tree	IRF, IRS & TIRF	B	100 %
11	*Avicennia alba* Blume	Tree	IRF, IRS & TIRF	A	100 %
12	*Avicennia marina* (Forsk.) Vierh.	Tree	IRF, IRS & TIRF	A	100 %
13	*Avicennia marina var. acutissima* Stapf.	Tree	IRF, IRS & TIRF	B	100 %
III.	**Family – Sonneratiaceae** (Monotypic genus with 3 species grow throughout in Sundarbans mangals.)				
14	*Sonneratia apetala* Buch. Ham.	Tree	IRF, IRS & TIRF	C	75%
15	*Sonneratia caseolaris* (L.) Engler	Tree	IRF & IRS	E	75%
16	*Sonneratia griffithii* Kurz. Medium Tree	Tree	IRF & IRS	D	75%
IV.	**Family – Combretaceae** (Single species was collected from India Sundarbans, but in threatened condition)				
17	*Lumnitzera racemosa* Willd.	Tree	TIRF & ICSA	D	75%
V.	**Family – Meliaceae** (Two-genera with 3 species were collected and reported from Sundarbans mangals).				
18	*Xylocarpus granatum* Koen.	Tree	IRS & TIRF	C	75%
19	*Xylocarpus mekongensis* Pierre	Tree	IRS & TIRF	D	75%
20	*Aglaia cucullata* (Roxb.) Pellegrin.	Tree	IRS & TIRF	E	75%
VI.	**Family – Arecaceae** (*nom. alt.* Palmae)(Two palms grow within the river flat land and tidal inundated ridge forest).				
21	*Nypa fruticans* (Thunb.) Wurmb.	Palm	IRF & IRS	D	75%
22	*Phoenix paludosa* Roxb.	Palm	TIRF & ATHL	A	75%
VII.	**Family - Sterculiaceae** (Single species was collected and reported from Indian Sundarbans mangals).				
23	*Heritiera fomes* Buch.- Ham.TallTree A	Tree	TIRF & ATHL	E	75%
VIII.	**Family- Aegialitadaceae** (*nom. alt.* Plumbaginaceae) (One shrub species grow within the inter-tidal river flat.)				
24	*Aegialitis rotundifolia* Roxb.	Shrub	IRF, IRS & TIRF	C	75%
IX.	**Family – Myrsinaceae** (Only one shrub species grow within the inter-tidal river flat land and inundated frequently).				
25	*Aegiceras corniculatum* (L.) Blanco,	Shrub	IRF, IRS & TIRF	C	75%
X.	**Family – Rubiaceae** (Only one shrub species grow within the inter-tidal river flat land, inundated frequently)				
26	*Scyphiphora hydrophyllacea* Gaertn. F.	Shrub	IRF & IRS	E	60%
	B. Minor Elements of the Mangroves and Mangrove Associated Plants of Indian Sundarbans				
XI.	**Family – Euphorbiaceae (One species is common in the tidal mangrove forests throughout).**				
27	*Excoecaria agallocha* L.	Tree	EWH	A	40%
XII.	**Family – Tiliaceae** (One tree species is present in the tidal mangrove forest area at Sundarbans).				
28	*Brownlowia lanceolata* (L.) Kosterm.	Tree	IRS D	40%	
XIII.	**Family – Acanthaceae (Two shrub species were collected from tidal mangrove forests of Sundarbans).**				
29	*Acanthus ilicifolius* L.	Shrub	EWH	B	40%
30	*Acanthus volubilis* Wall.	Shrub	IRS-TIRF	E	40%
XIV.	**Family – Fabaceae** (One medium tree species was collected and reported from the tidal mangrove forest).				
31	*Dalbergia spinosa* Roxb.	Tree	ATHL	D	40%
XV.	**Family – Caesalpiniaceae** (One small tree species was collected from the Indian Sundarbans mangals).				
32	*Cynometra ramiflora* L.	Tree	TIRF	E	40%
XVI.	**Family – Verbenaceae** (Two shrub species were collected from the Sundarbans tidal mangrove forest).				
33	*Clerodendrum inerme* Gaertn.	Shrub	IRSC	40%	
34	*C. nerilifolium var. macrocarpa* L.	Shrub	TIRF	E	40%

XVII.	**Family – Rutaceae** (One shrub species was collected from the tidal mangrove forest of Sundarbans in India).				
35	*Atalantia correa* M. Roem.	Shrub	TIRF	E	40%
XVIII.	**Family – Apocynaceae** (One tree species was collected from the Sundarbans tidal mangrove forest areas).				
36	*Cerbera odollam* Gaertn.	Tree	ATHL	E	40%
XIX.	**Family – Asclepiadaceae** (Two shrub species were collected from the tidal forest areas of Sundarbans in India)				
37	*Sarcolobus globosus* Wall.	Shrub	IRFC	30%	
38	*Sarcolobus carinatus* Wall.	Shrub	IRSE	25%	
	C. Back Mangrove trees and shrubs in Indian Sundarbans				
XX.	**Family- Barringtoniaceae** (*nom. alt.* Lecythidaceae/ Two tree species were reported from the Indian mangals)				
39	*Barringtonia racemosa* Roxb.	Tree	ATHL	E	25%
40	*Barringtonia acutangula* (L.) Gaertn.	Tree	ATHL	E	25%
XXI.	**Family–Clusiaceae (One tree species was collected from the Indian mangrove forest zones and elsewhere).**				
41	*Calophyllum inophyllum* L.	Tree	ATHL	E	25%
XXII.	**Family–Malvaceae** (Under two genera six species were collected from the forest areas in Sundarbans).				
42	*Thespesia populneoides* (Roxb.)Kostel.	Tree	ATHL	D	25%
43	*Thespesia populnea* (L.) Solander	Tree	ATHL	C	25%
44	*Thespesia lampus*(Cav.) Dalz. & Gibs.	Tree	ATHL	E	25%
45	*Hibiscus tiliaceous* L.	Tree	ATHL	E	25%
46	*Hibiscus tortuosus* Roxb.	Tree	ATHL	E	25%
47	*Hibiscus tetraphyllus* Roxb.	Tree	ATHL	E	25%
XXIII.	**Family–Tamaricaceae** (Three tree/ shrub species were collected from the forest areas of Sundarbans)				
48	*Tamarix dioica* Roxb.	Tree	ICSA- ATHL	C	25%
49	*Tamarix aphylla* (L.) Kanza	Tree	ICSA- ATHL	C	25%
50	*Tamarix troupii* Hole	Tree	ICSA- ATHL	D	25%
XXIV.	**Family – Euphorbiaceae** (One small tree species grow occasionally in the back mangrove communities)				
51	*Sapium indicum* Willd.	Tree	ATHL	E	25%
XXV.	**Family – Pandanaceae** (Six shrubs or tree species sporadically grow throughout the Sundarbans mangals)				
52	*Pandanus tectorius* Parkinson	Shrub	ICSA	E	40%
53	*Pandanus odoratissimus* Sol. ex Park..	Shrub	ICSA	E	40%
54	*Pandanus foetidus* Roxb.	Shrub	ICSA	E	40%
XXVI.	**Family – Fabaceae (Four shrubs and tree species grow throughout in the Indian Sundarbans mangals).**				
55	*Derris scandens* Benth.	Shrub	ATHL	D	25%
56	*Derris trifoliata* Lour.	Shrub	ATHL	C	25%
57	*Derris indica* (Lamk.) Bennet	Tree	ATHL	C	25%
58	*Intsia bijuga* (Colebr) Kuntze	Tree	ATHL	E	25%
XXVII	**Family – Caesalpiniaceae (Two species are common in the back mangrove communities at Sundarbans)**				
59	*Caesalpinia crista* L.	Shrub	ATHL	C	25%
60	*Caesalpinia bonduc* (L.) Roxb.	Shrub	ATHL	C	25%
XXVIII.	**Family – Verbenaceae**(Two species are common in the back mangrove communities of Sundarbans of India)				
61	*Premna corymbosa* Rottl. & Willd.	Shrub	ATHL	E	10%
62	*Vitex negundo* L.	Shrub	ATHL	E	10%
XXIX.	**Family – Sapindaceae (One species is frequent in the back mangrove communities at Indian Sundarbans).**				
63.	*Dodonaea viscosa* (L.) Jacq.	Shrub	ATHL	E	10%
XXX.	**Family–Salvadoraceae (One species is frequently present in the back mangrove communities at Sundarbans)**				
64	*Salvadora persica* L.	Shrub	ICSA	E	10%
XXXI.	**Family – Bignoniaceae** (One species is frequent in the back mangrove communities at Sundarbans).				
65	*Dolichandrone spathacea* (L.f.) Sch.	Tree	ATHL	E	10%
XXXII.	**Family – Sapotaceae** (One species are frequent in the back mangrove communities at Indian Sundarbans)				
66	*Manilkara hexandra* (Roxb. Dubard.	Tree	ATHL	E	10%
XXXIII.	**Family – Anacardiaceae *(One species occasionally grow in the above tidal higher level in Sundarbans)***				
67	*Lannea coromandelica* (Houtt.)Merr.	Tree	ATHL	E	0%
	D. Non-halophytic and not-mangrove associates but present in the mangrove habitats				
XXXIV.	**Family - Flagellariaceae** (One species is common in the back mangrove communities at Sundarbans)				
68	*Flagellaria indica* L.	Climber	ATHL	E	0%

XXXV.	**Family - Combretaceae**				
69	*Terminalia catappa* L.	Tree	ATHL	E	0%
XXXVI.	**Family - Fabaceae** (Eleven species are frequent in the back mangrove communities at Indian Sundarbans).				
70	*Mucuna gigantea* (Willd.) DC.	Shrub	ATHL	E	0%
71	*Crotolaria juncea* L.	Shrub	ATHL	E	0%
72	*Canavalia cathartica* Thour.	Shrub	ATHL	E	0%
73	*Canavalia microcarpa* (DC.) Piper	Climber	ATHL	E	0%
74	*Erythrina fuscha* Lour.	Tree	ATHL	E	0%
75	*Erythrina variegata* (L.) Merr.	Tree	ATHL	E	0%
76	*Abrus precatorius* L.	Climber	ATHL	E	0%
77	*Clotoria ternatea* L.	Climber	ATHL	E	0%
78	*Desmodium triquetrum* DC.	Shrub	ATHL	E	0%
79	*Desmodium umbellatum DC.*	Shrub	ATHL	E	0%
	Family – Verbenaceae (One shrub species was collected from the Sundarbans above tidal areas).				
80	*Clerodendrum viscosum* Vent.	Shrub	ATHL	E	0%
XXXVII.	**Family – Opuntiaceae** (*nom alt.* Cactaceae) (One species is frequent in the back mangrove communities)				
81	*Opuntia dillenii* (Ker. Gawler) Haw.	Shrub	ATHL	D	0%
XXXVIII.	**Family – Capparidaceae** (Three species are frequent in the back mangrove communities).				
82	*Crataeva religiosa* Forst. f.	Shrub	ATHL	E	0%
83	*Capparis zeylanica* L.	Shrub	ATHL	E	0%
84	*Crataeva roxburghii* R.Br.	Shrub	ATHL	E	0%
XXXIX.	**Family – Convolvulaceae** (Two species are frequent in the coastal sandy area/ back mangrove communities).				
85	*Ipomoea pes-caprae* Sw.	Herb	ICSA	D	0%
86	*Hewittia sublobata* (Linn. f.) O.K. Rev.	Herb	ATHL	D	0%
XL.	**Family – Cuscutaceae** *(One species is frequent in the back mangrove thickets and on* Excoecaria *sp. tree).*				
87	*Cuscuta reflexa* Roxb.	Herb	Parasitic	C	0%
XLI.	**Solanaceae** *(Two species are frequent in the back mangrove communities and sandy dry area at Sundarbans)*				
88	*Solanum trilobatum* L.	Herb	ATHL	D	0%
89	*Solanum surattense* Burm. f.	Shrub	ATHL	E	0%
XLII.	**Family – Ebenaceae (One species is frequent in the back mangrove communities at Sundarbans).**				
90	*Diospyros ferrea* (Lilld.) Bakh.	Tree	ATHL	E	0%
	E. Halophytic herbs, shrubs and weed flora of the Indian Sundarbans mangal				
XLIII.	**Family – Aizoaceae** (Three herbaceous species are frequent in the back mangrove sandy beach areas)				
91	*Trianthema portulacastrum* L.	Herb	IRF-IRS	E	0%
92	*Trianthema triquetra* Rott. & Willd.	Herb	IRF-IRS	E	0%
93	*Sesuvium portulacastrum* L.	Herb	IRF-IRS	E	0%
XLIV.	**Family – Araceae** (One species is frequent in the inter-tidal river flat land, at Indian Sundarbans)				
94	*Cryptocoryne ciliata* Fish. ex Wydler	Herb	IRF-IRS	E	0%
XLV.	**Family – Amaryllidaceae (Two species are frequent in the inter-tidal river flat land, at Indian Sundarbans)**				
95	*Crinum defixum* Ker. Gawlar	Herb	IRF-IRS	E	0%
96	*Crinum asiaticum* L.	Herb	ATHL	E	0%
XLVI.	**Family – Rupplaceae (One species is frequent as submerged condition in the stagnant brackish-water)**				
97	*Ruppia maritima* L.	Herb	SBR	D	0%
XLVII.	**Family – Chenopodiaceae (Four species are sometime grow in the back mangrove river-flat communities).**				
98	*Suaeda nudiflora* Roxb.	Herb	IRF-IRS	C	0%
99	*Suaeda maritima* (L.) Dumort.	Herb	IRF-IRS	C	0%
100	*Salicornia brachiata* Roxb.	Herb	IRSD	0%	
101	*Anthrocnemum indicum* (Willd.) Moq.	Herb	ATHL	D	0%
XLVIII.	**Family – Boraginaceae (One species is frequent in the salt crusted soil as back mangrove at Sundarbas).**				
102	*Heliotrophium curassavicum* L.	Herb	ATHL	D	05%
XLIX.	**Family – Sapindaceae (One species is frequent in the back mangrove communities, at Sundarbans).**				
103	*Allophylus cobbe* (L.) Bl.	Herb	ATHL	E	05%
L.	**Family – Asteraceae (Three species are frequent in the back mangroves at Indian Sundarbans)**				
104	*Pluchea indica* Less.	Herb	ATHL	E	Dry tolerant
105	*Launea sarmentosa* (Willd.)Sch.-Bip.	Herb	ATHL	E	Dry tolerant
106	*Wedelia biflora* DC.	Herb	ATHL	E	Dry tolerant

LI.	**Family - Celastraceae (One tree species is frequent in the back mangrove communities, at Indian Sundarbans)**				
107	*Salacia chinensis* L.	Shrub	ATHL	107-E	5%
LII.	**Family - Rubiaceae (One species is frequent in coastal/ beach communities, as associate in Sundarbans)**				
108	*Hydrophylax maritima* Linn.f.	Herb	ICSA	E	10%
LIII.	**Family - Poaceae** (*nom alt.* Graminae) (Seven grass species are frequent in the back mangrove communities).				
109	*Porteresia coarctata* Takeoka	Grass	IRF & IRS	A	Saline tolerant, 5%
110	*Myriostachya wightiana* Hook.f.	Grass	IRF & IRS	C	Saline tolerant, 5%
111	*Phragmites kakra* Trin ex Steud	Grass	IRF & IRS	D	Saline tolerant, 5%
112	*Aeluropus lagopoides* (L.) Trin.	Grass	ICSA	C	Saline tolerant, 5%
113	*Saccharum spontaneum* L.	Grass	ICSA	D	Saline tolerant, 0%
114	*Urochondra setulosa* (Trin.) Hubb.	Grass	ICSA	D	Saline tolerant, 0%
115	*Cynodon dactylon* (L.) Pers.	Grass	ATHL	D	Saline tolerant, 0%
LIV.	**Family - Cyperaceae** (Five sedge species are frequent in the back mangrove communities of Sundarbans).				
116	*Cyperus javonicus* Houtt	Sedge	IRF-ATHL	C	Saline tolerant, 0%
117	*Cyperus compactus*	Sedge	SBR	D	Saline tolerant, 0%
118	*Fimbristylis ferruginea* (L.) Vahl	Sedge	IRF-ATHL	C	Saline tolerant, 0%
119	*Fimbristylis dichotome* (L.) Vahl	Sedge	IRF-ATHL	C	Saline tolerant, 0%
120	*Scirpus littoralis* Schrad.	Sedge	IRF-ATHL	C	Saline tolerant, 0%
	F. Mostly epiphytic or parasitic shrubs/ fern on mangrove trees of Indian Sundarbans				
LV.	**Family - Asclepiadaceae (Several epiphytic and/ or parasitic species are frequent in the mangrove trees).**				
121	*Pentatropis capensis* (L. f.) Bullock	Herb	EP D	Epiphytic, 0%	
122	*Tylophora tenuis* Blume	Herb	ATHL	E	Saline tolerant, 0%
123	*Hoya parasitica* Wall.	Herb	EP D	Epiphytic, 0%	
124	*Dischidia benghalensis* Coleb.	Herb	Climber	E	Climber, 0%
125	*Dischidia nummularia* R.Br	Herb	Climber	E	Climber, 0%
126	*Dregia volubilis* Benth. & Hk.	Herb	Twiner	E	Twiner, 0%
127	*Finlaysonia obovata* Wall.	Herb	EP E	Epiphytic, 0%	
128	*Hemidesmus indicus (L.) Schubs.*	Herb	ATHL	E	Saline tolerant, 0%
LVI.	**Family - Menispermeaceae (One species is frequent in back mangrove communities).**				
129	*Tinospora cordifolia* Miers	Shrub	Twiner	E	Saline tolerant, 0%
LVII.	**Family - Lauraceae (One species is frequent in the back mangrove communities as epiphyte).**				
130	*Cassytha filiformis* L.	Herb	EP C	Twiner, 0%	
LVIII.	**Family - Loranthaceae (Four species are frequent as epiphytes in the mangrove communities).**				
131	*Dendrophthoe falcata* (L.f.) Etting	Herb	EP E	Epiphytic, 0%	
132	*Macrosolen cochinchinensis* (Lour.)	Shrub	EP C	Epiphytic, 0%	
133	*Viscum orientale* Willd.	Shrub	EP D	Epiphytic, 0%	
134	*Viscum monoicum* Roxb.	Shrub	EP D	Epiphytic, 0%	
LIX.	**Fern Family - Pteridaceae** (Two species are frequent in the degraded mangrove communities).				
135	*Acrostichum aureum* L.	Fern	ATHL	C	Saline tolerant, 5%
LX.	**Family - Polypodiaceae (Three species are present as epiphytic on mangrove communities or on ground).**				
136	*Pyrrosia lanceolata* (L.) Fawell	Fern	EP E	Epiphytic, 0%	
137	Pyrossia adnascens Sw.	Fern	EP E	Epiphytic, 0%	
138	*Drynaria quercifolia* (L.) J. Smith	Fern	ATHL	E	Saline tolerant, 5%
LXI.	**Family - Aspleniaceae (One species is occasionally present as epiphytic on mangroves communities).**				
139	*Asplenium nidus* L.	Fern	EP E	Epiphytic, 0%	
LXII.	**Family - Blechnaceae (One species is occasionally present as the epiphytic on mangroves communities).**				
140	*Stenochlaena palustre* (Burm.) Bedd.	Fern	EP D	Epiphytic, 0%	

Abbreviation Used

Dominance Categories in Indian Sundarbans = A > B > C > D > E

A = Very Common; B = Common; C = Frequent; D = Occasional; E = Very rarely

IRS = Inter-tidal River Slope; TIRF = Tidal inundated river flat; IRF = Intertidal River Flat; ICSA = Inter-tidal Coastal Sandy Area; ATHL = Above Tidal High Land; EWH = Everywhere in Sundarbans; EP = Epiphytic Plants; Climber = Climbing on mangrove & other trees; Twiner =Twining on mangrove trees; SBR=Submerged on Brackmish-water areas

Table - 10. Rare, Threatened and Endangered flora of the Indian Sundarbans

Family Names	Scientific Names	Status in Sundarbans	Cause of degradation in the Sundarbans Mangrove Forest of India
Rhizophoraceae	1. *Rhizophora apiculata*	Occasional	Over exploitation and habitat lost
	2. *Bruguiera parviflora*	Occasional	Loss of natural habitat, rise of salinity
	3. *Ceriops decandra*	Occasional	Excessive exploitation and, habitat lost
	4. *Kandelia candel*	Occasional	Loss of natural habitat, rise of salinity
Meliaceae	5. *Aglaia cucullata*	Rare	Loss of natural habitat, rise of salinity
	6. *Xylocarpus mekongensis*	Threatened	Excessive exploitation and habitat lost
	7. *Xylocarpus granatum*	Threatened	Excessive exploitation and habitat lost
Sterculiaceae	8. *Heritiera fomes*	Threatened	Excessive exploitation and habitat lost
Rubiaceae	9. *Scyphiphora hydrphyllacea*	Very Rare	Loss of natural habitat, rise of salinity
	10. *Hydrophyllax maritima*	Very Rare	Loss of natural habitat, rise of salinity
Tiliaceae	11. *Brownlowia lanceolata*	Occasional	Loss of natural habitat, rise of salinity
Arecaceae	12.*Nypa fruticans*	Occasional	Excessive exploitation and habitat lost
Acanthaceae	13.*Acanthus volubilis*	Very Rare	Loss of natural habitat, rise of salinity
Papilionaceae	14.*Cynometra ramiflora*	Rare	Loss of natural habitat, rise of salinity
	15.*Dalbergia spinosa*	Rare	Loss of natural habitat, rise of salinity
Sapotaceae	16.*Manilkara hexandra*	Rare	Loss of natural habitat, rise of salinity
Rutaceae	17. *Atalantia correa*	Very Rare	Loss of natural habitat, rise of salinity

Table - 11. List of Lichen Species from Mangrove Habitats
as reported by Santra (1998)) in Indian Biologist 30(2):76-78.

Sl. No.	Species	Family
1	*Arthopyrenia alboatra* (Krem.) Muell.	Pyrenalaceas
2	*Arthopyrenia cinefaciens* (Nyl.) Zahlbr.	Pyrenalaceas
3	*Pyrenula aspistea* (Afz.) Ach.	Pyrenalaceas
4	*Pyrenula nitida* (Weig) Ach.	Pyrenalaceas
5	*Pyrenula nitidella* Muell. Arg.	Pyrenalaceas
6	*Trypethelium luteum* Tayl.	Trypetheliaceae
7	*Trypethelium tropicum* (Ach.) Muell.	Trypetheliaceae
8	*Arthonia antillarum* Nyl.	Arthoniaceae
9	*Opegrapha laeta* Stirt.	Graphidaceae
10	*Opegrapha martii* Nyl.	Graphidaceae
11	*Opegrapha stironi* Zahlbr.	Graphidaceae
12	*Graphis scripta* Ach.	Graphidaceae
13	*Phaeographis leprosulans* Muell. Arg.	Graphidaceae
14	*Graphina obtecta* (Nyl.) Muell. Arg.	Graphidaceae
15	*Phaeographina grisea* (Nyl.) Zahlbr.	Graphidaceae
16	*Sarcographa labyrinthica* (Ach.) Muell.	Chiodectonaceae
17	*Chiodecton micrographum* (Nyl.) Zahlbr.	Chiodectonaceae
18	*Lecanactis salicina* Zahlbr.	Lecanactidaceae
19	*Collema pulcellum* Ach.	Collemaceae
20	*Lecidea caliginosa* Stirt	Lecideaceae
21	*Bacidia convexula* (Muell Arg) Zahlbr	Lecideaceae
22	*Bacidia medialis* (Tuck.) Zahlbr	Lecideaceae
23	*Lecanora distans* (Pers.) Nyl.	Lecanactidaceae
24	*Lecania pertenera* (Nyl.) Zahlbr	Lecanactidaceae
25	*Ramalina calicaris* Rohl.	Usneaceae
26	*Bombyliospora leprolyta* (Nyl.) Zahlbr.	Caloplacaceae
27	*Caloplaca aurantica* (Lightf.) Tl.	Caloplacaceae
28	*Buellia egrediens* (Stist.) Zahlbr.	Buelliaceae
29	*Rinodina intrusa* (Nyl.) Malme.	Buelliaceae
30.	*Dirinaria confluens* (Fr.) Awas.	Physciaceae
31	*Pyxine cocoes* (Sw.) Nyl.	Physciaceae
32	*Physcia aegialite* (Ach.) Nyl.	Physciaceae

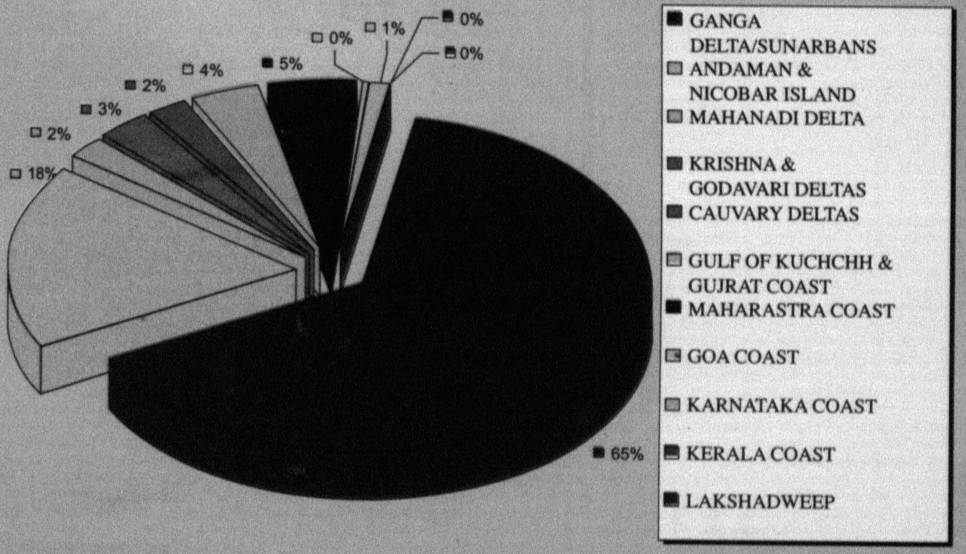
1.8.2. Algal Flora of Indian Sundarbans Mangals

The 'mangals' represent a unique band of ecosystem, which are transition zones with distinct ecological characteristics. Conditions are so suited that these transition regions are packed with life, so diverse and unique in forms, shapes, sizes and niches that they go on to making the most naturally fertile regions of the world. Three major life forms of autotrophs are often intermixed in these zones and play varying roles in maintaining a high gross rate of production, these are (i) phytoplankton; (ii) benthic microflora - algae living in and on mud, sand, rocks or other hard surfaces, viz., shells of animals and (iii) macroflora - large attached plants - the sea weeds, emergent marsh grasses and the tropical mangroves. The Sundarbans represent one such transitional zones; its coastal open water and the vast river expanse basically provides three different types of environment for the rich and abundant algal flora encountered here. The enormous open water systems, shallower water by the edge and the brackish water wetlands. It is in such areas we find the phytoplankton communities, benthic algae, periphytic algae, submerged/ emergent/ free floating wetland algae, littoral or sub littoral algae and even epiphytic algae.

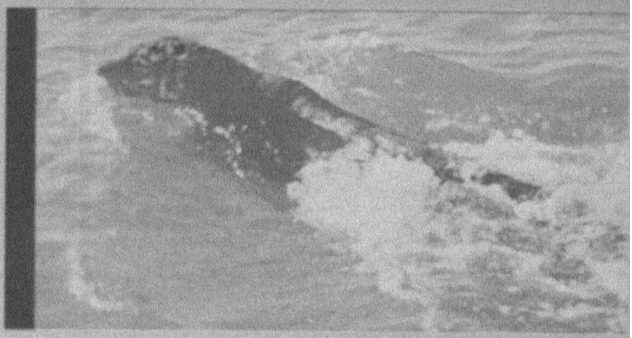
The Sundarbans provide three major different types of environment for the diverse algal groups and forms in this ecosystem. The enormous coastal open water systems and the shallower water by the edge are suitable for the free floating algal forms and the phyto plankton communities. At the edge, the water becomes shallow enough for algal attachment to the bottom, on the mud soil substratum, as well as, to various other hard substratum in the forms of pneumatophores, bark and other aerial root systems of mangroves, bricks, wooden and bamboo poles, concrete jetties etc. The second type of environment is more complex in terms of survival because of the tides. As the tides move in and out, the amount of water covering the algae changes from totally inundated to completely exposed, thus affecting the amount and quality of light reaching the algae, exposure to salinity regimes and current by varying degrees. Yet, we find a large number of algae that grow in these intertidal regions and others that can survive in the subtidal regions, as well. The third major niche for the algal flora of Sundarbans is the brackish water fisheries in the inland areas. The brackish water fisheries or wetlands (natural or man made) with wide range of salinity regimes offer habitats for a number of specific periphytic, free floating and planktonic algal forms, which are found to restrict themselves to such conditions only.

Algae play a substantial role in the mangrove ecosystem. They are the primary producer group of organism in the food web and contrari-wise they act as pollutants when uncontrolled growth occurs. As the algae require light, inorganic salts and a nitrogen source for their rapid growth, they are potential producers of proteins, lipids and carbohydrates for feeding humans and animals. With phenomenal increase in population during the last few decades, a few of the major problems faced by human society are those of quality and quantity of food, fodder, drinking water, disposal of sewage and industrial wastes and proper conservation of soil and water. Properly regulated algal growth can provide substantial assistance in tackling these problems (Sen, 2000). A large number of micro- and macro-algae occur in association with mangroves, some on the above- ground roots and some free-living on the mud. The more obvious epiphytic micro-algae in the mangals are the diatoms and blue green algae (Cyanobacteria). They occur on the roots of mangrove trees, as well as, epiphytically and entangled with macro-algae. Microscopic diatoms also occur on the soil, and are able to move by exuding mucilage. This left over mucilage then acts as a binding agent which traps and binds fine sediment particles. Diatoms thus increase sediment accretion within the mangrove ecosystem (Harris, 1986). In the mangrove habitats inundation by saline water is a regular feature. During high tide the mangrove areas get inundated with tidal river water thus receiving sufficient moisture along with frequent exposure to sunlight during low tide, which suitably provide ideal habitats for different groups of algal flora, *viz.*, benthic and planktonic. Of the 150 species collected and identified from the Indian Sundarbans 50 species belong to Cyanophyta, 39 species belong to Chlorophyta, 2 species belong to Phaeophyta, 44 species belong to Chrysophyta of which 42 species are diatoms and 15 species belong to Rhodophyta (Table - 12).

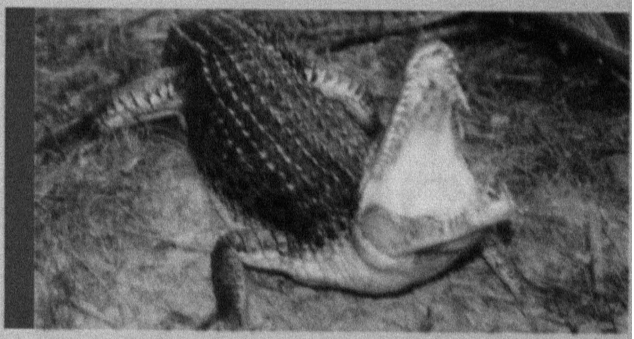
ESTIMATION OF MANGROVES AND MANGROVE AREA IN THE INDIAN SUB-CONTINENT



The Royal Bengal Tiger - *Panthera tigris tigris* of Sundarbans.

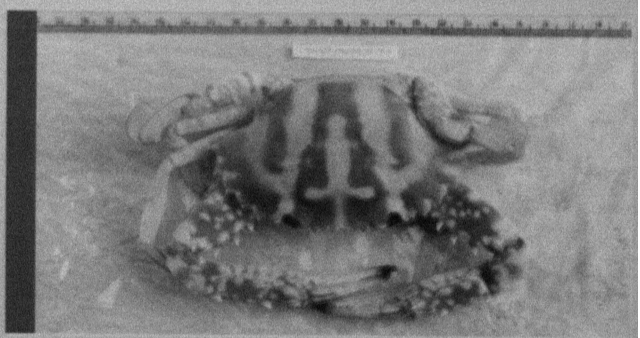


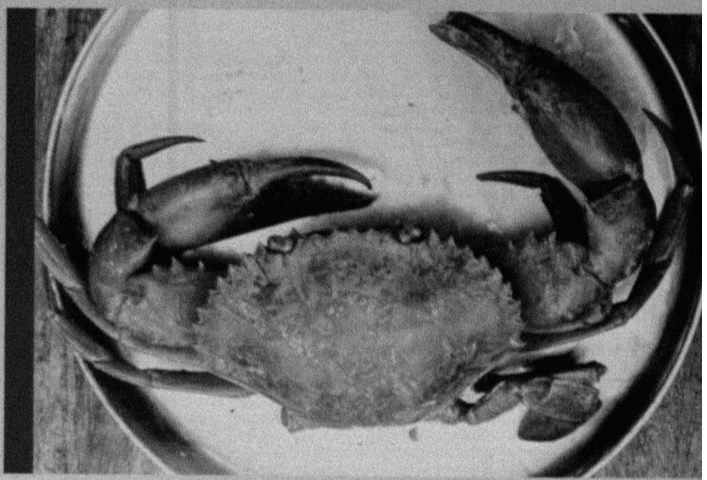
Crocodilus porosus - the estuarine crocodile.



Cervus axis - the spotted deer of Sundarbans.

The beautiful crab species of Sundarbans.





Scylla serrata the edible crab species of Sundarbans

Lates calcarifer from Sundarbans

Penaeus monodon the high priced prawn species of Sundarbans

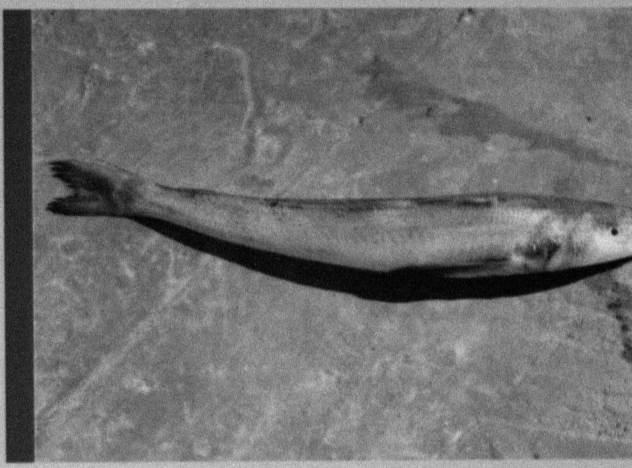
Research sample collection in the core area of Sundarbans.

Collection of litter from Sundari tree of Sundarbans.

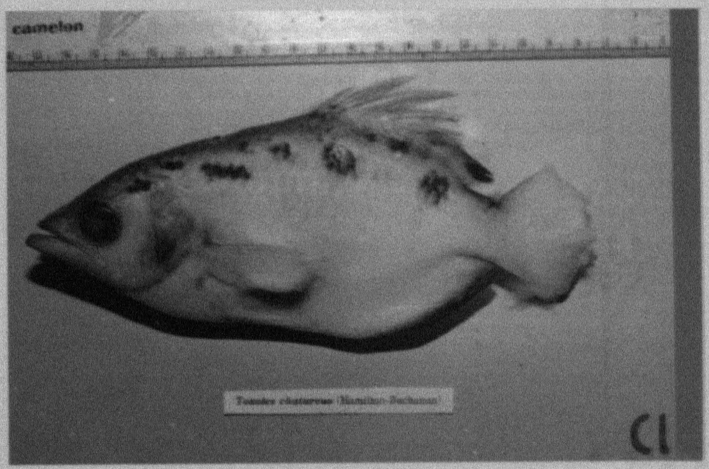
Collection of mangrove leaf litter from Hestuary of Sundarbans.

AssortedFish hauls from the Estuaries of Sundarbans.

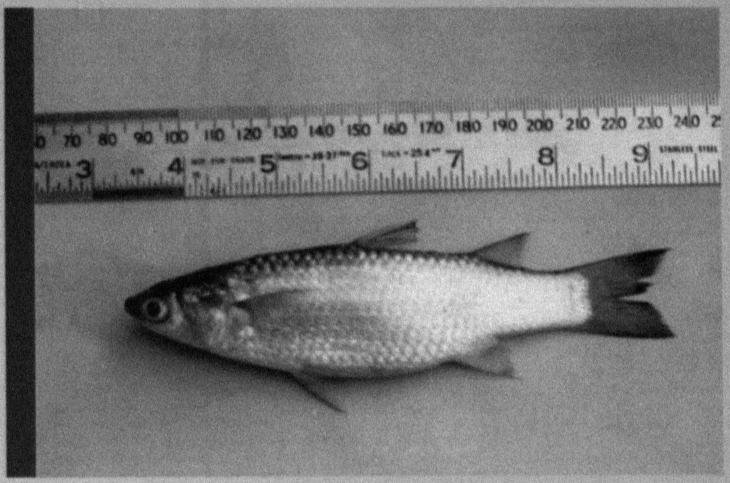
Different estuarine fishes of Sundarbans mangrove forest area.



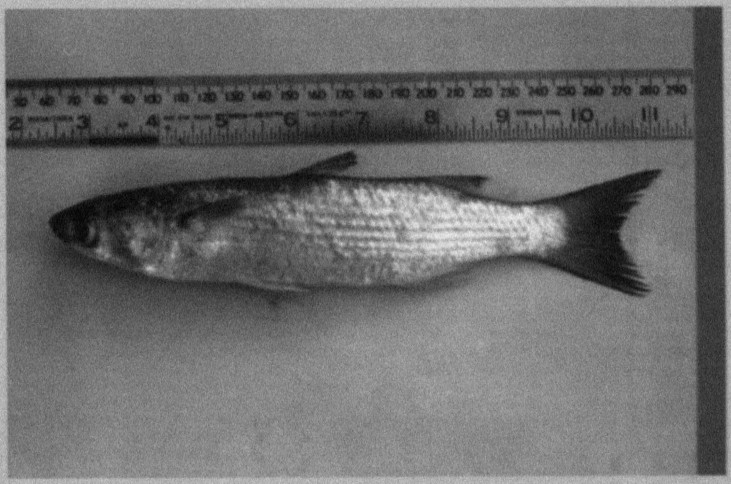
Sillgo sp.



Hemiramphus sp.



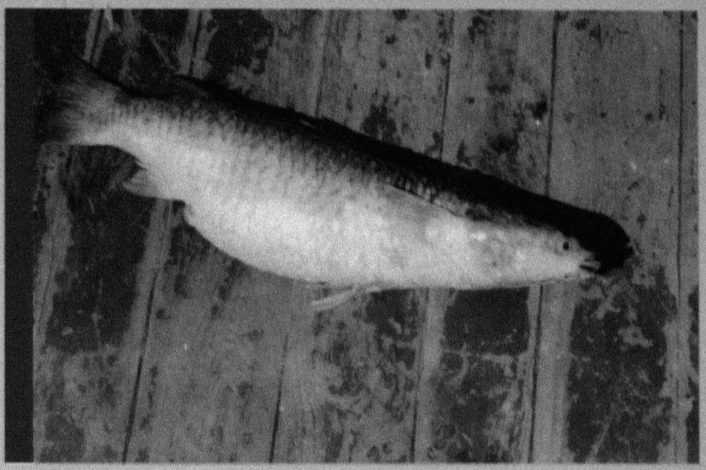
Mugil parsia



M. ceehalus

Haul of estuarine fishes

Mugil tade



Haul of estuarine fishes

Estuarin gobids

Bar Diagram - 1. Rate of population growth in the Indian Sundarbans during the last 50years

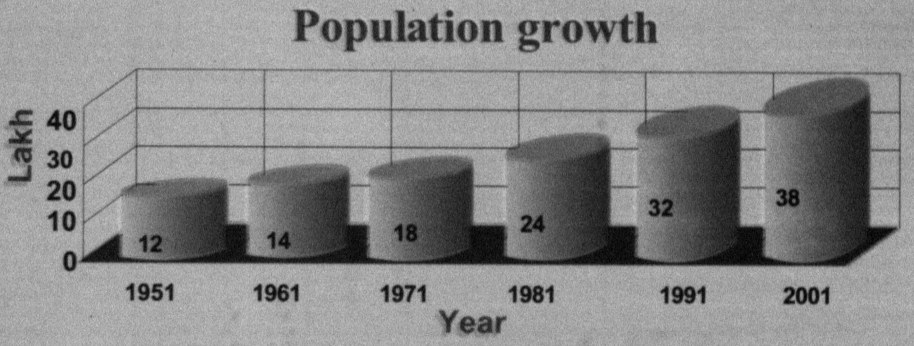


Table - 12. Algal flora of the Indian Sundarbans

SPECIES	ZONE I	ZONE II	ZONE III	HABITAT ECOLOGY
CHLOROPHYTA				
Volvox sp.	+	—	—	alkaliphilous, mesothermal, oligohaline, saprophobic, limnophilous
Pandorina morum	+	—	—	alkaliphilous, mesothermal, oligohaline, saprophobic, limnophilous
Uronema confervicola	+	+	—	alkaliphilous, mesothermal, oligohaline, saprophobic, limnophilous
Enteromorpha clathrata	++	++	—	alkaliphilous, mesothermal, oligohaline, saproxenous, limnobiontic
Enteromorpha compressa	—	++	—	alkaliphilous, mesothermal, euryhaline, saprophobic, rheophilous
Enteromorpha intestinalis	+++	+++	—	alkaliphilous, mesothermal, oligo – mesohaline, saprophilic, limnobiontic
Enteromorpha prolifera	+++	+++	—	alkaliphilous, mesothermal, oligo – mesohaline, saprophilic, limnobiontic
Ulva lactuca	—	+++	—	alkaliphilous, mesothermal, mesohaline, saprophobic, rheobiontic
Ulva patengensis	—	+++	—	alkaliphilous, mesothermal, mesohaline, saprophobic, rheobiontic
Ulva fasciata	—	+	—	alkaliphilous, mesothermal, mesohaline, saprophobic, rheobiontic
Chaetomorpha aerea	++	++	++	alkaliphilous, mesothermal, meso – euryhaline, saproxenous, limnophilous
Chaetomorpha gracilis	—	+++	++	alkaliphilous, mesothermal, meso – euryhaline, saproxenous, limnophilous
Chaetomorpha brachygona	++	+++	++	alkaliphilous, mesothermal, meso – euryhaline, saproxenous, limnophilous
Lola capillaris	+	+++	+	alkaliphilous, mesothermal, meso – euryhaline, saprophobic, limnophilous
Lola implexa	+	+	+	alkaliphilous, mesothermal, meso – euryhaline, saproxenous, limnophilous
Lola tortuosa	+	++	+++	alkaliphilous, mesothermal, meso – euryhaline, saprophobic, rheobiontic
Rhizoclonium grande	—	+	+++	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Rhizoclonium hookeri	—	+	+++	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Rhizoclonium riparium	—	+	+++	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Cladophora echinus	+	—	—	alkaliphilous, mesothermal, oligohaline, saprophobic, limnobiontic
Cladophorella sundarbanensis	—	+	++	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Oedogonium undulatum	+	++	—	alkaliphilous, mesothermal, oligohaline, saprophobic, limnobiontic
Spirogyra dubia	++	++	—	alkaliphilous, mesothermal, oligo - mesohaline, saproxenous, limnobiontic
Spirogyra setiformis	++	—	—	alkaliphilous, mesothermal, oligohaline, saproxenous, limnobiontic
Spirogyra ternata	—	++	—	alkaliphilous, mesothermal, mesohaline, saproxenous, limnobiontic
Triplastrum simplex	+	—	—	alkaliphilous, mesothermal, oligohaline, saproxenous, limnobiontic
Triplastrum abbreviatum	+	—	—	alkaliphilous, mesothermal, oligohaline, saproxenous, limnobiontic
Cosmarium striolatum	+	+	—	alkaliphilous, mesothermal, oligo – mesohaline, saprophobic, limnobiontic
Cosmarium depressum	+	+	—	alkaliphilous, mesothermal, oligo – mesohaline, saprophobic, limnobiontic
Closterium acutum	+	—	—	alkaliphilous, mesothermal, oligo – mesohaline, saprophobic, limnobiontic
Chlorella vulgaris	+	—	—	alkaliphilous, mesothermal, oligohaline, saprophobic, limnobiontic
Radiococcus sp.	+	—	—	alkaliphilous, mesothermal, oligohaline, saprophobic, limnobiontic
Pediastrum boryanum	+	+	+	alkaliphilous, mesothermal, oligo-meso-euryhaline, saprophobic, limnobiontic

SPECIES	ZONE I	ZONE II	ZONE III	HABITAT ECOLOGY
Pediastrum duplex	+	+	+	alkaliphilous, mesothermal, oligo-meso-euryhaline, saprophobic, limnobiontic
Pediastrum tetras	+	—	—	alkaliphilous, mesothermal, oligohaline, saprophobic, limnobiontic
Scenedesmus bijuga	+	—	—	alkaliphilous, mesothermal, oligohaline, saprophobic, limnobiontic
Scenedesmus quadricauda	+	—	—	alkaliphilous, mesothermal, oligohaline, saprophobic, limnobiontic
Boodleopsis sundarbanensis	—	++	—	alkaliphilous, mesothermal, meso-euryhaline, saprophilic, benthic
Chara zeylanica	—	+	—	alkaliphilous, mesothermal, oligohaline saprophobic, limnobiontic
CHRYSOPHYTA				
Vaucheria prescotti	—	++	+	alkaliphilous, mesothermal meso – euryhaline, saprophilic, benthic
***Vaucheria* sp.**	—	+	—	alkaliphilous, mesothermal, meso – euryhaline, saprophilic, benthic
Melosira moniliformis	—	+	—	alkaliphilous, mesothermal, mesohaline, saprophobic, rheophilous
Melosira sol	—	+	—	alkaliphilous, mesothermal, mesohaline, saprophobic, rheophilous
Cyclotella glomerata	—	—	+	alkaliphilous, mesothermal, mesohaline, saprophobic, rheophilous
Coscinodiscus excentricus	++	++	++	alkaliphilous, mesothermal, oligo-meso-euryhaline, saproxenous, limnophilous
Coscinodiscus gigas	++	++	++	alkaliphilous, mesothermal oligo-meso-euryhaline, saproxenous, limnophilous
Coscinodiscus granii	++	++	+++	alkaliphilous, mesothermal, oligo-meso-euryhaline, saproxenous, limnophilous
Stephanopyxis palmeriana	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Hemidiscus cuneiformis	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Biddulphia mobiliensis	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Biddulphia sinensis	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Chaetoceros curvisetus	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Chaetoceros flexuosus	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Chaetoceros laciniosus	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Chaetoceros tenuissimus	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Chaetoceros subsecundus	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Climacodium frauenfeldianum	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Bacteriastrum varians	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Bacteriastrum cosmosum	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Bacteriastrum delicatulum	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Corethron hystrix	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Rhizosolenia imbricata	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Rhizosolenia setigera	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Fragilaria vaucheriae	—	+	+	alkaliphilous, mesothermal, meso -euryhaline, saprophobic, rheobiontic
Asterionella japonica	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Synedra ulna	+	+	+	alkaliphilous, mesothermal, oligo-meso-euryhaline, saprophobic, rheobiontic
Diatoma vulgare	—	+	+	alkaliphilous, mesothermal, meso -euryhaline, saprophobic, rheobiontic

SPECIES	ZONE I	ZONE II	ZONE III	HABITAT ECOLOGY
Achnanthes microcephala	—	+	+	alkaliphilous, mesothermal, meso -euryhaline, saprophobic, rheobiontic
Achnanthes minutissima	—	+	+	alkaliphilous, mesothermal, meso -euryhaline, saprophobic, rheobiontic
Cocconeis placentula	—	+	+	alkaliphilous, mesothermal, meso -euryhaline, saprophobic, rheobiontic
Navicula cryptocephala	—	+	+	alkaliphilous, mesothermal, meso -euryhaline, saprophobic, rheobiontic
Navicula radiosa	+	+	—	alkaliphilous, mesothermal, oligo -mesohaline, saprophobic, rheobiontic
Anomoeoneis exilis	+	—	—	alkaliphilous, mesothermal, oligohaline, saprophobic, rheobiontic
Stauroneis phoenicenteron	—	+	—	alkaliphilous, mesothermal, mesohaline, saprophobic, rheobiontic
Pinnularia viridis	+	—	—	alkaliphilous, mesothermal, oligohaline, saprophobic, rheobiontic
Pleurosigma angulatum	—	+	+	alkaliphilous, mesothermal, meso -euryhaline, saprophobic, rheobiontic
Gyrosigma acuminatum	+	+	+	alkaliphilous, mesothermal, oligo-meso-euryhaline, saprophobic, rheobiontic
Gomphonema sphaerophorum	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Amphora veneta	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Cymbella ehrenbergii	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, rheobiontic
Nitzschia acicularis	+	+	+	alkaliphilous, mesothermal, oligo-meso-euryhaline, saprophobic, rheobiontic
Nitzschia obtusa	+	+	+	alkaliphilous, mesothermal, oligo-meso-euryhaline, saprophobic, rheobiontic
Nitzschia sublinearis	+	+	+	alkaliphilous, mesothermal, oligo-meso-euryhaline, saprophobic, rheobiontic
PHAEOPHYTA				
Colpomenia sinuosa	—	—	++	alkaliphilous, mesothermal, euryhaline, saprophobic, benthic (as littoral flora)
Dictyota ceylanica	—	+	+	alkaliphilous, mesothermal, euryhaline, saprophobic, periphytic
CYANOPHYTA				
Gloeocapsa decorticans	+	—	—	Alkaliphilous, mesothermal, oligohaline, saproxenous, limnobiontic
Gloeocapsa punctata	—	+	—	Alkaliphilous, mesothermal, oligohaline, saproxenous, limnobiontic
Gloeocapsa aeruginosa	—	+	—	Alkaliphilous, mesothermal, euryhaline, saprobiontic, rheophilous
Gloeocapsa rupestris	+	—	—	Alkaliphilous, mesothermal, mesohaline, saprobiontic, rheophilous
Gloeocapsa kuetzingiana	+	—	—	Alkaliphilous, mesothermal, mesohaline, saprobiontic, rheophilous
Microcystis bengalensis	+	+	—	alkaliphilous, mesothermal, oligo-meso-euryhaline, saprobiontic, limnobiontic
Aphanocapsa littoralis	—	—	+	alkaliphilous, mesothermal, euryhaline, saprobiontic, limnobiontic
Aphanocapsa pulchra	—	+	+	alkaliphilous, mesothermal, meso-euryhaline, saproxenous, benthic
Aphanothece stagnina	—	+	—	Alkaliphilous, mesothermal, oligohaline, saproxenous, limnobiontic
Merimopedia tenuissima	—	+	—	alkaliphilous, mesothermal, mesohaline, saproxenous, rheophilous
Johannesbaptistia pellucida	+	—	—	alkaliphilous, mesothermal, oligohaline, saproxenous, limnophilous
Chamaesiphon curvatus	—	+	+	alkaliphilous, mesothermal, meso-euryhaline, saproxenous, epiphytic
Dermocarpa leibleiniae	+	+	+	alkaliphilous, mesothermal, oligo-meso-euryhaline, saproxenous, epiphytic
Dermocarpa hemisphaerica	—	+	+	alkaliphilous, mesothermal, oligo-meso-euryhaline, saproxenous, epiphytic
Stichosiphon sansibaricus	+	+	+	alkaliphilous, mesothermal, oligo-meso-euryhaline, saproxenous, epiphytic
Xenococcus chaetomorphae	+	+	+	alkaliphilous, mesothermal, oligo-meso-euryhaline, saproxenous, epiphytic

SPECIES	ZONE I	ZONE II	ZONE III	HABITAT ECOLOGY
Xenococcus cladophorae	+	+	+	alkaliphilous, mesothermal, oligo-meso-euryhaline, saproxenous, epiphytic
Spirulina princeps	+	—	—	alkaliphilous, mesothermal, oligohaline, saproxenous, limnophilous
Spirulina major	+	—	—	alkaliphilous, mesothermal, oligohaline, saproxenous, limnophilous
Arthrospira platensis	+	—	—	alkaliphilous, mesothermal, oligohaline, saprobiontic, limnobiontic
Oscillatoria nigroviridis	+	+	+	alkaliphilous, mesothermal, oligo-meso-euryhaline, saprophilic, limnobiontic
Oscillatoria limosa	++	++	+	alkaliphilous, mesothermal, oligo-meso-euryhaline, saprophilic, limnophilous
Oscillatoria subbrevis	+	+++	—	alkaliphilous, mesothermal, oligo-mesohaline, saprophilic, limnophilous
Oscillatoria curviceps	+	++	+	alkaliphilous, mesothermal, oligo-meso-euryhaline, saprophilic, limnophilous
Oscillatoria princeps	+	+++	++	alkaliphilous, mesothermal, oligo-meso-euryhaline, saprophilic, limnophilous
Oscillatoria chlorina	—	+	+	alkaliphilous, mesothermal, meso-euryhaline, saprophobic, rheophilous
Oscillatoria tenuis	++	+++	+	alkaliphilous, mesothermal, oligo-meso-euryhaline, saproxenous, limnophilous
Phormidium stagnina	—	+	—	alkaliphilous, mesothermal, mesohaline, saprobiontic, limnobiontic benthic
Phormidium fragile	—	+	—	alkaliphilous, mesothermal, euryhaline, saprobiontic, limnobiontic benthic
Lyngbya birgei	+	+	—	alkaliphilous, mesothermal, oligo-mesohaline, saprophilic, limnobiontic
Lyngbya hieronymusii	+	+	—	alkaliphilous, mesothermal, oligo-mesohaline, saprophilic, limnobiontic
Lyngbya lutea	+	++	++	alkaliphilous, mesothermal, oligo-meso-euryhaline, saproxenous, limnobiontic
Lyngbya majuscula	—	++	++	alkaliphilous, mesothermal, meso-euryhaline, saproxenous, limnobiontic
Lyngbya confervoides	+	+	—	alkaliphilous, mesothermal, oligo-mesohaline, saproxenous, limnobiontic
Lyngbya semiplena	+	+	+	alkaliphilous, mesothermal, oligo-meso-euryhaline, saproxenous, limnobiontic
Schizothrix lamyii	—	++	—	alkaliphilous, mesothermal, mesohaline, saprophilic, limnobiontic/ benthic
Microcoleus chthonoplastes	—	+	+	alkaliphilous, mesothermal, meso-euryhaline, saprophilic, limnobiontic/benthic
Hydrocoleum lyngbyaceum	—	+	+	alkaliphilous, mesothermal, meso-euryhaline, saprophilic, limnobiontic/benthic
Nostoc punctiforme	+	+	+	alkaliphilous, mesothermal, oligo-meso-euryhaline, saproxenous, limnobiontic
Nostoc linckia	—	+	—	alkaliphilous, mesothermal, mesohaline, saprophobic, limnobiontic
Scytonema hofmanni	+	—	—	alkaliphilous, mesothermal, oligohaline, saproxenous, limnobiontic
Anabaena anomala	+	+	+	alkaliphilous, mesothermal, oligo-meso-euryhaline, saproxenous, limnobiontic
Anabaena dolioloum	+	+	—	alkaliphilous, mesothermal, oligo-mesohaline, saproxenous, limnobiontic
Anabaena iyengarii	—	—	+	alkaliphilous, mesothermal, euryhaline, saproxenous, limnobiontic
Anabaena gelatinicola	—	+	—	alkaliphilous, mesothermal, euryhaline, saprobiontic, rheophilous
Anabaenopsis arnoldii	+	—	—	alkaliphilous, mesothermal, oligo-mesohaline, saprophobic, limnobiontic
Raphidiopsis curvata	+	—	—	alkaliphilous, mesothermal, oligo-mesohaline, saprophobic, limnobiontic
Raphidiopsis indica	+	—	—	alkaliphilous, mesothermal, oligohaline, saproxenous, limnobiontic
Calothrix contarenii	—	+	—	alkaliphilous, mesothermal, mesohaline, saproxenous, limnobiontic
Mastigocoleus testarum	—	—	+	alkaliphilous, mesothermal, euryhaline, saprophobic, indifferent

SPECIES	ZONE I	ZONE II	ZONE III	HABITAT ECOLOGY
RHODOPHYTA				
Compsopogon coeruleus	+	—	—	alkaliphilous, mesothermal, mesohaline, saproxenous, limnophilous
Catenella nipae	—	+	+	alkaliphilous, mesothermal, meso-euryhaline, saprophobic, rheophilous/periphytic
Catenella impudica	—	+	+	alkaliphilous, mesothermal, meso-euryhaline, saprophobic, rheophilous/periphytic
Catenella repens	—	++	++	alkaliphilous, mesothermal, meso-euryhaline, saprophobic, rheophilous/periphytic
Caloglossa adnata	—	+	+	alkaliphilous, mesothermal, meso-euryhaline, saprophobic, rheophilous/periphytic
Caloglossa leprieurii	—	+	+	alkaliphilous, mesothermal, meso-euryhaline, saprophobic, rheophilous/periphytic
Polysiphonia mollis	—	+++	+++	alkaliphilous, mesothermal, meso-euryhaline, saprophobic, rheophilous/periphytic
Polysiphonia denudata	—	++	++	alkaliphilous, mesothermal, meso-euryhaline, saprophobic, rheophilous/periphytic
Pterosiphonia pinnata	—	++	++	alkaliphilous, mesothermal, meso-euryhaline, saprophobic, rheophilous/periphytic
Bostrychia radicans	—	++	++	alkaliphilous, mesothermal, meso-euryhaline, saprophobic, rheophilous/periphytic
Bostrychia tenella	—	++	++	alkaliphilous, mesothermal, meso-euryhaline, saprophobic, rheophilous/periphytic
Herposiphonia dendroidea	—	+	—	alkaliphilous, mesothermal, mesohaline, saprophobic, rheophilous/periphytic
Heterosiphonia sp.	—	+	+	alkaliphilous, mesothermal, meso-euryhaline, saprophobic, rheophilous/periphytic
Gelidiella acerosa	—	—	+	alkaliphilous, mesothermal, meso-euryhaline, saprophobic, rheophilous/periphytic
Gelidium pusillum	—	+	—	alkaliphilous, mesothermal, meso-euryhaline, saprophobic, rheophilous/periphytic

1.8.3. Microbial Population of the Indian Sundarbans

Microbes in the form of bacteria, fungus and protozoa are the most important detritus users and decomposers in this mangrove ecosystem, just like any other ecological system. Bacteria decompose the complex organic compounds (litter and other dead animal parts) that cannot be digested by animals and thereby increase the nutritive values of the organic matter in the soil, as well as, water. It is well known, that bacteria play an important role in marine aquatic detrital food webs. Studies have shown that bacteria are important in mediating the flux of carbon and nitrogen from the pool of dissolved organic matter to organisms in higher trophic levels. These bacteria by their decomposing activities release the nutrients from the dead organic parts and make them available to the organisms in the higher trophic levels like algae, protozoa and other higher plants. This process of nutrient release, mineralization of complex organic matter, converting the soil and water to a nutrient rich media for the growth of higher organisms are persued by these microflora. So these microbial communities play an important role in the coastal marine ecological trophic dynamics and food web, as well as, energy flow.

In the halophytic conditions of Sundarbans mangals, the following groups of soil and aquatic micro-flora are reported to be present -

Procarya	Eubacteria	True Bacteria, Green and Purple Sulfur Bacteria, Actinomycetes
Archaea	Euryarcheota	Sporogenic Bacilli, Cyanobacteria
Eucarya	Protozoa	Cilliates, Zooflagellates, Amoeba, Slime Molds
	Chromista	Oomycetes, Algae
	Mycota	Zygomycetes, Fungi

1.8.4. The Mangrove Habitat Faunal Assemblages in the Indian Sundarbans

In terms of faunal diversity the mangrove forests of Sundarbans exhibit till date a total of about 1,434 animal species from terrestrial, inter - tidal and aquatic environs. These animals comprise 989 species of invertebrates, one species of hemichordate and 445 species of vertebrates (Das & Nandi,1999). The mangrove areas are excellent nursery grounds for a variety of commercially important prawns, crabs and fin - fish species, as they provide abundant food and shelter for these aquatic organisms. The ecosystems also provide food, roosting and nesting site and shelter to a large variety of birds. Several insects, reptiles, birds and mammals inhibit the evergreen canopies of mangroves. The mangrove forests of Sundarbans with its unique and high bio-diversity thus supports many trophic levels of aquatic and terrestrial organisms by enriching the fertility of estuarine waters. The mangrove dwelling fauna or mangrove habitat animal species in the Indian Sundarbans are also important for their large species diversity, along with several important threatened, rare, endangered and endemic species. Till date, it was not possible to collect and to identify all these natural fauna of the Sundarbans mangals for difficult terrain. This is the only mangrove habitat tigerland of the world. So far the higher groups of fauna / animal species identified from the Indian Sundarbans are presented by Das & Nandi (1999). The different animal or faunal habitats in this Indian Sundarbans are presented in Table -13. These vast group of animal species are directly dependent on these dense mangrove habitats either for their food or safe shelter; these faunal species indirectly or directly protect these threatened mangrove forest from rapid destruction by the human beings.

For rapid change of the ecological conditions and also the drastic changes of the past physiognomy of this deltaic Sundarbans, like shifting of the main flow of the river Ganga towards Padma in Bangladesh and also for the large scale human interaction, several important fauna have become extinct from the Sundarbans mangal. These past dominant fauna and their evidence or proof of existence are also available from the earlier records and excavated bones, skulls of several of such extinct animals.

1.8.4.1. Mammalian Fauna of the Indian Sundarbans Mangals

The Sundarbans mangrove forest is well known or rather renowned for the ideal habitat for the Royal Bengal Tiger (*Panthera tigris tigris* L.). The tiger in the Sundarbans plays the important role in moulding the ecological balance and natural protection of this ecosystem. Besides tiger other 40 aquatic and terrestrial mammalian fauna are reported from this delta forest and estuarine waterways. The list of common mammals are presented in Table - 13.

Table - 13. Mammalian Fauna of the Indian Sundarbans Mangals

Aquatic Habitat Mammals in the Estuaries, Rivers and Offshore of the Indian Sundarbans		
Order - Cetacea	**Family**	**Common Name**
1. *Platinista gangetica* (Roxburgh)	Platinistidae	Gangetic Dolphin
2. *Neophocaena phocaenoides* (Cuvier)	Delphinidae	Little Porpoise
3. *Sotalia plumbea* (Cuvier)	Delphinidae	Plumbous Dolphin
4. *Stanella malayana* (Lesson)	Delphinidae	Malay Dolphin
5. *Orcella brevirostris* (Owen)	Delphinidae	Irrawady Dolphin
Terrestrial Habitat Mammals in the Mangrove Forest of Indian Sundarbans		
Order - Carnivora		
6. *Panthera tigris tigris* (Linn.)	Felidae	Royal Bengal Tiger
7. *Felis viverrina* Bennett	Felidae	Fishing Cat
8. *Felis bengalensis* Kerr.	Felidae	Leopard Cat
9. *Felis chaus* (Guldenstaedt)	Felidae	Jungle Cat
10. *Canis aureus* (Linn.)	Canidae	Jackal
11. *Vulpes bengalensis* (Shaw)	Canidae	Indian Fox
12. *Paradoxurus hermaphroditus* Gray	Viverridae	Small Indian Civert
13. *Viverricula indica* (Besmarest)	Viverridae	Common Grey Mingoose
14. *Herpestes edwardsir* (Geoffery)	Viverridae	Small Indian Mongoose
15. *Herpestes auropunctatus* (Hodgson)	Viverridae	Marsh Mongoose
Order - Mustelidae		
16. *Lutra perpicillata* Linn.	Mustelidae	Smooth Indian Otter
17. *Lutra lutra* (Linn.)	Mustelidae	Common otter
Order - Insectivora		
18. *Suncus murinus* (Linn.)	Soricidae	Grey Musk Shrew
Order - Artiodactyla		
19. *Sus scrofa*	Suidae	Wild Boar
20. *Cervus axis* (Erxleben)	Suidae	Spotted Deer
Order - Rodentia		
21. *Funambulus pennanti* Wroughton	Sciuridae	Five Stripped Squirrel
22. *Mus booduga* (Grey)	Muridae	Little Indian Field Mouse
23. *Mus musculus* Linn.	Muridae	House Mouse
24. *Rattus rattus* (Linn.)	Muridae	House Rat
25. *Bandicota indica* (Bechstein)	Muridae	Large Bandicoot Rat
26. *Bandicota bengalensis* (gray)	Muridae	Lesser Bandicoot Rat
27. *Hystrix indica* Keer	Erethizontidae	Indian Crested Porcupine
Order - Chiroptera		
28. *Pteropus giganteus* (Brunnich)	Pteropidae	Indian Flying Fox
29. *Cynopterus sphinx* (Vahl)	Pteropidae	Shortnosed Fruit Bat
30. *Pipistrellus mimus* (Wroughton)	Vespertilionidae	Pigmy Pipistrelle
31. *Scotophilus kuhli* Leach	Vespertilionidae	Lesser Yellow Bat
32. *Megaderma lyra* (Geoffroy)	Megadermatidae	Indian False Vampire
33. *Megaderma spasma* Linn	Megadermatidae	Vampire
34. *Rhinopoma hardwickii* (Gray)	Rhinopomatidae	Lesser Rat Tailed Bat
35. *Hipposideros bicolor* Temminck	Rhinopomatidae	Bicoloured Leafnosed Bat
36. *Hipposideros lankadiva* Kelaart	Rhinopomatidae	Cave Bat
37. *Taphozous longimanus* Hardwicke	Emballonuridae	
38. *Rhinolophus lepidus* Blyth	Emballonuridae	
Order - Primate		
39. *Macaca mulatta* (Zimmermann)	Cercopithecidae	Rhesus Monkey
Order - Pholidota		
40. *Manis pentadactyla* Linn.		Indian Pangolin

1.8.4.2. Reptilian Fauna of the Sundarbans Mangals

Next to mammals the reptilian fauna are the common dwellers in the estuarine water bodies, mangrove forest areas and the tree canopies as well. 60 dominant species of repilian fauna have been identified and reported during field studies. Most of these reptilian fauna depend on fish, crabs, prawns and the small reptiles found within this ecosystem. The aquatic habitat reptilian faunal components have been unlisted in Table - 14.

Table - 14. Reptilian Fauna of the Sundarbans Mangals (Class - Reptilia)

Order - Chelonia (Turtles, Tortoises, Terrapins)

Name of the Species	Family	Common Name
1. *Batagur baska* (Gray)	Emydidae	Common Batagur River Terrapin
2. *Geomyda tricarinata* Blyth	Emydidae	Three Keeled Terrapin
3. *Kachuga kachuga* (Gray)	Emydidae	
4. *Kachuga tecta* Tentbridge	Emydidae	
5. *Geoclemys hamiltoni* (Gray) Terrapin	Emydidae	Spotted Pond Turtle
6. *Morenia ocellata* (Dumerid & Bibron)	Emydidae	Bengal Eyed Terrapin
7. *Trionyx gangeticus* Cuvier	Trionychidae	Freshwater Turtles
8. *Trionyx hurum* Gray	Trionychidae	
9. *Lissemys punctata* (Bonnaterre)	Trionychidae	Pond Turtle
10. *Pelochelys bibroni* (Owen)	Trionychidae	Coast Soft Shell Turtle
11. *Chitra indica* (Gray)	Trionychidae	Chitra Turtle
12. *Lepidochelys olivacea* (Eschscholtz)	Chelonidae	Ridley Turtle
13. *Eretmochelys imbricata*		Hawk"s Bill

Order - Squamata

Sub - Order - Lacertillia (Lizard, Geckos & Monitors)

14. *Gekko gecko* (Linn.)	Gekkonidae	House Gecko
15. *Hemidactylus frenatus* Schelgab	Gekkonidae	
16. *Hemidactylus brooki* Gray	Gekkonidae	
17. *Hemidactylus leschenaulti* Dumeril & Bibron	Gekkonidae	
18. *Hemidactylus flaviviridis* Rupell	Gekkonidae	House Gecko
19. *Calotes versicolor* (Daudin)	Agamidae	Garden Lizard
20. *Chamaeleon zeylanicus* Laurenti	Chamaeleontidae	Indian Chamaeleon
21. *Mabuya carinata* (Schneider)	Scincidae	
22. *Mabuya dissimilis* (Hallowell)	Scincidae	
23. *Riopa punctata* (Daudin)	Scincidae	
24. *Riopa albopunctata* Gray	Scincidae	
25. *Varanus salvator* (Laurenti)	Varanidae	Water Monitor
26. *Varanus flavescence* (Gray)	Varanidae	Monitor Lizard
27. *Varanus bengalensis* (Daudin)	Varanidae	Monitor Lizard

Table - 14. Reptilian Fauna of the Indian Sundarbans (contd.)

Sub - Order Ophidia (Snakes)

Name of the Species	Family	Common Name
28. *Typhlops porrectus* Stoliczka	Typhlopidae	Blind Snake
29. *Typhlops braminus* (daudin)	Typhlopidae	Common Blind Snake
30. *Python molurus* Linnaeus	Boidae	Indian Python
31. *Acrochordus granulatus* Schneider	Boidae	Thicket Snake
32. *Eryx conicus* (Schneider)	Boidae	Rusell"s Sand Boa
33. *Elaphe helena* (Daudin)	Boidae	Trinket Snake
34. *Ptyas mucosus* Linnaeus	Boidae	Rat Snake
35. *Oligodon arnensis* Shaw	Boidae	Kukri Snake
36. *Ahaetulla nasutus* (Lacepede)	Boidae	Green Whip Snake
37. *Ahaetulla myctarijans* (Linnaeus)	Boidae	Bronze Back
38. *Lycodon aulicus* Linnaeus	Boidae	Common Wolf Snake
39. *Natrix stolata* Linnaeus	Boidae	Checkered Keelback
40. *Atretium schistosum* Daudin	Boidae	Olivaceous Keelback
41. *Dendrelaphis ahaetulla* (Linnaeus)	Boidae	Bronnze Back Snake
42. *Dendrelaphis tristis* (Daudin)	Boidae	Common Indian Bronze Snake
43. *Enhydris enhydris* Schneider	Boidae	Common Smooth Water Snake
44. *Cerberus rhynchops* Schneider	Boidae	Dog - faced Water Snake
45. *Gerardia frevostiana* Eydous & Gervais	Boidae	
46. *Bungarus caeruleus* Schneider	Elapidae	Common Indian Krait
47. *Bungarus fasciatus* Schneider	Elapidae	Banded Krait
48. *Naja naja* Linnaeus	Elapidae	Indian Cobra

Sub Order - Ophidia (Snakes)

Species	Family	Common Name
49. *Ophiophagus hannah* (cantor)	Elapidae	King Cobra
50. *Vipera russell* Shaw	Viperidae	Russell's viper
51. *Trimeresurus erythrurus* Cantor	Viperedae	Pit Viper
52. *Praesculata Viperina* Schmidt	Hydrophidae	
53. *Microcephalophis gracilis* Shaw	Hydrophidae	
54. *Microcephalophis cantoris* Gunther	Hydrophidae	
55. *Enhydrina schistosa* Daudin	Hydrophidae	
56. *Hydrophis nigrocinctus* Daudin	Hydrophidae	
57. *Hydrophis obscurus* Daudin	Hydrophidae	
58. *Hydrophis caerulescens* Shaw	Hydrophidae	

Order - Crocodilia (Crocodiles)

59. *Crocodylus porosus* (Schneider)	Crocodidae	Estuarine Crocodile

1.8.4.3. Amphibian Fauna of the Indian Sundarbans

The amphibian fauna are comparitively less in number in this frequently tidal inundated mangrove forest area. As the area is mostly influenced by saline water, the frogs, toads and other amphibians cannot find the area suitable for their habitat. So far, only 7 species of amphibians were identified and reported from this Sundarbans mangrove forest areas and tidal water ways. The amphibian fauna are enlisted in Table - 15.

Table - 15. Amphibian Fauna of the Indian Sundarbans

Name of the Species	Family	Common Name
1. *Rana cyanophlyctis* Schneider	Ranidae	Skipping Frog
2. *Rana tigarina* Daudin	Ranidae	Indian Bull Frog
3. *Rana limnocharis* Wiegmann	Ranidae	Paddy Field Cricket Frog
4. *Rana hexadactyla* Lesson	Ranidae	Pond Green Frog
5. *Microhyla ornata* Dumeril & Bibron	Microhylidae	Ornate Microhylid
6. *Bufo malanostictus* Schneider	Bufonidae	Common Indian Frog
7. *Rhacophorus maculatus* (Gray)	Rhacophoridae	Tree Frog

1.8.4.4. Birds of the Indian Sundarbans

Sundarbans has a very rich avi fauna. This vast avi-fauna can be further classified into resident, breeder, summer migrant, passage migrant, winter migrants and vagarant. This classification is based on how the birds use this mangrove habitat of Sundarbans. The habitat is also sub classified as per the preferred niche of the birds, *viz.*, flowing water with different salinity regimes, mud flats, sand banks, mud banks, sandy beach, tree forests in the beach, beach scrub forests, plantation forests on the beach, scrub mangroves, grasslands, fringe tree mangroves, inland tree mangroves, man – made structures, fresh water puddles and sweet water ponds. The survey of the avi - fauna was studied in detail during the study period. During the regular visits throughout the year (covering all seasons) in the Sundarbans and considering the available reports of bird surveys carried out by various bird watcher NGO's and ornithologists about 200 different species of birds have been reported from the Sundarbans particularly Sundarbans Tiger Reserve.

It has been observed that there was a monsoon - nesting ground at Sajnakhali covering 1.5 sq. km area of mixed heronary from middle June to late September. Birds mainly used *Avicennia officinalis* as their nesting ground. Reports indicate that the storm of 1988, which devastated the Sundarbans, had its toll on the big tree species of *Avicennia officinalis* and most of the trees lost their tops. Added to this the anthropogenic interferences due to Sajnakhali's proximity to human habitat areas and subsequent loss of eggs to poachers forced the birds to migrate further north to Jhilla. It has been noticed that Sajnakhali was the most preferred abode of the migratory bird species and ever since the loss of this particular niche the migratory groups have not been able to find another suitable habitat. In fact Sajnakhali Wildlife Sanctuary area continues to be a haven for water birds. It is also an important habitat for waders including the Asian Dowitcher, which is a rare winter migrant. Interesting marsh birds are reported from the reclaimed areas including Egrets, Purple Herons and Little Green Heron; also found are birds of prey including Osprey and White-bellied Sea Eagle. A variety of Terns and Kingfishers are very commonly seen on the large rivers and in flooded areas. The reason, why majority of these migratory groups do not travel far south in the Sundarbans can be attributed to the reigning saline conditions as most of these birds prefer sweet water. The avi-fauna forms an integral and important constituent of the ecosystem and play an imporant role in stabilising the trophic levels operating here. They not only enrich the soil and water phases by the faecal matter they release, but also keep a check on the insect population, which, if allowed to grow rapidly can destroy the canopy of the mangroves. Thus, bird conservation, *vis - a - vis*, conservation of their habitats is an important aspect for sustaining this ecosystem. Besides these, the birds attract tourists and bird watchers and add to the scenic beauty and glamour of this beautiful forest.

1.8.4.5. Important shell-fish and fin-fish species of the Sundarbans mangals

Fish, fisheries and fishing in the Sundarbans tidal estuaries, rivers, creeks and vast estuarine wetlands are very important in terms of rural economic set up and supply of cheaper protein food to the neighbours of the Sundarbans. Fish, prawn and crab species of the Sundarbans are transported to the local, as well as, the outside markets. The shrimp from Sundarbans is also exported to the International markets. Large number of rural people are engaged in the fishing activities and fisheries, which are the substantial source of earning.

Irrigation is not much developed in this lower part of Bengal; the traditional monsoon-fed rice cultivation is the main agricultural practice here. Moreover, here in this coastal areas the climate is very much hostile and frequent natural calamities cause frequent damage to the agricultural crop. Very often, the farmers have to face all such critical problems due to frequent floods, collapsing of the riverbank during cyclones and tidal thrusts. In these perspectives, lakhs of rural people have to depend on fishing in these estuarine rivers, canals, and creeks and in the off-shore fishing areas during winter months and occasionally through other periods of the year. Shrimp seed (*Penaeus monodon*) collection is also now the common occupation for lakhs of the rural women, men and even the children of the Sundarbans. The shellfish and finfish species collected from the waterways of the Indian Sundarbans are presented in Table - 16. Besides these fishing activities, about 40,000 ha brackishwater fisheries in this coastal Sundarbans areas are also available for culturing the brackishwater fish and shrimp species by traditional means. Some of the prawn farmers from the outside are now engaged in culture of export quality shrimp in semi-intensive practices. These in turn pollute the environment for discharging the untreated polluted fishery water in the side by open water canals and rivers. For the export demand, shrimp culture, *vis-à-vis*, collection of shrimp seed (*Penaeus monsoon*) ultimately damage the other less priced fish and prawn seeds. This has created tremendous detrimental effects and problems in the natural mangrove ecosystem. Besides these, capture of gravid shrimp (*P. monodon*) and mud crab (*Scylla serrata)* and export of the same to the foreign market has also created adverse effects or conditions by depleting the natural stock of these shrimp and mud-crab. These mud crabs take shelter in the mud holes in the mangrove forest floor and play important role in this ecosystem. But, for high demand for crab in the International markets the exploitation of this wild mud-crab are now threatening and hampering the natural balance. Until now, no artificial cultural practices or fattening of mud crab has proved economical in the Indian Sundarbans.

Netting with fine mesh nylon net on the rivers and river side forest lands of about 2 to 3 km length has also very adverse effect, as it kills or damages the juveniles of fish, prawn and shrimp species, indiscriminately. All these harmful, detrimental ecological damage require to be stopped on an urgent basis. Rules were framed against exploitation and damage of this coastal mangrove ecosystem, but the question of implementation still remains less attended.

Table - 16. List of Common Fish Fauna of the Indian Sundarbans

Common Fin - Fish Species

Class - Chondrichthyes

1. *Chiloscyllium griseum* Muller & Henle
2. *Stegostoma fasciatus* (Hermann)
3. *Carcharhinus limbatus* (Valenciennes)
4. *Glyphis gangeticus* (Muller & Henle)
5. *Eusphyra blochii* (Cuvier)
6. *Pristis microdon* (Latham)
7. *Rhinobatos anandalei* (Norman)
8. *Dasyatis bleekeri* (Blyth)
9. *Dasyatis zugei* (Muller & Henle)
10. *Dasyatis marginata* (Blyth)
11. *Dasyatis uranak* (Forsskal)
12. *Dasyatis sephen* (Forsskal)
13. *Aetobatus narinari* (Euphrasen)

Class - Osteichthyes

14. *Pelona ditchela* Valenciennes
15. *Scatophagus argus* (Linneaus)
16. *Streinateus sinensis* Day
17. *Pampus chinensis* (Euphrasen)
18. *Pampus argenteus* (Euphrasen)
19. *Cynoglossus cynoglossus* (Hamilton-Buchanan)
20. *Cynoglossus lingua* (Hamilton-Buchanan)
21. *Pama pama* (Hamilton-Buchanan)
22. *Daysciaena albida* (Cuvier)
23. *Nibea soldado* (Lacepede)
24. *Otolithoides biauritus* (Cantor)
25. *Johnius belangerii* (Cuvier)
26. *Johnius coitor* (Hamilton-Buchanan)
27. *Tenualosa (Hilsa) ilisha* (Hamilton-Buchanan)
28. *Tenualosa (Hilsa) toli* (Valenciennes)
29. *Ilisha elongata* (Bennett)
30. *Nematolosa nasus* (Bloch)
31. *Raconda russeliana* Gray
32. *Anodonstoma chaeunda* (Hamilton-Buchanan)
33. *Leiognathus blochi* (Valenciennes)
34. *Leiognathus equulus* (Forsskal)
35. *Leiognathus fasciatus* (Lacepede)
36. *Gerras oyena* (Forsskal)
37. *Gerreomorpha setifer* (Hamilton-Buchanan)
38. *Coilia dussumierii* Valenciennes
39. *Coilia neglecta* Whitehead
40. *Coilia ramcarati* (Hamilton-Buchanan)
41. *Coilia reynaldi* Valenciennes
42. *Setipinnia phasa* (Hamilton-Buchanan)
43. *Setipinnia taty* (Valenciennes)
44. *Corica soborna* (Hamilton-Buchanan)
45. *Gudusia chapra* (Hamilton-Buchanan)
46. *Stolephorus indicus (Van Hassett)*
47. *Trissocles hamiltonii* (Gray)
48. *Trissocles purava* (Hamilton)
49. *Chysocentrus dorab* (Forsskal)
50. *Boarius boarius* (Hamilton)
51. *Arius sona* (Hamilton-Buchanan)
52. *Thryssa purava* (Hamilton-Buchanan)
53. *Thryssa hamiltonii* (Gray)
54. *Megalops cyprinoides* (Broussoner)
55. *Anguilla bengalensis* (Gray & Hardwicke)
56. *Chanos chanos* (Forsskal)
57. *Acrichthys aor* (Hamilton)
58. *Mystus cavasius* (Hamilton-Buchanan)
59. *Mystus gulio* (Hamilton-Buchanan)
60. *Mystus vittatus* (Bloch)
61. *Rita rita* (Hamilton-Buchanan)
62. *Pangasius pangasius* (Hamilton-Buchanan)
63. *Plotosus canius* (Hamilton-Buchanan)
64. *Arius arius* (Hamilton-Buchanan)
65. *Arius gagora* (Hamilton-Buchanan)
66. *Arius jella* Day
67. *Arius sagor* (Hamilton-Buchanan)
68. *Arius sona* (Hamilton-Buchanan)
69. *Batrachocephalus mino* (Hamilton-Buchanan)
70. *Oesteogeniosus militaris* (Linnaeus)
71. *Harpodon nehereus* (Hamilton- Buchanan)
72. *Harpodon tumbil* (Bloch)
73. *Batrichthys grunnieus* (Linnaeus)
74. *Strongylura leiura* (Bleeker)
75. *Sillaginopsis panijus* (Hamilton-Buchanan)
76. *Sillago sihama* (Forsskal)
77. *Terapon jarbua* (Forsskal)
78. *Lates calcanifer* (Bloch)
79. *Valamugil speigleri* (Bleeker)
80. *Rhinomugil corsula* (Hamilton-Buchanan)
81. *Valamugil cunnesius* (Valenciennes)
82. *Awaonichthys menoni* (Chatterjee)
83. *Bathygobins orbicularis* (Visweswara Rao)
84. *Boleophthalmus boddarti* (Pallas)
85. *Brachygobius nunus* (Hamilton-Buchanan)
86. *Periophthalmodon schlosserri* (Pallas)
87. *Periophthalmus koelreuteri* (Pallas)
88. *Periophthalmus chrysospiles* Bleeker
89. *Periophthalmus malaccensis* (Eggert)
90. *Periophthalmus vulgaris* (Eggert)
91. *Periophthalmus weberi* (Eggert)
92. *Pseudapocryptes lanceolatus* (Bloch & Schneider)
93. *Scartelaos histophorus* (Valenciennes)
94. *Stigamatogobius sadanundio* (Hamilton-Buchanan)
95. *Kurtus indicus* Bloch
96. Trypauchen vagina (Bloch & Schneider)
97. *Eupleurogrammus muticus* (Gray)
98. *Trichiurus lepturus* (Linnaeus)
99. *Lepturacanthus gangeticus* (Gupta)
100. *Lepturacanthus pantuli* (Gupta)
101. *Lepturacanthus savala* (Cuvier)

Table - 16. List of Common Fish Fauna of the Indian Sundarbans (contd.)

102. *Polydactylus indicus* (Shaw)
103. *Ambassis nama* (Hamilton)
104. *Ambasis baculis* (Hamilton)
105. *Ambasis ranga* Hamilton
106. *Caranx carangus* (Bloch)
107. *Megalaspis cordyla* (Linnaeus)
108. *Lutjanus argentimaculatus* (Forsskal)
109. *Gazza minuta* (Bloch)
110. *Drepane punctatus* (Linnaeus)
111. *Etroplus suratensis* (Bloch)
112. *Scomberomorus commersoni* (Lacepede)
113. *Odontamblyopus rubicundus* (Ham.-Buchanan)
114. *Thycenophrya indicus* (L.)
115. *Platicephalus indicus* (Linnaeus)
116. *Colea bleekeri* (Bouleenger)
117. *Triacanthus brevirostris* (Temm & Sch.)
118. *Oryzias melastigma* (Mc. Chelland)
119. *Amphipnous cuchia* (Hamilton-Buchanan)
120. *Nandus nandus* (Hamilton-Buchanan)
121. *Elops saurus* (L.)
122. *Corcia sabomia* (Hamilton)
123. *Psiodonopsis boro* (Hamilton)
124. *Zenarchopterus dispar* (Valenciennes)
125. *Strongylura strongylura* (Van Hassalt)
126. *Xenentodon cancila* (Hamilton-Buchanan)
127. *Ambasis commersoni* (Cuvier)
128. *Lutjanus johni* (Bloch)
129. *Liza parsia* (Hamilton-Buchanan)
130. *Liza tade* (Forsskal)
131. *Liza macrolepis* (Smith)
132. *Mugil cephalus* (Linnaeus)
133. *Mugil oligolepis* (Bleeker)
134. *Eleutheronema tetradactylum* (Shaw)
135. *Polynemus paradiseus* Linn.
136. *Apocryptes bato* (Hamilton-Buchanan)
137. *Glossogobius giuris* (Hamilton-Buchanan)
138. *Gobiopterus chuno* (Hamilton-Buchanan)

Shell Fish

Class - Arthropoda; Order - Crustacea

1. *Carydina gracilipes* de Man
2. *Macrobrachium rosenburgi* (de Man)
3. *Macrobrachium malcomsonii* (Milne-Edw.)
4. *Macrobrachium lamarrei* (Milene-Edw.)
5. *Macrobrachium ruda* (Heller)
6. *Macrobrachium mirabili* Kemp
7. *Macrobrachium scrobiculum* (Heller)
8. *Macrobrachium javanicum* (Heller)
9. *Metapenaeus affinis* (Milne-Edw.)
10. *Metapenaeus brevicornis* (Milne-Edw.)
11. *Metapenaeus dobsonii* (Miers)
12. *Metapenaeus monoceros* (Fabricius)
13. *Palaemon styliferus* (Milne-Edw.)
14. *Palaemon tenuipes* (Henderson)
15. *Parapenaeopsis sculptilis* (Heller)
16. *Parapenaeopsis stylifera* (Milne-dw)
17. *Penaeus indicus* (Milne-Edw)
18. *Penaeus monodon* (Fabricius)
19. *Penaeus semisulcatus* de Mann
20. *Acetes indicus* (Milne-Edw)
21. *Acetes erythraeus* Nobilis

Order - Decapod

1. *Paratelphusa spinigera* (Wood-Mason)
2. *Paratelphusa jacquemontii* (Rothbun)
3. *Paratelphusa hydrodromus*
4. *Varuna litterata*
5. *Scylla serata* (Forsskal)
6. *Matuta plauipes* (Fabricius)
7. *Portunus pelagicus* (Linnaeus)
8. *Portunus sanguinolentus*
9. *Chrybdii rostata* (A.M.Edw.)
10. *Chrybdii orientalis* (Herbst)
11. *Chrybdii ornata* (A.M.Edw.)
12. *Chrybdii marguiensis* (de Man)
13. *Sesarma bidens* (de Man)
14. *Sesarma impressa* (M.Edw.)
15. *Sesarma taeniolatum* (White)
16. *Sesarum tetragona* (Fabricius)
17. *Sesarum edwadrsi* de Man
18. *Sesarum longipes* Krauss
19. *Sesarum quadrata* (Fabricius)
20. *Sesarum smithii* Edwards
21. *Metaplax crenulata* (Gerstaecker)
22. *Metaplax dentipes* (Heller)
23. *Metaplax distincta* H.M. Edwards
24. *Metaplax intermedia* de Man
25. *Metapograpsus maculatus* (Edw.)
26. *Metapograpsus messor* (Forsskal)
27. *Matuta victor* (Fabricius)
28. *Matuta lunaris* (Herbst)
29. *Calappa lophos* (Herbst)
30. *Dorippa facchino* (Herbst)
31. *Leucosia craniolaris* (Herbst)
32. *Ethusa indica* (Alcock)
33. *Hymenicus wood-masoni* (Alcock)
34. *Hymenicus inachoides* (Alcock)
35. *Philyra globosa* (Fabricius)
36. *Philyra globulosa* (Edwards)
37. *Doclea japonica* (Ortman)
38. *Doclea canalifera* (Stimpson)
39. *Uca acutus* Stimpson
40. *Uca lactea annulipes* (M.Edw.)
41. *Uca dussumieri* (M.Edw.)
42. *Uca triangularis* (M.Edw.)
43. *Macropthalmus pectinipes* (Guerin)
44. *Illyoplax gangeticus* (Kemp)
45. *Dottila blanfordi* Alcock
46. *Dotillopsis brevitarsis* (de Man)
47. *Ocypoda macrocienra* (M.Edw.)
48. *Scopimera globosa* (de Man)

1.8.4.6. Extinct, Threatened and Endangered Fauna of Indian Sundarbans

In the recent past, *i.e.*, not even a Century back, Sundarbans had under its jurisdiction a much larger area undivided by political barriers and unblemished by anthropogenic pressures and as such, this ecosystem could support a much richer and more diverse fauna. In the northern limits existed extensive swamp areas which used to be inhabited by megaherbivores 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 duvaueli*), sambar (*Cervus unicolor*), and the hog deer (*Cervus porcinus*) all of which have become extinct from this area. According to the Bengal District Gazetteer, by 1908 both the rhino and the buffalo had become rare and by 1914 the barking deer and hog deer were listed as uncommon. In Table - 17, an account of the threatened, endangered and extinct fauna of the Sundarbans Mangals has been given.

Table - 17. The extinct, endangered and threatened fauna of Sundarbans mangals

Scientific Name	Common Name	Status in the Sundarbans
Mammalia		
Rhinoceros unicornis	One-horned Rhino	Extinct
Rhinoceros sondaicus	One-horned Javan Rhino	Extinct
Bubalus bubalis	Water Buffalo	Extinct
Bos gaurus	Indian Bison	Extinct
Cervus duvaucelli	Swamp Deer	Extinct
Cervus unicolor	Sambar	Extinct
Cervus porcinus	Hog Deer	Extinct
Muntjanus muntjack	Barking Deer	Endangered
Panthera tigris tigris	Royal Bengal Tiger	Threatened
Felis bengalensis	Leopard Cat	Threatened
Felis viverrina	Fishing Cat	Threatened
Platinista gangetica	Gangetic Dolphin	Threatened
Orcaella brevirostris	Irrawady Dolphin	Threatened
Neophocaena phocaenoides	Little Indian Porpoise	Threatened
Manis pentadactyla	Chinese Pangolin	Threatened
Reptilia		
Crocodylus porosus	Estuarine Crocodile	Threatened
Lepidochelys olivacea	Olive Ridley Turtle	Threatened
Batagur baska	Batagur Turtle	Threatened
Lissemys punctata	Indian Flapshelled Turtle	Threatened
Trionyx gangeticus	Indian Softshelled Turtle	Threatened
Kachuga tecta	Indian Tent Turtle	Threatened
Varanus bengalensis	Common Indian Monitor	Threatened
Varanus flavescens	Yellow Monitor	Threatened
Varanus salvator	Water Monitor	Threatened
Python morulus	Indian Rock Python	Threatened
Avis		
Ardea goliath	Great Goliath Heron	Threatened
Pelecanus phillippensis	Dalmatian Pelican	Threatened
Leptotilos dubius	Lesser Adjutant Stork	Threatened

1.9. What makes Sundarbans mangroves unique

A lot of characteristrics and inherent specialities render the Sundarbans mangrove ecosystem as very unique and interesting. First of all, this deltaic mangrove ecosystem spread over the two neighbouring countries of India and Bangladesh represent the largest single chunk of mangroves in the world with highest biodiversity. The Sundarbans also represent the highest mangrove diversity in the world and represent a very high biodiversity in terms of other flora and fauna. Along with these the Sundarbans can boast of being the only mangrove tiger land on the face of this earth. The succession pattern observed in these mangrove areas is unique. The food webs operating in this ecosystem is very complex due to extensive overlapping within the trophic levels. The tidal amplitudes during the diurnal tides are very high. The Sundarbans estuarine system also act as sink for metropolitan pollutants released from the Kolkata Metropolis. Along with these, the Sundarbans mangrove ecosystem are a source of economic sustenance for the huge fringe area populations residing in the rural areas of Sundarbans, who have to depend upon these mangrove forests for their day to day needs.

1.9.1. Sundarbans Mangals - the largest single mangrove chunk of the Globe

Finlayson and Moser (1991) have reported that the total mangrove areas of the world to be about 14 million hectares. Out of these, the Old World tropical mangroves, *i.e.*, the Indo-West Pacific Tropical zones and Tropical Australia have the most dominant mangrove areas and mangrove species abundance along with its unique succession pattern. Finlayson and Moser (1991) have also reported that about 1.48 – 1.73 million acres or 6,00,000 – 7,00,000 ha mangrove cover area was present in the southern part of the four coastal districts of Bangladesh and two coastal districts of India, *viz.*, Khulna, Barisal, Noakhali and Chittagang of Bangladesh and 24 Parganas South and 24 Parganas North of India. These coastal zones are popularly known as Sundarbans, where good number of mangrove species grow gregariously. Mangrove species of the Sundarbans are estimated to be about 80% of total world mangrove species. This undivided Sundarbans mangal of Bangladesh and India spread over within the latitude 21°00′ N and 22° 31′ N and the longitude between 88°10′ E and 92°15′ E.

In the recent estimate it was shown that the total highest mangrove cover area is in Indonesia, which is about 42,510 sq. km., situated within the latitude 6°N and 11°S and longitude between 95°E and 141°E. The 2nd highest mangrove cover area present in Brazil, which is about 25,000 sq. km. and within the latitude 0° and 30°S and longitude between 30°W and 52°W. The 3rd dominant mangrove area present in the tropical and sub-tropical Australia, within the latitude between 8°S and 38°45′S and longitude between 115°E and 155°E, which cover about 11,500 sq. km. (Naskar & Mandal, 1999).

On the other hand, the total coverage under the mangroves in Indonesia is spread over in several countries and thousands of islands, *viz.*, Java, Sumatra, Sulawesi, Irian Jaya, Kalimantan and several other small to large islands; these Indonesian mangroves are also spread over both in the Indian and Pacific Oceans. Mangrove areas in the New World zones at Brazil and the Old World zones of Australia are more than Sundarbans, but these zones are scattered and mangrove species diversity in these areas is less than Sundarbans mangals. This undivided Sundarbans mangroves in Bangladesh and India is the single largest mangrove chunk of the world, where the mangrove species diversity is much more and important for harboring several endemic and threatened plant and animal species.

The mangrove area in the undivided Sundarbans, in the Ganga–Brahamaputra deltas, *i.e.*, the Hugly-Padma-Meghna mouths, grow very compactly in hundreds of deltaic islands; lies only within 21°00′N and 22° 31′N and the longitude between 88°10′E and 92°15′ E, which cover about 10,000 sq. km. These are very much dense and the species diversity there is higher than the other world mangals. Several endemic, threatened, endangered and rare flora and fauna are present in the Sundarbans mangals with their pristine glory. As such, IUCN included and ranked the Sundarbans mangals as the World Heritage Site, since 1984.

1.9.2. Highest bio-diversity of flora and fauna in the Sundarbans

During field survey and literature studies it was revealed that Sundarbans is the most important mangrove zone for its high biodiversity of flora and fauna. This ecosystem is not only the home to a large number plant components, *viz.*, mangroves, mangrove associates, back mangroves, beach flora, parasites, epiphytes (110 species published till date)[1] after further studies and collection till date 140 plant species were identified in the form of mangroves, mangroves associates, back mangroves and epiphytes on mangrove trees and shrubs and the list has been included in the Report; algal flora (150 species reported till date)[2], fungus (184 species reported till date)[3] and lichens (32 species reported till date)[4]; this ecosystem also sustains a diverse group of faunal components, *viz.*, mammals (41 species reported till date)[5], avi-fauna (200 species reported till date)[6], reptiles (60 species reported till date)[7], amphibians (7 species reported till date)[7] and fish fauna (about 140 species reported till date)[7]. All these flora and fauna are also in very much threatened condition due to heavy human pressure and over exploitation. It is felt as an urgent need to take effective measures for protection or conservation of these plant and animal diversity for the posterity of the future generations.

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1.9.3. Sundarbans mangals - the only mangrove Tiger-land of the World

The tigers of the World in the past were known to have a wide distribution stretching across Asia from Bali, through India, to the Russian Far East and West Asia, while origin of the tiger is Siberia. During early times there were 8 strains of tigers but presently there are only five strains surviving. Hunting, poaching and habitat destruction have taken their toll on the tigers through much of their previous preferred ranges. Most habitats are now isolated from each other, resulting in small patches of tiger habitats spread over the above mentioned range. Tigers feed predominately on large ungulates (hoofed mammals such as deer and wildcattle). They cannot survive if a habitat does not support sufficient densities of large ungulates. To meet its nutritional needs, a tiger must feed on a large ungulate approximately once every eight to ten days,and field studies suggest that an adult tiger requires a minimum of 3,000 kg of meat per annum to survive (Sunquist *et al*, 1999). A tigress raising cubs may need twice that amount.

Tigers are known to be solitary animals and require vast forest areas with a good prey base and water availability in which to roam, hunt and breed. Conserving the wild populations therefore requires protecting the quality of their habitat, as well as, their prey base. According to the Tiger Census of 2001, the Indian Sundarbans is presently home to 245 Royal Bengal Tigers (*Panthera tigris tigris*).The behaviour studies on the tigers of Sundarbans reveals a largely individual specific behaviour which cannot be generalized and is not replicable from the studies made on other tigers of the world or the country. Much used phrase - '*aberrations in behaviour of the Sundarbans tiger*' actually refers to the adaptation strategies of the tiger to a hostile land which renders it perpetually under stress. Sundarbans is not only a forest area but is also a deltaic area with huge water bodies in the form of rivers, creeks and canals, swamp and marsh land and also highly hostile forest beds. As such, the tigers in Sundarbans eat fish and crab, can swim very fast in the big rivers at the speed of about 60 km/hr., climb trees, drink salty water, take their prey in broad daylight, prey upon human beings and makes itself rarely visible though, tiger pugmarks are seen every where. All these render the Sundarbans tiger very strong, brave, ferocious and swift on land, as well as, water. For these reasons they are known world wide as the Royal Bengal Tiger. These make Sundarbans tigers a very unique and interesting group.

The mangrove forests of Sundarbans, however, provide a wide range of economic, social and environmental benefits to the fringe area people. These benefits contribute greatly to human welfare, but they are valued differently by different people and different groups. Tigers, as is evident, need extensive areas to hunt and breed thus protecting wild populations and sustaining their habitats will go into conservation of this majestic species. The role tigers play as a top predator of the food web operating in the Sundarbans mangals is vital in regulating and perpetuating ecological processes and systems. The Royal Bengal Tigers are large-bodied, obligate carnivores and usually come into conflict with humans by killing livestock and occasionally people. A further difficulty for conservation efforts is that these tigers occur in an area which has high incidence of rural poverty, high levels of human population density and growth and reports of fast forest degradation. Though, after the establishment of Project Tiger in the Sundarbans in the year 1973, forest boundaries appear to have stabilized, the major problem in conservation is most often related to how the fringe area people indiscriminately and unlawfully use the forest resources within the Buffer Area, Core Area, Primitive Zone, National Park and Wildlife Sanctuaries. The numerous forces threatening the tiger's survival in the Indian Sundarbans include poaching, prey depletion and habitat fragmentation due to land clearing, fuelwood and fodder extraction, smuggling for the illegal timber trade, honey collection, fishing activities including tiger prawn seed collection, etc. Tiger poaching and prey depletion are considered to be the most imminent threats to survival of the species in the short run.

1.9.4. Mangrove Zones and Succession in Different Stages

Most mangrove species are very much interesting for having specific ranges of salt tolerance. Different mangrove species have different ability for facing specific tidal inundation or frequent tidal floodings. They can also grow and survive in specific soil physical and chemical attributes along with distinct soil nutrient status. Several distinct mangrove species are distributed throughout the mangrove forests in different regions and geographical boundaries; all these are based on the availability of good number of reproducing mother plants or seeds, seedlings and specific soil physico-chemical properties, along with adequate tidal flushing and upstream fresh water discharge or frequent rains. Based on the specific land strata, tidal inundation nature, soil physical and chemical properties, position of the forest zone in the estuary, distance from the coastal areas or estuarine rivers and availability of viable seeds and seedlings, the Sundarbans mangrove forests and the successions of different mangrove species growing here are very distinct and characteristic.

Sundarbans, is the gradual silt deposited or silt accreted delta land, which has developed on different major estuarine river mouths or riverbeds; these are raised above 5m - 8m from MSL. During spring tides, most of the land in the Sundarbans mangals gets inundated with saline seawater, as because Spring Tide Water (HWSTL) rises up to 8m from MSL. During average and normal high tides (HWNTL) during most of the first moon and full moon periods, the tide water rises within 5m - 6m MSL. Consequently about 60% of the Sundarbans forest land gets inundated with the saline tidal water during these phases. During the rest of high tides, tidal rise occurs within 3m and 4m from the MSL and at that time about 35% – 40 % of these mangrove forest lands in Indian Sundarbans get inundated with this saline sea water. These delta lands and the characteristic mangrove forests are in dynamic stage (Sanyal, *et. al.*, 1984). Silt accretion, *vis-à-vis*, soil erosion and collapsing of this mangrove forest land is an ongoing continuous process, as frequent tidal inundation and water flow cause changes in the soil layer frequently. The stages of this delta land formations, tidal inundation nature, distance or position from the coast lines and availability of up stream fresh water source are different; as such, the soil and land types in different parts of the Sundarbans are identified as very distinct; where, succession of these different mangrove species in different intertidal and above tidal zones are also different.

Based on these above factors and causes, the following five categories of the Sundarbans mangrove zones and distinct mangrove successions were identified. These mangrove zones are - (i) Naked and vegetated river flats – ***1st zone***, ranges between Mean Low Water Neap and Mid Tide Lower Limit, *i.e.*, 2.14 m MSL and 4.42 m MSL; (ii) Dense and ridge mangrove forests – ***2nd zone***, within 5.0 m MSL, normal high tide water level; (iii) Ridged with dominant trees of mangrove forest species – ***3rd zone***, within 7 m MSL; (iv) Back mangrove area – ***4th zone***, beyond 7 m MSL and very occasionally inundate with high tide water during Spring Water High Tide and (v) Supra tidal zone- ***5th zone***, beyond 8 m MSL and very occasionally inundate with tide water. The mangrove species are found to decline in zone 5, and the mangroves are replaced by non-mangrove halophytes, mesophytes and xerophytic species. The climax phase of the mangrove succession is found in mature forests with gregarious

growth of *Phoenix paludosa* and fringes with *Excoecaria agallocha* and occasionally *Heritiera fomes*. In these mangrove succession stages, the important grass species, *Porteresia coarctata* is the pioneer species to grow on the newly silted up soil of the riverbeds; while, the pioneer and important mangrove tree species, *Avicennia* spp. and *Sonneratia* spp. grow on the river flat lands after silty soil is further consolidated by *Porteresia coarctata* (Roxb.) Takeoka. The **1st** succession zone inundates during all the high tides, 30 days in a month and twice in a day; **2nd** succession zone inundates with tide water during 20 days in a month and twice a day; **3rd** zone gets inundated during 15 days a month and the **4th** zone gets inundated only during 10 days in a month. In all the cases high tide inundates twice in a day. The **5th** succession zone normally does not get inundated with frequent tide water, except during exceptional or abnormal natural calamities and bow spring tides.

Due to different tidal inundation nature and position from the sea, along with factors related to existing sand, silt, and clay percentage and nutrient status of these different areas, different mangrove zones along with different mangrove species are formed. In these succession processes, the level of the accreted land rises up beyond the normal high tidal reach and the back mangrove species gradually appear. Felling of trees, shrubs and other deforestation activities in these upper elevated zones usually accelerate 'saline blank formation'; this is caused due to capillary movement of saltwater and successive evaporation of the surface water from the naked exposed soil surface. The water soluble salt remains on the surface soil and ultimately forms a salt crust. This formation of saline blank is also identified as a major problem in the mangals. Felling and deforestation in these mangrove zones is not advisable, as growth and regeneration of these mangrove trees is a very feeble and slow phenomenon.

From the critical field investigations, it is noted that in the Indian Sundarbans mangals the supply of fresh water on the eastern part is more than that of the western part. This has resulted in two distinct groups of mangrove habitats and distribution of different mangrove species in both eastern and western Sundarbans, within the Indian Territory. The central zone or islands form the transitory zone. The soil physical and chemical properties of these different zones are also distinct. Since 1974, due to increased fresh water discharge from the Farakka Barrage, the mouth region of the Hugly river has become less saline.

1.9.5. Trophic levels in the Sundarbans mangrove ecosystem

A major characteristic of all ecosystem in general is that the net production is either directly consumed as living material or is consumed later as dead material, likewise, it can be generalized that two different types of food chains are found to operate in nature - the Grazing Food Chain and the Detritus Food Chain. The food chains operating in the mangals of Sundarbans are of a complex type, with influx from both Grazing Food Chain and Detritus Food Chain. In the estuarine water it is a Detritus Food Chain operating, which begins with dead mangrove leaves (leaf litter) and other detritus that falls in, is blown in or washed down from the forest floor. These are transported by tides and currents over large areas of the bay. The leaf fragments, a very small amount of which is directly grazed upon by insects are acted upon by microorganisms, *viz.*, bacteria, protozoa and fungus and along with the algal forms of phytoplankton, benthos and periphyton are eaten and re-eaten by a key group of small animals, *viz.*, zooplankton (including rotifers, copepods, cladocerons and larval forms of molluscs and insects), nematodes, crabs, shrimps, small herbivorous fin - fish and molluscs. These animals though small in size make upto a large number of individuals. These are eaten by small fish, fish eating birds, fishing cats, snakes, water monitors etc.

Sundarbans a unique ecosystem in itself can be considered to be having a number of animals at the Top Consumer level, which includes the Tiger (*Panthera tigris tigris*), Estuarine Crocodile (*Crocodylus porosus*), Fishing Cat (*Felis viverrina*), Leopard Cat (*Felis bengalensis*), Common Jungle Cat (*Felis chaus*), Indian Python (*Python molurus*), Rusell's Viper (*Vipera russelli*), Pit Viper (*Trimeresurus erythrurus*), Common Krait (*Bungarus cacmleus*), King Cobra (*Ophiophagus hannah*), Indian Cobra (*Naja naja*), Large Indian Kite (*Milvus niigrans*), Whitebellied Sea Eagle (*Haliaectus leucogaster*) and Crested Serpent Eagle (*Spiloniis checla*). Interestingly these animals at the Top Consumer Level occupy different niches including terrestrial, aquatic, arboreal and aerial habitats. The units at different Trophic Levels do not restrict their movement in their respective territories but are usually found to migrate into each others terrains looking for food, *viz* , the tigers look for food in the aquatic environment, crocodiles look for terrestrial preys, monkeys find their food in the burrows of crabs, salvador lizards preys upon eggs of turtles in soil burrows and likewise. This kind of encroachment into others territories leads to increased overlapping resulting in a very complex ecosystem. Enrichment of trophic levels also occurs due to migration of different levels of animals from other ecosystems. The feacal matter and the organic matter of all these organisms go back into the ecosystem as detritus. Thus enriching the ecosystem which all the way goes into making these mangrove forests one of the most productive ecosystem of the World.

1.9.6. Tidal amplitude/ fluctuations of the Sundarbans mangals

The Sundarbans mangals are situated in the deltaic zones of the estuarine mouths, which are regularly under the influence of tidal regimes. The mangroves are well adapted to cope with the waves and currents of the marine and estuarine environments. However, the extent of current and tidal amplitude has it's influence on the floristic distribution of mangroves, mangrove associates and back mangroves. It also plays a decisive role in erosion and sedimentation prediction. Tidal amplitude and cycles have their effect on animal behavior and also govern anthropological activities in the forest areas like fishing, honey collection, timber collection, crab collection, catching of tiger prawn seeds, etc. For planning adequate protective measures it is necessary to study the nature of tidal impact, its cycles, rate of progress of tidal ingress and related factors including wave dynamics, littoral environment, near shore bathymetry etc., but collection of most of the relevant data regarding tidal fluctuations and amplitude through field measurement is prohibitive in time and cost. With the availability of satellite data, it is now possible to obtain useful data on land - form and land use changes, which is helpful for deciding management priorities. Tidal amplitude also has its impact on the interpretation of the land-form and land area data due to differences in the time of collection of these data by satellite imagery. A uniform and unanimous consensus is thus required through a common platform and holistic approach to arrive at a single decisive conclusion regarding land form, land area,species distribution, species diversity and tidal regimes in this ever changing ecosystem.

The deltaic Sundarbans experience semi-diurnal tides (*i.e.* two high tides and two low tides). The tidal amplitude and current has profound influence on the survival and growth of mangrove vegetation, it also influences the sedimentation and erosion processes. This tidal amplitude is in turn governed by quite a number of factors, including waves, wind direction, wind energy, season and temperature.

With the change of seasons, tidal interactions in the estuarine system in and around the Indian Sundarbans also change. During the monsoon months, the effect of flood tide is more or less countered and nullified by freshets and there is a strong predominance of ebb tide. The strength of flood tide over ebb tide is at a minimum during the post monsoon season. Conversely, during the pre-monsoon season, the effect of flood tide is considerably stronger than that of the ebb tide. During Norwesters, the wind speed rises considerably and is usually accompanied by huge tidal waves. When the cyclonic incidences coincide with the spring tides, wave height can rise over 7 m above MSL. Ripple waves appear in the month of October, November and December. In the month of April to August, large wavelets are formed in the shelf region and they start breaking as they approach the coastal margin. Wave height rises up to 2 m during this period, which causes maximum scouring on land masses. Wave actions, micro and macro-tidal cycles and long shore currents are recorded in most of the islands in this ecosystem.

1.9.7. Sundarbans mangals acts as the sink for metropolitan pollutants

Quite a substantial amount, on an average of 3,96,939 kg/ day of pollution load is discharged by the Calcutta Metropolitan city in the side by river system; out of these a very large part of it, *i.e.*, 22,900 kg/ day is diverted or released from the Calcutta Metropolis to the Hugli river directly and passes in the Sundarbans estuaries (Yadav, 1987). Enough evidences are also available that since 1939, different kinds of pollutants along with large volume of city sewage, different types of industrial effluent and waste water from the Calcutta Municipal Corporation have been indiscriminately discharged in the river Sakha Bidyadhari of Sundarbans (Kulti Gang), via (i) 33.8 km. Long Dry Weather Flow Channel (L.D.W.F. Canal), (ii) 35.40 km. long Storm Weather Flow Channel (S.W.F. Canal) and (iii) Town Headcut Pamarbazar Canal of 8.04 km. long (David, 1959). David (1959) also stated that the Sakha Bidyadhari or Kulti river no longer served as a seed source for culture fisheries, since 1939. On an average rate of 16.20 core gallon/ day sewage is discharged to the river Sakha Bidyadhari/ Kulti Gang, *via* Kulti Lock Gate at Ghushighata (Naskar, 1999).

This phenomenon is universal, as seen in the case of Rhine river of West Germany, during the month of November, 1986 the river water got entirely polluted due to toxic industrial discharges; which lead to death of all aquatic organisms; these river water pollution affected badly both the Germany and the Netherlands (Jadav, 1987).

The mangrove plants have high percentage tannin in their barks and leaves; mangrove plants can chelate some of the pollutants and its detrimental effect may be reduced naturally (Naskar and Mandal, 1999). Fortunately, the Coast Guard Act, 1978 provides measures for protection of coastal/ marine environment and over all control of marine environment; but implementation of all such rules and strict measure through mass awareness is must.

1.9.8. Sundarbans mangals - a source of economic sustenance for the rural population

Mangrove forests are the unique habitat for a good number of estuarine or brackish water species of fish, prawn, shrimp, crabs etc. The coastal dwelling people are solely dependent on these natural resources for their livelihood and comparitively cheap source of protein food. This is because mangrove forests provide nutrients to the estuarine and coastal water phases and also the organic manure in the tidal inundated mangrove forest floor provides a very unique breeding and grazing ground and nursery bed, as well, for good number of estuarine and off - shore species of fin - fish and shell - fish. Besides all these, the mangrove forests provide fuel wood, timber, poles and pillars or thatching materials to the rural and fringe area populations. Some times, the mangrove fodder are also important for the domestic cattle in this rural area. Mangrove flowers have plenty of nectar and the rock bee (*Apis dorsata*) use these during the winter months, *i.e.*, the blooming season of the mangrove flowers and large amount of sweet and scented natural honey is collected by the rural honey collectors from the Sundarbans. These mangrove forests of Sundarbans and elsewhere are important for diverse scenic beauty and natural abode of very interesting fauna, *viz.*, tiger, crocodile, deer, dolphin, etc. All these attract tourists who are the source of income to the rural people who cater to the tourism needs by providing their boat and guidance to the tourists.

1.10. Protection *vs.* Loss of Bio-diversity in the Indian Sundarbans

The Sundarbans mangal has been included within important conservation programmes by the State and Central Government for being an important 'World Heritage Site' and natural abode of vast group of the threatened mangrove species and mangrove dwelling fauna. For undertaking such conservation programmes, several National and International aided projects and conservation programmes were undertaken, since the year 1973. The 'Sundarbans Tiger Project' was initiated during 1973. Besides these, 'Bhagabatpur Crocodile Project' was initiated during 1976 and from the same year three 'Wildlife Sanctuaries' at Sajnakhali, Lothian Island and Haliday Island were declared. The 1,330 sq.km. core area of the Sundarbans Tiger Reserve was also declared as the 'National Park' during 1984 and in the same year the Sundarbans was considered as the 'World Heritage Site' by the IUCN. The 'Sundarbans Man and Biosphere Project' in the total area of 9,630 sq. km. has been functioning since the year 1989 .

In spite of all these efforts, the mangrove forest wood and timbers are exploited enormously and the poaching of the wild animals, *viz.*, tiger, deer, wild boars and birds could not be checked to a large extent, due to inadequate protection measures, non cooperation of the fringe area people and difficult access in these riverine mangrove forest zones of the Sundarbans. Inspite of all the existing Protection Acts and conservation measures, mangrove forest lands are still cleared for excavating shrimp farms, brick kilns, agricultural fields and human habitats. There is an urgent need for strict implementation of necessary measures by the local Government, *viz.*, the Gram Panchayet and local bodies like NGOs, local clubs, etc.

Taking these objectives under prior urgency, a 'Mangrove Ecological Museum', at CIFR Station, CGO Complex, Salt Lake, Calcutta-700 064 and a 'Mangrove Ecological Park' at Jharkhali, Sundarbans were set up during 1998 for creating awareness among the local people, students, administrators and the planners of Sundarbans. In the 'Mangrove Ecological Museum' and the 'Mangrove Ecological Park', the important mangrove plants and the collectible animal species have been displayed as samples, photographs, sketches and have been described for ready reference. In this effort, the Dept. of Environment, Govt. of West Bengal, Sundarbans Development Board and the Calcutta Wildlife Society - a NGO Body have supported the ICAR National Fellow for developing and highlighting the Sundarbans and its important mangrove ecosystem. These efforts have not only been highly acclaimed resulting in motivating two local clubs of the rural areas of Sundarbans to establish two 'Mangrove Ecological Museums' in the rural areas of Sundarbans. It is now well recognized that conservation of the Biodiversity in the Sundarbans is most urgent for the posterity of the threatened biota, production of fish for food and livelihood of the local people and protecting the existence of the Calcutta Metropolitan city from the devastating natural calamities in the long run.

1.10.1. Large scale deforestation of forest land for human settlements and needs in Indian Sundarbans

During the last two centuries, *i.e.*, since the later half of the 18th Century, more than 5,000 km² of mangrove forest area in the Indian Sundarbans alone were cleared and reclaimed for human settlement. Now, only 4,267 km² mangrove forest and river area exists out of 9,630 km² area of the Sundarbans Biosphere Reserve. Till date, several hectares of mangrove zones at Jharkhali (Tridiv Nagar), Henry's Island at Bakkhali, Jamboo Dwip and other areas are on the verge of reclamation and clearing, which is a very dangerous and alarming situation in the way for the existence of this vulnerable ecosystem.

In spite of large number of very effective projects and protection measures, the mangrove forests in Indian Sundarbans are on the verge of extinction and degradation, very rapidly. This is due to rapidly growing human population and for their large scale demand for fuel wood, timber and the livelihood from these natural resources. These rural poor people are mostly land-less day labourers and most of them are engaged in destruction and exploitation of these natural forest and estuarine resources for their day to day sustenance. The business men and the money lenders too involve them in these destruction activities; these moneyed men and selfish business classes engage the poor people for harvesting and exploiting mangrove timbers, fish, shrimp and other natural resources and the poor villagers and bonded labourers are rather forced to do these devastating activities taking every day risk of their lives. The protection measures and management practices are too inadequate to tackle these bio-diversity destruction activities, which is mostly controlled by the selfish people.

1.10.2. Large scale netting out of shrimp seeds *vs.* damage of the other juveniles

Lakhs of rural people in the Indian Sundarbans are self engaged in netting out the shrimp (*Penaeus monodon*) seeds from the vast estuarine rivers and canals with the help of scoop nets of 2m X 1m size or by bigger sized fine mesh nylon nets operated by country boats. Besides these, fine meshed nylon nets (charpata jal) of 1 km - 2 km are very often fixed on the river side during high tide to screen the large sized shrimp, prawn and other fish during low tide, and in the process, vast number of aquatic biota fish, prawn and shrimp juveniles are killed or damaged indiscriminately. These netting operations lead to large scale exploitation of other fish and prawn seeds and their juveniles are being killed and damaged. During these netting operations, the river dykes also get eroded very seriously and damage of the mangrove plantations and mangrove forests flora becomes inevitable. During these collection works rural women and children also spend major part of the day in the high saline river water which cause skin and other diseases and several other social problems are also inevitible due to this. All these activities are now noted to be very much detrimental to the existing ecosystem. Different people have estimated the prawn seed collectors from 1 lakhs- 4 lakhs due to lack of thorough and critical survey or estimation in this regard. But these damages caused during netting of shrimp seeds is also highlighted by different groups of people differently;

1. Some people opined that as there are no alternative livelihood or job security the rural people are rather forced to engage themselves in these activities. These groups of people have pointed out that without any alternative job provision this practice cannot be stopped and till date this practice is continuing without any preventive measure being taken by the Government or Public Sector.

2. Some others believe that these vast aquatic systems may not be damaged by his shrimp seed collection as the resource are plenty here.

3. And others believe that these collection systems are bound to stop when the availability of these shrimp seeds will go down due to shrimp mortality or other unexpected causes during cultural stages in the brackish water fisheries. These practices need to be avoided and stopped to restore social health and ecological balance of this ecosystem.

1.10.3. Large-scale operation of fine mesh nets and exploitation of fish juveniles

Fishing by fine mesh nylon nets and exploitation of the fish, shrimp, prawn and other estuarine fauna and juveniles are largely practiced in the Sundarbans estuaries. Besides these, fishing of gravid fish, shrimps, prawns, crabs during breeding period is not checked in spite of existing strict rules and existence of laws and regulations.These uncontrolled rural practices enormously damage the biota of the estuarine environment in Sundarbans. These need protection and control measures through mass awareness programmes.

1.10.4. Siltation on river bed cause frequent flood and over flow of the rivers

Siltation on the riverbed is also alarming, which causes frequent flood and over flow of the estuarine rivers and subsequently saline water frequently enters the human settlement areas and the agricultural fields. This alarming situation happens every year, in some place or the other in the Indian Sundarbans and the poor rural people suffer a lot by losing their expected crop, domestic cattles and residential houses. This river bed siltation can also be considered a result of the rapid rate of deforestation activities in the upstream river bank forests, mangrove forest zones and barraging or closing of the upstream flowing rivers and canals. Besides all these, the tilting effect of the Ganga (Hugli) water flow due to neo-tectonic movement of the Ganga river from western part in West Bengal towards the eastern part in Bangladesh causes serious problems in the Indian Sundarbans, this is due to decreased supply of sufficient or adequate upstream freshwater in the Sundarbans mangals throughout the year.

1.10.5. Uncontrolled population growth and very marginal socio-economic status

During 1951 census, the population of the Indian Sundarbans was only about twelve lakhs and during 1991 census this rural population in Sundarbans amounted to about 32 lakhs. This has further been estimated to be more than 40 lakhs during the end of 21st Century. But, the agricultural land and production from agricultural fields and brackishwater fisheries has almost remained static. As such, the question arises as to how this ever increasing population will survive in the problem stricken land, where agriculture is not much developed and uncertain for lack of adequate irrigation facilities. Obviously, pressure on the natural forest ecosystems and natural resources of the Sundarbans mangals will increase, day by day. Thus, the foremost steps towards any conservation programme in the Sundarbans mangals must include introduction of strategies for effective population control, specially in the fringe areas to reduce anthropogenic pressures on the ecosystem.

1.10 6. Pressures on the natural forest is enormous and destruction is inevitable

Sundarbans rural areas suffer from heavy population pressures and very less scope for perennial engagement in the agriculture fields, also there are no industries in these areas, as such, the opportunity for employment for the people of Sundarbans is scarce. As such, these rural poor people enter the mangrove forests in search of fuel wood, timber, honey and wax, fish, prawns and crabs, taking life risks. The large scale interaction and dependence of at least 10-12 lakhs rural people on these Sundarbans mangrove forests and estuarine water bodies for extracting the natural forest and estuarine resources have turned the mangal ecosystem poor. Thus the natural resources of the mangroves are sharply declining here.

1.10.7. Developmental activities without assessment of environmental impact

Every developmental activity in the interest of human society is very important, but care should be taken that development must not affect the ecosystem, particularly if the ecosystem is fragile, vulnerable and important in respect of being unique habitat of threatened or endangered biota. Sundarbans in West Bengal is such a vulnerable ecosystem. As such, the Environment Department, Govt. of India and Govt. of West Bengal have declared the mangrove forests of Sundarbans within the Coastal Regulatory Zone – I (CRZ – I); furthermore, within this CRZ – I any developmental activity is strictly banned. Protection rules exist, but protection practices and strict conservation measures are not enough. In most cases, the interest of the common people *vis - a - vis*, developmental issues of these remote areas are highlighted, by tactfully ignoring the consequent damages on the ecosystem. As such, steps should be taken for undertaking strict conservation measures in a holistic manner. In this way, if any developmental work is hampered for the sake of conservation activities in Sundarbans areas, it should be remebered that it is worth it and is much more desirable for the long run interest and sustainable resource management of this ecosystem.

1.11. Transport facilities is not much developed in Sundarbans

Manually operating country boats, mechanized country boats (*Bhat Bhati*) and occasionally motor launches are the main means of transport from island to island. Because of this poor transport facilities the timely marketing of fish, vegetable, rice and other local produces becomes problematic. Health schemes, education facilities, entertainment opportunities, cultural-aesthetic scopes and others in Sundarbans remain neglected due to lack of proper transport facilities. However, in recent times steps are being taken to improve transport facilities in the rural areas of Sundarbans but still the question arises about how these improved facilities will reflect upon the well being and posterity of this fragile mangrove ecosystem.

1.12. Agriculture is not much developed due to lack of irrigation facilities

The mangrove reclaimed tidal delta initially developed as silted up river flat lands surrounded by number of criss cross tidal rivers, canals and creeks; through these tidal water ways, flows highly saline sea water. As such, there was no freshwater river or any such reservoir, where the rain water or the upstream freshwater could be stored for utilisation during the dry summer months. Besides these, the underground non saline freshwater remain in much deeper zones, which is difficult to pump out for irrigation in the agricultural fields. Electricity is also not available in the remote areas of the different deltaic islands in Sundarbans. Furthermore, adequate measures have not been taken to develop the substitute for all these difficulties and to overcome these problems through water shed management programmes. As such, agriculture in Sundarbans is still dependent on monsoon precipitation, which is concentrated during 4–5 months in a year, *i.e.*, during middle of June to the middle of October. During rest of the year, rain is irregular and based on these routine agriculture cannot be practiced in the proper sense. Agricultural lands in Sundarbans are very fertile, but occasional salinity and lack of adequate irrigation, proper selection of crops, non - availability of storage and marketing facilities worsen the situation.

1.13. Renewal of Natural Wealth and the Prospects of Sundarbans Mangals

A much discussed issue is that nothing is sustainable in this Universe. Though it is correct, but it should not imply that exploitation of the natural resources should, within a very limited period of time, exploit the natural resources without maintaining its basic stock for future availability. Nature has the great power of renewing its resources, but all the activities related to exploitation should follow some process and provide adequate time for renewal. In this connection, it is most urgent to ascertain the basic stock and its renewal abilities. Taking these consideration in mind, extraction or harvest and exploitation activities may be undertaken for natural resources. Such prior considerations and planned exploitation measures should help in long term benefit building and sustenance of the ecosystem. The harvest of forest wood and timber from the slow growing trees of Sundarbans mangals and the large scale collection of *Penaeus monodon* juveniles and destruction of other fish and prawn seeds in Sundarbans estuarine systems are detrimental for these forest ecosystem. As such, all these need to be considered very sympathetically and logically without taking any biased opinion and optimistic arguments. Development is must for every society, but it is not desirable to destroy and destruct the natural ecosystem and resources without thinking about its renewal and rejuvenation.

1.14. Major problems in the Indian Sundarbans

Following major problems were identified during field studies in the Indian Sundarbans, these are:

1. Large scale destruction of forest land, deforestation of mangroves for human settlements and rapid growing needs;
2. Management problems: Protection *vs.* loss of Bio-diversity in the Sundarbans is acute;
3. Self engagement of vast rural people in the large scale netting out of shrimp seeds *vs.* exploitation and damage of other fish, prawn and crab species and damage of river dykes and mangrove forest areas have created lot of problems and degradation of aquatic fauna ;
4. Large scale operation of fine mesh nylon nets and exploitation of estuarine fish juveniles indiscriminately, create problems towards loss of aquatic species diversity;
5. Siltation on the river bed is alarming, which also cause frequent flood and over flow of the estuarine rivers and frequent saline water ingress in the human settlement areas and on the agricultural fields;
6. Transport facilities is not developed, only the country boats are common means of transport;
7. Uncontrolled population growth and very marginal socio-economic status of the rural people of Sundarbans is the main cause for all these aforesaid problems;
8. Agriculture is not much developed in this areas due to lack of irrigation facilities, though these zones are very much potential;
9. As such, pressure on the natural mangrove forest is enormous and protection of forest resources is not manageable.
10. Last but most common problem is that the Sundarbans is a frequent and severe cyclone prone area.

In this context, mention may be made that these cyclones and the other natural calamities are inevitable and the mangrove forests cannot altogether stop these natural phenomenon, but can protect as buffer and minimise the devastating effects of these natural calamities in this deltaic region.

As such, prior to undertaking any developmental activities in this coastal region, due considerations should be taken for proper planning and strict conservation or management practices for this important but threatened mangrove ecosystem.

1.15. Recommendations for future strategies

General Recommendations

1. Embankment of the shores and river banks need to be strengthened and more river flat area should be kept inside the river dyke with dense plantation of different mangrove species within the inter tidal zone.
2. Irrigation system, coastal zone management, afforestation and plantation programme need a lot of attention in these estaurine and coastal areas. These jobs must be undertaken with prior consideration of other consequences.
3. Pollution free freshwater supply need to be accelerated and effective measures in this regard need to be undertaken.
4. Foreign trawlers should be banned and capture of gravid prawn and fish need to be checked.
5. Complete co-ordination among he Universities, Research Organisations and NGO's should be ascertained in order to avoid duplication of research work.
6. Awareness should be generated among the people through mass awareness campaign.
7. Directory of Bio-data of Sundarbans workers should be compiled and printed.
8. A committee in conjuncture with Panchayet should be made for controlling prawn seed collections.
9. Open Tourism should not be encouraged and killing of wild animals should be checked.

Scientific Recommendations

1. Gradual and rapid siltation on the river bed - its causes, effects and possible remedial methods or suggestive recommendations need to be focussed and highlighted.
2. Formation of 'saline blank' is a major problem, these need to be converted with suitable plant coverage, without jeoardising the indigenous ecosystem for the conservation of this 'World Heritage Site'.
3. Study methods for changing salinity regimes in the different zones of Sundarbans in need to be standardised.
4. Methodology for studying tidal regimes in different parts of Sundarbans need to be ascertained to know the effect of tidal regimes on the presence or absence of specific plant species.
5. There is urgent need to undertake critical survey and identification of the cryptogamic flora, *viz.*, algae, fungi, lichens, bryophytes and pteridophytes, which are associated with these Sundarbans mangroves.
6. The microbial flora, *viz.*, bacteria, fungus and protozoa need to be studied extensively along with their role in the detritus food chain.
7. The medicinal values of different mangrove flora need to be studied critically along with introduction of more medicinal species in Sundarbans and establishment of experimental medicinal plant gardens in the saline tract of Sundarbans.
8. Development of mangrove gardening with the total available mangrove species are essential for interpretation among the students and researchers and also to the interested people. More emphasis and care is required to transplant the threatened and endangered species and to preserve these species in their own habitat. Also efforts on introduction of other mangrove species from other parts of India and abroad, which are not available in the Sundarbans need to be undertaken for fulfilling this aim.