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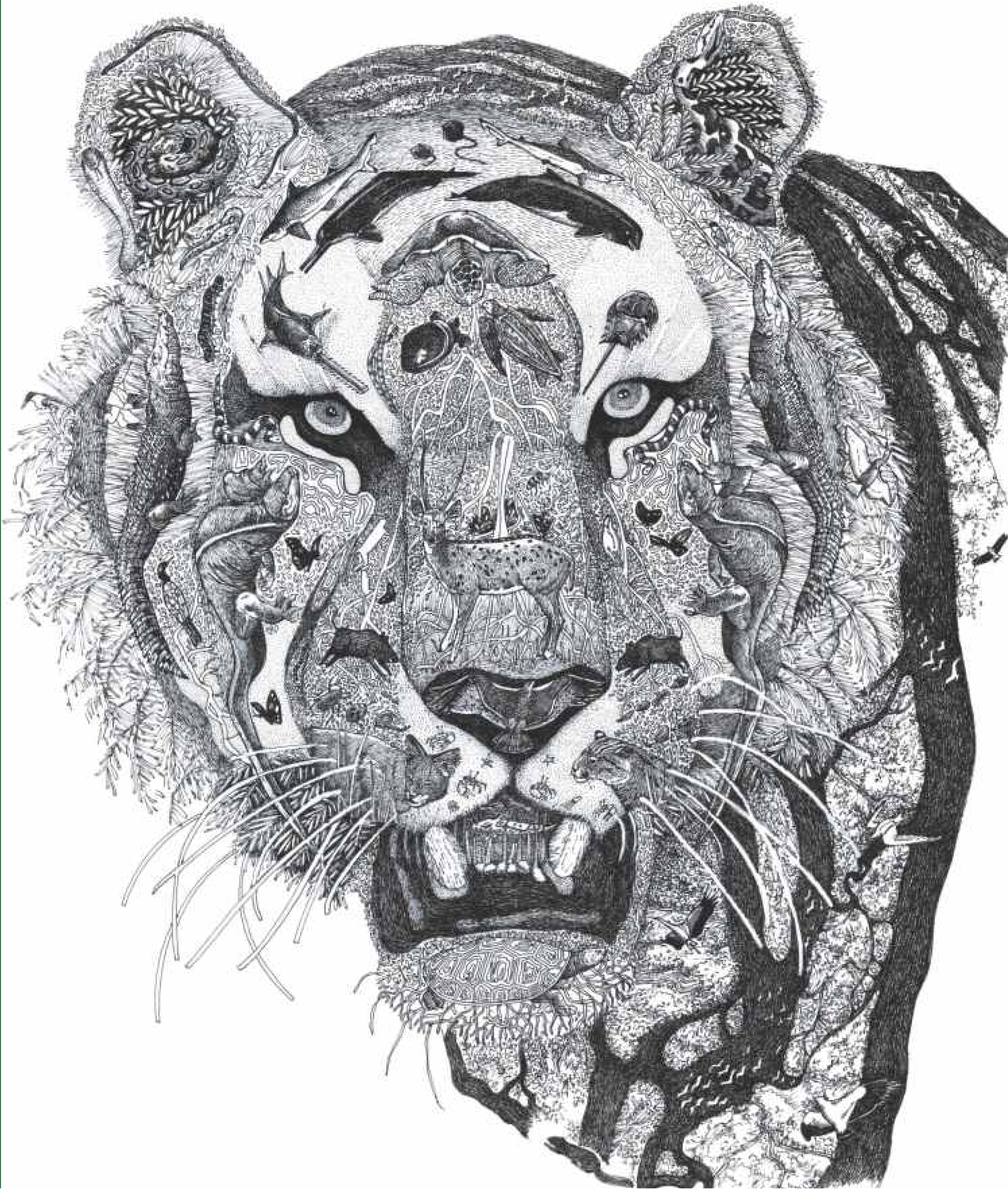
State of Art Report on Biodiversity in Indian Sundarbans



State of Art Report on Biodiversity in Indian Sundarbans

Editors
A. Anurag Danda, Anupam Joshi, Asish Kumar Ghosh and Ratul Saha

Coordinator
Ratul Saha

Contributors
Amales Misra, Anindita Mitra, Anirban Roy, Anirudha Dey, Asok Kanti Sanyal, Chandan Surabhi Das, Dipankar Saha, G.P. Sinha, Joydeep Mukherjee, Kaushik Deuti, Kushal Mookherjee, M. K. Dev Roy, Neera Sen Sarkar, N. C. Nandi, Punyasloke Bhadury, P.Venu, Ratul Saha, Rina Chakraborty, Subrat Mukherjee, Sujit Chakraborty and Tapan Kumar Chatterjee

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Illustrations
Arnab Roy

Maps
Abhijit Choudhury

Photographs in addition to authors
Anjan Guha, Arijit Banerjee, Arjun Kumar Manna, Debmalya Roy Chowdhury, Pankaj Kumar Sarkar, Satyaranjan Behra, Soma Saha, Soumyajit Chowdhury, Subhro Sen and Sunit Kumar Das

Designing
www.dsdesignclub.in

Processing & Printing
JS Print O Pack

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LIST OF CONTRIBUTORS

Microbes

ANINDITA MITRA

Post-Doctoral Fellow, Max-Planck Research Institute in Garching, Germany

JOYDEEP MUKHERJEE

Reader, Department of Environmental Studies, Jadavpur University, Kolkata

Algae

NEERA SEN SARKAR

Assistant Professor, Dept. of Botany, University of Kalyani, Kalyani

Planktons

PUNYASLOKE BHADURY

Assistant Professor, Dept. of Biological Sciences, Indian Institute of Science Education and Research – Mohanpur

Lichens

G.P. SINHA

Scientist –D, Botanical Survey of India, Central Regional Centre, Allahabad

Mangrove and associated flora

SUBRAT MUKHERJEE

Field Director, Sunderban Tiger Reserve, Canning

NEERA SEN SARKAR

Assistant Professor, Dept. of Botany, University of Kalyani, Kalyani

ANIRBAN ROY

Research Officer, West Bengal Biodiversity Board, Kolkata

P. VENU

Scientist - F, Central National Herbarium, Botanical Survey of India, Howrah

Protozoa

N. C. NANDI

Scientist-F (Retd.), Zoological Survey of India, Kolkata

Mollusca

ANIRUDHA DEY

Emeritus Scientist, Zoological Survey of India, Kolkata

Polychaetes

AMALES MISRA

Scientist-C (Retd.), Zoological Survey of India, Kolkata

Xiphosuran

DIPANKAR SAHA

Senior Scientist & Head- Air Laboratory Division, Central Pollution Control Board, Delhi

Crustacea

M. K. DEV ROY

Scientist-B, Zoological Survey of India, Kolkata

Araneae

RATUL SAHA

Coordinator- Biodiversity Conservation, WWF-India: Sundarbans Program, Kolkata

Acarina

ASOK KANTI SANYAL

Scientist-F, Zoological Survey of India, Kolkata

Insects

RATUL SAHA

Coordinator- Biodiversity Conservation, WWF-India: Sundarbans Program, Kolkata

Coastal fishes

TAPAN KUMAR CHATTERJEE

Scientist-E (Retd.), Zoological Survey of India, Kolkata

Herpetofauna

KAUSHIK DEUTI

Scientist, Zoological Survey of India, Kolkata

Aves

KUSHAL MOOKHERJEE

Secretary- Prakriti Sansad, Kolkata

Mega-Fauna

SUBRAT MUKHERJEE

Field Director, Sunderban Tiger Reserve, Canning

Small Mammals

SUJIT CHAKRABORTY AND RINA CHAKRABORTY

Emeritus Scientist, Zoological Survey of India, Kolkata

Human Wildlife Conflicts in Sundarbans

CHANDAN SURABHI DAS

HOD- Dept. of Geography, Taki Government College, North 24 Parganas

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EDITORS' NOTE

Objectives and Scope

The Sundarbans forest is the largest mangrove forest ecosystem in the world. It is home to much of India's irreplaceable biodiversity, including the Gangetic river dolphin, estuarine crocodile, Indian python, and the iconic Royal Bengal Tiger. The Sundarbans' tiger population is, quite possibly, the world's best hope for preventing the extinction of tigers in the wild since they are one of the largest, best-protected, and most-contained populations of wild tigers.

In addition to harboring tremendous biodiversity in terms of bird, insect, and fish species, it also serves several vital ecological functions. The Sundarbans is the nursery ground for roughly 90 percent of the aquatic species on the east coast of India; the livelihoods of millions of fisher people are directly dependent on its continued health. It also serves as a physical bio-shield, attenuating the wind and wave energy of the ravaging Bay of Bengal cyclones that are otherwise capable of threatening the millions of people who live on the outskirts of Kolkata.

However, there are also very few biodiversity hotspots that face the sort of existential threats that are now confronting the Sundarbans: it is sandwiched between a densely populated and extremely poor rural area and a rising sea. The Sundarbans faces both climactic and demographic challenges that, left unchecked, will drastically reduce the biodiversity of the forest ecosystem.

If the forest is going to survive until the year 2100, it will need to successfully navigate every challenge that the 21st century has to offer: population pressure, spatial transformation, excessive resource extraction, salinization, sea-level rise, and climate change.

The Sundarbans is one of the only global biodiversity hotspots situated within the metropolitan region of a tier-one city. Already, the suburbs of Kolkata—whose metro region, with 14 million inhabitants, is the 3rd largest in India and the 14th largest in the world—are moving toward the western flanks of the mangrove forest.

Aside from urbanization, the Sundarbans' populated fringe is a densely inhabited rural area that is subject to incredible poverty. For instance, out of every 1,000 inhabitants of the Indian Sundarbans area, 190 eat just one meal a day and 510 are malnourished. When Cyclone Aila hit in 2009, 250 out of every 1,000 residents were subject to flooding when nearby embankments collapsed. Only 12 out of those 250 had access to any kind of cyclone shelter.

This poverty, combined with periodic natural disasters arising from the powerful cyclones that sweep into the area from the Bay of Bengal, contributes to a situation in which a resource-strapped and highly vulnerable population is often forced to fall back upon forest resources, exploiting them illegally simply to survive. Fishing, firewood collection, and other resource harvests are major drivers of biodiversity loss.

Even if the Sundarbans manages to escape damage from population pressures, it also faces serious climate-related threats. The entire Sundarbans delta is currently sinking at a rapid rate. Climate-fueled sea-level rise is expected to significantly exacerbate the current rate over the next 100 years. Since, the ecological balance of a mangrove forest hinges upon periodic inundation, this would ordinarily not be a problem; the forests would just shift to find the new intertidal region. However, the borders of the forest are currently fixed by government mandate. Outside the current boundaries, there is no forest protection.

Furthermore, the regions that flank the forests are densely inhabited and under extensive cultivation. With no room for movement, it is expected that rising sea levels will result in shrinking forest area and damage the ecological balance. Additionally, upstream impacts are also affecting salinity of the river waters that fuel the delta. As salinity increases, plants face conditions to which they are ill adapted, resulting in decreasing forest cover and biodiversity.

However, the custodians of this ecosystem have only a very slim budget for dealing with these challenges. India and Bangladesh face many demands for their resources, and they, not unreasonably, prioritize those areas that seem to have the best chance of measurably improving the lives of their citizens. The biodiversity of the Sundarbans forest is a priceless resource that provides immeasurable benefits to every person in the world, but there is, as yet, no mechanism for the rest of the world to pay one of the world's poorest regions for the costs of preserving that biodiversity.

Nonetheless, the governments of India and Bangladesh have made serious efforts to preserve the Sundarbans forest. Both countries have set up mechanisms to protect valuable ecosystems and protect them from development, and they are active participants in major international measures and initiatives on environmental issues.

In recognition of the gravity of the situation in the Sundarbans, the government of the People's Republic of Bangladesh, the government of India (GoI), and the Government of West Bengal (GoWB) are attempting, with World Bank support, to identify interventions that respond to the development challenges of the Sundarbans region.

Their objective is to identify which of the ecosystem's challenges are the direst and which ones can be addressed in the most

[1]Because of their protected status, the Indian and Bangladesh Sundarbans forests do not have any permanent inhabitants. However, roughly 7 million people live within 20 km of the forest's boundaries. This population came to be settled in the region as reclamation of the Sundarbans mangrove in the lower Ganga Brahmaputra Meghna delta started in the 1770s (Pargiter 1934). Due to unauthorized reclamation, during 1831–32, a line was drawn to delineate settled agricultural area from the forested part of the Sundarbans region in India. This came to be known as the Dampier-Hodges line, south of which is the Indian Sundarbans region covering approximately 9,630 km^2 of land and water area including the forests spread over 4,263 km^2.

effective way. Although work first began in the Indian Sundarbans at the end of 2009, a similar effort began in the Bangladesh Sundarbans soon after in 2010. Both efforts have proceeded in parallel. The work in each country was carried out using substantively similar methodologies and by many of the same specialists. They were informed by each other's results and came to fairly similar conclusions. This book is an outcome of those activities.

Creating an Inventory of the Sundarbans' Biodiversity.

To formulate a plan for dealing with these threats, the governments of India and Bangladesh decided to undertake a broad-ranging analysis of the current state of biodiversity in the Sundarbans. To achieve this objective, a group of experts was selected to provide stand-alone reports covering numerous topics ranging from microbes to flowering plants and from unicellular organisms to mammals. At every stage, terms of reference were vetted by government officials from federal and state agencies. This study used field visits, stakeholder workshops, discussions with village-level focus groups that comprised different forest user groups, consultations with government officials and specialists, and apparent flora and fauna observations. Workshops and public consultations were also held to solicit the opinion of the public on the emerging findings of these studies. In addition, an analysis of existing secondary information, consisting mainly of reports, scientific publications, and maps was also carried out.

This compendium is the outcome of that task and serves as a first-of-its-kind detailed baseline of biodiversity of the Indian Sundarbans and provides a critical evaluation of the current state of biodiversity in the area. Its objective is to combine a detailed assessment of the current status of this threatened ecosystem with a sober assessment of policy options for mitigating further loss of biodiversity. It contains the following chapters:

Introduction - This chapter provides a summary of the overarching ecology of the Sundarbans. It describes the dynamics of mangrove ecosystems and the complex interplay of conditions under which these intertidal regions can continue to thrive.

Sundarbans Biodiversity Groups - Eighteen sub-chapters on biodiversity groups that range from microbes to fish to insects and birds to megafauna. Each is written by an internationally recognized expert on the topic and each details (a) the status of the group within the Sundarbans; (b) how that status compares to the group's status within the world at large; (c) the threats faced by that group within the Sundarbans; and (d) knowledge gaps that could be filled and policy options that could be implemented to protect the group.

Ongoing and Predicted Impacts on Biodiversity - This chapter synthesizes and contextualizes current knowledge on the threats that face the Sundarbans: climate change, sea level rise, salinization, population pressure, and many more. As far as the data allows, the chapter attempts to put these threats in perspective and rank them according to priority.

The Way Forward - This chapter summarizes the findings of the biodiversity analysis. The chapter sets forth a research program for completing a truly comprehensive analysis of the Sundarbans' ecosystem and also brings in the broader policy perspective and tries to envision a sustainable future for the Sundarbans. It examines the relative priority of the threats faced by the ecosystem and sets forth options for policy makers who are seeking cost-effective ways to address those threats.

1 INTRODUCTION

The Sundarbans forest is one of the world's most valuable biodiversity hotspots, but there is also not a single threat that it does not face: it is sandwiched between a densely populated and extremely poor rural area and a rising sea.

If the forest is going to survive until the year 2100, it will need to successfully navigate every challenge that the 21st century has to offer: population pressure, excessive resource extraction, salinization, sea level rise, and climate change. Exacerbating these challenges is the cash-strapped nature of the organizations that are tasked with preserving the forest. India and Bangladesh face many challenges and demands for their resources, and they, not unreasonably, prioritize those areas that seem to have the best chance of measurably improving the lives of their citizens. The biodiversity of the Sundarbans forest is a priceless resource that provides immeasurable benefits to every person in the world, but there is, as yet, no mechanism for the rest of the world to pay one of the world's poorest regions for the costs of preserving that biodiversity.

Nonetheless, the governments of India and Bangladesh have made serious efforts to preserve the Sundarbans forest. Strategies of the two countries for the conservation of priceless ecosystems include providing special status and protection. Their commitment to conserving biodiversity is apparent in their participation and involvement in major international measures and initiatives on environment issues, including the Convention on Biological Diversity. The key objectives of the convention are conservation of biodiversity, sustainable use of biodiversity components, and fair and equitable sharing of benefits arising out of the utilization of genetic resources. In accordance with the convention, India enacted the Biological Diversity Act (2002) while Bangladesh prepared the National Biodiversity Strategy Action Plan (2004).

Realizing the criticality of the situation and the need to ensure conservation of the rich biodiversity of the Sundarbans forest along with enhancing the socioeconomic profile of the region, the government of the People's Republic of Bangladesh, the Government of India (GoI), and the government of West Bengal (GoWB) requested World Bank support to design a comprehensive program that responds to the development challenges of the Sundarbans region through non-lending technical assistance (NLTA). The NLTA supported the preparation of various studies that would enable the governments to develop strategic action plans that integrate clearly defined and prioritized interventions to address (a) protection of life, property, and assets; (b) income growth and poverty reduction; and (c) biodiversity conservation.

The objective of the work carried out under the NLTA was to identify which of the challenges mentioned above were the direst and which ones could be addressed most effectively. Although work first began in the Indian Sundarbans in June of 2009, a similar effort began in the Bangladesh Sundarbans soon after. Both efforts proceeded in parallel and ended at roughly the same time, in the third quarter of 2012. The studies were carried out using substantively similar methodologies and by many of the same consultants and contractors. They were informed by each other's results and came to fairly similar conclusions.

In both countries, initial reports on the status of biodiversity in the Sundarbans were developed to provide a critical evaluation of the current state of biodiversity in the area. To achieve this objective, a group of experts was selected to provide stand-alone reports covering numerous topics ranging from microbes to flowering plants and from unicellular organisms to mammals. At every stage, terms of reference were vetted by government officials from federal and state agencies. This study used field visits, stakeholder workshops, discussions with village-level focus groups that comprised different forest user groups, consultations with government officials and specialists, and apparent flora and fauna observations. Workshops and public consultations were also held to solicit the opinion of the public on the emerging findings of these studies. In addition, an analysis of existing secondary information, consisting mainly of reports, scientific publications, and maps, was also carried out.

As part of the NLTA biodiversity study, World Wildlife Fund (WWF) India was assigned the task of preparing a state-of–the-art report on biodiversity in the Indian Sundarbans. This compendium is the outcome of that task and serves as the first-of-its-kind detailed baseline of biodiversity of the Indian Sundarbans and provides a critical evaluation of the current state of biodiversity in the area.

1.1 THE SUNDARBANS

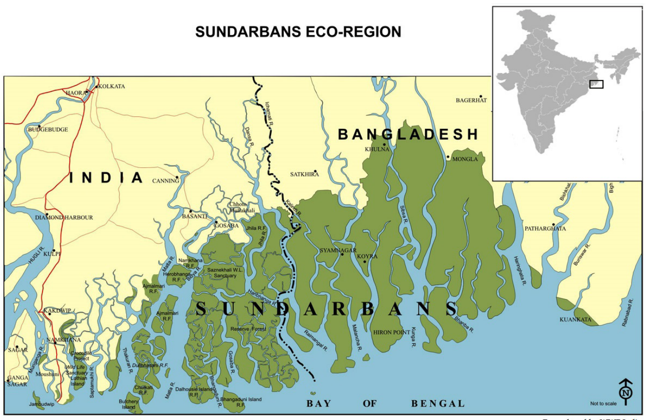
The Sundarbans region is one of the richest ecosystems in the world. The region contains arguably the world's largest remaining mangrove forests, with globally high levels of floral and faunal diversity.

The Sundarbans region is one of the richest ecosystems in the world. The region contains arguably the world's largest remaining mangrove forests, with globally high levels of floral and faunal diversity. The mangrove forest—which covers approximately 10,200 km^2 in Bangladesh and India—is known for its exceptional biodiversity, including numerous threatened species such as the estuarine crocodile, Indian python, and several species of river dolphins. It is also home to one of the largest and most unique populations of tigers in the wild. The Sundarbans' tiger population is, quite possibly, the world's best hope for preventing the extinction of tigers in the wild since they are one of the largest, best-protected, and most-contained populations of wild tigers.

Recognizing the importance and uniqueness of the Sundarbans, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) declared the Indian portion of the forest a World Heritage Site in 1987, and the Sundarbans Biosphere Reserve was designated under the UNESCO Man and the Biosphere program in 2001. The Bangladesh Sundarbans was declared a Ramsar site in 1992, making it subject to the standards of the Ramsar Convention on Wetlands, an international treaty that promotes the conservation of natural resources in wetlands. Also, roughly 1,400 km^2 of the Bangladesh Sundarbans, consisting of three wildlife sanctuaries namely, Sundarban East (in Bagerhat), West (in Satkhira), and South Wildlife Sanctuary (in Khulna), were declared a separate World Heritage site in 1997 (UNESCO 1998).

However, there are also very few biodiversity hotspots that face the sort of existential threats that are now confronting the Sundarbans. The Sundarbans faces both climactic and demographic challenges that, left unchecked, will drastically reduce the biodiversity of the forest ecosystem.

The Sundarbans is one of the only global biodiversity hotspots situated within the metropolitan region of one of the world's tier-one cities. Already, the suburbs of Kolkata—whose metro region, with 14 million inhabitants, is the 3rd largest in India and the 14th largest in the world—are moving toward the western flanks of the mangrove forest. Aside from urbanization, the Sundarbans' populated fringe is a densely inhabited rural area that is subject to incredible poverty. For instance, out of every 1,000 inhabitants of the Indian Sundarbans area, 190 eat just one meal a day and 510 are malnourished. When Cyclone Aila hit in 2009, 250 out of every 1,000 residents were subject to flooding when nearby embankments collapsed. Only 12 out of those 250 had access to any kind of cyclone shelter.



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Poverty, combined with periodic natural disasters arising from the powerful cyclones that sweep into the area from the Bay of Bengal, contributes to a situation in which a resource-strapped and highly vulnerable population is often forced to fall back upon forest resources, exploiting them illegally just to survive. Fishing, firewood collection, and other resource harvests are major drivers of biodiversity loss. Even if the Sundarbans manages to escape damage from population pressures, it also faces serious climate-related threats. The entire Sundarbans delta is currently sinking at a rate of 20–80 cm per century. Climate-fueled sea-level rise is expected to exacerbate, increasing the rate to 46–139 cm over the next 100 years. Since the ecological balance of a mangrove forest hinges upon periodic inundation, this would ordinarily not be a problem; the forests would just shift to find the new intertidal region. However, the borders of the forest are currently fixed by government mandate. Outside the current boundaries, there is no forest protection. Furthermore, the regions that flank the forests are densely inhabited and under extensive cultivation. With no room for movement, it is expected that rising sea levels will result in shrinking forest area and damage to the ecological balance. Additionally, upstream impacts are also affecting salinity of the river waters that fuel the delta. As salinity increases, plants face conditions to which they are ill adapted, resulting in decreasing forest cover and biodiversity.

Box 1. Climate Vulnerability: Lessons From Cyclone Aila

One added dimension to conservation efforts in the Sundarbans area is the frequent occurrence of calamitous cyclones. Although these cyclones do not appear to affect forest biodiversity, they have substantial impacts on the human population of the forests' fringe region, and, in the end, these impacts tend to increase population pressure upon the forest.

Cyclone Aila, which made landfall in 2009, affected two-thirds (67 percent) of households in the Sundarbans districts. As a result of Cyclone Aila, many households saw their dwellings fully or partially destroyed (69 percent), and almost all (94 percent) saw some damage from the storms. Around a quarter of households lost livestock and more than half of all households had to evacuate (55 percent). Of these households, around 43 percent were displaced for three months or more.

In addition to being caught off guard by extreme weather events, households often face adverse conditions during recovery. The household survey of the Sundarbans blocks found that in the three months after an extreme event, households faced price increases for essential food, goods, and services. In addition, the value of livestock and other assets also dropped during this time, undermining food and livelihood security.

It is estimated that one response to cyclones like Aila is an increased dependence on forest resources. Many forest-related livelihoods are illegal, so it is difficult to gauge the level and characteristics of forestry livelihoods, but timber felling and poaching are natural avenues for income generation during times, such as after cyclones, when other income sources are constrained.

More information on this and other topics related to the Sundarbans can be accessed in the full report arising from the GoI's analysis of the challenges facing the Sundarbans region.

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1.2 PROTECTION AND CONSERVATION OF SUNDARBANS

The oldest of the current human settlements in the Sundarbans region came into being after forest clearing about 220 years ago, which on the human civilization scale is rather short.

Incredibly though, the protection and conservation history of the Sundarbans is more than 135 years old. Reclamation of the Sundarbans forests was initiated in the 1770s, and since the 1790s, under the British colonial administration, the state, landlord, and cultivator, pushed the reclamation frontier deeper into the Sundarbans forests to bring more land under agriculture and increase government revenue. Nevertheless, the first century of British colonial rule in lower Bengal had minimal impact on the delta. However, by the 1870s, the colonial administration was getting anxious to expedite settlement in the lower delta area to generate new revenues from potentially fertile wild land lying idle in the Sundarbans.

Between 1873 and 1904, a spurt of clearing and settlement ensued. During this period, as cultivation progressed, the forested Sundarbans diminished by about 2,608 km^2—from 19,510 km^2 to 16,902 km^2—a decrease of about 13.3 percent. This shrinkage reflected successful conversion of wetlands to cultivation and settlement in the area, most of it in Bakarganj District rather than Khulna District or 24-Parganas District. In Bakarganj District, despite substantial increase in the land area due to accretion (18 percent between 1793 and 1905), the settled area of the district expanded by 36 km^2 per year, three times the rate of natural accretion. In 24-Parganas District, fear of damaging floods from breaks in the steep river embankments and tidal action inhibited settlement.

For three-quarters of the nineteenth century, the Sundarbans witnessed a constant assault on the ecosystem. It was some time before the importance of the Sundarbans for purposes other than cultivation was realized. Dr. Dietrich Brandis, the first Inspector General of Forests in India and Dr. William Schlich, the then Conservator of Forests had long emphasized the importance of scientific forestry. There were varying ideas of the forests' importance and roles, but eventually it had become clear to some within the government that protecting part of the forests would be advantageous. Schlich understood the importance in the Sundarbans' supply of timber, thatching grasses, and fuel wood. In places where the forests had been cleared extensively, Schlich and others were uncertain of the Sundarbans' chances of regeneration. By the time the then Bengal Government shifted its attention to the 24-Parganas Sundarbans, the countervailing force against expansion of agriculture had gained ground on receiving crucial support from the Lieutenant Governor Richard Temple. In 1874, Sundarbans was brought under scientific management which helped avoid complete obliteration of the remaining forests. It was the existence of much-needed products such as wood, fish, and honey that increased the eco-region's chance for continued survival through changes in management policy that offered protection to this area and its living resources.

The Sundarbans came under forest management in 1875. Vide Act VII of 1878, parts of the forests were constituted as 'Reserved' or 'Protected' forests, designed to protect the Sundarbans forests against the forces of the land market and reclamation pressures. The state preserved these mangrove forests primarily as a means of ensuring a continuing supply of timber and other forest products. The Sundarbans forests remained a production unit run as a state monopoly until 1980. Since then the Sundarbans' stature as a significant bio-geographic region has only increased, culminating in 1987 when the Sundarbans National Park was included in the list of World Heritage Sites.

However, the watercourses outside the National Park and sanctuaries remain open to fishing and are accessible as a commons where excluding potential beneficiaries from obtaining benefits is impossible. This has given rise to a situation where absolute degradation of the commons is a possibility in the near future, about which marine biologists and conservationists remain concerned. Given the socioeconomic state of the eco-region and lay of the land, riparian Sundarbans as of now does not lend itself to institutional arrangements that help resource users to allocate benefits equitably and sustainably over long periods. A new sanctuary spread over 556 km^2 has been constituted (taking the count to four) in the western part of the Sundarbans forests where existing licensed fishers continue to exercise their rights—essentially turning the common pool resource into common property—which may help resource users (with the exclusion of some) to allocate benefits equitably and sustainably over long periods.

1.3 COSTS AND BENEFITS OF BIODIVERSITY CONSERVATION IN THE SUNDARBANS

Sundarbans ecosystem directly supports 1.3 million people through subsistence activities like fishing, crab hunting and collection of NTFP.

The Sundarbans ecosystem directly supports 1.3 million people through subsistence activities like fishing, crab hunting, and collection of NTFP. Besides, they provide sanctuary to threatened and endangered wildlife; contribute to maintenance of fish diversity by acting as nursery, breeding, and feeding grounds; and are a repository of medicinal plants, timber, and non-timber forest produce. In addition to being home to a rich wildlife, the bottom-up process of the study revealed that the Sundarbans are associated with a wide variety of ecosystem services.

As table 1 illustrates, the Sundarbans ecosystem provide a wide range of services that are crucial for the livelihoods of the local populace and generate local, regional, and global benefits.

Table 1: Ecosystem services provided by or derived from the Sundarbans wetlands

Category	Service	Examples and Comments
Provisioning	Food	Production of ish, prawn, honey, grains, and fruits
	Fresh water	Storage and retention of lows from the Ganga, Brahmaputra and Megha rivers for domestic and other uses
	Fibre and fuel	Production of fuelwood, *golpatta*, *hantal*, and *hogla*
	Biochemical	Extraction of medicines and other materials from biota
	Genetic Material	Genes for resistance to plant pathogens, ornamental species
Regulating	Climate regulation	Source of and sink of greenhouse gases; inluence local and regional temperature, precipitation, and other climatic processes
	Water regulation	Groundwater recharge/discharge
	Water puriication and waste treatment	Retention, recovery, and removal of excess nutrients and other pollutants
	Erosion regulation	Retention of soils and sediments
	Natural hazard regu-lation	Flood control and storm protection, which is crucial given the high frequency and intensity of storms in the Bay of Bengal
	Pollination	Habitat for pollinators
Cultural	Spiritual and inspira-tional	Source of inspiration, religious and cultural values, sense of place, cultural heritage
	Recreational	Opportunities for ecotourism
	Aesthetic	Beauty or aesthetic value in aspects of wet-land ecosystems
	Educational	Opportunities for formal and informal education
Supporting	Soil formation	Sediment retention and accumulation or organic matter
	Nutrient cycling	Storage, recycling, processing and acquisi-tion of nutrients

Source: Adapted by the authors from Millennium Ecosystem Assessment, 2005.

Recently, efforts have been undertaken across the world to better understand and estimate the economic value of ecosystem services. A recent study using the value+ approach has estimated the annual flow of benefits from Sundarban Tiger Reserve to be worth INR 12.8 billion (Verma et al. 2015). As part of the priority-setting process, the governments of India and Bangladesh used state-of-the-art analytical techniques to attempt to quantify the economic costs of environmental degradation in the Sundarbans.

In the Indian Sundarbans, the estimated cost of environmental damage associated with ecosystem degradation and biodiversity loss is about INR 6.7 billion per year (at the 2009 exchange rate of USD 1 = INR 45), accounting for about 5 percent of the estimated gross domestic product of the Sundarbans in 2009 (Strukova 2010). Because of lack of relevant data, this estimate of total damage only partly captures losses due to mangrove degradation and overfishing. The largest categories of damage were from cyclone damage and from losses to the ecosystem and fisheries yield due to unsustainable fishing practices.

A valuation of the Indian Sundarban Mangrove Forests shows the current value of the total flow of benefits from ecosystem services from 2050 to 2100 to be about 1,107,090 billion taking into account carbon sequestration (695,380.66 billion); fishery production (84,621.69 billion); storm protection (327,033.43 billion); and tourism (54.89 billion) (Ghosh 2011: 41).

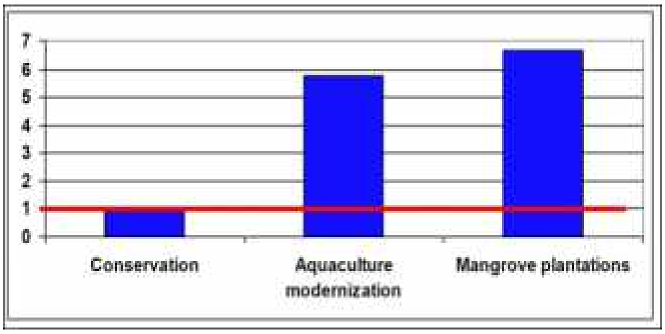
With these analyses in hand, it is easy to see that conservation and biodiversity preservation efforts should, if possible, also include elements that reduce damage due to cyclones and losses in the fisheries sector. Through consultations and meetings with expert, the governments of India and Bangladesh designed a number of programs that would both conserve biodiversity and reduce economic losses in the region.

Then these programs were subjected to a cost-benefit analysis. Estimates of benefits and costs (benefit-cost ratios) of three programs for reducing environmental damage are presented in figure 1. Mangrove plantation and aquaculture modernization (shrimp hatcheries) appear to be the most efficient programs for protecting the Sundarbans and reducing economic loss. However, the benefits of mangrove plantation are contingent upon getting funding for the carbon benefits that accompany planting trees. Land conservation has an estimated benefit-cost ratio close to 1, suggesting that conservation is favorable on low-yield agricultural land. Improved education and reduced illiteracy are key conditions for conservation and mangrove plantation. The cost of improved education is therefore included as part of the cost of interventions and reflected in the benefit-cost ratios in figure 1.

A ranking of the main ecological priorities in the Sundarbans found that the prime ecological issue was increased cyclone damage as a result of mangrove deforestation, followed by fisheries losses due to unsustainable practices. Then, programs to address these issues were designed and evaluated. Mangrove plantation and fisheries modernization were found to have substantial benefits while conservation is also a workable priority, particularly for marginal lands. More details on these proposals are outside the scope of this book, but they are available in the full final report on the work in the Indian and Bangladesh Sundarbans.

The end result of this work was to introduce a human face into biodiversity conservation efforts in the Sundarbans. Conservation work is not just being undertaken because tigers, Sundari trees, and riverine dolphins are important (although they are indisputably important). It is also being undertaken because the lives of people in the region are important. As such, these governments made every effort to design conservation programs that would provide concrete benefits to people in the region and, to a large extent, they have succeeded.

Figure 1: Benefit-Cost Ratio of Programs to Reduce The Cost Of Environmental Degradation



Box 2. The Uneven Benefits of Aquaculture in the Sundarbans

Aquaculture is the Sundarbans' only thriving industry. Based on the total production for 2007–08, the state of West Bengal alone would be the 19th biggest fish producer in the world. Within West Bengal, the districts that border the Sundarbans—North 24 and South 24 Parganas—are the leading producers of fish and prawns, with both districts combined accounting for roughly 31 percent of the total inland fish and prawn production. In the Sundarbans area, there are large shrimp aquaculture operations that generate substantial profits for their owners. However, these capital-intensive operations do not have much of a direct labor requirement—often employing just one or two people per pond—and their owners often live outside the region. Most of the employment that is generated by aquaculture arises from a piece rate that is paid for seed stock—prawn larvae that is illegally harvested from the estuary. One study found that capturing one tiger prawn seed generates, on average, the following by-catch: 161 juveniles of other prawns, 7 fishes, 30 crabs, 1 mollusk, and 8 types of meroplankton. This by-catch results, in turn, in reduced fishing productivity and thus, further depresses income in the area. Due to these by-catch losses and the uneven distribution of benefits from aquaculture operations, the net benefits of aquaculture in the region are somewhat unclear. For more information on this and other topics related to the Sundarbans resources should access the full report arising from the GoI's analysis of the challenges facing the Sundarbans region.

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2 SUNDARBANS BIODIVERSITY GROUPS

Being a geomorphologically dynamic environment, the Sundarbans creates high habitat heterogeneity. These habitats have been occupied in succession by a wide array of halophytic plants and the only population of tigers found in a coastal mangrove habitat.

In addition to this, the ecosystem provides habitat for a wide range of terrestrial and aquatic species, including large numbers of migrant and resident bird species, fish, and invertebrate assemblages as well as important endangered and highly threatened species. The Sundarbans ecosystem also contains numerous species of microbes, algae, and lichens (see table 1). It also serves as a breeding ground for two of the four most primitive Horse Shoe Crabs which travel across the AsiaPacific region. In some groups—for example, mollusks—the Sundarbans has a very high number of species, genera, and families compared to similar ecosystems. The existence of such a wide array of globally threatened animals significantly increases the value of the Sundarbans in the context of the global commons.

Reclamation over time has led to a number of local extinctions as well as reduction in habitat for a number of species. Five species are known to be extirpated from the Indian Sundarbans: the water buffalo (*Bubalus bubalis*); the swamp deer (*Cervus duvaucelli*); the Javan rhinoceros (*Rhinoceros sondaicus*); the gharial (*Gavialis gangeticus*); and the chitra turtle (*Chitra indica*) (Chaudhuri and Choudhury 1994, Das and Nandi 1999). The faunal composition is undergoing changes, with more species being included in the Red List of Threatened Species of the International Union for Conservation of Nature (IUCN) as a result of habitat degradation and ecological changes.

A brief assessment of the biodiversity in the Indian Sundarbans is given in table 1. The matrix takes into account the ecosystem services provided by biodiversity groups discussed in this volume. It also lists the role that each of the biodiversity groups play in the dynamics of the Sundarbans ecosystem and the threats to each of these biodiversity groups.

Table 1: Assessment of Biodiversity in Sundarbans

Sr. No.	Biodiversity Group	No. of Species	Ecosystem services	Threats	Impacts on Sundarban ecosystem if absent
1	Microbes	Bacteria: 34 genera Fungi: 5 genera Virus: 1 genera	(i) Nutrient transformation and role in energy flow -biogeochemical cycles (ii) Consume gases that effect global climate (iii) Destroys pollutants and treat waste (iv) Potential source for medicine agriculture and industry	(i) Change in habitat and land use	(i) Plant productivity (ii) Impact on decomposition process
2	Algae	270	(i) Contribute as primary producer group and serve as food for the fishes (ii) Fuels detrital food chain (iii) Succession of algae (blue-green algae - green algae -diatoms) increase sediment accretion to support the growth of herbs, grass and tall mangrove trees - a new typical mangrove succession. (iv) Effectively alters the physico-chemical status of the soil - act as pollution remediators; bio-fertilizers and bio-indicators of soil reclamation.	(i) Increase sea surface temperature and pollution (ii) Change in water quality of rivers estuaries and other aquatic bodies	(i) Impact on nursery grounds on aquatic population in the wild (ii) Impact on natural fish feed. (iii) As primary colonisers, alteration of physicochemical properties of soil.

Sr. No.	Biodiversity Group	No. of Species	Ecosystem services	Threats	Impacts on Sundarban ecosystem if absent
3	Phyto-planktons	Diatoms: 76 Copepods: 52	(i) Support primary productivity (ii) Remineralisation of organic matter (iii) Help in transfer of energy flow	(i) Rise in atmospheric CO_2 concentration-alters the physicochemical conditions (ii) Acid base imbalance, reduced oxygen transport capacity	(i) Impact on the rich fishery resources; lead to large scale ecological disasters (ii) Impact on assemblage pattern of phytoplankton's due to change in temperature and salinity
4	Lichens	167	(i) Pioneers in habitat colonisation (ii) Fixes nitrogen and fertilises forest soil (iii) Sequesters carbon- 30% of body weight. (ii) Accumulates toxic chemicals or radioactive nucleotides- acts as bio indicator (iii) Medicinal usage- from secondary metabolites (iv) Primary producer (v) Home for invertebrates and provide benefits to insects-camouflage and mimicry	(i) Decline in vegetation cover. (ii) Developmental activities (iii) Fuel wood collection (iv) Impact of climate change.	(i) Impact on Ecosystem energetics
5	Mangrove and associated flora	180	Promote wide array of ecosystem services which also includes the following : (i) Acts as buffer from natural calamities. (ii) Mangrove swamps support a wide variety of aquatic, benthic and terrestrial organisms (iii) Mangrove detritus act as substrate for microbial activity and nutrient generation thus a nutrient and carbon sink. (iv) Non mangrove provides coastal stability through increasing planktonic productivity. (V) Non mangrove initiates island formation and development of niche (vi) Non mangrove removes excessive salt from soil	(i) Devoid of any high elevation zone (landward side) for the species to re-establish due to sea level rise (ii) Habitat degradation due to industrial pollution and human disturbances along the beaches (iv) Timber poaching and fuel-wood collection	(i) Land mass vulnerable to tropical cyclones (ii) Absence of substrate for microbial activity thus impact on nutrient dynamics of estuarine ecosystem. (iii) A possible change in mangrove community due to destruction of lichen species characteristic to the habitat. (iv) Successional seral stages of plant communities would be impacted

Sr. No.	Biodiversity Group	No. of Species	Ecosystem services	Threats	Impacts on Sundarban ecosystem if absent
			(vii) Provide NWFP/NTFP to the forest dependant community ; (v) Medicinal importance (vi) Promotes ecotourism		(v) Habitats for a number of faunal resources would be impacted.
6	Protozoa	67	(i) Initiate the decomposition process. (ii) Ecologically important in carbon-cycling. (iii) Role in food chain; preyed upon by zooplankton, fish and invertebrates. (i) Act as Bio indicators	(i) Change in Sea-surface temperature. (ii) Industrial pollution.	(i) Impact on energy flow in food chain.
7	Mollusca	177	(i) Role in formation of organic detritus in estuaries. (ii) Source of bird-feed. (ii) Aesthetic; commercial; gastronomic; biomedical importance	(i) Habitat and shore line change (ii) Indiscriminate exploitation and collection of undersized specimens (iii) Commercialization of marine shells. (iv) Industrial pollution.	(i) Impact on energy flow in food chain.
8	Poly-chaetes	57	(i) Diet of fish (demersal) and invertebrates (ii) Act as an indicator to the status of benthic community	(i) Anthropogenic and climate change impact in shore habitat	(i) Impact on energy flow in food chain.
9	Xipho-surans	2	(i) Plays a vital role in the ecology of estuarine and coastal communities. (ii) Carapaces frequently serve as a substrate for encrusting invertebrates and algae. (ii) Biomedical Research and Traditional usage	(i) Change in shoreline and formation of undulating terrain. (ii) Red crabs destroy their nests-breeding grounds	(i) No information on Sundarban impacts
10	Crustacea	329	(i) Recycling of minerals and organic matters (ii) Maintain the balance of productivity of oceans. (iii) Degradation of plant matters to detritus particles. (iv) Aquaculture and fisheries are very much dependent upon	(i) Destruction of habitat (ii) Change in salinity and erosion (ii) Pollution from inland waters (oil pollution) (iv) Shrinking of tiger prawn population	(i) Impact on detritus food chain. (ii) Impact on livelihood

Sr. No.	Biodiversity Group	No. of Species	Ecosystem services	Threats	Impacts on Sundarban ecosystem if absent
11	Spiders	114	(i) Regulate insect populations (ii) Ecological indicators of overall biodiversity in many terrestrial communities.	(i) Change in composition and properties of mangrove flora (ii) Extremely sensitive to small changes in the habitat structure; including habitat complexity, litter depth and microclimate characteristics.	(i) Impact on pest population and detrital food chain.
12	Mites	121	(i) Decomposer and helps in nutrient cycling.	(i) Impact on population of mites due to changing trends in precipitation, soil temperature, moisture and organic carbon-thus affecting the trophic cascade of detrital web.	(i) Impact on detritus food chain
13	Insects	497	(i) Ecology of forest ecosystems (ii) Role in nutrient cycles, nutrient availability in soils and Biogeochemical cycles (iii) Role in the carbon cycle during the decomposition process (iv) Pollination	(i) Climatic variability (trends in precipitation, soil temperature, moisture and organic carbon-thus affecting the trophic cascade of detrital web. (ii) Impact of pesticide on non-target species	(i) Significant impact on tree growth, form, survivorship curve, reproductive output and forest ecology. (ii) Impact on pollinator dependant host plants
14	Fish	364	(i) Major source of livelihood for local community	(i) Pollution from inland waters (oil pollution) (ii) Usage of destructive fishing gear such as mosquito nets. iii) Indiscriminate seed collection	(i) Socioeconomic impacts and reduced protein source
15	Herpetofauna	Amphibia:11 Reptiles: 71	(i) Indicators of the microhabitats in ecosystems (ii) Determine relative health of ecosystem (iii) Role in energy flow	(i) Increase in salinity (ii) Industrial pollution	(i) Impact on energy flow in food chain.

Sr. No.	Biodiversity Group	No. of Species	Ecosystem services	Threats	Impacts on Sundarban ecosystem if absent
16	Aves	234	(i) Nutrient transport to or from the ecosystem (ii) Pollination,	(i) Habitat disturbance/land use change (ii) Sea level rise (iii) Unplanned tree plantation at mud flats (iv) Climatic variability	(i) Impact on Ecosystem energetics. (ii) Impact on mangrove species which are dependent on bird pollinators.
17	Mammals	47	(i) Serve as primary, secondary and Tertiary consumer (ii) Crucial member of local food web (iii) Recycle nutrients, agents of pollination and germination, seed dispersal, modification of vegetation structure and nutrition pathways (iv) Disperse seeds and mycorrhizae.	(i) Urbanisation (ii) Change in crop pattern (iii) Breaches in embankments along the river banks due to flood.	(i) Impact on large predator and in prey base.

Note: Non-wood forest product NWFP = Non Wood Forest Product; NTFP = Non Timber Forest Product.

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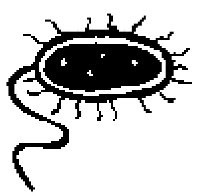
2.1 MICROBES

Located in the tropics, it is obvious that the Sundarbans harbors plenty of bio-resources.

ANINDITA MITRA
Microbiologist

JOYDEEP MUKHERJEE
Environmental microbiologist with specialization in microbial ecology and biotechnology

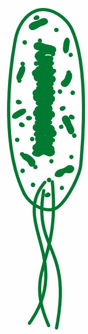
Located in the tropics, it is obvious that the Sundarbans harbors plenty of bio-resources. The periodical variations in hydrological regimes due to freshwater influx and inundation of tides, the continuous change of geomorphology and topography of the substratum, and salinity result in the dynamic nature of the ecosystem that ultimately supports numerous diversified microorganisms (Gopal and Chauhan 2006).



Tropical mangrove constitute 91% bacteria and fungi, 7% algae and 2% protozoa of the total microbial biomass.

Microorganisms play a key role in the nutrient transformations and energy flow of this fragile ecosystem. According to Alongi et al. (1988), of the total microbial biomass, tropical mangrove constitute 91 percent bacteria and fungi, 7 percent algae, and 2 percent protozoa. In the microbial sense, biodiversity is described as the number of different types (species) and their relative abundance in a given community in a given habitat (Garbeva et al. 2004) and it is expressed as different biodiversity indices of evenness and richness. In the practical sense, it is difficult to achieve the real number of the microorganisms of a particular area as it is dependent on the techniques used. In the traditional approach, microorganisms are cultivated in different culture media with an objective to maximize the number of diverse microorganisms. Unfortunately, cultivation-based methods have limitations as it is not possible to recreate all of the specific require-ments that every microorganism needs and the vast majority of microbial biodiversity has been missed by cultivation-based methods. Only 0.1–10 percent of all microorganisms observed in nature can be cultured under conventional laboratory conditions (Zeyaullah et al. 2009).

To fully understand the modern approach toward microbial taxonomy, a review of basic cell biology may be appropriate. Ribosomes are the components of cells that make proteins from amino acids. The ribosomes are further made up of subunits. The unit of measurement of the ribosomal subunit is the Svedberg unit (S), a measure of the rate of sedimentation in centrifugation rather than size and accounts for the reason why fragment names do not add up. Prokaryotes have 70S ribosomes, each consisting of a small (30S) and a large (50S) subunit. Their large subunit is composed of a 5S ribonucleic acid (RNA) subunit, a 23S RNA subunit and 34 proteins. The 30S subunit has the 16S RNA subunit bound to 21 proteins. The deoxyribonucleic acid (DNA) sequence coding for the 16S ribosomal RNA (rRNA) is conserved through evolution within a species, but different when compared between species. The relative similarities of the 16S rRNA gene (DNA) sequence is a measure of the relatedness between species. Two closely related bacteria may share 99 percent sequence similarity and the DNA sequences of two distantly related bacteria may be only 5–10 percent similar. Comparison of the bacterial 16S rRNA gene sequence has emerged as a preferred genetic technique because analysis can better identify poorly described, rarely isolated, or phenotypically aberrant strains. Thus, the 16S rRNA gene (DNA) sequence analysis is not only the gold standard in modern phylogenetic analysis but also the basis of cultivation of the so-called non culturable bacteria, missed out by traditional methods.



48 strains of bacteria were found from the decomposed litters and from different animals

Attempts to cultivate non culturable microbes led to the emergence of metagenomics, the study of metageno-megenetic material recovered directly from environmental samples. This broad field may also be referred to as environmental genomics, ecogenomics, or community genomics as opposed to traditional microbiology and microbial genome sequencing that rely upon cultivated clonal cultures. This relatively new field of genetic research enables studies of microorganisms that are not easily cultured in a laboratory as well as studies of organisms in their natural environment. Environmental gene sequencing is based on the cloning of specific genes (often the 16S rRNA gene) to produce a profile of diversity in a natural sample.

Despite a host of modern techniques available, it is regrettable that the partial 16 rDNA sequences of only 163 microorganisms of the Indian Sundarbans (National Center for Biotechnology Information [NCBI] nucleotide database accessed on June 17, 2010) are available and that too only by two research groups, Dr. J. Mukherjee's research group at Jadavpur University and Prof. (Dr.) D. J. Chatterjee's research group at Calcutta University. Modern taxonomic approaches are costly; however, such costs should override the need to fill the gaps in knowledge of microbial biodiversity in terms of its importance as potential biotechnological resources as well its role in ecosystem maintenance.

Diversity of Bacteria

A total of 48 bacterial strains from the decomposed litters and from different animals, for example, gut of *Mystus gulio*, *Uca* sp., *Boleophthalmus* sp. and haemocoelie fluid of *A. branchiorhynchus*, were isolated and described by Bhowmik et al. (1986) using conventional methods. The genera *Micrococcus* and *Brevibacterium* were found to be the predominating.

A number of cellulolytic, pectinolytic, ligninolytic, amylolytic, and lipolytic bacteria were successfully isolated following traditional approaches by Biswas et al. (1986). Predominance of chitinolytic bacteria in the 'detritus' of the Sundarban complex degrading chitin derived from marine and estuarine arthropods was noted. Isolation of ammonifying and nitrifying bacteria also point toward their role in the breakdown of litters of the mangrove floors as well as soil mineralization in the deltaic Sundarbans.

Two 16S rRNA gene libraries were constructed and partial sequencing of the selected clones were carried out to identify bacterial strains present in the sediment (Ghosh et al. 2010). Phylogenetic analysis of partially sequenced 16S rRNA gene sequences revealed the diversity of bacterial strains in the sediments of Netidhopani (21°55′13′′ N, 88°44′46′′ E). At least eight different bacterial phyla were detected as described in detail by the authors. The study indicated probable hydrocarbon and oil contamination in this sediment. A number of clones were identified that have shown similarity with bacterial clones or isolates responsible for the maintenance of the S-cycle in the saline environment. In marine ecosystems, the S-cycle is an important biogeochemical factor that dictates the flow of electrons along the biological systems under anaerobic conditions. Identification of sulfur-oxidizing and sulfur- and sulfate-reducing bacterial clones refer to the anaerobic condition in this sediment and a possible maintenance of the biogeochemical cycle in Sundarban sediment.

Sana et al. (2006) isolated a serine protease-producing true marine bacterium (isolate DGII) from the sediment of the Lothian Island (20°50′ N, 88°19′E) at a depth of 1 m. The isolate was characterized as a gram-negative, rod-shaped bacterium which has an obligate requirement for NaCl and can grow in the Marine Broth (MB) 2216 medium containing up to 30 percent(w/v) NaCl, optimum growth being with 2 percent NaCl. The 1301 bp of the 16S rRNA gene was sequenced and submitted to NCBI Gen Bank (accession no. AY584868). Based on the nucleotide sequence of the 16S rRNA gene, the isolate DGII was classified as a new gamma-Proteobacterium. The first ribonuclease (RNase) from the Cytophaga-Flavobacterium-Bacteroides phylum, dominant in the marine environment, and also from the first *Bizionia* species isolated from the tropics was purified and characterized by Sana et al. (2008). The isolate BSR01 obtained from the sediments of the Lothian Island is an aerobic, gram-negative, psychro, and halotolerant obligate marine bacterium growing in the MB 2216 medium containing up to 13 percent(w/v) NaCl and at a minimum temperature of 20°C. The isolate has been deposited in the Microbial Type Culture Collection, Institute of Microbial Technology, Chandigarh, India. The 16S rRNA gene of the isolate was partially sequenced and the 1270 bp sequence submitted to NCBI GenBank (Accession no. AY723743). Comparison of this gene sequence with others in existing databases by standard computational methods and the characteristics with the described species show that BSR01 is a new member of the genus *Bizionia*. A *Bacillus sp.* isolated from the Lothian Island which can tolerate 10 percent (w/v) NaCl, produces esterase optimally in MB 2216 medium containing 1 percent (w/v) NaCl (Sana et al. 2007). The isolate BSE01 is an aerobic, gram-positive, rod-shaped, halotolerant bacterium that can grow in the MB 2216 medium containing up to 10 percent (w/v) NaCl. This strain grows and produces esterase optimally in the MB 2216 medium containing 1 percent (w/v) NaCl. Phylogenetic analysis of the 16S rRNA gene sequence (NCBI GenBank accession no. AY723697) shows that the isolate is a member of the family *Bacillaceae*.

An actinomycete (group of gram-positive bacteria with high G+C ratio) isolated from the Lothian Island of the Sundarbans showed potent antimicrobial activity against gram-positive and gram-negative bacteria, molds, yeast, and several multiple-drug resistant (MDR) bacteria, including methicillin-resistant *Staphylococcus aureus* (MRSA). Preliminary examination showed that isolate MS 3/20 is gram positive, forms brownish aerial and substrate mycelium, and produces spores. Based on the sequence of the 16S rRNA gene, isolate MS 3/20 was shown to belong to the *Streptomyces* genus (Saha et al. 2005). The active compound (MW 300.2, predicted molecular formula $C_{20}H_{28}O_2$) from an actinomycetes isolated from the Lothian Island was inhibitory to three gram-positive and three gram-negative MDR bacteria, seven non-clinical gram-positive, four gram-negative bacteria, and five fungi (MIC: 3.5–4.0 μg/ml). Also, 54 percent of human leukemia (HL-60) cells were killed by the compound at 0.05 μg/ml. Molecular phylogenetic analysis showed this typical intertidal inhabitant to be a member of the *Streptomyces* genus and distinct from other salt-tolerant actinomycetes (Saha et al. 2006).2-allyloxyphenol (MW 150; $C_9H_{10}O_2$), a synthetic drug and chemical intermediate, was also obtained as a natural product for the first time from this bacterium. Serendipitous natural occurrence provided new insights into the synthetic molecule, with potential as a new flavor compound (Arumugam et al. 2010). This strain MS1/7 ^{T} was identified as *Streptomyces sundarbansensis*, the first validly described bacterium from the Sundarbans.

Growth on International Streptomyces Project (ISP) media, 2, 3, 4, 5, and 7 produced olivegreen to gray aerial hyphae that carried smooth-surfaced spores in a flexuous (*Rectiflexibiles)* arrangement. The strain contained LL-diaminopimelic acid but no diagnostic sugars in whole-cell hydrolysates. Hexa, octa, and a minor amount of tetra-hydrogenated menaquinones with nine isoprene units (MK-9 [H_4, H_6, H_8, and H_{10}]) were present as isoprene analogs. Diagnostic phospholipids consisted of phosphatidylethanolamine and diphosphatidyl glycerol. The predominant fatty acids were anteiso $C_{15:0}$ (34.8 percent); iso $C_{16:0}$ (16.45 percent); C_{16} (10.53 percent); and anteiso $C_{17:0}$ (10.92 percent). The strain showed higher than 99 percent similarity

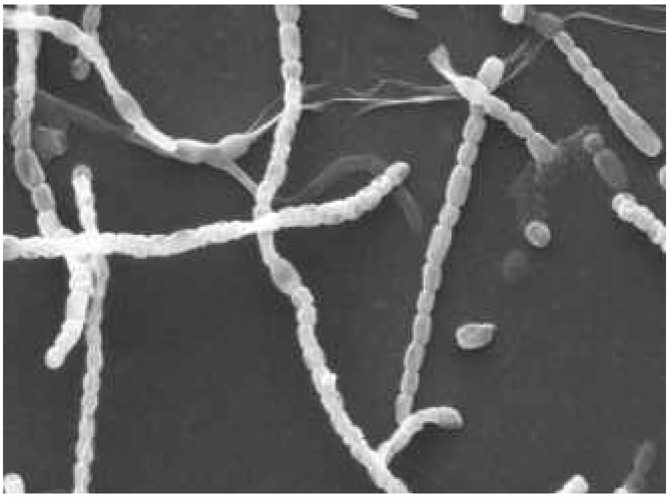


Figure 1. Scanning electron micrograph showing spore chains and spore surface ornamentation of 14-day culture cells of *Streptomyces sundarbansensis* grown on yeast-malt extract agar (ISP 2) Bar, 5.0 μm

with several *Streptomyces* species but formed a distinct monophyletic line within the 16S rRNA gene sequence phylogenetic tree and demonstrated the closest relationship with the viomycin producers (*Streptomyces californicus* NRRL B-1221 ^{T}, *Streptomyces floridae* MTCC 2534 ^{T}(=NRRL 2423 ^{T}) and *Streptomyces puniceus* NRRL B-2895 ^{T}). However, strain MS1/7 ^{T} could be distinguished from these and other nine closely related species by low levels of DNA–DNA relatedness (less than 44 percent) and disparate physiological features, principally amino acid utilization and growth in NaCl. Strain MS1/7 ^{T} (=MTCC 10621 ^{T}=DSMZ 42019 ^{T}) is proposed as the type strain of a novel species, for which the name *Streptomyces sundarbansensis* sp. nov. was proposed (Arumugam et al. 2011).

Another actinomycete (MS310) was isolated from the sediment of the Sajnekhali Island in the Sundarbans (22°7′ N; 88°50′ E). Preliminary examination showed that the isolate MS310 is gram positive, forms gray aerial and yellow substrate mycelium, and produces spores. Shake-flask studies showed that this isolate had no obligate requirement of NaCl for growth; can tolerate up to 20 percent NaCl concentration and biomass increase (up to 10 percent NaCl concentration) as recorded by counting the Colony Forming Units (CFUs); and displayed a graded response to variation in NaCl concentration. Based on the sequence of the 16S rRNA gene (GenBank accession number AY546088), isolate MS310 was shown to be 99 percent similar to a known producer of actinomycin D, *Streptomyces parvallus*. Thin Layer Chromatography (TLC) analysis of the culture filtrate showed that only actinomycin D and no other actinomycin analogues are produced by MS310 (Sarkar et al. 2008).

Mitra et al. (2008) examined the relationship between distribution of actinomycetes (figure 2) and antagonistic behavior with the physicochemical characteristics of the Sundarbans. Soil/sediment samples were collected from three regions: near the sea, intertidal regions, and mangrove forests. The highest number of actinomycetes were isolated from an intertidal region having alluvial soil and the lowest from a site containing sandy sediments. Antimicrobial activity was dependent upon seawater. This is the first study that attempted an ecologically guided bioprospecting approach for finding novel antimicrobial producers by defining antimicrobial score and antagonistic potential as discussed in Mitra et al. (2008). Pearson's correlation between soil chemical parameters and microbiological parameters revealed soil nitrogen as the key factor determining the antagonistic activity.

A survey of petroleum-degrading bacteria was carried out in the Sundarbans (Sankarpur, Cheemaguri, Kachuberia, Kakdweep, and Haldia) to evaluate the distribution of the naturally occurring petroleum-degrading aerobic bacteria. Bacteriological analysis of surface water samples collected from five different locations in the Hooghly–Matla river mouth showed that, depending on the location, 0.08–2.0 percent of the heterotrophic bacteria culturable in marine agar medium by the traditional approach could degrade crude petroleum hydrocarbons as the sole source of carbon as described by Roy et al. (2002). There were a maximum number of petroleum-degrading bacteria in the waters of Haldia Port and its surrounding areas, where the water was highly polluted by hydrocarbon discharges from a nearby oil refinery and from the ships docking at the port.

Choudhury and Kumar (1998) collected a shrimp of the species *Penaeus monodon* from the coastal region (Haroa) of the deltaic Sundarbans. *Klebsiella pneumoniae* was isolated from the alimentary canal and gills of the shrimp as the sole isolate. All ten isolated strains were resistant to erythromycin, ampicillin, furazolidone, and penicillin. These strains were able to grow in the presence of silver, cobalt, cadmium, nickel, lead, copper, and zinc. In 2000, Bhattacharya et al. isolated enteropathogenic strains of *Vibrio parahaemolyticus* from the same shrimp species, *Penaeus monodon*, collected from the deltaic region of the Sundarbans.

Among ten different isolates collected from four coastal regions of the deltaic Sundarbans, three were enteropathogenic. They were *Vibrio cholerae* non-01 (CT^{+}); enterotoxinogenic *Escherichia coli* (ETEC); and *Pseudomonas aeruginosa*. These enteropathogens were able to grow in the presence of zinc, cadmium, lead, cobalt, copper, nickel, and silver. They also showed resistance against 5 to 10 antibiotics. Enteropathogens isolated from the deltaic Sundarbans were thus well adapted for growth in the saline environment with higher concentrations of toxic metals (Choudhury and Kumar 1996).

Surface soils (0–15cm) from upland and mudflat land situations of five different locations of the Sundarbans were tested for their aerobic heterotrophic diazotrophic populations and dinitrogen fixation. Culturable diazotrophic populations in the upland soils, irrespective of locations and NaCl concentrations in the culture media, were statistically greater than that of the mudflat soils. The diazotrophic counts as well as nitrogen fixation of the soils were the highest with extraneous addition of 1 percent

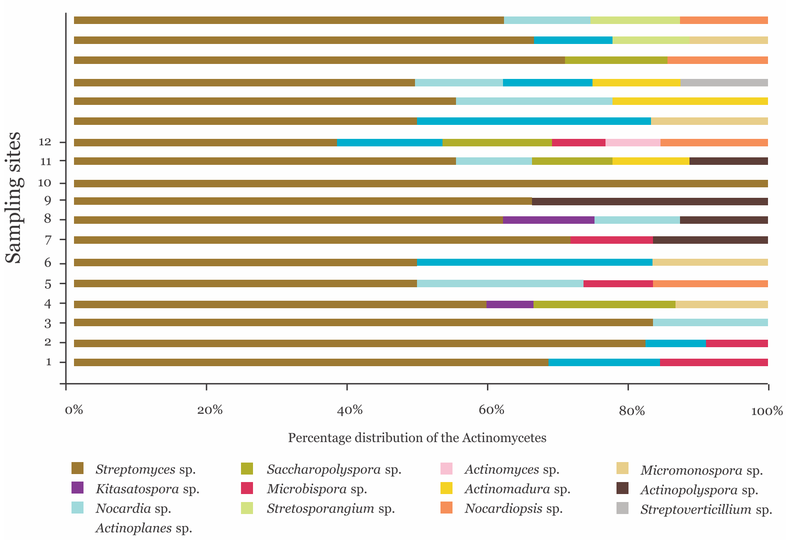


Figure 2. Distribution of the various Actinomycetes genera among the different sampling sites following a preliminary identification

Note: The sampling sites - 1: Kachuberia; 2: Harinbari; 3: Lighthouse;

4: Chemaguri; 5 Rudranagar; 6: Gangasgar; 7: Canning; 8: Golabari; 9: Garanbouse; 10: Jharkhali 1; 11: Jharkhali 2; 12: Amlamethi;

13: Bally jetty; 14: Pakhiralaya 1; 15: Pakhiralaya 1; 16: Jamespore; 17: Dattar forest; 18: Bally forest (according to Mitra et al. 2008).

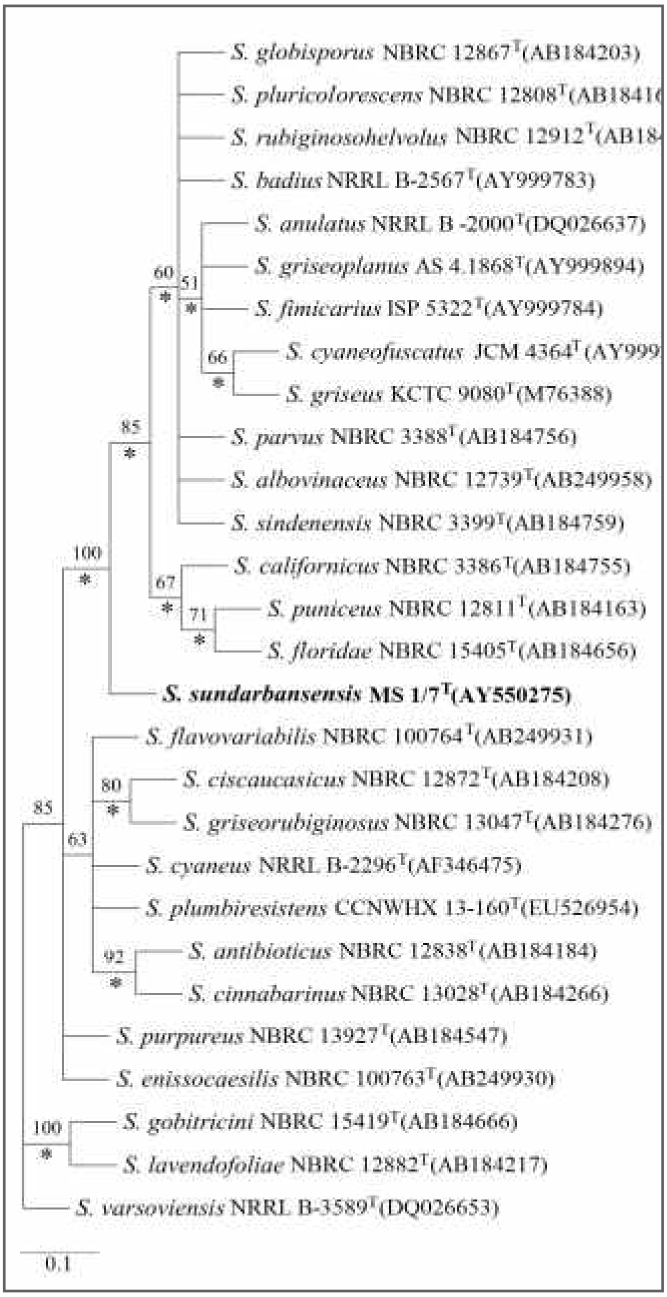


Figure 3. Unrooted phylogenetic tree based on 16S rRNA gene sequences obtained by the neighbor-joining (NJ) method showing the position of *Streptomyces sundarban - sensis* among its phylogenetic neighbors

Note: Numbers at nodes indicate levels of bootstrap support (%) based on an NJ analysis of 1,000 resampled datasets; only values greater than 50 percent are shown. Asterisks indicate branches that were also recovered using the maximum parsimony and maximum likelihood algorithms. NCBI accession numbers are given in parentheses. Bar, 0.1 nucleotide substitutions per site. The sequence of *Streptomyces varsoviensis* NRRL B-3589 ^{T} was used as outgroup.

NaCl in the media and then gradually decreased with further increase in salt concentration in the culture media. 16S rDNA sequences of the 8 out of 12 bacterial isolates were similar to the genera *Agrobacterium*, *Klebsiella*, *Pseudomonas*, *Bacillus*, and *Vibrio* (Barua et al. 2008).

Sengupta and Chaudhuri (1991) investigated heterotrophic dinitrogen fixation in root associations of four distinct eco successional stages of the Sundarbans: (a) formative mangrove swamps, (b) developed mangrove swamps, (c) declining ridge mangroves, and (d) 'declined' mangroves on embankment-protected highlands where crop agriculture and forestry have been introduced. High to very high rates of nitrogenase activity were associated with washed excised roots of seven common, early-successional mangrove species at the inundated swamps. Declining, late-successional mangroves at the occasionally inundated ridges had considerably lower values and the 'declined' mangroves and other non-littoral species at embankment-protected highlands had very low to insignificant values of root nitrogenase activity. Total and inorganic nitrogen contents of the mangrove sediments were low and were positively related to the stages of physiographic succession.

Eight obligately halophilic, euryhaline cyanobacteria from intertidal soil of the Sagar and Lothian Islands were isolated by Pramanik et al. (2011). Antimicrobial activity, 16S rRNA gene sequences, and phenotypic characters as well as growth and antibiosis in response to variable salinity, temperature, phosphate concentration, and pH were studied. Morphologically, six cyanobacteria were assigned to the *Lyngbya-Phormidium-Plectonema* Group B and one each to *Oscillatoria* and *Synechocystis* genera. Molecular phylogenetic analysis based on the 16S rRNA gene sequences of the filamentous isolates validated the previous taxonomic affiliations established on morphological characteristics. This is the first study of antimicrobial producing halophilic cyanobacteria from the mangroves.

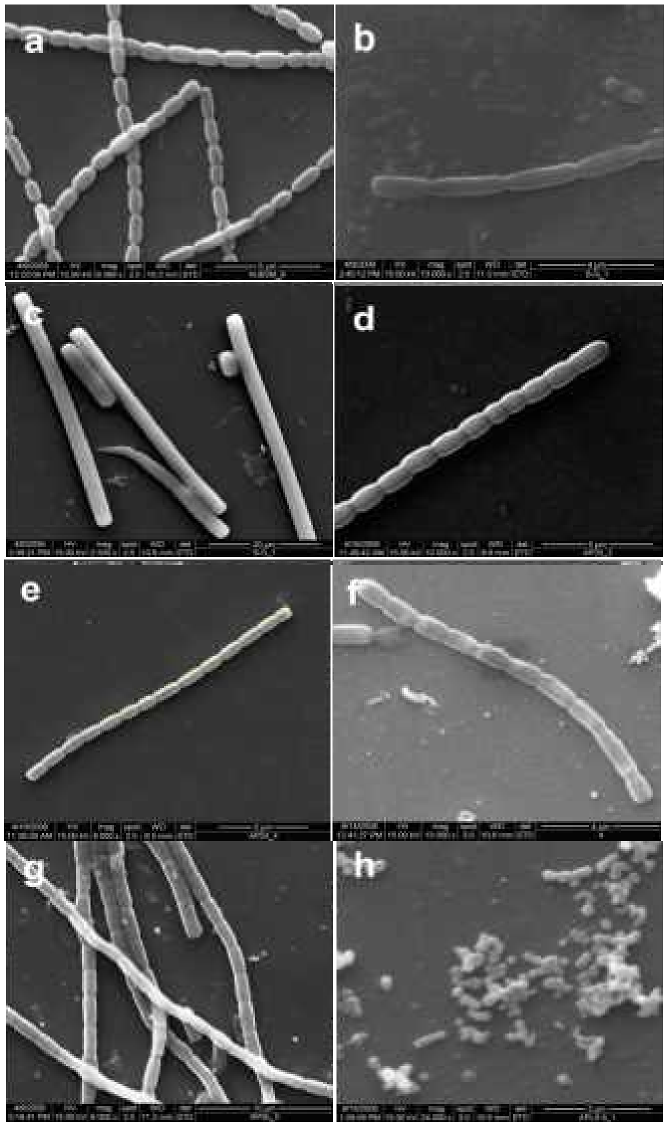


Figure 4. Scanning electron micrographs of eight cyanobacterial isolates obtained from the Sundarbans (a) AP3 (b) AP9F (c) AP17 (d) AP20 (e) AP24 (f) AP25 (g) AP3b and (h) AP9U. Scale bar shown on each photomicrograph.

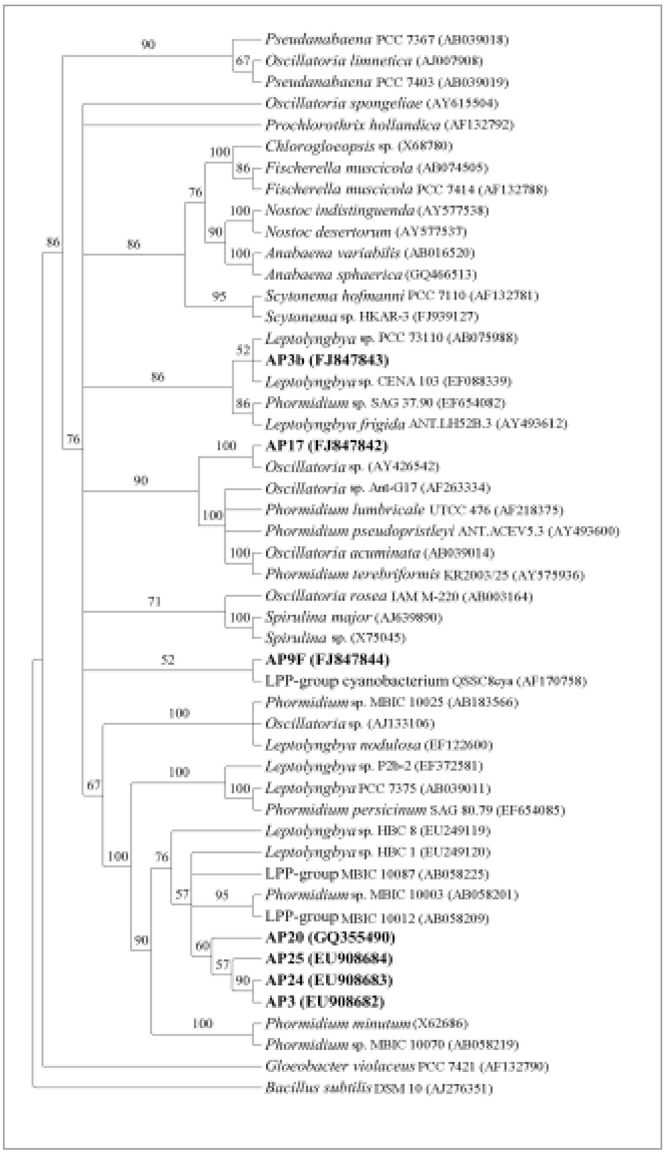


Figure 5. Phylogenetic relationships among seven cyanobacterial phylotypes of the Sundarbans (shown in boldface) and related cyanobacteria

Note: based on the 16S rRNA gene sequences with *Bacillus subtilis* as the out group. Maximum likelihood (ML) tree topologies supported by bootstrap values for 1,000 replications, shown for branches supported by more than 50% of the trees. Scale bar represents nucleotide changes per position.

Diversity of Fungi

In the Sundarbans detritus ecosystems, mangrove fungi are considered as the second largest group among the marine fungi. Available organic matter present in the Sundarban swamp is mainly responsible for the activity of the fungi despite of high salinity and anaerobic conditions

In the Sundarbans detritus ecosystems, mangrove fungi are considered as the second largest group among the marine fungi (Sridhar 2004). Compared to bacteria, studies on fungi started earlier, for example, by Rai et al. in 1978. The authors isolated 184 species of fungi from mangrove swamps using soil plate, dilution plate, and baiting technique methods. The authors concluded that the amount of available organic matter present in the swamp were mainly responsible for the activity of the fungi despite high salinity and anaerobic conditions.

Rhizosphere, the region under the influence of the plant root is one of the favorable niches of mangrove fungi. There are also host-specific fungi, whose distribution and frequency are plant dependent, as described by Garg (1981). A similar study was carried out by Chowdhury et al. in 1982, where they targeted the rhizosphere, rhizoplane, and non-rhizosphere zones of four mangroves.

Arbuscular mycorrhizal fungi constitute an important component of the soil microbial community by forming mutualistic symbiosis with the plant species. Arbuscular mycorrhizae (AMs) fall under the phylum Glomeromycota. They form unique structures such as arbuscules and vesicles and penetrate the cortical cells of the roots of a host plant. Sengupta and Chaudhuri (1990, 1994, and 2002) extensively studied the occurrence of AM fungi in association with mangrove plants. In 1990, they found vesicular AM colonization in four species of pioneer salt marsh plants. In 2002, to find out AM root association, they examined thirty-one species of mangrove and mangrove associates and 23 species of transported flora, belonging to 25 families at four physiographic succession stages of the mangrove plant community. They predicted that the AM fungal isolates were brought in the mangrove ecosystem as spores or root fragments by riverine sediments and with time they adapted the salinity and inundation pattern of the area.

In 2008, Kumar and Ghose investigated the relative abundance, frequency, and spore richness of AMs in fifteen mangroves and one mangrove associate. Roots and rhizospheric soil samples were collected from 27 sites of six different areas: Manmathanagar, Sajnekhali, Sudhanyakhali, Dhanchi Island, Bhagwatpur, and Lothian Island of the Sundarbans. Sites were broadly divided into three inundation types—namely, diurnal (10 sites), usual springtide (9 sites), and summer springtide (8 sites). It was revealed that compared to tidal inundation the host plants had direct effects on spore density and frequency of mycorrhizal colonization in the roots. In both studies (Sengupta and Chaudhuri 2002;Kumar and Ghose 2008), statistical analyses showed significant negative correlation of the mycorrhizal frequency and AM fungi spore with soil salinity and spore richness with available phosphorus.

Pal and Purkayastha (1992a) conducted a survey for the first time on leaf-inhabiting fungi of mangrove plants of the Indian Sundarbans not only from mangrove roots and reported seven fungi. Among them, *Khuski oryzae* H.J. was reported for the first time from India. In the same year, they (Pal and Purkayastha 1992b) isolated two new species and later they (Purkayastha and Pal 1998) detected the uredinial stage of *Skierka agallocha*, a fungi on leaves of *Excoecaria agallocha* by applying light microscopy and scanning electron microscopy. Bera and Parkayastha (1992) isolated three strains of *Pestalotiopsis versicolor* from *Ceriops decandra* (Grifi) Ding Hou, growing in different localities of the Indian Sundarbans and conducted a series of physiological experiments, including the effect of pH on growth, salt tolerance, and the nature of sporulation. In 1996, Varshney and Sarbhoy collected *A. sunderbanii*, a new species from the Gosaba Sundarbans. In general, cellulolytic activity of pneumatophore-inhabiting fungi decreased with increasing salt concentration of the medium (Garg 1982). Among the tested fungi, the highest enzyme activity was recorded in *Chaetomium globosum* and *Aspergillus terreus* at 0 and 6 percent salt levels, respectively, and the lowest cellulolytic activity at 0 and 6 percent salt levels in *Aspergillus niveus* and *Scopulariopsis brevicaulis*, respectively.

Mangroves, especially the *Rhizophoraceae* family, contain a large amount of tannins (Basak et al. 1999), a class of polyphenols. Tannin is mostly water soluble and highly reactive to suppress microbial activity (Kuiters 1990; Kraus et al. 2003), and thus, if it remains in the soil, it could affect the biogeochemical cycling of the ecosystems. De et al. (1999) isolated three fungal species which could grow in the presence of low tannin concentration (0.05 percent). Among the 16 tested fungi, 4 were highly sensitive to tannin, with low pectolytic enzyme activity.

Diversity of Viruses

1.5 MILLION
SPECIES OF FUNGI EXIST AS SUGGESTED BY CURRENT EVIDENCE YET ONLY 5% ARE DESCRIBED

During the survey of microorganisms around the coastal water of the deltaic Sundarbans, several bacterial strains were isolated, for example, *Escherichia coli*, *Alcaligenes*, *Acinetobacter*, *Klebsiella spp.*, *Micrococcus spp.*, *Vibrio spp.*, *Pseudomonas spp.*, *Burkholderia spp.*, and *Vibrio parahaemolyticus*. Among the strains, *Burkholderia cepacia* DR11 was used in a study by Hens et al. (2005). This strain always released temperate phage BcP15 into culture supernatant. Ultraviolet (UV) irradiation of the strain also induced phage induction. Bacteria of the *B. cepacia* complex have been increasingly isolated as pathogens from cystic fibrosis patient's populations. Therefore, the phylogenetic relationship between *B. cepacia* complex and the environmental isolate (DR11) is remote. The next study was designed by the authors (Hens et al. 2006) to determine the role of the new temperate DNA phage BcP15 in relation to drug resistance. The MDR *Shigella flexneri* NK1925 was isolated from a patient of the Infectious Diseases Hospital, Kolkata, India. Results indicated that these three antibiotic resistances in plasmid less clones were due to the BcP15 phage lysogen in the plasmid less version of *S. flexneri* NK 1925.

Comparative Account

A comparative account of the distribution and bioactivities of bacteria isolated from different parts of the world (including other mangroves of India) is provided in this section (table 1).

Mitra et al. (2010) have described the applications of the microbial diversity of the mangroves. Antibacterial activity has been reported from Venezuela, China, and Bhitarkanika (India). A novel actinomycete, *Micromonospora rifamycinica*, was isolated from China and mosquito cidal *Bacillus* strains from the Andaman mangroves (India). Significant cytotoxic activity by *Streptomycetes* of China has also been reported. Scientists from Nigeria, Australia, and Egypt have investigated the removal of pollutants by bacteria residing in mangroves. While enzymes such as laccase, agarose, and protease have been found in India, glucosidase was isolated from the Chinese mangroves. Dinitrogen fixation was studied in the Florida mangroves as well as in Mexico. Other interesting applications of the microbial biodiversity of the mangroves include isolation of phosphate solubilizing (bacteria isolated from Mexico), bio-surfactant-producing bacteria (isolated from Brazil), fermentative hydrogen production, and studies on silver nanoparticles synthesized by a marine fungus (Tamil Nadu, India).

Table 1: Some of the microorganisms found in mangrove habitat in different parts of the World

Microorganisms	Sampling location	References
Proteobacteria (alpha,beta,gamma), Firmicutes, Actinobacteria	Danshui in Taiwan	Liao et al. 2007
Actinomadura, Microbispora, Nonomuraea, Actinoplanes, Micromonospora, Verrucosispora, Arthrobacter, Isoptericola, Micrococcus, Microbacterium, Nocardia, Rhodococcus, Strepomyces	China	Hong *et. al.*, 2009
Alteromonadales, Burkholderiales, Pseudomonadales, Rhodobacterales and Rhodocyclales	Rio de Janeiro, Brazil	Marcial Gomes *et. al.*, 2008
Proteobacteria (α, γ, β, δ- subdivisions) Azotobacter, Desulfuromonas, Sphingomonas, Geobacter, Pseudomonas, Bradyrhizobium and Derxia	Sanya, Hainan Island, China	Zhang *et. al.*, 2008

Conclusions and Recommendations

Based on the data currently available (see annexure) on the Indian Sundarbans, the total numbers of bacterial phyla are 9, species diversity is 34; the total numbers of fungal species diversity are 7 under 5 genera while 1 virus has been reported.

Microorganisms have been evolving for nearly 4 billion years and are capable of exploiting a vast range of energy sources and thriving in almost every habitat. For two billion years microbes were the only form of life on Earth. During this long history, all of the basic biochemistries of life evolved, and all life forms have developed from these microbial ancestors. It is estimated that 50 percent of the living protoplasm on this planet is microbial. Microorganisms represent by far the richest repertoire of molecular and chemical diversity in nature. They underlie basic ecosystem processes such as the biogeochemical cycles and food chains as well as maintain vital and often elegant relationships between themselves and higher organisms. Microbes provide the fundamental underpinning of all ecosystems. Without microorganisms, all life on Earth would cease. Because microorganisms are small, they are least known, and this gap in knowledge is particularly apparent for bacteria and other small organisms. Current evidence suggests that perhaps 1.5 million species of fungi exist, yet only 5 percent are described. There may be 300,000 to 1 million species of bacteria on Earth yet only 3,100 bacteria are described in Bergey's Manual of Systematic Bacteriology. A gram of typical soil contains about 1 billion bacteria, but only 1 percent of those can be cultured. Similarly low fractions of microorganisms have been cultured from fresh water and ocean environments. Hence, most microbes remain to be discovered. Diverse microorganisms are essential to a sustainable biosphere. They are able to recycle nutrients, produce and consume gases that affect global climate, destroy pollutants, and treat our wastes and they can be used for biological control of plant and animal pests. The study of microbial diversity is also important to solve problems related to new and emerging diseases and to advance biotechnology. New technologies, particularly in nucleic acid analysis, computer science, analytical chemistry, molecular biology, and habitat sampling and characterization place the study of microbial diversity on the cutting edge of science. Humans over the ages have been highly successful in applying processes carried out by microorganisms to solve problems in agriculture, food production, human health, environmental quality, and industry.

Forty-three scientists with expertise in different habitats and groups of organisms, different methodological expertise, and from different regions of the world met to discuss and identify research and infrastructure needs in microbial diversity. The workshop participants identified four general areas of importance to better understand, manage, and use our vast microbial resource. The first area addresses gaps in our basic understanding of how microbial diversity originates and where it resides. The second area focuses on the discovery of the unknown microbes, including the new methods that are needed to culture and rapidly characterize the previously unculturable organisms. The third area addresses the need to preserve newly discovered, often fastidious organisms, including in situ and consortia preservation as well as more rapid and efficient methods for preservation. The fourth area focuses on organizational and infrastructure needs, including improvements in databases, centralized facilities for specialized and routine efforts, and training of a new generation of microbial diversity and taxonomy experts. The group recommends that microbial diversity efforts be coordinated at an international level in so far as possible to bring the full talents of the scientific community to this large and exciting problem (CME 2003).

The need for new and useful compounds to provide assistance and relief in all aspects of the human condition is ever growing. Drug resistance in bacteria, the appearance of life-threatening viruses, recurring problems with disease in persons with organ transplants, and the tremendous increase in the incidence of fungal infections in the world's population only underscore our inadequacy to cope with these medical problems. Added to this are enormous difficulties in raising enough food on certain areas of Earth to support local human populations. Environmental degradation, loss of biodiversity, and spoilage of land and water also add to problems facing mankind (Stroebel and Daisy 2003).

The status of microbial biodiversity shows that microorganisms of the Sundarbans are relatively less studied but can be rich potential sources of novel natural products for exploitation in medicine, agriculture, and industry. A report on the status of the biotechnology industry in India published in 'Biospectrum', October 18, 2006, states that marine biotechnology—also called marine bioprospecting in India—began in the early nineties as the national project on development of potential drugs from the sea. The Central Drug Research Institute, Lucknow is the coordinating body together with several other collaborating institutes and universities. Organisms from both the long Indian coastlines, particularly the mangroves of the Sundarbans and the Andaman and Nicobar Islands were identified and screened and specimens stored at the national repository at the National Institute of Oceanography, Goa.

The Convention on Biological Diversity recognizes the sovereign rights of states over their natural resources in areas within their jurisdiction. Parties to the convention therefore have the authority to determine access to genetic resources in areas within their jurisdiction. Parties also have the obligation to take appropriate measures with the aim of sharing the benefits derived from their use. This is one of the three fundamental objectives of the convention. Genetic resources whether from plants, animals, or microorganisms may be used for different purposes (for example, basic research or commercialization of products). Users of genetic resources may include research institutes, universities, and private companies operating in various sectors such as pharmaceuticals, cosmetics, agriculture, horticulture, and biotechnology. Benefits derived from genetic resources may include the result of research and development carried out on genetic resources, the transfer of technologies which make use of those resources, participation in biotechnological research activities or monetary benefits arising from the commercialization of products based on genetic resources. One example of monetary benefits could be the sharing of royalties arising from patented products based on genetic resources. Unfortunately, these regulations are flouted by some biotechnology companies, as evident in the report published in *Nature* (Cyranoski 2002).

Researchers from the Chinese Academy of Sciences were mired in controversy as it embarked on a search for commercially useful microbes in the politically contested areas of Tibet and Inner Mongolia. The scientists were looking for previously unknown extremophiles in salt lakes and hot springs. The project was led by microbiologist Dr. Bill Grant from the University of Leicester, United Kingdom and included scientists from the University of Seville in Spain and the Netherlands branch of the U.S. genomics company Genencor. Its main sponsor was the European Commission, which has donated €1 million (US$1 million).The University of the Western Cape in Cape Town, South Africa, brought its own funding to the consortium.

The researchers isolated microbial DNA on site directly from the soil. They sequenced the DNA and searched DNA databases for sequences encoding enzymes that give the microbes their special characteristics. Dr. Grant and Genencor had already shown that the strategy can be commercially successful. A collaborative expedition to Kenya in 1992 found an extremophile in a soda lake that has an enzyme that breaks down cellulose over an unusually wide range of temperatures. In 1998, Genencor exploited this property in a process for stonewashing jeans. China would gain commercially from the project. Its Ministry of Science had negotiated with the consortium to retain 'sovereign rights' over biological resources found and a share in any commercialization. However, there was no indication that a fair share of the benefits would filter back to Tibet and Inner Mongolia. China's autonomous regions were supposed to retain a degree of control over local economic interests but many commentators argued that Beijing has neglected these rights.

Therefore, in view of the current national and international scenarios, the following recommendations are being made as high priority needs if we are to better understand, manage, and use the vast and largely unknown microbial resource of the Sundarbans.

- Achieve a better understanding of spatial and temporal patterns of microbial diversity and how the environment determines those patterns.
- Discover new microbial forms, biochemistries, evolutionary branches, and habitats. Improve methodologies to characterize, isolate, and identify non-culturable and rare members of communities.
- Foster research on polyphasic taxonomy, particularly the integration of phenotypic, genetic, and ecological information.
- Conduct research leading to the preservation of mixed communities, for example, consortia and natural communities.
- Improve culture preservation strategies such as miniaturization and optimized regimes for difficult-to-preserve microbial groups.
- Promote serious bioprospecting efforts in accordance with the tenets of the Convention on Biological Diversity (CBD), ensuring fair and equitable sharing of profits with the local people of the Sundarbans. The microbial resources are renewable; therefore, there would be no requirement of expensive aqua cultural equipment or agricultural cultivation in the ecologically sensitive area. Industrial production with modern process-controlled reactors would allow intensive production in a place far away from the Sundarbans. This would also provide employment to the local people of this region. If only one product (for example, the cellulase enzyme used for stonewashing jeans, isolated by Genencor, as mentioned before) is a commercial success, it would bring a huge revenue share which can be given to the local community of the Sundarbans, through a biodiversity fund controlled by the Biodiversity Management Committee (BMC), thus providing them relief from the current ecosystem-damaging livelihoods like fishing and agriculture.
- Develop integrated electronic databases that include

habitat, geographic, phenotypic, genotypic, morphological, and accession information.

- Involve researchers from other fields, especially computer science, optics, electronics, chemical engineering, chemistry, and remote sensing, as well as macro ecologists and systematists.
- Expand the training of young scientists knowledgeable in modern microbial diversity, physiology, and taxonomy.
- Enhance the public's awareness of the vital role microbial diversity plays in their lives and the prospects this field offers.

ANNEXURE

Bacterial Phyla
Acidobacteria
Actinobacteria
Chloroflexi
Cytophaga–Flavobacterium–Bacteroides
Firmicutes
Flexibacteria
Gammatimonadates
Planctomycetes
Proteobacteria (alpha, beta, gamma, and delta)

Bacterial Diversity
Acinetobacter sp.
Actinomadura sp.
Actinomyces sp.
Actinoplanes sp.
Actinopolyspora sp.
Agrobacterium sp.
Alcaligenes sp.
Bacillus sp.
Bizionia sp.
Brevibacterium sp.
Burkholderia sp.
Burkholderia cepacia
Escherichia coli
Kitasatospora sp.
Klebsiella sp.
Klebsiella pneumoniae
Lyngbya-Phormidium-Plectonema Group B
Microbiospora sp.
Micrococcus sp.
Micromonospora sp.
Nocardia sp.
Nocardiopsis sp.
Oscillatoria sp.
Pseudomonas aeruginosa
Pseudomonas sp.
Saccharopolyspora sp.
Streptomyces sp.
Streptomyces sundarbansensis
Streptosporangium sp.
Streptoverticillium sp.
Synechocystis sp.
Vibrio sp.
Vibrio cholerae
Vibrio parahaemolyticus

Fungal diversity
Aspergillus niveus
Aspergillus sunderbanii
Aspergillus terreus
Chaetomium globosum
Khuskia oryzae
Pestalotiopsis versicolor
Scopulariopsis brevicaulis

Viral diversity
phage BcP15

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2.2 ALGAE

Algae comprise avast assemblage of phylogenetically unrelated organisms. As a group, algae are capable of photosynthesis by means of their diversely structured apparatus for photosynthesis — the chloroplast and various pigment attributes of the same.

NEERA SEN SARKAR
Botanist with specialization in Phycology

9
LINEAGES OF ALGAL GROUPS

These organisms are all unified by the feature that none are differentiated into roots or leafy shoots and neither do they possess vascular tissues, which makes up for a thalloid appearance in the case of the multicellular organisms belonging to this group. Nonetheless, an amazing array of life is represented by algae all acrossthe earth; more so, because of their ubiquitous presence and capacity to survive in the most unlikely habitats. At the same time, it is interesting to note that representatives of this group were one of the very few early organisms to have colonized Earth when life began.

Classically, algae were classified based on their color, which is imparted by the pigments present within and their distinct micro-morphological characters. By the end of the 20th century, DNA-based molecular systematics had largely superseded ultrastructure-based systematics as it was shown that the morphological and biochemical diversity of the algae results from their polyphyletic origins. Since then, phycologists have based their classification on phylogenetic systems.

The latest proposed classification scheme—the 'six kingdom' model based on molecular, ultrastructural, and paleontological evidences by Cavalier-Smith (2004)—includes the kingdoms of Bacteria, Protozoa, Animalia, Fungi, Plantae, and Chromista, with the algal taxa included within three kingdoms of the bikonts: Protozoa, Chromista, and Plantae. These include nine lineages of algal groups: Chlorophyta, Rhodophyta, and Glaucophyta under kingdom plantae; Euglenophyta and Chlorarachniophyta under Protozoa and Heterokonta; and Cryptophyta, Haptophyta, and Dinoflagellates under Chromista. The last four are grouped together as Chromalveolates (Chromista) or chromophyte algae because they contain various xanthophylls that make them appear yellow or brown, in addition to the light harvesting pigments chlorophyll *a* and *c*. Moreover, although it is a chromalveolate, lineage Alveolata has been included within the kingdom protozoa. Another lineage, of the highly debated algal group Cyanophyta, has been designated to the kingdom Bacteria within this classification system.

Overview of the Group

Inventorizing all species on earth is undoubtedly a mammoth task. This is the reason why the exact number of species on earth is far from known till date. Moreover, description of species has so far been dominated by the world of animals and flowering plants. In fact, viruses, bacteria, algae, fungi, insects, and nematodes are among the least described species inhabiting Earth. A conservative estimate made by World Conservation Monitoring Centre (WCMC) way back in 1992 regarding described and projected estimates of different organisms suggested that, out of a projected estimate of 200,000 algal species inhabiting Earth, only 40,000 have been described (WCMC 1992). An estimate by UNEP (1995) suggests a low of 150,000 and a high of 1,000,000 algal species that can be expected to be found on Earth with a working figure of 400,000 species. This projection shows that 90 percent of algal species found on Earth remain unknown to mankind till date. Much of the comprehensive data of the 10 percent algal species described till date pertain mainly to the orders and families of larger green algae, brown algae, red algae, marine (seaweed) flora, and stoneworts. The most recent information accredited by the UNEP-WCMC is the listing in *Algae Base*—a regularly updated database of information on algae that includes terrestrial, marine, and freshwater organisms. *Algae Base* presently has a listing of 130,649 species and infra-specific names, 14,515 images, 47,744 bibliographic items, and 197,784 distributional records in the database (Guiry and Guiry 2010).

7,175
ALGAL
SPECIES FROM INDIA

1,925
ENDEMIC SPECIES IN INDIA

In the Fourth National Report submitted to the Convention on Biological Diversity (2009) by the Ministry of Environment and Forests, the government of India accounts for 7,175 algal species from India which is 17.9 percent of the known world species. These species falling within 666 genera include 4,495 species belonging to Chlorop -hyceae, 1,453 species belonging to Cyanophyceae, and 516 species belonging to Bacillariophyceae and the remaining711 species belong to the other algal families combined. The report mentions the endemecity of 1,925 species to India, which is 26.8 percent of the described Indian algal species. The report also highlights the well-documented account for marine algae from India and has reported the occurrence of 844 marine algae species belonging to 217 genera.

The algae associated with the mangroves offer an interesting area of investigation, and a considerable number of publications exist on the same. In the mangrove areas, the algae occur as either free-floating planktonic forms, which vary from unicellular to colonial to filamentous thalli, or as periphytic forms when attached to a substratum and vary in being branched or unbranched filaments or *parenchymatous thalli*; they may also occur as benthic forms or as epiphytes. An assessment of the publications on mangrove-inhabiting algae by Adhikary (2000); Babu et al. (2002); Bopaiah and Neelakantan (1982); Chandrasekaran (2000); Dhargalkar and Untawale (1991); Jagtap (1994); Kannan (1994); Mani (1992 and1994); Panigrahi et al. (2001); Rao and Venkanna (2004); Yeragi and Yeragi (2002); and other available references indicates the presence of about 749 species of algae, including seaweed and phytoplankton in areas under mangrove cover taken together, other than the Sundarbans of West Bengal. This accounts for about 10 percent of the algae described from India according to the Ministry of Environment and Forests Report (2009). If the algae reported and described from the Sundarbans Biosphere Reserve (SBR) are included in this estimate (259 species), the total number adds up to 1,008 species and the percentage contribution to Indian algal flora increases to about 14 percent of the total. Though the algae reported from the SBR include not only mangrove-inhabiting algae but also algae from other water bodies within the area—namely, rivers, channels, ponds, ditches, brackish-water wetlands, freshwater wetlands, and the benthic and terrestrial species outside the mangrove areas.

SYNOPTIC VIEW

Diversity

270
SPECIES IN SUNDARBANS

The assessment of the algal bio- diversity of the Indian Sundarbans is based on published information available in scientific journals and includes information on the algae of the Indian Sundarbans in existing 'grey literature'. The earliest information available dates back to 1949, where Biswas had given an account of the common freshwater and brackish-water algae of India and Burma. The most recent comprehensive work is from Naskar (2008). Naskar and Santra (1986) recorded *Enteromorpha tubulosa* in brackish water mixed with sewage-fed fisheries from the Sundarbans, West Bengal. Sen and Naskar (2000) reported *Colpomenia sinuosa* (Roth.) for the first time from the Indian Sundarbans. Sen et al. (2001) reported, for the first time, the occurrence of a green benthic alga *Codium taitense* Setchell from the Indian Sundarbans.

The above literature has been complemented with primary data collected during July 2010 from 5 different sampling points in the Sundarbans Tiger Reserve area and from the brackish-water fisheries under Minakhan Block. The Sundarbans has an algal diversity (table 1) of 270 species.

Rhizoclonium sp. on Heritiera buttresses

Functional Groups/Associations

Studies on the phytoplankton of the Sundarbans suggest that the diatoms constitute the most important and dominant algae in freshwater, estuarine, and marine habitats whereas the desmids and other green algae are important in the freshwater and brackish-water habitats and the blue green algae (BGA) are mostly found to prefer a eutrophic environment.

Banerjee and Santra (2007) have illustrated four different patterns with regard to spatial variation of plankton.

(a) *Biddulphia heteroceros*, *Campylodiscus clypeus*, *Fragilaria* sp., *Phacus* sp., *Tropidoneis elegans*, and spicules dominate the eastern estuaries of the SBR.

(b) *Ceratium furca*, *Coscinodiscus* sp., *Ditylum* sp., *Peridinium* sp., *Pleurosigma* sp., *Skeletonema* sp., and members of Pyrrophyceae in general and zooplankton like *Calanoid copepoda*, Nauplius larvae, and polychaeta larvae are found in smaller numbers in the eastern estuaries of the SBR.

(c) *Bacteriastrum* sp., *Biddulphia mobiliensis*, *Biddulphia sinensis*, *Ceratium triops*, *Ceratium extensum*, *Chaetoceros* sp., *Lauderia annulata*, *Rhizosolenia* sp., *Thalassiothrix frauenfeldii*, *Thallassionema nitzschioides*, *Thalassiosira* sp., and zooplankton like *Appendicularia* and *Herpacticoid* nauplius are found in smaller numbers on the eastern and western margins of the estuaries of SBR.

(d) Chlorophycean algae, *Acanthamoeba*, and Tintinnid protozoa are found in higher numbers on the eastern and western margins of the estuary.

MacNae (1968) reported an association of algae called *Bostrychietum* comprising several species of the genera *Bostrychia*, *Caloglossa*, *Catenella* and of *Murrayella* on the pneumatophores of *Avicennia* and *Sonneratia*, the prop roots of *Rhizophora*, and the knee roots of *Bruguiera gymnorhiza*.

In the present treatise, these have been appended and slightly modified from the original according to more recent personal

Table 1: Number of Algal Classes, Orders, Families, Genera & Species reported from Indian Sundarbans

Class	No. of Orders	No. of Families	No. of Genera	No. of Species
Cyanophyceae	5	11	31	85
Dinophyceae	4	6	6	16
Euglenophyceae	1	1	1	1
Bacillariophyceae	23	37	50	98
Xanthophyceae	1	1	1	1
Phaeophyceae	2	2	2	2
Chlorophyceae	9	16	28	51
Charophyceae	1	1	1	1
Compsopogonophyceae	1	1	1	1
Florideophyceae	3	5	9	14
Total (10 Classes)	50 Orders	81 Families	130 Genera	270 Species

observation and other publications, leading to the description of twelve typical associations. The algal communities occupying different niches in the Indian Sundarbans indicate some specific associations or assemblages of species recurring under apparently similar ecological conditions in different places. The assemblages either have a single species as the dominant species with one or a number of subdominant species or are assemblages of a few subdominant species. Though the BGA cannot be referred to as macro algae, they are included in the associations as they are observed to form an integral component of the associations in which they find mention.

A1 *Catenella*, *Polysiphonia*, *Bostrychia*, *Caloglossa*, and BGA

A2 *Polysiphonia*, *Catenella*, *Bostrychia*, and BGA

A3 Pterosiphonia, Polysiphonia, Catenella, Caloglossa, and *Bostrychia*

A4 *Gelidiella*, *Dictyota*, *Catenella*, and *Bostrychia*

A5 *Rhizoclonium*, *Cladophora*, *Chaetomorpha*, and *Catenella*

A6 *Boodleopsis*, *Vaucheria*, *Cladophorella*, and BGA

A7 *Enteromorpha*, *Chaetomorpha*, *Spirogyra*, *Lola*, and BGA

A8 *Ulva*, *Enteromorpha*, and BGA

In recent times, two more associations have been identified, the first one being a slight deviation from the A5 association, where *Rhizoclonium* dominates, with a few interspersed *Catenella* and *Ulva*. This association, referred to as A5i, has been found to be very common in the northern forest fringes of the Sundarbans Tiger Reserve. The other association encountered only once in areas adjoining the brackish-water *bheries* of Minakhan in recent times (post Cyclone Aila) is primarily dominated by

Cladophorella sundarbanensis, with a few associated *Chaetomorpha* filaments. This is an association which is benthic and the dominant species, that is, *Cladophorella sundarbanensis* was earlier reported only from forest floors of high saline areas (Sen et al. 2002). This association is referred to as A9 in the present treatise. Moreover, the algal association A7 encountered in the brackish-water areas of the Sundarbans is further differentiated into A7i, A7ii, and A7iii according to the changing dominant and subdominant species along a salinity gradient and differences in sewage influx into the environment. The different composition spectra of the associations encountered are represented in figure 1.

A5i *Rhizoclonium*, *Catenella*, and *Ulva*.

A7i In mid-saline areas with high sewage influx, *Enteromorpha* dominates with *Spirogyra* and *Chaetomorpha*as subdominant species.

A7ii In mid-saline areas with low sewage influx, *Chaetomorpha* dominates with some *Spirogyra* as subdominant species.

A7iii In high-saline areas, *Lola* dominates and *Enteromorpha* sub-dominates.

A9 *Cladophorella* and *Chaetomorpha*.

Extensive field collections of the studied associations in different habitats reveal that the most commonly encountered association of macro-algae comprises *Catenella*, *Polysiphonia, Bostrychia, Caloglossa*, and BGA, where *Catenella* dominates the association (A1 association). The next most common association encountered is that of *Rhizoclonium*, *Catenella*, and *Ulva*, where *Rhizoclonium* dominates (A5i association). The next in line of commonly encountered associations is that of *Polysiphonia, Catenella, Bostrychia*, and BGA, where *Polysiphonia* forms the dominant species (A2 association). All the three associations are largely encountered as periphytic

Enteromorpha sp. & Chaetomorpha sp. on tidal mud flat

communities growing on the pneumatophores of *Sonneratia* sp., the aerial roots of *Bruguiera* sp., and the trunk base areas of *Aegialitis rotundifolia*. It is also very common to find the A5i association growing luxuriantly on the well-consolidated forest floors, regularly inundated by tidal water. Another common association is that of *Ulva, Enteromorpha*, and BGA (A8 association). This association is found in areas with high salinity on hard substrata near riversides and which experience regular inundation. The association is dominated by *Ulva* with some interspersed *Enteromorpha* species, usually *E. compressa* and *E. prolifera*, whereas the brackish-water/sewage-fed habitat associations of *Enteromorpha* are dominated by *E. intestinalis* and *E. clathrata*.

The algal communities are observed to exhibit preferences for the habitats that they occupy (figure 2). The habitats in which these associations are commonly found in the study area can be broadly classified into five categories: sewage-fed fisheries; brackish-water fisheries; forest floor areas; aerial root systems, including the exposed trunk regions of the mangrove species; and other hard substrata; namely, concrete structures, bricks, and any hard embankment.

The study of the spatial distribution of coexisting macro- algae in different habitats of the Sundarbans reveal some general patterns which can be summarized as large quantitative dominance and qualitative predominance of a few species and niche preemption, in which one or a few species occupy most of the environmental resources (in this case, substratum) and the other species compete for the remaining resources (Sen Sarkar 2007). It is also obvious that the species forming these associations are quite closely related at times, implying similar resource utilization patterns. Mayr (1963) had underlined two properties which make coexistence of closely related species possible. These include mechanisms guaranteeing reproductive isolation and the ability to resist competition from other species using the same or similar resources of the environment through subtle factors, including all differences in use of the habitat, that is, all niche differences. Where several morphologically similar species coexist, it is to be assumed that there is a region of non-overlap between their ecological niches. The most obvious differences in ecological niches among the macro algae forming associations in the Sundarbans are related to moisture utilization patterns and salinity tolerance (Sen Sarkar 2007).

On analyzing the community A1 which comprises *Catenella, Polysiphonia, Bostrychia, Caloglossa*, and BGA, it is observed that *Catenella* dominates and *Polysiphonia* sub dominates. It is also noted that *Catenella* in such situations occupies the central areas of the assemblage and *Polysiphonia* along with the other species are found in the periphery of the assemblage, with very few *Polysiphonia* individuals occupying some central areas. These peripheral *Polysiphonia* individuals are found to let out longer rhizoidal structures to the central areas. Since the central areas have more moisture, it implies that competition is for moisture and space. It is also observed that *Catenella* is capable of wiping out most of the other coexisting species and occupies the habitat as a single dominant species (niche preemption). On analysis, the communities A7i, A7ii, and A7iii reveal that *Enteromorpha* dominates in mid-saline areas with high sewage influx; *Spirogyra* and *Chaetomorpha* are also present substantially in such assemblages. Under similar salinity regimes, wherever the influx of sewage is low, the assemblages have *Chaetomorpha* as the dominant species along with *Spirogyra*. With rise in salinity, *Lola* shows a tendency for niche preemption, wiping out *Spirogyra* and *Chaetomorpha* and reducing *Enteromorpha* substantially. In this case, salinity plays an important role in controlling the composition of assemblages. The communities A4, A5, A5i, and A6 are all forest floor communities. On analysis, A4 is found to be represented by a community where *Dictyota* and *Gelidiella* are co-dominant with *Catenella* and *Rhizoclonium* as subdominant species. In the case of the A5 association, *Rhizoclonium* dominates the assemblage, interspersed with *Cladophora* and *Chaetomorpha*, whereas A5i is a typical northern forest association, with *Rhizoclonium* dominating the association and very few *Catenella* and *Ulva* individuals. However, A6 is a community which is represented by the co-dominant population of *Rhizoclonium, Cladophora, Chaetomorpha*, and *Catenella*. The association A9, with its dominant species of *Cladophorella sundarbanensis* and very few individuals of *Chaetomorpha*, has been found for the first time to be inhabiting areas of brackish-water wetlands in Minakhan, 24 Parganas (North). Earlier, it was reported from the high-saline forest floor areas of Dhanchi Island. Subject to further studies, it can be referred to as a post-Aila effect on the diversity of algae in the Sundarbans.

Interestingly, *Cladophorella sundarbanensis* and another green algae, *Boodleopsis sundarbanensis*, are found to be endemic to the Sundarban areas.

Fig – 1. Composition of Macroalgal Associations in Indian Sundarbans

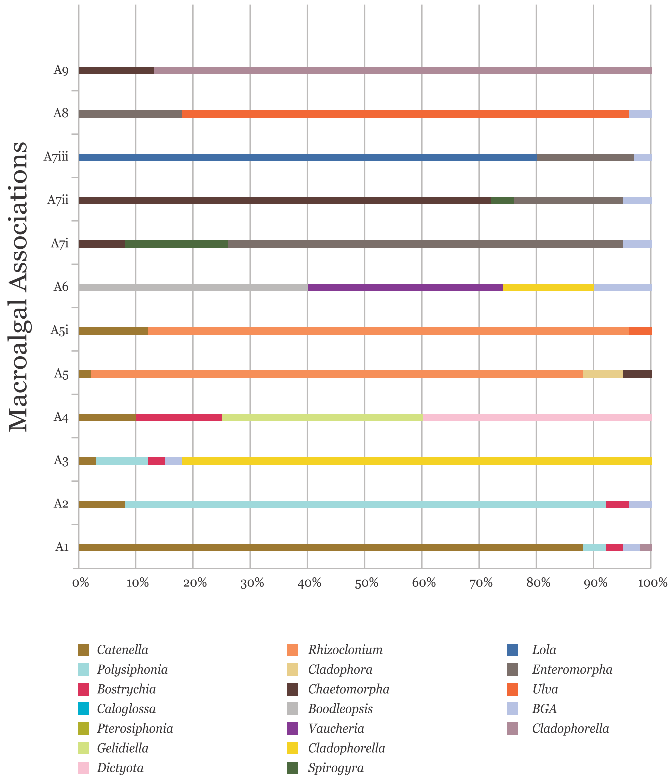
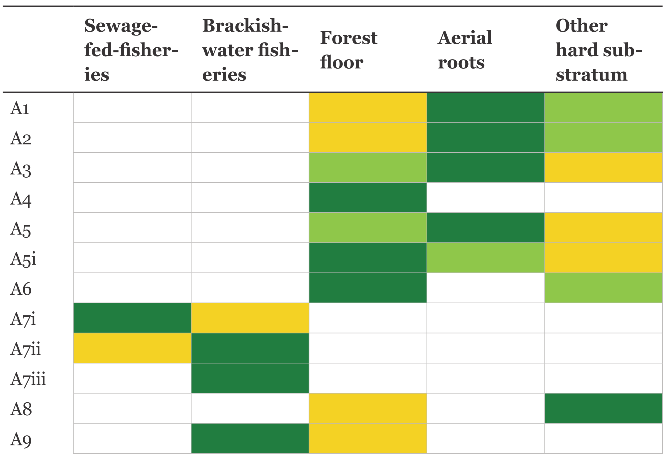
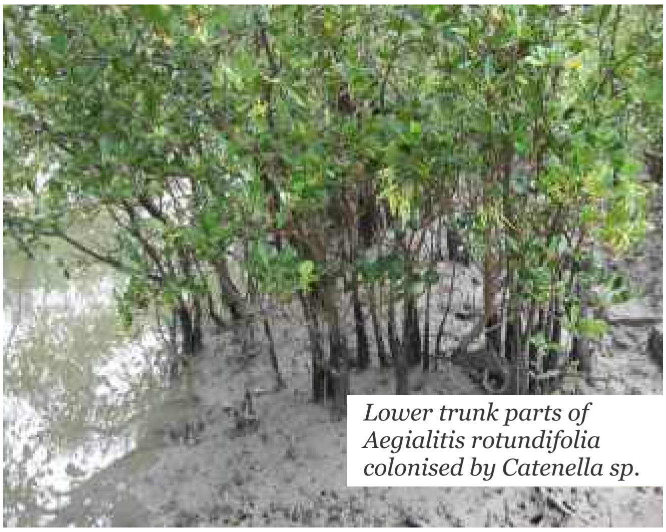


Figure 2. Habitat preference of different macroalgal associations



Distribution

The algae of the Sundarbans are found to inhabit varied habitats in different ranges of conditions related to chemical parameters of soil and water and other inherent soil and water conditions; namely, texture and various levels of consolidation of the soil and lotic/lentic condition of the water bodies. Observations have established that these different habitats, regardless of their individual, uniform appearances to the casual observer, offer a variety of niches with sufficient diversity to allow several morphologically similar or related algal species to coexist, and conversely, the algal species exhibit enough diversity in ecological niche requirement to occupy a superficially uniform


Lower trunk parts of Aegialitis rotundifolia colonised by Catenella sp.

environment (Sen et al. 2002). Most algae are found to show substratum preferences. The BGA are noted to prefer a soft, hydrophilic, biologically active mud, rich in organic matter. They are also known to secrete mucilaginous substances around their habitats which further help in the soil binding processes, whereas the green algae prefer a more consolidated type of soil rich in nutrients which have previously been released by the activity of the BGA and bacterial flora in the soil. Similarly, the red and brown algal groups seem to prefer hard consolidated soil in the supra-littoral zones or the peripheral zones of mangroves which are regularly inundated (Sen et al. 2002).

The SBR provides four major types of environment for the diverse micro and macro algal forms. The first two types include the enormous coastal open water systems and the shallower water by the edge. These are suitable for the free-floating algal forms and the phytoplankton communities. At the edge, the water becomes shallow enough for algal attachment to the bottom, on the muddy soil substratum as well as to various other hard substrata in the form of pneumatophores, bark, and other aerial root systems of mangroves; bricks; wooden and bamboo poles; and concrete jetties. The second type of environment is more complex for survival because of the tides. As the tides move in and out, the quantity of water covering the algae changes from totally inundated to completely exposed, thus affecting the amount and quality of light reaching the algae and 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 sub tidal regions as well. The third major niche for the algal flora of the Sundarbans is the brackish-water fisheries in the inland areas. The brackish-water fisheries or wetlands (natural or manmade) with a wide range of salinity regimes offer habitats for a number of specific algal forms, which are found to restrict themselves only to such conditions. The fourth type of environment that is home to numerous algal species is the aquatic and moist terrestrial habitat within the SBR; namely, fresh water ponds, ditches, paddy fields, small irrigation canals, and the like, which are normally not influenced by tidal or salinity regimes.

A checklist of the SBR algae prepared from available published reports is included in the annexure. The block-wise(community development [CD] and forest) distribution of algae is highlighted in table 2 and figures 3 and 4, including all major life forms found in the SBR—phytoplankton, seaweeds, periphytes, epiphytes, and free-floating forms based on major publications.

The distribution of the macro algal associations under different salinity conditions in the Sundarbans reveal that the mid-saline areas (5–15 ppt salinity) support a larger variety of algal flora. The distribution of these identified associations along a salinity gradient is represented in figure 5, and in map 1, the distribution

Aerial roots of mangroves colonised by estuarine algal species

of the associations is depicted.

Community Dependencies and Traditional Use

Though not much is known about the local communities of the Sundarbans using algae directly or any other traditional use of algae, people across the globe have put algae to different uses like medicines, food, fodder and fish food, cosmetics, and in rituals. The algae that are put to maximum use include seaweed and, to some extent, the BGA.

Seaweed is used in several industries. The top 10 countries producing seaweed are China; Republic of Korea; Japan; the Philippines; Indonesia; Chile; Taiwan, China; Vietnam; the Russian Federation; and Italy. The current phycocolloids (seaweed gels) industry stands at over US$6.2 billion. The world production of commercial seaweed has grown by 119 percent since 1984 and presently, 221 species of seaweed are used commercially, including 145 species for food and 110 species for phycocolloid production.

In the health food sector, polyunsaturated fatty acids (PUFA) are quite in demand because of their value in prevention and treatment of heart and circulatory diseases, inflammation, asthma, arthritis, atherosclerosis, thrombosis, diabetes, ageing, and certain viral infections. Quite a number of macro algae (*Catenella, Polysiphonia, Pterosiphonia*, and *Chaetomorpha*) from the Sundarbans have been reported to be rich in PUFA, especially docosahexanoic acid (DHA) and eicosapentaenoic acid (ESA) (Sen et al. 2000 and 2002). The source of these PUFA in the booming health food sector is currently being attributed to algae though the conventional source is of animal origin (sardine oil and white seer oil). The algal source and other microbial sources are obviously preferred by the vegetarian population across the world, thus the demand. The conventional animal source also has other inherent problems such as lack of availability everywhere and a disagreeable odor. Thus, the algal source of PUFA shows promise for entrepreneurship development in the cultivation, extraction, and marketing sectors.

An important use of algae in an agriculture-dependent country like India is its utility as a readily available bio-fertilizer and as fodder, poultry, and fish food. The nitrogen-fixing algae that grows naturally in rice fields are a boon for farmers. Studies have also shown a remarkable improvement in the health and milk yield of cattle with substitution of just one-fifth of conventional animal feed with microalgae. The role of algae as an excellent fish food is an avenue which needs no introduction since these are the organisms that take care of the fish and other aquatic population in the wild, not just by providing food but also providing suitable nursery grounds. Technological intervention followed by proper lab-to-land transfer can immensely benefit the huge population in the Sundarbans that is dependent on fishing and fishery resources. Pertinently, Ray (2008) has calculated the percentage dependency of various commercially important consumer groups—namely, benthic filter feeders, macro benthic carnivores, pelagic detritivores, pelagic carnivores, and top carnivores on benthic algae and phytoplankton among other groups in virgin and reclaimed mangrove islands of the Sundarbans. The results highlight the fact that between the two, it is the benthic algae on which all these major commercially important compartments are more dependent, with percentage dependency varying between 8.8 and 37.6 percent, the highest being the benthic filter feeder dependency on benthic algae in reclaimed islands. The highest dependency on phytoplankton is found in the pelagic carnivore compartment, showing a high of 41.9 percent dependency in reclaimed islands.

An avenue of research and development that has gained momentum throughout the world in the recent past relates to using algae for meeting the ever increasing fuel needs. In the scenario of meeting the challenges of climate change and fast dwindling sources of fuel, this definitely holds good and has scope in West Bengal in general and the Sundarbans in particular as well. It is to be noted that simple rural technologies can be developed to take up this challenge of converting waste to wealth since the unused and obnoxious algal scums and blooms that are seen every day are nothing but waste unless and until properly used. With such immense potential, notwithstanding the high rate of turnover and huge yield from so small an area as a ditch or a pond, it would be wrong on our part not to be sustainably using the algae (Sen Sarkar 2010).

Ecological Importance and Need for Conservation

The algae as a group have contributed immensely to the natural environments that they inhabit. With relevance to the Sundarbans, they are the most important contributors as the primary producer group which sustains the total ecosystem at large and takes care of the diverse consumer groups, which eventually form the backbone of the economics related to the fisheries of the area. It is commonly thought that there is very little direct grazing on mangrove algae and that most algal production in the *mangals* enters the food webs through detrital pathways. However, grazing by small herbivores such as amphipods and isopods is difficult to estimate, so the estimates usually remain incomplete, thus adding to the anomaly. A variety of other organisms, including a number of fish species, are found to feed directly on mangrove micro algae (Sen et al. 2001). Nevertheless, detrital pathways are very important in the system, but the macro algae associated with mangroves may be equally important as leaf litter in fueling detrital food chains in these areas.

The area under consideration is primarily built up by silt deposition, which in the initial stage is a very ill-consolidated soil substratum. The algae, predominantly the BGA, appear as

Plankton rich estuarine creek in Sundarbans

Table – 2. Block wise distribution of algal species in the Sundarbans Biosphere Reserve

CD/ Forest Block	A	B	C	Total	Remarks
Community Development (CD) Blocks					
Canning I	9			9	
Canning II	10			10	
Joynagar I				#	NA
Joynagar II				#	NA
Basanti	47	21		68	
Gosaba	32	30		62	4 species common in A & B
Mathurapur I				#	NA
Mathurapur II				#	NA
Kultali	18			18	
Patharpratima	26	31		57	2 species common in A & C
Kakdwip	21	19		40	
Sagar		64		64	
Namkhana	30	12		42	2 species common in A & C
Haroa	20		34	54	1 species common in A & C
Hasnabad		7	7	14	
Minakhan	21		23	44	3 species common in A & C
Sandeshkhali I	2		2	4	
Sandeshkhali II			7	7	
Hingalganj		9	6	15	
Forest Blocks under Sundarban Tiger Reserve					
Jhilla	18			18	
Arbesi	17			17	
Pirkhali*	27	8		35	5 species common in A & B
Khatuajhuri	22			22	
Panchmukhani	26			26	
Netidhopani	17			17	
Harinbhanga	27			27	
Goashaba	12			12	
Matla				#	NA
Chottahardi				#	NA
Chamta				#	NA
CD/ Forest Block	**A**	**B**	**C**	**Total**	**Remarks**
Mayadwip				#	NA
Gona				#	NA
Chandkhali				#	NA
Baghmara				#	NA
Forest Block under Basirhat Range					
Bagna		1		1	Outside SBR but adjoining STR
Forest Blocks under 24 Parganas (South) Division					
Saptamukhi**	24	3		27	
Muriganga				#	NA
Thakuran				#	NA
Chulkati				#	NA
Ajmalmari				#	NA
Dhulibhasani				#	NA
Herobhanga				#	NA

A Sen et. al., (2002), Sen & Naskar, (2003) & Sen et. al., (2003)

B Maity & Santra (1985), Santra et. al., (1988, 1991), Santra & Pal. (1988), Banerjee & Santra, (1999, 2001 & 2007) and Banerjee et. al., (2001)

C Naskar, (2007), Naskar & Naskar, (2007 & 2008) & Naskar et. al., (2006, 2007, 2008 & 2009)

* Includes Sajnekhali & Sudhanyakhali

** Includes Dhanchi & Lothian Islands

Profuse growth of Rhizoclonium sp. on pneumatophore surface

Fig- 3. Community Development Block wise distribution of algal species in the Sundarbans Biosphere Reserve

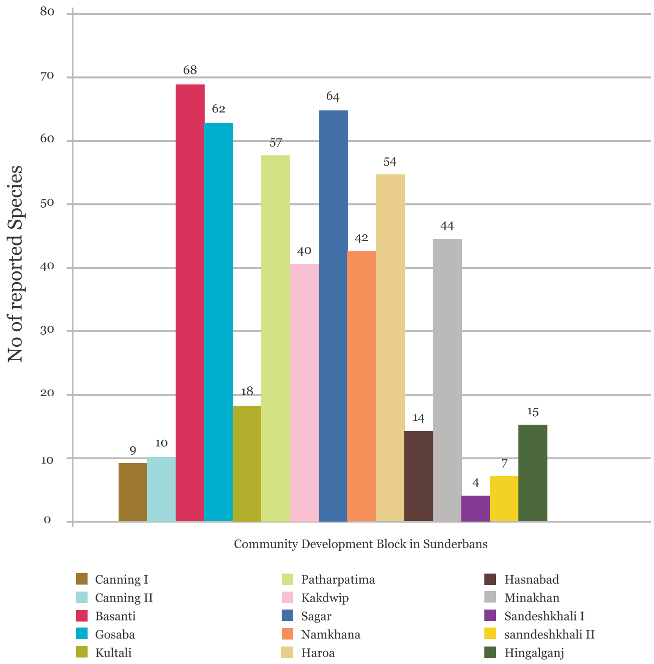
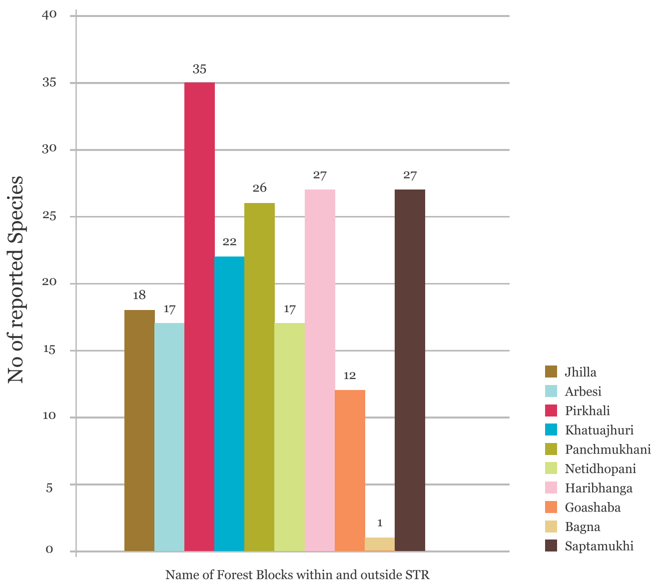


Fig- 4. Forest Block wise distribution of algal species in the Sundarbans Biosphere Reserve

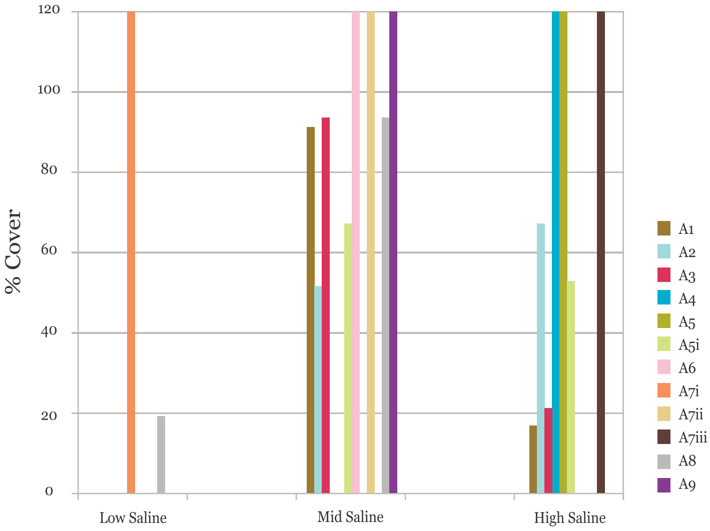


Catenella, *Polysiphonia*, *Pterosiphonia* and *Chaetomorpha* are rich sources of PUFA.

primary colonizers. The mucilage secreting abilities of these BGA contribute toward accretion of the loose and ill-consolidated, newly formed mangrove soil, paving way for the next group of algae, the green algae. Diatoms also occur on/in the soil and are able to move by exuding mucilage. This leftover mucilage then acts as a binding agent which traps and binds fine sediment particles, thus increasing sediment accretion within the mangrove ecosystem. By this time, the soil gets consolidated enough to support the growth of herbs and grasses and finally the tall mangrove trees colonize the area to start anew a typical mangrove succession. Maity et al. (1987) have highlighted the importance of algalization in effectively altering the physico-chemical status of soil, especially increased salinity, in comparison to application of gypsum under similar situations. The algae, as such, play important ecological roles as pollution remediators, bio-fertilizers, and bio-indicators and are also significantly associated in the process of soil reclamation in these areas.

The above inferences on diversity, zonation, distribution, and associations of the algal flora, especially the ones in the Sundarbans Tiger Reserve areas, were made based on collections from the forest fringes of the blocks and

Fig– 5. Distribution of macroalgal associations in Sundarbans based on salinity gradient



compartments mostly from areas which have established forest camps. These camps are usually built at distances of 300 to 800 m from the point of entry, that is, the jetties on the river bank into the forest. Thus, the study is limited only to such distances. In other areas where camps are not present, collections were made from just the periphery of the islands. This again limits the study as observations on the algal diversity from within the forest areas could not be included, and certainly creates gaps in knowledge. The study also does not include information from forest compartments southward from Chamta Block except for the collections made from Goashaba Block (see map 1). Moreover, in the human habitation areas, all the 19 CD blocks have not been covered. Even the blocks that have been covered here state information particularly regarding the algal diversity of areas adjoining or connected to the mangrove ecosystem through rivers or channels, have adjoining forests, or are brackish-water fisheries, except for some information from

As a primary producer group, the algae forms backbone of the economics related to the fisheries of the region

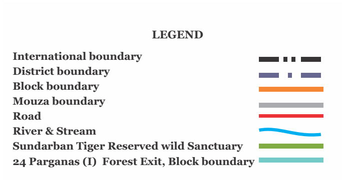
Catenella sp. on concrete jetty

Santra et al. (1988) on rice field BGA and Sen and Naskar (2003), who have included a few adjoining freshwater systems as well in the study. Areas within typical village systems such as ponds, other closed aquatic bodies, and moist terrestrial environments that have no connection with the saline water of the Sundarbans usually fail to attract comprehensive studies because working in the Sundarbans invariably encompasses the objective of studying the mangroves or related systems. This, in essential, is a disadvantage as a major algal diversity growing in such areas is left untouched.

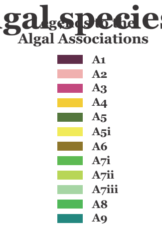
Status and Threats

Critical evaluation of the algal species in the context of conservation is needed.

Worldwide, certain factors have been identified to be causes of threats to the algal population. These include climate change, El Niño events, pollution (sewage and agricultural runoffs), increase in grazing predators, human-induced modifications, invasive species, overexploitation, and oil spills. The 2007 International Union for Conservation of Nature and Natural Resources (IUCN) Red List for the first time included 75 Galapagos seaweed, or macro algae, as species which need special attention from a conservation point of view, with 10 of them receiving the most threatened status of 'critically endangered'. The major groups of algae included therein belong to Chlorophyceae (green algae), Florideophyceae (red algae), Ulvophyceae (green algae), and Phaeophyceae (brown algae). Under the Florideophyceae, one species is mentioned as extinct, six as critically endangered, and three as vulnerable, and within the Phaeophyceae, four species are mentioned as critically endangered, one species to be endangered, and another as vulnerable. Though none of these species are reported from the Sundarbans, critical evaluation of the species inhabiting the areas have not been done to highlight the status of the species in the context of conservation. Nonetheless, on a more local note, there is growing concern regarding the changes in environmental quality of (particularly) the rivers, estuaries, and other aquatic bodies in and around the Sundarbans. Rapid urbanization and encroaching metropolitan habits are showing their effects on not only the algal spectrum but the biodiversity in entire type of the pristine Sundarbans. To evaluate the situation in its entirety, extensive monitoring on spatial as well as temporal scale is needed. For the time being, gaps in knowledge, especially pertaining to diversity studies in areas not studied till date and taxonomic groups not handled, need to be addressed so as to determine the present status of the algal resources of the Sundarbans.



Map 1: Distribution of Algal species



ANNEXURE

List of algae reported from Sundarban Biosphere Reserve from different cited literature

Class, Subclass & Order	Family	Species	Habit & Habitat
KINGDOM: Bacteria; SUBKINGDOM: Negibacteria; PHYLUM: Cyanobacteria; CLASS: Cyanophy - ceae			
Chroococcales	Chroococcaceae	*Microcystis littoralis* (Hans.) Forti	Planktonic in a high saline area ditch
		Microcystis bengalensis Banerjee	Planktonic in low saline brackish - water fisheries
		Microcystis marginata (Me- negh.) Kutz.	Planktonic in low saline fishery
		Microcystis flos-aquae Wittr. Kirchner	Planktonic in brackishwater fishery
		Microcystis viridis (A.Br.) Lemm.	Planktonic along with green algae

Class, Subclass & Order	Family	Species	Habit & Habitat
		Microcystis pulverea var. *incerta* (Lemm.) Crow	In saline water ditches in high saline areas
		Gloeocapsa decortican (A. Br.) Richter	On wet soil at high saline area, near fresh water pond
		Gloeocapsa punctata Näg. ex Kutzing	On brick and cemented stairs of a fresh water pond
		Gloeocapsa aeruginosa (Carm.) Kutz.	As crusts on bricks and walls by a high saline canal
		Gloeocapsa kuetzingiana Näg.	On moist soil in mid saline area
		Gloeocapsa calcarea Tilden	In paddy field
		Gloeocapsa Montana Kuetz.	In paddy field
		Aphanocapsa littoralis Hansgirg	Planktonic/ alongwith other algae in high saline brackishwater fisheries.
		Aphanocapsa pulchra (Kutz.) Rabenh	On wet soil as benthic flora.
		Aphanocapsa biformis A. Br.	Planktonic in brackish water with other BGA
		Aphanocapsa virescens (Hass.) Rabenh.	Planktonic in brackishwater fishery
		Aphanocapsa grevillei (Hass.) Rabenh.	Planktonic in brackishwater fishery
		Aphanothece stagnina (Spreng.) A. Br.	Free floating in a fresh water pond
		Coelosphaerium kuetzingianum Näg	Planktonic in brackish water with other algae
		Merismopedia tenuissima Lemm.	On wet soil and planktonic in high saline areas.
		Merismopedia glauca (Ehrenberg) Näg.	Planktonic in estuarine system
	Entophysalidaceae	*Johannesbaptistia pellucida* (Dickie) Taylor *et* Drouet	Planktonic in low saline brackishwater fishery.
Chamaesiphonales	Chamaesiphonaceae	Chamaesiphon curvatus *Nordst.*	Epiphytic on *Bostrychia, Polysiphonia* & *Caloglossa* in high saline areas.
	Dermocarpaceae	*Dermocarpa leibleiniae* (Reinsch.) Born. *et* Thur.	Epiphytic on *Lyngbya* sp. in high saline areas.
		Dermocarpa hemisphaerica Setchell *et* Gardner	On *Cladophora* in mangrove forest floor
		Dermocarpa sphaerica Setchell *et.* Gardner	Epiphytic on *Lyngbya* sp. in brackishwater fisheries
		Stichosiphon sansibaricus (Heiron.) Drouet *et* Daily	Epiphytic on *Lyngbya* sp. in high saline areas.
Pleurocarpales	Hyellaceae	*Xenococcus chaetomorphae* Setchell *et* Gardner	Epiphytic on *Chaetomorpha* filament.

Class, Subclass & Order	Family	Species	Habit & Habitat
		Xenococcus cladophorae (Tilden) Setchell *et* Gardner	Epiphytic on *Cladophora* and *Enteromorpha*.
Nostocales	Oscillatoriaceae	*Spirulina princeps* W. *et* G. S. West	Planktonic in brackishwater fisheries at low saline – mid saline areas.
		Spirulina major Kutz. *ex* Gomont	Planktonic in stagnant water alongwith other BGA.
		Spirulina meneghiniana Zanard. *ex* Gomont	Planktonic in medium and low saline wetlands
		Spirulina subtilissima Kutz. *ex* Gomont	Associated with other algae in low to medium saline wetlands
		Arthrospira platensis (Nordst.) Gomont	In stagnant water
		Oscillatoria nigroviridis Thwaites ex Gomont	Planktonic/bottom biota in high saline areas
		Oscillatoria limosa Ag. ex Gomont	Periphytic on submerged substratum in high saline areas.
		Oscillatoria subbrevis Schmidle	From dried up river bed on *Porteresia coarctata* at high saline area.
		Oscillatoria curviceps Ag. ex Gomont	Planktonic in low saline bheries.
		Oscillatoria princeps Voucher ex Gomont	Planktonic in brackishwater fisheries
		Oscillatoria chlorina Kurtz. *ex* Gomont	On river bed soil at high saline areas.
		Oscillatoria tenuis Ag. ex Gomont	On river bed soil at high saline areas.
		Oscillatoria corallinae (kutz.) Gomont	Found with green algae in low saline fisheries
		Oscillatoria margaritifera (Kuetz.) Gomont	On muddy soil substratum in high saline areas
		Oscillatoria jasorvensis Vouk.	In river bank soil in high saline areas
		Oscillatoria irrigua (Kutz.) Gomont	Planktonic in brackishwater fisheries
		Oscillatoria proboscidea Gomont	On muddy substratum in brackishwater fisheries
		Oscillatoria chalybea Mertens	Free floating with other BGA in brackishwater fisheries
		Phormidium stagnina Rao	Planktonic & with other algae in high saline brackishwater fisheries.
		Phormidium fragile (Meneghini) Gomont	On fallen twigs in the forest in high saline areas
		Phormidium anomala Rao	At the edge of brackishwater fisheries

Class, Subclass & Order	Family	Species	Habit & Habitat
		Phormidium ambiguum Gomont	At the edge of brackishwater wet-land with green algae
		Phormidium corium var. *capitatum* Gardner	Attached to bamboo sticks in brackishwater
		Phormidium retzii (Ag.) Gomont	In small water channels
		Lyngbya birgei Smith	Free floating and with other algae from paddy fields at high saline areas.
		Lyngbya hieronymusii Lemm.	Planktonic and as free floating mass in high saline brackishwater fisheries.
		Lyngbya lutea (Ag.) Gom.	On wet soil adjacent to brackish-water fishery at high saline areas.
		Lyngbya majuscula Harvey *ex* Gomont	Bottom biota of brackishwater fishery at high saline areas.
		Lyngbya confervoides C. Ag. *ex* Gomont	Bottom biota of brackishwater fishery at high saline areas.
		Lyngbya semiplena (C. Ag.) J. Ag. ex Gomont	Among other algae in brackishwa-ter fisheries at high saline areas.
		Lyngbya rubida Fremy	On root network of halophytes
		Lyngbya martensiana Me-negh *ex* Gomont	Free floating or in stagnant brack-ishwater wetlands
		Lyngbya sordida (Zanard.) Gomont	Free floating at the edge of brack-ishwater fishery
		Lyngbya gracilis (Menegh.) Rabenh.	Free floating in brackishwater fishery
		Lyngbya spirulinoides Gomont	In brackish water wetlands
		Schizothrix lamyii Gomont	In stagnant water and on decom-posed matter in high saline areas.
		Microcoleus chthonoplastes Thuret *ex* Gomont	On high saline muddy substra-tum.
		Hydrocoleum lyngbyaceum Kuetz. *ex* Gomont..	On high saline muddy substratum
		Hydrocoleum meneghini-anum Kuetz.	On river bank muddy substratum
		Trichodesmium thiebautii Gomont	Marine phytoplankton
		Trichodesmium erythraeum Ehrenberg	Marine phytoplankton
		Katagnymene pelagica Lemm.	Free floating with other green algae in brackishwater fisheries
	Nostocaceae Sub Family - Anabaenae	*Nostoc punctiforme* (Kutz.) Hariot	Free floating among other green algae in brackishwater fisheries.

Class, Subclass & Order	Family	Species	Habit & Habitat
		Nostoc linckia (Roth.) Bornet *ex* Born. *et* Flah	On wet river bed in mid saline area.
		Anabaena anomala Fritsch	In high saline water bodies
		Anabaena doliolum Bharadwaja	Planktonic in brackishwater fisheries.
		Anabaena gelatinicola Ghose	On *Porteresia coarctata* in high saline area.
		Anabaenopsis arnoldii Aptekarj	Planktonic in low saline fisheries
		Pseudoanabaena sp.	Planktonic in estuarine system
		Raphidiopsis indica Singh	Planktonic from high saline areas.
		Raphidiopsis curvata Fritsch *et* Rich	Planktonic in low saline fisheries
	Scytonemataceae	*Scytonema hofmanni* Ag. ex Born. *et* Flah.	On stones and bricks in stagnant pools in mid saline areas
	Rivulariaceae	*Calothrix contarenii* (Zanard.) Born. *et* Flah.	Epiphytic on green algae at high saline areas.
		Gloeotrichia raciborskii var. *kashiense* Rao, C. B.	In muddy saline soil of high saline areas
Stigonematales	Nostochopsidaceae	*Mastigocoleus testarum* Lagerh.	Growing on shells
	Stigonemataceae	*Stigonema hormoides* (Kuet.) Born. *et* Flah.	Planktonic and also on roots of halophytes
KINGDOM: Protozoa; SUBKINGDOM: Biciliata; INFRAKINGDOM: Alveolata; CLASS: Dinophyceae			
Dinophysiales	Dinophysiaceae	*Dinophysis caudata* Saville-Kent	Estuarine phytoplankton
Noctilucales	Noctilucaceae	*Noctiluca* sp.	Estuarine phytoplankton
Peridiniphycidae Gonyaulacales	Ceratiaceae	*Ceratium extensum* (Gourret) Cleve	Marine phytoplankton
		Ceratium extensum f. *strictum* (Okamura & Nishikawa) Steeman Nielsen	Marine phytoplankton
		Ceratium furca (Ehren.) Claparede *et* Lachmann	Marine phytoplankton
		Ceratium tripos (O.F. Muller) Nitzsch.	Marine phytoplankton
		Ceratium horridum Gran.	Marine phytoplankton
		Ceratium trichoceros (Ehrenberg) Kofoi	Marine phytoplankton
		Ceratium trichoceros var. *contrarium* (Gourret) Schiller	Marine phytoplankton
		Ceratium teres Kofoid	Marine phytoplankton
		Ceratium inflatum (Kofoid) E. G. Jorgensen	Marine phytoplankton

Class, Subclass & Order	Family	Species	Habit & Habitat
	Pyrophacaceae	*Pyrophacus horologicum* Stein	Estuarine phytoplankton
Peridiniales	Protoperidiniaceae	*Protoperidinium depressum* (Bailey) Balech	Marine phytoplankton
		Protoperidinium crassipes (Kofoid) Balech	Marine phytoplankton
		Protoperidinium ovatum Pouchet	Marine phytoplankton
	Peridiniaceae	*Peridinium brevipes* Paulsen	Marine phytoplankton
KINGDOM: Protozoa; SUBKINGDOM: Biciliata; INFRAKINGDOM: Excavata; CLASS: Euglenophy - ceae			
Euglenales	Euglenaceae	*Phacus triqueter* (Ehren.) Dujardin	Estuarine phytoplankton
KINGDOM: Chromista; INFRAKINGDOM: Heterokonta; PHYLUM: Bacillariophycophyta			
Coscinodisco-phyceaeCosci-nodiscophycidae Melosirales	Melosiraceae	*Melosira moniliformis* (Muel.) Agardh	Planktonic from high saline river water.
		Melosira sol (Eher.) Kuetz.	Planktonic from high saline river water.
		Melosira sulcata (Ehren.) Kuetz.	Estuarine phytoplankton
	Stephanopyxidaceae	*Stephanopyxis palmeriana* (Grev.) Grun.	Planktonic from high saline river water.
		Stephanopyxis turris (Gre-ville) Ralfs	Estuarine phytoplankton
Asterolamprales	Asterolampraceae	*Asteromphalus flabellatus* (Brebisson) Greville	Estuarine phytoplankton
Coscinodiscales	Coscinodiscaceae	*Coscinodiscus eccentricus* Ehr.	Planktonic from high saline river water.
		Coscinodiscus gigas Ehr.	Planktonic from high saline river water.
		Coscinodiscus granii Gough	Planktonic from high saline river water.
		Coscinodiscus oculus-iridis Ehr.	Marine phytoplankton
		Coscinodiscus concinnus W. Smith	Marine phytoplankton
		Coscinodiscus perforatus var. *pavillardi* (Forti) Hus-tedt	Marine phytoplankton
		Coscinodiscus asteromphalus Ehrenberg	Marine phytoplankton
		Coscinodiscus jonesianus (Greville) Ostenfeld	Marine phytoplankton
	Hemidiscaceae	*Hemidiscus cuneiformis* Wallich	Planktonic from high saline river water

Class, Subclass & Order	Family	Species	Habit & Habitat
Paraliales	Paraliaceae	*Paralia* sp.	Estuarine phytoplankton
Corethrophycidae Corethrales	Corethraceae	*Corethron hystrix* Hensen	Planktonic from high saline river water.
		Corethron inerme Karsten	Estuarine phytoplankton
Chaetocerotophycidae Leptocylidrales	Leptocylindraceae	*Leptocylindrus danicus* Cleve	Estuarine phytoplankton
Mediophyceae Thalassiosirales	Stephanodiscaceae	*Cyclotella glomerata* Bach-mann	Planktonic from high saline river water.
		Cyclotella striata (Kuetz.) Grunow	Marine phytoplankton
		Planktoniella sol (Wallich) Schutt	Marine phytoplankton
	Skeletonemaceae	*Skeletonema costatum* (Grev.) Cleve	Marine phytoplankton
	Thalassiosiraceae	*Thalassiosira* sp.	Estuarine phytoplankton
	Lauderiaceae	*Lauderia annulata* Cleve	Marine phytoplankton
Lithodesmiales	Lithodesmiaceae	*Ditylum brightwelli* (T. West) Grunow	Marine phytoplankton
		Ditylum sol (Grunow) De Toni	Marine phytoplankton
Chaetocerotales	Chaetocerotaceae	*Chaetoceros curvisetus* Cleve	Planktonic from high saline river water.
		Chaetoceros flexuosus Mangin	Planktonic from high saline river water.
		Chaetoceros laciniosus Schutt	Planktonic from high saline river water.
		Chaetoceros tenuissimus Meunier	Planktonic from high saline river water.
		Chaetoceros subsecundus (Grunow) Hustedt	Planktonic from high saline river water
		Chaetoceros eibenii Grunow	Marine phytoplankton
		Chaetoceros peruvianus Brightwell	Marine phytoplankton
		Chaetoceros lorenzianus Grunow	Marine phytoplankton
		Chaetoceros indicus R. Sub-ramanyan	Estuarine phytoplankton
		Bacteriastrum varians Lauder	Planktonic from high saline river water.
		Bacteriastrum cosmosum Pav.	Planktonic from high saline river water.
		Bacteriastrum delicatulum Cleve	Planktonic from high saline river water.
		Bacteriastrum hyalinum Lauder	Marine phytoplankton

Class, Subclass & Order	Family	Species	Habit & Habitat
		Bacteriastrum hyalinum var. *princeps* (Castracane) Ikari	Marine phytoplankton
Biddulphiophycidae Hemiaulales	Hemiaulaceae	*Climacodium frauenfeldianum* Grunow	Planktonic from high saline river water
		Eucampia zodiacus Ehrenberg	Marine phytoplankton
		Eucampia cornuta (Cleve) Grunow	Estuarine phytoplankton
		Eucampia balaustium Castracane	Estuarine phytoplankton
		Hemiaulus sp.	Estuarine phytoplankton
Biddulphiales	Biddulphiaceae	*Biddulphia mobiliensis* Bailey	Planktonic from high saline river water.
		Biddulphia sinensis Greville	Planktonic from high saline river water.
		Biddulphia heteroceros Grunow	Planktonic in the estuaries
		Biddulphia pulchella S. F. Gray	Estuarine phytoplankton
		Biddulphia longicruris Greville	Estuarine phytoplankton
		Isthmia enervis Ehrenberg	Estuarine phytoplankton
Rhizosoleniophycidae Rhizosoleniales	Rhizosoleniaceae	*Rhizosolenia imbricata* Brightwell	Planktonic from high saline river water.
		Rhizosolenia setigera Brightwell	Planktonic from high saline river water
		Rhizosolenia robusta Norman	Marine phytoplankton
		Rhizosolenia alata Brightwell	Marine phytoplankton
		Rhizosolenia stolterfothii H. Peragallo	Marine phytoplankton
Triceratiales	Triceratiaceae	*Triceratium favus* Ehr.	Marine phytoplankton
Bacillariophyceae Bacillariophycidae-Fragilariales	Fragilariaceae	*Asterionella japonica* Cleve	Planktonic from high saline river water
		Fragilaria vaucheriae (Kutz.) Peterson, A. Cl.	Planktonic from high saline river water.
		Synedra ulna (Nitzsch.) Ehr.	Planktonic from low -high saline river water/ brackishwater fisheries
	Diatomaceae	*Diatoma vulgare* Bory	Planktonic from high saline river water
Climacospheniales	Climacospheniaceae	*Climacosphenia elongata* Mereschkowsky	Estuarine phytoplankton

Class, Subclass & Order	Family	Species	Habit & Habitat
Thalassiophysales	Catenulaceae	*Amphora veneta* Kuetz.	Planktonic from high saline river water
		Amphora sp.	Estuarine phytoplankton
Achnanthales	Achnanthaceae	*Achnanthes microcephala* (Kuetz.) Grunow	Epiphytic on red algae in high saline areas.
		Achnanthes minutissima (Kuetz.) var. *cryptocephala* Grunow	Epiphytic on red algae in high saline areas
	Cocconeidaceae	*Cocconeis placentula* Ehr.	Epiphytic on red algae in high saline areas
Bacillariales	Bacillariaceae	*Nitzschia acicularis* W. Smith	Planktonic from low -high saline river water/ brackishwater fisher - ies.
		Nitzschia obtusa W. Smith	Planktonic from low -high saline river water/ brackishwater fisher - ies.
		Nitzschia sublinearis Hus- tedt	Planktonic from low -high saline river water/ brackishwater fisher - ies
		Nitzschia longissima (Breb.) Ralfs	Estuarine phytoplankton
		Nitzschia scalaris (Ehren.) Smith	Estuarine phytoplankton
		Nitzschia closterium (Ehren.) Smith	Estuarine phytoplankton
		Nitzschia sigma (Kuetz.) Smith	Estuarine phytoplankton
		Nitzschia linearis West	Estuarine phytoplankton
		Nitzschia seriata Cleve	Marine phytoplankton
		Bacillaria paradoxa Gmelin	Marine phytoplankton
Naviculales	Naviculaceae	*Navicula cryptocephala* Kuetz.	Planktonic from high saline river water
		Navicula radiosa Kuetz.	Planktonic from low -high saline river water/ brackishwater fisher - ies
	Stauroneidaceae	*Stauroneis phoenicenteron* (Nitzsch.) Ehr.	Planktonic from high saline river water
	Pinnulariaceae	*Pinnularia viridis* (Nitzsch.) Ehr.	Planktonic from low -high saline river water/ brackishwater fisher - ies
	Pleurosigmataceae	*Pleurosigma angulatum* (Quekett) W. M. Smith	Planktonic from high saline river water
		Pleurosigma elongatum W. Smith	Marine phytoplankton
		Pleurosigma normanii Ralfs	Marine phytoplankton
		Gyrosigma acuminatum (Kuetz.) Rabh.	Planktonic from low -high saline river water/ brackishwater fisher - ies

Class, Subclass & Order	Family	Species	Habit & Habitat
		Gyrosigma balticum (Ehren.) Rabenh.	Estuarine phytoplankton
	Diploneidaceae	*Diploneis robustus* R. Subramanyan	Marine phytoplankton
	Amphipleuraceae	*Tropidoneis elegans* (W. Smith) Cleve	Estuarine phytoplankton
		Frustulia sp.	Estuarine phytoplankton
		Amphiprora sp.	Estuarine phytoplankton
Cymbellales	Anomoeoneidaceae	*Anomoeoneis exilis* (Grun.) Cleve	Planktonic from high saline river water
	Gomphonemataceae	*Gomphonema sphaerophorum* Ehr.	Planktonic from high saline river water
	Cymbellaceae	*Cymbella ehrenbergii* Kuetz.	Planktonic from high saline river water.
Surirellales	Surirellaceae	*Campylodiscus clypeus* (Ehr.) Ehr. *ex* Kuetz.	Estuarine phytoplankton
Eunotionphycidae Eunotiales	Eunotiaceae	*Eunotia* sp.	Estuarine phytoplankton
KINGDOM: Chromista; INFRAKINGDOM: Heterokonta; CLASS: Xanthophyceae			
Vaucheriales	Vaucheriaceae	*Vaucheria prescotti* Islam	Dense mat on decomposed matter on forest floor in high saline area.
		Vaucheria sp.	Among the bottom biota of brackishwater fishery at mid saline area.
KINGDOM: Chromista; INFRAKINGDOM: Heterokonta; CLASS: Phaeophyceae			
Scytosiphonales	Scytosiphonaceae	*Colpomenia sinuosa* (Roth.) Derb & Sol.	On highly consolidated soil substratum in the littoral zone at high saline areas
Dictyotales	Dictyotaceae	*Dictyota ceylanica* Kuetzing	Periphytic on pneumatophores alongwith other red algae at high saline areas
KINGDOM: Plantae; SUBKINGDOM: Viridaeplantae; CLASS: Chlorophyceae			
Volvocales	Volvocaceae	*Volvox* sp.	Planktonic in brackishwater fishery at low saline area.
		Pandorina morum (Mull.) Bory	Planktonic in brackishwater fishery at low saline area.
		Eudorina sp.	Estuarine phytoplankton
Ulotrichales Ulotrichineae	Ulotrichaceae	*Uronema confervicola* Lagerheim	Epiphytic on other green algae in brackishwater fisheries
	Sphaeropleaceae	*Sphaeroplea soleirolli* var. *crassisepta* (Reith) Comb. nov	Free floating with green and blue green algae in brackishwater wetlands
Ulvales	Ulvaceae	*Enteromorpha clathrata* (Roth.) Greville	Alonwith *Ulva* spp. attached to bricks and other hard substratum at high saline areas.

Class, Subclass & Order	Family	Species	Habit & Habitat
		Enteromorpha compressa (Linn.) Greville	Periphytic on twigs/ submerged plant parts in brackishwater fisheries at mid saline areas.
		Enteromorpha intestinalis (Linn.) Link.	Abundant in brackishwater fisheries at low to mid saline areas.
		Enteromorpha prolifera (Muller) J. Agardh	Abundant in brackishwater fisheries at low to mid saline areas.
		Ulva lactuca Linnaeus	Attached to bricks on the high saline river bank.
		Ulva patengensis Salam *et* Khan	Attached to bricks on the high saline river bank.
		Ulva fasciata Delile	Attached to bricks on the high saline river bank.
Cladophorales	Cladophoraceae	*Chaetomorpha aerea* (Dillwyn) Kuetz.	Free floating mass in high saline brackish water fisheries.
		Chaetomorpha gracilis Kuetzing	Alongwith *Ulva* sp. thallus on bricks.
		Chaetomorpha brachygona Harvey	Free floating/ attached to submerged substratum in high saline brackishwater fisheries.
		Lola capillaries (Kuetz.) Hamel	Free floating algal mass in brackishwater fisheries at mid to high saline areas.
		Lola implexa (Harv.) Hamel	Free floating in brackishwater fisheries at mid to high saline areas.
		Lola tortuosa (Dulw.) Chapman	Free floating in brackishwater fisheries at high saline areas.
		Rhizoclonium grande Boergesen	Periphytic on pneumatophores at high saline areas.
		Rhizoclonium hookeri Kuetz.	Periphytic on pneumatophores at high saline areas.
		Rhizoclonium riparium (Roth.) Harvey	Periphytic on pneumatophores at high saline areas.
		Cladophora echinus (Bias.) Kuetz.	Epiphytic on submerged substratum in brackishwater fisheries at high saline areas.
		Cladophorella sundarbanensis Islam	Benthic on forest floor in high saline area and also more recently in brackishwater fisheries
Oedogoniales	Oedogoniaceae	*Oedogonium undulatum* (Brebisson) Al. Braun	On submerged substratum/ free floating in brackishwater fisheries at high saline areas.
Zygnematales	Zygnemataceae	*Spirogyra dubia* Kg.	Free floating in water bodies at low saline areas.
		Spirogyra setiformis (Roth.) Kg.	Floating in water bodies at low to mid saline areas.

Class, Subclass & Order	Family	Species	Habit & Habitat
		Spirogyra ternata Ripart	Floating in water bodies at low to mid saline areas.
		Spirogyra irregularis Nageli	Free floating in brackishwater fishery
		Spirogyra juergensii Kuetz.	Free floating with BGA in brack - ish water fisheries
		Triplastrum simplex (P. Allorge) Iyengar & Ramana - than	Planktonic in mid saline brackish - water fisheries.
		Triplastrum abbreviatum (Turner) Iyengar & Ramana - than	Planktonic in mid saline brackish - water fisheries.
Desmidiales	Desmidiaceae	*Triplocerus gracile* Bailey	Planktonic in mid saline brackish water fisheries
		Cosmarium paucigranula - tum Borge fa.	Planktonic in mid saline brackish water fisheries
		Cosmarium regenlii Wille fa	Planktonic in mid saline brackish water fisheries
		Cosmarium striolatum Näg	Planktonic in mid saline brackish - water fisheries.
		Cosmarium depressum (Näg) Lund	Planktonic in mid saline brackish - water fisheries.
		Closterium acutum (Lyngb.) Breb. *ex* Ralfs	Planktonic in brackishwater fish - eries at mid to high saline areas.
Chlorococcales	Chlorellaceae	*Chlorella vulgaris* Beijerinck	Planktonic in low saline brackish - water fisheries.
	Radiococcaceae	*Radiococcus* sp.	Planktonic in brackishwater fish - ery at low saline areas.
	Hydrodictyaceae	*Pediastrum boryanum* (Turp.) Menegh.	Planktonic in brackishwater fish - ery at low to mid saline areas.
		Pediastrum duplex (Meyen)	Planktonic in low to mid saline brackishwater fisheries.
		Pediastrum simplex Meyen	Estuarine phytoplankton
		Pediastrum tetras (Ehr.) Ralfs	Planktonic in low saline brackish - water fisheries.
	Scenedesmaceae	*Scenedesmus bijuga* (Turp.) Lagerheim	Planktonic in low saline brackish - water fisheries
		Scenedesmus quadricauda (Turp.) Brebisson	Planktonic in low saline brackish - water fisheries
	Chlorochytriaceae	*Phyllobium dimorphum* Klebs Phillipose	Planktonic in brackishwater fisheries
	Oocystaceae	*Franceia dorescheri* Lemm.	Planktonic in low to mid saline fisheries
		Chlorella salina Butcher	Marine phytoplankton
		Chlorella marina Butcher	Marine phytoplankton

Class, Subclass & Order	Family	Species	Habit & Habitat
	Dictyosphaeriaceae	*Dictyosphaerium pulchellum* Wood	Free floating among filamentous green algae
Siphonales	Codiaceae	*Boodleopsis sundarbanensis* Islam	On muddy substratum at upper littoral zone at high saline zone
KINGDOM: Plantae; SUBKINGDOM: Viridaeplantae; CLASS: Charophyceae			
Charales	Characeae	*Chara zeylanica* Wildenow	In brackishwater fisheries at high saline areas
KINGDOM: Plantae; SUBKINGDOM: Biliphyta; CLASS: Compsopogonophyceae			
Compsogonales	Compsopogonaceae	*Compsopogon coeruleus* (Balbis) Montagne	Attached to twigs submerged in brackishwater fisheries in low to mid saline areas
KINGDOM: Plantae; SUBKINGDOM: Biliphyta; CLASS: Florideophyceae			
Gigartinales	Rhabdoniaceae	*Catenella nipae* Zanardini	On the barks of *E. agallocha* in the upper littoral zones
		Catenella repens (Lightfoot) Batters	Creeping on pneumatophores and trunks of mangroves and other hard substrata in high saline areas
		Catenella impudica (Mont.) J. Ag.	Creeping on pneumatophores and trunks of mangroves and other hard substrata in high saline areas
Ceramiales	Delesseriaceae	*Caloglossa adnata* (Zanardini) De Toni	On pneumatophores and trunks of mangroves and other hard substrata in high saline areas
		Caloglossa leprieurii (Mont.) J. Ag.	On pneumatophores and trunks of mangroves and other hard substrata in high saline areas
	Rhodomelaceae	*Polysiphonia mollis* Hooker & Harvey	On pneumatophores and other hard substrata in dense tufts in high saline areas
		Polysiphonia denudate (Dillwyn) Kuetzing	Creeping on pneumatophores and other hard substrata in high saline areas
		Pterosiphonia pinnata (Roth.) Falkenberg	On pneumatophores in above littoral zone in high saline areas
		Bostrychia radicans (Montagne) Mont.	On pneumatophores in littoral and above littoral zones in high saline areas
		Bostrychia tenella (Vahl.) Ag. J.	On pneumatophores in high saline areas
		Herposiphonia dendroidea Hollenberg	On the forest floor in littoral and above littoral zones in high saline areas
	Dasyaceae	*Heterosiphonia* sp.	On the bark of *Aegialitis rotundifolia* and other mangroves in high saline areas
Gelidiales	Gelidiaceae	*Gelidiella acerosa* (Forsskal) Feldmann et Hamel	As littoral forest floor flora and also on barks of mangroves in high saline areas.
		Gelidium pusillum (Stackh.) Le Jolis	On hard substratum in high saline areas.

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2.3 PLANKTONS

Phytoplankton assemblages in the majority of the mangrove environments in the Indian subcontinent are usually dominated by diatoms and dinoflagellates and their distribution and abundance is controlled by seasonal environmental fluctuations.

PUNYASLOKE BHADURY
Marine Biologist with specialization in Marine microbiology

The term plankton refers to any small biota (size range from a few microns to centimeters) living in the water and drifting at the mercy of the currents from minute bacteria to the microscopically visible phytoplankton and small invertebrate larvae to large gelatinous zooplankton. As there are significant ecological and physiological implications of body size, size is used as a first step for classification of plankton (Peters 1983). The various size categories of plankton are as listed:

- **Megaplankton** (>20 cm) include very large jellyfish, salps, and relatives.
- **Macroplankton** (2–20 mm) include large organisms such as krill, comb jellies, and jellyfish.
- **Mesoplankton** (0.2 mm–2mm) include copepods, cladocerans, small salps, the larvae of many benthic organisms and fish, and others.
- **Microplankton** (20–200 micron) include large phytoplankton (diatoms and dinoflagellates); foraminiferans; ciliates; nauplii (early stages of crustaceans such as copepods and barnacles); and others.
- **Nanoplankton** (2–20 micron) include small phytoplankton (mostly single-celled diatoms); flagellates (both photosynthetic and heterotrophic); small ciliates; radiolarians; coccolithophores, and others.
- **Picoplankton** (0.2–2.0 micron) include eukaryotic protists, bacteria, and archaea.

The size categories do not reflect specific taxonomic divisions as sizes vary widely within most taxonomic groups. Based on function or trophic level, plankton can be classified into **bacterioplankton** (represented mainly by bacteria and archaea) which play an important role in the ecosystem for remineralization of organic matter; **phytoplankton** (autotrophic, prokaryotic, or eukaryotic algae) that are found near the surface water, require light for photosynthesis, and are key to primary productivity; and **zooplankton** or grazers that feed on other plankton, including phytoplankton, and help in the transfer of energy flow.

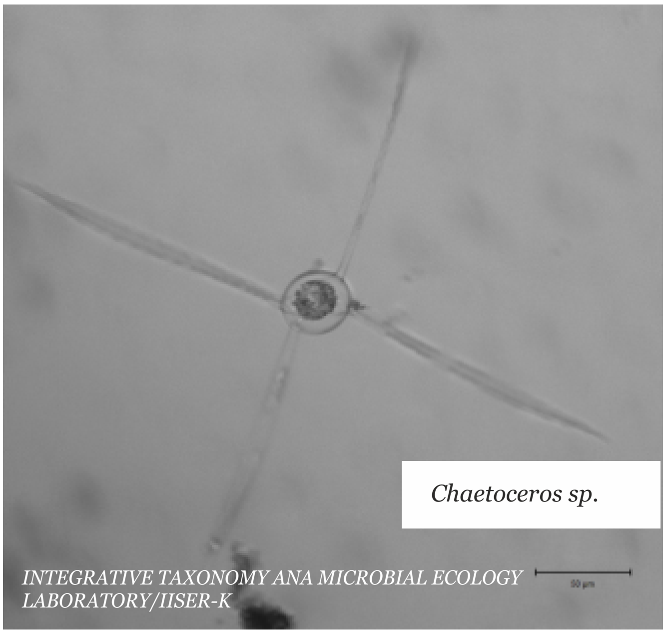
The most important elements for phytoplankton growth are the macronutrients nitrogen (N) and phosphorus (P) and for diatoms, silica (Si). While the growth of phytoplankton cells in freshwater system is controlled on the availability of P, growth in estuarine and ocean environments is commonly regulated by N availability. Grazers represent an essential trophic pathway for the transfer of organic carbon from phytoplankton to fish, and they contribute to the nutrient pool by excreting faecal pellets that are either recycled within the water column or used by bottom feeders. Nutrient recycling is also assisted by partial ingestion of cells by herbivorous zooplankters such as copepods. It is now accepted that a significant proportion of phytoplankton production is not consumed directly by zooplankton grazers but is cycled by the microbial community (also known as 'microbial loop') before it becomes available to consumers.

OVERVIEW

On a global scale, numerous studies have been undertaken to study the distribution and diversity patterns of phytoplankton and zooplankton assemblages and their role in the flow of energy to higher organisms in different ecosystems including in mangroves. In the Indus River delta mangrove ecosystem, primary productivity was found to be higher despite extreme turbidity in the water column and the productivity values were very similar to the mangrove ecosystem in Goa, India. Phytoplankton communities in the Indus mangroves were dominated by centric diatoms, including *Chaetoceros teres, C. decipiens, Leptocylindrus danicus*, and *Coscinodiscus tori* (Harrison et al. 1995). Gunbua et al. (1997) studied the phytoplankton community structure in mangroves from the Klong Sikao Trang and Tha Chin Estuary, Samut Sakhon Province (Thailand) and reported the presence of 55 phytoplankton genera. Diatoms, including *Leptocylindrus* spp., *Nitzschia* spp., *Thalassiosira* spp., and *Cyclotella* spp., were dominant in the studied sites. The average cell density was 9,918 cells per liter in Klong Sikao and 709,311 cells per liter in Tha Chin. Tanaka and Choo (2000) have shown that the phytoplankton abundance is usually linked to tidal amplitudes and availability of nutrients in the mangrove estuaries in Malaysia. It was also evident that abundance of copepod communities was directly linked to chlorophyll, a concentration (phytoplankton biomass) in the Matang mangroves in Malaysia (Chew and Chong 2010).

Phytoplankton taxa from the Sundarbans vary between 40 and 65 while the phytoplankton abundance in the ecoregion varied between 45.15±8.05-170.77±44.07 x 105 m-3 from 1990-2007

Phytoplankton assemblages in the majority of the mangrove environments in the Indian subcontinent (for example, the Pichavaram mangroves and the Gautami Godavari mangroves) are usually dominated by diatoms and dinoflagellates and their distribution and abundance is controlled by seasonal environmental fluctuations (Rajkumar et al. 2009). Average cell density varied from 400 to 321,000 cells per liter in these locations. Trends observed in different mangrove ecosystems are also well reflected in the case of phytoplankton assemblages



Chaetoceros sp.

from the Sundarbans ecoregion. Diatoms dominate among the phytoplankton functional groups and, in particular, certain species of centric diatoms as found in other mangrove environments constitute an important component of the natural assemblages and during bloom formation (Biswas et al. 2010). Reported phytoplankton taxa from the Sundarbans vary between 40 and 65 while the phytoplankton abundance in the ecoregion varied between 45.15 ± 8.05 and 170.77 ± 44.07 x 10^5 m^{-3} from 1990 to 2007 (Biswas et al. 2010). Environmental parameters, including salinity, rainfall, and temperature, are known to play an important role in determining the distribution and diversity of phytoplankton assemblages in the Sundarbans.

COPEPODS CONSTITUTE MORE THAN 80% OF THE TOTAL POPULATION IN SOME PARTS OF SUNDARBAN

Similarly, zooplankton community composition and dynamics are extensively studied in different mangrove environments across the globe. Zooplankton studies undertaken in an Australian mangrove ecosystem showed overwhelming dominance of copepods and there was no strong correlation between environmental parameters and dynamics of zooplankton (Robertson et al. 1988). Mckinnon and Klumpp (1997) reported the dominance of copepods, particularly representatives of the genus *Oithona* in the mangrove estuaries of six rivers in northeastern Australia and the mean abundance of zooplankton greater than 37 µm ranged between 60 and 500 /litre. They found that physical forcing influenced the zooplankton of mangrove estuaries much more than the measured biological variables. Krumme and Liang (2004) showed the occurrence of positive relationships between increased copepod abundances, high sediment loads, and decreased salinities during the wet season and synchronous temporal patterns between zooplankton and fish abundance in a mangrove channel in northern Brazil. From an Indian context, several studies have reported dominance of copepods in different mangrove environments. For example, Mohan and Sreenivas (1998) found copepods as the dominant zooplankton group in the mangrove ecosystem at Gaderu Canal on the southeast coast of India and overall, the zooplankton abundance varied between 17,401 and 27,053 m^{-3}. Saravanakumar et al. (2007) found copepods to be the most dominant group in the mangroves of the Gulf of Kachchh-Gujarat and zooplankton population density varied between 30,000 and 210,000 organisms per m^{-3}. Karuppasamy and Perumal (2000) studied the population density, species diversity, species evenness and species richness of zooplankton in the Pichavaram mangroves (southeast coast of India). Out of 55 species of zooplankton recorded, the copepod was the dominant group (36.5 percent). The zooplankton density varied from 200 to 61,650 individuals per liter, with the maximum during summer. Zooplankton communities in the Indian Sundarbans exhibit similar trends as reported earlier in other mangrove ecosystems. Copepods constitute more than 80 percent of the total population in some parts of the Sundarbans and the dominant genera are *Acartia, Paracalanus, Acrocalanus, Eucalanus, Labidocera*, and *Oithona*, some of which are characteristic of mangrove fauna and reported from different locations globally. Zooplankton densities vary between 4 and 3,680 m^{-3} in some parts of the Sundarbans, resembling general trends observed in other mangrove environments. The abundance of zooplankton communities in the ecoregion is controlled by environmental factors and primary productivity, with reports of highest abundance in the months of June/July and October/November following phytoplankton blooms.

The Indian Sundarbans at the apex of the Bay of Bengal (between 21°40′ N, 88°03′ E and 22°40′ N, 89°07′ E) located on the southern fringe of West Bengal, on the northeast coast of India, is a dynamic environment with a complex of features and biogeochemical properties. The aquatic biodiversity in the Sundarbans delta is largely controlled by freshwater flux, nutrient inputs, and changing environmental conditions such as salinity and temperature. Plankton communities are generally well studied in the deltaic ecosystem over a time scale encompassing more than three decades and show patterns or trends similar to those found in other mangrove ecosystems at a regional and global scale.

SYNOPTIC VIEW

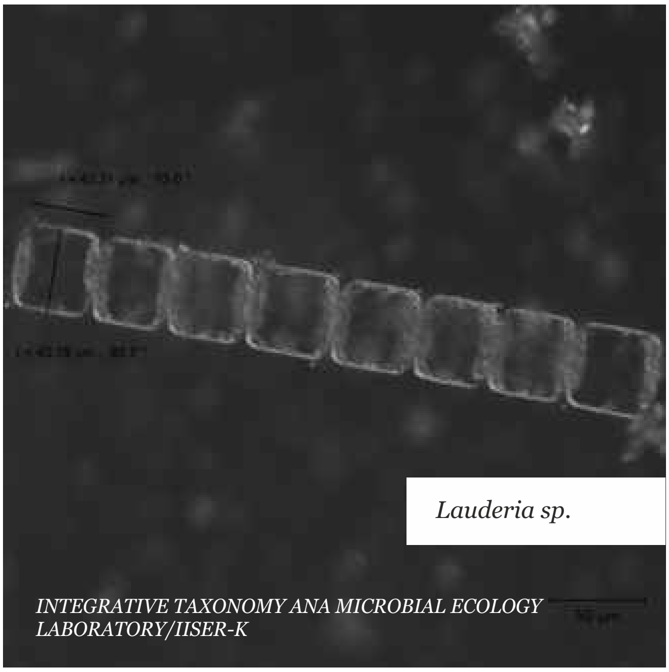
Diversity

a. Phytoplankton of the Sundarbans

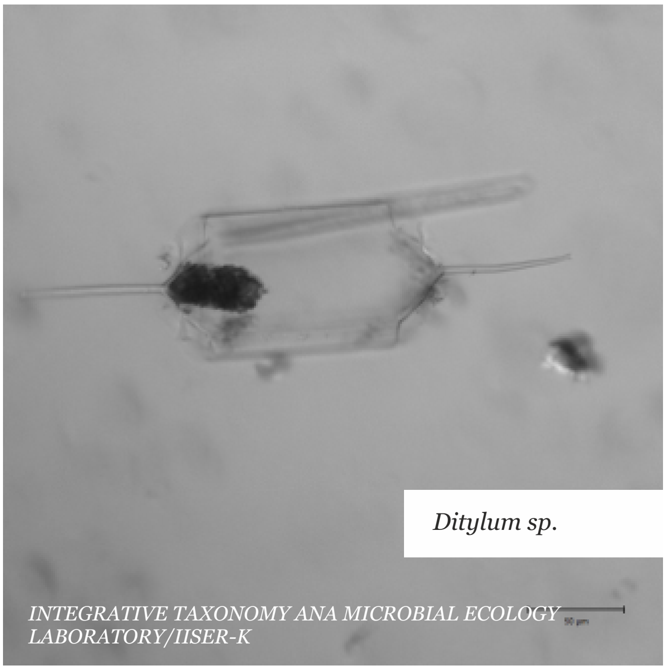
DIATOM TAXA OF 76 SPECIES FOUND IN SUNDARBANS

Phytoplankton communities, which are key to primary production and the resulting flow of energy along the trophic levels, were thoroughly studied in the delta. Annual variations of phytoplankton abundance and community organization have been observed for over two decades along with physico-chemical parameters within the Sundarban mangroves. It has become increasingly clear from different studies that the number of definable diatom species (Bacillariophyceae) exceeds other phytoplankton functional groups, including those of dinoflagellates. The most comprehensive and authenticated list of phytoplankton taxa detected over a period of two decades in the delta was reported by Biswas et al. (2010). A list of diatom taxa of 76 species found in the Sundarbans is detailed in annexure A. Besides diatoms, dinoflagellates and chlorophytes are also found in this ecoregion. Some of the abundant dinoflagellate taxa detected in these waters are *Dinophysis caudate*, *Protoperidinium* spp., and *Prorocentrum micans*. Other phytoplankton functional groups, including Cyanophyceae (majority of them benthic); Euglenop-hyceae; and Chrysophyceae, have been also reported (Manna et al. 2010).

Various published reports on phytoplankton distribution in the Indian Sundarbans provide only a patchy picture as they are usually based on short-term surveys of small areas in the ecoregion. Nevertheless, the information does reveal a general trend of phytoplankton distribution. For example, in the Baro Herobhanga Khal adjacent to Jharkhali Island of the Indian Sundarbans, 46 phytoplankton taxa represented by 6 major phyto-plankton functional groups—namely, Bacillariophyceae (diatoms); Chlorophyceae; Cyanophyceae; Dinophyceae; and Chrysophyceae—were reported in a recent study (Manna et al. 2010). The majority of the phytoplankton genera belonged to diatoms (27 genera belonging to 46 species) in Baro Herobhanga Khal (Manna et al. 2010). The same study also reported the occurrence of *Prorocentrum concavum*, a dinophyte which was recorded for the first time in the Indian Sundarbans but has been widely reported from other subtropical mangrove habitats outside India. Bhattacharjee et al. (2012), while studying the eukaryotic phytoplankton community structure along a temporal scale in Chemaguri Creek of Sagar Island, found an overwhelming dominance of diatoms in their study sites (20 out of 22 reported genera belonging to diatoms). This study also found a gradual shift in diatom community structure (from centric to pennate forms) with change in water temperature along a temporal gradient. Biswas et al. (2004), while studying the air-water carbon dioxide exchange in the Sundarbans mangrove environment (northeast coast of the Bay of Bengal off the Mooriganga, Saptamukhi, and Thakuran Estuaries), found a dominance of diatoms (36 genera) compared to other phytoplankton functional groups. The eastern part of the estuary is dominated by phytoplankton species such as *Biddulphia* (diatom), green algae, and BGA. The central part is dominated by a variety of diatom genera, including *Chaetoceros, Coscinodiscus,*



Lauderia sp.



Ditylum sp.

Phytoplankton biovolume is lower during monsoon than in premonsoon and postmonsoon periods

Bacteriastrum, Cyclotella, Ditylum, Skeletonema, Thalassiothrix, Thalassionema, and *Triceratium*. In contrast, the western part is represented by species of *Fragillaria, Gyrosigma, Nitzschia*, and *Bacillaria*.

Generally, phytoplankton abundance in the Indian Sundarbans is controlled by the semidiurnal tidal pattern, with a higher abundance of phyto-plankton cells during high tide compared with low tide. From a seasonal perspective, phyto-plankton biovolume is lower during the monsoon than in the pre-monsoon and post-monsoon periods. During premonsoon, the dominant phytoplankton includes species of *Ditylum, Ceratium, Biddulphia, Chaetoceros, Coscinodiscus, Thalassiothrix, Rhizosolenia*, and *Thalassionema*. However, during the postmonsoon period, phytoplankton species of *Bacteriastrum, Biddulphia*, and *Protoperidinium* were most dominant. During the monsoon, species of *Skeletonema, Fragillaria*, and some blue green algae are quite common. The mean numerical abundance of phytoplankton was three times higher in 2007 than in 1990 (De et al. 1991) and 2000 (Biswas et al. 2004). However, phytoplankton bio volume was the highest in 2000 (Biswas et al. 2010), indicating major differences between years in size class structure.

Diatoms are known to dominate the waters of the Sundarbans in numerical abundance and bio volume. Moreover, low salinity and high nutrient levels in the water column may be contributing to the dominance of diatoms over other phytoplankton in the Sundarbans. Almost all the blooms that have been recorded in the Sundarbans involved diatom species and are dominated by large-celled species such as *Coscinodiscus eccentricus* and *Ditylum brightwellii* while the small-celled species are usually represented by *Navicula rhombica, Leptocylindricus* sp., *Nitzschia seriata, N. sigma, Thalassiosira decipiens*, and *Skeletonema costatum*. Phytoplankton blooms are generally dominated by diatoms in most parts of the delta with one post monsoon and the other in the month of February.

Overall, the diurnal and seasonal variability of phytoplankton in the Sundarbans delta appear to be mainly controlled by tidal amplitude and the intensity of the monsoon. This trend of phytoplankton dynamics, including the bimodal seasonal cycle, is similar to the ones observed across the mangrove and coastal regions of the rest of India and at a global scale.

b. Zooplankton of the Sundarbans

COPEPOD TAXA OF 52 SPECIES ARE REPORTED FROM SUNDARBANS

When compared to phytoplankton, most of the zooplankton studies in the Sundarbans are centered on the Hooghly Estuary near Sagar Island (for example, Sarkar et al. 1984, 1986; Baidya and Choudhury 1984). Zooplankton communities in the Sundarbans are represented by members of aphragmophora, beroida, rotifers, tintinnids, copepoda, cladocera, cyclopoida, decapoda, doliolida, harpacticoida, and diverse plankton larval forms. Copepods constitute more than 80 percent of the zooplankton population in these waters. For example, in and around Sagar Island, copepods were found to be the most dominant group followed by chaetognaths and mysids whereas cladocerans, hydromedusae, amphipods, isopods, and ctenophores were the less abundant groups (Sarkar et al. 1984). Copepod taxa of 52 species reported previously from the Sundarbans are detailed in annexure B.

Two key hydrological parameters, temperature and salinity, seemed to have an impact on the distribution and abundance of zooplankton in some of the creeks in Sagar Island (Baidya and Choudhury 1984). Generally, two peak periods of zooplankton abundance, one in March/April and the other in November/December, have been encountered in Sagar Island (Baidya and Choudhury 1984). Sarkar et al. (1986) found higher numerical counts and biomass of zooplankton during the high-saline premonsoon period in the Hooghly Estuary and with the onset of monsoon efflux, reported disappearance of most of the stenohaline species. Only oligohaline species such as *Acartiella keralensis, Halicyclops tenuispina*, and *Mesocyclops* were able to thrive in the estuary. Copepod genera are mostly dominated by *Acartia, Paracalanus, Acrocalanus, Eucalanus, Labidocera, Oithona*, and *Pseudodiaptomus* in the Sundarbans. Besides copepods, rotifers are represented by *Asplancha* spp. and *Brachionus* spp. whereas chaetognaths are represented by epipelagic euryhaline species—namely, *Sagitta bedorti* and *S. enflata*. Ichthyoplankton assemblages in the Hooghly Estuary close to Sagar Island were reported by Sasmal and Choudhury (2009) and found to be represented by 65 taxa belonging to the Engraulida, Mugilidae, Clupcidae, Gobiidae, and Cynoglossidae families. Unlike phytoplankton, zooplankton distribution patterns in the Indian Sundarbans are less marked.

While a lot is known about the plankton communities from the

Ditylum sp.

INTEGRATIVE TAXONOMY ANA MICROBIAL ECOLOGY LABORATORY/IISER-K

Indian Sundarbans, there are areas where knowledge gaps exist even today. Until the 1970s, the importance of picoplankton, relative to the larger nano and micro-phytoplankton such as diatoms and dinoflagellates, was largely overlooked. It is now known that picoplanktonic cells which are about the size of an average bacterium can dominate the phytoplankton assemblage, contributing up to half the chlorophyll-a content in coastal waters and up to 90 percent in nutrient-poor open ocean environments. However, we know almost nothing about the distribution and diversity patterns of picoeukaryotes and their contribution to primary production in the Sundarbans ecoregion. Preliminary studies have revealed the presence of picoeukaryotes in significant number in a creek on Sagar Island (Bhattacharjee et al. 2012) and a high-throughput functional gene sequencing approach as adopted in other studies (Bhadury and Ward 2009) has been applied to elucidate picoeukaryote diversity and understand their contribution in primary production along with lesser known phytoplankton groups such as Pelagophyceae and Haptophyceae in the Sundarbans ecoregion (Samanta and Bhadury 2014). Samanta and Bhadury (2014) has shown that phytoplankton community structure and their functional diversity in Sundarbans undergo shifts due to changes in environmental conditions and that many small sized photosynthetic chromophytic cells (less than 5 micron) are important players in this ecosystem. More recently, Samanta and Bhadury (2015) have described a new species of estuarine diatom, *Thalassiosira sundarbana*, highlighting that cryptic biodiversity and their associated functional importance in Indian Sundarbans has largely remain unaccounted for to date. Similarly, nothing is known about the role of bacterioplankton, particularly the role of archaea in organic mineralization process in the Sundarbans. As evident from the earlier section, the zooplankton studies in the delta are more localized in certain sectors and thorough studies are needed in other sectors of the ecoregion. Overall, serious scientific effort has to be initiated to study and elucidate the role of the above groups in the Sundarbans environment and more so when the ecoregion is reeling from the effects of anthropocene-related activities.

Ecological Importance and Need for Conservation

> Pivotal role in maintaining the balance of the aquatic food chain of Indian Sundarbans by contributing to overall primary production and subsequent grazing activities and resulting recycling of elemental components in the aquatic domain

Plankton communities play a pivotal role in maintaining the balance of the aquatic food chain of the Indian Sundarbans by contributing to overall primary production and subsequent grazing activities and the resulting recycling of elemental components in the aquatic domain. Both phytoplankton and zooplankton communities in the Indian Sundarbans directly or indirectly support the very rich estuarine and coastal marine fisheries. It is expected that as a result of increased anthropocene activities, including climate change, there will be increased intrusion of seawater in the Indian Sundarbans and that will affect the biota, particularly the plankton community structure, and may also have an impact on the rich fisheries. In addition, the collection of fish fauna, including shrimp juveniles and other planktonic forms, has increased manifold, particularly for aquaculture-related activities in the Sundarbans. During shrimp collection, a significant quantity of by catch is discarded, which is a substantial proportion of zooplankton forms and is a major negative influence on the aquatic biodiversity in the ecoregion. Therefore, it is imperative to develop long-term strategies, including sustainable fishing and alternative livelihood, for the local communities in the ecoregion coupled with thorough scientific studies on the aquatic biota, particularly plankton, so as to develop an adaptive and mitigation strategy from climate change in this unique deltaic mangrove ecosystem.

STATUS AND THREATS

Climate Change Threats to the Sundarbans Ecoregion

> Different CO2 levels caused a shift in dominance of diatom species in the phytoplankton assemblage of the Equatorial Pacific and Southern Ocean

Climate change is an impending threat which in the longer run can have a disastrous impact on the aquatic biodiversity of the Sundarbans, including on plankton assemblages. Rising atmospheric carbon dioxide (CO_2) concentration induced by human activities is causing global warming, as a result of which changes in environmental conditions are presently occurring at an unprecedented rate (Caldeira and Wickett 2003; Orr et al. 2005). With the beginning of the industrial revolution, CO_2 emissions from the burning of fossil fuel and changes in land use led to atmospheric CO_2 concentrations well above the upper limit of the last several million years (Luthi et al. 2008). At present, the pCO_2 has reached about 380 µatm and is expected to rise to 750 µatm by the end of this century (Houghton et al. 2001) or even values greater than 1,000 µatm (Raven et al. 2005). Such changes are altering the physico-chemical conditions in different ecosystems, including in mangrove and coastal environments. Changes in atmospheric pCO_2 will directly affect the carbonate system of the ocean since the atmosphere and surface ocean exchange CO_2 on time scales of several months (Zeebe and Wolf-Gladrow 2001).

Very few studies have focused on the potential effect of CO_2 release and resulting 'ocean acidification' on planktonic life forms, including phytoplankton. Field studies have demonstrated that different CO_2 levels caused a shift in dominance of diatom species in the phytoplankton assemblage of the equatorial Pacific and Southern Ocean (Tortell et al. 2002, 2008), led to an increase in phytoplankton productivity, and promoted the growth of larger chain-forming diatoms. With respect to the process of silification, diatoms do not appear to be particularly CO_2 sensitive (Milligan et al. 2004). While the effect of CO_2 on photosynthesis and growth may yet be small in diatoms, at least when compared to other taxa, the predicted changes in stratification—and thus light and nutrient availability—will certainly affect this group strongly. Future studies on diatoms, including in the Indian Sundarbans, should therefore investigate carbonate chemistry effects in combination with nutrient and light availability based on field manipulation experiments.

N_2-fixing cyanobacteria support a large fraction of total biological productivity in tropical and subtropical areas, including in mangroves. Currently, there is little information available on the sensitivity of this group to more realistic CO_2 scenarios. Fu et al. (2007) observed higher rates of growth and photosynthesis in *Synechococcus* spp. when grown at 750 µatm CO_2. *Prochlorococcus* spp. remained unaffected by elevated CO_2

in the present study. Such species-specific difference in CO_2/pH sensitivity could lead to shifts in community structure. Our current knowledge is, however, based on too few studies (and species). In view of the potential ecological and biogeochemical implications, investigation of diazotrophic and other cyanobacteria is clearly a research priority, including in the Sundarbans.

Apart from phytoplankton, the potential effects of elevated CO_2 concentration on zooplankton communities are not well studied. However, CO_2 can influence the physiology of marine organisms as well through acid-base imbalance and reduced oxygen transport capacity. Therefore, the ability of certain holoplankton groups most importantly, pteropods and foraminifera—to produce calcareous skeletal structures could be directly affected by changing seawater CO_2 chemistry (McNeil and Matear 2008).

Studies are being undertaken on a global scale to understand how marine organisms, including plankton, may respond to changes in aquatic carbon chemistry. However, there lacks a serious effort from India on how resulting impacts of climate change, particularly changing carbonate chemistry and 'ocean acidification', is going to affect the aquatic biota, including phytoplankton and zooplankton communities in the Sundarbans. Studies have already shown changes in temperature and salinity in the coastal waters of the Sundarbans (Mitra et al. 2009), but what is not clear is the impact of these changes on the aquatic biota. One of the newest initiatives is the Path Finders Ocean Acidifcation project that aims to assess the effect of ocean acidification on large marine ecosystems such as the Bay of Bengal including Indian Sundarbans (Land et. al., 2015). Since the plankton distribution and diversity in the Sundarbans is largely controlled by environmental variables, any alteration in these variables as a result of climate change may affect the assemblage patterns in the long run. Such alteration could seriously affect the rich fishery resources in the region which are dependent on planktons and may lead to large-scale ecological disaster in the decades to follow.

ANNEXURE A

Diatoms from Sundarbans belonging to the phylum Bacillariophyta

Class	Subclass	Order	Family	Genus and species name
Bacillariophyceae	Bacillariophycidae	Thalassiophysales	Catenulaceae	*Amphora hyalina*
Bacillariophyceae	-	Naviculales	Amphipleuraceae	*Amphipleura* sp.
Bacillariophyceae	-	Naviculales	Amphipleuraceae	*Amphiprora constricta*
Bacillariophyceae	-	Fragilariales	Fragilariaceae	*Asterionella japonica*
Bacillariophyceae	-	Fragilariales	Fragilariaceae	*Asterionellopsis glacialis*
Bacillariophyceae	-	Bacillariales	Bacillariaceae	*Bacillaria paradoxa*
Bacillariophyceae	-	Bacillariales	Bacillariaceae	*Bacillaria paxillifer*
Bacillariophyceae	-	Bacillariales	Bacillariaceae	*Bacteriastrum hyalinum*
Coscinodiscophyceae	-	Chaetocerotales	Chaetocerotaceae	*Bacteriastrum delicatulum*
Coscinodiscophyceae	-	Chaetocerotales	Chaetocerotaceae	*Bacteriastrum* sp.
Mediophyceae	Biddulphiophycidae	Hemiaulales	Bellerocheaceae	*Bellerochea malleus*
Mediophyceae	Biddulphiophycidae	Biddulphiales	Biddulphiaceae	*Biddulphia regia*
Mediophyceae	Biddulphiophycidae	Biddulphiales	Biddulphiaceae	*Biddulphia sinensis*
Dinophyceae	Dinophycidae	Gonyaulacales	Ceratiaceae	*Ceratium tripose*
Dinophyceae	Dinophycidae	Gonyaulacales	Ceratiaceae	*Ceratium furca*
Dinophyceae	Dinophycidae	Gonyaulacales	Ceratiaceae	*Ceratium fusus*
Mediophyceae	Biddulphiophycidae	Hemiaulales	Hemiaulaceae	*Cerataulina pelagica*
Mediophyceae	-	Chaetocerotales	Chaetocerotaceae	*Chaetoceros* sp.
Mediophyceae	-	Chaetocerotales	Chaetocerotaceae	*Chaetoceros curvisitum*
Mediophyceae	-	Chaetocerotales	Chaetocerotaceae	*Chaetoceros affinis*
Mediophyceae	-	Chaetocerotales	Chaetocerotaceae	*Chaetoceros atlanticum*
Mediophyceae	-	Chaetocerotales	Chaetocerotaceae	*Chaetoceros cinctum*
Mediophyceae	-	Chaetocerotales	Chaetocerotaceae	*Chaetoceros gracile*
Mediophyceae	-	Chaetocerotales	Chaetocerotaceae	*Chaetoceros holsaticum*
Mediophyceae	-	Chaetocerotales	Chaetocerotaceae	*Chaetoceros diversum*
Mediophyceae	-	Chaetocerotales	Chaetocerotaceae	*Chaetoceros lorenzianus*
Mediophyceae	-	Chaetocerotales	Chaetocerotaceae	*Chaetoceros lassionasum*
Mediophyceae	-	Chaetocerotales	Chaetocerotaceae	*Chaetoceros peruvianus*
Bacillariophyceae	Bacillariophycidae	Achnanthales	Cocconeidaceae	*Cocconeis* sp.
Coscinodiscophyceae	Corethrophycidae	Corethrales	Corethraceae	*Corethron criophilum*
Coscinodiscophyceae	Coscinodiscophycidae	Coscinodiscales	Coscinodiscaceae	*Coscinodiscus concinnus*
Coscinodiscophyceae	Coscinodiscophycidae	Coscinodiscales	Coscinodiscaceae	*Coscinodiscus gigas*
Coscinodiscophyceae	Coscinodiscophycidae	Coscinodiscales	Coscinodiscaceae	*Coscinodiscus eccentricus*
Coscinodiscophyceae	Coscinodiscophycidae	Coscinodiscales	Coscinodiscaceae	*Coscinodiscus lineatus*
Coscinodiscophyceae	Coscinodiscophycidae	Coscinodiscales	Coscinodiscaceae	*Coscinodiscus radiatus*
Mediophyceae	-	Thalassiosirales	Stephanodiscaceae	*Cyclotella stylorum*
Bacillariophyceae	-	Naviculales	Diploneidaceae	*Diploneis* sp.
Mediophyceae	Lithodesmiophycidae	Lithodesmiales	Lithodesmiaceae	*Ditylum brightwellii*

Class	Subclass	Order	Family	Genus and species name
Mediophyceae	Biddulphiophycidae	Hemiaulales	Hemiaulaceae	*Eucampia zodiacus*
Coscinodiscophyceae	Rhizosoleniophycidae	Rhizosoleniales	Rhizosoleniaceae	*Guinardia flacida*
Bacillariophyceae	-	Naviculales	Pleurosigmataceae	*Gyrosigma* sp.
Mediophyceae	Biddulphiophycidae	Hemiaulales	Hemiaulaceae	*Hemiaulus sinensis*
Mediophyceae	-	Thalassiosirales	Lauderiaceae	*Lauderia annulata*
Coscinodiscophyceae	-	Leptocylindrales	Leptocylindraceae	*Leptocylindrus danicus*
Coscinodiscophyceae	-	Leptocylindrales	Leptocylindraceae	*Leptocylindrus minimus*
Coscinodiscophyceae	Coscinodiscophycidae	Melosirales	Melosiraceae	*Melosira granulata*
Coscinodiscophyceae	Coscinodiscophycidae	Melosirales	Melosiraceae	*Melosira numuloides*
Coscinodiscophyceae	Coscinodiscophycidae	Melosirales	Melosiraceae	*Melosira variance*
Bacillariophyceae	-	Naviculales	Naviculaceae	*Navicula rhombica*
Bacillariophyceae	-	Bacillariales	Bacillariaceae	*Nitzschia closterium*
Bacillariophyceae	-	Bacillariales	Bacillariaceae	*Nitzschia longissima*
Bacillariophyceae	-	Bacillariales	Bacillariaceae	*Nitzschia seriata*
Bacillariophyceae	-	Bacillariales	Bacillariaceae	*Nitzschia sigma*
Bacillariophyceae	-	Bacillariales	Bacillariaceae	*Nitzschia spatulata*
Mediophyceae	Biddulphiophycidae	Triceratiales	Triceratiaceae	*Odontella mobilensis*
Mediophyceae	Biddulphiophycidae	Triceratiales	Triceratiaceae	*Odentella regia*
Mediophyceae	Biddulphiophycidae	Triceratiales	Triceratiaceae	*Odentella sinensis*
Coscinodiscophyceae	Coscinodiscophycidae	Paraliales	Paraliaceae	*Paralia sulcata*
Bacillariophyceae	-	Naviculales	Pinnulariaceae	*Pinnularia* sp.
Mediophyceae	-	Thalassiosirales	Thalassiosiraceae	*Planktoniella blanda*
Bacillariophyceae	-	Naviculales	Pleurosigmataceae	*Pleurosigma elongatum*
Coscinodiscophyceae	Rhizosoleniophycidae	Rhizosoleniales	Rhizosoleniaceae	*Rhizosolenia alata*
Coscinodiscophyceae	Rhizosoleniophycidae	Rhizosoleniales	Rhizosoleniaceae	*Rhizosolenia cylindricus*
Coscinodiscophyceae	Rhizosoleniophycidae	Rhizosoleniales	Rhizosoleniaceae	*Rhizosolenia hebetate*
Coscinodiscophyceae	Rhizosoleniophycidae	Rhizosoleniales	Rhizosoleniaceae	*Rhizosolenia shrubsolei*
Coscinodiscophyceae	Rhizosoleniophycidae	Rhizosoleniales	Rhizosoleniaceae	*Rhizosolenia stolteriotni*
Coscinodiscophyceae	Rhizosoleniophycidae	Rhizosoleniales	Rhizosoleniaceae	*Rhizosolenia setigera*
Coscinodiscophyceae	Rhizosoleniophycidae	Rhizosoleniales	Rhizosoleniaceae	*Rhizosolenia styliformis*
Mediophyceae	-	Thalassiosirales	Skeletonemaceae	*Skeletonema costatum*
Bacillariophyceae	-	Fragilariales	Fragilariaceae	*Synedra* sp.
Bacillariophyceae	Bacillariophycidae	Thalassione-matales	Thalassionemataceae	*Thalassionema nitzchoides*
Bacillariophyceae	Bacillariophycidae	Thalassione-matales	Thalassionemataceae	*Thalassionema* sp.
Mediophyceae	-	Thalassiosirales	Thalassiosiraceae	*Thalassiosira decipiens*
Mediophyceae	-	Thalassiosirales	Thalassiosiraceae	*Thalassiosira leptota*
Mediophyceae	-	Thalassiosirales	Thalassiosiraceae	*Thalassiosira subtilis*
Mediophyceae	-	Thalassiosirales	Thalassiosiraceae	*Thalassiosira hyalina*
Bacillariophyceae	Bacillariophycidae	Thalassione-matales	Thalassionemataceae	*Thalassiothrix* sp.

ANNEXURE B

Identified taxa in Sundarbans belonging to the Subclass Copepoda

Infraclass	Superorder	Order	Family	Genus and species name
Neocopepoda	Gymnoplea	Calanoida	Acartiidae	*Acartia spinicauda*
Neocopepoda	Gymnoplea	Calanoida	Acartiidae	*Acartiella keralensis*
Neocopepoda	Gymnoplea	Calanoida	Acartiidae	*Acartiella sewelli*
Neocopepoda	Gymnoplea	Calanoida	Acartiidae	*Acartia spinicauda*
Neocopepoda	Gymnoplea	Calanoida	Paracalanidae	*Acrocalanus chilkaensis*
Neocopepoda	Gymnoplea	Calanoida	Paracalanidae	*Acrocalanus gracilis*
Neocopepoda	Gymnoplea	Calanoida	Paracalanidae	*Acrocalanus* sp.
Neocopepoda	Gymnoplea	Calanoida	Candaciidae	*Candacia bradyi*
Neocopepoda	Gymnoplea	Calanoida	Calanidae	*Canthocalanus pauper*
Neocopepoda	Gymnoplea	Calanoida	Centropagidae	*Centropages furcatus*
Neocopepoda	Podoplea	Poecilostomatoida	Corycaeidae	*Corycaeus agilis*
Neocopepoda	Podoplea	Poecilostomatoida	Corycaeidae	*Corycaeus catus*
Neocopepoda	Podoplea	Poecilostomatoida	Corycaeidae	*Corycaeus danae*
Neocopepoda	Podoplea	Cyclopoida	Cyclopidae	*Cyclops kuckarti*
Neocopepoda	Podoplea	Cyclopoida	Cyclopidae	*Cyclops* sp.
Neocopepoda	Gymnoplea	Calanoida	Eucalanidae	*Eucalanus crassus*
Neocopepoda	Gymnoplea	Calanoida	Eucalanidae	*Eucalanus subcrassus*
Neocopepoda	Gymnoplea	Calanoida	Eucalanidae	*Eucalanus elongatus*
Neocopepoda	Gymnoplea	Calanoida	Euchaetidae	*Euchaeta concinna*
Neocopepoda	Gymnoplea	Calanoida	Euchaetidae	*Euchaeta marina*
Neocopepoda	Gymnoplea	Calanoida	Euchaetidae	*Euchaeta tenuis*
Neocopepoda	Gymnoplea	Calanoida	Euchaetidae	*Euchaeta wolfendeni*
Neocopepoda	Podoplea	Harpacticoida	Euterpinidae	*Euterpina acutifrons*
Neocopepoda	Podoplea	Cyclopoida	Cyclopidae	*Halicyclops tenuispina*
Neocopepoda	Podoplea	Harpacticoida	Harpacticidae	*Harpacticus* sp.
Neocopepoda	Gymnoplea	Calanoida	Pontellidae	*Labidocera euchaeta*
Neocopepoda	Gymnoplea	Calanoida	Pontellidae	*Labidocera minuta*
Neocopepoda	Podoplea	Harpacticoida	Miraciidae	*Macrosetella gracilis*
Neocopepoda	Podoplea	Harpacticoida	Miraciidae	*Macrosetella rosa*
Neocopepoda	Podoplea	Cyclopoida	Cyclopidae	*Mesocyclops* sp.
Neocopepoda	Gymnoplea	Calanoida	Diaptomidae	*Neodiaptomus strigilipes*
Neocopepoda	Podoplea	Cyclopoida	Oithonidae	*Oithona brevicornis*

Infraclass	Superorder	Order	Family	Genus and species name
Neocopepoda	Podoplea	Cyclopoida	Oithonidae	*Oithona rigida*
Neocopepoda	Podoplea	Poecilostomatoida	Oncaeidae	*Oncaea venusata*
Neocopepoda	Gymnoplea	Calanoida	Paracalanidae	*Paracalanus parvus*
Neocopepoda	Gymnoplea	Calanoida	Paracalanidae	*Paracalanus* sp.
Neocopepoda	Gymnoplea	Calanoida	Pontellidae	*Pontellopsis scotti*
Neocopepoda	Gymnoplea	Calanoida	Pseudodiaptomidae	*Pseudodiaptomus annandalei*
Neocopepoda	Gymnoplea	Calanoida	Pseudodiaptomidae	*Pseudodiaptomus aurivilli*
Neocopepoda	Gymnoplea	Calanoida	Pseudodiaptomidae	*Pseudodiaptomus binghami*
Neocopepoda	Gymnoplea	Calanoida	Pseudodiaptomidae	*Pseudodiaptomus daughlishi*
Neocopepoda	Gymnoplea	Calanoida	Pseudodiaptomidae	*Pseudodiaptomus hickmani*
Neocopepoda	Gymnoplea	Calanoida	Pseudodiaptomidae	*Pseudodiaptomus masoni*
Neocopepoda	Gymnoplea	Calanoida	Pseudodiaptomidae	*Pseudodiaptomus serricaudatus*
Neocopepoda	Gymnoplea	Calanoida	Pseudodiaptomidae	*Pseudodiaptomus tollingerae*
Neocopepoda	Podoplea	Poecilostomatoida	Clausidiidae	*Saphirella indica*
Neocopepoda	Podoplea	Harpacticoida	Tachidiidae	*Tachidius discipes*
Neocopepoda	Gymnoplea	Calanoida	Temoridae	*Temora discaudata*
Neocopepoda	Gymnoplea	Calanoida	Temoridae	*Temora turbinata*
Neocopepoda	Gymnoplea	Calanoida	Tortanidae	*Tortanus forcipatus*
Neocopepoda	Gymnoplea	Calanoida	Tortanidae	*Tortanus gracilis*
Neocopepoda	Gymnoplea	Calanoida	Calanidae	*Undinula darwini*

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2.4 LICHENS

Lichens are symbiotic organisms composed of a fungal partner, the mycobiont, and one or more photosynthetic partners, the photobiont, that may be either a green alga or a cyanobacterium.

G.P. SINHA
Lichenologist

They are widely spread in almost all climatic conditions. They are the dominant autotrophs in the polar and subpolar regions of the world. They exhibit a wide range of colors like white, green, grey, orange, yellow, red, brown, and black. Among the terrestrial autotrophs of the world, lichens exhibit intriguing variation in size. The size varies from less than 1 mm^2 to long, pendulous forms that hang over 2 m from tree branches (Nash III 1996).

Their varied roles in ecosystem functioning and use in air pollution monitoring are significant. They are increasingly being used as 'biomonitors' or 'bioindicators' of air pollution and radioactive nuclides because of their sensitivity toward pollutants and efficiency in accumulating toxic chemicals or radioactive nuclides.

Lichens are also unique in producing over 900 secondary metabolites, which does not occur in any other group of organisms. This has made them very useful to people in diverse ways, especially as a source of food, dyes, perfumes, crude drugs, medicines, and other useable bioactive compounds. Recently, a variety of secondary metabolites isolated from lichens have been found to exhibit a wide range of potentially useful biological activities such as inhibition of prostaglandin biosynthesis, melanin biosynthesis, cancer growth, analgesic, herbicidal, pesticidal, nematocidal, anti-inflammatory, antiviral, antibacterial, antifungal, anticholesterol, antiproliferative, antitumour, antioxidant, and enzyme-inhibitory activities.

OVERVIEW OF THE GROUP

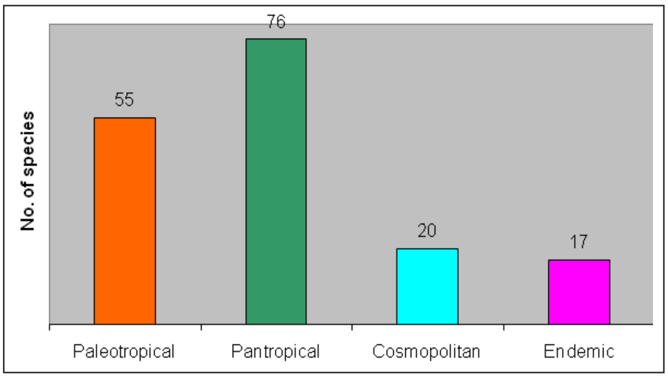
2303
SPECIES OF LICHENS INCLUDING 520 ENDEMIC SPECIES UNDER 305 GENERA AND 75 FAMILIES IN INDIA

India is endowed with enormous lichen diversity. There have been appreciable contributions on various aspects of Indian lichens during the last six decades. Lichenology and its progressive historical development in India have already been discussed by Awasthi (1965, 2000) and Singh (1980). More recently, Singh and Sinha (2010b) presented a consolidated account on Indian lichens. They listed 2,303 species, including 520 endemic species under 305 genera and 75 families. Their major centers of diversity and occurrence in the country are Eastern Himalaya including northeastern India, the Western Ghats, Western Himalaya, and the Andaman and Nicobar Islands. Documentation is poor for several states in the country except Arunachal Pradesh, Himachal Pradesh, Maharashtra, Nagaland, Sikkim, and West Bengal.

The state of West Bengal is one of the lichen-rich states in the country. The richness in diversity is due to the two distinct floristic regions, Eastern Himalaya and the Gangetic plains. A lichenological study in the state was initiated by Nylander (1860) from the Darjeeling hills. Subsequently, he also reported several species from the plains of Bengal, particularly from Kolkata and its surroundings (Nylander 1867, 1869). Later, Müller Argoviensis (1895) and Smith (1926) described some species from the state. Since 1934, several Indian and foreign workers added several species from the state and now the number of species has crossed over 400. Singh and Sinha (2010a) provided the list of various contributors and the distributional details of lichens in the state. Lichens show distinctive patterns of distribution at both micro and macro levels; their mapped distributions show patterns similar to other major groups of organisms (Galloway 1996).

Galloway (1996) distinguished 16 major patterns of distributions in the world. As the SBR falls under tropical region, it possesses 4 kinds of elements: paleotropical, pantropical, cosmopolitan, and endemic or restricted. Out of the 151 species identified, 55 are paleotropical, 76 pantropical, and 20 cosmopolitan (figure 1). Of the 55 paleotropical species, 17 species are so far known from India and at present these are considered as endemic. These are *Anthracothecium bengalense, Arthonia ravida, A. subvelata, Arthothelium atro-olivaceum, A. bessale, A. confertum, A. nigrodiscum, Bacidia convexula, Chrysothrix septemseptata, Cryptothecia alboglauca, C. bengalensis, C. multipunctata, Graphis capillacea, G. sundarbanensis, Laurera subphaeomelodes, Pyrenula subcylindrica, Stirtonia alboverruca,* and *Trypethelium nigrorufum.* These may occur across the political boundaries of neighboring countries, especially in the mangrove forests and the plains of Bangladesh.

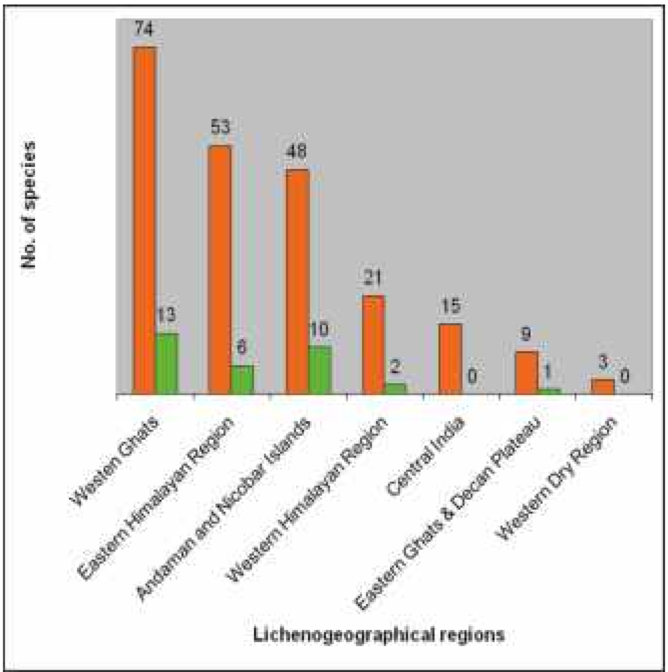
Fig 1: Major distributional elements



The Sundarbans area falls in the lower Gangetic Plains and the lichen flora shows affinity with other geographical regions of India and shares a maximum number of 74 species which are common with the Western Ghats, followed by the Eastern Himalayan region (53 spp.); Andaman and Nicobar Islands (48 spp.); the Western Himalayan region (21 spp.); Central India (15 spp.); the Eastern Ghats and Deccan Plateau (9 spp.); and the Western Dry region (3 spp.) (Figure 2).

Within India, about 48 species of the study area are only found in the lower Gangetic Plains, especially in the surroundings of Kolkata. Thirteen common species were found in the SBR and the Western Ghats: *Arthopyrenia minor, Arthothelium nigrodiscum, Buellia curatellae, Chiodecton congestulum, Diorygma hieroglyphicum, Graphis dendrogramma, Laurera subphaeomelodes, Ochrolechia subpallescens, Opegrapha bonplandii, O. subvulgata, Phaeographis medusiformis, Relicinopsis dahlia,* and *R. malaccensis.* Similarly, 9 species occur both in SBR and Andaman islands: *Anisomeridium ubianum, Arthothelium adveniens, A. atro-olivaceum, A.*

Fig 2: Species showing phytogeographical affinities



bessale, Bactrospora metabola, Opegrapha vulgata, Stirtonia alboverruca, Trypethelium nigrorufum, and *T. nitidiusculum.* Six common species were found both in the SBR and the Eastern Himalayan region: *Arthothelium abnorme, A. confertum, Bacidia convexula, Diorygma pruinosum, Pallidogramme chlorocarpoides,* and *Phaeographis caesioradians*; 2 species were found between the SBR and the Western Himalayan region: *Anisomeridium consobrinum* and *Arthonia radiate;* and 1 species, *Arthopyrenia analepta,* between the SBR and the Eastern Ghats and the Deccan Plateau. Most of the above common taxa recorded from the study area were usually found at lower elevations in their respective lichenogeographical regions.

SYNOPTIC VIEW

Diversity

> 67 SPECIES OF LICHENS IN SUNDARBANS UNDER 56 GENERA AND 25 FAMILIES, WHICH INCLUDE 8 NEW SPECIES, 2 NEW GENERIC AND 22 SPECIFIC RECORDS FOR INDIA.

The mangrove trees in the reserve forests and along rivers, creeks, and canals in the habitation area as well as the non-mangrove trees in the habitation of the biosphere reserve harbor rich lichen flora on their trunks, branches, and leaves. Lichens from the Sundarbans were unexplored till 1960. Roychowdhury (1985) made good collections from the 24-Parganas district, including parts of the SBR, especially the habitation and fringe areas of the reserve forests. Based on his collections, Singh and Roychowdhury (1982, 1984); Upreti et al. (1983); and Roychowdhury (1985) reported 161 species, including a new species (*Anthracothecium bengalense* Ajay Singh) and 4 new records (*Arthothelium distendens* [Nyl.] Müll. Arg.; *Pyrenula confinis* [Nyl.] R.C. Harris; *P. ochraceoflava* [Nyl.] R.C. Harris; and *P. parvinuclea* [Meyen and Flot.] Aptroot) for India from the entire 24-Parganas district although the whole reserve forests remained unexplored.

More recently, between 2001 and 2004, over 2,000 specimens were gathered from the SBR. The above specimens and the earlier collections deposited in the Central National Herbarium of Botanical Survey of India at the Indian Botanical Garden, Howrah, resulted in the documentation of the lichen flora of the SBR in a series of publications. The documentation includes several new species, new records for India, and new records for the state of West Bengal (Jagadeesh Ram and Sinha 2003, 2004, 2005c, 2009a, b, 2010a; Jagadeesh Ram et al. 2005a, b, d, 2006a, b, c, 2007a, b, 2008, 2009, 2010).

The detailed study of lichens resulted in 167 species (annexure) under 56 genera and 25 families, which include 8 new species, 2 new generic, and 22 specific records for India. The species reported as new to science were *Chrysothrix septemseptata* Jagadeesh et al., *Cryptothecia alboglauca* Jagadeesh et al., *C. bengalensis* Jagadeesh et al., *C. multipunctata* Jagadeesh et al., *Enterographa bengalensis* Jagadeesh et al., *Graphis sundarbanensis* Jagadeesh and G.P. Sinha, *Megalaria bengalensis* Jagadeesh et al., and *Pyrenula subcylindrica* Jagadeesh and Upreti.

Twenty-two species were reported as new records for India: *Amandinea insperata* (Nyl.) Mayrhofer and Ropin; *Anisomeridium leptospermum* (Zahlbr.) R.C. Harris; *A. tamarindi* (Fée) R.C. Harris; *Arthonia dispersula* (Nyl.); *A. obesa* (Müll. Arg.) R. Sant.; *Bactrospora jenikii* (Vězda) Egea and Torrente; *Dirinaria leopoldii* (Stein) D.D. Awasthi; *Enterographa anguinella* (Nyl.) Redinger; *E. divergens* (Müll. Arg.) Redinger; *E. mesomela* Sparrius et al.; *E. multiseptata* R. Sant.; *Fissurina egena* (Nyl.); *Helminthocarpon leprevostii* Fée; *Julella geminella* (Nyl.) R.C. Harris; *Lecanographa rufa* (Müll. Arg.) Ertz; *L. subnothella* (Nyl.) Ertz; *Myriotrema subminutum* Homchantara and Coppins; *Parmotrema overeemii* (Zahlbr.) Elix; *Phaeographis epruinosa* (Redinger) Staiger; *Pseudopyrenula subnudata* Müll. Arg.; *Pyrenula thelemorpha* Tuck. *Strigula hypothallina* R.C. Harris; and *Synarthonia bicolor* Muüll. Arg. Among these, *Helminthocarpon leprevostii* Fée and *Synarthonia bicolor* Mll. Arg. were found as new generic and specific records for India.

Eight species were recorded for the first time from the mainland of India: *Anisomeridium ubianum* (Vain.) R.C. Harris; *Arthothelium adveniens* (Nyl). Müll. Arg.; *A. atro-olivaceum* Makhija and Patw.; *A. bessale* (Nyl.) Zahlbr.; *Bactrospora metabola* (Nyl.) Egea and Torrente; *O. vulgata* (Ach.); *Stirtonia alboverruca* Makhija and Patw.; and *Trypethelium nigrorufum* Makhija and Patw. These species were earlier found in the Andaman Islands.

Twenty eight species were recorded for the first time from West Bengal: *Aderkomyces albostrigosus* (R. Sant.) Lücking; *Anisomeridium consobrinum* (Nyl.) Aptroot; *A. terminatum* (Nyl.) R.C. Harris; *Arthopyrenia analepta* (Ach.) A. Massal.; *Arthothelium confertum* (A.L. Sm.) Makhija and Patw.; *A. nigrodiscum* Makhija and Patw., *Buellia betulinoides* R. Schub. and Klem.; *B. curatellae* Malme, *Caloplaca bassiae* (Willd. ex Ach.) Zahlbr.; *C. ferruginea* (Huds.) Th. Fr., *Chiodecton congestulum* Nyl.; *Coccocarpia palmicola* (Spreng.) Arv. and D.J. Galloway; *Cryptothecia scripta* G. Thor; *Diorygma pruinosum* (Eschw.) Kalb et al.; *Dirinaria aegialita* (Afzel.) Moore; *Dyplolabia afzelii* (Ach.) A. Massal.; *Fellhanera bouteillei* (Desm.) Vězda; *Leucodecton occultum* (Eschw.) A. Frisch; *Ochrolechia subpallescens* Verseghy; *Opegrapha graphidiza* Nyl.; *Parmotrema ravum* (Krog and Swinscow) Sérus.; *Pertusaria leucosorodes* Nyl.; *Phaeographis caesioradians* (Leight.) Staiger; *Polymeridium proponens* (Nyl.) R.C. Harris; *Pyxine consocians* Nyl.; *Ramalina pacifica* Asahina; *Relicinopsis dahlii* (Hale) Elix and Verdon; and *R. malaccensis* (Nyl.) Elix and Verdon.

The lichen family *Arthoniaceae* shows maximum species diversity and is represented by 33 species. It is followed by *Graphidaceae* and *Roccellaceae* (22 spp. each); *Physciaceae* (16 spp.); and *Pyrenulaceae* (15 spp.). Family *Graphidaceae* shows the highest generic diversity with 8 genera, followed by *Arthoniaceae* and *Roccellaceae* with 6 genera each, and *Physciaceae* with 5 genera. All the families and the number of genera and species are given in table 1. Similarly, *Arthonia* is the largest genus, represented by 17 species, followed by *Pyrenula* (13 spp.); *Opegrapha* (10 spp.); *Graphis* (7 spp.); and *Anisomeridium*, *Pertusaria,* and *Trypethelium* (6 spp. each). Interestingly, 6 families are represented by 1 species each and 24 genera by 1 species each. All the genera and their growth forms and number of species are shown in table 2.

Out of the 167 species recorded, 139 are crustose, 26 foliose, and 2 fruticose forms (figure 3). Fifty-seven species belong to ascoloculars and the remaining 110 species to ascohymeniales. Within ascohymeniales, 37 species are pyrenocarpous. The crustose forms are commonly distributed in almost all localities or islands whereas the foliose and fruticose forms, except *Dirinaria* spp. and *Pyxine cocoes,* are distributed only in the reserve forests. The crustose genera are *Aderkomyces*, *Amandinea*, *Anisomeridium*, *Anthracothecium*, *Arthonia*, *Arthopyrenia*, *Arthothelium*, *Bacidia*, *Bactrospora*, *Buellia*, *Caloplaca*, *Chiodecton*, *Chrysothrix*, *Coenogonium*, *Cresponea*, *Cryptothecia*, *Diorygma,* *Dyplolabia*, *Enterographa*, *Fellhanera*, *Fissurina*, *Glyphis*, *Graphis*, *Helminthocarpon*, *Pallidogramme*, *Julella*, *Laurera*, *Lecanographa*, *Lecanora*, *Letrouitia*, *Leucodecton*, *Malcolmiella*, *Megalaria*, *Myriotrema*, *Ochrolechia*, *Opegrapha*, *Pertusaria*, *Phaeographis*, *Polymeridium*, *Porina*, *Pseudopyrenula*, *Pyrenula*, *Sarcographa*, *Stirtonia*, *Strigula*, *Synarthonia,* and *Trypethelium*. *Coccocarpia*, *Collema*, *Dirinaria*, *Leptogium*, *Parmotrema*, *Physcia*, *Pyxine,* and *Relicinopsis* are the foliose genera and *Ramalina* is the only fruticose genus found growing in the area.

Fig 3: Major growth forms diversity

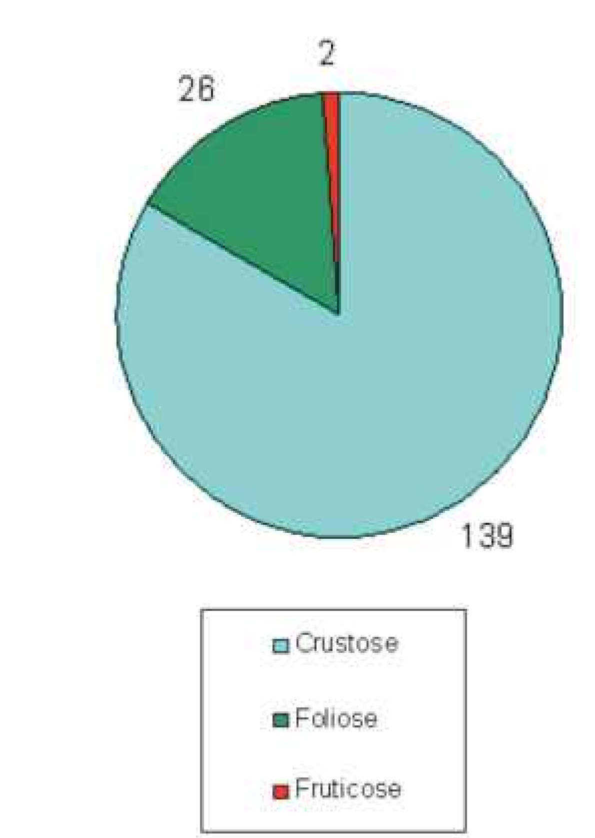


Table 1: Families showing the number of genera and species in SBR

Family	No. of genera	No. of species
Arthoniaceae	5	33
Arthopyreniaceae	2	4
Bacidiaceae	1	2
Chrysothricaceae	1	1
Coccocarpiaceae	1	3
Collemataceae	2	2
Gomphillaceae	1	1
Graphidaceae	8	22
Gyalectaceae	1	1
Lecanoraceae	1	2
Letrouitiaceae	1	1
Megalariaceae	1	1
Monoblastiaceae	1	6
Parmeliaceae	3	7
Pertusariaceae	2	7
Physciaceae	5	16
Pilocarpaceae	2	2
Pyrenulaceae	2	15
Ramalinaceae	1	2
Roccellaceae	6	23
Strigulaceae	1	2
Teloschistaceae	1	2
Thelotremataceae	2	2
Trichotheliaceae	1	1
Trypetheliaceae	4	8

Table 2: Genera showing their respective family, habit and number of species in SBR

Name of Genera	Families	Growth forms	Number of species
Aderkomyces	*Gomphillaceae*	C	1
Amandinea	*Physciaceae*	C	1
Anisomeridium	*Monoblastiaceae*	C	6
Anthracothecium	*Pyrenulaceae*	C	2
Arthonia	*Arthoniaceae*	C	18
Arthopyrenia	*Arthopyreniaceae*	C	3
Arthothelium	*Arthoniaceae*	C	7
Bacidia	*Bacidiaceae*	C	2
Bactrospora	*Roccellaceae*	C	3
Buellia	*Physciaceae*	C	3
Caloplaca	*Teloschistaceae*	C	2
Chiodecton	*Roccellaceae*	C	2
Chrysothrix	*Chrysothricaceae*	C	1
Coccocarpia	*Coccocarpiaceae*	F	3
Coenogonium	*Gyalectaceae*	C	1
Collema	*Collemataceae*	F	1
Cresponea	*Roccellaceae*	C	1
Cryptothecia	*Arthoniaceae*	C	5
Diorygma	*Graphidaceae*	C	3
Dirinaria	*Physciaceae*	F	7
Dyplolabia	*Graphidaceae*	C	1
Enterographa	*Roccellaceae*	C	6
Fellhanera	*Pilocarpaceae*	C	1

Fissurina	*Graphidaceae*	C	3
Glyphis	*Graphidaceae*	C	2
Graphis	*Graphidaceae*	C	6
Helminthocarpon	*Arthoniaceae*	C	1
Julella	*Arthopyreniaceae*	C	1
Laurera	*Trypetheliaceae*	C	1
Lecanographa	*Roccellaceae*	C	2
Lecanora	*Lecanoraceae*	C	2
Leptogium	*Collemataceae*	F	1
Letrouitia	*Letrouitiaceae*	C	1
Leucodecton	*Thelotremataceae*	C	1
Malcolmiella	*Pilocarpaceae*	C	1
Megalaria	*Megalariaceae*	C	1
Myriotrema	*Thelotremataceae*	C	1
Ochrolechia	*Pertusariaceae*	C	1
Opegrapha	*Roccellaceae*	C	10
Pallidogramme	*Graphidaceae*	C	1
Parmotrema	*Parmeliaceae*	F	5
Pertusaria	*Pertusariaceae*	C	6
Phaeographis	*Graphidaceae*	C	4
Physcia	*Physciaceae*	F	3
Polymeridium	*Trypetheliaceae*	C	1
Porina	*Trichotheliaceae*	C	1
Pseudopyrenula	*Trypetheliaceae*	C	1
Pyrenula	*Pyrenulaceae*	C	13
Pyxine	*Physciaceae*	F	2
Ramalina	*Ramalinaceae*	Fr	2
Relicinopsis	*Parmeliaceae*	F	2
Sarcographa	*Graphidaceae*	C	3
Stirtonia	*Arthoniaceae*	C	2
Strigula	*Strigulaceae*	C	2
Synarthonia	*Arthoniaceae*	C	1
Trypethelium	*Trypetheliaceae*	C	5

(C – Crustose; F – Foliose; Fr – Fruticose)

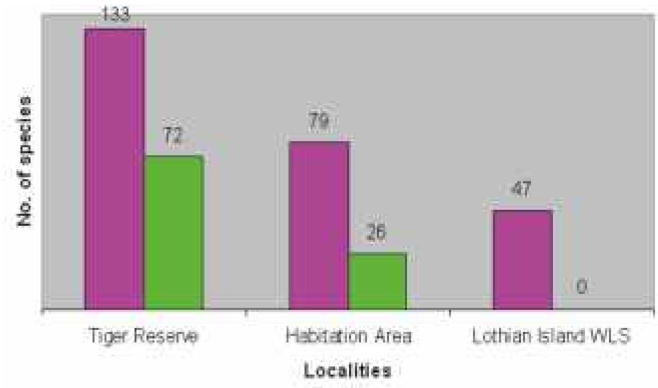
Distribution

The SBR comprises two major protected areas, namely the Sundarbans Tiger Reserve and Lothian Island Wildlife Sanctuary. The Sundarbans Tiger Reserve includes the Sundarbans National Park (core area), Sajnekhali Wildlife Sanctuary, Haliday Island Wildlife Sanctuary, and the buffer zone of the Tiger Reserve. The area is considered as the true mangrove zone of the biosphere reserve. Observations of species distribution within the biosphere reserve (figure 4) indicate that the Tiger Reserve and the surrounding reserve forests harbor the maximum of 133 (79.64 percent) species, followed by the habitation area with 79 (47.30 percent) species and the Lothian Island Wildlife Sanctuary with 47 (28.14 percent) species. About 72 species were found only in the Tiger Reserve and 26 species in the habitation area. The maximum species diversity in the Tiger Reserve is presumably because of the phorophytes diversity, the undisturbed habitat, and less human interferences.

Functional Association/Phorophyte Preference

The most tangible element of a plant's environment is its substrate, the material on or in which the plant grows. It is observed that lichens have substrate preferences. Identification keys are often based on this substrate classification (Brodo 1973). As the SBR is situated in the delta of the Ganges and Brahmaputra Rivers, rock substratum was not found in the area. Moreover, because of the frequent inundation, low and high tides, cyclones, and marshy terrain, the land does not support any terricolous species. However, the various mangrove and non-mangrove trees in the reserve forests as well as in the habitation area are the available substrates which support the growth of lichens on their trunks, branches, and rarely on leaves.

Fig 4: Distribution within SBR



Latex bearing *Excoecaria agallocha* supports the maximum number of 89 species of lichens.

Observations on the occurrence of lichens on the various phorophytes (figures 5 and 6) revealed that 142 species occur in the mangrove forest area. Out of these, 139 are corticolous and 3 foliicolous. Among the mangrove trees, the latex-bearing *Excoecaria agallocha* supports the maximum number of 89 (53.29 percent) species of lichens, followed by *Xylocarpus mekongensis* with 63 spp. (37.72 percent); *Heritiera fomes* with 60 spp. (35.93 percent); *Ceriops* spp. with 56 spp. (33.53 percent); *Avicennia* spp. with 54 species (32.34 percent); *Rhizophora* spp. with 43 species (25.75 percent); *Bruguiera* spp. with 38 species (22.75 percent); *Aegiceras corniculatum* with 37 species (22.16 percent); *Sonneratia* spp. with 36 species (21.56 percent); *Xylocarpus granatum* with 9 species (5.39 percent); and *Tamarix* spp. with 6 species (3.59 percent). About 68 species (40.72 percent) of lichens were also recorded from the non-mangrove trees: *Acacia* spp., *Albizia* spp., *Azadirachta indica*, *Borassus flabellifer*, *Casuarina equisetifolia*, *Citrus* spp., *Cocos nucifera*, *Jatropha* sp., *Phoenix sylvestre*, *Pithecellobium dulce*, and others.

Interestingly, about 100 species of lichens have been recorded only on various mangrove trees. Out of these, 49 species have been found only on one of the mangrove tree species. *Arthonia radiata, Arthonia* sp. 7, *Arthothelium abnorme, Bactrospora jenikii, Enterographa divergens, Lecanographa subnothella, Opegrapha medusulina, O. ochrocheila, O. subrimulosa, O. vulgata, Pyrenula subcylindrica,* and *Stirtonia alboverruca* were only found on *Avicennia* species. Similarly, *Chiodecton congestulum, Cryptothecia subtecta, Dyplolabia afzelii* were found on *Bruguiera* spp.; *Myriotrema subminutum* on *Ceriops* spp.; *Arthonia* sp. 9, *Arthothelium bessale, A. confertum, Coccocarpia glaucina, C. rottleri, Collema pulcellum, Cryptothecia bengalensis, C. multipunctata, Enterographa bengalensis, Graphis handelii, Lecanora* species, *Malcolmiella granifera, Parmotrema overeemii, Pertusaria* sp. 1, *Physcia* species, *Pyrenula* species, and *Synarthonia bicolor* on *Excoecaria agallocha*; *Laurera subphaeomelodes, Opegrapha* species, *Pallidogramme chlorocarpoides, Phaeographis epruinosa, Relicinopsis malaccensis, Sarcographa labyrinthica, Trypethelium nigrorufum,* and *T. nitidiusculum* on *Heritiera fomes*; *Arthonia* sp. 4 and *Aderkomyces albostrigosus* on *Rhizophora* spp.; *Coccocarpia palmicola* and *Opegrapha graphizida* on *Sonneratia* spp.; *Arthonia* *subgyrosa* on *Tamarix* spp.; and *Anthracothecium assamiense, Leptogium denticulatum, Opegrapha bonplandii* and *Strigula smaragdula* on *Xylocarpus mekongensis*.

Twenty-four species have been found only on non-mangrove trees: *Arthonia antillarum, A. obesa, A. subvelata, Arthopyrenia analepta, Arthothelium nigrodiscum, Coenogonium luteum, Enterographa mesomela, E. multiseptata, Fissurina egena, Glyphis scyphulifera, Graphis glaucescens, G. scripta, Lecanographa rufa, Letrouitia leprolyta, Opegrapha subvulgata, Phaeographis caesioradians, P. medusiformis, Porina belanospora, Pyrenula acutalis, P. confinis, P. leucostoma, P. thelemorpha, Sarcographa glyphiza* and *Strigula hypothallina*. The occurrence of lichen species on various phorophytes is presented in the annexure.

Fig 5: Venn Diagram showing the occurrence of species on mangrove and non-mangrove phorophytes

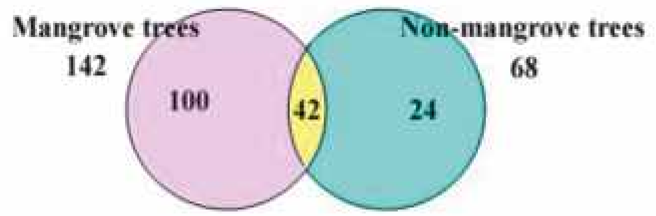
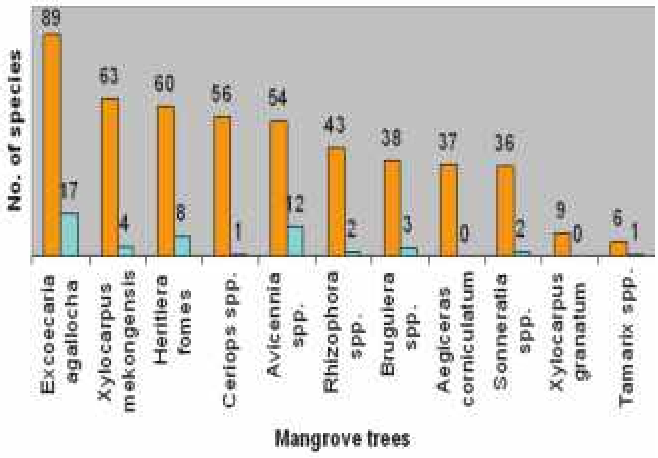


Fig 6: Mangrove phorophytepreference and specificity



Ecological Importance and Need for Conservation

Lichens are a significant component of biodiversity in many of the world's ecosystems. They are one of the dominant organisms in ecosystems, covering over as much as 8 percent of Earth's surface. They are among the dominant autotrophs in the polar and subpolar regions of the world. They are important in colonization, primary succession, and soil stabilization. They are responsible for nitrogen fixation and play a unique role in the cycling of elements essential to life on Earth. Lichens also fix atmospheric carbon dioxide photosynthetically. They also remove carbon dioxide from the atmosphere through the conversion of silicates to oxalates. They are the most significant bio-indicators of air pollution besides having many economic and ecological applications. Due to their sensitivity to environmental factors, whether pollutants or of natural origin, lichens provide low-cost options for the monitoring of environmental quality, habitat disturbance, and ecosystem health.

They are also important in animal food chains. A large number of species are eaten by higher animals (reindeer, rodents, sheep, and others) and invertebrates (protozoa, nematodes, insects, mites, and mollusks). Besides, they shelter several invertebrates. The ecological significance pertaining to the monitoring of environmental quality, habitat disturbance, and ecosystem health and their role in the food chain of invertebrates and higher animals in the biosphere reserve need to be studied thoroughly.

STATUS AND THREATS

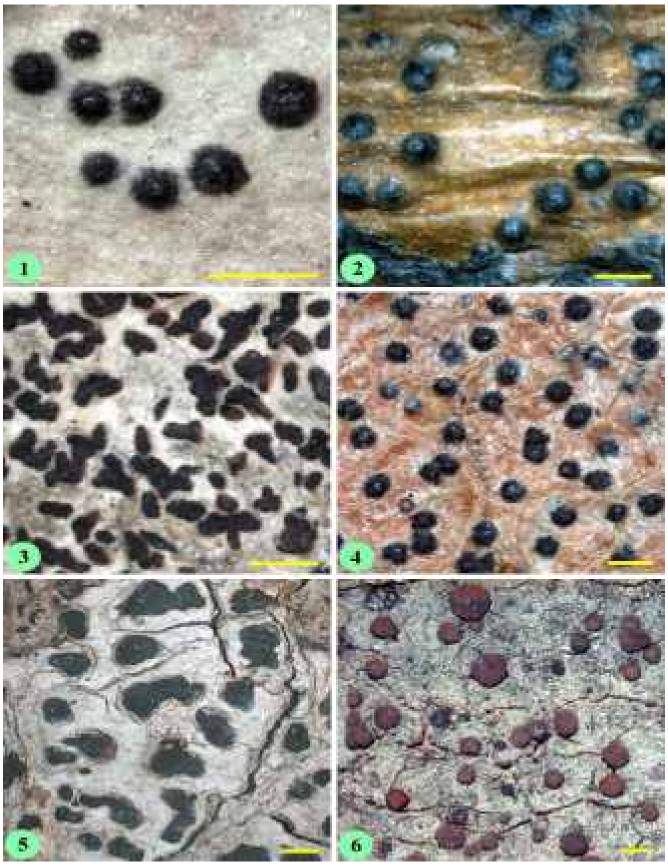
Decline of forest cover, urbanization, construction of roads, buildings on hills, mineral extraction, hydroelectric projects, shifting cultivation, logging, forest fire, excessive use of firewood for the preparation of charcoal, excessive collections from nature for ethanobotanical and commercial utilization, air pollution, tourism, climate change, and agriculture are the factors responsible for depletion of many lichen-rich habitats (Upreti 1995; Wolsely 1995; Singh and Sinha , 2010b). The lichen communities can be conserved in both 'in situ' and 'ex situ' methods. 'In situ' conservation is possible by declaring lichen-rich sites as lichen reserves or these are naturally conserved within the boundaries of wildlife sanctuaries, national parks, or biosphere reserves (Singh and Sinha, 2010a). The latter is the most common practice adapted so long as it does not require any additional management skill and budget. 'Ex situ' conservation is by (a) transplantation in botanical gardens under suitable environmental conditions and (b) in vitro culturing and maintenance in a gene bank.

Mangrove ecosystems are considered as the most productive ecosystems. The ever-increasing populations on these coastal estuarine areas lead to the conversion of mangrove ecosystems into agricultural lands, renovation of brackish water fisheries, prawn and shrimp farms, salt pans, development of ports, harbors, tourist spots, rural habitation, cities, and so on. During the last two centuries, more than 50 percent of the mangrove areas in the Indian part of the Sundarbans were reclaimed and converted into agricultural fields, brackish water fisheries, and rural habitation (Naskar and Mandal 2000). However, at present, the remaining area is well conserved by the initiation of the Tiger Reserve Project (1973), the Biosphere Reserve Project (1989), and the declaration of one national park and three wildlife sanctuaries.

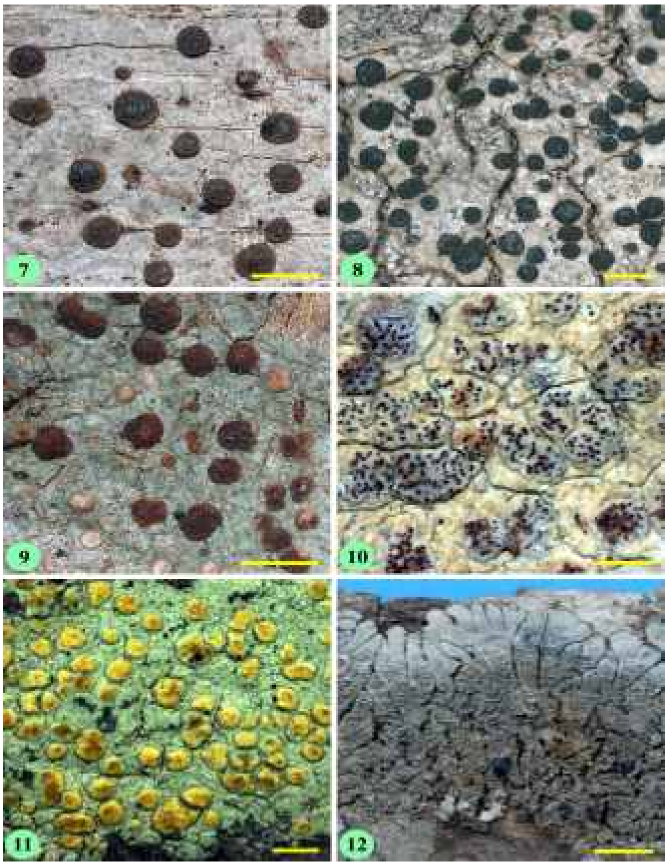
Lichenologically, out of the 167 species recorded from the biosphere reserve, 8 species were exclusively known from the area and 11 other Indian species show extensive distribution in the SBR. Most of these species have been found on the well-protected Sundarbans Tiger Reserve area. Five foliose lichens known for their commercial value as spices—*Parmotrema overeemii*, *P. ravum, P. reticulatum, P. saccatilobum* and *P. tinctorum*—have also been found in the area. As these species grow abundantly only in the Sundarbans Tiger Reserve area of the biosphere reserve, these are conserved naturally due to the lack of knowledge of their economic potential in the area and fear of the Royal Bengal Tiger.

The reserve forests in the Sundarbans Tiger Reserve area show the maximum phorophyte and lichen diversity. The remaining reserve forests, namely Ajmalmari, Chulkati, Dulibhasani, Herobhanga, Thakuran, and Lothian Island Wildlife Sanctuary and the river banks of human habitation areas mainly have *Avicennia* spp.-based monoculture in practice. Therefore, to sustain the diversity for posterity, it is suggested that multiculture forestry practice is adopted using mixed planting of the lichen-rich mangrove phorophytes, *Aegiceras corniculatum*, *Avicennia* spp., *Bruguiera* spp., *Ceriops* spp., *Excoecaria agallocha, Heritiera fomes*, *Rhizophora* spp., *Sonneratia* spp., *Tamarix* spp., *Xylocarpus granatum* and *Xylocarpus mekongensis*.

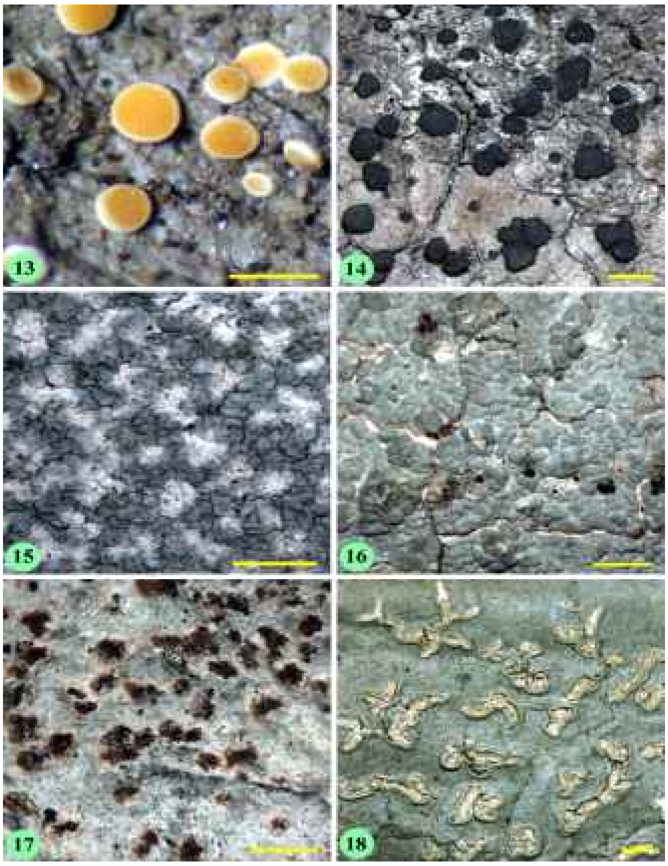
PLATES



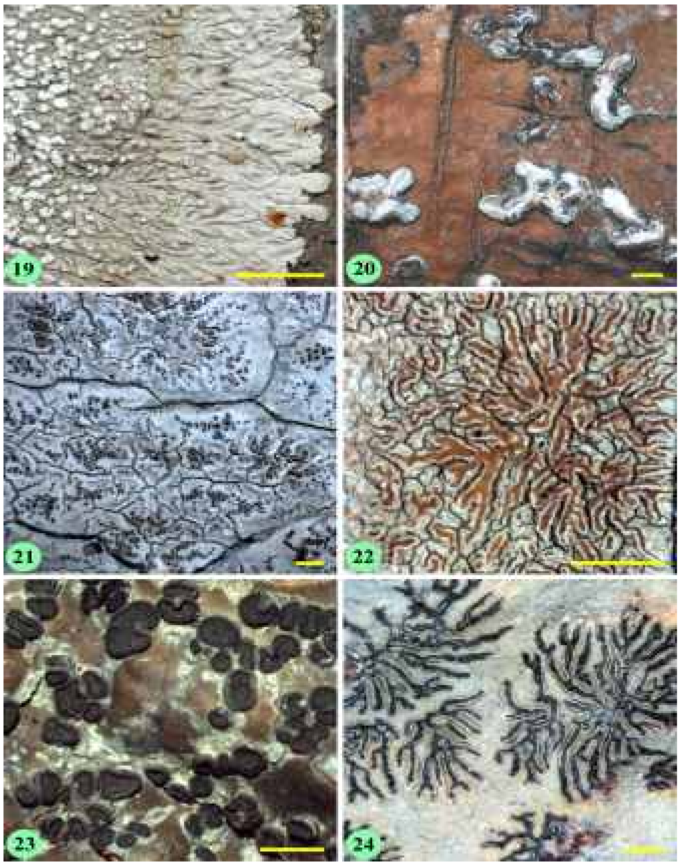
1. *Anisomeridium consobrinum* (Nyl.) Aptroot; 2. *Anthracothecium bengalense* Ajay Singh; 3. *Arthonia ravida* Stirt.; 4. *Arthopyrenia majuscula* (Nyl.) Zahlbr.; 5. *Arthothelium bessale* (Nyl.) Zahlbr.; 6. *Bacidia convexula* (Müll. Arg.) Zahlbr. Scale = 1 mm.



7. *Bactrospora myriadea* (Fée) Egea & Torrente; 8. *Buellia betulinoides* R. Schub. & Klem.; 9. *Caloplaca ferruginea* (Huds.) Th. Fr.; 10. *Chiodecton leptosporum* Müll. Arg.; 11. *Chrysothrix septemseptata* Jagadeesh et al.; 12. *Coccocarpia palmicola* (Spreng.) Arv. & D.J. Galloway. Scale = Figs 7, 8, 9, 10, 11 = 1 mm; Fig 12 = 5 mm.

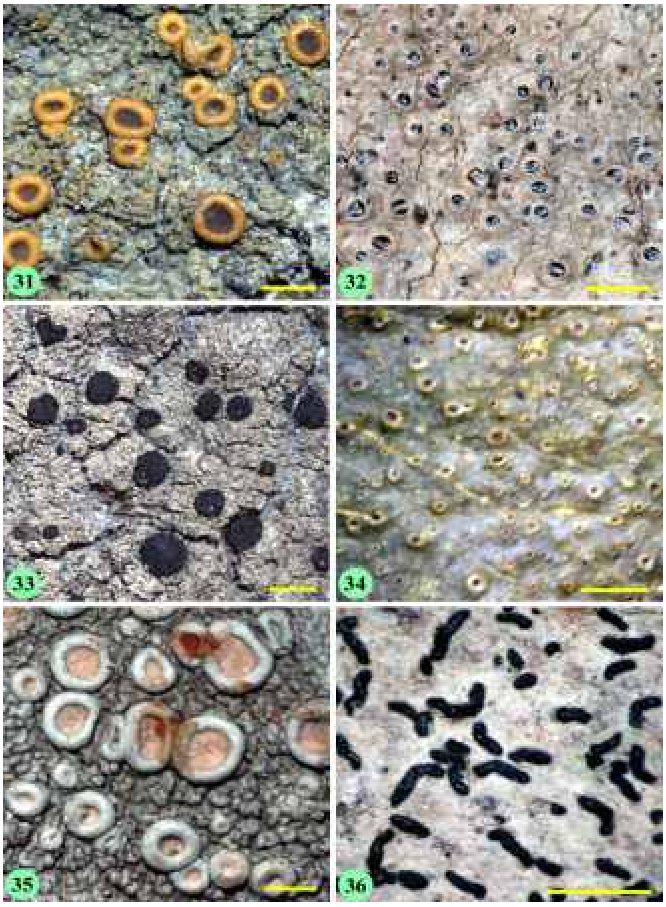


13. *Coenogonium luteum* (Dicks.) Kalb & Lücking; 14. *Cresponea proximata* (Nyl.) Egea & Torrente; 15. *Cryptothecia alboglauca* Jagadeesh et al.; 16. *C. bengalensis* Jagadeesh et al.; 17. *C. multipunctata* Jagadeesh et al.; 18. *Diorygma hieroglyphicum* (Pers.) Staiger & Kalb. Scale = 1 mm.



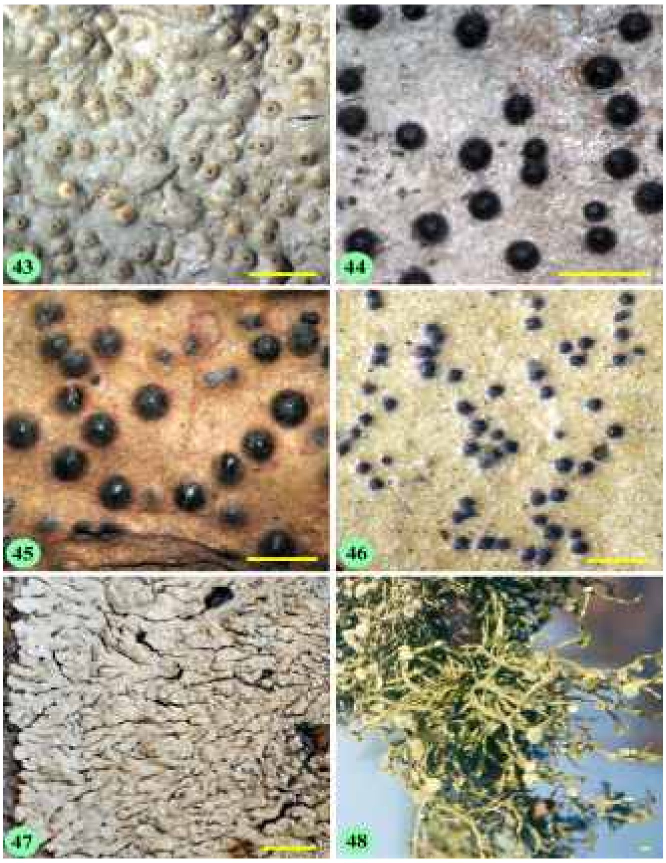
19. *Dirinaria applanata* (Fée) D.D. Awasthi; 20. *Dyplolabia afzelii* (Ach.) A. Massal.; 21. *Enterographa bengalensis* Jagadeesh et al.; 22. *E. pallidella* (Nyl.) Redinger; 23. *Glyphis scyphulifera* (Ach.) Staiger; 24. *Graphis capillacea* Stirt. Scale = Fig 19 = 5 mm; Figs 20, 21, 22, 23, 24 = 1 mm.

25. *Graphis sundarbanensis* Jagadeesh & G.P. Sinha; 26. *Helminthocarpon leprevostii* Fée; 27. *Julella geminella* (Nyl.) R.C. Harris; 28. *Lecanographa rufa* (Müll. Arg.) Ertz; 29. *Lecanora leprosa* Fée; 30. *Leptogium denticulatum* Nyl. Scale = Figs 25, 26, 27, 28, 29 = 1 mm; Fig 30 = 5 mm.



31. *Letrouitia leprolyta* (Nyl.) Hafellner; 32. *Leucodecton occultum* (Eschw.) A. Frisch; 33. *Megalaria bengalensis* Jagadeesh et al.; 34. *Myriotrema subminutum* Homchantara & Coppins; 35. *Ochrolechia subpallescens* Verseghy; 36. *Opegrapha vulgata* (Ach.) Ach. Scale = 1 mm.

37. *Parmotrema ravum* (Krog & Swinscow) Sérus.; 38. *P. saccatilobum* (Taylor) Hale; 39. *Pertusaria velata* (Turner) n; 40. *Phaeographis brasiliensis* (A. Massal.) Kalb & Matthes-Leicht; 41. *Physcia aipolia* (Ehrh.) Furnr; 42. *Polymeridium proponens* (Nyl.) R.C. Harris. Scale: Figs 37, 38, 41 = 1 mm; Figs 39, 40, 42 = 1 mm.



43. *Porina belanospora* (Nyl.) Müll. Arg.; 44. *Pseudopyrenula subnudata* Müll. Arg.; 45. *Pyrenula acutalis* R.C. Harris; 46. *P. subcylindrica* Jagadeesh & Upreti; 47. *Pyxine cocoes* (Sw.) Nyl.; 48. *Ramalina leiodea* (Nyl.) Nyl. Scale: Figs 43, 44, 45, 46, 48 = 1 mm; Fig 47 = 5 mm.

49. *Relicinopsis malaccensis* (Nyl.) Elix & Verdon; 50. *Sarcographa tricosa* (Ach) Müll. Arg.; 51. *Stirtonia obvallata* (Stirt.) A.L. Sm.; 52. *Strigula hypothallina* R.C. Harris; 53. *Synarthonia bicolor* Müll. Arg. 54. *Trypethelium tropicum* (Ach.) Müll. Arg. Scale: Fig 49 = 5 mm; Figs 50, 51, 52, 53, 54 = 1 mm.

ANNEXURE

Lichens of SBR showing their distribution and phorophyte preference

(R : rough bark; S : smooth bark; + : present)

Name of species	**Distribution**			**Phorophytes**											
				Mangrove Tree Species											**Non-mangrove Tree species***
	S. Tiger Reserve	Lothian WLS	Habitation area	*Aegiceras corniculatum* (S)	*Avicennia* spp. (S)	*Bruguiera* spp. (R)	*Ceriops* spp. (S)	*Excoecaria agallocha* (R)	*Heritiera fomes* (R)	*Rhizophora* spp. (R)	*Sonneratia* spp. (R)	*Tamarix* spp. (R)	*Xylocarpus granatum* (S)	*Xylocarpus mekongensis* (R)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Aderkomyces albostrigosus (R.Sant.) Lücking, Sérus. & Vězda	+									+					
Amandinea insperata(Nyl.) H. Mayrhofer & Ropin			+									+			+
Anisomeridium biforme (Borrer) R.C. Harris	+			+											+
A. consobrinum (Nyl.) Aptroot	+							+	+					+	+
A. leptospermum (Zahlbr.) R.C. Harris	+										+			+	
A. tamarindi (Fée) R.C. Harris	+	+	+	+	+			+	+						+
A. terminatum (Nyl.) R.C. Harris	+	+					+	+						+	
A. ubianum (Vain.) R.C. Harris	+					+	+						+	+	
Anthracothecium assamiense (Stirt.) Ajay Singh	+													+	
A. bengalense Ajay Singh	+						+						+		
Arthonia antillarum (Fée) Nyl.			+												+

Name of species	Distribution			Phorophytes											
				Mangrove Tree Species											Non-mangrove Tree species*
	S. Tiger Reserve	Lothian WLS	Habitation area	*Aegiceras corniculatum* (S)	*Avicennia* spp. (S)	*Bruguiera* spp. (R)	*Ceriops* spp. (S)	*Excoecaria agallocha* (R)	*Heritiera fomes* (R)	*Rhizophora* spp. (R)	*Sonneratia* spp. (R)	*Tamarix* spp. (R)	*Xylocarpus granatum* (S)	*Xylocarpus mekongensis* (R)	
A. cinnabarina (DC.) Wallr.	+	+	+	+	+	+	+	+	+	+	+			+	+
A. dispersula Nyl.	+				+			+						+	
A. obesa (Müll. Arg.) R. Sant.			+												+
A. radiata (Pers.) Ach.			+		+										
A. ravida Stirt.			+		+										+
A. subgyrosa Nyl.			+									+			
A. subvelata Nyl.			+												+
Arthonia sp. 1	+	+	+	+	+	+	+	+	+	+	+			+	+
Arthonia sp. 2	+	+	+	+	+	+	+	+	+	+	+			+	+
Arthonia sp. 3			+		+			+							
Arthonia sp. 4	+									+					
Arthonia sp. 5	+	+			+		+	+		+	+			+	
Arthonia sp. 6	+	+	+	+	+	+	+	+	+	+	+	+		+	+
Arthonia sp. 7					+										
Arthonia sp. 8								+	+						
Arthonia sp. 9								+							
Arthopyrenia analepta (Ach.) A. Massal.	+														+
A. majuscula (Nyl.) Zahlbr.	+	+	+		+		+	+					+	+	+
A. minor R.C. Harris	+						+						+		
Arthothelium abnorme (Ach.) Müll. Arg.	+	+	+		+										

Name of species	Distribution			Phorophytes											
				Mangrove Tree Species											Non-mangrove Tree species*
	S. Tiger Reserve	Lothian WLS	Habitation area	*Aegiceras corniculatum* (S)	*Avicennia* spp. (S)	*Bruguiera* spp. (R)	*Ceriops* spp. (S)	*Excoecaria agallocha* (R)	*Heritiera fomes* (R)	*Rhizophora* spp. (R)	*Sonneratia* spp. (R)	*Tamarix* spp. (R)	*Xylocarpus granatum* (S)	*Xylocarpus mekongensis* (R)	
A. adveniens (Nyl.) Müll. Arg.	+						+	+			+				
A. atro-olivaceum Makhija & Patw.	+					+	+	+			+			+	
A. bessale (Nyl.) Zahlbr.	+							+							
A. confertum (A.L. Sm.) Makhija & Patw.	+							+							
A. distendens (Nyl.) Müll. Arg.	+			+	+	+	+	+	+					+	
A. nigrodiscum Patw. & Makhija			+												+
Bacidia convexula (Müll. Arg.) Zahlbr.	+	+	+	+	+	+	+	+	+	+	+			+	+
B. medialis (Tuck.) Zahlbr.	+		+			+	+			+				+	
Bactrospora jenikii (Vězda) Egea & Torrente	+				+										
B. metabola (Nyl.) Egea & Torrente	+						+	+						+	
B. myriadea (Fée) Egea & Torrente	+	+	+	+	+	+	+	+	+	+	+			+	+
Buellia betulinoides R. Schub. & Klem.	+		+			+			+		+				+
B. curatellae Malme	+			+	+	+	+	+	+		+			+	+
B. lauricassiae (Fée) Müll. Arg.	+	+	+	+	+		+	+		+				+	+
Caloplaca bassiae (Willd. ex Ach.) Zahlbr.	+	+	+		+										+

Name of species	Distribution			Phorophytes											
				Mangrove Tree Species											Non-mangrove Tree species*
	S. Tiger Reserve	Lothian WLS	Habitation area	*Aegiceras corniculatum* (S)	*Avicennia* spp. (S)	*Bruguiera* spp. (R)	*Ceriops* spp. (S)	*Excoecaria agallocha* (R)	*Heritiera fomes* (R)	*Rhizophora* spp. (R)	*Sonneratia* spp. (R)	*Tamarix* spp. (R)	*Xylocarpus granatum* (S)	*Xylocarpus mekongensis* (R)	
C. ferruginea (Huds.) Th. Fr.	+		+					+							+
Chiodecton congestulum Nyl.	+					+									
C. leptosporum Müll. Arg.	+			+											
Chrysothrix septemseptata Jagadeesh et al.	+		+			+			+		+	+			+
Coccocarpia glaucina Kremp.	+							+							
C. palmicola (Spreng.) Arv. & D.J. Galloway	+										+				
C. rottleri (Ach.) Arv.	+							+							
Coenogonium luteum (Dicks.) Kalb & Lücking	+		+												+
Collema pulcellum Ach.	+							+							
Cresponea proximata (Nyl.) Egea & Torrente	+					+								+	
Cryptothecia alboglauca Jagadeesh et al.	+							+	+						
C. bengalensis Jagadeesh et al.	+							+							
C. multipunctata Jagadeesh et al.	+							+							
C. scripta G. Thor	+			+				+	+					+	
C. subtecta Stirt.	+					+									
Diorygma hieroglyphicum (Pers.) Staiger & Kalb	+			+	+			+	+	+				+	+

Name of species	Distribution			Phorophytes											
				Mangrove Tree Species											Non-mangrove Tree species*
	S. Tiger Reserve	Lothian WLS	Habitation area	*Aegiceras corniculatum* (S)	*Avicennia* spp. (S)	*Bruguiera* spp. (R)	*Ceriops* spp. (S)	*Excoecaria agallocha* (R)	*Heritiera fomes* (R)	*Rhizophora* spp. (R)	*Sonneratia* spp. (R)	*Tamarix* spp. (R)	*Xylocarpus granatum* (S)	*Xylocarpus mekongensis* (R)	
D. megasporum Kalb et al.	+			+				+	+	+				+	
D. pruinosum (Eschw.) Kalb et al.	+			+		+		+	+					+	
Dirinaria aegialita (Afzel.) B.J. Moore	+	+				+					+				+
D. applanata (Fée) D.D. Awasthi	+	+	+	+	+	+	+	+	+	+	+			+	+
D. confluens (Fr.) D.D. Awasthi	+	+	+	+	+	+	+	+	+	+	+			+	+
D. consimilis (Stirt.) D.D. Awasthi	+						+	+	+						
D. leopoldii (Stein) D.D. Awasthi	+					+	+	+	+					+	
D. papillulifera (Nyl.) D.D. Awasthi	+						+	+							
D. picta (Sw.) Clem. & Shear	+	+	+	+	+	+	+	+	+	+	+			+	+
Dyplolabia afzelii (Ach.) A. Massal.	+					+									
Enterographa anguinella (Nyl.) Redinger			+								+				
E. bengalensis Jagadeesh et al.	+							+							
E. divergens (Müll. Arg.) Redinger		+	+		+										
Enterographa mesomela Sparrius et al.			+												+

Name of species	Distribution			Phorophytes											
				Mangrove Tree Species											Non-mangrove Tree species*
	S. Tiger Reserve	Lothian WLS	Habitation area	*Aegiceras corniculatum* (S)	*Avicennia* spp. (S)	*Bruguiera* spp. (R)	*Ceriops* spp. (S)	*Excoecaria agallocha* (R)	*Heritiera fomes* (R)	*Rhizophora* spp. (R)	*Sonneratia* spp. (R)	*Tamarix* spp. (R)	*Xylocarpus granatum* (S)	*Xylocarpus mekongensis* (R)	
E. multiseptata R.Sant.			+												+
E. pallidella (Nyl.) Redinger	+	+	+	+	+	+	+	+	+	+	+			+	+
Fellhanera bouteillei (Desm.) Vězda	+								+						+
Fissurina egena (Nyl.) Nyl.			+												+
Glyphis cicatriosa Ach.	+	+	+					+					+	+	+
G. scyphulifera (Ach.) Staiger			+												+
Graphis capillacea Stirt.	+		+		+										+
G. crebra Vain.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
G. dendrogramma Nyl.			+					+							+
G. glaucescens Fée			+												+
G. handelii Zahlbr.	+							+							
G. scripta (L.) Ach.			+												+
G. sundarbanensis Jagadeesh & G.P. Sinha	+							+						+	+
Helminthocarpon leprevostii Fée	+						+	+		+			+		
Julella geminella (Nyl.) R.C. Harris	+	+			+								+		
Laurera subphaeomelodes Upreti & Ajay Singh	+								+						
Lecanographa rufa (Müll. Arg.) Ertz			+												+
L. subnothella (Nyl.) Ertz	+				+										

Name of species	**Distribution**			**Phorophytes**											
				Mangrove Tree Species											**Non-mangrove Tree species***
	S. Tiger Reserve	Lothian WLS	Habitation area	*Aegiceras corniculatum* (S)	*Avicennia* spp. (S)	*Bruguiera* spp. (R)	*Ceriops* spp. (S)	*Excoecaria agallocha* (R)	*Heritiera fomes* (R)	*Rhizophora* spp. (R)	*Sonneratia* spp. (R)	*Tamarix* spp. (R)	*Xylocarpus granatum* (S)	*Xylocarpus mekongensis* (R)	
Lecanora leprosa Fée	+	+	+	+	+	+	+	+	+	+	+	+		+	+
Lecanora species	+							+							
Leptogium denticulatum Nyl.	+													+	
Letrouitia leprolyta (Nyl.) Hafellner	+		+												+
Leucodecton occultum (Eschw.) A. Frisch	+	+	+	+	+	+	+	+	+	+	+			+	
Malcolmiella granifera (Ach.) Kalb & Lücking	+							+							
Megalaria bengalensis Jagadeesh et al.	+	+			+		+	+	+	+				+	
Myriotrema subminutum Homchantara & Coppins	+						+								
Ochrolechia subpallescens Verseghy	+		+	+	+		+	+	+	+	+				
Opegrapha agelaeotera Vain.	+	+						+	+					+	
O. bonplandii Fée	+													+	
O. graphidiza Nyl.	+		+												+
O. medusulina Nyl.	+	+	+		+										+
O. ochrocheila Nyl.			+		+										
O. subrimulosa Nyl.		+													
O. subvulgata Nyl.			+												+
O. varia Pers.	+		+											+	+
O. vulgata (Ach.) Ach.			+		+										
Opegrapha species	+								+						

Name of species	Distribution			Phorophytes											
				Mangrove Tree Species											Non-mangrove Tree species*
	S. Tiger Reserve	Lothian WLS	Habitation area	*Aegiceras corniculatum* (S)	*Avicennia* spp. (S)	*Bruguiera* spp. (R)	*Ceriops* spp. (S)	*Excoecaria agallocha* (R)	*Heritiera fomes* (R)	*Rhizophora* spp. (R)	*Sonneratia* spp. (R)	*Tamarix* spp. (R)	*Xylocarpus granatum* (S)	*Xylocarpus mekongensis* (R)	
Parmotrema overeemii (Zahlbr.) Elix	+							+							
P. ravum (Krog & Swinscow) Sérus.	+	+		+	+	+	+	+	+	+	+			+	
P. reticulatum (Taylor) M. Choisy	+	+		+	+	+	+	+	+	+	+			+	+
P. saccatilobum (Taylor) Hale	+	+		+	+	+	+	+	+	+	+			+	
P. tinctorum (Despr. ex Nyl.) Hale	+						+	+	+	+					
Pallidogramme chlorocarpoides (Nyl.) Staiger et al.	+								+						
Pertusaria leucosorodes Nyl.	+							+	+	+					
P. pertusella Müll. Arg.	+	+					+	+		+				+	
P. pycnothelia Nyl.	+							+	+						
P. velata (Turner) Nyl.	+	+	+					+		+				+	
Pertusaria sp. 1	+							+							
Pertusaria sp. 2	+			+	+		+	+		+					
Phaeographis brasiliensis (A. Massal.) Kalb & Matthes-Leicht	+	+	+				+	+	+	+				+	
P. caesioradians (Leight.) Staiger			+												+
P. epruinosa (Redinger) Staiger	+								+						

Name of species	Distribution			Phorophytes											
				Mangrove Tree Species											Non-mangrove Tree species*
	S. Tiger Reserve	Lothian WLS	Habitation area	*Aegiceras corniculatum* (S)	*Avicennia* spp. (S)	*Bruguiera* spp. (R)	*Ceriops* spp. (S)	*Excoecaria agallocha* (R)	*Heritiera fomes* (R)	*Rhizophora* spp. (R)	*Sonneratia* spp. (R)	*Tamarix* spp. (R)	*Xylocarpus granatum* (S)	*Xylocarpus mekongensis* (R)	
P. medusiformis (Kremp.) Müll. Arg.			+												+
Physcia aipolia (Ehrh.) Furnr	+	+	+				+	+	+					+	+
P. undulata Moberg	+		+					+	+						
Physcia species	+							+							
Polymeridium proponens (Nyl.) R.C. Harris	+			+					+						
Porina belanospora (Nyl.) Müll. Arg.			+												+
Pseudopyrenula subnudata Müll. Arg.	+						+	+							
Pyrenula acutalis R.C. Harris			+												+
P. anomala (Ach.) Vain.	+		+						+						+
P. astroidea (Fée) R.C. Harris	+						+	+		+			+	+	
P. concatervans (Nyl.) R.C. Harris	+	+	+		+		+	+						+	
P. confinis (Nyl.) R.C. Harris			+												+
P. leucostoma Ach.			+												+
P. nitida (Weigel) Ach.	+	+	+	+	+	+	+	+	+	+	+			+	+
P. ochraceoflava (Nyl.) R.C. Harris	+	+	+	+	+	+	+	+	+	+	+			+	+
P. parvinuclea (Meyen & Flot.) Aptroot	+	+	+		+		+	+		+				+	
P. quassiaecola Fée	+		+				+	+						+	+

Name of species	Distribution			Phorophytes											
				Mangrove Tree Species											Non-mangrove Tree species*
	S. Tiger Reserve	Lothian WLS	Habitation area	*Aegiceras corniculatum* (S)	*Avicennia* spp. (S)	*Bruguiera* spp. (R)	*Ceriops* spp. (S)	*Excoecaria agallocha* (R)	*Heritiera fomes* (R)	*Rhizophora* spp. (R)	*Sonneratia* spp. (R)	*Tamarix* spp. (R)	*Xylocarpus granatum* (S)	*Xylocarpus mekongensis* (R)	
P. subcylindrica Jagadeesh & Upreti	+		+		+										
P. thelemorpha Tuck.	+		+												+
Pyrenula species	+							+							
Pyxine cocoes (Sw.) Nyl.	+	+	+		+			+	+	+	+			+	
P. consocians Vain.	+	+	+				+	+						+	+
Ramalina leiodea (Nyl.) Nyl.	+	+	+	+	+	+	+	+	+	+	+			+	
R. pacifica Asahina	+	+	+	+	+	+	+	+	+	+	+			+	
Relicinopsis dahlii (Hale) Elix & Verdon	+					+		+		+					
R. malaccensis (Nyl.) Elix & Verdon	+								+						
Sarcographa glyphiza (Nyl.) Kr.P. Singh & G.P. Sinha															+
S. labyrinthica (Ach.) Müll. Arg.	+								+						
S. tricosa (Ach) Müll. Arg.	+	+	+	+	+		+	+	+					+	+
Stirtonia alboverruca Makhija & Patw.	+				+										
S. obvallata (Stirt.) A.L. Sm.	+	+	+	+	+	+	+	+	+	+	+			+	
Strigula hypothallina R.C. Harris			+												+
S. smaragdula Fr.	+													+	
Synarthonia bicolor Müll. Arg.	+							+							

Name of species	**Distribution**			**Phorophytes**											
				Mangrove Tree Species											**Non-mangrove Tree species***
	S. Tiger Reserve	Lothian WLS	Habitation area	*Aegiceras corniculatum* (S)	*Avicennia* spp. (S)	*Bruguiera* spp. (R)	*Ceriops* spp. (S)	*Excoecaria agallocha* (R)	*Heritiera fomes* (R)	*Rhizophora* spp. (R)	*Sonneratia* spp. (R)	*Tamarix* spp. (R)	*Xylocarpus granatum* (S)	*Xylocarpus mekongensis* (R)	
Trypethelium eluteriae Spreng.	+	+	+	+	+	+	+	+	+	+	+			+	+
T. nigrorufum Makhija & Patw.	+								+						
T. nitidiusculum (Nyl.) R.C. Harris	+								+						
T. ochroleucum (Eschw.) Nyl.	+						+	+	+					+	
T. tropicum (Ach.) Müll. Arg.	+	+	+	+	+	+	+	+	+	+	+			+	+

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2.5 MANGROVES & ASSOCIATED FLORA

The word 'Mangrove' has been applied to identify trees and shrubs that have developed morphological adaptations against the stressful tidal environment they live in.

SUBRAT MUKHERJEE
Protected area Manager with specialization in mangrove conservation
NEERA SEN SARKAR
Botanist with specialization in Phycology
ANIRBAN ROY
Botanist with Ecology & Plant Geography
P. VENU
Botanist with specialization in mangroves

Over two third of the total mangroves tracts are found in just 12 countries

These include specialized osmo-regulatory mechanisms, viviparous germination, air breathing roots (known as pneumatophores), root buttresses, rapid seedling establish-ment, and seed polymorphism (FAO 2007). They are basically found in the inter tidal zones of the tropical and subtropical coasts and are found in river deltas, lagoons, and estuarine complexes. They are distributed on the sheltered shores and permeate the estuaries where salt water penetrates. Macnae (1968) described them as trees or bushes growing between the level of high water of spring tides and a level close to but above mean sea level. Mangrove forests comprise taxonomically diverse plant groups which are salt-tolerant trees, shrubs, ferns, and palms. These are highly productive ecosystems and prized, with distinctive plant communities that have fascinated the attention of researchers world over (Thom 1982). They are distributed globally over 123 countries with an area of 152,000 km^2 (Spalding et al. 2010). Despite their broad spread, over two-thirds of the total mangroves tracts are found in just 12 countries (table 1) which together account for over 68 percent of the world's mangrove coverage of 104, 552 km^2. Mangroves in India account for about 4,326 km^2 that constitutes nearly 3 percentof the world's mangrove wealth. The mangrove spread in the Indian subcontinent is viewed as an extension of the Persian Gulf around the coast of India, Pakistan, and Sri Lanka to Myanmar, including the Andaman and Nicobar Islands. The best known of the mangrove formations is seen in the Sundarbans that are shared between India and Bangladesh. The Indian part of the Sundarbans covers approximately 4263 km^2, out of which 1,781 km^2 is of watercourses.

Besides being highly productive, these ecosystems act as nursery areas for a wide range of commercially valued fish and crustacean stocks. They act as energy barriers in protecting low-lying coastal communities from the wrath of the offshore storms (Secretariat of the Convention on Biological Diversity, 2010). A recent valuation of Ecosystem Services for the Indian Sundarbans Delta (WWF –India, 2011) shows the total flow of benefits at INR 9633.967 billion for a period of forty years (2011 to 2050); contributions coming from carbon sequestration (INR 6051.2427 billion); fishery production (INR 736.3828 billion); storm protection (INR 1743.9939 billion); and tourism (INR 0.4776 billion).

OVERVIEW OF THE GROUP

Chapman (1976) reported 90 mangrove species representing worldwide whereas Saenger et al. (1983) recorded 83 species. UNDP/UNESCO (1986) reported 65 species, but Tomlinson (1986) mentions only 48 true mangrove species, out of which 40 are found in the Old World Tropics (Indo-West Pacific region) and 8 from the New World Tropics. He recognized two types of mangroves: (1) *Major elements/True mangroves*—the species with complete fidelity to the mangrove environment and (2) *Minor elements* of mangals—not conspicuous in mangrove habitats and may rather prefer the peripheral habitats. Several researchers, Watson (1928), Tomlinson (1980), Chai (1982), Mepham and Mepham (1984), and Naskar (1993) have applied the term 'Mangrove associate' as an equivalent to minor elements for the plant found in areas bordering the tidal periphery of mangrove habitats. Spalding et al. (2010) documented 73 mangrove species and hybrids from the Indo-

Table 1: Countries with larger mangrove areas in world.

Country	Mangrove Area (sq km)	Percentage of global wealth
Indonesia	31894	20.9
Brazil	13000	8.5
Australia	9910	6.5
Mexico	7701	5.0
Nigeria	7356	4.8
Malaysia	7097	4.7
Myanmar	5029	3.3
Bangladesh	4951	3.2
Cuba	4944	3.2
India	4326	2.8
Papua New Guinea	4265	2.8
Colombia	4079	2.7
Total	**104552**	**68.4**

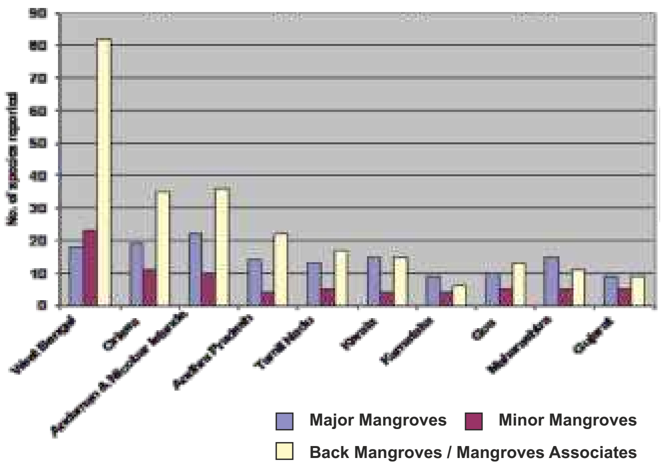
West Pacific and Atlantic East Pacific floras, out of which he recognized 38 species as core mangrove species Kathiresan and Rajendran (2005a) have reported 69 mangrove species from India, excluding salt marshes under 42 genera and 27 families. They further reported that out of these, 63 species (41 genera under 27 families; 91 percent) are present on the east coast; 37 species (25 genera under 16 families; 53 percent) on the west coast; and 44 species (28 genera under 20 families; 63 percent) are found in the Andaman and Nicobar Islands. The state-wise distribution of different mangrove species, including back mangroves, mangrove associates, and minor mangroves, is represented in figure 1.

With regard to spread, on the East Coast, the mangrove distribution is 43.63 percent (West Bengal), 4.41 percent (Orissa), 8.15 percent (Andhra Pradesh), 0.43 percent (Tamil Nadu), and 19.83 percent (Andaman and Nicobar Islands), while on the West Coast, it is 21.17 percent (Gujarat), 2.22 percent (Maharashtra), 0.1 percent (Goa), 0.06 percent (Karnataka), and sparsely in Kerala (Sanjappa et al. 2010). It is evident that West Bengal has the maximum mangrove cover in the country, followed by Gujarat and the Andaman and Nicobar Islands. Gujarat has seen considerable increase in mangrove cover in the past few years due to intensive afforestation

Table 2: Core mangrove species of the world

Family	Species	Family	Species
Indo-West pacific Species			
Avicenniaceae	*Avicennia alba*		*Rhizophora apiculata*
	A. integra		*R. mucronata*
	A. marina		*R. samoensis*
	A. officinalis		*R. stylosa*
	A. rumphiana	Sonneratiaceae	*Sonneratia alba*
Combretaceae	*Lumnitzera littorea*		*S. apetala*
	L. racemosa		*S. caseolaris*
Meliaceae	*Xylocarpus granatum*		*Sonneratia griffithi*
	X. moluccensis		*S. lanceolata*
Rhizophoraceae	*Bruguiera cylindrica*		*S. ovata*
	B. exaristata		
	B. gymnorhiza		
	B. hainesii		
	B. parviflora		
	B. sexangulata		
	Ceriops australis		
	C. decandra		
	C. tagal		
	Kandelia candel		
	K. obovata		
Atlantic East Pacific Species			
Avicenniaceae	*Avicennia bicolor*	Pellicieraceae	*Pelliciera rhizophorae*
	A. germinans	Rhizophoraceae	*Rhizophora mangle*
	A. schaueriana		*R. racemosa*
Combretaceae	*Conocarpus erectus*		
	Languncularia racemosa		

Fig– 1. State-wise reports of mangrove species in India



programs (GEER 2000, 2004) while Maharashtra exhibited a decline, attributable to industrial development and change in land-use patterns (Anon. 1987,1992).

SYNOPTIC VIEW

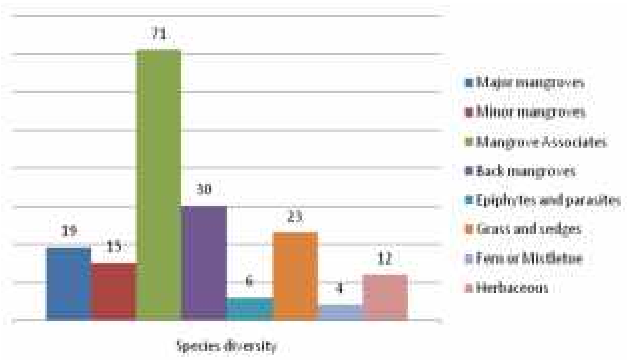
Diversity

The floristic components of the Sundarbans have drawn attention since the 19th century. In 1895, a comprehensive list of Sundarban plants was presented by C.B. Clarke in the presidential address of the Linnaean Society of London. Later, Prain (1903) published the Flora of Sundarbans. The working plans prepared thereafter have taken into account the Sundarban flora (Curtis 1933). Several floristic surveys were done for the flora of the Sundarbans after 1947 that includes Naskar and Guha Bakshi (1987) who recorded 1,175 angiosperm species from 24 Parganas (North and South), which includes many mangroves.

180 SPECIES UNDER 54 FAMILIES AND 118 GENERA IDENTIFIED FROM THE SUNDARBANS BIOSPHERE RESERVE

A summary of the studies of Maiti (1999), Ghosh et al. (2003), Mukherjee (2004), and Sharma and Naskar (2010) gave an estimate of about 180 species (in annexure) under 54 families and 118 genera identified from the SBR. The recognized categories and their numbers in the Indian Sundarbans is depicted in figure 2. (table 2).

Fig – 2. Diversity of mangroves and other species in the Indian Sundarbans



In view of the availability of substrate water, water quality, and the characteristics of a plant-water relationship, the vascular plants are grouped under major broad categories: (a) Helophytes, (b) Xerophytes, (c) Mesophytes, (d) Halophytes, (e) Oxylophytes, (f) Psychoxerophytes, (g) Lithophytes, and (h) Psammophytes (Warming 1909). The first four categories, that is, Helophytes, Xerophytes, Mesophytes, and Halophytes, are the major flora in the Sundarban mangrove forest. The present work is concentrated mostly on halophytes, mangrove, and helophytes.

The habitats where halophytes grow are frequently inundated with tidal seawater, thus necessitating them to counter physiologically dry soils/conditions. These plants exhibit selective water absorption mechanisms and tolerance for dissolved salts. Halophytes grow on salt-dominant soil. They adapt to a saline environment by osmo-regulatory mechanisms to overcome the toxic effect of excessive salts. They have succulent, small, evergreen, and leathery foliage with thick cuticles and prominent water storage and palisade tissues.

Mangroves share many of the characteristics of halophytes and are either trees or shrubs with exposure to variance in salinity and a degree of waterlogging. They develop pneumatophores, knee roots, prop roots, and root buttresses and have unique viviparous, crypto-viviparous, or pseudo-viviparous germination mechanism. These adaptations are not seen in halophytes.

FUNCTIONAL GROUPS

True Mangroves

The flora classified as mangrove taxa exhibit more of the features which include viviparous germination, salt tolerance mechanisms, and aerial roots in the form of pneumatophores, Mangrove species grow mostly in the intertidal areas of Sundarbans and are dispersed by water-buoyant propagules.

pneumatothodes, stilt roots, prop roots, root buttresses, plank roots, and knee roots. Families such as Rhizophoraceae, Avicenniaceae, Sonneratiaceae, Combretaceae, Arecaceae, Sterculiaceae, Meliaceae, Euphorbiaceae, Rubiaceae, Agialitidaceae, Poaceae, and Acanthaceae possess characters (Mandal and Naskar 2008). Major elements of mangrove or true mangrove species grow mostly in the intertidal areas of the Sundarbans and minor elements of the mangroves consist of intertidal salt-resistant trees and shrubs as mangal communities (Sharma and Naskar 2010).

Most mangrove species are found to be typically dispersed by their water-buoyant propagules. This allows them to take advantage of operating currents both to replenish existing stands and to establish new ones. Two types of propagules are found in mangrove ecosystems. In the first type, the propagules that fall from the mother plant are transported to another location by the effects of tidal currents (as in *Avicennia, Sonneratia, Aegiceras,* and *Aegialitis*). In the other type, the propagules with well-grown hypocotyles (as in *Rhizophora, Bruguiera, Ceriops,* and *Kandelia*) find substratum for establishment as soon as they fall from the mother plant. Soil substratum and tidal inundation play a major role in spelling success for establishment. The propagules of *Avicennia* are the most commonly available ones in the Sundarbans with high survival. This can be attributed to the fact that these propagules have the highest probability of establishing themselves before the viability period. The establishment of the seedlings also depends on light, where *Avicennia* turns out to be the best adapted as it grows faster than the other species such as *Bruguiera* and *Rhizophora*.

Mangrove Associates

There are several plant species which are very intricately associated with the arborescent mangrove community in riverine forests. Due to inundation of the island during high tide, the herbaceous non-mangroves generally grow as climbers and lianas with the mangrove trees and shrubs. *Derris heterophylla, D. scandens,* and *D. trifoliata* are common lianas and *Cassytha filiformis, Finlaysonia obovata, Macrosolen cochinensis, Pentatropis capensis, Tylophora tenuis, Viscum monoicum,* and *V. orientale*are epiphytic climbers. Sometimes, they form shrubberies or coastal scrubs, with some small trees or shrubs. *Mucuna gigantea, Abrus precatorius, Canavalia maritima,* and *C. microcarpa* associated with some twiners like *Ipomoea gracilis, Hewittia sublobata,* and *Stictocardia tiliifolia* are the major components of this formation.

Back Mangroves

Back mangroves are not subject to the same degree of tidal inundations as experienced by 'true mangrove' species that

Most mangrove species are found to be typically dispersed by their water-buoyant

grow near mangrove stands toward the landward side. Though they are able to withstand the high salinity and low-nutrient soils associated with coastal areas, these plants are generally not found in the intertidal areas colonized by true mangrove plants. *Excoecaria agallocha* or *Sonneratia* spp. are found toward the mainland or along the small canals of villages. Among them, *Hibiscus tiliaceous, Thespesia populneioides,* and *T. populnea* are common. Some other trees such as *Dalbergia spinosa, D. monosperma, D. candenatansis, Instia bijuga,* and *Cerbera odollam* are admixed with mangrove plants but not more toward the mainland like other mangrove associates trees. The species of *Barringtonia (B. acutangula* and *B. racemosa)* are generally not found with mangroves but occur in swampy areas that are exposed to partial freshwater inundation. The three species of *Pandanus* reported from the Sundarbans are mostly distributed on the back of the dunes that form coastal thickets. Due to extensive stilt roots, they have the capacity of checking beach erosion. In the inhabited island, they are usually found on the canal banks. There are several associated shrubby species-inhabited islands on the canal banks. *Clerodendron inerme* forms its dense population along the canal bank, on the seashore, and even on the roadside. The appearance of this species indicates the proximity of coastal regions. Some species like *Pluchia indica* also has dense population on human-inhabited islands and also more inland on the roadsides. It is also a coastal indicator species. *Caesalpinia major, Capparis zeylanica, Opuntia dilleni,* and *Solanum trilobatum* are the other species in the SBR. Apart from these, a good number of herbaceous plants, including grasses and sedges, are found as mangrove associates. *Porteresia coarctata*, a close, wild relative of paddy, is the pioneer colonizer and distributed in most of the areas of the Sundarbans, especially on newly formed islands and at the river-island interface. The mangrove fern *Acrostichum aureum*, though growing with salt marshes, sometimes forms dense patches on riverbanks and other water-logged areas.

Twelve species of Orchidaceae were reported from Sundarbans

Twelve species of Orchidaceae were reported from the Sundarbans: *Bulbophyllum roxburgjii*, *Cleisostoma ramosum*, *Dendrobium anceps*, *D. pieradi*, *Luisia brachystachyos*, *L. zeylanica*, *Oberonia gammiei*, *Saccolobium longifolium*, *S. ochaceum*, *Sarcanthus appendiculatus*, *S insectifer*, and *Trias oblonga* (Maiti 1999). Among the epiphytic ferns, *Stenochlaena palustre is* found on some mangrove and non-mangrove trees. *Dryneria quercifolia is* also very frequent on non-mangrove trees, mostly on human-inhabited islands. *Cuscuta reflexa* and *Dendropthoe falcata* are the parasitic angiosperms growing on the mangrove and mangrove-associated trees of the Sundarbans.

Salt Marshes

Salt marshes are found growing with mangrove fern Acrostichum aureum

Salt marshes are coastal wetlands that are flooded and drained by salt water brought in by the tides. Because salt marshes are frequently submerged by the tides and contain a lot of decomposing plant material, oxygen levels are extremely low—a condition called hypoxia. *Sesuvium portulacastrum* is the pioneer species. *Aeluropus lagopoides*, *Salicornia brachiata*, *Suaedamaririma,* and *S. nudiflora* are other halophytes growing in this zone. In the Sundarbans, salt marshes are found growing with the mangrove fern *Acrostichum aureum*. The species of *Tamarix* (*T. dioica*, *T. gallica,* and *T. troupii*) have a shrubby nature and are found growing on slightly higher regions of the islands, sometimes along the canal banks where tidal water flow is occasional. *Trianthema portulacastrum* and *T. triquetra* (Aizoacae) form dense mats in water-logged areas in inhabited areas. *Heliotropium curassivicum*is sporadically distributed in the saline marshy places, especially along the canal bank of the villages of the SBR.

Sea Grasses

Sea grasses are the submerged marine angiosperms belonging to three monocotyledonous families (Hydrocharitaceae, Potamogetonaceae, and Ruppiacae). Out of 15 species of sea grasses found on Indian coasts, only one species, *Ruppia maritima*, under the family Ruppiaceae, has been reported from the SBR. *Ruppia maritima* grows mostly in brackish water conditions with its pure population or is sometimes associated with seaweeds like *Enteromorpha* or *Ulva*. It also grows in brackish water inundation with less tidal flow. Ponds, *Bheris*, and canals with moderate saline condition are the main habitats of *Ruppia maritima* in the Sundarbans.

Other Brackish Water Aquatics

There are very few wetland plants that grow in ecotonic regions of some creeks and rivers, more toward the mainland. These plants have partial submergence during high tide and complete exposure at low tide. They are mostly found growing in patches along with some sporadically distributed mangroves such as *Avicennia alba, Excoecaria agallocha,* and *Sonneratia caseolaris*. *Cryptocoryne ciliata* forms stands of considerable areas while *Crinum asiaticum, Crinum defixum,* and other *Crinum* spp. are found in isolated patches. They are distributed more toward freshwater in eutrophic conditions. *Mimulus orbicularis* is very rare in Sundarbans. It is only distributed in Orissa (Chilka Lake [not found in recent times] and the Dhamra River mouth) and West Bengal (Raidighi, Mani River mouth).

Sand Binders

> Sand Binders play a very important ecological role in the dune formation, visà-vis, coastal stabilization against erosion and sea ingression

Sand binders have prostrate habit, an extensive proliferated root system, long runners with an extensive nodal root system, and thick fleshy leaves to withstand tidal action. They play a very important ecological role in dune formation, relative to coastal stabilization, against erosion and sea ingression. In the SBR, they occur on the beaches of Bakkhali, the southern ends of Lothian, Prentice, and Dhanchi Islands. Some that are found to be associated with *Avicennia marina*. *Cyperus arenarius*, *Launnea sarmentosa,* and *Sesuvium portulucustrum* grow to form a pioneer semi stabilized strand-type community. A little away from these pioneer semi stabilized plant types, the area is free from tidal waves except for a few occasional high tides. This area constitutes a stabilized strand plant community consisting of herbaceous creepers such as *Hydrophyllax maritima*, *Launnea sarmentosa*, *Ipomoea pes-caprae*, *Sporobolus tremulus,* and *Zoysia matrella*.

The stabilized strand follows dune strands of various sizes and shapes. They have a sea-facing side and a lee side on which the zonation of plant communities are different, depending upon the impact of salt spray, wind force, and sunlight. The lower slopes consist of plants with long horizontal runners and nodal roots for protecting the windblown sand. The middle and upper layers are covered with bushy herbs and shrubs. The lee-side plant components are very similar to the inland plants. The prostrate herbs, on the sea-facing side, are *Hydrophyllax maritima*, *Ipomoea pes-caprae*, *Launnea sarmentosa*, *Spinifex littoreus,* and *Trianthema triquetra*.

DISTRIBUTIONAL PATTERN

There are 19 community development blocks and about 50 forest compartments in the SBR. Tree species are found in distinctive associations and twelve such associations have been identified in the Sundarbans Tiger Reserve (STR). Chakrabarti (1978) reported that pH was as low as 6.9 in case of an *Excoecaria-Ceriops* association and as high as 9.7 in case of a *Rhizophora-Bruguiera* association. The pH value fluctuates in-between in pure *Xylocarpus* and *Heritiera* strands found in Baghmara; *Ceriops* strands in Haldi within Goasaba; *Bruguiera parviflora* and *Ceriops tagal* strands in Chottahardi; *Nypa* strands in the Baghmara, Khatuajhuri, and Harinbhanga Blocks; and *Sonneratia griffithi* strands in the Khatuajhuri, Baghmara, and Chandkhali Blocks (Table 3).

Table - 3. Vegetation association data from Sundarbans Tiger Reserve

Vegetation association	EC Mhos/Cm	pH	TSS	Salt (%)
Avicennia-Sonneratia	13.7	8.0	136.5	0.60
Avicennia - Porteresia	12.5	8.4	125.1	0.60
Pure *Porteresia*	8.6	8.2	85.9	0.46
Rhizophora - Bruguiera	10.9	9.7	108.8	0.49
Excoecaria - Ceriops	14.6	6.9	145.6	0.96
Pure Ceriops	22.0	7.0	219.5	1.2
Pure Excoecaria	12.1	8.1	12.5	0.66
Pure Phoenix	13.4	8.0	134.5	0.72
Excoecaria - Phoenix	9.0	8.2	90.2	0.49
Heritiera – Excoecaria - Ceriops	16.1	7.8	161.1	0.84
Heritiera - Excoecaria	9.4	8.0	94.0	0.49
Heritiera - Phoenix	10.4	7.8	104.5	0.69

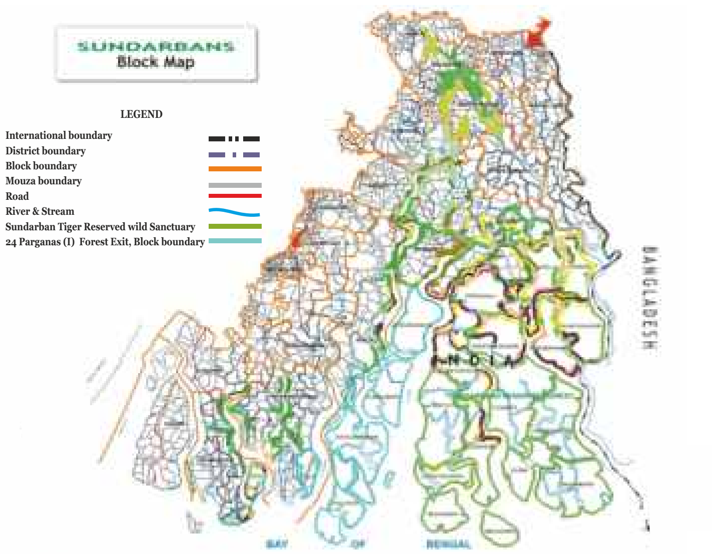
(Source - Chakrabarty, 1978)

Note: **E.C.**- Electrical Conductivity; **mmhos/cm-** millimhos/cm

pH- a measure of the acidity or alkalinity of an aqueous solution

TSS- Total suspended solids

Fig 3- Forest Blocks & Community Development (CD) Blocks of the Sundarban Biosphere Reserve



Analysis of studies by Ghosh et al. (2003) and Mukherjee (2004) at the SBR forest (figure 3) provides an estimate of 72 species (table 4) from the southern blocks (Bagmara, Gona, Mayadwip, and Ajmalmari) with maximum species diversity. The northern blocks (Jhilla, Pirkhali, and Panchmukhani) and the eastern blocks (Arbesi, Khatuajhuri, and Harinbhanga) exhibit moderate species diversity and the western blocks (Matla, Netidhopani, and Chottohardi) exhibit minimum diversity of mangroves. The central blocks (Chamta, Chandkhali, and Goasaba) and the blocks of 24 Parganas (South) Forest Division (Herobhanga, Ajmalmari, Dhulibhasani, Chulkati, Thakuran, Saptamukhi, and Muriganga) are home to 58 species.

Within the STR and the reserve forest of 24 Parganas (South) Division, a few other species are found, namely *Crotolaria juncea*, *Canavelia cathartica*, *Calophyllum inophyllum*, *Erythrina fusca*, *Borassus flabellifer*, *Hewittia sublobata*, *Tinospora cordifolia,* and *Tylophora tenuis*. These are neither mangrove associates nor back mangroves but are present due to migration and dispersal of fruits by any biotic or abiotic influence or carrier.

Table 4: Mangroves and associated flora with Distribution in Sundarbans Biosphere Reserve

Name of species	Distribution class	Distribution					
		Zone A	Zone B	Zone C	Zone D	Zone E	Zone F
Rhizophora apiculata	A, CD	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, S
R. mucronata	A	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T, S, Mg
Bruguiera gymnorhiza	CD	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T, S, Mg
B. sexangula	O	Pmk, J	-	Gb	A, K, H	Cd	**Cl**
B. cylindrica	O	Pk, Pmk	Md	Gb, C, Ck	-	M, Cd	Hb, Aj, D, Cl, T, S
B. parviflora	O	Pk, Pmk	B, G, Md	C, Ck, Gb	H	M, N Cd	Cl
Ceriops decandra	A, CD	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T, S, Mg
C. tagal	F	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl,
Kandelia candel	O	Pk, Pmk	B, G, Md	C, Ck, Gb	A, K, H	M, Cd	Hb, Aj, D, Cl, T
Avicennia alba	A	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T, S, Mg
A. officinalis	A	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T, S, Mg
A. marina	A	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T, S, Mg
Sonneratia caseolaris	L	-	B	-	-	-	Mg
S. griffithii	O	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T, S, Mg
S. apetala	F	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T, S, Mg
Lumnitzera racemosa	O	-	B, G, Md	C, Ck, Gb	_	M, N, Cd	D
Nypa fruticans	O	Pk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Aj, D, Cl,

Name of species	Distribution class	Distribution					
		Zone A	Zone B	Zone C	Zone D	Zone E	Zone F
Phoenix paludosa	A, CD	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T, S, Mg
Xylocarpus granatum	F	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T, S, Mg
X. mekongensis	F	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T, S, Mg
Heritiera fomes	O	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, S, Mg
Aegiceras corniculatum	A, CD	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T
A. rotundifolia	A	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T, S
Excoecaria agallocha	A	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T, S, Mg
Brownlowia tersa	O	Pk, Pmk, J	B, Md	C, Ck, Gb	A, K, H	M, N, Cd	Aj, Cl, T, S
Aglaia cucullata	L	J	Md	-	K	-	-
Scyphiphora hydrophyllacea	L	Pmk	-	-	-	-	S, Mg
Acanthus ilicifolius	F	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T, S, Mg
A. volubilis	R	-	-	-	-	M	Aj
Cynometra ramiflora	O	-	B, G, Md	Gb	-	N, Cd	T, S
Derris scandens	R	-	B	Ck, Gb	A, K	-	-
D. trifoliata	F	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T, S, Mg
Dalbergia sp.	O	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	N, Cd	Hb, Aj, D, Cl, T, S, Mg
Sarcolobus globosus	F	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T, S

Name of species	Distribution class	Distribution					
		Zone A	Zone B	Zone C	Zone D	Zone E	Zone F
S. carinatus	F	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T, S
Pentatropis capensis	R	Pk, Pmk, J	B, G, Md	Ck, Gb	A, K	M, N, Cd	Hb, Aj, D, Cl, T, S, Mg
Clerodendrum inerme	F	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj
C. neriifolium var. *macrocarpa*	R, L	Pmk	-	Gb	-	Cd	-
Premna corymbosa	R	-	G	-	-	-	-
Suaeda nudiflora	F	Pk, Pmk, J	B, G	C, Ck	A, K, H	N, Cd	Hb, Aj, D, Cl, T, S, Mg
S. maritima	F	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Cl, T, S
Salichornia brachiata	R	-	B	-	-	-	-
Sesuvium portulacastrum	O	-	-	G	-	-	Mg
Trianthema portulacastrum	O	-	-	-	-	-	S, Mg
T. triquetra	O	-	-	-	-	-	S, Mg
Porteresia coarctata	F	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T, S
Myriostachya wightiana	R, O	Pk, Pmk	G, Md	Ck, Gb	-	Cd	Hb, Aj
Phragmites karka	O	-	-	-	-	-	Mg
Ruppia maritima	F	-	-	-	-	-	Mg
Salacia chinensis	R, L	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Aj
Scirpus littoralis	O	-	-	-	-	-	Mg
Cerbera odollam	R, L	-	B	-	-	-	-
Dodoneaea viscosa	R, L	-	B	-	-	-	-
Calophyllum inophyllum	R, L	-	B	-	-	-	-
Acrostichum aureum	R	Pk, Pmk, J	B	C, Ck	A, K, H	N, Cd	Hb, Aj, D, Cl, T, S, Mg

Name of species	Distribution class	Distribution					
		Zone A	Zone B	Zone C	Zone D	Zone E	Zone F
Hydrophyllax maritima	R	-	B, Md	C	-	-	-
Derris indica	R	-	-	-	-	-	S, Mg
Crotolaria juncea	R, L	-	B, Md	Gb	-	-	-
Canavalia cathartica	R, L	-	B	-	-	-	-
Erythrina fuscha	F	-	B	-	-	-	-
Caesalpinia crista	O	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T, S, Mg
C. bonduc	R, L	-	B, G, Md	Gb	-	-	Mg
Tylophora tenuis	R	Pmk	-	-	-	-	-
Tamarix dioica	F	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	-
T. gallica	F	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	-
Thespesia populnea	R	-	B, G, Md	-	A	N, Cd	S, Mg
T. populneoides	R	-	B	-	-	N	-
T. lampus	R	-	-	-	-	-	S
Hibiscus tortuosus	R	-	-	-	-	-	S
H. tiliaceous	R	-	B, G	-	-	M, N	D, S
Manilkara hexandra	R	-	-	-	-	N	
Allophyllus cobbe	Reported from outside the forest Blocks in southern SBR						
Heliotrophium curassavicum	R	Pk, Pmk, J	-	-	A	N, Cd	Hb, Aj, T, S
Cryptocoryne ciliata	Reported from outside the forest Blocks in southern SBR						
Crinum defixum	Reported from outside the forest Blocks in southern SBR						
Cassytha filiformis	Reported from outside the forest Blocks in southern SBR						
Atalantia correa	R	-	-	-	-	-	Hb, Aj
Aeluropus lagopoides	Reported from outside the forest Blocks in central SBR						
Dolichandrone spathacea	Reported from outside the forest Blocks in central & southern SBR						
Barringtonia acutangula	Reported from outside the forest Blocks in northern SBR						
Barringtonia racemosa	Reported from outside the forest Blocks in northern SBR						
Capparis zeylanica	Reported from outside the forest Blocks in central SBR						

Name of species	Distribution class	Distribution					
		Zone A	Zone B	Zone C	Zone D	Zone E	Zone F
Crataeva roxburghii	Reported from outside the forest Blocks in central SBR						
Opuntia dillenii	Reported from outside the forest Blocks all over SBR						
Pandanus tectorius	O	-	-	-	-	-	S, Mg
P. odoratissima	Reported from outside the forest Blocks in northern & central SBR						
P. foetidus	Reported from outside the forest Blocks in northern SBR						
Lannea coromandelica	R, L	-	G	Gb	-	-	-
Tinospora cordifolia	R	-	-	-	-	N	-
Solanum trilobatum	O	-	-	-	-	-	S
Diospyros ferrea	Reported from outside the forest Blocks in central SBR						
Alternanthera paronychiodes	Reported from outside the forest Blocks all over SBR						
Finlaysonia obovata	Reported from outside the forest Blocks in central SBR						
Hoya parasitica	F	Pk, Pmk	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, Cl, T
Viscum orientale	F	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M	Hb, Aj, D,
V. monoicum	R	Pmk, Pk	-	-	H	N	-
Dendropthoe falcata	F	Pk, Pmk, J	B, G, Md	C, Ck, Gb	A, K, H	M, N, Cd	Hb, Aj, D, T
Cuscuta reflexa	Reported from outside the forest Blocks all over SBR						
Macrosolen cochinchinensis	R	Pmk	-	Ck	-	-	-
Vitex negundo	R	-	B, Md	Gb	-	-	Mg
Ipomoea pes-caprae	O	-	B, G, Md	C	Gb	M	D, Mg
Hewittia sublobata	R	-	B	-	-	-	-
Saccharum spontaneum	R	-	B	Gb	A	-	Mg
Solanum suratense	Reported from outside the forest Blocks in northern & central SBR						
Terminalia catappa	R, L	-	B	-	-	-	-

Abbreviations Used:

Zone A (Northern Blocks-STR) - Pirkhali (**Pk**), Panchmukhani (Pmk), Jhilla (**J**) | **Zone B** (Southern Blocks-STR) - Bagmara (**B**), Gona (**G**), Mayadwip (**Md**) | **Zone C** (Central Blocks-STR) - Chamta (**C**), Chandkhali (**Ck**), Goashaba (Gb) | **Zone D** (Eastern Blocks-STR) - Arbesi (**A**), Khatuajhuri (**K**), Harinbhanga (**H**) | **Zone E** (Western Blocks-STR) - Matla (**M**), Netidhopani (**N**), Chottohardi (**Cd**) | **Zone F** (S-24 Parganas) - Herobhanga (**Hb**), Ajmalmari (**Aj**), Dhulibhasani (**D**), Chulkati (**Cl**), Thakuran (**T**), Saptamukhi (**S**), Muriganga (**Mg**)

A - abundant; **F** - frequent; **R** - rare; **O** - occasional; **L** - local; **CD** - co- dominant

Community Dependencies and Traditional Use

The local communities use mangrove resources for a number of purposes which include fuelwood, fodder, tannin suitable for leather work and also for curing and dyeing of fishing nets, timber for construction of houses and boats, thatching of roofs, medicinal requirements, fish, honey, and many other uses. Honey collection is a traditional group activity in the Sundarbans for a two-month period, from April to May. Though honey collection is purely seasonal, it serves as a livelihood source for the population.

The mangrove trees are also traditional sources of a number of treatments for common ailments. The details of the medicinal uses of mangrove plants as reported are highlighted in table 5.

Table – 5. Traditional uses of Mangroves and associated flora for Medicinal Purposes in the Indian Sundarbans

Name of the Family	Name of the Species	Traditional Use
Rhizophoraceae	*Rhizophora mucronata*	Treatment of Heamaturia, Parturition, Angina, Diabetes, Hemorrhage and as an astringent.
	Ceriops tagal	Treatment of parturition, sores and malaria.
	Kandelia candel	Treatment of diabetes.
Avicenniaceae	*Avicennia officinalis*	Treatment of boils, poultice and tumours.
	Avicennia spp.	Known to have contraceptive properties.
Sonneratiaceae	*Sonneratia caseolaris*	Treatment of cough, dysuria, hematuria, swelling, sprains and even smallpox. It is also used as a vermifuge.
	S. griffithii	Treatment of ringworm
Meliaceae	*Xylocarpus granatum*	Treatment of cholera, diarrhea and fever.
Myrsinaceae	*Aegiceras corniculatum*	Known to have piscicidal properties
Arecaceae	*Nypa fruticans*	Treatment of toothaches, herpes, sores and is at times used as an intoxicant.
Sterculiaceae	*Heritiera fomes*	Treatment of fever
Combretaceae	*Lumnitzera racemosa*	Treatment of herpes and itch.
	Terminalia catappa	Treatment of dysentery and rheumatism.
Euphorbiaceae	*Exoecaria agallocha*	Used as an antidote to dermatosis, leprosy, paralysis, rheumatism, sores and tumor.
Rubiaceae	*Scyphiphora hydrophyllacea*	Treatment of abdominal aches.
Acanthaceae	*Acanthus ilicifolius*	Treatment of lymphadenitis, neophasia, neuralgia, rheumatism and splenomegaly.

Name of the Family	Name of the Species	Traditional Use
Fabaceae	*Cynometra ramiflora*	Treatment of dermatosis and leprosy.
	Derris scandens	Often used as piscicides
	D. trifoliata	
	Crotolaria juncea	Used as a depurative and poison.
Caesalpiniaceae	*Caesalpinia crista*	Treatment of tooth aches, colics, convulsion, dropsy, fever, malaria, pimples and is also used as a tonic and laxative.
	C. bonduc	Treatment of cough, diarrhea, jaundice and swelling.
Asclepiadaceae	*Tylophora tenuis*	Used in the treatment of scabies, smallpox and swelling.
Tamaricaeae	*Tamarix dioica*	Used as an astringent.
	T. gallica	Used in treatment of tumor.
Verbenaceae	*Clerodendrum inerme*	Treatment of dysentery, headaches, stomach aches, pneumonia and as an anticoagulant.
	Vitex negundo	Treatment of headaches, angina, coughs, dysentery, fever, gastritis, dropsy and as a bacteriacide, tonic, tranquilizer and analgesic.
Malvaceae	*Thespesia populnea*	Treatment of headaches, cholera, colic, itches, dysentery, malaria, inflammation and is also used as purgative and sedative.
Sapotaceae	*Manilkara hexandra*	Used as an astringent and tonic.
Loranthaceae	*Viscum monoicum*	Treatment of itches, ear aches and is used as poison, narcotic, excitant and CNS stimulant.
	Dendropthoe falcata	Treatment of asthma, mania, menoxenia and tuberculosis.
Convolvulaceae	*Ipomoea pes-caprae*	Treatment of stomache aches, boils, cramps, stings and swelling.
Hippocrateaceae	*Salacia chinensis*	Treatment of diabetes, amenorrhea, dysmenorrheal and as an astringent.
Apocynaceae	*Cerbera manghas*	Treatment of cold and rheumatism.
Sapindaceae	*Dodonaea viscosa*	Used as an astringent, stimulant and piscicide and is also used in the treatment of bruises, colics, fevers, gout, poultice, rheumatism, sores and sprains.
Cluciaceae	*Calophyllum inophyllum*	Used in the treatment of conjunctivitis, gonorrhea, metrorrhagia, parturition and rheumatism.
Bignoniaceae	*Dolichandrone spathacea*	Used as an antiseptic and in the treatment of spasma.
Pandanaceae	*Pandanus odoratissimus*	Treatment of ear aches, head aches, arthritis, giddiness, rheumatism, smallpox, spasms and leprosy.
	P. tectorius	Treatment of dizziness, dysentery, elephantiasis, sores and swelling.

Among the mangrove associates of the Sundarbans, only 7 species are used as fuel, out of which 5 are trees or shrubs and 2 are salt marshes. *Cynometra ramiflora, Clerodendrum inerme, Dalbergia spinosa,* and *Thespesia populnea* are the major fuelwood plants. Timber is obtained only from 8 tree species. Twelve species of fodder plants have been reported and most of them are herbaceous. Ten species of non-mangroves supply their different parts for food to local inhabitants. It has been known that 40 species have medicinal potentialities and local people are using these plants as and when required (Naskar 2007). Twelve species locally used for thatching materials, tannins, mats, dye, paper pulp, oil, and vermifuge and help in cottage industries. The use of non-mangrove plants is shown in table 6.

Table – 6. Number of mangrove associates used for traditional and consumtion purpose.

Sl. No.	Name of the species	Local name	Use
Salt Marsh			
1	*Suaeda nudiflora*	Giria shak	Vegetable
2	*S. maritima*	Giria shak	Vegetable
3	*Salicornia brachiata*	-	Occasionally used
4	*Arthrocnemum indicum*	Jadupalang	Famine food
5	*Sesuvium portulacastrum*	Gada bani	Vegetable, Fodder potential for salt extraction
6	*Trianthema portulacus-trum*	Sabuni	Medicinally used: in heart trouble blood disease & anaemia
7	*Heliotropium curassivicum*	Nona Hatisur	Fodder, Medicinally used: in old sores and wounds
8	*Tamarix dioica*	Local jhau	Medicinally used: as astringent Fuel & Tannin
9	*T. gallica*	Bon jhau	Industrial used: In tanning & dyeing
10	*T. troupii*	Jhau	Fuel & Tannin
Sea Grass/ Brackish water aquatics			
11	*Ruppia maritima*	Nona jhanjhi	Fish & Prawn food
12	*Crinum defixum*	Sukh darshan	Medicinally used to cure ear sore
13	*C. asiaticum*	Sukh darshan	Medicinally used to cure ear sore
14	*Cryptocoryne ciliata*	Kerali	Not known
Sand Binder			
15	*Ipomoea pescaprae*	Chagal kuri	Medicinally used as astrin-gent
16	*Launea sarmentosa*	Tik-chana	Medicinally used and famine food
17	*Zoysia matrella*		Fodder
18	*Sporobolus tremulus*	Benajoni	Fodder
Riverine Non Mangrove/ Climbers/Liana/Creeper/Twiner			
19	*Derris scandens*	Noalata	Fibres, Insecticide,
20	*D. trifoliata*	Panlata	Medicinally used as anti-spasmodic & used as fodder
21	*Mucuna gigantea*	Aalkushi	Medicinal, seeds oil

Sl. No.	Name of the species	Local name	Use
22	*Canavalia cathartica*	Barasim	Vegetable
23	*Abrus precatorius*	Kunch	Medicinal
24	*A. pulchellus*	-	Medicinal
25	*Cletoria ternatia*	Aparajita	Medicinal
26	*Sarcolobus globosus*	Baoli-lata	Poisonous
27	*S. carinatus*	Baoli-lata	Medicinal
28	*Solanum suratense*	Kantikari	Medicinally used in cough, asthma
29	*Ipomoea tuba*	-	Fruits as fish food
30	*Evolvulus numularius*	Ankra	Fodder
31	*E. alsinoides*	Chutialutur	Fodder
32	*Flagellaria indica*	Bon chanda	Used in basket making
33	*Tylophora tenuis*	-	Medicinal: leaves used in asthma
34	*Finlaysonia obovata*	Dudhi lata	Medicinal use: anti asthma
35	*Salacia chinensis*	Madhuphal	Edible fruit and medicinally used
Riverine Trees & Shrubs			
36	*Derris indica*	Karanja	Medicinally used, insecticidal, Fish poison
37	*Dalbergia spinosa*	Chulia kanta	Fuel, fodder, fruits as fish food
38	*Hibiscus tiliaceous*	Bhola	Fibres used as cordage, fire wool, medicinal-root, leaves
39	*H. tectraphyllus*	Ban bhendi	Fruits edible but very occasionally
40	*Thespesia populneoides*	Paras	Used as medicine and yellow dye
41	*T. populnea*	-	Timber, fuel wood, fodder
42	*T. lampus*	Ban kapas	Medicinally used in gonorrhoea & syphilis
43	*Cerbera odollam*	Dabur	Medicinally used as purgative, narcotive & poisonous & in hydrophobia
44	*Pandanus tectorius*	Keya kanta	Fibres used in cordage, leaves as vegetable/ medicine
45	*P. foetidus*	Keya	Leaves used for matting, paper making, thatching

Sl. No.	Name of the species	Local name	Use
46	*Barringtonia acutangula*	Hijal	Medicinally used, wood used in boat making, fruits as astringent
47	*B. racemosa*	Sumudra	Medicinal
48	*Manilkara hexandra*	-	Timber
49	*Calophyllum inophyllum*	-	Timber, oil yielding
50	*Diospyros ferres*	-	Timber
51	*Crotalaria juncea*	San	Fibre
52	*Desmodium umbellatum*	-	Fodder
53	*Cynometra ramiflora*	Shinger	Fuel and timber
54	*C. iripa*	Shinger	Fuel and timber
55	*Caesalpinia crista*	Nata karanja	Cosmetics & medicinal
56	*C. major*	Nata karanja	Cosmetics & medicinal
57	*Clerodendrum inerme*	Batraj	Fuel, fodder
58	*C. viscosum*	Ghentu	Vermifuge
59	*Vitex negundo*	Nisinda	Insect repelent
60	*Premna corymbosa*	Gamiari or Bhui biravi	Medicinal
61	*Salvadora persica*	-	Medicinal: toothache & infectim
62	*Opuntia dillenii*	Nag phana	Vegetable
63	*Capparis zeylamica*	-	Medicinal (Aphrodisiac, tuberculosis, paralysis)
64	*Crataeva roxburghii*	Barun	Medicinal
65	*C. religiosa*	Barun	Medicinal
66	*Allophyllus cobbe*	-	Medicinal (Cuts, ulcers & wound)
Epiphyte/ Parasite			
67	*Viscum orientale*	Manda	Medicinal & Poisonous
68	*V. monoecum*	Manda	Narcotic & poisonous
69	*Microsolen cochinchinensis*	Chhota manda	Medicinal (headache & poultice)
70	*Cassytha filiformis*	Akash bel	Medicinal (Rib & muscle pain, anti hermetic)
71	*Cuscuta reflexa*	Sarna lata	Medicinal (Purgative, Di-phoretic & demulcent)

Sl. No.	Name of the species	Local name	Use
Other Herbaceous Plants			
72	*Solanum trilobatum*	-	Vegetable
73	*Wedelia biflora*	Bhimraj	Food, flavour
74	*Porteresia coarctata*	Dhani ghas	Fodder
75	*Myriostachya wightiana*	Nalai	Fodder (Deer & Pig)
76	*Phragmites karka*	Nalor dharma	Paper pulp
77	*Saccharum spontaneum*	Kash	Paper pulp
78	*Cyperus exaltatus*	Mutha ghas	Mat making material
79	*C. procerus*	-	Fodder
80	*Fimbristylis ferrugiana*	-	Fodder
81	*F. campanula*	-	Fodder

Status and Threats

Acanthus volubilis is restricted to Sundarbans

Kathiresan (2002) has critically evaluated the Indian mangrove species and designated 25 species as either rare, endemic, or restricted in distribution in India. These include *Aegialitis rotundifolia* (confined to West Bengal, Orissa, and Andhra Pradesh); *Aglaia cucullata*, *Brownlowia tersa*, *Heritiera fomes*, *Merope angulata*, *Tylophora tenuis*, and *Thespesia populneoides* (restricted to West Bengal and Orissa); *Phoenix paludosa*, *Finlaysonia obovata*, *Sonneratia griffithii*, *Xylocarpus granatum*, and *Xylocarpus mekongensis* (restricted to West Bengal, Orissa, and Andamans) ; *Nypa fruticans* (restricted to West Bengal and Andaman); *Acanthus volubilis* (restricted to the Sundarbans); and *Sarcolobus carinatus* (restricted to the Sundarbans, the Godavari delta, and Andaman).

Publications by Naskar and Guha Bakshi (1987), Naskar and Mandal (1999), and Ghosh et al. (2002) have mentioned the presence of *Scyphiphora hydrophyllacea* in the western and southern parts of the Indian Sundarbans and the abundance of *Sonneratia apetala* in the Indian Sundarbans.

Mangrove species has been categorized under IUCN (2011): Red List of Threatened Species (table7).

Table 7 : Red list categories of Mangrove

Family	Species	IUCN Status
Rhizophoraceae	*Ceriops decandra* (Griff.) Ding Hou	Near Threatened
Sonneratiaceae	*Sonneratia griffithii* Kurz.	Critically Endan-gered
Arecaceae	*Phoenix paludosa* Roxb.	Near Threatened
Sterculiaceae	*Heritiera fomes* Buch.- Ham.	Endangered
Aegialitidaceae	*Aegialitis rotundifolia* Roxburgh	Near Threatened
Meliaceae	*Aglaia cucullata* (Roxb.) Pellegrin	Data Deficient-Declining Population

According to IUCN (2011), *Hertiera fomes* has a very restricted distrubution in South

According to IUCN (2011), *Hertiera fomes* has a very restricted distribution in South Asia. IUCN (2011) also reports that populations of this species in India and Bangladesh are rapidly declining and may qualify as 'critically endangered' at a regional level. This rapid decline of the species in the case of the Indian Sundarbans can be attributed to habitat degradation in the form of decline in sweet water influx and also to some extent, poaching pressures on this high-quality timber-producing tree.

Major mangrove ecosystems worldwide occur between the ranges of mean sea level and high tidal elevations and have distinct species zonations that are controlled by the elevation of the substrate relative to mean sea level. With the rise in sealevel, the habitat requirements of each species will obviously be disrupted and species zones will suffer mortality at their present locations and reestablish at higher elevations in areas that were previously landward zones. However, the Sundarbans is an area devoid of any such distinct elevation zones and in the context of sea-level rise. Although many models suggest and record sea-level rise in the area, GIS maps of the last 16 years indicate both erosion and accretion, with erosion rates slightly more than accretion ranges.

The threats, which are also perceived to be problems for habitat maintenance of the mangroves in the Indian Sundarbans, include pollution from sewage effluents, solid wastes, siltation, oil, and agricultural and urban runoff. Natural threats include frequent cyclones, hurricanes, and tidal surges. Other problems which deteriorate the conditions for survival and maintenance of the ecosystem include poaching, illegal timber harvest, illegal fishing and honey collection activities, and indiscriminate prawn seed collection.

Though considerable and viable populations of *Xylocarpus granatum* and *Xylocarpus mekongensis* exist within the forests of the Indian Sundarbans, these two species face significant threat due to poaching and illegal felling as both of them have high quality and are much sought after timber, comparable to teak. Two more species, which are afflicted by illegal felling pressures, include *Ceriops decandra, Avicennia* spp., and *Excoecaria agallocha*. These two are mainly illegally collected for supplementing fuel wood requirements of the fringe area populations.

ECOLOGICAL IMPORTANCE AND NEED FOR CONSERVATION

Xylocarpus granatum and *Xylocarpus mekongensis, Ceriops decandra, Avicennia spp.* and *Excoecaria agallocha* face significant threat

Mangrove swamps not only have a high rate of primary productivity but also export organic matter and support a wide variety of aquatic, benthic, and terrestrial organisms. The decomposition of mangrove litter produced is an important stage in nutrient dynamics in these estuarine ecosystems and is mainly governed by factors like the availability of oxygen, substrate characteristics, and animal and microorganism activity. Mangrove detritus is probably more important as a substrate for microbial activity and represents more of a nutrient and carbon sink rather than a source for adjacent habitats (Kathiresan and Bingham 2001).

The ability of mangroves to deal with intense sunlight rays and solar UV-B radiation have been reported by Moorthy and Kathiresan (1997). Mangrove foliage produces flavonoids that serve as UV-screen compounds. Rhizophoracean species show greater solar UV-B tolerance than other mangrove species. This ability of mangroves makes the environment free from the deleterious effects of UV-B radiation. Mangroves like *Rhizophora* spp. are also reported to act as a protective force against these natural calamities (McCoy et al.1996). Kathiresan and Rajendran (2005b) have concluded that tsunami-induced human deaths and property losses were lower behind mangroves and sand dunes in Pichavaram. The role of mangroves and sand dunes in mitigating the effects of tsunamis has been proved using satellite data in the same area (Danielsen et al. 2005). It is believed that the dense growth of mangroves in the Sundarbans saved West Bengal in India and Bangladesh from the impact of the tsunami.

The mangroves of the Sundarbans provide a wide variety of ecosystem services, namely protection from natural calamities as buffer, erosion control, and imparting shoreline stability by controlling nutrient and sediment distribution in estuarine waters; maintenance of water quality and supply; maintenance of near-shore marine habitats, providing food, shelter, and breeding grounds to a variety of terrestrial, benthic, inshore, offshore, and marine organisms; replenishment, rejuvenation, and reclamation of soil; and clean air and other common property resources that all have economic as well as intrinsic value. Although not traded in conventional markets, these are eventual reasons for which conservation efforts are imperative.

The studies on litter fall made by Mukherjee (2004) reported 10 species to be quite dominant in the Indian Sundarbans: *Rhizophora mucronata, Bruguiera gymnorhiza, Bruguiera parviflora, Ceriops decandra, Avicennia officinalis, Sonneratia apetala, Heritiera fomes, Xylocarpus mekongensis, Xylocarpus granatum,* and *Excoecaria agallocha*. Out of these, the maximum litter fall was found during the summer season, for the species *Rhizophora mucronata*, *Bruguiera gymnorhiza*, *Ceriops decandra*, *Heritiera fomes*, *Xylocarpus granatum*, *Xylocarpus mekongensis,* and *Excoecaria agallocha*. However, on the basis of a single collection during summer, *Excoecaria agallocha* showed the highest value. The case is the reverse for *Bruguiera parviflora,* which showed the least litter fall in summer and the highest during monsoon. The other two species, *Avicennia officinalis* and *Sonneratia apetala,* produce the highest litter fall in monsoon. In a single season, *Excoecaria agallocha* was found to produce the highest litter fall. This may be attributed to the fact that *Excoecaria agallocha* experiences total leaf fall during summer.

Mukherjee (2004) also observes that when the dissiminules were isolated in the case of *Rhizophora mucronata* during post-monsoon collection, the highest litter fall was found in the form of leaves and twigs and the least litter fall in the form of bark. Other species follow the same trend, that is, in all the species, the maximum litter fall is found in the form of leaves and twigs during different seasons for different species. Minimum litter fall in the case of *Bruguiera parviflora* was found in the form of fruits during winter; in *Ceriops decandra* it was found in the form of flower during monsoon; in *Avicennia officinalis* it was found in the form of flower during post monsoon. Minimum litterfall in *Sonneratia apetala* was found in the form of bark during summer season. The species like *Heritiera fomes* and *Xylocarpus mekongensis* showed the least litter fall in the form of flower in the same season, that is, in winter. The other species of *Xylocarpus*, that is, *Xylocarpus granatum* showed minimum litter fall in the form of bark. *Excoecaria agallocha* showed minimum litter fall during summer in the form of flower. During monsoon, all the species except *Sonneratia apetala* and *Avicennia officinalis* exhibited reduced litter fall, whereas these two species exhibited increased litter fall. It was evident that taller mangroves of the evergreen species, namely *Rhizophora, Bruguiera,* and *Sonneratia* are more productive in litter production in the context of the Sundarbans mangrove ecosystem.

Erosion is a major threat to species stability and regeneration in the entire Sundarbans. In recent times, plantation works related to mangrove regeneration have been undertaken by the Forest Department in inshore mudflat areas which have suitable soil profiles and only mangrove species are planted with a view to stop soil erosion. Afforestation in the mudflats, which are prone to erosion and are close to the villages, is one of the major ways of controlling soil erosion. Species which are planted as potted seedlings include *Xylocarpus granatum* (Dhundul), *Sonneratia apetala* (Keora), and *Heritiera fomes* (Sundari). The species that are planted with naked roots are *Rhizophora apiculata* (Garjan), *Bruguiera gymnorhiza* (Kankra), and *Nypa fruticans* (Golpata). The species whose seeds are dibbled are *Avicennia* spp. (Baen), *Excoecaria agallocha* (Genwa), and *Ceriops* spp. (Goran). Mukherjee (2004) studied the phenology of the major mangrove species of the Indian Sundarbans, which gives a calendar of suitable time for seed collection and nursery works (table 8).

Table - 8. Phenology of Mangrove Species in the Indian Sundarbans

Sl. No.	Species	Flowering - Fruiting	Time of seed collection
1.	*Avicennia alba* (Peyara Bain)	April-June	July-August
2.	*A. officinalis* (Jat Bain)	March-May	July-August
3.	*A. marina* (Kalo Bain)	February-June August-September	September-November
4.	*Heritiera fomes* (Sundari)	January-April October-January	June-July
5.	*Xylocarpus mekongensis* (Passur)	February-April	March
6.	*X. granatum* (Dhundul)	February-April	March
7.	*Bruguiera gymnorhiza* (Kankra)	April-May	July-August
8.	*B. sexangula* (Kankra)	March-April	June-July
9.	*B. cylindrica* (Ban Bakul)	May-June	July-August
10.	*B. parviflora* (Kankra)	May-June	June-July
11.	*Aegiceras corniculatum* (Khalsi)	March-April October-November	August-September
12.	*Sonneratia apetala* (Keora)	April-May	September-December
13.	*Excoecaria agallocha* (Gewa)	May-June	July-August
14.	*Ceriops decandra* (Garan)	Throughout the Year	August-September
15.	*Phoenix paludosa* (Hental)	January-February April-May	April-May
16.	*Nypa fruticans* (Golpata)	April - October	October
17.	*Rhizophora mucronata* (Garjan)	March-April	July-August

An assessment of the status of these plantations by means of regular monitoring reveals that *Avicennia* and *Bruguiera* are the only species which are able to withstand the biotic and abiotic pressures on these plantations, along with which a very negligible population of *Rhizophora* and *Sonneratia* were found to survive (Mukherjee 2004).

Inevitably, management of most mangrove species involves management of the ecosystem at large. On a more precise scale, it is understood that the threat to each mangrove species varies in magnitude and dimensions. The reasons and extent of vulnerability of each species and the management thereof is an important research area. The knowledge would facilitate assessment of mangrove species' resilience to different disturbances. The other domains of information and knowledge that are imperative to formulating proper management strategies include comprehensive data on hydrogeological components related to both land and water phases that govern the dynamics of the ecosystem and creation of a detailed stock map of the area using remote sensing, GIS technology, and intensive ground truth verification.

Another major perceivable threat comes in the form of climate change, with the IUCN (2011) attributing this as a major cause for decline of a number of mangrove species worldwide. It is a matter of concern that if the present rates of change prevail, the Sundarban mangroves could disappear as sea levels rise because the forests' natural response to retreat further inland is blocked by natural features and man-made obstructions. The management strategy for the Sundarbans should include limiting coastal development and creating provisions for the mangrove forests to spread inland. Rehabilitation of former mangrove areas and creation of new mangrove habitats through intensified afforestation programs should also be an integral component of such policies.

With regard to harnessing economic benefits from the mangrove species, a dilemma ensues on whether we really need to use every natural resource available on the face of this earth directly, in the name of sustainable utilization or elsewise. In any case, the wide variety of ecosystem services that the mangroves provide are valuable commodities though not traded in conventional markets and this is reason enough for imperative conservation efforts.

Considering the conservation aspects, development of tools and techniques for in situ and ex situ conservation of the mangrove species is an area of research most needed, especially for the dwindling species identified to be under maximum threat. The techniques under consideration would include tissue culture, cryopreservation, and DNA banks to begin with. Moreover, the mangroves play a major role in sustaining and enhancing the livelihoods of the large fringe area population. This indicates not only the importance of people's participation in the conservation efforts as accepted worldwide but also a situation where it is absolutely necessary to involve local participation in the conservation exercise, keeping in mind the limited livelihood options available and extreme periodic climate incidents. Although participation alone cannot serve as an exhaustive tool for conservation, the success story will definitely depend on factors such as institutional or legal frameworks and capacity building of various stakeholders of the system.

Flowers - 1. *Acanthus ilicifolius* 2. *Aegialitis rotundifolia* 3. *Avicennia officinalis* 4. *Bruguiera gymnorrhiza* 5. *Ceriops decandra* 6. *Heritiera fomes*

Fruits - 1. *Phoenix paludosa* 2. *Ceriops decandra* 3. *Aegiceras corniculatum* 4. *Avicennia officinalis* 5. *Excoecaria agallocha* 6. *Sonneratia caseolaris*

Fruits - 1. *Acrostichum aureum L.* 2. *Clerodendrum inerme (L.) Gaertn.* 3. *Derris scandens (Roxb.) Benth.* 4. *Heliotropium curassavicum L.* 5. *Pentatropis capensis (L.f.) Bollock* 6. *Sesuvium portulucastrum (L.) L.*

ANNEXURE

Sr. No.	Family	Name of the species
Major Elements/True mangrove (Intertidal, salt resistant trees/shrubs)		
1	Rhizophoraceae	*Rhizophora apiculata* Blume
2	Rhizophoraceae	*R. mucronata* Lamk.
3	Rhizophoraceae	*Bruguiera gymnorhiza (L.)* Lamk.
4	Rhizophoraceae	*B. sexangula (L.)* Poir
5	Rhizophoraceae	*B.cylindrica (L.)* Blume
6	Rhizophoraceae	*Bruguiera parviflora* W. & A.
7	Rhizophoraceae	*Ceriops decandra* (Griff.) Ding Hou
8	Rhizophoraceae	*C. tagal* (Perr.) Robin
9	Rhizophoraceae	*Kandelia candel* (L.) Druce
10	Avicenniaceae	*Avicennia alba* Blume
11	Avicenniaceae	*A. officinalis* L.
12	Avicenniaceae	*A. marina* (Forsk.) Vierh.
13	Avicenniaceae	*A. marina* . Var. *acutissima* Stapf.
14	Sonneratiaceae	*Sonneratia caseolaris* (L.) Engler
15	Sonneratiaceae	*S. griffithii* Kurz.
16	Sonneratiaceae	*S. apetala* Buch.- Ham.
17	Combretaceae	*Lumnitzera racemosa* Willd.
18	Arecaceae	*Nypa fruticans* (Thunb.) Wurmb.
19	Arecaceae	*Phoenix paludosa* Roxb.
Minor Elements (Intertidal, salt resistant trees and shrubs in mangal)		
20	Meliaceae	*Xylocarpus granatum* Koen.
21	Meliaceae	*X. mekongensis* Pierre
22	Meliaceae	*Aglaia cucullata* (Roxb.) Pellegrin
23	Myrsinaceae	*Aegiceras corniculatum* (L.) Blanco
24	Euphorbiaceae	*Excoecaria agallocha* L.
25	Aegialitidaceae	*Aegialitis rotundifolia* Roxburgh
26	Sterculiaceae	*Heritiera fomes* Buch.- Ham.
27	Rubiaceae	*Scyphiphora hydrophyllacea* Gaertn.f.
28	Tiliaceae	*Brownlowia tersa* Kost.
29	Rutaceae	*Merope angulata* (Wild.) Swingle
30	Rutaceae	*Atalantia correa* M. Roem.
31	Acanthaceae	*Acanthus ilicifolius* L.
32	Acanthaceae	*A.volubilis* Wall.
33	Acanthaceae	*A. ebracteatus* Vahl.
34	Pteridaceae	*Acrostichium aureum* L.

Mangrove associates (Salt resistant trees, shrubs, climbers, herbs)

35	Fabaceae	*Derris scandens* Benth
36	Fabaceae	*D. trifoliata* Lour
37	Fabaceae	*D. heterophylla* (L.) Merr.
38	Fabaceae	*D. indica* (Lamk.) Bennet
39	Fabaceae	*D. spinosa* Roxb.
40	Fabaceae	*Dalbergia spinosa* Roxb.
41	Fabaceae	*D. candenatansis* Prain
42	Fabaceae	*D.monosperma* Delz.
43	Fabaceae	*Instia bijuga* (Colebr.)Kuntz.
44	Fabaceae	*Mucuna gigantea* (Willd) DC.
45	Fabaceae	*Crotolaria juncea* L.
46	Fabaceae	*Canavalia cathartica* Thour
47	Fabaceae	*C. maritima* (Aubl) Piper
48	Fabaceae	*C. microcarpa* (Aubl) Piper
49	Fabaceae	*Abrus precatorius* L.
50	Fabaceae	*A.pulchellus* Wall.ex.Thw.
51	Fabaceae	*Cletoria ternatia* L.
52	Fabaceae	*Vigna marina* (Burm.f.) Merr.
53	Fabaceae	*Sophora tomentosa* L.
54	Fabaceae	*Pterocarpus dalbergioides* Roxb.
55	Fabaceae	*Desmodium triquetrum* DC.
56	Fabaceae	*D. umbellatum* DC.
57	Fabaceae	*Cynometra ramiflora* L.
58	Fabaceae	*C. iripa* Kostel
59	Fabaceae	*Caesalpinia crista* L.
60	Fabaceae	*C.major* (Medik.) Dandy *et*. Excell.
61	Fabaceae	*C. bonduc* (L.) Roxb.
62	Fabaceae	*Entada scandens* L.
63	Fabaceae	*Erythrina fuscha* Lour.
64	Asclepiadaceae	*Sarcolobus globosus* Wall.
65	Asclepiadaceae	*S. carinatus* Wall.
66	Malvaceae	*Hibiscus tiliaceous* L.
67	Malvaceae	*H. tortuosus* Roxb.
68	Malvaceae	*H. tetraphyllus* Roxb.
69	Malvaceae	*Thespesia populneoides* (Roxb.) Kostel
70	Malvaceae	*Thespesia populnea* (L.) Solandar
71	Malvaceae	*T. lampus* (Cav.) Dalz. Gibs
72	Verbenaceae	*Clerodendrum inerme* Gaertn.

73	Verbenaceae	*C. nerifolium* var. macrocarpa L.
74	Verbenaceae	*C. viscosum* Vent
75	Verbenaceae	*Vitex negundo* L.
76	Verbenaceae	*Premna corymbosa* Rottb. & Willd
77	Apocynaceae	*Cerbera odollam* Gaertn.
78	Tamaricaceae	*Tamarix dioica* Roxb.
79	Tamaricaceae	*T. gallica* L.
80	Tamaricaceae	*T. troupii* Hole
81	Pandanaceae	*Pandanus tectorius* Parkinson
82	Pandanaceae	*P. foetidus* Roxb.
83	Pandanaceae	*P.sodoratissima* Par.
84	Pandanaceae	*P. leram* Jones
85	Salvadoraceae	*Salvadora persica* L.
86	Anacardiaceae	*Lannea coromandelica* L.
87	Menispermaceae	*Tinospora cordifolia* Willd.
88	Solanaceae	*Solanum suratense* Burm.
89	Solanaceae	*S. trilobatum* L.
90	Combretaceae	*Terminalia catappa* L.
91	Scrophulariaceae	*Mimulus orbicularis* Wall. *ex* Benth.
92	Araceae	*Cryptocoryne ciliata* (Roxb.) Fish.Wydler
93	Amarythidaceae	*Crinum defixum* Ker.Gawlar
94	Amarythidaceae	*C.asiaticum* Roxb.
95	Ruppiaceae	*Ruppia maritima* L.
96	Convolvulaceae	*Ipomoea pes-caprae* Sw.
97	Convolvulaceae	*I. tuba* (Schld.) G.Don
98	Convolvulaceae	*I. gracilis* R.Br.
99	Convolvulaceae	*Hewittia sublobata* (L.f.) O.K.Rev.
100	Convolvulaceae	*Stictocardia tillifolia* (Desr.) Hall.f.
101	Chenopodiaceae	*Suaeda nudiflora* Roxb.
102	Chenopodiaceae	*S.maritima* (L.) Dumort
103	Chenopodiaceae	*Salicornia brachiata* Roxb.
104	Aizoaceae	*Sesuvium portulacastrum* L.
105	Rubiaceae	*Hydrophyllax maritima* L.f.
Back mangrove (Trees, shrubs and epiphytes in mangal commmunity)		
106	Bignoniaceae	*Dolichandrone spathacea* Sch.
107	Barringtoniaceae	*Barringtonia acutangula* (L.) Gaertn.
108	Barringtoniaceae	*B. racemosa* Roxb.
109	Barringtoniaceae	*B. asiatica* (L.) Kurz.
110	Sapotaceae	*Manilkara hexandra* (Roxb.) Dub.
111	Opuntiaceae	*Opuntia dillenii* (Ker-Gawler) Haw.

112	Capparidaceae	*Capparis zeylamica* L.
113	Capparidaceae	*Crataeva roxburghii* R.Br.
114	Sapindaceae	*C. religiosa* Forst.f.
115	Euphorbiaceae	*Sapium indicum* Wild.
116	Flagellariaceae	*Flagellaria indica* L.
117	Clusiaceae	*Calophyllum inophyllum* L.
118	Viscaceae	*Viscum orientale* Willd.
119	Viscaceae	*V. monoicum* Wight
120	Loranthaceae	*Macrosolen cochinchinensis* (Lour.)
121	Loranthaceae	*Dendropthoe falcata* (L.f.) Etting
122	Lauraceae	*Cassytha filiformis* L.
123	Convolvulaceae	*Cuscuta reflexa* Roxb.
124	Convolvulaceae	*Evolvulus numularius* (L.) L.
125	Convolvulaceae	*E. alsinoides* (L.)L.
Back mangrove (Herbs,grasses, sedges and ferns in mangal commmunity)		
126	Aizoaceae	*Trianthema portulacustrum* L.
127	Aizoaceae	*T. triquetra* Rottb. & Willd
128	Chenopodiaceae	*Arthrocnemum indicum* (Willd.) Moq.
129	Asteraceae	*Pulchea indica* Less.
130	Asteraceae	*Launea sarmentosa* (Willd.) Sch.
131	Asteraceae	*Wedelia biflora* DC.
132	Ebenaceae	*Diospyros ferrea* (Willd.) Bakh
133	Amaranthaceae	*Alternanthera paronychiodes* St. Hill.
134	Sapindaceae	*Dodonaea viscosa* (L.)Jacq.
135	Sapindaceae	*Allophyllus cobbe* (L.)Bl.
Mostly Epiphytic or parasitic on mangrove trees		
136	Asclepiadaceae	*Pentatropis capensis* (L.f.) Bullock
137	Asclepiadaceae	*Tylophora tenuis* Blume
138	Asclepiadaceae	*Finlaysonia obovata* Wall.
139	Asclepiadaceae	*Hoya parasitica* Wall.
140	Celastraceae	*Salacia chinensis* L.
141	Celastraceae	*S.prionoides* DC.-
Common grass/sedge on the intertidal areas and on sand		
142	Poaceae	*Porteresia coarctata* Takeoka
143	Poaceae	*Myriostachya wightiana* (Nees.*ex*.Steud) Hook.f.
144	Poaceae	*Phragmites karka* Trin enstend
145	Poaceae	*Aeluropus lagopoides* (L.) Trin.
146	Poaceae	*Saccharum spontaneum* L.
147	Poaceae	*Urochondra setulosa* (Trin) Hubb.
148	Poaceae	*Hemathria compressus* L.

149	Poaceae	*Apluda mutica* L.
150	Poaceae	*Eragrostis tenella* Beauv.
151	Poaceae	*Spinifex littoreus* (Burm.f.) Merr.
152	Poaceae	*Zoysia matrella* (L.) Merr.
153	Poaceae	*Sporobolus tremulus* (Willd.) Kunth.
154	Cyperaceae	*Cyperus javonicus* Houtt.
155	Cyperaceae	*C. exaltatus* Retz. var. *dives* (Del.)C.B.Clarke
156	Cyperaceae	*C. procerus* Roxb.
157	Cyperaceae	*Fimbristylis ferrugiana* (L.) Vahl.
158	Cyperaceae	*F. campanulata* Link.
159	Cyperaceae	*F. polytrichoides* Vahl.
160	Cyperaceae	*F. dichotoma* (L.) Vahl.
161	Cyperaceae	*Cyperus arenarius* Hetz.
162	Cyperaceae	*Fimbristylis cymosa* R.Br.
163	Cyperaceae	*Schoenoplectus litoralis* (Schrad.) Palla
164	Boraginaceae	*Heliotropium curassavicum* L.
Fern or Mestletoes, Semi-parasites and Epiphytes		
165	Blechnaceae	*Stenochlaena palustre* (Burm.) Bedd
166	Polypodiaceae	*Pyrrosia lanceolata* (L.) Fawell
167	Polypodiaceae	*Drynaria quercifolia* (L.) J.Smith
168	Aspleniaceae	*Asplenum nidus* L.
Other herbaceous plants		
169	Cyperaceae	*Cyperus malaccensis* Lamk.
170	Cyperaceae	*C. tegetiformis* Roxb.
171	Cyperaceae	*C. scariosus* R.Br.
172	Cyperaceae	*Eleocharis spirals* (Rottb.) Roem. & Schult.
173	Cyperaceae	*Juncellus inundatus* (Roxb.) C.B.Clarke
174	Cyperaceae	*Machaerina rubiginosa* (Spreng.) T.Koyama
175	Cyperaceae	*Mariseus javanicus* (Houtt.) Merr. *et* Metc.
176	Cyperaceae	*Pyereus polystaethos* (Rottb.) Beauv.
177	Cyperaceae	*Schoenoplectus praelongatus* (Poir) J.Rayn.
178	Cyperaceae	*S. triqueter* (L.) Palla var. *segergata* (C.B.Clarke) Karthik
179	Cyperaceae	*Scripodendron ghaeri* (Gartn.) Merr.
180	Cyperaceae	*Scleria sumatrensis* Retz.

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2.6 PROTOZOA

Protozoa literally mean the first animals. It was Goldfuss (1817) who introduced the term protozoa (in Greek, proto means first and zoon means animal) but earlier applied it to a variety of simple organisms, including unicells, sponges, cnidarians, rotifers, and bryozoans.

N. C. NANDI
Protozoologist

Later, the cellular nature of living organisms was discovered and the distinction between unicellular and multicellular organisms was clarified. Von Siebold (1845) restricted the term protozoa only to 'one-celled animals'. Protozoa can be characterized as microscopic, single-celled, eukaryotic organisms, ranging between 5 µm and 250 µm in length, that occur in all sorts of habitats and hosts, from the deepest ocean bed to the highest mountain tops and from tropical soils to Antarctic snows, and even habitats with little moisture. They represent highly heterogeneous groups of organisms and sometimes they may appear to be simple but these are the most complex cells known because all the biological and biochemical mechanisms for a complex lifestyle are contained within these single cells (Sleigh 1991). None of these single-celled animalcules, even if they lead a colonical ('polycellular') life, either joined by cytoplasmic threads or embedded in a common matrix, depend on other cells of the colony for survival. As such, all protozoa, whether unicellular or 'polycellular', are unified by the fundamental concept of single-celled organization. Protozoans may be free-living, in soil and water, and parasitic among vertebrate and invertebrate hosts.

Protozoans being diverse organisms with divergent lifestyles, morphologies, habits, and reproductive cycles, debate continues on the phylogenetic relationships among unicellular organisms and about their evolutionary relationship to multicellular plants, animals, and fungi. However, for the purpose of this study, protozoa, as a group, is considered as the subkingdom Protozoa under the kingdom Protista comprising seven phyla: Sarcomastigophora, Labyrinthomorpha, Apicomplexa, Microspora, Ascetospora, Myxozoa, and Ciliophora. This is according to the classification scheme of Levine et al. (1980) even though the phylum Myxozoa has been excluded from the kingdom Protista on both morphological and molecular phylogenetic evidences for its origin in a clade of parasitic cnidarians, as reviewed by Siddal et al. (1995).

Historically, it was Annandale (1907), the first Director of the Zoological Survey of India, Kolkata, who made the first report of two protozoan ciliate species from the brackish-water ponds of Port Canning from the Sundarbans. Pearse (1932) reported a gregarine from the intestine of an estuarine crab *Metaplax dentipes*, also from Port Canning. Afterwards, Ray and Dasgupta (1936, 1937) recorded a coccidian parasite from the intestine of the Indian cobra *Naja naja* from the Sundarbans. Tripathi (1952) reported a myxosporidian parasite, *Sphaeromyxa theraponi,* from the estuarine fish *Therapon jarbua* from Port Canning. Shetty et al. (1961) and Gopalakrishnan (1971) reported a number of free-living flagellates, rhizopods, and ciliates from the planktonic samples of the Hugli-Matla estuary. Mandal and his co-workers (1964–1984) made valuable contributions in reporting haemoflagellates and the coccidian parasites of fishes and birds of this region. Choudhury and Nandi (1973) described two new species of myxosporean parasites of the estuarine gobiid fish, *Boleophthalmus boddaerti*. Tiwari (1978) recorded five species of termite flagellates from Sagar Island. Mandal and Choudhury (1981–1988) contributed to the study on intestinal parasites and reported two species of piroplasms of wild mammals of the STR. Nandi et al. (1984) reported a few species of avian haemoproteids from Sagar Island. Ray and Sarkar (1985) recorded a new species of coccidian parasite in wild boar, *Sus scrofa*. Ghosh and Choudhury (1986, 1987) and Basu et al. (1987) isolated a few species of amoebae from the soil of Sagar Island. Jamadar and Choudhury (1988) made major contributions to the entocommensal ciliates of marine and estuarine mollusks, while Ray and Choudhury (1992–2003) made such studies from anuran hosts. Nandi et al. (1993) recorded a number of free-living protozoa from the Sundarbans and furnished a consolidated list of 104 protozoan species of the Sundarban mangrove ecosystem. Asmat (2001); Bandyopadhyay and his associates (2004–2006); Basu and Haldar (2004); Gangopadhyay and Ray (2005); Sarkar (1994–2008); and Mandal and Ray (2006–2009) described several new species of protozoan parasites belonging to different phyla. However, in this place, an updated list of protozoan species is prepared based on scattered records as well as consolidated documents available relating to different groups from various sources (Das et al. 1993; Nandi 1984; Basu 2002; Haldar et al. 2002; Nandi and his co-workers 1983–2004; Mandal 1984; and so on)

OVERVIEW

2577 SPECIES
OF PROTOZOA FROM INDIA WHICH CONSTITUTE ABOUT 8 PER CENT OF THE TOTAL 31,250 PROTOZOAN SPECIES OF THE WORLD

Taxonomically, protozoa are considered the most primitive animals in the classical classification, but in the current classification, they have been treated as more primitive than animals and hence, they are placed under the kingdom Protista.

At the global level, there are about 65,000 known species of protozoa. Of these, more than half are fossil forms and over 10,000 species are parasitic in nature. Among the living species of Protozoa in the world, Sarcomastigophora account for about 60 percent, Ciliophora 23 percent, Apicomplexa 13.75 percent, Microspora 1.75 percent, and Myxozoa 1.5 percent of the total number (Mandal et al. 1991; Das 1998).

Mandal et al. (1991) and Das (1998) estimated a total of 2,577 species of protozoa from India, which constitute about 8 per cent of the total 31,250 protozoan species of the world. A comparative estimate of living protozoan species of the world as well as from India, according to a 1993 estimate, is presented in table 1.

Table 1. Estimated number of families, genera and species reported from the world and in India (Source : Mandal et al., 1991; Das, 1998)

Group	Approximate number of					
	Family		Genera		Species	
	W	I	W	I	W	I
Phylum Sarcomastigophora						
Subphylum Mastigophora	90	28	800	60	6900	400
Subphylum Sarcodina	100	35	950	85	11300	650
Subphylum Opalinata	1	1	5	4	250	30
Phylum Ciliophora	197	70	1135	150	7200	600
Phylum Apicomplexa	71	20	330	42	4550	750
Phylum Microspora	5	2	18	4	550	20
Phylum Myxozoa	15	4	40	12	500	125
Phylum Labyrinthomorpha	1	-	2	-	0	-
Phylum Ascetospora	3	1	5	1	0	2
Total	383	161	3285	358	31250	2577

171 PROTOZOAN SPECIES ARE REPORTED FROM INDIAN SUNDARBANS

SYNOPTC VIEW

A total of 104 species have earlier been recorded from the Sund -arban mangrove ecosystem by Nandi et al. (1993). At present, a total of 171 protozoan species belonging to 86 genera that have been reported from the Indian Sundarbans are summarized in table 2 and enlisted in the annexure. These protozoan species belong to four phyla: Sarcomastigophora (62 species under 29 genera); Apicomplexa (36 species under 15 genera); Myxozoa (25 species under 12 genera); and Ciliophora (44 species under 19 genera). Out of 62 species belonging to the phylum Sarcomastigophora, 25 species represent the subphylum Mastigophora while 36 species represent the subphylum Sarcodina and one species comes under the subphylum Opalinata.

It is worth mentioning that out of seven phyla, three phyla, namely Microspora, Ascetospora, and Labyrinthomorpha, have not so far been reported from the Indian Sundarbans. Also, there is no such account of protozoan diversity from other mangrove ecosystems in India and elsewhere, including the Bangladesh Sundarbans (Macnae 1968; Das and Dev Roy 1989; Hong and Hoang 1993; Chaudhuri and Choudhury 1994; Hussain and Acharya, 1994). Among the free-living protozoan species, dinoflagellates and foramiiferans are two important groups of marine and estuarine Sarcomastigophora which have not yet been adequately explored from the Sundarban region; this is also true of the tintinnid ciliate species. Among the parasitic protozoa, gregarines, haemogregarines, and piroplasms are the least-studied group. The phylum Myxozoa, whose members are well-known fish parasites, is represented by four species only. The entocommensal ciliates of shellfish from this region are also well studied. The symbiotic protozoan species from termites were reported by Tiwari (1978), but no study of ruminant ciliates has so far been made from the wild deer population or from any domesticated ruminant mammals of the Sundarbans. A comparison of the protozoan species reported so far from the Sundarbans as well as West Bengal (Das et al. 1993a, b, c; Nandi et al. 1993) reveals the dearth of protozoa faunal investigation from the Sundarbans (see table 3). It may be mentioned here that the free-living protozoa are available in all possible aquatic and terrestrial niches where little moisture is found, while more than two protozoan parasites (including symbiotic species) on average are expected to be recovered from each invertebrate and vertebrate host species (Mandal et al. 1991; Das 1998). On this ground, it is assumed that the protozoa from the Indian Sundarbans may increase manifold if a thorough investigation is undertaken by taxonomic experts of this branch of science.

Table 2. Number of families, genera and species reported herein from Indian Sundarban

Group	Number of					
	Family		Genera		Species	
	1993	Present	1993	Present	1993	Present
Phylum Sarcomastigophora						
Subphylum Mastigophora	9	10	9	13	19	25
Subphylum Sarcodina	11	11	14	15	26	36
Subphylum Opalinata	-	1	-	1	-	1
Phylum Ciliophora	16	21	23	26	31	
Phylum Apicomplexa	6	15	7	19	24	44
Phylum Microspora	-	-	-	-	-	-
Phylum Myxozoa	2	9	3	12	4	25
Phylum Labyrinthomorpha	-	-	-	-	-	-
Phylum Ascetospora	-	-	-	-	-	-
Total	48	67	56	86	104	171

Table 3. Estimated number of genera and species reported from West Bengal (1993) and the Sundarbans (present report)

Ecological category/ Group	Estimated number of					
	Genera			Species		
	West Bengal (1993)	Sundarbans		West Bengal (1993)	Sundarbans	
		In 1993	Pre-sent		In 1993	Present
Free-living Protozoa	76	27	29	248	41	53
Parasitic Protozoa	63	15	55	596	68	123
Symbiotic Protozoa	8	2	2	127	5	5
Total	147	44	86	971	104	171

It is evident from the listed species (annexure) that the collection localities of protozoan species in several cases are not specified, for example, the Hugli-Matla estuary, mangrove forest, and so on. As such, the distribution pattern of protozoans recorded from the Indian Sundarbans could not be effectively indicated at the development block level. In fact, locality records of the species simply indicate the sites from where the collections were made by the researchers and do not reflect actual distribution pattern of protozoan diversity in the Sundarbans region. In general, many protozoan species may occur throughout the Sundarbans if they are not ecologically restricted by habitat and host.

A perusal of available data reveals that several species of protozoa are well-known as the causative agents of dreadful diseases of man and domestic animals of the Sundarbans, such as malaria, kala-azar, amoebiasis, giardiasis, and coccidiosis. In the human intestine, for instance, a few species of amoebae are found, of which only one, *Entamoeba histolytica*, is a widely prevalent parasitic species causing amoebic dysentery in man while others are harmless to the human they inhabit, living on bacteria and food fragments. Such a relationship is known as commensalism. Mandal and Choudhury (1982–1988) reported a considerable number of parasitic protozoans comprising intestinal flagellates, coccidians, and amoebae, including *Entamoeba* infection of cervid animals in the STR. Sarkar (1994–2008) recorded several myxosporean infections in estuarine and marine fishes. Myxosporean parasites have been known to cause the disease 'myxosporidiosis' and the death of fishes by infecting vital organs like the gills, brain, heart, and skeletal system (Kalavati and Nandi 2007). Jamadar and Choudhury (1988) observed a number of ciliated protozoa inhabiting marine and estuarine gastropods and bivalves.

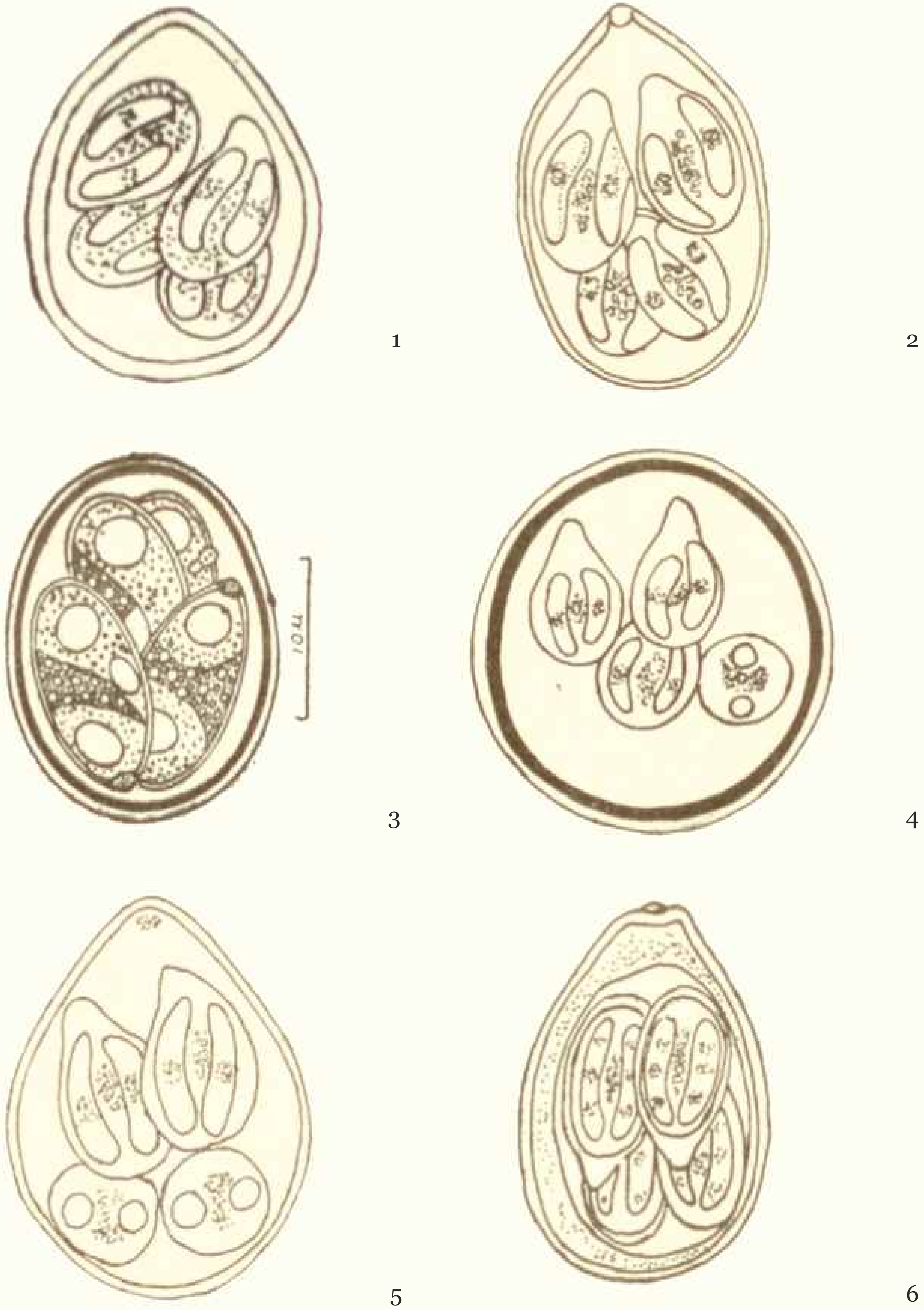
In India as well as at the global level, despite reports of the disease being caused by protozoan species, studies dealing with pathology in fishes, shellfish, and wild animals are very few and fragmented. Though the exact nature of many of these protozoan parasites of man and his domesticated animals as well as from fishes and shellfish are not known, it is felt that their prevalence and pathogenecity need to be understood to prevent and control disease and/or for management purposes. However, there are a large number of beneficial protozoa that form an important component of zooplankton, and their skeletons (tests and lorica) may contribute to calcium and chalk deposits.

Further research can be directed initially toward investigation and documentation of protozoans, especially estuarine and marine protozoans of the Sundarban coast to determine their role in the ecosystems as well as the production potentials of testacids and foraminiferans occurring in this region. Besides these, protozoan diseases of wild animals and fishes need to be thoroughly investigated for overall growth, production, and management of commercially important species in addition to wildlife.

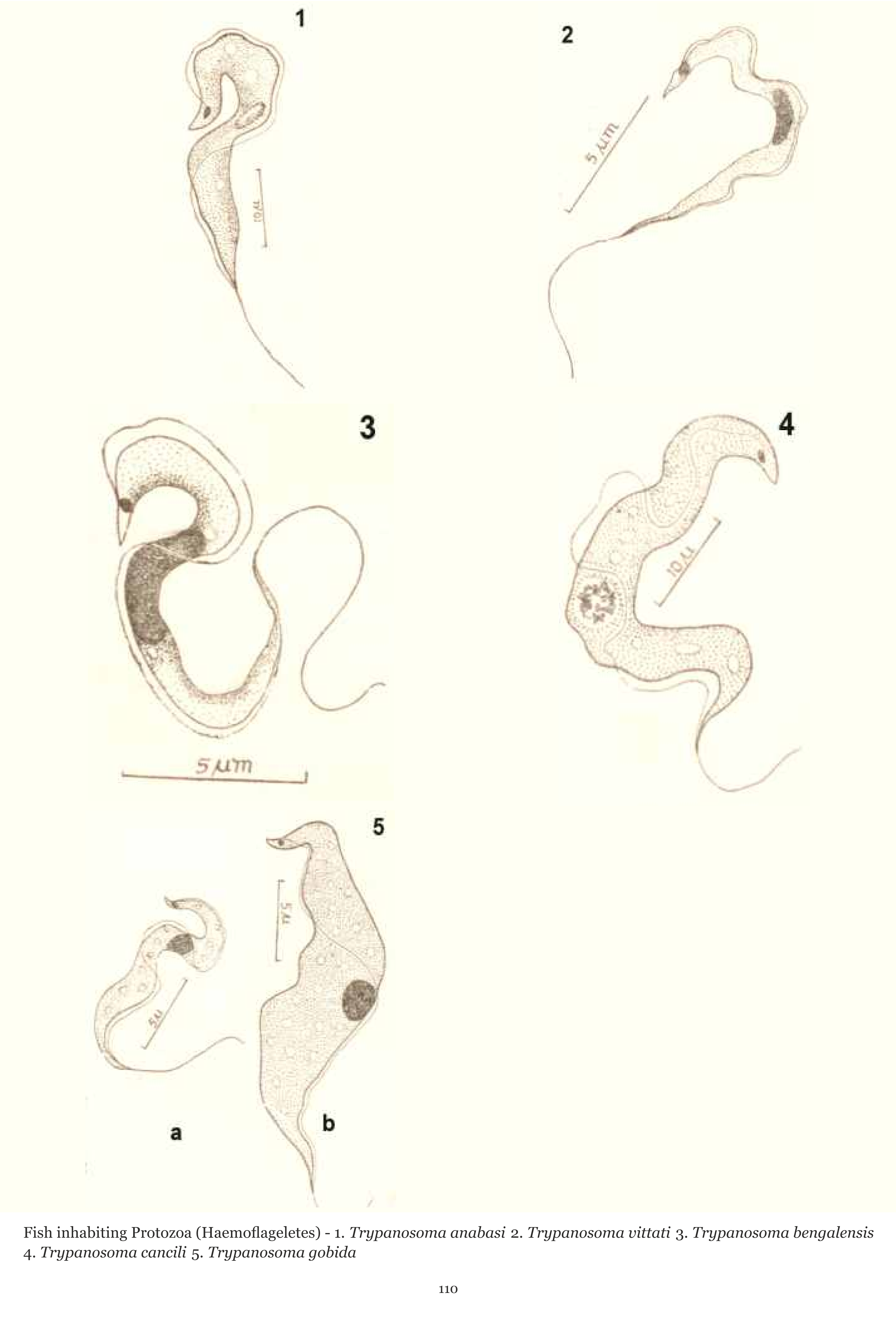
STATUS AND THREATS

However, so far no protozoan species has been recognized as threatened or endangered species per se and none of the species of protozoa occurring in freshwater, marine, estuarine, or terrestrial ecosystems of the Sundarbans could be ascertained as keystone species. Thus, no specific conservation measure for protozoan species is suggested. However, strategies adopted for conservation of ecosystems as well as macro-invertebrates and particularly vertebrates will ensure the conservation of protozoan species in the Sundarbans. In fact, protozoan species will be conserved if their habitats and hosts are conserved.

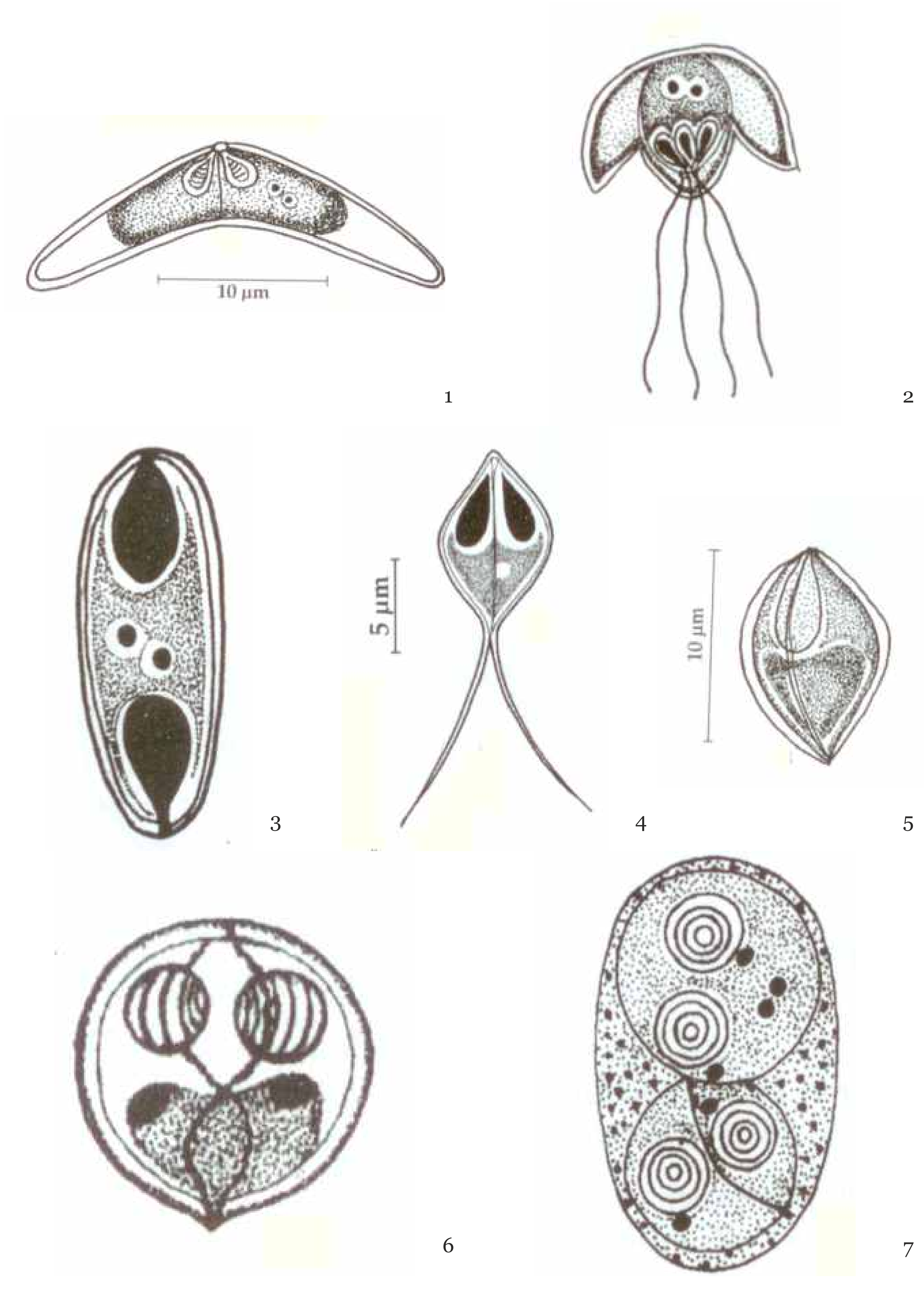
PLATES



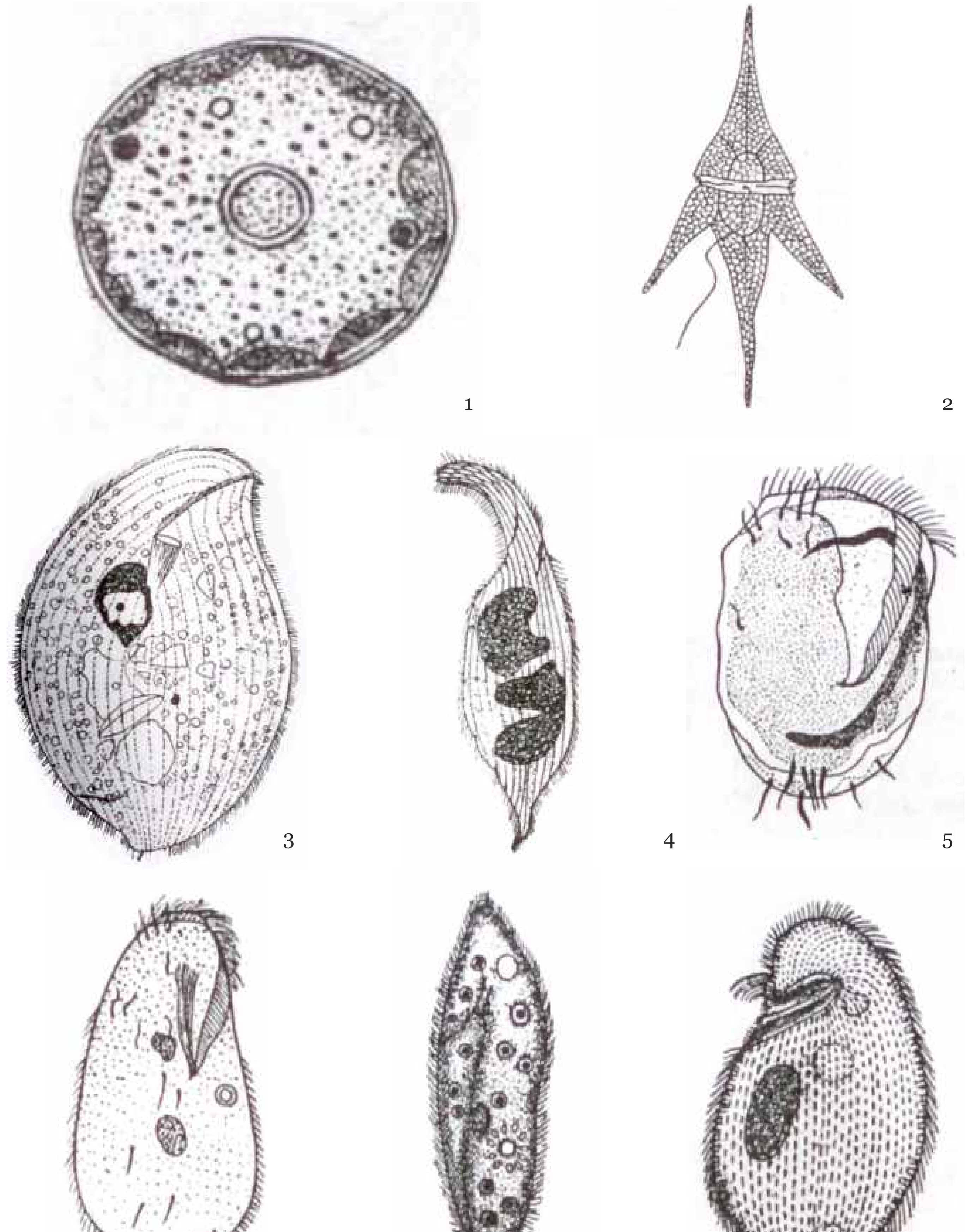
Coccidian parasites of wild animals - 1. *Eimeria charadrii* 2. *Eimeria gallinagoi* 3. *Eimeria neodebliecki* 4. *Eimeria numeni* 5. *Eimeria rocoviensis pluviana* 6. *Eimeria vanelli*



Fish inhabiting Protozoa (Haemoflageletes) - 1. *Trypanosoma anabasi* 2. *Trypanosoma vittati* 3. *Trypanosoma bengalensis* 4. *Trypanosoma cancili* 5. *Trypanosoma gobida*



Fish inhabiting Protozoa (Myxosporea) - 1. *Ceratomyxa syanoglossi* 2. *Kudoa haridasae* 3. *Myxidium lepidocephalicthysum* 4. *Myxobilatus anguillaris* 5. *Myxobolus parsi* 6. *Sinuolinea indica* 7. *Zachokkela cascasiensis*



Freeliving Protozoa - 1. *Arcella vulgaris* 2. *Ceratium hirudonella* 3. *Chirodonella cuculus* 4. *Dileptus americanus* 5. *Euplotes patella* 6. *Oxytricha fallax* 7. *Paramecium caudatum* 8. *Plagiopyla nausuta*

ANNEXURE

List of protozoan species so far recorded from Indian Sundarbans

Sl. No.	Classified list of species	Habitat/ Host	Locality
	Kingdom PROTISTA		
	Subkingdom PROTOZOA		
	Phylum SARCOMASTIGOPHORA		
	Subphylum MASTIGOPHORA		
	Class PHYTOMASTIGOPHOREA		
	Order DINOFLAGELLIDA		
	Family NOTILUCIDAE		
	Genus ***Notiluca*** Suriray		
1.	*N. miliaris* Suriray	Estuarine/ coastal waters	Hugli-Matla estuary
	Family PERIDINIDAE		
	Genus ***Peridinium*** Ehrenberg		
2.	*P.* sp.	Estuarine waters	Hugli-Matla estuary
	Genus ***Ceratium*** Schrank		
3.	*C. hirudinella* Müller	Estuarine waters	Hugli-Matla estuary
4.	*C. tripos* Nitzsch	Estuarine waters	Hugli-Matla estuary
	Order EUGLENIDA		
	Family EUGLENIDAE		
	Genus ***Euglena*** Ehrenberg		
5.	*E.* sp.	Estuarine waters	Hugli estuary
	Genus ***Phacus*** Dujardin		
6.	*P.* sp.	Estuarine waters	Hugli-Matla estuary
	Family ASTASIIDAE		
	Genus ***Copromonas*** Dobell		
7.	*C. ruminantum* Woodcock	*Sus scrofa*	Bhagabatpur
	Class ZOOMASTIGOPHOREA		
	Order KINETOPLASTIDA		
	Family TRYPANOSOMATIDAE		
	Genus ***Leishmania*** Ross, 1903		
8.	*L. donovani* (Laveran and Mesnil, 1903)	*Homo sapiens*	Sundarbans
	Genus ***Trypanosoma*** Gruby, 1843		
9.	*T. anabasi* Mandal, 1978	*Anabas testudineus*	Canning
10.	*T. bengalensis* Mandal, 1979	*Mystus bleekeri*	Canning
11.	*T. cancili* Mandal, 1978	*Xenentodon cancila*	Raidighi
12.	*T. gobida* Mandal, 1990	*Glossogobius giuris*	Canning

Sl. No.	Classified list of species	Habitat/ Host	Locality
13.	*T. striati* Qadri, 1955	*Channa striatus*	Canning
14.	*T. vittati* Tandon and Joshi, 1973	*Mystus vittatus*	Taldi
15.	*T. avium* Danilewsky, 1885	*Acrocephalus dume-torum*	Sagar Island
	Order DIPLOMONADIDA		
	Family HEXAMITIDAE		
	Genus ***Giardia*** Kuntsler, 1882		
16.	*G. intestinalis* (Lambl, 1859)	*Homo sapiens*	Sundarbans
	Order TRICHOMONADIDA		
	Family MONOCERCOMONADIDAE		
	Genus ***Monocercomonas*** Grassi		
17.	*M. ruminantium* (Braune)	*Axis axis*	Sundarbans forest
	Family TRICHOMONADIDAE		
	Genus ***Trichomonas*** Donne, 1836		
18.	*T. vaginalis* Donne, 1836	*Homo sapiens*	Sundarbans
	Genus ***Tetratrichomonas*** Parlsi		
19.	*T. butteryi* (Hibler *et al*., 1960)	*Sus scrofa*	Sundarbans
	Order HYPERMASTIGIDA		
	Family HOLOMASTIGOTOIDAE		
	Genus ***Holomastigotoides*** Grassi and Foa, 1911		
20.	*H. bengalensis* Chakravarty and Banerjee, 1956	*Coptotermes heimi*	Sagar Island
21.	*H. hartmanni* Koidznmi, 1921	*Coptotermes heimi*	Sagar Island
22.	*H. ogivalis* de Mello, 1937	*Heterotermes indicola*	Sagar Island
	Family SPIROTRICHONYMPHIDAE		
23.	Genus ***Pseudotrichonympha*** Grassi and Foa		
24.	*P. cordiformis* Karandikar and Vittal, 1954	*Heterotermes indicola*	Sagar Island
25.	*P. subapicalis* Karandikar and Vittal, 1954	*Coptotermes heimi*	Sagar Island
	Subphylum OPALINATA		
	Class OPALINATEA		
	Order OPALINIDA		
	Family OPALINIDAE		
	Genus **Cepedia** Metcalf, 1920		
26.	*C. sundarbanensis* Gangopadhyay and Ray, 2005	*Rana limnocharis limnocharis*	Sundarbans
	Subphylum SARCODINA		
	Class LOBOSEA		
	Subclass GYMNAMOEBIA		

Sl. No.	Classified list of species	Habitat/ Host	Locality
	Order AMOEBIDA		
	Suborder TUBULINA		
	Family ENDAMOEBIDAE		
	Genus ***Entamoeba*** Cassagrandi and Barbagallo, 1895		
27.	*E. cervis* Mandal and Choudhury, 1981	*Axis axis*	STR
		Macaca mulatta	STR
28.	*E. chattoni* Swellengrebal, 1914	*Macaca mulatta*	Sundarbans forest
29.	*E. chiropteris* Mandal and Choudhury, 1980	*Scotophilus kuhli kuhli*	STR and Sajnakhali
30.	*E. coli* (Grassi, 1879)	*Macaca mulatta*	STR
31.	*E. histolytica* Schaudinn, 1903	*Macaca mulatta*	Sundarbans forest
		Homo sapiens	Sundarbans
32.	*E. muris* (Grassi, 1879)	*Rattus rattus arboreus*	STR
33.	*E. suis* Hartman, 1931	*Sus scrofa*	STR
	Genus ***Dientamoeba*** Jepps and Dobell, 1918		
34.	*D. fragilis* Jepps and Dobell, 1918		
	Genus ***Iodomoeba*** Dobell		
35.	*I. butschlii* (Prowazek, 1912)	*Macaca mulatta*	Sundarbans forest
	Suborder THECINA		
	Family THECAMOEBIDAE		
	Genus ***Thecamoeba*** Formental		
36.	*T.* sp.	Mangrove soil	Mangrove forest
	Genus ***Platymoeba*** Page		
37.	*P.* sp.	Mangrove soil	Mangrove forest
	Genus ***Vanella*** Bovee		
38.	*V.* sp.	Mangrove soil	Mangrove forest
	Suborder FLABELLINA		
	Family FLABELLULIDAE		
	Genus ***Flabellula*** Schaefer		
39.	*F.* sp.	Mangrove soil	Mangrove forest
	Suborder CONOPODINA		
	Family PARAMOEBIDAE		
	Genus ***Mayorella*** Schaeffer		
40.	*M.* sp.	Mangrove soil	Mangrove forest
	Suborder ACANTHOPODINA		
	Family ACANTHAMOEBIDAE		
	Genus ***Acanthamoeba*** Volkonsky		

Sl. No.	Classified list of species	Habitat/ Host	Locality
41.	*A. astronyxis* (Ray and Hayes, 1954)	Intertidal soil	Sagar Island
42.	*A. culberstoni* (Singh and Das, 1970)	Intertidal soil	Sagar Island, Kakdwip
43.	*A. palestinensis* (Reich, 1933)	Intertidal soil	Sagar Island
44.	*A. rhysodes* (Singh, 1952)	Intertidal soil	Sagar Island
45.	*A.* sp.	Mangrove soil	Mangrove forest
	Order SCHIZOPYRENIDA		
	Family VAHLKAMPFIIDAE		
	Genus ***Naegleria*** Alexieff		
46.	*N. thortoni* (Singh, 1952)	Grassy field soil	Sagar Island
	Subclass TESTACEALOBOSIA		
	Order ARCELLINIDA		
	Family ARCELLIDAE		
	Genus ***Arcella*** Ehrenberg, 1832		
47.	*A. vulgaris* Ehrenberg, 1832	Freshwaters	Lakshmikantapur
48.	*A.* sp.	Estuarine waters	Hugli-Matla estuary
	Genus ***Diplochlamys*** Greef		
49.	*D. leidyi* Greef	Freshwaters	Gocharan
	Genus ***Pyxidicola*** Ehrenberg		
50.	*P. operculata* Agardh	Freshwaters	Gocharan
	Family DIFFLUGIDAE		
	Genus ***Centropyxis*** Stein, 1859		
51.	*C. aerophila* Deflandre, 1929	Moss inhabiting	Gocharan
52.	*C. ecornis* (Ehrenberg, 1843)	Freshwaters	Lakshmikantapur
53.	*C.* sp.	Estuarine waters	Hugli-Matla estuary
	Genus ***Cucurbitella*** Penard		
54.	*C. mespiliformis* Penard	Freshwaters	Chandkhali (Taldi)
	Genus ***Difflugia*** Leclerc		
55.	*D. globulus* (Ehrenberg)	Freshwaters	Gocharan
	Genus ***Heliopera*** Leidy		
56.	*H. sylvatica* Penard, 1909	Tree mosses mixed with lichens	Gocharan
	Class FILOSEA		
	Order GROMIIDA		
	Family EUGLYPHIDAE		
	Genus ***Paraeuglypha*** Penard		
57.	*P. indica* Nair and Mukherjee, 1968	Freshwaters	Lakshmikantapur

Sl. No.	Classified list of species	Habitat/ Host	Locality
	Genus ***Placocista*** Leidy		
58.	*P. lens* Penard, 1902	Freshwaters	Lakshmikantapur
	Class GRANULORETICULOSEA		
	Order FORAMINIFERIDA		
	Suborder ROTALINA		
	Family CALCARINIDAE		
	Genus ***Calcarina*** d' Orbigny		
59.	*C. calcar* Parkar and Jones	Estuarine waters	Sundarbans
60.	*C.* sp.	Estuarine waters	Sundarbans
	Suborder MILIOLINA		
	Family MILIOLIDAE		
	Genus ***Quinqueloculina*** d' Orbigny		
61.	*Q.* sp.	Estuarine waters	Sundarbans
	Suborder ROTALIINA		
	Family NONIONIDAE		
	Genus **Elphidium** Montfort		
62.	*E.* sp.	Estuarine waters	Sundarbans
	Phylum APICOMPLEXA		
	Class SPOROZOEA		
	Subclass GREGARINIA		
	Order EUGREGARINIDA		
	Suborder ASEPTATINA		
	Family MONOCYSTIDAE		
	Nematocystis Hesse, 1909		
63.	*N. indicus* Bandyopadhyay *et al.*, 2006	*Perionyx excavatus*	Sandeshkhali
	Family ZYGOCYSTIDAE		
	Genus ***Zygocystis*** Stein, 1848		
64.	*Z. levinei* Bandyopadhyay and Mitra, 2004	*Amynthas nicholsoni*	Gosaba
65.	*Z. perionyxae* Bandyopadhyay and Mitra, 2005	*Perionyx gravelleyi*	Canning
	Suborder SEPTATINA		
	Family CEPHALOIDOPHORIDAE		
	Genus ***Cephaloidophora*** Mawrodiadi		
66.	*C. metaplaxi* (Pearse, 1933)	*Metaplax dentipes*	Port Canning
	Family GREGARINIDAE		
	Genus ***Gregarina*** Dufour, 1866		

Sl. No.	Classified list of species	Habitat/ Host	Locality
67.	*G. basantii* Mandal and Ray, 2007	*Periplaneta americana*	Basanti
68.	*G.* sp.	*Menochilus sexamaculatus*	Sagar Islands
	Genus ***Retractocephalus*** Haldar and Chakraborty, 1976		
69.	*R.* sp.	*Aulacophora foveicollis*	Sagar Islands
	Family HIRMOCYSTIDAE		
	Genus ***Hirmocystis*** Laabe, 1899		
70.	*H. oxyae* Mandal and Ray, 2007	*Oxya fuscivittata*	Basanti
71.	*H. psyllae* Mandal and Ray, 2008	*Psylla* sp.	Basanti
	Family NEOHIRMOCYSTIDAE		
	Genus ***Neohirmocystis*** Ghose *et al.,* 1986		
72.	*N. trogodermae* Mandal and Ray, 2009	*Trogoderma granarium*	Canning II
	Family MONODUCTIDAE		
	Genus ***Phlaeobum*** Haldar and Chakravarty, 1976		
73.	*P.* sp.	*Atractomorpha crenulata*	Sagar Islands
	Family ACTINOCEPHALIDAE		
	Genus ***Quadruspinospora*** Sarkar and Chakravarty, 1969		
74.	*Q.* sp.	*Oxya hyla hyla*	Sagar Islands
	Genus ***Odonaticola*** Sarkar and Haldar, 1981		
75.	***O.*** sp.	*Neurothemis t. tulia*	Sagar Islands
	Family GIGADUCTIDAE		
	Genus ***Gigaductus*** trawley, 1903		
76.	*G.* sp.	*Euconocephalus incertus*	Sagar Islands
	Subclass COCCIDIA		
	Order EUCOCCIDIIDA		
	Suborder ADELINA		
	Family HAEMOGREGARINIDAE		
	Genus ***Haemogregarina*** Danilewsky, 1885		
77.	*H. colisa* Mandal *et. al.* 1984	*Colisa fasciatus*	Sagar Island, Canning
	Suborder EIMERIINA		
	Family EIMERIIDAE		
	Genus ***Eimeria*** Schneider, 1875		

Sl. No.	Classified list of species	Habitat/ Host	Locality
78.	*E. harpodoni* Setna and Bana, 1935	*Harpodon nehereus*	Port Canning
79.	*E. southwelli* Halwani, 1930	*Scoliodon sorrakowah*	Sundarbans
80.	*E. zygaenae* Mandal and Chakravarty, 1965	*Zygaena blochii*	Sundarbans
81.	*E. najae* Ray and Dasgupta, 1937	*Naja naja*	Sundarbans
82.	*E. charadrii* Mandal, 1965	*Charadrius asiaticua*	Narayantal
83.	*E. gallinagoi* Mandal, 1965	*Gallinago gallinago*	Basani
84.	*E. numeni* Mandal, 1965	*Numenis arquata*	Basanti, Namkhana
85.	*E. roscoviensis pluviana* Mandal, 1965	*Pluvialis appricaria*	Namkhana
86.	*E. vanelli* Mandal, 1965	*Vanellus malabaricus*	Basanti
87.	*E. ashata* Honess, 1942	*Capra hircus*	Basanti
88.	*E. arloingi* (Marotel, 1905)	*Capra hircus*	Basanti
89.	*E. cervis* Mandal and Choudhury, 1982	*Axis axis*	STR
90.	*E. neodeblicki* Vetterling, 1965	*Sus scrofa*	Sundarbans forest
91.	*E. sundarbanensis* Bandyopadhyay, 2004	*Capra hircus*	Sundarbans
	Genus ***Isospora*** Schneider, 1881		
92.	*I. emberizae* Mandal and Chakravarty, 1964	*Emberiza bruniceps*	Sundarbans
93.	*I. sundarbanensis* Ray and Sarkar, 1985	*Sus scrofa*	Sajnakhali
	Suborder HAEMOSPORINA		
	Faimily PLASMODIDAE		
	Genus ***Plasmodium*** Marchiafava and Celli,		
94.	*P. falciparum* (Welch, 1897)	*Homo sapiens*	Sundarbans
95.	*P. malariae* (Grassi and Feletti, 1892)	*Homo sapiens*	Sundarbans
96.	*P. vivax* (Grassi and Feletti, 1890)	*Homo sapiens*	Sundarbans
	Family HAEMOPROTEIDAE		
	Genus ***Haemoproteus*** Kruse, 1890		
97.	*H. columbae* Kruse, 1890	*Columba livia inter-media*	Kakdwip
98.	*H. oryzivorae* Anschutz., 1909	*Turdoides striatus*	Sagar Island
99.	*H. pastoris* de Mello, 1935	*Sturnus malabaricus*	Sagar Island
100.	*H.* sp.	*Acrocephalus dume-torum*	Sagar Island
	Subclass PIROPLASMIA		
	Order PIROPLASMIDA		
	Family BABESIIDAE		
	Genus ***Babesia*** Starcovici, 1893		
101.	*B. muris* (Fantham, 1906)	*Rattus rattus arboreus*	STR
102.	*B. vesperuginis* (Dionisi, 1899)	*Scotophilus kuhli kuhli*	STR
	Family HAEMOHORMIDAE		

Sl. No.	Classified list of species	Habitat/ Host	Locality
	Genus ***Haemohormidium*** Henry		
103.	*H.* sp.	*Muraenesox* sp.	Canning market
	Family DACTYLOSOMIDAE		
	Genus ***Dactylosoma*** Laabe		
104.	*D.* sp.	*Mystus vittatus*	Taldi
	Phylum MYXOZOA		
	Class MYXOSPOREA		
	Order BIVALVULIDA		
	Suborder SPHAEROMYXINA		
	Family SPHAEROMYXIDAE		
	Genus ***Sphaeromya*** Thelohan, 1892		
105.	*S. theraponi* Tripathi, 1952	*Therapon jarbua*	Port Canning
	Genus **Zschokkela** Auerbach, 1910		
106.	*Z. cascasiensis* Sarkar, 1995	*Sicamugil cascasia*	Bhery fishery
107.	*Z. pseudosciaena* Sarkar, 1996	*Pseudosciaena coibor*	Hugli esuary
	SUBORDER VARIISPORINA		
	Family MYXIDIIDAE		
	Genus ***Myxdium*** Butschli, 1881		
108.	*M. boddaerti* Choudhury and Nandi, 1973	*Boleophthalmus boddaerti*	Port Canning, Kakdwip
109.	*M. lepidocephalicthysum* Sarkar and Raychaudhury, 1997	*Lepidocephalicthys thermalis*	Canning
110.	*M. lieberkuhni* Butschli, 1881	*Boleophthalmus boddaerti*	Port Canning, Kakdwip
	Family SINUOLINEIDAE		
	Genus ***Sinuolinea*** Davis, 1917		
111.	*S. indica* Sarkar, 1997	*Pseudosciaena coibor*	Hugli estuary
	Genus ***Myxoproteus*** Doflein, 1898		
112.	*M. cujaeus* Sarkar, 1996	*Macrospinosa cuja*	Hugli estuary
	Family CERATOMYXIDAE		
	Genus ***Ceratomyxa*** Thelohan, 1892		
113.	*C. cyanoglossi* Das, Pal and Ghosh, 1988	*Cyanoglossus lingua*	Jambu Island, Kakdwip
114.	*C. daysciaenae* Sarkar and Pramanik, 1994	*Daysciaena albida*	Hugli estuary
115.	*C. sagarica* Choudhury and Nandi, 1973	*Boleophthalmus boddaerti*	Port Canning
116.	*C. tenulosae* Sarkar and Pramanik, 1994	*Tenulosa toli*	Hugli estuary (Kakdwip)
	Family SPHAEROSPORIDAE		

Sl. No.	Classified list of species	Habitat/ Host	Locality
	Genus ***Sphaerospora*** Thelohan, 1892		
117.	*S. corsulae* Sarkar and Ghosh, 1991	*Rhinomugil corsula*	Hugli estuary
	Genus ***Myxobilatus*** Davis, 1944		
118.	*M. anguillaris* Basu and Haldar, 2003	*Taenioides anguillaris*	Canning
119.	*M. odontamblyopusi* Basu and Haldar, 2004	*Odontamlyopus rubi-cundus*	Canning
120.	*M.* sp.	*Taenioides cirratus*	Canning
	Family PARVICAPSULIDAE		
	Genus ***Neoparvicapsula*** Gavaeskaya *et al*., 1982		
121.	*N. monolata* Sarkar, 1999	*Microspinosa cuja*	South 24-Parganas
	Suborder PLATYSPORINA		
	Family MYXOBOLIDAE		
	Genus ***Myxobolus*** Butschli, 1882		
122.	*M. bankimi* Sarkar, 1999	*Sicamugil cascasia*	South 24-Parganas
123.	*M. labeosus* Sarkar, 1995	*Labeo fimbriatus*	Bheri fishery
124.	*M. parsi* Das, 1996	*Liza parsia*	Kakdwip
	Order MULTIVALVULIDA		
	Family TRILOSPORIDAE		
	Genus ***Unicapsula*** Davis, 1924		
125.	*U. maxima* Sarkar, 1999	*Pseudosciaena coibar*	South 24-Parganas
	Family KUDOIDAE		
	Genus ***Kudoa*** Meglitsch, 1947		
126.	*K. cascasia* Sarkar and Raychaudhury, 1996	*Sicamugil cascasia*	Hugli estuary
127.	*K. coibari* Sarkar, 1999	*Pseudosciaena coibar*	South 24-Parganas
128.	*K. haridasae* Sarkar and Ghosh, 1991	*Mugil parsia*	Hugli estuary
129.	*K. sagarica* Das, 1996	*Liza parsia*	Sagar Island
	Phylum CILIOPHORA		
	Class KINETOFRAGMINIPHOREA		
	Subclass GYMNOSTOMATIA		
	Order PROSTOMATIDA		
	Suborder PRORODONTINA		
	Family PRORODONTIDAE		
	Genus ***Pseudoprorodon*** Blochman		
130.	*P. lieberkuhni* Butschli, 1889	Freshwater pond	Lakshmikantapur

Sl. No.	Classified list of species	Habitat/ Host	Locality
	Suborder HAPTORINA		
	Family TRACHELIIDAE		
	Genus ***Dileptus*** Dujardin		
131.	*D. americanus* Kahl	Alga-mud scum	Rajat Jubilee
	Order PLEUROSTOMATIDA		
	Family AMPHILEPTIDAE		
	Genus ***Loxophyllum*** Dujardin		
132.	*Loxophyllum levgatum* Sauerbey, 1928	Freshwater	Lakshmikantapur
	Subclass VESTIBULIFERIA		
	Order TRICHOSTOMATIDA		
	SuborderTRICHOSTOMATINA		
	Family PLAGIOPYLIDAE		
	Genus ***Plagiopyla*** Stein		
133.	*P. nasuta* Stein	Freshwater pond algal mass and floating fun-gal mass	Kalas and Datta river respectively
	Family BALANTIDIIDAE		
	Genus ***Balantidium*** Claparede and Lachmann		
134.	*B. coli* (Malmsten, 1857)	*Sus scrofa*	Sundarbans forest
135.	*B.* sp.	*Sus scrofa*	Sundarbans forest
	Subclass HYPOSTOMATIA		
	Superorder NASULIDEA		
	Order NASULIDA		
	Suborder MICROTHORACINA		
	Family MICROTHORACIDAE		
	Genus ***Drepanomonas*** Fresenius		
136.	*D. revoluta* Penard	Mud scum	Gosaba
	Superorder PHYLLOPHARYNGIDEA		
	Order CYRTOPHORIDA		
	Suborder CHLAMYDODONTINA		
	Family CHLAMYDOMONIDAE		
	Genus ***Chlamydomonas*** Eherenberg		
137.	*C. mnenosyne* Ehrenberg	Floating fungal mass and mud scum	Datta river and Gosaba respectively
	Family CHLODONELLIDAE		
	Genus ***Chilodonella*** Strand, 1926		
138.	*C. cucullus* (Muller, 1883)	Freshwater pond algal mass and mud scum	Kalas and Gosaba respec-tively

Sl. No.	Classified list of species	Habitat/ Host	Locality
	Superorder RHYNCHODEA		
	Order RHYCHODIDA		
	Family ANCISTROCOMIDAE		
	Genus ***Ancistrocoma*** Chatton and Lwoff, 1926		
139.	*A. pelseneeri* Chatton and Lwoff, 1926	*Mactra luzonica*	Hugli estuary
	Genus ***Raabella*** Chatton and Lwoff, 1950		
140.	*R. helensis* Chatton and Lwoff, 1950	*Modiolus striatulus*	Hugli estuary
	Class OLIGOHYMENOPHOREA		
	Subclass HYMENOSTOMATIA		
	Order HYMENOSTOMATIDA		
	Suborder PENICULINA		
	Family PARAMECIIDAE		
	Genus ***Paramecium*** Hill		
141.	*P. caudatum* Ehrenberg, 1833	Freshwater pond algal mass	Kalas
	Family FRONTONIIDAE		
	Genus ***Frontonia*** Ehrenberg		
142.	*F. leucus* (Ehrenberg, 1838)	Mud scum	Gosaba
	Order SCUTICOCILIATIDA		
	Suborder PLEURONEMATINA		
	Family CYCLIDIIDAE		
	Incertae sedis		
	Genus ***Cristigera*** Roux, 1901		
143.	*C. susmai* Jamadar and Choudhury, 1988	*Crossotrea cucullata*	Sagar Island
	Suborder THIGMOTRICHINA		
	Family ANCISTRIDAE		
	Genus ***Ancistrumina*** Raabe, 1959		
144.	*A. barbata* (Issel, 1903)	*Cerithidea obtusa*	Sagar Island
145.	*A. obtusae* Jamadar and Choudhury, 1988	*Cerithidea obtusa*	Sagar Island
	Genus ***Boveria*** Stevenws, 1901		
146.	*B. teredinidi* Nelson, 1923	*Mactra luzonica*	Hugli estuary
	Genus ***Fenchelia*** Raabe, 1970		
147.	*F. kapili* Jamadar and Choudhury, 1988	*Cerithidea obtusa*	Sagar Island
148.	*F. sagarica* Jamadar and Choudhury, 1988	*Cerithidea obtusa*	Sagar Island
	Genus ***Protophrya*** Kofoid, 1903		
149.	*P. indica* Jamadar and Choudhury, 1988	*Littorina melanostoma*	Sagar Island
	Subclass PERITRICHIA		

Sl. No.	Classified list of species	Habitat/ Host	Locality
	Order PERITRICHIDA		
	Suborder SESSILINA		
	Family VORTICELLIDAE		
	Genus ***Carchesium*** Ehrenberg		
150.	*C. polypinum* (Linnaeus, 1767)	Brackishwater and freshwater ponds	Port Canning
151.	*C.* sp.	*Liza parsia*	Kakdwip
	Genus ***Vorticella*** Linnaeus		
152..	*V.* sp.	Estuarine waters	Matla estuary
	Genus ***Zoothamnium*** Bory, 1826		
153.	*Z.* sp.	Mud scum	Rajat Jubilee
	Family SCYPHIDIDAE		
	Genus ***Scyphidia*** Dujardin, 1841		
154.	*S. bengalensis* Jamadar and Choudhury, 1988	*Cerithidea cingulata*	Sagar Island
155.	*S. ubiquita* Horshfield, 1969	*Littorina scabra* *L. melanostoma*	Sagar Island Sagar Island
	Suborder MOBILINA		
	Family TRICHODINIDAE		
	Genus ***Trichodina*** Ehrenberg, 1838		
156.	*T. canningensis* Asmat, 2001	*Mystus gulio*	Matla river, Port Canning
157.	T. japonica	*Lates calcarifer*	Canning
158.	*T. mukundai* Ray and Choudhury, 2003	*Bufo melanostictus*	Nalgora
159.	*T. mystusi* Asmat and Haldar, 1998	*Mystus Gulio*	Matla river
	Tripartiella Sramenk-Husek		
160.	Tripartiella copiosa	*Mystus vittatus*	Canning
	Class POLYHYMENOPHOREA		
	Subclass SPIROTRICHIA		
	Order HETEROTRICHIDA		
	Suborder COLIPHORINA		
	Genus ***Folliculina*** Lamarck		
161.	*F. ampula* (Muller)	Brackishwater pond	Port Canning
	Suborder CLEVELANDELLINA		
	Family NYCTOTHERIDAE		
	Genus ***Nyctotheroides*** Grasse, 1928		
162.	*N. kaloulae* Ray and Choudhury, 1992	*Kaloula pulohra*	Nalgora
163.	*N. ornatae* Ray and Choudhury, 2002	*Rana limnocharis* *Rhacophorus maculatus*	Nalgora Nalgora

Sl. No.	Classified list of species	Habitat/ Host	Locality
164.	*N. sundarbanensis* Ray and Choudhury, 1992	*Rana cyanophlyctis*	Nalgora
	Order OLIGOTRICHIDA		
	Suborder OLIGOTRICHINA		
	Family STROBILIDIIDAE		
	Genus ***Strobilidium*** Schewiakoff		
165.	*S. gyrans* Stokes, 1887	Freshwaters	Chandkhali (Taldi)
	Suborder TINTINNINA		
	Family TINTINNIDIIDAE		
	Genus ***Tintinnidium*** Stein		
166.	T. sp.	Estuarine waters	Hugli-Matla estuary
	Order HYPOTRICHIDA		
	Suborder SPORADOTRICHINA		
	Famly OXYTRICHIDAE		
	Genus ***Oxytricha*** Bory		
167.	*O. fallax* Stein, 1859	Mangrove fungal mass (culture) Freshwater algal mass	Datta river Kalas
	Family EUPLOTIDAE		
	Genus ***Euplotes*** Ehrenberg		
168.	*E. gracilis* Kahl, 1932	Mangrove mud scum	Gosaba
169.	*E. patella* (Muller, 1786)	Freshwater pond	Datta river
170.	*E.* sp.	Freshwater pond Mangrove fungal mass Mud scum	Kalas Rajat jubilee Gosaba
	Genus ***Diophrys*** Dujardin		
171.	*D. appendiculata* (Ehrenberg)	Fungal mass	Rajat Jubilee

Source : Nandi et al. (1993), Das et al. (1993), Asmat (2001), Basu (2002), Haldar et al. (2002), Mitra and Haldar (2004), Mitra and Bandyopadhyay (2005), Bandyopadhyay and his associates (2004-2006), Basu and Haldar (2004), Gangopadhyay and Ray (2005), Sarkar (1994-2008) and Mandal and Ray (2006-2009) Nandi and Das (2010).

Abbreviation : STR = Sundarban Tiger Reserve.

Note : The list of species is prepared based on literature consulted from West Bengal State Fauna Series volume 3 (part 12) by Das et al. (1993) and also from Nandi et al. (1993) as well as consulting researchers, internet and other relevant literatures on the subject. Still, there are possibilities of omissions in consulting relevant records as a number of related references could not be specifically recognized as originating from Sundarban region based on their titles. Such omissions would be incorporated and updated as and when pointed out by researchers in this field of science.

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2.7 MOLLUSCA

Molluscs are the largest group in the animal kingdom after insects, are highly adaptive, and occupy all possible habitats except aerial. Originally marine, they have spread into freshwater and from there into the land, where they now are almost equal to the marine forms in species number. Primarily inhabitants of the intertidal and littoral zones of the ocean, molluscs descend to great depths.

ANIRUDHA DEY
Malacologist

Molluscs are structurally a heterogeneous group of organisms, which are popularly known as shells or by different names such as snails, slugs, mussels, oysters, clam, cuttle fishes, octopuses, and squids. They are a highly diversified group of animals, with different shapes, sizes, habits, and habitats. Molluscs appeared in the Cambrian period, about 600 million years ago and grouped into different classes. Ancient molluscs, which crawled about on rocks and other hard substrata of the oceans gradually passed through a transitional tubellariform stage and a transitional mollusca stage before evolving into the advanced molluscan stage by the Cambrian period. At present, the molluscs are represented by seven classes, of which five are represented from India.

Molluscs are distinguished into 7 classes: Aplacophora, Polyplacophora, Monoplacophora, Gastropoda, Cephalopoda, Bivalvia, and Scaphopoda, of which classes Aplacophora and Monoplacophora are not represented from India. It is difficult to precisely mention the number of families in each group; however, a general estimate is 586 families in the phylum and 279 families from the Indian territory.

Molluscs have successfully adapted to different ecological conditions. They act as an important component of biomass. They are the first living creatures to have hard shells and the early man was perhaps attracted to these shells. The association of man and molluscs date back to prehistoric times.

Telescopium sp.

major classes, namely Polyplacophora, Gastropoda, Bivalvia, Scaphopoda, and Cephalopoda, are represented from India. These include 3,509 species in all, of which 2,181 are marine, 1,129 are land, and 199 are freshwater. At the family level, about 47.6 percent of the families known from the world are represented in India, and the Sundarbans represents 26.49 percent of the total Indian representation.

Among the five classes represented, Polyplacophora is represented by 20 species from India, which is 4.0 percent of the total global representatives. Of the total global representation,

OVERVIEW

The occurrence of diverse ecosystems and habitats in India has given scope for rich species' diversity. Globally, molluscs are estimated between 50,000 and 150,000 by different authors. Abbott (1954) estimates a total of 100,000 existing species, of which 80,000 are snails, 15,000 are bivalves, and the remaining 5,000 are in other classes. A more conservative estimate of species by Winckworth (1932) lists 31,643 marine, 8,765 freshwater, and 24,503 terrestrial species.

Table 1: Estimated species number under each class

Class	Global (n)	Indian (n)	Sundar-bans (n)	% in respect of global species	% in respect of Indian species
Aplacophara	130	Nil	Nil	-	-
Polyplacophora	500	20	Nil	-	-
Monoplacophora	05	Nil	Nil	-	-
Gastropoda	50000	2706	102	0.20	3.77
Cephalopoda	300	56	07	2.33	12.5
Bivalvia	15000	709	67	0.45	9.45
Scaphopoda	600	18	01	0.17	5.56
Total	66535	3509	177	0.27	5.04

Molluscan diversity in India is about 5.28 percent (table 1) of the global diversity, which is less than the total Indian faunal diversity of 6.67 percent. The work on the Indian malacofauna has been mainly concentrated on common and easily available molluscs, which do not need any special techniques for collection. However, the actual molluscan diversity may be higher than the present diversity estimates.

> Indian molluscan diversity is about 5.8% of the global diversity and less than the Indian faunal diversity of 6.67%

Molluscs constitute an important component of the marine biodiversity of India on the East and West coasts, the islands of Lakshadweep, and the Andaman and Nicobar Islands. Five

the class Gastropoda is represented by 2,706 (5.41 percent); Cephalopoda 56 (18.67 percent); Bivalvia 709 (4.73 percent); and Scaphopoda by 18 (3.0 percent).

Further, all the earlier investigations in the Indian mangroves were biased toward the more conspicuous and easy-to-collect gastropods and bivalves. However, from the data available it is seen that no other mangroves have such a diversity of species as the Sundarbans. The total number of marine species recorded from various mangroves are Sundarbans 133 (6.09 percent);

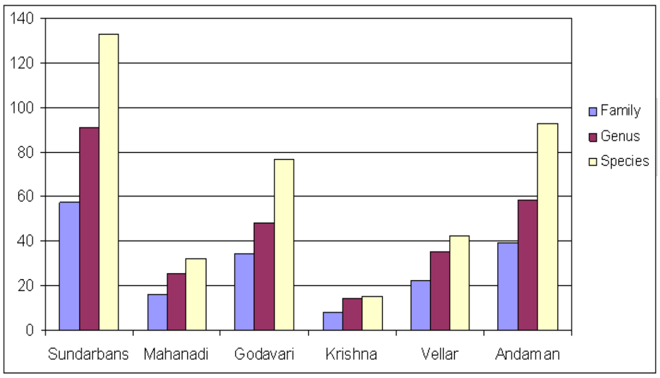
Mahanadi 32 (1.46 percent); Godavari 77 (3.53 percent); Krishna 15 (0.68 percent); Vellar 42 (1.92 percent); and Andamans 93 (4.26 percent) (table 2 and figure 1). The sheltered marine mangroves support a rich diversity of the malacofauna in the Andaman Islands.

Table: 2. Marine Molluscan diversity in different Estuaries /Mangroves of India.

	Sundar-bans	Maha-nadi	Godavari	Krish-na	Vellar Coleron	Anda-mans
Family	57	16	34	8	22	39
Genus	91	25	48	14	35	58
Species	133	32	77	15	42	93

The Indian mangroves are considered as part of estuarine ecosystems and major molluscs found are estuarine and marine molluscs. The families that have been the major contributors toward molluscan diversity are Neritidae, Littorinidae, Stenothyridae, Assimineidae, Potamididae, Ellobiidae, Onchidiidae, Arcidae, Mytilidae, Ostreidae, Solenidae, Tellinidae, Corbiculidae, Veneridae, Pholadidae, and Teredinidae. The richness of the Andaman fauna, after the Sundarbans, is due to the presence of more marine components.

Fig. 1: Molluscan diversity, Families, Genera and Species in different mangroves of India.



The gastropods (snails and slugs) species which are common to all Indian mangroves and estuaries are *Neritina (Dostia) violacea* (Gmelin); *Littoraria (Littorinopsis) scabra* (Linnaeus); *Littoraria (Palustorina) melanostoma* (Gray); *Assiminea brevicula* Nevill; *Cerithidea cingulata* (Gmelin); *Cerithidea obtusa* Lamarck; *Telescopium* Linnaeus; *Natica tigrina* (Roeding); *Natica gualteriana* Recluz; *Nassarius stolatus* (Gmelin); *Cassidula nucleus* (Gmelin); and *Ellobium aurisjudae* (Linnaeus). *Terebralia palustris* (Linnaeus), which has been reported from other Indian mangroves and estuaries, is conspicuously absent from the Sundarbans. On the other hand, *Salinator burmana* (Blanford) is known from the Sundarbans and the Irawaddy delta. *Mainwaringia paludomidea* (Nevill) is endemic to the Sundarbans.

SYNOPTIC VIEW

Diversity

In the Sundarbans, the molluscs are represented by 177 species under 80 families (Dey 2008), of which 14 species are terrestrial, 30 species are freshwater species, and 133 are estuarine and marine species (annexure and table 3). Gastropoda

SUNDARBAN MOLLUSCAN DIVERSITY REPRESENTED BY 177 SPECIES UNDER 80 FAMILIES

Pythia sp.

is represented by 102 species (3.77 percent); Cephalopoda by 7 species (12.5 percent); Bivalvia 67 species (9.45 percent); and Scaphopoda by single species (5.56 percent) of the total Indian species. The cephalopods representations are generally more in the cases of molluscs but the Sundarbans area is exempt from that. However, the bivalves representation, 9.45 percent, which is higher than the normal range of 5.04 percent, may be due to the suitability of the substratum and the presence of mangroves from these areas.

Among the bivalves, two typical mangrove associates, *Isognomon isognomon* (Linnaeus) and *Enigmonia aenigmatica* (Holten), occur in all the mangroves, but the former is absent from the Sundarbans. The molluscan diversity in the Sundarbans is rich in comparison to other Indian estuaries and mangroves. Some of the families have their representatives only in the Sundarbans and not in other estuaries and mangroves. The age and size of the Hugli-Matlah estuary, rich sediments, and more stable conditions in certain areas may be the factors that have contributed to the richness of molluscan diversity.

DISTRIBUTION

Major molluscs found at the Sundarbans are estuarine and marine; however, some occur in freshwater and terrestrial ecosystems. Most of them are of intertidal habit except the cephalopods. The estuarine and marine molluscs of the Sundarbans mainly represent the malacofauna of the Hugli-Matlah estuary.

The macro-benthic estuarine and marine molluscs of the Sundarbans can be broadly grouped under three categories: (a) those living attached to stems, pneumatophores, and leaves of the living plants (arboreal); (b) those living or attached in the crevices of dykes, bricks, wooden pillars, and jetties; and (c) those living on the muddy substratum, either moving freely on it (epifauna) or burrowing into it (infauna). A few gastropod species may have overlapping habitats. Species which are arboreal usually do not occur on the ground except for a short duration. Those living in the crevices of dykes, jetties, and so on do not usually forsake the crevice-dwelling habit. However, there are certain exceptions like *Potamacmaea fluviatilis* and *Nerita (Amphinerita) articulata* which are usually attached to mangroves, but when the area is devoid of mangrove vegetation, the snails are found in crevices, jetties, and so on. *Pseudanachis duclosiana* are found attached to pneumatophores and in clusters in brick crevices but are often found crawling on the muddy substratum.

Thirteen species of gastropods dwell in the crevices of dykes, jetties, and brickwork or under pillars. Eight species of bivalves are recorded as borers. Seven species of cephalopods that are inhabitants of the sea are regular migrants to the estuary. The maximum numbers of species (52 gastropods, 41 bivalves, and

Table 3: Diversity of Mollusca

Sr. No.	Class	Family		Genera		Species	
		India	Sundar-bans	India	Sundar-bans	India	Sundar-bans
1	***Terrestrial*** (Ramakrishna *et. al.,* 2010)						
	Gastropoda	34	8	138	11	1129	14
2	***Fresh Water*** (Ramakrishna and Dey, 2007)						
	Gastropoda	19	11	41	15	136	21
	Bivalvia	7	4	18	6	63	9
3	***Marine*** (Ramakrishna and Dey, 2010a)						
	Polyplacoph-ora	10	-	13	-	20	-
	Gastropoda	140	27	340	41	1441	67
	Cephalopoda	28	3	24	5	56	7
	Bivalvia	61	26	171	44	646	58
	Scaphopoda	3	1	2	1	18	1
4	**Total**	302	80	747	123	3509	177

Note: a) Two families of Gastrpoda and one family of Bivalvia are common in Freshwater and Marine forms. b) Terrestrial molluscs represented by Class Gastropoda; Freshwater represented by Gastropoda and Bivalvia.

one scaphopod) are sub -stratum dwellers. Bivalves live buried in the mud whereas a few gastropods species have the habit of getting below the mud surface.

A number of gastropods are amphibious or semiter -restrial. The snails of the families Littorinidae, Nerit -idae, Assimineidae, Potam -ididae, and Ellobidae occur in areas which remain exposed during a large part of the day. These families have a good representation in the mangrove biotope. There are certain species which live entirely submerged in water even during the low tide. Species of *Stenothyra, Haminoea,* and *Nassarius* are always found partly submerged in water. Ellobids occur at the supralittoral level, followed by littorinids which generally occur at the high-water mark.

Based on the salinity (table 4 and figure 2) (in an upward concentration range) and other physical parameters, this estuary has been divided into five zones (Jhingran 1982):

(a) Zone - I : Upper zone - Nabadwip to Konnagar

(b) Zone - II : Middle zone or gradient zone Konnagar to Diamond Harbour

© Zone - III : Lower or marine zone Diamond Harbour to the mouth of the estuary

(d) Zone - IV : River Rupnarayan

(e) Zone - V : River Matla

The first three zones integrate into each other and are within the stretch of the main Hugli River which debouches into the Bay of Bengal at Sandhead. Zones IV and V are somewhat isolated but have connections with the main estuary. *Littoraria scabra, Onchidium tenerum, O. tigrinum, O. typhae, Assiminea francessi, Neritina (Dostia) violacea, Stenothyra deltae,* and *Telescopium* have wider distribution. All these species, except *Assiminea francessi,* do not occur in Zone I, whereas *Assiminea francessi* has not extended its distribution to Zone V. *Telescopium telescopium* and *Natica tigrina* occur in Zones III and V, with little extension to Zone II. Among littorinids, *Littoraria scabra* is found from Zone II to Zone V. Except the six freshwater species, all other bivalves are restricted to Zones II and V, with preponderance in the latter. Freshwater species are restricted to Zone I, and at the other extreme, there are a number of species which do not extend their distribution above or the lower reaches of Zone V. In general, there is a paucity of molluscs in Zone IV.

Table 4: Distribution of molluscs - zone wise in Sundarbans

	Gastropoda		Bivalvia		Scaphopoda		Cephalopoda		Total	
	Genus	Species	Genus	Species	Genus	Species	Genus	Species	Genus	Species
Zone I	11	17	4	6	0	0	0	0	15	23
Zone II	19	23	6	6	0	0	0	0	25	29
Zone III	27	36	24	26	1	1	4	5	56	68
Zone IV	16	20	5	5	0	0	0	0	21	25
Zone V	46	63	41	51	1	1	5	7	93	122

Cerithidea sp.

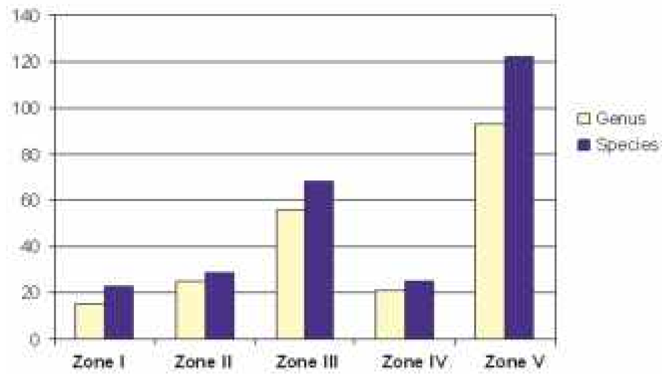
Nerita articulata

The distribution and relative abundance of molluscs is not uniform throughout. Their abundance varies from 2 to 10 per m^2 in the case of *Cerithidea obtusa*, 5 per m^2 for *Pugilina cochlidium*, 1,400 to 1,500 per m^2 in the case of *Cerithidea cingulate* and *C. alata,* and 2,320 to 2,800 per m^2 for *Meretrix meretrix*. The maximum population density recorded for any molluscs was that of *M. meretrix* (Misra and Barua 1987). The gastropod species, in order of relative abundance in their habitats, are *Gangetic miliacea, Assiminea brevicula, Cerithidea cingulata, C. alata, Stenothyra deltae, A. beddomeana, Littoraria (Littorinopsis) scabra, Haminoea crocata, Telescopium telescopium,* and *Pugilinus cochlidium*. All other species do not form large populations. Bivalves, in order of their abundance, are *Meretrix meretrix*, *Pelecyora trigona, Macoma birmanica, Saccostrea cucullata,* and *Sphenia perversa*. Most of the bivalves occur in beds which have concentrations of their population. The majority of bivalves were observed to prefer a sheltered estuarine zone, usually in the lower or middle zone of the exposed mudflats. In Matla River, the bivalves are so dominant in the middle zone that out of four broad zones based on indicator animals, two were recognized in the lower zone (*Meretrix)* and the lowest *Dosinia* zone (*Pelecyora*) (Misra and Barua 1987).

Bivalves are found in creeks and mudflats. Since a majority of them are burrowers, intertidal water is enough for maintaining the moist conditions needed for their survival. The majority of them are found at mid-water level as the exposure time is less compared to the zone at high-water level. However, *Pharella javanicus* occurs near high-water level, buried within the substratum, with a population of 6 to 8 numbers per m^2 (Subba Rao et al. 1992). Out of the total 92 species recorded, 19 species inhabit the substratum either near or within the mangrove isotope.

Based on the salinity tolerance, the animals of the Sundarbans

Fig. 2: Zone wise distribution of genus and species of molluscs in Sundarban.



can be placed in five categories as oligohaline, true estuarine, euryhaline, stenohaline, and migrants. The majority of molluscs are sedentary and come under the first five categories, and a few species (cephalopods) fall under the category of migrants. Seven species of cephalopods have been found to migrate into Matla River (Zone V). The occurrence of their eggshells at Jharkhali, about 60 km from the sea suggests that these species are regular migrants to this river when conditions are favorable. There is no influx of freshwater into Matla River and the drop in salinity not very significant, as a result of which a large number of stenohaline marine molluscs occur in this zone.

In Zone I, typical freshwater conditions prevail and 17 species (14 gastropods and 3 bivalves) are recorded, of which two species *Septaria lineata* and *Thiara scabra* are oligohaline and also extend into Zone II; *Assiminea francessi* is a true estuarine mollusc, extending its distribution to Zones I and II. Two other assiminids, *A. beddomeana* and *A. brevicula*, are not found to penetrate into Zone III.

Local Community Dependencies and Traditional Usage

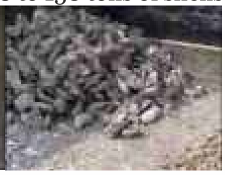
14 LAND AND 30 FRESHWATER SPECIES ARE OF IMPORTANCE TO LOCAL COMMUNITY

The association of molluscs and man is very old, dating back to prehistoric times. Evidences are there to show that the shell trade existed in ancient Iran and southern Asia (Durante 1979). Shells have fascinated man from the time they came in contact with molluscs. These natural objects were considered as mysterious and marvelous creations of nature, and gradually, man attributed magical and mythical powers to shells and started creating various articles out of them.

In the Sundarbans, 14 land molluscs were recorded under 11 genera and 8 families, including one introduced species, the giant African snail *Achatina fulica* (Bowdich). None of them have any commercial value except two species, *Achatina fulica fulica* and *Macrochlamys indica*, which are agri-horticultural pests and are common in vegetable gardens. Very few shells of aesthetic value are found from the Sundarbans.

Freshwater molluscs are represented by 30 species, under 21 genera and 15 families, of which 6 species are used as food for humans as well as for birds and fishes (Dey 2008). These species also have medicinal value and are used to cure asthma, arthritis, joint swelling, and rheumatism and quick healing of wounds, rickets in children, and conjunctivitis. The freshwater molluscs have high nutritive value and are easily digestible. Some species are intermediate hosts for many important parasites of sheep, cattle, and man.

Molluscan shells are important raw material for calcium and calcium-based industries since 33 to 40 percent of the shell is calcium and 90 to 98 percent in the form of calcium carbonate. These shells are used in the preparation of stalked lime in many parts of the country but are mainly used for poultry feed in the Sundarbans. Huge quantities of shells collected from the river beds, river mouth, canals, and different areas of the Sundarbans are brought to Canning, where they are crushed into powder and sent to different parts of West Bengal to be used as a source of calcium in poultry feed. Bojan (1984) reported that about 1,200 tons of shells were crushed annually and used for making poultry feed. Dey (2008) reported that 100 to 150 tons of shells



LEFT - **Fig. 3**: A view of Meretrix shells deposited at Canning Shell factory, Canning

CENTRE - **Fig. 4:** A view of shell factory from where powdered shells collected and used in Poultry feed

Right - **Fig. 5**: A view of Oyster shells deposited at Canning Shell factory, Canning

Littoraria melanostoma

of *Anadara* sp., *Crassostrea* spp., *Meretrix* sp., and *Pelecyora* sp. are crushed annually at a shell factory in Canning and used for poultry feed (figures 3, 4, and 5).

Ecological Importance and Need for Conservation

Molluscs have an important role in ecosystems by drawing a small amount of calcium from the environment for the formation of shells and releasing more into the environment. The estuarine molluscs play an important role in the formation of organic detritus in the estuaries. The *Littoraria* species (mainly *L. [Palustorina] melanostoma*) show an obligate association with mangrove trees or salt marsh vegetation. This species is most common near the seaward edge of swamps, where the mangrove vegetation provides the two most important habitats—areas with more frequent submergence and areas which are mainly bare wet mud. A number of bivalves are highly specialized and are clearly mangrove associates. *Enigmonia aenigmatica* and *Pharella javana* are indicators of a mangrove habitat. *Polymesoda (Geloina) bengalensis* is reported to be endemic to mangrove habitats. Mangrove representatives like *Laternula truncata* and *Galuconome sculpta* have remarkable adaptation to thrive close to the seaward fringe.

Research reveals that the bioaccumulation of metals in organisms is metal, organ, and organism specific (Saha et al.2006). Intertidal bivalves are the major macrozoobenthos of the Sundarban estuary and are widely distributed along the eastern and western part of the Sundarbans. These species are tolerant to a wide range of temperatures and salinity and are readily distinguishable from other species. All these characteristics enhance their value as index species for biomonitoring.

Saha et al. (2006) evaluated the status of metal conce -ntrations in the representative biota inhabiting the Sundarban wetland environment to assess their potential for biomonitoring of metal contamination. The high concentration of copper, cadmium, and zinc found in *Saccostrea cucullata* makes it a prime candidate for biological monitoring of pollutants in terms of bioaccumulation potential.

Zuloaga et al. (2009) reported higher levels of polycyclic aromatic hydrocarbons (PAHs) in the visceral mass of *Sanguilonaria acuminata*. The carcinogenic compounds benzo (a) phenanthrene, benzo (k) fluoranthene, and benzo (a) anthracene seem to prevail in the visceral mass and gills of *Sanguilonaria acuminata* in Ganga Sagar, and this could be efficiently used as a bioindicator of PAH contamination. The prevalence of these PAHs draws immediate attention as they are hazardous to the health of many organisms feeding on them, especially shore birds. The year-round availability of this multicolored species, together with its easy handling, ample biomass for chemical testing, and unique bioaccumulation potential, also provides sound reasoning for its use as a bioindicator species.

STATUS AND THREATS

Habitat alteration and indiscriminate exploitation by man threaten the molluscs, like all other animal groups. Molluscs are characterized by low mobility, small populations, and patchy and isolated distributions. They are very sensitive to environmental changes. The majority of marine molluscs respond to external disturbances. Even the construction of a jetty in Port Blair adversely affected the pearl oyster (*Pinctada fucata*) population. Patterson Edward and Ayyakkanu (1992) report that the dredging operation in the lagoon of Minicoy affected the population of the giant clam (*Tridcna maxima*).

The coastal environment of the Sundarbans also suffers from environmental degradation due to intensive boating, tourist activities, and agricultural and aqua-cultural practices. A significant ecological change has been taking place in the Hugli estuarine environment due to the huge discharge of domestic and industrial wastes (Sarkar et al. 2007). The delta is further vulnerable to chemical pollutants such as heavy metals, organochlorine pesticides, polychlorinated biphenyls (PCBs), and PAHs; all these have changed the geochemical nature of the estuary and have affected the local coastal environment (Sarkar et al. 2002, 2004, 2007; Guzzella et al. 2005; Binelli et al. 2007).

A major threat to molluscan diversity is the overexploitation and collection of undersized specimens. Earlier, in the Sundarbans, Cerithids shells (figure 6) and Anadara shells were used for poultry feed (figure 7). Now these molluscs are hardly available for this purpose. At present, *Crassostrea* shells are the major sources for preparation of poultry feed. More than 100 tons of these shells are crushed for this purpose. If the exploitation of these shells continues at the current rate without assessing the impact on their population, this species will soon be wiped out from the natural habitats.

Fig. 6: *Cerithidea* sp. crawling on the mud at Jharkhali.

Fig. 7: Heap of *Meretrix* shells at Chandipur collected for making poultry feed

Commercialization of marine shells has been on the rise and has led to indiscriminate collection of shells. Since there is no regulation in collection of shells, molluscan resources are treated as open access resources and due to indiscriminate collection of shell population of many species, the species are on the decline. *Amalda ampula*, the ivory white olive once common on Digha beach, Bakhali, and Ganga Sagar, is rare nowadays.

Recently, 14 species in India (9 under Schedule I and 15 under Schedule IV) of molluscs have been included in the Wildlife Protection Act, 1972. Window-pane oyster, *Placuna placenta*, which is also found in the Sundarbans is protected under Schedule IV of the amended Wildlife Protection Act, 1972.

The following measures are suggested to conserve the molluscan diversity in the Sundarbans:

- **Contamination control and monitoring program.** High accumulation of several metals in species like *S. cucullata* and *N. articulata* (Saha et al. 2006) and *S. acuminata* (Zuloaga et al. 2009) needs the implementation of suitable contamination control and a regular monitoring program to avoid any potential threat to humans. The coastal areas of West Bengal and especially the Sundarban estuary face an inherent toxic threat from the anthropogenic sources of pollution located upstream. These point sources may mobilize the metals in Ganges estuary and expose the biota to chronic contamination, affecting the marine environment as well as causing public health and economical hazards. Systematic mapping of sources of pollution and assessment of the heavy metal inputs into the Ganges estuary are recommended with a view to implement various pollution control measures by environmental managers, public health officials, and persons responsible for enforcing policy standards (Sarkar et al. 2004).
- **Regulation of catches.** Control exploitation of estuarine and marine shells through management of fishing and regulate collection of certain species by setting limits on the number, weight, and size of the species. Commercial collectors should be licensed and answerable to the Fisheries or Forest department.
- **Establishment of protected areas.** Prohibit collection of shells or restrict collection to certain zones. These areas act as reservoirs from which adult molluscs and larvae can spread to neighboring areas.
- **Improved collection method.** The collectors should understand the importance of conserving stocks and using collecting methods which do not damage the habitat. The main ideas are as follows:
    - Eggs, juvenile, and breeding groups should not be collected.
    - Shells with defects (unsaleable) should not be collected.
    - The habitat should not be disturbed.
- **Control on export and imports.** Introduce legislation to control exports of shells. Export may be controlled through permit systems and prohibition of the export of particular species and unworked shells. Many countries involved in shell trade have such legislations.
- **Mariculture.** To relieve the pressure on the stock of wild shells, appropriate mariculture may be introduced, with requisite training for capacity building. Considerable success has been achieved with several of these species, larvae, and juveniles being reared in hatcheries and the adults being kept in tanks for production of spawn and ultimately for harvesting. It is possible to use hatchery breed shells to reseed depleted areas. This management technique is being applied in the Philippines (Wood and Wells 1995).

ANNEXURE

List of Mollusc in Sundarban and their habitat.

Land molluscs

Systematic Position	Scientific Name	Common Name	Habitat	Value
Class Gastropoda Subclass Gymnomorpha Order Soleolifera Family Veronicellidae Genus *Filicaulis* Simroth	*Filicaulis (Eleuthero-caulis) alte* (Ferussac)	Slug	Inhabitant of cultivated gardens.	-
Subclass Pulmonata Order Stylommatophora Family Pupillidae Genus *Pupilla* Leach	*Pupilla barrackpo-rensis* Gude	Snail	Under fallen leaves, stems, wooden logs in dump shady areas.	-
Family Vertiginidae Genus *Pupisoma* Stoliczka	*Pupisoma orcula* (Benson)	Snail	Occurs on trunks, leaves and bark of large trees	-
Family Cerastuidae Genus *Rachis* Albers	*Rachis bengalensis* (Lamarck)	Snail	Occurs on stems, branches or leaves of trees.	-
Family Subulinidae Genus *Glessula* von Martens	*Glessula gemma* (Reeve)	Snail	Dump shady areas with vegetations.	-
Genus *Lamellaxis* Strebel & Pfeiffer	*Lamellaxis (Allopeas) gracile* (Hutton)	Snail	Dump shady areas of kitch- en gardens, damp wall etc.	-
Family Achatinidae Genus *Achatina* Lamarck	*Achatina fulica fulica* (Bowdich)	Shamuk/ Snail	Dump shady areas of kitchen gardens with vegetable plants.	Agri-horticultural pest
Family Succineidae Genus *Succinea* Draparnaud	*Succinea daucina f. hraswasikhara* Rao	Snail	Close to water bodies, under bark of trees, or on rocks	-
	Succinea crassinuclea Pfeiffer	Snail	Close to water bodies, under bark of trees, or on rocks	-
	Succinea snigdha Rao	Snail	Close to water bodies, under bark of trees, or on rocks	-
	Succinea godivariana f. vangiya Rao	Snail	Close to water bodies, under bark of trees, or on rocks	-

Systematic Position	Scientific Name	Common Name	Habitat	Value
Family Ariophantidae Genus *Ariophanta* Desmoulins	*Ariophanta interrupta* (Benson)	Snail	Under wooden logs,crevices in damp shady areas.	-
Genus *Cryptoaustenia* Cockrell	*Cryptoaustenia bensoni* (Pfeiffer)	Snail	Under wooden logs crevices in damp shady areas.	-
Genus *Macrochlamys* Gray	*Macrochlamys indica* Godwin-Austen	Snail	Damp areas near kitchen gardens, walls with algae.	-

Freshwater molluscs

Systematic Position	Scientific Name	Common Name	Habitat	Value
Class Gastropoda Subclass Prosobranchia Order Archaeogastropoda Family Neritidae Genus *Septaria* Ferussac	*Septaria lineata* (Lamarck)	-	Coastal freshwater bodies with some tidal influence .	-
Order Mesogastropoda Family Viviparidae Genus *Bellamya* Jousseaume	*Bellamya bengalensis* (Lamarck)	Gengri/ Googli/ Shamuk	Mud dweller, occurs in all types of freshwater bodies	Gastronomic and Biomedical
	Bellamya dissimilis (Mueller)	Gengri/ Googli/ Shamuk	Mud dweller, occurs in all types of freshwater bodies	Gastronomic and Biomedical
Family Ampullariidae Genus *Pila* Bolten Roeding	*Pila globosa* (Swainson)	Apple snail / Shamuk	Mud dweller, occurs in all types of freshwater bodies	Gastronomic and Biomedical; Carrier of trematodes parasites.
Family Bythyniidae Genus *Bithynia* Leach	*Bithynia (Digoniostoma) cerameopoma* (Benson)	-	Occurs in stagnant water bodies, including paddy fields	Carrier of trematodes parasites.
	Bithynia (Digoniostoma) pulchella (Benson)	-	Mud dweller, occurs in stagnant water bodies, including paddy fields	Carrier of trematodes parasites.

Systematic Position	**Scientific Name**	**Common Name**	**Habitat**	**Value**
Genus *Gabbia* Tryon	*Gabbia orcula* var. *producta* (Nevill)	-	Mud dweller, occurs in stagnant water bodies, including paddy fields	Carrier of trematodes parasites.
Family Iravadiidae Genus *Iravadia* Blanford	*Iravadia ornata* Blanford	-	Occurs under crecks.	-
Family Assimineidae Genus *Assiminea* Fleming	*Assiminea francessi* (Wood)	Snail	Occurs in ponds, canals link with river Hugli; and muddy substratum of river.	-
Family Thiaridae Genus *Thiara* Roeding	*Thiara (Thiara) scabra* (Mueller)	Snail	Occurs in ponds, canals and paddy fields. Prefers slow moving water	Used for feeding ducks.
Genus *Melanoides* Olivier	*Melanoides tuberculata* (Mueller)	Snail	Occurs in all water bodies of stagnant and slow moving; also in low saline water.	Used for feeding ducks.
Genus *Tarebia* H. & A. Adams	*Tarebia granifera* (Lamarck)	Snail	Occurs in ponds, canals and paddy fields.	Used for feeding ducks.
	Tarebia lineata (Gray)	Snail	Occurs in ponds, canals and paddy fields.	Used for feeding ducks.
Family Pleuroceridae Genus *Brotia* H. Adams	*Brotia (Antimelania) costula* (Rafinesque)	Mochra Samuk	Occurs in muddy water and muddy bottom of rivers and stagnant water.	Used for feeding ducks.
Subclass Pulmonata Order Basommatophora Family Lymnaeidae Genus *Lymnaea* Lamarck	*Lymnaea stagnalis* (Linnaeus)	Snail	Water bodies with abundant vegetations.	Intermediate host of different type of Flukes.
	Lymnaea (Pseudosuccinea) acuminata Lamarck	Snail	Water bodies with abundant vegetations.	Intermediate host of different type of Flukes.
	Lymnaea (Pseudosuccinea) luteola Lamarck	Snail	Water bodies with abundant vegetations.	Intermediate host of different type of Flukes.

Systematic Position	Scientific Name	Common Name	Habitat	Value
Family Planorbidae Genus *Gyraulus* Agassiz	*Gyraulus convexiusculus* (Hutton)	-	Occurs in ponds, ditches, drains attached to aquatic vegetations.	Intermediate host of many parasites.
	Gyraulus labiatus (Benson)	-	Occurs in ponds, ditches, drains attached to aquatic vegetations.	Intermediate host of many parasites.
Family Bullinidae Genus *Indoplanorbis* Annandale & Prashad	*Indoplanorbis exustus* (Deshayes)	Snail	Water bodies with abundant vegetations.	Intermediate host for number of trematodes.
Class Bivalvia Subclass Pteriomorphia Order Arcoida Family Arcidae Genus *Scaphula* Benson	*Scaphula deltae* Blanford	-	Found in water bodies connected with river Hugli.	-
Subclass Paleoheterodonta Order Unionoida Family Unionidae Genus *Lamellidens* Simpson	*Lamellidens corrianus* (Lea)	Jhinuk / Katli	Mud dwellers	Gastronomic and Biomedical ; producer of pearls
	Lamellidens marginalis (Lamarck)	Jhinuk / Katli	Mud dwellers	Gastronomic and Biomedical; producer of pearls
Genus *Parreysia* Conrad	*Parreysia (Parreysia) corrugata* (Mueller)	Jhinuk / Katli	Mud dwellers	Gastronomic and Biomedical
	Parreysia (Parreysia) favidens (Benson)	Jhinuk / Katli	Mud dwellers	Gastronomic and Biomedical
	Parreysia (Radiatula) caerulea (Lea)	Jhinuk / Katli	Mud dwellers	Gastronomic and Biomedical

Systematic Position	Scientific Name	Common Name	Habitat	Value
Subclass Heterodonta Order Veneroida Family Corbiculidae Genus *Corbicula* Megerle von Müehlfeld	*Corbicula striatella* Deshayes	Jhinuk	Sand dwellers	-
Genus *Polymesoda* Rafinesque	*Polymesoda (Geloina) bengalensis* (Lamarck)	Jhinuk	Mud dwellers	Commercial
Family Pisidiidae Genus *Pisidium* L. Pfeiffer	*Pisidium (Afropisidium) clarkeanum* G. and H. Nevill	-	Mud dwellers	-

Eustarine and Marine molluscs

Systematic Position	Scientific Name	Common Name	Habitat	Value
Class Gastropoda Subclass Prosobranchia Order Archaeogastropoda Family Lottiidae Genus *Potamacmaea* Peile	*Potamacmaea fluviatilis* (Blanford)	True Limpet	Stem of mangrove plants, crevices, algal coated bricks and dykes.	-
Family Trochidae Genus *Umbonium* Link	*Umbonium vestiarum* (Linnaeus)	Common Button Top	Occurs in sandy or sandy muddy beaches	Raw material for shell craft.
Genus *Solariella* Wood	*Solariella satparaensis* Preston	-	Occurs in sandy or sandy muddy beaches	-
Family Skeneidae Genus *Tubiola* A. Adams	*Tubiola microscopica* (Nevill)	-	Mud and sand mixed muddy area	-
Family Neritidae Genus *Nerita* Linnaeus	*Nerita (Amphinerita) articulata* Gould	Nerites	Mangrove plants, wooden pillars, crevices of dykes,	Used in shell craft
Genus *Neritina* Lamarck	*Neritina (Vittina) smithi* Wood	Nerites	Occurs in crevices of mud or undersurface of bricks and dykes	-
	Neritina (Dostia) violacea (Gmelin)	Violet Nerite	Upper mud flats, attached to pillars/crevices of bricks	-
	Neritina (Pseudonerita) obtusa (Benson)	Nerites	Wooden barks, empty tunnel of shipworms, crevices of dykes	-

Systematic Position	Scientific Name	Common Name	Habitat	Value
	Neritina (Pseudonerita) sulculosa Von Martens	Nerites	Wooden barks, empty tunnel of shipworms, crevices of dykes	-
Genus *Theodoxus* Montfort	*Theodoxus (Clithon) reticularis* (Sowerby)	Nerites	Muddy bottom or attached to substratum	-
Order Mesogastropoda Family Littorinidae Genus *Littoraria* Griffith & Pidgeon	*Littoraria (Littoraria) undulata* (Gray)	Periwinkles	Occurs on mangroves and shurbs	-
	Littoraria (Littorinopsis) scabra scabra (Linnaeus)	Scabra Periwinkles	Attached to mangroves and shrubs; also occurs on rocks, bricks or dykes.	-
	Littoraria (Palustorina) melanostoma (Gray)	Periwinkles	Attached to mangroves and shurbs	-
Genus *Mainwaringia* Nevill	*Mainwaringia paludomidea* (Nevill)	-	Occurs in submerged mangroves plants	-
Family Stenothyridae Genus *Stenothyra* Benson	*Stenothyra blanfordiana* Nevill	-	Muddy substratum	-
	Stenothyra deltae (Benson)	-	Muddy substratum; freshwater as well as brackish water.	-
	Stenothyra soluta Annandale and Prasad	-	Muddy substratum	-
	Stenothyra woodmasoniana Nevill	-	Muddy substratum	-
Genus *Gangetica* Ancey	*Gangetica miliacea* (Nevill)	-	Muddy substratum	-
Family Assimineidae Genus *Assiminea* Fleming	*Assiminea beddomeana* Nevill	-	Hole of the crevice in muddy substratum	-
	Assiminea brevicula (Pfeiffer)	-	Muddy substratum or attached to grasses	-
	Assiminea microsculpta Nevill	-	Muddy substratum	-
	Assiminea theobaldiana Nevill	-	Muddy substratum	-

Systematic Position	Scientific Name	Common Name	Habitat	Value
	Assiminea woodmasoniana Nevill	-	Muddy substratum	-
Family Potamididae Genus *Cerithidea* Swainson	*Cerithidea alata* (Philippi)	Horn shell/ Cerithid Shell	Mud and sand mixed muddy area	Used as calcium resources in poultry feed.
	Cerithidea cingulata (Gmelin)	Horn shell/ Cerithid Shell	Mud and sand mixed muddy area	- do -
	Cerithidea obtusa Lamarck	Horn shell / Cerithid Shell	Crawling on mud or plants which wet during spring tides	-
Genus *Telescopium* Montfort	*Telescopium telescopium* Linnaeus	Telescope snail	Mud and sand mixed muddy area	Used as calcium resources in poultry feed.
Family Xenophoridae Genus *Xenophora* Fischer	*Xenophora solaris* (Linnaeus)	Carrier Shells		-
Family Naticidae Genus *Polinices* Montfort	*Polinices didyma* (Roeding)	Moon shell	Occurs in sand or mud mixed sand	Used in shell craft.
	Polinices tumidus (Swainson)	Moon shell	Occurs in sand or mud mixed sand	- do -
Genus *Natica* Scopoli	*Natica gualteriana* Recluz	Moon shell	Mud and sand mixed muddy area	- do -
	Natica lineata (Roeding)	Moon shell	Sand or mud dweller	- do -
	Natica tigrina (Roeding)	Tiger Moon	Mud and sand mixed muddy area	- do -
	Natica vitellus (Linnaeus)	Moon shell	Sand or mud dweller	- do -
Genus *Sinum* Roeding	*Sinum neritoideum* (Linnaeus)	Ear Moon	Sand or mud dweller	- do -
Family Tonnidae Genus *Tonna* Bruennich	*Tonna dolium* (Linnaeus)	Tun shell	Sand dweller	- do -
	Tonna sulcosa (Born)	Banded Tun	Sand dweller	- do -
Family Ficidae Genus *Ficus* Roeding	*Ficus gracilis* (Sowerby)	Fig shell	Sand dweller	-

Systematic Position	Scientific Name	Common Name	Habitat	Value
	Ficus variegata (Roeding)	Fig shell	Sand dweller	-
Family Cassidae Genus *Phalium* Link	*Phalium bisculcatum* (Schubert and Wagner)	Japanese Bonnet	Sand dweller	-
Family Ranellidae Genus *Gyrineum* Link	*Gyrineum natator* (Roeding)	Triton shell	Sand or mud dweller	Used in shell craft.
Family Bursidae Genus *Bursa* Roeding	*Bursa spinosa* (Lamarck)	Frog shell	Sand dweller	- do -
Family Epitoniidae Genus *Amaea* H.&A. Adams	*Amaea (Acrilla) acuminata* (Sowerby)	Wentle trap	Mud and sand mixed muddy area	- do -
Order Neogastropoda Family Muricidae Genus *Thais* Roeding	*Thais lacera* (Born)	Rock shell	Attached to bricks, boulders, pillars and decomposed mangroves	- do -
	Thais blanfordi (Melvill)	Rock shell	- do -	- do –
Family Columbellidae Genus *Pseudanachis* Theile	*Pseudanachis duclosiana* (Sowerby)	Mangrove dove shell	Attached to pneumatophores and in clusters in bricks crevices, decomposed mangroves.	-
Family Nassariidae Genus *Nassarius* Dumeril	*Nassarius foveolata* (Reeve)	Mud snail/Dog whelk	Mud and sand mixed muddy area	-
	Nassarius orissaensis (Preston)	Mud snail/Dog whelk	Mud and sand mixed muddy area	-
	Nassarius stolatus (Gmelin)	Mud snail / Dog whelk	Mud and sand mixed muddy area	Used in shell craft.
Family Melongenidae Genus *Pugilina* Schumacher	*Pugilina (Hemifusus) cochlidium* (Linnaeus)	Spiral Melongena	Mud or sand dweller	Medicinal and commercial
Family Olividae Genus *Olivancillaria* d'Orbigny	*Olivancillaria gibbosa* (Born)	Olive Shell	Sand dweller	Used in shell craft.
Genus *Amalda* H. & A. Adams	*Amalda ampla* (Gmelin)	White mouth Ancilla	Mud and sand mixed muddy area	- do -
Family Turridae Genus *Turricula* Schumacher	*Turricula javana* (Linnaeus)	Java turrid	Sand dweller	- do -

Systematic Position	Scientific Name	Common Name	Habitat	Value
Genus *Asthenotoma* Harris & Burrows	*Asthenotoma vertebrata* (Smith)	-	Mud or sand dweller	-
Subclass Heterbranchia Order Cephalaspidea Family Architectonicidae Genus *Architectonica* Roeding	*Architectonica perspectiva* (Linnaeus)	Clear Sundial	Mud or sand dweller	Used in shell craft.
Subclass Opisthobranchia Order Cephalaspidea Family Hamineidae Genus *Haminoea* Turton & Kingston	*Haminoea crocata* Pease	Bubble Shell	Mud and sand mixed muddy area	-
Subclass Gymnomorpha Order Systellommatophora Family Onchidiidae Genus *Onchidium* Buchanan	*Onchidium tenerum* Stoliczka	Jomra Poka/ Nona Jounk	Inside mud of mangrove areas, crevices of dykes and bricks	-
	Onchidium tigrinum Stoliczka	Jomra Poka/ Nona Jounk	Inside mud of mangrove areas, crevices of dykes and bricks	-
	Onchidium typhae Buchanan	Jomra Poka/ Nona Jounk	Inside mud of mangrove areas, crevices of dykes and bricks	-
Subclass Pulmonata Order Archaeopulmonata Family Ellobiidae Genus *Ellobium* Roeding	*Ellobium aurisjudae* (Linnaeus)	Juda Ear Cassidula	Holes or crevices of mud flats of mangrove areas.	-
	Ellobium gangeticum (Pfeiffer)	Ellobium shell	Holes or crevices of mud flats of mangrove areas.	-
Genus *Cassidula* Ferussac	*Cassidula nucleus* (Gmelin)	Cassidula shell	Attached to mangrove, also crawling on mud.	-
Genus *Pythia* Roeding	*Pythia plicata* (Ferrussac)	Common Pythia	Crawling on mud of mangrove areas.	-
Genus *Melampus* Montfort	*Melampus pulchella* Petit	Melampus shell	Logs, undersurface of leaves,crecvices of stones in damp and wet places.	-

Systematic Position	Scientific Name	Common Name	Habitat	Value
Family Amphibolidae Genus *Salinator* Hedley	*Salinator burmana* (Blanford)	-	Muddy or sandy substratum of mangrove areas.	-
Class Cephalopoda Subclass Coleoidea Order Sepiida Family Sepiidae Genus *Sepia* Linnaeus	*Sepia aculeata* d'Orbigny	Cuttle Fish	Offshore and free swimming	Used as food. Shells has medicinal value
Genus *Sepiella* Gray	*Sepiella inermis* d'Orbigny	Cuttle Fish	Offshore and free swimming	- do -
Order Teuthida Family Loliginidae Genus *Loligo* Schneider	*Loligo duvanceli* d'Orbigny	Loligo	Offshore and free swimming	- do -
	Loligo (Doryteuthis) singhalensis Ortmann	Loligo	Offshore and free swimming	- do -
Genus *Loliolus* Steenstrup	*Loliolus investigatoris* Goodrich	Loligo	Offshore and free swimming	- do -
Order Octopoda Family Octopodidae Genus *Octopus* Lamarck	*Octopus macropus* Risso	Octopus	Offshore and free swimming	- do -
	Octopus rugosus (Bosc)	Octopus	Offshore and free swimming	- do -
Class Bivalvia Subclass Protobranchia Order Nuculoida Family Nuculidae Genus *Nucula* Lamarck	*Nucula convexa* Hinds	Nut Clam	Offshore, in muddy shell gravel.	-
	Nucula mitralis Hinds	Nut Clam	Offshore, in muddy shell gravel.	-
Family Nuculanidae Genus *Nuculana* Link	*Nuculana (Jupiteria) fragilis* (Chemnitz)	Nut Clam	Offshore, in mud.	-
Genus *Yoldia* Moller	*Yoldia nicobarica* (Bruguiere)	Nicobar Yoldia	Offshore, in mud.	-
Order Arcoida Family Arcidae Genus *Anadara* Gray	*Anadara granosa* (Linnaeus)	Granular Ark / Padma Jhinuk	Mud and sand mixed muddy area	Commercial

Systematic Position	Scientific Name	Common Name	Habitat	Value
	Anadara (Scapharca) inequivalvis (Bruguiere)	Padma Jhinuk	Mud and sand mixed muddy area	Commercial
Family Noetiidae Genus *Striarca* Conard	*Striarca lactea* (Linnaeus)	Ark Clam	Mud and sand mixed muddy area	-
Order Mytiloida Family Mytilidae Genus *Modiolus* Lamarck	*Modiolus striatulus* (Hanley)	Mussels	Mud and sand mixed muddy area	--
	Modiolus undulatus (Dunker)	Mussels	Mud and sand mixed muddy area	-
Order Pterioida Family Pinnidae Genus *Atrina* Gray	*Atrina pectinata pectinata* (Linnaeus)	Pecten	Sandy bottom, in meso-littoral zone.	-
Order Ostreoida Family Ostreidae Genus *Crassostrea* Sacco	*Crassostrea cuttackensis* (Newton and Smith)	Kausturi Jhinuk	Attached to jetties, bricks, dykes, also in the mud of inside the river.	Commercial
	Crassostrea gryphoides (Schlotheim)	Kausturi Jhinuk	Occurs on muddy substratum inside the river.	Commercial
Genus *Saccostrea* Dollfus & Dautzenberg	*Saccostrea cucullata* (Born)	Oysters	Attached to jetties, bricks, dykes, mangrove stem.	Commercial
Family Anomiidae Genus *Enigmonia* Iredale	*Enigmonia aenigmatica* (Holten)	Saddle Oyster	On the mangrove plants.	-
Family Placunidae Genus *Placuna* Solander	*Placuna placenta* (Linnaeus)	Windopane Oyster	Mud and sand mixed muddy area	Used for door hanging.
Subclass Heterodonta Order Veneroida Family Lucinidae Genus *Eamesiella* Chavan	*Eamesiella philippinarum* (Hanley)	Lucina clam	Mud and sand mixed muddy area	-
Family Cardiidae Genus *Trachycardium* Moerch	*Trachycardium asiaticum* (Bruguiere)	Asiatic Cockle	In shallow water, near low tide, on sandy shore.	-
Family Mactridae Genus *Mactra* Linnaeus	*Mactra (Mactra) luzonica* Deshayes	Mactra clam	Sandy bottom in infra littoral zone.	Used in shell craft.
	Mactra (Mactra) mera Deshayes	Mactra clam	Sandy bottom in infra littoral zone.	- do -

Systematic Position	Scientific Name	Common Name	Habitat	Value
	Mactra (Coelomactra) turgida Gmelin	Turgid Mactra	Sandy bottom in infra littoral zone.	- do -
	Mactra (Coelomactra) violacea Gmelin	Violet Mactra	Sandy bottom in infra littoral zone.	- do -
	Mactra (Mactrinula) plicataria Linnaeus	Surf clam	Sandy bottom in infra littoral zone.	- do -
Family Solenidae Genus *Solen* Linnaeus	*Solen brevis* Gray	Jack knife clam	Mud and sand mixed muddy area	-
Family Cultellidae Genus *Cultellus* Schumacher	*Cultellus subelliptica* Dunker	Razor clam	Mud and sand mixed muddy area	-
Genus *Neosolen* Ghosh	*Neosolen aqua-dulcuris* Ghosh	Razor clam	Mud and sand mixed muddy area	-
Genus *Pharella* Gray	*Pharella javanicus* (Lamarck)	Razor clam	Burrow inside the hard mudflats of mangrove areas.	-
Genus *Siliqua* Megerele Von Muehlfeld	*Siliqua albida* Dunker	Razor clam	Mud and sand mixed muddy area	-
Genus *Tanysiphon* Benson	*Tanysiphon rivalis* Benson	Razor clam	Mud and sand mixed muddy areas of mangroves.	-
Family Tellinidae Genus *Tellina* Linnaeus	*Tellina (Pharonella) iridescens* (Benson)	Tellin/Sunset shell	Mud dweller in the bank of creeks and canals.	-
	Tellina (Tellinides) sinuata Spengler	Tellin/Sunset shell	Muddy sand, intertidal and offshore.	-
Genus *Strigilla* Turton	*Strigilla splendida* (Anton)	Tellin/Sunset shell	Mud and sand mixed muddy areas.	-
Genus *Macoma* Leach	*Macoma birmanica* (Philippi)	Tellin/Sunset shell	Mud and sand mixed muddy areas.	-
Family Semelidae Genus *Theora* H. & A. Adams	*Theora opalina* (Hinds)	-	Mud and sand mixed muddy area	-
Family Psammobiidae Genus *Sanguinolaria* Lamarck	*Sanguinolaria (Soletellina) acuminata* (Deshayes)	Acuminate Gari	Sandy clay substratum, with organic matters.	Used in shell craft.
Genus *Novaculina* Benson	*Novaculina gangetica* Benson	-		-

Systematic Position	Scientific Name	Common Name	Habitat	Value
Family Trapeziidae Genus *Trapezium* Megerle	*Trapezium sublaevigatum* (Lamarck)	Trapezium shell	Attached to hole of the pneumatophores in the vicinity of mangoves.	-
Family Veneridae Genus *Timoclea* Brown	*Timoclea imbricata* (Sowerby)	Imbricate venus	Mud dwellers, occurs in the canal and small creeks.	Used in shell craft.
Genus *Meretrix* Lamarck	*Meretrix meretrix* (Linnaeus)	Jat Jhinuk	Mud dwellers, occurs in the creeks.	Commercial
Genus *Pitar* Roemer	*Pitar alabastrum* (Reeve)	Venus clam	In mud, Offshore.	-
Genus *Pelecyora* Dall	*Pelecyora trigona* (Reeve)	Venus clam	Intertidal mudflats.	Commercial
Genus *Tapes* Megerle Von Müehlfeld	*Tapes bruguiere* (Hanley)	Bruguiere venus	Offshore	Used in shell craft.
Genus *Paphia* Roeding	*Paphia malabrica* (Schroeter)	Malabar venus	Intertidal mudflats.	-
	Paphia textile (Gmelin)	Textile venus	Intertidal mudflats.	Used in shell craft.
Family Glauconomidae Genus *Glauconome* Gray	*Glauconome sculpta* (Sowerby)	-	In hard mud of littoral zone.	-
Order Myoida Family Myidae Genus *Sphenia* Turton	*Sphenia perversa* Blanford	-	Nestling in crevices, lower shore.	-
Family Corbulidae Genus *Corbula* Lamarck	*Corbula abbreviata* Preston	Corbule shell	In mud, deep water.	-
	Corbula calcarea Preston	Corbule shell	In mud, deep water.	-
	Corbula gracilis Preston	Corbule shell	In mud, deep water.	-
Family Pholadidae Genus *Barnea* Leach	*Barnea candida* (Linnaeus)	Pholad/ Piddock	Burrows in hard muddy intertidal substrate	-
Genus *Martesia* Sowerby	*Martesia fragilis* Verrill and Bush	Fragile Martens	Boring into the brickworks and submerged wood	-
Family Teredinidae Genus *Bactronophorus* Tapparone-Canefri	*Bactronophorus thoracites* (Gould)	Shipworm/ Nonapoka	Inside the submerged wooden logs, jetties, boats and living mangroves	-

Systematic Position	Scientific Name	Common Name	Habitat	Value
Genus *Dicyathifer* Iredale	*Dicyathifer manni* (Wright)	Shipworm/ Nonapoka	-do-	-
Genus *Bankia* Gray	*Bankia companellata* Moll and Roch	Shipworm/ Nonapoka	-do-	Inside the submerged wooden logs, jetties, boats, living and dead mangroves
	Bankia nordi Moll	Shipworm/ Nonapoka	-do-	-
	Bankia rochi Moll	Shipworm/ Nonapoka	-do-	-
Genus *Nausitora* Wright	*Nausitora dunlopei* Wright	Shipworm/ Nonapoka	-do-	-
Subclass Anomalodesmata Order Pholadomyoida Family Laternulidae Genus *Laternula* Roeding	*Laternula truncata* (Lamarck)	-	In mud and muddy sand, intertidal flats and offshore.	-
Family Cuspidariidae Genus *Cuspadaria* Nardo	*Cuspadaria chilkaensis* (Preston)	-	In mud, deep water.	-
Class Scaphopoda Order Dentaliida Family Dentaliidae Genus *Dentalium* Linnaeus	*Dentalium octangulatum* Donovan	Tusk shell	Intertidal and Offshore in sand.	Used in shell craft.

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2.8 POLYCHAETES

Polychaetes are common marine animals. A majority of the species is 5–10 cm long with diameter ranging from 2 to 10 mm. Deep-water forms are no longer than 1 mm whereas one species attains a length of 3 m.

AMALES MISRA
Polychaete Taxonomist

The majority of these worms are benthic; only a few are pelagic. Benthic polychaetes mostly prefer sandy or muddy substrata extending from the seashore to the greatest depths of the tidal zone; some are found to be comfortable in the crevices of rocks or coral reefs. Basically being inhabitants of marine environment, the polychaetes are also common in estuaries that enjoy an ever-changing brackish-water environment, and a few tolerant species may even extend up to the freshwater zone.

Polychaetes, a class of ubiquitous, segmented bristle-bearing worms of class Polychaeta in phylum Annelida, are usually the most abundant animals living within the sand and mud on the seashore. Polychaete means 'many hairs', a reference to the chitinous hairs that protrude from either side of these animals' bodies, with an identical set of hairs per segment. Polychaetes can be divided into two groups, as errant (free-moving) forms and sedentary forms, although the distinction between the two groups is not always definitive. The errant polychaetes, or Errantia, include some species that are strictly pelagic, some that crawl about beneath rocks and shells, some that are active burrowers in sand and mud, and many species that construct and live in tubes. The sedentary polychaetes, or Sedentaria, are largely tube dwellers or inhabit permanent burrows. Usually only the head of the worm ever emerges from the opening of the tube or burrow. Many polychaetes are strikingly beautiful and are red, pink, or green or possess a combination of colors. Some are iridescent due to the presence of crossed layers of collagen fibers in the cuticle.

Polychaetes are mostly raptorial feeders. They include members of many families of surface-dwelling, pelagic groups and tubicolous groups. The prey consists of various small invertebrates, including other polychaetes, which are usually captured by means of an eversible pharynx (proboscis). A scavenger or omnivorous habit has evolved in many polychaetes. Apart from this, a few members are categorized under non-selective deposit feeders and selective feeders. The non-selective feeders consume sand or mud directly when the mouth is applied against the substratum. The selective feeders lack a proboscis. Special head structures extend out over the substratum. Deposit materials adhere to mucous secretions on the surface of the feeding structure which is then conveyed to the mouth. Gills are common among the polychaetes, but they vary greatly in both structure and location, indicating that they have arisen independently within the class a number of times.

Tube nest of Dioptra cuprea

Most polychaetes reproduce only sexually, and the majority of species are diecious. There are some hermaphroditic polychaetes. The larval stage in the life history is the trochophore.

Polychaetes are one of the most important groups of soft bottom communities in terms of species, individuals, and biomass (Knox 1977). By exhibiting a short life-span with a high population growth, polychaetes are established as an important link in the food chain and are important as food for many fishes and invertebrates (Amaraal and Migotto 1980). It is a well-documented fact that these benthic polychaetes are subjected to multiple predations, that is, they are preferred as food by snails, larger crustaceans, fishes, and birds (Mukherjee 1969; Reish and Ware 1976).

As many of these worms are sedentary in nature and very specific regarding different environmental parameters, they are used as a bioindicator in environmental monitoring, particularly in estuaries. Most of the polychaete species are very small in size, are in the diets of many bottom-dwelling (demersal) fishes, and are considered as an important link in marine and estuarine food webs. As many of the polychaetes are sedentary in nature, changes in their abundance and diversity have been used in environmental monitoring, particularly in assessing the health of estuaries (Khan and Murugesan 2005; Khan et al. 2004). The variety and abundance of species that are present can often be used as indication of the cleanliness of the environment in which they live (Jones 1969; Moore 1972). Many polychaete species have shown a relatively high ability to regulate organic contaminants such as polycyclic aromatic hydrocarbons (PAHs) and pesticides.

Estuaries are highly productive habitats due to the continuous replenishment of nutrients from both the seaside and the landside brought to riverine waters in the form of silt, clay, and organic matter. They also serve as breeding and spawning ground for several commercially important fin fishes and shellfish and act as a nursery for several invertebrates of the adjoining sea (Rao 2004). Most of the major estuaries (Hugli-Matla, Mahanadi, Rushikulya, Basishtha-Godavari, Krishna, and Vellar) on the east coast were investigated for the faunal diversity, but the intertidal fauna of estuarine environment were less explored. The Sundarbans falls under Hugli-Matla Estuarine System.

170 SPECIES OF POLYCHAETES FROM THE ESTUARINE AND BRACKISH WATER ENVIRONMENTS ALONG THE INDIAN COAST

OVERVIEW OF THE GROUP

Polychaetes, an ancient group of Annelida that originated nearly 500 million years ago, are common inhabitants of virtually all marine environments. Among the estimated 9,000–12,000 or more species (Glasby et al. 2009) worldwide, relatively few of the non-marine polychaetes have colonized freshwater habitats. Fauvel (1953) reviewed all the earlier works on polychaetes from India and its adjacent areas, where she recorded 450 species, of which 283 belong to the Indian territory, including 47 brackish-water forms. A careful review by Misra (1995) reveals that 167 species of polychaetes under 38 families are from brackish-water localities from India.

Polychaetes are traditionally separ -ated into two large orders, Errantia and Sedentaria (Audouin and Milne Edwards 1834). Fauchald (1977) proposed a scheme of classification based on the phylogenetic concept and recognized 17 orders and 7 suborders to include 71 families. Fauchald's Key (1977) helped alleviate much of the difficulties associated with the identification of the polychaetes.

The most important works on the taxonomy of polychaetes pertaining to Indian waters are those of Fauvel (1932 and 1953). However, Southern (1921) is the pioneer in providing a comprehensive account of the brackish-water polychaetes in India. Fauvel (1932) made the first extensive studies on the collection of the Zoological Survey of India and recorded 300 species of polychaetes, including only 40 species from the brackish-water environments of India, out of which 30 were from West Bengal. A total of about 170 species of polychaetes are reported so far from the estuarine and brackish-water environments along the Indian coast out of 500 species of polychaetes reported from the Indian waters. A total number of 143 species of polychaetes are recorded from the estuaries of the east coast. Information on species diversity of polychaetes is available only from 9 estuaries (table 1) of the 33 estuaries on the east coast of India. In contrast to the east coast, the west coast estuaries are less studied.

SYNOPTIC VIEW

Diversity

Due to a lack of adequate information on the composition, density, diversity, and distribution of polychaetes inhabiting the intertidal and subtidal sediments of different blocks of the Sundarbans delta, it is difficult to make any definite comment on these features. An analysis of the known distribution of polychaete species of the estuarine complex shows that the area is dominated by the species restricted to the Indian Ocean habitats. Thirty-three species have this type of distribution, of which 27 species have been found to be endemic in Indian waters. In addition, 19 species are known from the Indo-west Pacific region and another two from the Indo-Pacific region. Further, one species has been observed to be widely distributed in the warm and tropical waters of the globe, another in warm and tropical Atlantic Ocean and Indian Ocean, and the remaining 13 species are found to be cosmopolitan in distribution.

The most characteristic features observed by Misra (1999) is the high diversity of the polychaete species toward the mouth of the estuary. This may be explained by the prevalence of the extensive marine condition in the mouth region of the estuary except during floods. A total of 55 species has been recorded from the 19 blocks of the Sundarbans.

Table 1: Comparative account of Polychaetes species diversity of the estuaries along the coasts of India.

Sr. No.	Name of the Estuary	Species Diversity	Reference
	Eastern Coasts		
1	Hugli-Matla stretch	69	Misra *et.al.,*1984,1985
2	Godavari	44	Srinivas Rao and Rama Shar - ma,1983
3	Vellar	98	Srikrishnadhas *et.al.,*(1987)
4	Mahanadi	33	Rao, 1993
5	Brahmani-Baitarani	11	Fauvel, 1932 and 1953; Soota and Rao, 1977 and Misra *et.al.,*(1987)
6	Burhabalang	16	
7	Rushikulya	18	Rao, 1992
8	Krishna	45	Rao (2004)
9	Subarnarekha	25	Mitra *et.al.,* (2006 & 2010)
	Western Coasts		
10	Cochin	19	
11	Mandovi-Juari	10	
12	Ashtamudi	7	
13	Mulki	5	
14	Nethravathi, Karnataka	9	Gowda *et.al.,* (2009)

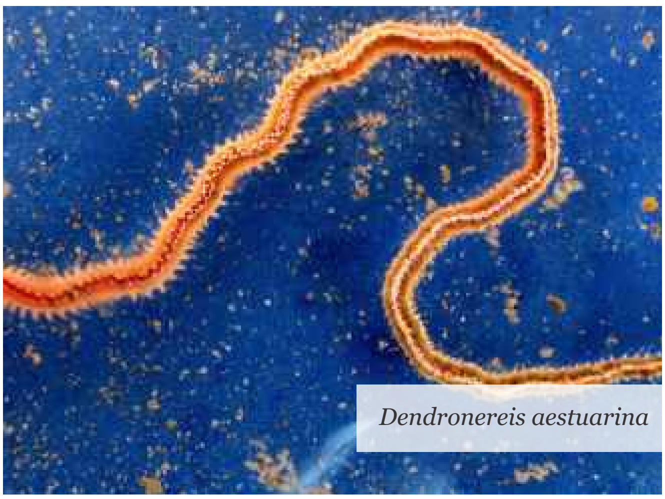
Ceratonereis burmensis

The species composition of the polychaete fauna in the Sundarban region belonging to different families (table 2 and annexure) shows that the errantiate polychaetes are more abundant than the sedentarians. The errantiate families are well represented with 38 species, while the sedentarians are comparatively less with 17 species. The family Nereididae includes the maximum number of species (13) while the families such as Amphinomidae, Hesionidae Talehsapidae, Onuphidae, Orbinidae, Maldanidae, Owenidae, Sternaspidae, Terebellidae, Ampharetidae, Sabellidae, and Serpulidae contain the minimum number of species, one species in each family.

Distribution Pattern

An analysis of the distributional pattern shows that a majority of the species is restricted to the areas located at the lower reaches, with the number of species gradually decreasing toward the upper reaches. Of the total 55 species of polychaetes recorded so far, 53 species are observed to be restricted to the lower reaches. Of these, 18 species were recorded only from the mouth region of the estuarine complex. It is well-known that the fluctuations of salinity in the estuary compel the colonization of the species with such severe problems that a decrease in species number is almost a certainty with increased distance from the sea. Maximum species diversity (figure 1) was found at Sagar Island (32), Canning (15), Kakdwip (14), Bakkhali (13), Jingakhali (12), and Namkhana (10).

55 SPECIES HAS BEEN RECORDED FROM THE 19 BLOCKS OF SUNDARBAN; ERRANTIATE FAMILIES WITH 38 SPECIES, WHILE SEDENTARIANS WITH 17 SPECIES

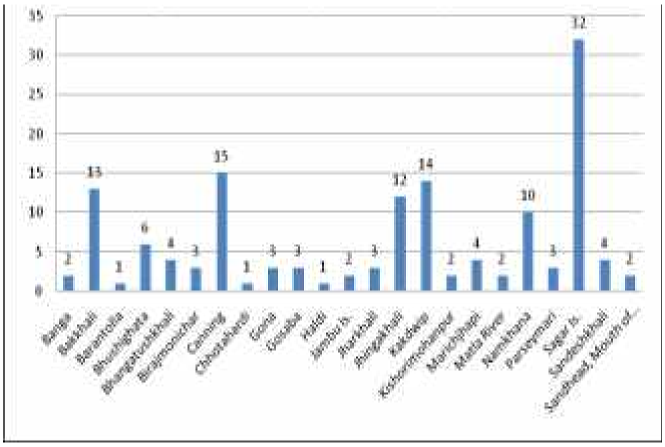


Dendronereis aestuarina

Table 2: Family wise composition of the polychaete fauna of Sundarban

Family	No. of Species	Family	No. of Species
Polynoidae	3	Orbinidae	1
Amphinomidae	1	Spionidae	4
Phyllodocidae	2	Capitellidae	3
Hesionidae	1	Maldanidae	1
Pilargidae	2	Oweniidae	1
Tahlesapiidae	1	Sternaspidae	1
Nereididae	13	Sabellariidae	2
Glyceridae	4	Terebellidae	1
Goniadidae	2	Ampharetidae	1
Onuphidae	1	Sabellidae	1
Eunicidae	4	Serpulidae	1
Lumrinereidae	4		

Fig 1: Distribution pattern of Polychaetes



Gunter (1961) stated that the number of aquatic species increases from the freshwater sector of an estuary to the saltwater sector where marine organisms are able to invade and survive and this is particularly true with respect to the polychaete fauna of the estuarine complex in the Sundarban region. Therefore, salinity is the most ecological factor affecting the distributional pattern of estuarine organisms—the normal scenario when compared with the abnormal solution following the adverse effects of pollution, which often results in a decline in the number of species but an increase in the number of individuals of tolerant species (Perkins 1974). The situation in the concerned region is complicated as both the conditions of fluctuating salinity and pollution are prevalent.

53 species are observed to be restricted to lower reaches of the estuary. Of these 18 species were recorded only from the mouth region of the estuarine complex

Polychaete fauna of the present estuarine complex is dominated by the brackish-water component. The most commonly occurring brackish-water species are *T. annandelai, D. heteropoda, D. estuarine, G. sootai, N. fauveli, N. indica, N. chingrighatensis, N. meggiti, N. oligobranchia, N. polybranchia, G. aciculate, L. polydesma,* and *M. indicus.* Among them, *D. heteropoda, N. indica, N. fauveli, N. meggiti, N. oligobrnchia*, and *N. polybranchia* have been found to be confined mostly to the upper and middle reaches of the estuary where freshwater conditions prevail almost throughout the year. It is not always easy to differentiate the brackish-water component from the marine euryhaline one. However, depending on the occurrence and nature of distribution, species like *Gattyana fauveli, Gaudichaudius cimex, Diopatra cuprea, Owenia fussiformis,* and *Loimia medusa* and most of the Glycerid and Goniadid species may be considered as marine euryhaline component.

Ecological Importance and Need for Conservation

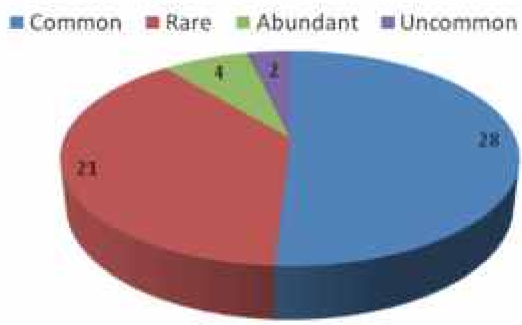
Among polychaetes, most of the species have a short life-span which involves secondary production and act as an important link for marine food webs and feed for many demersal fishes. In aquaculture practices, some species of polychaetes were used in the diet of shrimp's brood stock and in the treatment of organic wastes discharged from shrimp hatcheries.

Reish and Bernard (1960) first used the polychaete species *C. capitata* in toxicological testing and many have continued this line of research using many other polychaete species as test organisms. Polychaetes being the most abundant taxon in benthic communities have been most often used as indicator species of environmental conditions (Dean 2008). The extensive use of polychaetous annelids as indicators of various degrees of marine pollution is known (Harkantra and Rodrigues 2004). The polychaetes have long been an obvious choice to act as representative species in the analysis of the health of benthic communities as they are usually the most abundant taxon taken in benthic samples, both in the number of species and numerical abundance. Additionally, unlike nektonic organisms, the polychaetes usually live within the sediments or attached to hard surfaces, and while their larvae may be capable of long-distance transport, the adults are relatively inert. This relative immobility ensures chronic exposure to any toxic materials in the environment rather than the periodic exposures of a more vagile organism. Any long-term changes in the well-being of the benthos should be reflected in the polychaete community. The variety and abundance of species present can often be used as indication of the cleanliness of the environment in which they live (Jones 1969; Moore 1972). Many polychaete species have shown a relatively high ability to regulate organic contaminants such as PAHs and pesticides. Therefore, the polychaetes can be of important use as indicators of community diversity, benthic species diversity, organic enrichment, heavy metal pollution, and organic contaminants.

STATUS AND THREATS

Sarkar et al. (2005) studied the colonization and community structure of polychaetes in two ecologically distinct locations of the SBR on the northeast coast of India. Polychaete assemblages are characteristically different at the two sites in the extreme northern (Ghusighata) and southern (Ganga Sagar) portions of the biosphere reserve. Levels of heavy metals in polychaete body tissues also reveal interspecific and regional variations. The predominant polychaete fauna exhibited a distinct and unique assemblage of two types: (a) *Mastobranchus indicus - Dendronereides heteropoda* in the sewage-fed substratum at Ghusighata and (b) *Lumbrinereis notocirrata - Ganganereis sootai - Glycera tesselata* at Ganga Sagar at the mouth of the Hugli estuary, where chronic anthropogenic stress and contamination with agricultural and industrial effluents occur. Species found in moderately polluted parts include *Lumbrinereis polybranchia* and *Perheteromastes tenuis*. The local status of the polychaete diversity in the Sundarbans is represented in figure 2.

Fig 2: Local Status of Polychaetes in Sundarbans



Indicators of community diversity, benthic species diversity, organic enrichment, heavy metal pollution and organic ontaminants

The faunistic composition of polychaetes and their potential for the accumulation of heavy metals from the ambient medium are distinctly different. The study demonstrates that textural composition of the sediments, together with hydrodynamic and geotechnical properties, seem to have the greatest control to quantify the differences of the polychaete community in the two study sites.

With the initiation of various developmental plans for the Sundarban mangrove belt in recent years, increasing ecological investigations is imperative. Such investigations cannot be successfully carried out without comprehensive knowledge of the faunal resources. Hedgpeth (1957) recommended that the first procedure in any ecological research is the 'exercise in systematics'. It is, therefore, imperative that taxonomic studies of the organisms of the present estuarine complex, especially of the particular group of animals which constitutes one of the major components of macro-benthic fauna of the area, both numerically and qualitatively, shall ultimately be helpful to ecological works for the assessment of the benthic condition as well as the quality of the environment.

Dendronereides heteropoda

ANNEXURE

Polychaetes of Sundarban with their habiat, distribution and local status

Sl No.	Family and Species	Habitat		Status	Distribution
		Substratum	**Tidal zone**		
FAMILY POLYNOIDAE					
1.	*Lepidonotus tenuisetosus* (Gravier, 1901)	Rocks/woods/ shells	LWM 8%-19%	C	Sagar Is., Bakkhali, Jhingakhali, Gona
2.	*Gattyana fauveli* Misra,1999	Burrow of echiuran worm	LWM 18%	R	Sagar Is
3.	*Gaudichaudius cimex* (Quatrefages, 1866)	Hermit crab shell	LWM 19%-22%	C	Sagar Is, Bakkhali
FAMILY AMPHINOMIDAE					
4.	*Chloeia parva* Baird, 1870		-		Sand Head
FAMILY PHYLLODOCIDAE					
5.	*Anaitides madeirensis* (Langerhans,1800)	Soft mud	MTL-LWM 8-15%	C	Canning, Kakdweep, Jhingakhali, Parseymari
6.	*Eteone barantollae* Fauvel,1932	Soft mud with fine sand mixed	MTL-LWM 12-19%	C	Sagar Is.
FAMILY HESIONIDAE					
7.	*Hesione splendida* Savigny, 1818	Soft mud	MTL	C	Kishorimohanpur
FAMILY PILARGIDAE					
8.	*Sigambra constricta* (Southern, 1921)	Soft mud with fine sand mixed	LWM 10%	C	Bakkhali, Marichjhapi
9.	*Sigatargis commensalis* Misra, 1999	Mud	MTL_LWM 25%	R	.Birajmonichar, Gosaba
FAMILY TAHLESAPIIDAE					
10.	*Talehsapia annandalei* Fauvel, 1932	Hard claey soil	MTL 5-17%	C	Sagar Is, Kakdweep,Namkhana, Canning, Jhingakhali, Banga
FAMILY NEREIDIDAE					
11.	*Namalycastis fauveli* Rao, 1981	Soft clay	HWM-LWM 0-10%	A	SagarIs, Kakdweep, Bhushighata, Marichjhapi
12.	*Namalycastis indica* (Southern,1921)	Soft clay	HWM-LWM 0-10%	C	Sagar Is, Kakdweep, Bakkhali, Bhushighata
13.	*Ceratonereis burmensis* Monro, 1937	Clayey sand	LWM 8-10%	C	Birajmonichar, Gosaba

Sl No.	Family and Species	Habitat		Status	Distribution
		Substratum	Tidal zone		
14.	*Dendronereides gangetica* Misra, 1999	Soft mud	LWM 0-12%	R	Sagar Is, Jhingakhali,
15.	*Dendronereides heteropoda* Southern, 1921	Soft mud	MTL-LWM 0-12%	A	Kakdwip, Bakkhali, Bhusighta
16.	*Dendronereis aestuarina* Southern,1921	Soft mud	LWM 8-12%	C	Sagar Is, Namkhana, Sandeshkhali, Jhingakhali
17.	*Dendronereis dayi* Misra,1999	Soft mud	LWM 5-15%	R	Kakdwip, Bakkhali, Canning, Bhangatushkhali
18.	*Ganganereis sootai* Misra, 1999	Clayey soil	MTL-LWM 8-15%	R	Sagar Is, Jhingakhali, Jharkhali
19.	*Lycastonereis indica* Rao, 1981	Soft black soil	MTL 5-10%	C	Kakdweep, Bhushighta, Marichjhapi
20.	*Neanthes chingrighattensis* (Fauvel,1932)	Rotten woods, algae etc.	MTL-LWM 5-16%	C	Sagar is. Kakdwip
21.	*Perinereis cavifrons* (Ehlers,1920)	Clayey soil	LWM 5%	R	Kakdwip
22.	*Perinereis cutrifera* (Grube, 1840)	Soft mud	LWM 12%	C	Sagar Is.
23.	*Perinereis nigropunctata* (Horst, 1889)	Soft mud	LWM 6-12%	R	Sagar Is.Canning, Jhingakhali
FAMILY GLYCERIDAE					
24.	*Glycera convoluta* Keferstein,1862	Silty Sand	MTL-LWM 10-19%	C	Jambu Is, Sagar Is.
25.	Glycer*a lancadivae* Schmarda,1861	Silty sand	LWM 16%	R	Sagar Is
26.	*Glycera rouxii* Audouin &Milne Edwadrs,1833	Silty Sand	LWM 12-15%	C	Sagar Is., Canning
27.	*Glycera tesselata* Grube, 1863	Soft mud	MTL 10-15%	R	Sundarban
FAMILY GONIADIDAE					
28.	*Glycinde oligodon* Southern,1921	Soft mud	LWM 8%	C	Namkhana, Canning
29.	*Goniada emerita* Audouin &Milne Edwadrs,1833	Soft mud with fine sand mixed	MTL 12-16%	C	Haldi, Jharkhali, Sagar Is.

Sl No.	Family and Species	Habitat		Status	Distribution
		Substratum	Tidal zone		
FAMILY ONUPHIDAE					
30.	*Diopatra cuprea* (Bosc,1802)	Mud/sand	MTL-LWM 8-16%	A	Sagar Is., Bakkhali, Canning, Bhngatush-khali
FAMILY EUNICIDAE					
31.	*Marphysa mosambica* (Peters, 1854)	Soft mud	LWM 5-12%	R	Sagar Is, Jhingakhali, Gona, Parseymari
32.	*Marphysa sanguinea*	-	-	R	Sagar Is, Sandesh Khali
33.	*Lycidice natalensis* Kingberg, 1865	Soft mud	-	R	Sagar Is.
34.	*Eunice aphroditois*(Pallas, 1788)	Sandy Mud	-	R	Sagar Is.
FAMILY LUMBRINEREIDAE					
35.	*Lumbrinereis bilabiata* Misra,1999	Soft mud	MTL 0-19%	C	Sagar Is, Kakdweep, Bakhkhali
36.	*Lumbrinereis heteropoda* (Marenzeller,1879)	Silty sand	MTL_LWM	C	Bhangatushkhali
37.	*Lumbrinereis notocirrata* (Fauvel, 1932)	Mud	MTL-LWM 14-20%	C	Sagra Is , Canning , Sandeshkhali
38.	*Lumbrinereis polydesma*	Mud with fine sand	MTL-LWM 5-12%	C	Sagar Is, Kakdweep, Canning, Jhingakhali
FAMILY ORBINIIDAE					
39.	*Scoloplos (Scolopolos) sagarensis* Misra,1999	Silty sand	LWM 15%	R	Sagar Is.
FAMILY SPIONIDAE					
40.	*Minuspio cirrifera* (Wiren 1833)	Silty Mud	LWM	R	Canning (Taldi)
41.	*Polydora normalis* Day, 1957	Soft mud	MTL	R	Namkhana , Canning
42.	*Spio bengalensis* Willey, 1908	Soft mud	Brack. pond	R	Canning
43.	*Pherusa bengalensis* (Fauvel, 1932)	River Bed	-	R	Sandhead, Mouth of the Hooghly river
FAMILY CAPITELLIDAE					
44.	*Capitella capitata* (fabricius, 1780)	Soft mud	MTL	R	Matla river
45.	*Mastobranchus sp*.	Clayey soil	HWM-MTL 5-16 %	C	Sagar Is. Kakdweep, Bhusighta, Bakkhali
46.	*Parheteromastus tenuis* Monro,1937	Clayey soil	HWM-MTL 5-24 %	A	Sagar Is, Namkhana, Bakkhali

Sl No.	Family and Species	Habitat		Status	Distribution
		Substratum	Tidal zone		
FAMILY MALDANIDAE					
47.	*Asychis gangeticus* Fauvel, 1932	River Bed	-	U	Sandhead , Hooghly river mouth
FAMILY OWENIIDAE					
48.	*Owenia fusiformis* delle Chia-je,1841	Silty sand	LWM 5-12%	C	Sagar Is, Namkhana, Bakkhali
FAMILY STERNASPIDAE					
49.	*Sternaspis scutata* (Renier, 1907)	Slty mud/sand	LWM/ST 14%	C	Jharkhali
FAMILY SABELLARIIDAE					
50.	*Sabellaria pectinata intermedia* Fauvel, 1932	In tubes on hard substrata	MTL-LWM 5-12%	C	Kakdwip, Namkhana
51.	*Sabellaria alcocki* Gravier, 1906	Attached with Bricks	-	U	Matla river
FAMILY TEREBELLIDAE					
52.	*Loimia medusa* (Savigny, 1818)	In sandy tube on fine sand	MTL 5-21%	C	Sagar Is
FAMILY AMPHARETIDAE					
53.	*Isolda pulchella* Muller, 1858	Soft muddy tube on hard clay	MTL	R	Chhotahardi
FAMILY SABELLIDAE					
54.	*Potamilla leptochaeta* Southern, 1921	In leathery tube on soft mud	MTL 6-10%	C	Bakkhakli, Namkhana, Canning, Jhingakhali
FAMILY SERPULIDAE					
55.	*Ficopomatus macrodon* Southern, 1921	Calcareous tube on hard sub-strata	LWM 6-14%	C	Namkhana, Canning, Jhingakhali

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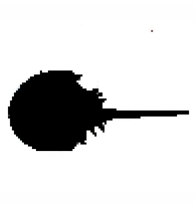
2.9 XIPHOSURA

Quite a few marine organisms suspected to be extinct from the ocean still flourish as living animals. The xiphosuran arthropods, popularly known as horseshoe crabs or horse-footed crabs, belong to the class Merostomata (sub-phylum Chelicerata) and are considered to be the oldest living fossils.

DIPANKAR SAHA
Senior Scientist with specialization on Xiphosurans



The horseshoe crab has descended from mud-dwelling primitive arthropods called Trilobites which lived in the Precambrian seas, nearly 600 million years ago. After the next 150 million years or so, the horseshoe crab evolved into its present shape, remaining unchanged all these 350 million years (Chatterji and Abidi 1993). These strange xiphosurans are marine in origin, as evidenced by their long fossil history beginning in the early Paleozoic era (Barnes 1968; Shuster 1982).

They should in no way be considered as King Crabs and they equal, if not exceed, in zoological interest, animals such as coelacanth, platypus, and nautilus (Barthel 1974). All the xiphosuran representatives of the present day bear an army helmet-shaped body and a swordtail. The body is composed of three distinct divisions (fused head and thorax, known as prosoma; segmented abdomen, called ophisthosoma; and a swordlike postanal tail, popularly known as telson) and resembles an armored tank rolling along on wheels as the horseshoe crab walks. The animal can tide over all kinds of situations arising in its estuarine and coastal shallow habitats. It can tolerate a wide range of salinity, temperature, desiccation, and submergence conditions.

Horse Shoe Crab (Carcinoscropius rotundicauda)

OVERVIEW OF THE GROUP

REPRESENTED BY 4 EXTANT SPECIES

The xiphosuran has extensive fossil records. The two suborders Synxiphosurida and Limulidae of the order Xiphosura, span 500 million years of evolution. The xiphosuran includes three major ancient groups, Aglaspida, Synxiphosurida, and Limulina.

Horseshoe crabs in the world are now represented by four extant species: *Limulus polyphemus* (Linnaeus); *Tachypleus tridentatus* (Leach); *Tachypleus gigas* (Muller); and *Carcinoscorpious rotundicauda* (Latreille) (Sekiguchi and Nakamura 1979). The first one survives only along the western shores of the Atlantic coast of North America and the remaining three are endemic to the Indo-Pacific region (Shuster 1982). *Tachypleus gigas* (triangular-tailed moluccan) can be located along the shores of the Bay of Bengal from Indonesia to Northern Vietnam, including Bangladesh and India, while *Carcinoscorpious rotundicauda* (round tailed) extends its distribution along the western shores of the Bay of Bengal (Bangladesh and India) to the southern coast of the Philippines (Sekiguchi et al. 1976). *Tachypleus tridentatus* occurs along the western and southern shores of Japan, south along the coast of China to southern Vietnam, and along the western islands of the Philippines (Sekiguchi and Nakamura 1979).

Annandale (1909), Rama Rao and Surya Rao (1972), and Sekiguchi and Nakamura (1979) have stated that the species *Carcinoscorpius rotundicauda* is more adaptive to sweet water compared to *Tachypleus gigas*. Such an advanced adaptive feature was also demonstrated by the presence of a complicated broom-like structure on the entire body of *Carcinoscorpius rotundicauda* (Saha 1989). The characteristic feature was found to be simple in structure, which suggests that *Carcinoscorpius rotundicauda* is more primitive in nature compared to *Tachypleus gigas* (Saha 1989).

The entire coastal water of West Bengal, Orissa, and Andhra Pradesh is enriched with plenty of horseshoe crabs. In Orissa's coastal water (along the coastline of Balasore), the dominating species is *Tachypleus gigas*. *Carcinoscorpius rotundicauda* dominates in the muddy Sundarbans estuarine complex in West Bengal (about 3,000 km^2 area and further upstream) (Saha 1989).

SYNOPTIC VIEW

Diversity

Occurrence of two of the four horseshoe crabs species, *Carcinoscorpius rotundicauda* and *Tachypleus gigas*, are a unique feature of the Sundarban Mangrove Ecosystem. Thus, both the extant species of the Indian region are the key faunal components of ancient origin and are represented in the Indian Sundarbans (Saha 1989).

Carcinoscorpius rotundicauda & Tachypleus gigas are represented in Indian Sundarbans

The very presence of these animals in a coastal zone indicates the health of the environment (Chen et al. 2004), that these conditions are suitable for their survival, reproduction, and development.

Displays distinct seasonal fluctuations wherever maximum weight coincides with low salinity of environment

Eco-biological Status

The horseshoe crab is a hardy animal and can thrive well in estuarine dilution or saturation of seawater by maintaining osmotic steady state. Salinity changes significantly influence the weight of the horseshoe crab and the volume of blood (haemolymph). The body weight displays distinct seasonal fluctuations, where maximum weight coincides with low salinity of the environment. At high salinity, the body weight of the horseshoe crab decreases considerably. Similarly, seasonal variations in the volume of the haemolymph also increase at low salinity. The differences in body weight and volume of haemolymph are more pronounced in females than males (Chatterji and Abidi 1993).

All the extant species of xiphosurans are bisexual, with distinct sexual dimorphism. Breeding starts during the warmer months (Roonwal 1944) in the coastal waters of both West Bengal and Orissa, which are tropico-temperate regions.

The dominant breeding season for *Carcinoscropius rotundicauda* was noted to be March to July; however, the species was found to breed recessively throughout the year. *Tachypleus gigas* has a restricted breeding season from February to August (Saha 1989).

Saha et al. (1988) demonstrated that the breeding time is restricted only in dominant lunar phases, starting from two days of the preceding half lunar cycle (that is, before the new or full moon) to the fourth day of the subsequent half lunar cycle. Breeding takes place only at the highest tide on these days, that is, for a few minutes, twice a day, four days a fortnight, and eight days a month (Saha 1989), which was found to be adequate for maintaining the humidity level for natural incubation. Comparative data (Saha 1989; Mishra 2009) of the natural habitat, nesting pattern, and number of eggs of the two species found in the Sundarbans are given in table 1.

Table 1: Nesting behavior of *T. gigas* and *C. rotundicauda*

Sr. No.	Species	Natural Habitat	Salinity	pH range	Nest Size		Number of eggs	Egg size	Larva
					Diameter (cm)	Depth of egg laying (cm)			
1	*T. gigas*	Off shore water (20–30m depth)	36-11 mg/l	7.29 -8.35	12-30	10-13	60-720	3.7	Trilobites found swimming to the sea with the ebbing tide
2	*C. rotundi-cauda*	Man-grove Mud flats	33-2 mg/l	6.90 – 7.55	-	3-7	80-200	2.3	Juveniles found in the mangrove mud flats

Carcinoscropius rotundicauda

Breeding behaviour of Tachypleus gigas

Such unique breeding behavior can also be observed in the Olive Ridley marine turtle, one of the threatened marine fauna (which has retained a dinosaurian type of breeding behavior), which also breeds in the upper intertidal water of the Sundarbans (Saha 1987 a, b, c, and 1989).

It may be mentioned that both animals (invertebrate Indian Xiphosurans and vertebrate Indian Olive Ridley) share the same breeding ground; however, the former is found to breed in the summer months, while the latter breeds in the winter months (Saha 1987b). Multiple effects of temperature, moisture, clutch sizes (number of eggs in a nest), and so on are the major controlling factors for natural incubation of eggs, while the other factors need to be investigated.

Distribution

Carcinoscorpius rotundicauda has its distribution from the Sundarbans to the confluence of River Mahanadi in Orissa. *Tachypleus gigas* is distributed in the coastal waters of West Bengal, particularly from Kanak Island (bordering Sundarbans in the Bay of Bengal and to the Ganjam coast of the Bay of Bengal in Andhra Pradesh). The former has a preference for sweet water, while the latter prefers brackish water (Roonwal 1944). The author has confirmed that Kanak Island and Sagar Island (sand heads) are the common breeding areas for both horseshoe crabs and the Olive Ridley Marine turtle within the Sundarbans territory in India.

Uses

Traditional and ethnic use

The body parts of horseshoe crabs are sold in the market by quack medical practitioners to cure body pain, arthritis, and so on. This practice has been observed in the coastal states of Andhra Pradesh, Orissa, and West Bengal. The blue blood of the animal is also sold as ointment for joint pains. Majumder and Dey (2007) reported a drug prepared from *Carcinoscorpius rotundicauda* for the remedy of various diseases by the tribes (Santhal, Oraon, and Munda) in the Sundarbans. Five medicinal applications have been reported from the Sundarbans. Most of these applications are applied externally for the cure of diseases such as wrist rheumatism, bronchitis, pneumonia, spondylosis, and intestinal colic.

> The potential impacts of horseshoe crabs as predators are intertwined with their effects as sediment disturbers

Biomedical use

Extensive research has been conducted on the eyes of horseshoe crabs, which has resulted in important findings pertaining to the manufacture of surgical sutures and development of dressings for burn patients. Hartline (1903–1983) was the pioneer in the field of vision research from smaller insects to man, through *Limulus polyphemus*. He performed extensive research on the visual system, which is common to many animals, including *Limulus polyphemus* (having compound eyes) and man (having simple eyes). In recognition of his work on the visual system, he was awarded the Nobel Prize for physiology and medicine in 1967 with Ragnar Granit and George Wald. He discovered the retinal function, which is common in many animals, including man and *Limulus polyphemus* (Hartline 1969, 1972).

Since 1970, research revealed that the blood extract of *Limulus polyphemus* can be used for the detection of endotoxins (mostly available in bacterial cell walls) even in human beings. This investigation has been termed as the Limulus Amoebocyte Lysate (LAL) test (Watson et al. 1982). The Indian Institute of Chemical Biology (IICB), Calcutta had initiated this investigation in 1985 using both the Indian extant species; however, not much success could be achieved due to failure in captive rearing of the animals. Even a small amount of endotoxin is harmful for the human body and may sometimes cause death, thus necessitating investigation of the amount required for all body fluids. India being the largest source of horseshoe crabs, research on this subject needs to be carried out without any further delay.

Biomedical companies now harvest blood from horseshoe crabs to produce LAL. NASA is now testing the use of LAL in space to assist in the diagnosis of astronauts (Sacred Heart University 2010). The worldwide market for LAL is currently estimated to be approximately US$50 million per year. The biomedical industry pays approximately US$375,000 per year for horseshoe crabs based on an estimate of 250,000 horseshoe crabs harvested at an average price of US$1.50 per crab (ERDG 2010).

Ecological Importance and Need for Conservation

Horseshoe crabs play a vital role in the ecology of estuarine and coastal communities. Most ecological studies involving adult *Limulus polyphemus* have been conducted at only a few locations while much less is known about the three Indo-Pacific species.

Adult horseshoe crabs are omnivorous, feeding on a wide variety of benthic invertebrates, including bivalves, polychaetes, crustaceans, and gastropods. Bivalves are the most important macrobenthic prey found in the stomachs of adult *T. gigas*. (Debnath et al. 1989). The horseshoe crab's digestive system contains the enzyme cellulase (Debnath et al. 1989), demonstrating that the plant detritus may be nutritionally useful. Botton (1984) found that the exclusion of predators led to significant increases in total invertebrate abundance, biomass, and species diversity (average number of species per core) than unprotected sediments. The potential impacts of horseshoe crabs as predators are intertwined with their effects as sediment disturbers. A significant amount of sediment disturbance by horseshoe crabs also occurs during egg deposition (Jackson et al. 2005; Nordstrom et al. 2006; Smith 2007), and this may be an extremely important mechanism by which eggs in deep sediments are moved to the sediment surface where they are accessible to foraging shorebirds.

Chatterji et al. (1992) reported that diets of trilobite larvae of *T. gigas* include mollusks, insects, crustaceans, and polychaetes. Decayed organic material, sand, and plant detritus were highest from July to October, coinciding with the period when preferred molluscan species were lowest.

Horseshoe crabs' carapaces frequently serve as a substrate for encrusting invertebrates and algae. These associations are neither parasitic nor commensal and are better described by the term epibiosis (Wahl 1989): a non-symbiotic, facultative association between the substrate organism and sessile animals (epizoans) or algae (epiphytes). Bryozoans, barnacles, tube-building polychaetes, and sessile mollusks such as mussels, oysters, and slipper limpets are among the more conspicuous epibionts on the three species of horseshoe crabs that have been studied, namely *T. gigas* (Key et al. 1996; Patil and Anil 2000) and *C. rotundicauda* (Key et al. 1996). Horseshoe crabs are dietary generalists, and adult crabs are ecologically important bivalve predators in some locations.

The considerable economic value of horseshoe crabs for lysate, bait, and ecotourism makes a very forceful case for the need for sustainable horseshoe crab populations (Berkson and Shuster 1999; Manion et al. 2000). Limited knowledge exists about predation and other ecological factors affecting horseshoe crabs. We are also unaware whether the increase in salinity or any shift in environmental parameters has any impact on the survivability of these species (Saha 1989).

STATUS AND THREATS

The greatest threat to horseshoe crab populations in India is the destruction of beaches where the adults spawn. Less information exists on the impact or threats of biomedical industry or from large-scale fisheries to the populations of horseshoe crabs at the Sundarbans.

Both the habitat destruction and the removal of spawning animals are localized problems which can be managed by increasing the awareness and involvement of the people who are directly or indirectly involved with the coastal environment. In recent times, global climate change may also be playing a major role in the form of an increasing number and/or intensity of

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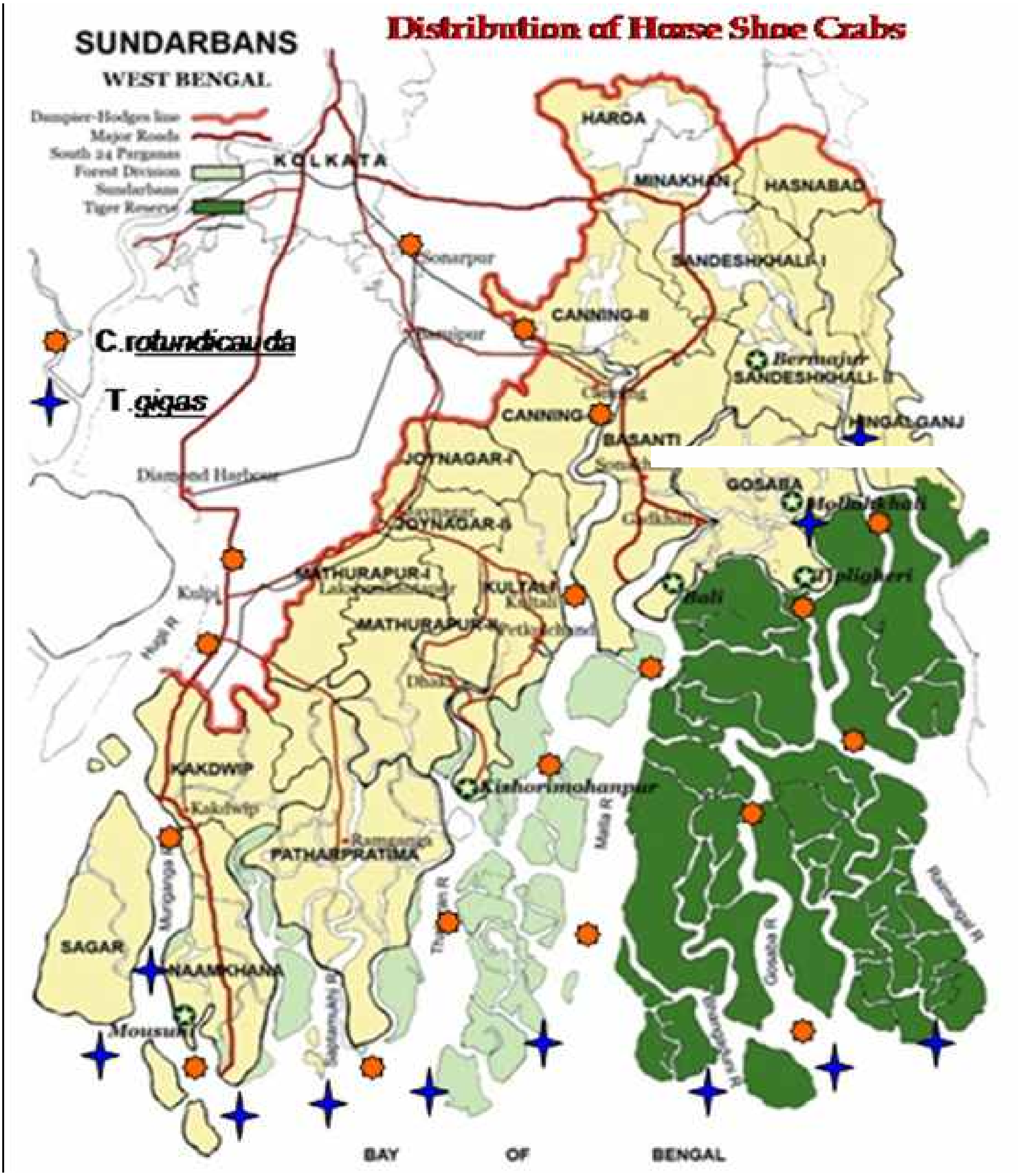
[1]ERDG (The Ecological Research and Development Group). 2010. “Ecological Importance of Horseshoe Crabs” (accessed September 18, 2010). http://www.horseshoecrab.org/con/con.html#bio.

natural calamities in the form of super cyclones and tsunamis, which destroy the coastal environment and breeding beaches.

The Ministry of Environment, Forests, and Wildlife (Government of India) through its Man and Biosphere Committee (MAB-India) and the Zoological Survey of India (ZSI), launched 'Bio-ecological studies of Horseshoe Crabs in Indian Coastal Region' to gather more information on these two animal species found in the Sundarbans. In the same year, the STR in India realized the need for protection of these animals and appealed and launched an awareness campaign for deep sea, estuarine, and coastal fishermen not to slaughter the harmless and priceless animals available in its territory. Captive rearing of these animals at the Sajnekhali Bird Sanctuary area and at Gosaba (across Sajnekhali Bird Sanctuary) were started. Protection measures were also initiated while issuing fishing permits within the biosphere area (Sanyal 1987; Saha 1989).

Distribution of Horse Shoe Crabs



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2.10 CRUSTACEA

The name crustacea is derived from the Latin word crusta which means 'hard shell'. It was used originally to designate an animal with a hard but flexible crust in contrast to a brittle shell like that of oysters or clams.

M. K. DEV ROY
Carcinologist

OF THE TOTAL 547 SPECIES OF CRUSTACEANS RECORDED SO FAR FROM THE STATE OF WEST BENGAL, 329 SPECIES ARE KNOWN FROM SUNDARBAN

Crustacea belong to the phylum Arthropoda and include familiar groups such as barnacles, crabs, shrimps, crayfishes, lobsters, and wood-lice, as well as a myriad of small animals that mostly go unnoticed. They are the third largest group of the phylum. Although they contain a lesser number of species than either insects or arachnids, in terms of diversity of form they exceed both the groups taken together. Crustaceans are essentially aquatic (freshwater, marine, and brackish) although some have adapted successfully on land also. As a group, the subphylum is of great importance. They, especially the small, inconspicuous ones play a vital role in global ecology as the major trophic link between primary producers (phytoplankton) and higher-level consumers (fishes) in marine and freshwater food webs. Apart from this role in food webs, some of the largest species of crustaceans are of considerable economic importance. Lobster, shrimp, crab, and even freshwater crayfish support important fishing industries. Crustaceans are also becoming increasingly important in aquaculture. The value of crustaceans produced in aquaculture has been estimated to be as great as that of fish.

The enormous morphological and ecological heterogeneity exhibited by crustacea rivals that of any other animal taxon. It includes tiny forms ranging in size from less than a millimeter in length to giant spider crabs with a leg span of 4 m. There are nearly 60,000 described species of crustaceans; about 10 percent of these occur in freshwater. Unlike other groups of arthropods, crustaceans capitalize on the widely varied habitat possibilities offered by specialization of a large number of appendages.

Crustacea represents one of the oldest arthropod groups. It is one of the largest, most diverse, and most successful groups of invertebrates. The taxonomic status of crustaceans has been a subject of much debate among carcinologists. In the classical system, the group has been considered to consist of several taxa which were traditionally recognized as classes although they do not have the same rank in the cladistic analysis. Some authors (Bowman and Abele 1982) have assigned the group as one of the phylum, subphylum, or superclass levels with 5, 6, or even 10 classes. However, most of the recent authors consider crustacea as subphylum under the phylum Arthropoda and for this study, this system has been followed.

OVERVIEW OF THE GROUP

The crustacean fauna of the Sundarban region is rich and varied. Of the total 547 species of crustaceans recorded so far from the state of West Bengal, 329 species are known from the Sundarbans (tables 1 and 2). In terms of species diversity, crustaceans represent 61.1 percent of the species hitherto known from West Bengal. However, the first comprehensive work on Sundarban fauna was by Mandal and Nandi (1989) while the first consolidated work on crustacean diversity of the Sundarban mangroves was published by Dev Roy and Nandi (2001).

SYNOPTIC VIEW

Crustacea are of great ecological, economic, and medical importance. They are the major sources of protein next only to fish. A few species are also indicators of pollution.

Diversity

At the global level, there are about 60,000 described species of crustacea known so far, belonging to 860 families under 8,030 genera. In India, approximately 3,549 species belonging to 315 families and 1,297 genera have been recorded, which is roughly 5.91 percent of the total global crustacean species (table 1). The

Table 1. Estimated number of crustacean genera, family and species reported so far from the world, India and Sundarban

Faunal group	Occurrence of family			Occurrence of genera			Occurrence of species		
	W*	I	S	W	I	S	W	I	S
Notostraca	1	1	-	2	1	-	16	5	-
Diplostraca	5	3	1	19	9	1	450	39	1
Cladocera	12	10	3	52	41	3	600	144	3
Anostraca	7	5	1	25	5	1	200	7	1
Cirripedia	47	11	7	203	23	10	1025	95	14
Copepoda	219	72	27	2300	265	41	14000	767	76
Branchiura	1	1	1	4	1	1	200	14	1
Ostracoda	54	23	2	693	76	2	7500	204	2
Stomatopoda	17	9	4	90	26	10	412	77	21
Bathynellacea	3	1	-	23	5	-	253	8	-
Mysidacea	6	2	1	140	34	2	1023	93	2
Amphipoda	157	35	5	840	95	9	6700	161	10
Isopoda	120	22	4	700	155	10	11,000	301	20
Tanaidacea	21	3	-	100	6	-	850	6	-
Cumacea	8	5	1	102	15	1	800	55	1
Euphausiacea	2	1	-	12	7	-	90	23	-
Decapoda	180	111	39	2725	533	92	14, 756	1550	177
Total	**860**	**315**	**96**	**8030**	**1297**	**183**	**59, 875**	**3549**	**329**

* Of extant families only

Abbreviations used: W= World I= India S= Sundarban diversity is contributed mainly by the marine groups. Decapoda contain the maximum number of species (1,550) and among the decapods, brachyurans represent the highest number of species (916). Out of 1,297 genera recorded from India, 183 genera occur in the Indian Sundarbans (table 2). The familial and generic diversity of crustaceans from the Sundarban mangrove ecosystem indicates higher taxic diversity than other mangrove ecosystems in India (table 3).

Species Richness and Functional Groups

5.91% OF THE TOTAL GLOBAL SPECIES ARE IN INDIA

The list of crustacean species recorded so far from India is provided in annexure. Out of six classes recognized by Bowman and Abele (1982), two classes, namely Cephalocarida and Remipedia, do not occur in the Indian Sundarbans. Of 3,549 species of crustaceans recorded from India, 329 species have been found to occur in the Indian Sundarbans. This accounts for 9.3 percent of the species recorded from India. Species richness and their functional guilds of the Sundarbans are presented in table 4 and figure 1 and listed in the annexure.

Blue Fiddler (Uca triangularis)

Table 2: Number of family, genera and species in West Bengal and Sundarban

Faunal Groups	Estimated number of					
	Families		Genera		Species	
	West Bengal	Sunda-rbans	West Bengal	Sunda-rbans	West Bengal	Sunda-rbans
Diplostraca	1	1	1	1	1	1
Cladocera	9	3	37	3	81	3
Anostraca	1	1	1	1	1	1
Cirripedia	7	7	10	10	15	14
Copepoda	32	27	63	41	114	76
Branchiura	1	1	1	1	3	1
Ostracoda	4	2	11	2	16	2
Stomatopoda	5	4	11	10	24	21
Mysidacea	1	1	4	2	4	2
Amphipoda	7	5	14	9	16	10
Isopoda	10	4	22	10	40	20
Tanaidacea	1	-	1	-	1	-
Cumacea	1	1	1	1	1	1
Decapoda						
Dendrobranchiata	4	3	11	7	26	16
Pleocyemata	40	36	103	85	204	161
Total	**124**	**96**	**291**	**183**	**547**	**329**

Table 3. Familial and generic diversity of crustaceans from mangrove ecosystems in India

Faunal Group	Sundar-bans, West Bengal		Bhitar-kanika, Orissa		Pichavar-am, Tamil Nadu		Kerala		A&N islands	
Macrofauna	**F**	**G**	**F**	**G**	**F**	**G**	**F**	**G**	**F**	**G**
Cirripedia	7	10	1	1	1	1	-	-	1	1
Stomatopoda	3	7	-	-	-	-	-	-	1	2
Amphipoda	5	9	4	4	3	4	2	2	1	1
Isopoda	4	9	2	2	3	3	2	2	2	4
Decapoda										
Dendrobrachiata	3	7	2	3	1	2	1	1	2	6
Pleocyemata	25	57	6	8	8	16	13	21	24	45
Microfauna										
Diplostraca	1	1	-	-	-	-	-	-	-	-
Cladocera	2	2	-	-	-	-	-	-	-	-
Anostraca	1	1	-	-	-	-	-	-	-	-
Copepoda	26	40	14	32	-	-	-	-	8	13
Branchiura	1	1	-	-	-	-	-	-	-	-
Ostracoda	2	2	-	-	-	-	-	-	1	2
Mysidacea	1	2	-	-	-	-	-	-	-	-
Tanaidacea	-	-	2	3	2	2	1	1	-	-
Cumacea	1	1	-	-	-	-	-	-	-	-
Total	**82**	**149**	**31**	**53**	**18**	**28**	**19**	**27**	**40**	**74**

Note: F- families; G-Genus

*Revised and updated from Dev Roy and Nandi (2001)

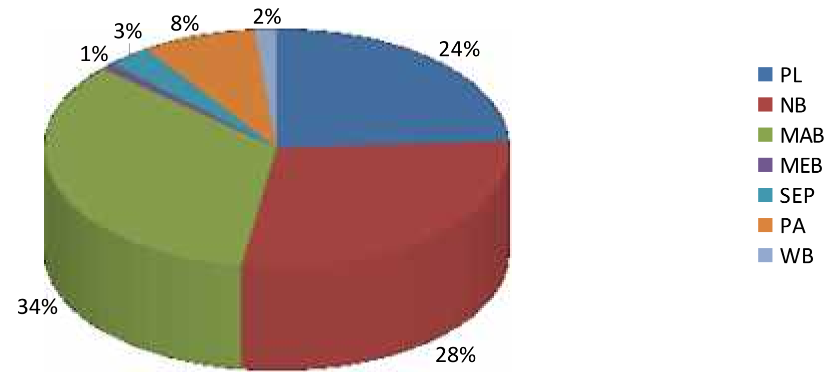
Table 4. Species richness and ecological groups of crustacean fauna of Sundarbans

Group	PL	NB	MAB	MEB	SEP	PA	WB
Cladocera	1	-	-	-	-	-	-
Cladocera	3	-	-	-	-	-	-
Anostraca	1	-	-	-	-	-	-
Cirripedia	-	-	-	-	10	4	-
Calanoida	49	-	-	-	-	-	-
Harpacticoida	7	-	-	3	-	-	-
Cyclopoida	10	-	-	-	-	6	-
Branchiura	-	-	-	-	-	1	-
Ostracoda	2	-	-	-	-	-	-
Stomatopoda	-	21	-	-	-	-	-
Mysidacea	2	-	-	-	-	-	-
Amphipoda	1	-	9	-	-	-	-
Isopoda	1	-	-	-	-	14	5
Cumacea	1	-	-	-	-	-	-
Debdrobranchiata	1	15	-	-	-	-	-
Pleocyemata	-	57	103	-	-	1	-
Total	**79**	**93**	**112**	**3**	**10**	**26**	**5**

* Terminologies adopted here are after Dev Roy and Nandi (2001)

Abbreviation used: PL= Pelagic/Planktonic NB= Nektobenthos MAB= Mac - robenhos MEB= Meiobenthos SEP=Sedentary Epibenthos PA= Parasitic WB= Wood-borer

Fig 1: Functional Guild strucure of crustacean fauna



Distribution

Distribution pattern of crustacean diversity from the world, including India, is shown in table 5. A comparison of species biodiversity in Indian mangroves and other mangroves in the world shows that the species richness is highest in the Sundarbans. However, distribution of crustaceans by development or forest block in the Sundarbans is fragmentary (see annexure) due to lack of such survey conducted specially for the purpose.

Table 5. Species diversity in Indian mangroves and other mangroves in the world

Faunal Group	Indian Mangroves				Other mangroves		
	West Bengal	Orissa	Tamil Nadu	Kerala	Andaman & Nicobar Islands	Singapore	Australia
Macrofauna							
Cirripedia	14	-	2	-	1	2	18
Isopoda	16	2	4	2	4	2	14
Amphipoda	12	4	4	2	1	1	7
Stomatopoda	16	-	-	-	2	-	-
Decapoda							
Dendrobrachiata	16	1	3	3	11	9	3
Pleocyemata							
Caridea	20	1	-	-	5	-	8
Anomura	6	1	-	-	5	7	2
Brachyura	87	8	49	26	54	78	98
Microfauna							
Diplostraca	1	-	-	1	-	-	-
Cladocera	2	-	-	-	-	-	-
Anostraca	1	-	-	-	-	-	-
Copepoda	56	43	39	-	15	-	-
Branchiura	1	-	-	-	-	-	-
Ostracoda	2	-	-	-	2	-	-
Mysidacea	1	-	-	-	2	-	-
Tanaidacea	1	3	3	1	-	-	1
Cumacea	1	1	-	-	-	-	-
Total	**257**	**71**	**109**	**35**	**97**	**99**	**162**

*Revised and updated from Dev Roy and Nandi, (2001)

Community Dependencies and Traditional Usage

Economically important:
21 species of prawns
15 species of crabs
2 species of lobsters

The estuaries, creeks, and mudflats of the Sundarbans support a good number of commercially important crustacean species such as prawns (21 species), crabs (15 species), and lobsters (2 species). The commercially important prawns belong to three families—Penaeidae, Palaemonidae, and Sergestidae—and crabs to four families—Portunidae, Grapsidae, Parathelphusidae, and Calappidae. Out of the 21 species of prawns recorded (table 6), 19 species are widely used for human consumption and the remaining two are used mainly in the fish meal industry. Among these most important species are *Penaeus monodon*, *P. indicus*, *Metapenaeus monoceros*, *M. brevicornis*, and *Macrobrachium rosenbergii*. *Penaeus monodon* is often referred to as the 'Living dollar' of the Sundarbans. The collection of prawn seed of *Penaeus monodon* has become a part of the economy in the Sundarbans. Large numbers of men, women, and children are engaged in seed collection from dawn to dusk.

The average landing of prawns was 18,840 metric tons in 2002 (Dev Roy and Nandi 2004). However, the total crustacean landing from the State of West Bengal during 2007 was recorded as 28,135 tons. All the species of prawns are available almost throughout the year. Their market price is highly variable, from INR 200–1,000 per kg depending upon the size. The giant freshwater prawn, *Macrobrachium rosenbergii*, is widely cultured and is an important export item from West Bengal.

Giant freshwater prawn, (Macrobrachium rosenbergii)

Table 6. Economically important species of crustaceans of West Bengal

Sl. No.	Name of the species	Occurrence	Fishing Season
	Family Penaeidae		
1.	*Fenneropenaeus indicus*	Common	Throughout the year
2.	*Fenneropenaeus merguiensis*	Common	Throughout the year
3.	*Fenneropenaeus penicillatus*	Common	Throughout the year
4.	*Marsupenaeus japonicas*	Occasional	Throughout the year
5.	*Metapenaeus a inis*	Abundant	Throughout the year
6.	*Metapenaeus brevicornis*	Abundant	Throughout the year
7.	*Metapenaeus lysianasa*	Abundant	Throughout the year
8.	*Metapenaeus monoceros*	Abundant	Throughout the year
9.	*Parapenaeopsis sculptilis*	Abundant	Throughout the year
10.	*Parapenaeopsis stylifera*	Common	Throughout the year
11.	*Penaeus (Penaeus) monodon*	Abundant	Throughout the year
12.	*Penaeus (Penaeus) semisulcatus*	Common	Throughout the year
	Family Palaemonidae		
13.	*Exopalaemon styliferus*	Abundant	Throughout the year
14.	*Macrobrachium equidens*	Common	Throughout the year
15.	*Macrobrachium lamarrei*	Abundant	Throughout the year
16.	*Macrobrachium mirabile*	Common	Throughout the year
17.	*Macrobrachium rosenbergii*	Common	Throughout the year
18.	*Macrobrachium rude*	Common	Throughout the year
19.	*Nematopalaemon tenuipes*	Abundant	Throughout the year

Sl. No.	Name of the species	Occurrence	Fishing Season
	Family Sergestidae		
20.	*Acetes erythraeus*	Common	Throughout the year
21.	*Acetes indicus*	Abundant	Throughout the year
	Family Parathelphusidae		
22.	*Sartoriana spinigera*	Common	Almost throughout the year but mainly during the monsoon
23.	*Spiralothelphusa hydrodromus*	Common	Same as above
	Family Portunidae		
24.	*Scylla serrata*	Abundant	Throughout the year
25.	*Scylla tranquebarica*	Abundant	Throughout the year
26.	*Portunus pelagicus*	Occasional	Winter
27.	*Portunus sanguinolentus*	Occasional	Winter
28.	*Charybdis (Charybdis) feriatus*	Occasional	Winter
29.	*Charybdis (Charybdis) helleri*	Rare	Winter
30.	*Charybdis (Charybdis) orientalis*	Rare	Winter
31.	*Charybdis (Charybdis) rostrata*	Occasional	Almost throughout the year
	Family Varunidae		
32.	*Varuna litterata*	Abundant	April to June
	Family Matutidae		
33.	*Ashtoret lunaris*	Common	Almost throughout the year
34.	*Matuta planipes*	Abundant	Almost throughout the year
	Family Calappidae		
35.	*Calappa lophos*	Occasional	Winter
36.	*Calappa pustulosa*	Occasional	Winter

Among the brachyurans, the two species of mud crabs, namely *Scylla serrata* and *S. tranquebarica*, are considered a delicacy and highly priced for their large size, high-quality meat content. About 1,000–1,400 tons of mud crabs are landed annually from the Sundarbans. This crab species is exported live to countries like Japan; Hong Kong SAR, China; and Singapore. As many as 10,000 families are dependent on crab fishing (either full-time or part-time) for their livelihood in the Sundarbans. Besides, the varunid crab, *Varuna litterata*, commonly known as 'Chiti Kankra', has appreciable commercial value in the local markets of the Sundarbans.

Among the portunid crabs, *Scylla serrata* and *S. tranquebarica* are harvested throughout the year; the remaining species are landed during winter fishing. The Matutid and calappid crabs are, however, not consumed by the local people but these are sun dried, powdered, and used as poultry feed. The parathelphusid crabs, *Sartoriana spinigera* and *Spiralothelphusa hydro-dromus*, are available in appreciable quantities and mostly marketed in the suburban and rural areas of the state, including the Sundarbans. Their fishing period is, however, restricted to only certain months of the year. *V.*

Mud crab (Scylla seratta)

litterata is landed from April to June while *S. spinigera* and *S. hydrodromous* are mainly available during the monsoon.

Ecological Importance and Need for Conservation

The crustacea are directly important to man mostly as food. Dried isopods and several species of crabs are used as traditional medicines in many parts of the world. Aquaculture and fisheries are dependent upon the smaller species of crustacean or micro crustaceans. It is believed that the presence of isopods in Caribbean fishes indicates that the fish is free from ciguatera (fish poisoning) toxins (not tested). Crustacea are also used as fish bait. Some crustaceans such as crayfish, ghost crab, and land crab are beneficial as they play an important role as scavengers and help keep the beaches clean by way of feeding on decaying animal matter.

The ecological role of crabs in the degradation of plant matters to detritus is now well established. The repeated burrowing and reburrowing activities of the burrowing decapod crustaceans cause an increase in aeration of soil, mixing of soil, and even decrease in salinity. The decapods also play a vital role in the recycling of minerals and organic matters. Such activities of decapods create suitable microhabitats for the sustenance of other animal species. The construction of a wide variety of bioturbation structures by crabs are also of much significance for they trap sediments and mangrove seeds.

Varunid crab (Varuna litterata)

Ghost crab (Ocypode macrocera)

However, several crustaceans become pests when they occur in large numbers. Crabs cause much damage to cultivated crops by eating the tender parts of plants and by digging tunnels on the earthen bunds (*kazins/aal*) of paddy fields so that water leaks and the rice plant is killed due to drying action of the sun. Others such as isopods which also feed on vegetation may become pests in greenhouses and fields when sufficiently numerous. Some of the sesarmine and fiddler crabs are considered as forest pests and in some parts of South Asian countries such as Peninsular Malaysia, the severity of their attack is of such magnitude that forest plantation often becomes almost impossible. These crabs usually girdle the root collar and consume the fleshy cambium of the propagules. Crustaceans also bore into marine timber structures (such as wooden jetties, piles, poles, and country boats). Bopyrid isopods pose threats to the prawn industry, as also reported in Australia, by infecting about US$1.5–2.0 million dollar worth of prawns annually. Fouling crustaceans, such as barnacles, can cause serious damage by attaching themselves to the hulls of ships, lowering the speed by about 50 percent, and resulting in more fuel consumption. Millions of rupees are involved annually in the removal of fouling organisms by docking, scraping, and repainting of ships.

Red fiddler (Uca rosea)

Acorn Barnacle

STATUS AND THREATS

> To catch each Tiger Prawn seed, collectors destroy 161 juveniles of other prawns, 7 fishes, 30 crabs, 1 mollusc & 8 unidentified meroplanktons

While many crustacean species occur in large numbers, however, there are species which are much rarer. Hilton-Taylor (2000) enlisted 479 species of crustaceans as extinct, 57 as critically endangered, and 77 as endangered. In the Red List published by IUCN in 2008, 89 species of crabs and copepods are included from India as nearly threatened, vulnerable, least concerned, and data deficient. Of these, two species, *Sartoriana spinigera* (Wood-Mason 1871) and *Spiralothelphusa hydrodromus* (Herbst 1794), are known to occur in the Indian Sundarbans. Both the species are however very common in this part of the country.

Main threats to crustacean components are destruction of habitat and pollution. Destruction and alteration of habitats for human settlement, agriculture, and intensive aquacultural practices without appropriate planning have resulted in the loss of faunal diversity in the recent past. Encroachment of mangrove areas for setting up industries and construction of jetties have resulted in large-scale destruction of mangrove forests. The other threats to crustacean diversity are from over-exploitation and collection of undersized specimens as well as large-scale exploitation of prawn seeds. Over-exploitation is also likely to have an adverse effect on the population of commercially important species. Improper planning in setting up tourist resorts in coastal areas may lead to a 'threat' to the mangroves and other estuarine ecosystems. Poor management and sewage disposal can bring about irreparable damage to the mangroves, which may even lead to the disappearance of mangrove biota.

In the Sundarbans, natural mangrove habitats have reportedly declined considerably due to reclamation for various developmental purposes like aquaculture and agriculture. The semi-intensive and modified intensive shrimp culture in the brackish-water *bheries* of the Sundarbans is leading to large inflow of organic and inorganic pollutants. Besides, there are also natural threats like soil erosion, recurrence of floods and storms, and changes in salinity in the estuarine ecosystem that pose a threat to faunal diversity.

> Reclamation, pollution from semi-intensive and modified intensive shrimp culture as well as changes in salinity in the estuarine ecosystem poses threat.

The unabated pollution of rivers, creeks, and ponds coupled with large-scale reclamation of land for human settlement and industrial development and also use of insecticides in agricultural fields are especially posing serious threats to aquatic crustacean fauna. In addition, large-scale removal of juveniles and berried females by fishing trawlers and use of fine-mesh nets during 'Bagda' seed collections also affect the crustacean population, leading to the loss of biodiversity. According to a report, to catch 1 tiger prawn seed in the Sundarbans, collectors destroyed juveniles of 161 other prawns, 7 fishes, 30 crabs, 1 mollusc, and 8 unidentified meroplanktons (Das and Nandi 1999). Often many species are harvested indiscriminately without knowing the effects of over-exploitation on the species and the ecosystem.

Due to continuous growth of coastal population, pressures of the environment from land-based to marine-based human activities have increased manifold. As a result, coastal and marine living resources and their habitats are being lost or damaged in ways that are diminishing biodiversity, including crustacean biodiversity. The dependency on the ecosystem, however, can be brought down substantially by way of encouragement to alternate means of livelihood such as paddy-cum-fish culture, paddy-cum-prawn culture, apiary, duckery, mussel culture, and so on.

ANNEXURE

Systematic list of species occurring in Sundarbans

Sl. No.	Group and Species	Habitat	F. G.*	Locality & References
	Subhylum CRUSTACEA Brünnich, 1772			
	Class BRANCHIOPODA Latreille, 1817			
	Order CONCHOSTRACA Sars, 1867			
	Family **CYCLESTHERIIDAE** Sars, 1899			
1.	*Cyclestheria* sp.	FW	PL	Sundarban (Anonymous, 1987)
	Class BRANCHIOPODA Latreille, 1817			
	Subclass DIPLOSTRACA Gerstaecker, 1866			
	Superorder CLADOCERA Latreille, 1829			
	Order ANOMOPODA Stebbing, 1902			
	Family **BOSMINIDAE** Baird, 1845			
2	*Bosminopsis* sp.	FW	PL	Sundarbans (Mandal & Nandi, 1989)
	Family **DAPHNIIDAE** Straus, 1820			
3	*Ceriodaphnia cornuta* Sars, 1825	BW	PL	Port Canning (Annandale, 1907)
	Order ONYCHOPODA Sars, 1865			
	Family **PODONIDAE** Mordukhai-Boltovskoi, 1968			
4.	*Evadne* sp.	BW	PL	Mandirtala (Anonymous, 1987)
	Subclass SARCOSTRACA Tasch, 1969			
	Order ANOSTRACA Sars, 1867			
	Family **ARTEMIIDAE** Grochowski, 1896			
5.	*Artemia salina* (Linnaeus, 1758)	BW	PL	Sundarbans (Mandal & Nandi, 1989)
	Class MAXILLOPODA Dahl, 1956			
	Subclass CIRRIPEDIA Burmeister, 1834			
	Order THORACICA Darwin, 1854			
	Superfamily LEPADOMORPHA Pilsbry, 1916			
	Family **LEPADIDAE** Darwin, 1852			
6.	*Lepas antifera* Linnaeus, 1767	BW/ CW	SE	Sundarbans (Mandal & Nandi, 1989)
7.	*Conchoderma hunteri* (Owen, 1830)	BW/ CW	SE	Sundarbans (Mandal & Nandi, 1989)
	Family **POECILASMATIDAE** Annandale, 1909			
8.	*Octolasmis cor* (Aurivillius, 1892)	BW/ CW/	PA	Sundarbans (Nilsson-Cantell, 1938)
9.	*Octolasmis orthogonia* (Darwin, 1851)	BW/ CW	PA	Sundarbans (Mandal & Nandi, 1989)
10.	*Octolasmis warwickii* Gray, 1825	BW/ CW	PA	Sundarbans (Mandal & Nandi, 1989)
	Superfamily CHTHAMALOIDEA Darwin, 1854			
	Family **CHTHAMALIDAE** Darwin, 1854			

Sl. No.	Group and Species	Habitat	F. G.*	Locality & References
11.	*Eurapia withersi* (Pilsbry, 1916)	BW/ CW	SE	Port Canning (Nilsson-Cantell, 1938)
12.	*Chthamalus malayensis* Pilsbry, 1916	BW/ CW	SE	Port Canning (Annandale, 1906); Sundarbans (Mandal & Nandi, 1989)
	Superfamily BALANOIDEA Leach, 1817			
	Family **ARCHAEOBALANIDAE** Newmann and Ross, 1976			
13.	*Chirona amaryllis* (Darwin, 1854)	BW/ CW	SE	Port Canning (Nilsson-Cantell, 1938)
	Family **BALANIDAE** Leach, 1817			
14.	*Amphibalanus cirratus* Darwin, 1854	BW/ CW	SE	Sandheads (Nilsson-Cantell, 1938)
15.	*Amphibalanus variegatus (* Darwin, 1854)	BW/ CW	SE	Port Canning (Nilsson-Cantell, 1938)
16.	*Balanus patellaris* (Spengler, 1780)	BW/ CW	SE	Canning (Annandale, 1906)
	Family **MEGABALANIDAE**			
17.	*Megabalanus tintinnabulum* (Linnaeus, 1758)	BW/ CW	SE	Sandheads (Nilsson-Cantell, 1938)
	Superfamily CORONULOIDEA Lesch, 1817			
	Family **CHELONIBIIDAE** Pilsbry, 1916			
18.	*Chelonibia testudinaria* (Linnaeus, 1758)	BW/ CW	SE	Sundarbans (Mandal & Nandi, 1989)
	Order RHIZOCEPHALA F. Müller, 1862			
	Family **SACCULINIDAE** Lilljeborg, 1861			
19.	*Sacculina carcini* Thompson, 1836	CW	PA	Mouth of the River Hugli (Annandale, 1911)
	Subclass COPEPODA H. Milne Edwards, 1840			
	Order CALANOIDA Sars, 1903			
	Superfamily CENTROPAGOIDEA Giesbrecht, 1892			
	Family **ACARTIIDAE** Sars, 1903			
20.	*Acartia (Odontacartia) centrura* Giesbrecht, 1889	BW/CW	PL	Hugli-Matla estuary (Khan, 1995)
21.	*Acartia (Odontacartia) erythraea* Giesbrecht, 1889	BW/CW	PL	Hugli-Matla estuary (Khan, 1995)
22.	*Acartia (Odontacartia) spinicauda* Giesbrecht, 1889	BW	PL	Chemaguri (Anonymous, 1987)
23.	*Acartiella keralensis* Wellershaus, 1969	BW/CW	PL	Kachuberia (Anonymous, 1987)
24.	*Acartiella major* Sewell, 1919	BW	PL	Gazikhali (Roy, 1998)
25.	*Acartiella sewelli* Steuer, 1934	FW/BW	PL	Kachuberia (Anonymous, 1987)
26.	*Acartiella tortaniformis* (Sewell, 1919)	BW	PL	Bidya River, Pirkhali, Sundarban (Roy, 1998)
	Family **CANDACIIDAE** Giesbrecht, 1892			

Sl. No.	Group and Species	Habitat	F. G.*	Locality & References
27.	*Candacia bradyi* A. Scott, 1902	BW/CW	PL	South Sagar (Anonymous, 1987)
	Family **CENTROPAGIDAE** Giesbrecht, 1892			
28.	*Centropages alcocki* Sewell, 1912	BW	PL	Hugli-Matla estuary (Khan, 1995)
29.	*Centropages dorsispinatus* Thompson and Scott, 1903	BW/CW	PL	South Sagar, Mandirtala, Mooriganga (Anonymous, 1987)
30.	*Centropages furcatus* Dana, 1849	BW	PL	South Sagar (Anonymous, 1987)
	Family **DIAPTOMIDAE** Baird, 1850			
31.	*Heliodiaptomus (Heliodiaptomus) viduus,* (Gurney, 1916)	FW/BW	PL	Hugli-Matla estuary (Khan, 1995)
32.	*Heliodiaptomus (Indodiaptomus) cinctus* (Gurney, 1907)	BW	PL	Hugli-Matla estuary (Khan, 1995)
33.	*Heliodiaptomus (Indodiaptomus) contortus* (Gurney, 1907)	BW	PL	Hugli-Matla estuary (Khan, 1995)
34.	*Neodiaptomus schmackeri* (Poppe and Richard, 1892)	FW/BW	PL	Hugli-Matla estuary (Khan, 1995); Kachuberia, Mandirtala (Anonymous, 1987)
35.	*Phyllodiaptomus blanci* (De Guerne and Richard, 1896)	FW	PL	Hugli-Matla estuary (Khan, 1995)
	Family **PONTELLIDAE** Dana, 1853			
36.	*Calanopia elliptica* (Dana, 1849)	BW/CW	PL	Hugli-Matla estuary (Khan, 1995)
37.	*Labidocera acuta* Dana, 1849	BW/CW	PL	Hugli-Matla estuary (Khan, 1995)
38.	*Labidocera euchaeta* Giesbrecht, 1889	BW	PL	Chemaguri, Mandirtala (Anonymous, 1987)
39.	*Labidocera minutum* Giesbrecht, 1889	BW/CW	PL	South Sagar (Anonymous, 1987)
40.	*Labidocera pavo* Giesbrecht, 1889	BW	PL	Bidyadhari river and Kachia Khal (Roy, 1998)
41.	*Labidocera pectinata* Thompson & A. Scott, 1903	BW/CW	PL	Hugli-Matla estuary (Khan, 1995)
42.	*Pontella andersoni* Sewell, 1912	BW/CW	PL	Chemaguri, South Sagar (Anonymous, 1987)
43.	*Pontellopsis herdmani* Thompson & A. Scott., 1903	BW/CW	PL	South Sagar (Anonymous, 1987)
	Family **PSEUDODIAPTOMIDAE** Sars, 1902			
44.	*Pseudodiaptomus aurivilli* Cleve, 1901	BW/CW	PL	Kachuberia, Chemaguri (Anonymous, 1987)
45.	*Pseudodiaptomus binghami* Sewell, 1912	BW	PL	Kachuberia (Anonymous, 1987); Gazikhali (Roy, 1998)
46.	*Pseudodiaptomus daughlishi* Sewell, 1932	BW	PL	Mandirtala, South Sagar (Anonymous, 1987)
47.	*Pseudodiaptomus hickmani* Sewell, 1912	BW/CW	PL	Mandirtala, South Sagar (Anonymous, 1987)
48.	*Pseudodiaptomus lobipes* Gurney, 1907	BW	PL	Gazikhali (Roy, 1998)
49-.	*Pseudodiaptomus masoni* Sewell, 1932	BW/CW	PL	Mandirtala, South Sagar (Anonymous, 1987)
50.	*Pseudodiaptomus tollingeri* Sewell, 1919	FW/BW	PL	Mandirtala, Chemaguri (Anonymous, 1987); Pirkhali, Gazikhali (Roy, 1998)
51.	*Schmackeria annandalei* (Sewell, 1912)	BW	PL	Kachuberia, Chemaguri, South Sagar, Mooriganga (Anonymous, 1987)

Sl. No.	Group and Species	Habitat	F. G.*	Locality & References
52.	*Schmackeria serricaudatus* (T. Scott, 1894)	BW	PL	Hugli-Matla estuary (Khan, 1995)
	Family **TEMORIDAE** Giesbrecht, 1892			
53.	*Temora discaudata* Giesbrecht, 1889	BW/CW	PL	Chemaguri, South Sagar (Anonymous, 1987)
54.	*Temora turbinata* (Dana, 1849)	BW/CW	PL	Chemaguri, South Sagar (Anonymous, 1987)
	Family **TORTANIDAE** Sars, 1902			
55.	*Tortanus forcipatus* (Giesbrecht, 1889)	BW/CW	PL	Chemaguri, South Sagar (Anonymous, 1987)
56.	*Tortanus gracilis* Brady, 1883	BW/CW	PL	Chemaguri (Anonymous, 1987)
	Superfamily CLAUSOCALANOIDEA Giesbrecht, 1892			
	Family **EUCHAETIDAE** Giesbrecht, 1892			
57.	*Euchaeta concinna* Dana, 1849	BW/CW	PL	South Sagar, Mandirtala (Anonymous, 1987)
58.	*Euchaeta marina* (Prestandrea, 1833)	BW/CW	PL	Moorganga, Chemaguri, South Sagar (Anonymous, 1987)
59.	*Euchaeta tenuis* Esterly, 1906	BW/CW	PL	South Sagar (Anonymous, 1987)
60.	*Euchaeta wolfendeni* A. Scott, 1909	BW/CW	PL	Mooriganga, South Sagar (Anonymous, 1987)
	Superfamily EUCALANOIDEA Giesbrecht, 1892			
	Family **EUCALANIDAE** Giesbrecht, 1892			
61.	*Eucalanus elongatus* (Dana, 1848)	BW/CW	PL	South Sagar, Chemaguri (Anonymous, 1987)
62.	*Eucalanus subcrassus* Giesbrecht, 1888	BW/CW	PL	South Sagar (Anonymous, 1987)
	Superfamily MEGACALANOIDEA Sewell, 1947			
	Family **CALANIDAE** Dana, 1849			
63.	*Acrocalanus inermis* Sewell, 1912	BW/CW	PL	Sundarbans (Khan, 1995)
64.	*Acrocalanus similis* Sewell, 1914	BW/CW	PL	Sundarbans (Khan, 1995)
65.	*Canthocalanus pauper* (Giesbrecht, 1888)	BW/CW	PL	South Sagar (Anonymous, 1987)
66.	*Undinula darwini* (Lubbock, 1860)	BW/CW	PL	South Sagar, Chemaguri (Anonymous, 1987)
	Family **PARACALANIDAE** Giesbrecht, 1892			
67.	*Paracalanus dubia* Sewell, 1912	BW/CW	PL	Sundarbans (Khan, 1995)
68.	*Paracalanus parvus* (Claus, 1863)	BW/CW	PL	Sundarbans (Khan, 1995)
	Order HARPACTICOIDA Sars, 1903			
	Superfamily TACHIDIOIDEA (pro Tachidiidi - morpha Lang, 1948)			
	Family **CLYTEMNESTRIDAE** Scott, 1909			
69.	*Clytemnestra scutellata* Dana, 1849	BW	PL	Chemaguri, South Sagar (Anonymous, 1987)
	Family **HARPACTICIDAE** Dana, 1846			
70.	*Harpacticus* sp.	BW	PL	Sundarbans (Mandal & Nandi, 1989)
	Family **TACHIDIIDAE** Sars, 1909			

Sl. No.	Group and Species	Habitat	F. G.*	Locality & References
71.	*Tachidius (Tachidius) disciples* Giesbrecht, 1881	BW	PL	Kahcuberia (Anonymous, 1987)
	Infraorder PODOGENNONTA Lang, 1948			
	Superfamily CLETODOIDEA (pro Cletodidimor - pha Lang, 1948)			
	Family **CLETODIDAE** T. Scott, 1904			
72.	*Enhydrosoma vervoorti* Fiers, 1987	BW	MEB	Sagar Island (Fiers, 1987
73.	*Nitocra lacustris lacustris* (Schmankevitsch, 1875)	BW	MEB	Sagar Island (Fiers, 1987)
	Family **LAOPHONTIDAE** T. Scott, 1904			
74.	*Laophonte* sp.	BW/CW	MEB	South Sagar, Chemaguri, Mooriganga (Anonymous, 1987)
	Superfamily THALESTROIDEA (pro Thalestridi - morpha Lang, 1948)			
	Superfamily			
	Family **MIRACIIDAE** Dana, 1846			
75.	*Cladorostrata brevipoda* Shen and Tai, 1963	BW/CW	PL	Chemaguri (Anonymous, 1987)
76.	*Macrosetella gracilis* (Dana, 1848)	BW/CW	PL	Chemaguri, South Sagar (Anonymous, 1987)
77.	*Microsetella rosea* (Dana, 1849)	BW/CW	PL	South Sagar (Anonymous, 1987)
	Family **EUTERPINIDAE** Brian, 1921			
78.	*Euterpina acutifrons* (Dana, 1849)	BW/CW	PL	Kachuberia, South Sagar, Mooriganga (Anonymous, 1987)
	Order CYCLOPOIDA Burmeister, 1834			
	Family **CYCLOPIDAE** Rafines ue, 1815			
79.	*Halicyclops tenuispina* Sewell, 1924	BW	PL	Kachuberia (Anonymous, 1987)
80.	*Megacyclops viridis* (Jurine, 1820) = *Cyclops viridis* Jurine, 1820	FW	PL	Hugli-Matla estuary (Khan, 1995)
81.	*Mesocyclops hyalinus* (Rehberg, 1880)	FW/BW	PL	Hugli-Matla estuary (Khan, 1995)
82.	*Mesocyclops leuckarti* (Claus, 1939)	FW/BW	PL	Gazikhali (Roy, 1998)
	Family **OITHONIDAE** Dana, 1853			
83.	*Oithona brevicornis* Giesbrecht	BW	PL	Piali River (Khan, 1995)
	Order POECILOSTOMATOIDA Thorell, 1859			
	Family **CLAUSIDIIDAE** Giesbrecht, 1895			
84.	*Saphirella indica* Sewell, 1924	BW/CW	PL	Kachuberia, Chemaguri (Anonymous, 1987)
	Family **CORYCAEIDAE** Dana, 1852			
85.	*Corycaeus agilis* Dana, 1849	BW/CW	PL	South Sagar (Anonymous, 1987)
86.	*Corycaeus catus* F. Dahl, 1894	BW/CW	PL	South Sagar (Anonymous, 1987)
87.	*Corycaeus danae* Giesbrecht, 1891	BW/CW	PL	Mandirtala, Chemaguri (Anonymous, 1987)
	Family **ERGASILIDAE** Nordmann			

Sl. No.	Group and Species	Habitat	F. G.*	Locality & References
88.	*Ergasilus hamiltoni* Southwell and Prashad, 1918	BW	PA	Gosaba (Southwell and Prashad, 1918)
	Family **ONCAEIDAE** Giesbrecht, 1892			
89.	*Oncaea venusta* Philippi, 1843	BW/CW	PL	Chemaguri (Anonymous, 1987)
	Order SIPHINOSTOMATOIDA Thorell, 1859			
	Family **LERNANTHROPIDAE** Kabata, 1979			
90.	*Lernanthropus chrysophrys* Shishido, 1898	BW	PA	Port Canning (Tripathi, 1962a)
91.	*Lernanthropus pami* Tripathi, 1962	BW/CW	PA	Hugli estuary (Tripathi, 1962a)
92.	*Mitrapus engraulis* (Tripathi, 1962)	BW/CW	PA	Hugli (Tripathi, 1962a)
	Family **LERNAEOPODIDAE** Olsson, 1869			
93.	*Clavellisa ilishae* Tripathi, 1962	BW/CW	PA	Hugli estuary (Tripathi, 1962b)
94.	*Clavellisa pellonae* Tripathi, 1962	BW/CW	PA	Hugli estuary (Tripathi, 1962b)
95.	*Clavellisa phasa* Tripathi, 1962	BW/CW	PA	Hugli-Matla (Tripathi, 1962b)
	Subclass BRANCHIURA Thorell, 1864			
	Order ARGULOIDA Rafines ue, 1815			
	Family **ARGULIDAE** Leach, 1819			
96.	*Argulus siamensis* Wilson, 1926	BW	PA	Sundarbans (Mandal and Nandi, 1989); Champahati (present record) Ram - akrishna, 1951
	Class OSTRACODA Latreille, 1806			
	Subclass MYODOCOPA Sars, 1866			
	Order MYODOCOPIDA Sars, 1866			
	Superfamily CYPRIDINOIDEA Baird, 1850			
	Family **PHILOMEDIDAE** Müller, 1906			
97.	*Philomedes* sp.	BW	PL	Chemaguri (Anonymous, 1987)
	Subclass PODOCOPA Müller, 1894			
	Order PODOCOPIDA Sars, 1866			
	Superfamily CYPRIDOIDEA Baird, 1845			
	Family **CYPRIDIDAE** Baird, 1845			
	Subfamily CYPRIDINAE Baird, 1845			
98.	*Cypris* sp.	FW	PL	Sundarbans (Mandal & Nandi, 1989)
	Class MALACOSTRACA Latreille, 1806			
	Subclass HOPLOCARIDA CALMAN, 1904			
	Superfamily SQUILLOIDEA Latreille, 1803			
	Family **HARPIOSQUILLIDAE** Manning, 1980			
99.	*Harpiosquilla annandalei* (Kemp, 1911)	CW	NB	Sundarbans (Mandal & Nandi, 1989); Sandheads (Ghosh, 1998)
100.	*Harpiosquilla harpax* (De Haan, 1844)	CW	NB	Sandheads (Ghosh, 1995)
101.	*Harpiosquilla raphidea* (Fabricius, 1798)	CW	NB	Mouth of River Hooghly and Ganges Delta (Kemp, 1913); Sundarbans (Man - dal & Nandi, 1989); Bakkhali, Fraser-gunj, Kakdwip; Ganga Sagar (Ghosh, 1995)
	Family **SQUILLIDAE** Latreille, 1803			

Sl. No.	Group and Species	Habitat	F. G.*	Locality & References
102.	*Alimopsis supplex* (Wood-Mason, 1875)	CW	NB	Jambudwip (Ghosh, 1995)
103.	*Carinosquilla multicarinata* (White, 1848)	CW	NB	Sundarban (Ghosh, 1995)
104.	*Clorida decorata* Wood-Mason, 1875	CW	NB	Sundarbans (Mandal & Nandi, 1989); Bakkhali and Frasergunj (Ghosh, 1995)
105.	*Clorida latreillei* Eydoux and Souleyat, 1841	CW	NB	Sandheads and Gangetic Delta (Kemp, 1913); Sundarbans (Mandal & Nandi, 1989); Jambudwip (Ghosh, 1998)
106.	*Cloridopsis bengalensis* (Tiwari and Biswas, 1952)	BW/CW	NB	Jhingakhali (Mandal & Nandi, 1989); Sajnakhali, Piali River and Jharkhali (Ghosh, 1998)
107.	*Cloridopsis immaculata* (Kemp, 1913)	BW/CW	NB	Canning, Sajnakhali, Jhingakhali; Choto Mollakhali, Gosaba and Raimangal River (Mandal & Nandi, 1989)
108.	*Cloridopsis scorpio* (Latreille, 1825)	CW	NB	Frasergunj (Ghosh, 1998)
109.	*Dictyosquilla foveolata* (Wood-Mason, 1895)	CW	NB	Sandheads (Ghosh, 1998)
110.	*Oratosquilla holoschista* (Kemp, 1911)	CW	NB	Sundarbans (Mandal & Nandi, 1989); Sandheads (Ghosh, 1998)
111.	*Oratosquilla inornata* (Tate, 1883)	CW	NB	Gangetic Delta (Kemp, 1913); Sandheads (Kemp, 1913; Ghosh, 1998; Sundarbans (Mandal & Nandi, 1989)
112.	*Oratosquilla interrupta* (Kemp, 1911)	CW	NB	Sundarbans (Mandal & Nandi, 1989); Bakkhali, Jambudwip and Ganga Sagar (Ghosh, 1998)
113.	*Oratosquilla nepa* (Latreille, 1825)	CW	NB	Sandheads and Gangetic Delta (Kemp, 1913); Sundarbans (Mandal & Nandi, 1989); Jambudwip (Ghosh, 1998)
114.	*Oratosquilla hindustanica* Manning, 1978	CW	NB	Hoogly Delta (Kemp, 1913); Sandheads (Kemp, 1913; Ghosh, 1998)
115.	*Oratosquilla woodmasoni* (Kemp, 1911)	CW	NB	Sandheads and Gangetic Delta (Kemp, 1913); Sundarbans (Mandal & Nandi, 1989); Sagar Is. (Ghosh, 1998)
116.	*Squilloides gilesi* (Kemp, 1911)	CW	NB	Sundarbans (Mandal & Nandi, 1989); Sandheads (Ghosh, 1998)
	Superfamily LYSIOSQUILLOIDEA Giesbrecht, 1910			
	Family **LYSIOSQUILLIDAE** Giesbrecht, 1910			
117.	*Lysiosquilla tredecimdentata* Holthuis, 1944	CW	NB	Sandheads (Ghosh, 1998)
	Family **NANNOSQUILLIDAE** Manning, 1980			
118.	*Acanthosquilla acanthocarpus* (Miers, 1880)	CW	NB	Sundarbans (Mandal & Nandi, 1989); Sandheads (Ghosh, 1998)
119.	*Acanthosquilla multifasciata* (Wood-Mason, 1895)	CW	NB	Sundarban (Ghosh, 1998)
	Subclass EUMALACOSTRACA Grobben, 1892			
	Superorder PERACARIDA Calman, 1904			
	Order MYSIDACEA Haworth, 1825			
	Family **MYSIDAE** Haworth, 1825			
120.	*Gastrosaccus muticus* W. Tattersall, 1932	BW	PL	Matla River, Gangetic delta (present record)

Sl. No.	Group and Species	Habitat	F. G.*	Locality & References
121.	*Mesopodopsis orientalis* (W. M. Tattersall, 1908)	BW	PL	Port Canning (Tattersall, 1908); Man - dirtala (Anonymous, 1987)
	Order AMPHIPODA Latreille, 1816			
	Suborder COROPHIOIDEA Leach, 1814			
	Family **AORIDAE** Walker, 1908			
122.	*Grandidierella megnae* (Giles, 1888)	BW	MAB	Port Canning (Stebbing, 1908)
123.	*Microdeutopus* sp.	BW	MAB	Sundarbans (Chaudhuri & Choudhury, 1994)
124.	Paraoroides unistylus	BW	MAB	Sagar Is. (Anonymous, 1987)
	Family **PHOTIDAE** Boeck, 1871			
125.	*Dodophotis digitata* (Barnard, 1935)	BW	MAB	Mandirtala, South Sagar (Anonymous, 1987)
126.	*Microphotis* sp.	BW	MAB	Sundabans (Anonymous, 1987)
	Suborder GAMMARIDEA Latreille, 1802			
	Family **AMPELISCIDAE** Costa, 1857			
127.	*Ampelisca pusilla* Sars, 1891	BW	MAB	Gangetic delta (Annandale, 1906)
128.	*Ampelisca zamboanza* Stebbing, 1888	BW	MAB	Sagar Is. (Anonymous, 1987)
129.	*Byblis* sp.	BW	MAB	Sundarbans (Anonymous, 1987)
	Family **GAMMARIDAE** Latreille, 1802			
130.	*Gammarus* sp.	BW	MAB	Sundarbans (Chaudhuri & Choudhury, 1994)
	Family **MERIDAE** Krapp-Schickel, 2008			
131.	*Quadrivisio bengalensis* Stebbing, 1907	BW	PL	Port Canning (Stebbing, 1907); Gangetic delta (Annandale, 1906)
	Order ISOPODA Latreille, 1817			
	Suborder PHREATOICIDEA Stebbing, 1893			
	Suborder CYMOTHOIDEA			
	Family **BOPYRIDAE** Rafines ue, 1815			
132.	*Bopyrus bimaculatus* Chopra, 1923	BW	PA	Gangetic delta and Matla River (Chopra, 1923); Sundarban (Mandal & Nandi, 1989)
133.	*Epipenaeon elegans* Chopra, 1923	BW	PA	Gangetic delta (Chopra, 1923); Sundarban (Mandal & Nandi, 1989)
134.	*Probopyrus abhoyai* (Chopra, 1923)	BW	PA	Sundarban (Mandal & Nandi, 1989)
135.	*Probopyrus alcocki* (Chopra, 1923)	BW	PA	Sundarban (Mandal & Nandi, 1989)
136.	*Probopyrus bengalensis* (Chopra, 1923)	BW	PA	Sundarban (Mandal & Nandi, 1989)
137.	*Probopyrus brachysoma* (Chopra, 1923)	BW	PA	Sundarban (Mandal & Nandi, 1989)
138.	*Probopyrus buitendijki* Horst, 1910	BW	PA	Sundarban (Mandal & Nandi, 1989)
139.	*Probopyrus demani* Weber, 1892	BW	PA	Sundarban (Mandal & Nandi, 1989)
140.	*Probopyrus gangeticus* (Chopra, 1923)	BW	PA	Gangetic delta (Chopra, 1923); Sundarban (Mandal & Nandi, 1989)
141.	*Probopyrus prashadi* (Chopra, 1923)	BW	PA	Gangetic delta (Chopra, 1923); Sundarban (Mandal & Nandi, 1989)
	Family **CIROLANIDAE** Dana, 1852			

Sl. No.	Group and Species	Habitat	F. G.*	Locality & References
142.	*Annina mannai* Schotte, 1994	FW	PL	Mouth of the Ganges (Schotte, 1994)
143.	*Cirolana parva* Hansen, 1890	BW	WB	Sundarbans (Chaudhuri and Choudhury, 1994)
144.	*Dolicholana elongata* (H. Milne Edwards, 1840)	CW	WB	Mouth of the Ganges (H. Milne Edwards, 1840)
	Family **CYMOTHOIDAE** Leach, 1814			
145.	*Cymothoa indica* Schioedt and Meinert	BW	PA	Port Canning (Ghatak, 1995)
146.	*Nerocila madrasensis* Ramakrishna and Ramaniah, 1978	BW	PA	Bakkhali (Ghatak, 1995)
147.	*Nerocila phaeopleura* Bleeker, 1857	BW	PA	Port Canning (Ghatak, 1995)
148.	*Nerocila trivittata* Milne Edwards	BW	PA	Port Canning (Ghatak, 1995)
	Suborder SPHAEROMATIDEA			
	Family **SPHAEROMATIDAE** Latreille, 1825			
149.	*Sphaeroma annandalei* Stebbing, 1911	CW	WB	Port Canning (Stebbing, 1911)
150.	*Sphaeroma triste* Heller, 1865	CW	WB	Hugli-Matla Estuary (Ghatak, 1995)
151.	*Exosphaeroma parva* Chilton, 1924	CW	WB	Bakkhali (Ghatak, 1995)
	Order CUMACEA Krøyer, 1846			
	Family **DIASTYLIDAE** Bate, 1856			
152.	*Paradiatylis* sp.	BW	PL	Chemaguri and Prentice Is. (Anonymous, 1987)
	Order DECAPODA Latreille, 1802			
	Suborder DENDROBRANCHIATA Bate, 1888			
	Superfamily PENAEOIDEA Rafines ue, 1815			
	Family **PENAEIDAE** Rafines ue, 1815			
153.	*Metapenaeus affinis* (H. Milne Edwards, 1837)	BW	NB	Canning, Kakdwip, , Gosaba, Raidighi, Sandeshkhali, Dhanchi and Sajnekhali (Reddy, 1995b)
154.	*Metapenaeus brevicornis* (H. Milne Edwards, 1837)	BW	NB	Sundarbans (Anonymous, 1987)
155.	*Metapenaeus dobsoni* (Miers, 1878)	BW	NB	Canning (Reddy, 1995b)
156.	*Metapenaeus lysianasa* (De Man, 1888)	BW	NB	Canning, Kakdwip, Namkhana, Sagar Is., Basanti, Netidhopani, Gosaba, Golabari, Haldibari, Sandeshkhali, Nazat, Raidighi, Marich Jhanpi, Arbesi, Panchamukhani, Sajnekhali, and Mayadwip (Reddy, 1995b)
157.	*Metapenaeus monoceros* (Fabricius, 1798)	BW	NB	Sundarbans (Anonymous, 1987)
158.	*Parapenaeopsis sculptilis* (Heller, 1862)	BW	NB	Kakdeip, Namkhana, Canning, Gosaba, Patharpratima, Jambu Is., Sagar Is., Basanti, Balasurai, Frasergunj, Netidhopani, Saimari, Jharkhali, Kultali, Sandeshkhali, Kalas and Bhangaduni Is. (Reddy, 1995b)
159.	*Parapenaeopsis stylifera* (H. Milne Edwards, 1837)	BW	NB	Gosaba, Goashaba, Netidhopani and Pratham Gheri (Reddy, 1995b)
160.	*Fenneropenaus indicus* H. Milne Edwards, 1837	BW	NB	Canning, Pratham Gheri, Namkhana, Patharptatima, Basanti, Goashaba, Netidhopani, Sandeshkhali, Arbesi, Marich Jhanpi, Panchamukhani, Gona Is., and Sajnekhali (Reddy, 1995b)

Sl. No.	Group and Species	Habitat	F. G.*	Locality & References
161.	*Fenneropenaus merguiensis* De Man, 1888	BW	NB	Gosaba, Namkhana, Goashaba, Dhanchi, Netidhopani, Arbesi, Sandehkhali, Marich Jhanpi and Bhangaduni Is. (Reddy, 1995b)
162.	*Fenneropenaus penicillatus* Alcock, 1905	BW	NB	Hingalguni, Chulkati and Bhangaduni Is. (Reddy, 1995b)
163.	*Marsupenaeus japonicus* Bate, 1888	BW	NB	Gosaba and Kalas (Reddy, 1995b)
164.	*Penaeus (Penaeus) monodon* (Fabricius, 1798)	BW	NB	Canning, Goashaba, Netidhopani, Dhanchi and Sandeshkhali (Reddy, 1995b)
165.	*Penaeus (Penaeus) semisulcatus* De Haan	BW	NB	Sundarbans (Chaudhuri & Choudhury, 1994)
	Superfamily SERGESTOIDEA Dana, 1852			
	Family **SERGESTIDAE** Dana, 1852			
166.	*Acetes erythraeus* Nobili, 1905	BW	NB	Haliday Is. and Sajnekhali (Reddy, 1995b)
167.	*Acetes indicus* H. Milne Edwards, 1837	BW	NB	Basanti, Namkhana, Pathatpratima, Canning, Gosaba, Sudhanykhali and Goashaba (Reddy, 1995b)
	Family **LUCIFERIDAE** De Haan, 1849			
168.	*Lucifer hanseni* Nobili, 1905	BW	PL	Chemaguri (Anonymous, 1987)
	Suborder PLEOCYEMATA Burkenroad, 1963			
	Infraorder CARIDEA Dana, 1852			
	Superfamily ATYOIDEA De Haan, 1849			
	Family **ATYIDAE** De Haan, 1849			
169.	*Caridina nilotica bengalensis* De Man, 1908	FW	NB	Port Canning, De Man, 1908
	Superfamily PALAEMONOIDEA Rafines ue, 1815			
	Family **PALAEMONIDAE** Rafines ue, 1815			
170.	*Exopalaemon styliferus* (H. Milne Edwards, 1840	FW	NB	Gangetic delta (Kemp, 1917a); Kakd - wip, Chhayer Gheri, Sagar Is., Canning, Namkhana, Basanti, Hingalgunj, Jambu Is., Kultali, Netidhopani, Sandeshkhali, Arbesi and Marich Jhanpi (Reddy, 1995)
171.	*Nematopalaemon tenuipes* (Henderson, 1893)	BW	NB	Gangetic delta (Kemp, 1917a); Sundar - bans (Chaudhuri & Choudhury, 1994)
172.	*Macrobrachium equidens* (Dana, 1852)	BW	NB	Kakdwip, Namkhana, Patharpratima, Gosaba, Canning, Sudhanyakhali, Net - idhopani, Sandeshkhali and Raidighi (Reddy, 1995b)
173.	*Macrobrachium javanicum* (Heller, 1862)	FW	NB	Confluence of Matla and Bidya Rivers (Reddy, 1995b)
174.	*Macrobrachium lamarrei* (H. Milne Edwards, 1844)	FW	NB	Port Canning (De Man, 1908); Kakdwip and Patharpratima (Reddy, 1995b)
175.	*Macrobrachium malcomsonii* (H. Milne Ed-wards, 1844)	BW	NB	Sundarbans (Anonymous, 1987)
176.	*Macrobrachium mirabile* (Kemp, 1917)	BW	NB	Port Canning, Sandheads (Kemp, 1914, 1917a); Kakdwip (Reddy, 1995b)
177.	*Macrobrachium rosenbergii* (De Man, 1879)	FW/BW	NB	Kakdwip, Chulkati and Marich Jhanpi (Reddy, 1995b)

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178.	*Macrobrachium rude* (Heller, 1862)	FW/BW	NB	Basanti and Marich Jhanpi (Reddy, 1995b)
179.	*Macrobrachium scabriculum* (Heller, 1862)	BW	NB	Sundarbans (Mandal & Nandi, 1989)
	Superfamily ALPHEOIDEA Rafines ue, 1815			
	Family **ALPHEIDAE** Rafines ue, 1815			
180.	*Alpheus crassimanus* Heller, 1862	BW	NB	Sundarbans (Anonymous, 1987)
181.	*Alpheus edwardsii* Audouin, 1827	BW	NB	Sandheads (present record)
182.	*Alpheus paludicola* Kemp, 1915	BW	NB	Sundarbans (Anonymous, 1987)
	Family **HIPPOLYTIDAE** Dana, 1852			
183.	*Exhippolysmata ensirostris* (Kemp, 1914)	CW	NB	Chhayer Gheri (Reddy, 1995b); Sandheads (present record)
184.	*Saron marmoratus* (Olivier, 1811)	BW	NB	Port Canning (Kemp, 1914)
	Superfamily CRANGONOIDEA Haworth, 1825			
	Family **CRANGONIDAE** Haworth, 1825			
185.	*Pontocaris pennata* Bate, 1888	CW	NB	Gangetic delta (Kemp, 1916); Sandheads (present record)
	Infraorder GEBIIDEA De Saint Laurent, 1979			
	Family **THALASSINIDAE** Latreille, 1831			
186.	*Thalassina anomala* (Herbst, 1804)	BW	MAB	Sundarbans (Anonymous, 1987)
	Infraorder PALINURA Latreille, 1803			
	Superorder PALINUROIDEA Latreille, 1803			
	Family **PALINURIDAE** Latreille, 1803			
187.	*Panulirus homarus* (Linnaeus, 1758)	CW	NB	Sundarbans (Anonymous, 1987)
188.	*Panulirus polyphagus* (Herbst, 1793)	CW	NB	Sundarbans (Anonymous, 1987)
	Infraorder ANOMURA H. Milne Edwards, 1832			
	Superfamily COENOBITIDEA Dana, 1851			
	Family **COENOBITIDAE** Dana, 1851			
189.	*Coenobita cavipes* Stimpson, 1859	BW	NB	Arbesi; Chhota Hardi; Bhangaduni Is.; Baghmara and Mechua Khal (Reddy, 1995a)
	Family **DIOGENIDAE** Ortmann, 1892			
190.	*Clibanarius clibanarius* (Herbst, 1791)	CW	NB	Sandheads (Reddy, 1995a)
191.	*Clibanarius infraspinatus* Hilgendorf, 1869	BW	NB	Bakkhali (Reddy, 1995a)
192.	*Clibanarius olivaceus* Henderson, 1915	BW	NB	Sagar Is., Chhoto Mollakhali and Gosaba (Reddy, 1995a)
193.	*Clibanarius padavensis* De Man, 1888	BW	NB	Port Canning, Sajnekhali, Sagar Is., Bak - khali, Arbesi, Kedo Block, Jhingakhali, Bhangaduni Is., Baghmara, Parghumti, Chhoto Mollakhali, Gosaba and Bhangon-Khalighat (Reddy, 1995)
194.	*Diogenes avarus* Heller, 1865	BW	NB	Bakkhali and Sagar Is (Reddy, 1995a)
195.	*Diogenes costatus* Henderson, 1893	CW	NB	Sandheads (Reddy, 1995a)
196.	*Diogenes custos* (Fabricius, 1798)	CW	NB	Sandheads (Reddy, 1995a)
197.	*Diogenes diogenes* (Herbst, 1791)	CW	NB	Sandheads (Reddy, 1995a)

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198.	*Diogenes investigatoris* Alcock, 1905	BW	NB	Bakkhali and Sagar Is (Reddy, 1995a)
199.	*Diogenes planimanus* Henderson, 1893	CW	NB	Sandheads (Reddy, 1995a)
200.	*Dardanus hessi* (Miers, 1884)	CW	NB	Sandheads (Reddy, 1995a)
	Superfamily PAGUROIDEA Latreille, 1803			
	Family **PAGURIDAE** Latreille, 1803			
201.	*Profundorum spiriger* Alcock, 1905	CW	NB	Sandheads (Reddy, 1995a)
	Section PODOTREMATA Guinot, 1977			
	Superfamily DROMIOIDEA De Haan, 1833			
	Family **DROMIIDAE** De Haan, 1833			
202.	*Conchoecetus artificiosus* (Fabricius, 1798)	CW	MAB	Hugli delta (Alcock;1899); Sandheads (Chopra, 1934a)
	Superfamily RANINOIDEA De Haan, 1839			
	Family **RANINIDAE** De Haan, 1839			
203.	*Raninoides personatus* Henderson, 1888	CW	MAB	Sandheads (Deb, 1998)
	Section EUBRACHYURA Saint Laurent, 1980			
	Subsection HETEROTREMATA Guinot, 1977			
	Superfamily AETHROIDEA Dana, 1851			
	Family **AETHRIDAE** Dana, 1851			
204.	*Drachiella morum* (Alcock, 1896)	CW	MAB	Sandheads (Chopra, 1934a)
	Superfamily CALAPPOIDEA De Haan, 1833			
	Family **CALAPPIDAE** De Haan, 1833			
205.	*Calappa lophos* (Herbst, 1790)	CW	MAB	Ganges delta (Alcock, 1896); Sandheads (Chopra,1933)
206.	*Calappa pustulosa* Alcock, 1896	CW	MAB	Sandheads (Chopra, 1933)
	Family **MATUTIDAE** De Haan, 1835			
207.	*Ashtoret lunaris* (Forskål, 1775)	BW/CW	NB	Sundarbans (Alcock, 1896); Sand-heads (Chopra, 1933); Sagar Island (Chakraborty *et al*., 1986); Gazikhali, Patibunia, Bhangaduni Is.,Kakdwip, Frasergunj, Canning, Salt-Gheri, Hatkhali, Chhoto Seara, Sambu-nagar, Sarupkhali, Atapur, Kalinagar, Moina char and Bagna (present record)
208.	*Matuta planipes* Fabricius, 1798	BW/CW	NB	Sandheads (Chopra, 1933); Jambu Is.,Namkhana, Ukil Bazar, Thumkati, Purandar; Mainachar and Frasergunj, Kishorimohanpur – char, Sitagunge and Salt Gheri(present record)
209.	*Matuta victor* (Fabricius, 1781)	BW/CW	NB	Ganges delta (Alcock, 1896)
	Superfamily CORYSTOIDEA Samouelle, 1819			
	Family **CORYSTIDAE** Samouelle, 1819			
210.	*Jonas indica* (Chopra, 1935)	CW	MAB	Sandheads (Chopra, 1935)
	Superfamily DORIPPOIDEA MacLeay, 1838			
	Family **DORIPPIDAE** MacLeay, 1838			
211.	*Dorippe quadridens* (Fabricius, 1793)	CW	MAB	Sandheads (Chopra, 1933)

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212.	*Dorippoides facchino* (Herbst, 1785)	CW	MAB	Sandheads (Chopra, 1933);
213.	*Neodorippe callida* (Fabricius, 1798)	CW	MAB	Sandheads (Dev Roy & Nandi, 2001)
	Family **ETHUSIDAE** Guinot, 1977			
214.	*Ethusa indica* Alcock, 1894	CW	MAB	Gangetic delta (Alcock, 1896)
	Superfamily ERIPHIOIDEA Macleay, 1838			
	Family **MENIPPIDAE** Ortmann, 1893			
215.	*Menippe rumphii* (Fabricius, 1798)	CW	MAB	Sandheads (Deb, 1998)
216.	*Myomenippe hardwickii* (Gray, 1831)	BW/CW	MAB	Sandheads (Chopra, 1935); Saimari, Parsamari and Chara-Ba-Dweep; (pre - sent record)
	Superfamily GECARCINUCOIDEA Rathbun, 1904			
	Family **PARATHELPHUSIDAE** Alcock, 1909			
217.	*Sartoriana spinigera* (Wood-Mason, 1871)	FW/BW	MAB	Sundarban (Nandi & Pramanik, 1994)
218.	*Spiralothelphusa hydrodromus* (Herbst, 1794)	FW/BW	MAB	Sundarban (Nandi & Pramanik, 1994)
	Superfamily GONEPLACOIDEA MacLeay, 1838			
	Family **SCALOPIDIIDAE** Stevcic, 2005			
219.	*Scalopidia spinosipes* Stimpson, 1858	CW	MAB	Sandheads (Chopra, 1935)
	Superfamily LEUCOSIOIDEA Samouelle, 1819			
	Family **IPHICULIDAE** Alcock, 1896			
220.	*Iphiculus spongiosus* Adams and White, 1848	CW	MAB	Sandheads (Chopra, 1933)
221.	*Pariphiculus mariannae* (Herklot, 1852)	CW	MAB	Sandheads (Chopra, 1933)
	Family **LEUCOSIIDAE** Samouelle, 1819			
	Subfamily EBALIINAE Stimpson, 1871			
222.	*Arcania erinaceus* (Fabricius, 1793)	CW	MAB	Sandheads (Chopra, 1933)
223.	*Arcania septemspinosa* (Fabricius, 1787)	CW	MAB	Gangetic delta (Alcock, 1896); Sand - heads (Chopra, 1933)
224.	*Ixa cylindrus* (Fabricius, 1787)	CW	MAB	Sandheads (Chopra, 1933)
225.	*Ixa inermis* Leach, 1817	CW	MAB	Sandheads (Chopra, 1933)
226.	*Myra elegans* Bell, 1855	CW	MAB	Sandheads (Chopra, 1933)
227.	*Myra fugax* (Fabricius, 1798)	CW	MAB	Gangetic delta (Chopra, 1933)
228.	*Philyra globus* (Fabricius, 1775)	CW	MAB	Sandheads (Alcock, 1896; Chopra, 1933)
	Subfamily LEUCOSIINAE Samouelle, 1819			
229.	**Euclosia rotundifrons* Chopra, 1933	CW	MAB	Sandheads (Chopra, 1933)
230.	*Seulocia rhomboidalis* De Haan, 184	CW	MAB	Sandheads (Chopra, 1933)
231.	*Leucosia craniolaris* (Linnaeus, 1758)	CW	MAB	Sandheads (Alcock, 1896)
	Superfamily MAJOIDEA Samouelle, 1819			
	Family **EPIALTIDAE** MacLeay, 1838			
	Subfamily PISINAE Dana, 1851			
232.	*Doclea armata* De Haan, 1839	CW	MAB	Sandheads (Alcock, 1895; Chopra, 1933)
233.	*Doclea canalifera* Stimpson, 1857	CW	MAB	Sandheads (Alcock, 1895)
234.	*Doclea muricata* (Fabricius, 1787)	CW	MAB	Sandheads (Chopra, 1935)

Sl. No.	Group and Species	Habitat	F. G.*	Locality & References
235.	*Doclea ovis* (Fabricius, 1787)	CW	MAB	Sandheads (Chopra, 1935)
236.	*Doclea rissonii* Leach, 1815	CW	MAB	Sandheads (Alcock, 1895; Chopra, 1935)
237.	*Hyastenus diacanthus* (De Haan, 1839)	CW	MAB	Sandheads (Chopra, 1935)
238.	*Phalangipus longipes* (Linnaeus, 1758)	CW	MAB	Sandheads (Chopra, 1935)
	Family **HYMENOSOMATIDAE** MacLeay, 1838			
239.	*Neorhynchoplax inachoides* (Alcock, 1900)	BW	MAB	Port Canning (Alcock, 1900)
240.	*Neorhynchoplax nasalis* (Kemp, 1911)	BW	MAB	Bidyadhari River and Chingrighata (Kemp, 1917b)
241.	*Neorhynchoplax woodmasoni* (Alcock, 1900)	BW	MAB	Port Canning (Alcock, 1900)
242.	*Trigonoplax unguiformis* (De Haan, 1839)	BW	MAB	Sundarbans (Mandal & Misra, 1985)
	Superfamily PARTHENOPOIDEA MacLeay, 1838			
	Family **PARTHENOPIDAE** MacLeay, 1838			
	Subfamily DALDORFIINAE Ng and Rodriguez, 1986			
243.	*Cryptopodia angulata* H. Milne Edwards and Lucas, 1841	CW	MAB	Sandheads (Chopra, 1935)
	Subfamily PARTHENOPINAE MacLeay, 1838			
244.	*Enoplolambrus pransor* (Herbst, 1796)	CW	MAB	Sundarban (Deb, 1998)
	Superfamily PILUMNOIDEA Samouelle, 1819			
	Family **GALENIDAE** Alcock, 1898			
	Subfamily GALENINAE Alcock, 1898			
245.	*Galene bispinosa* (Herbst, 1783)	CW	MAB	Sandheads (Chopra, 1935)
	Subfamily HALIMEDINAE Alcock, 1898			
246.	*Halimede fragifer* De Haan, 1835	CW	MAB	Sandheads
247.	*Halimede tyche* (Herbst, 1801)	CW	MAB	Sandheads (Chopra, 1935)
	Family **PILUMNIDAE** Samouelle, 1819			
	Subfamily PARAPANOPINAE Stevcic, 2005			
248.	*Parapanope euagora* De Man, 1895	CW	MAB	Sandheads (Deb, 1995)
	Subfamily PILUMNINAE Samouelle, 1819			
249.	*Eurycarcinus bengalensis* Deb, 1998	BW	MAB	Canning, Gosaba, Jharkhali, Baghmara and Champatala (Deb, 1995) ; Chamta Block (Deb, 1998)
250.	*Eurycarcinus natalensis* (Krauss, 1843)	BW	MAB	Canning, Basanti and Sajnakhali (Deb, 1995); Sagar, Lothian & Prentice Islands (Chakraborty *et al*., 1986); Haldibari, Gona Is., Chhotahardi, Fatikpur and Keorasuti (present record)
251.	*Eurycarcinus orientalis* A. Milne Edwards, 1867	BW	MAB	Haldibari, Gona Is., Chhotahardi and confluence of Bidya and Matla rivers (present record)
252.	*Heteropanope glabra* Stimpson, 1858	BW	MAB	Jharkhali, Bakkhali, Sagar Islands and Canning (Deb, 1995, 1998)
253.	*Heteropanope neolaevis* Deb, 1998	BW	MAB	Kachuberia (Deb, 1998)
254.	*Heteropilumnus ciliatus* (Stimpson, 1858)	BW	MAB	Sundarban (Deb, 1995)

Sl. No.	Group and Species	Habitat	F. G.*	Locality & References
	Subfamily RHIZOPINAE Stimpson, 1858			
255.	*Typhlocarcinus nudus* Stimpson, 1858	BW	MAB	Sandheads (Alcock, 1900)
	Superfamily PORTUNOIDEA Rafines ue, 1815			
	Family **PORTUNIDAE** Rafines ue, 1815			
	Subfamily CAPHYRINAE Paul'son, 1875			
256.	*Lissocarcinus arkati* Kemp, 1923	CW	NB	Sandheads (Kemp, 1923)
	Subfamily PORTUNINAE Rafines ue, 1815			
257.	*Portunus (Lupocycloporus) gracilimanus* (Stimpson, 1858)	CW	NB	Sandheads
258.	*Portunus (Monomia) gladiator* Fabricius, 1758	CW	NB	Sundarbans (Alcock, 1899); Sandheads and Matla River (Bhadra, 1995)
259.	*Portunus (Portunus) pelagicus* (Linnaeus, 1758)	CW	NB	Sandheads and Port Canning; (Chakraborty *et al*., 1986)
260.	*Portunus (Portunus) pubescens* (Dana, 1852)	CW	NB	Sagar Is. (Bhadra, 1995)
261.	*Portunus (Portunus) sanguinolentus* (Herbst, 1790)	CW	NB	Sandheads
262.	*Portunus (Xiphonectes) hastatoides* Fabricius, 1798	CW	NB	Sandheads (Bhadra, 1998)
263.	*Portunus (Xiphonectes) pulchricristatus* (Gordon, 1931)	CW	NB	
264.	*Scylla serrata* (Forskål, 1775)	BW	NB	Port Canning (Annandale, 1906); Sagar, Lothian, Prentice & Jambu Islands (Chakraborty *et al*., 1986); Basanti, Gosaba, Bakkhali, Chhoto Mollakhali, Baghmara; Bhangaduni Is., Chhotahardi, Nikarikhal, Hatkhali, Gobinokati, Kalitala, Pakhiraloi, Sundarkhali and Jharkhali (present record)
265.	*Scylla tranquebarica* (Fabricius, 1798)	BW	NB	Basanti, Gosaba, Chhoto Mollakhal (present record)
	Subfamily THALAMITINAE Paul'son, 1875			
266.	*Charybdis (Charybdis) affinis* Dana, 1852	CW	NB	Bakkhali (Bhadra, 1998)
267.	*Charybdis (Charybdis) callianassa* (Herbst,	CW	NB	Sandheads (Bhadra, 1998)
268.	*Charybdis (Charybdis) feriatus* (Linnaeus, 1758)	CW	NB	Sandheads and Port Canning (Chakraborty *et al*., 1986); Bakkhali and Jharkhali (Bhadra, 1995); Jambu Is. (present record)
269.	*Charybdis (Charybdis) helleri* (A. Milne Edwards, 1867)	CW	NB	Sandheads and Gosaba (Bhadra, 1998); Dabbu, Prentice Is.,Gazikhali; Purandar and Ajmalmari (present record)
270.	*Charybdis (Charybdis) miles* (De Haan, 1852)	CW	NB	Sandheads (Bhadra, 1995)
271.	*Charybdis (Charybdis) orientalis* Dana, 1852	BW	NB	Sundarbans (Mandal & Misra, 1985); Gosaba (Bhadra, 1995)

Sl. No.	Group and Species	Habitat	F. G.*	Locality & References
272.	*Charybdis (Charybdis) rostrata* (A. Milne Edwards, 1861)	BW/CW	NB	Sandheads (Bhadra, 1998); Ganga Sagar, Piali River, Frasergunj, Matla River, Bakkhali,Gosaba and Sagar Is. (Bhadra, 1995); Dabbu, Nazat, Bakkhali, Thumkati, Sapkhali, Phuldubi, Namkhana, Bagna, Mainachar, Kultali, Thumkati, Gosaba, Sardarpara and Chhoto Mollakhali (present record)
273.	*Charybdis (Charybdis) variegata* (Fabricius, 1798)	CW	NB	Sandheads (Bhadra, 1998)
274.	*Charybdis (Goniohellenus) truncata* (Fabricius, 1798)	CW	NB	Sandheads (Alcock, 1899)
275.	*Charybdis (Goniohellenus) vadorum* Alcock, 1899	CW	NB	Sandheads (Chopra, 1935; Bhadra, 1998)
276.	*Thalamita crenata* (Latreille, 1829)	BW	NB	Dhanchi (Dev Roy and Nandi, 2001)
	Superfamily XANTHOIDEA MacLeay, 1838			
	Family **XANTHIDAE** MacLeay, 1838			
	Subfamily XANTHINAE MacLeay, 1838			
277.	*Liagore erythematica* Guinot, 1971	CW	MAB	Sandheads (Kemp, 1923; Guinot, 1971)
278.	*Orphanoxanthus microps* (Alcock and Anderson, 1894)	CW	MAB	Bay of Bengal around West Bengal coast (Deb, 1998)
	Superfamily GRAPSOIDEA MacLeay, 1838			
	Family **GRAPSIDAE** MacLeay, 1838			
279.	*Metopograpsus latifrons* (White, 1874)	BW	MAB	Bhangaduni Is. (Ghosh, 1995); Sagar, Prentice & Lothian Islands (Chakraborty *et al*., 1986)
280.	*Metopograpsus messor* (Forskål, 1775)	BW	MAB	Canning (Mandal & Misra, 1985); Sagar Is. (Ghosh, 1995); Sagar, Prentice & Lothian Islands (Chakraborty *et al*., 1986); Achipur, Raychak, Bhangonkhali Ghat, Gosaba, Gobindapur, Himchakhali, Nikarighat, Belekhali, Sonakhali, Jharkhali, Saimari and Marichjhapi (present record)
281.	*Pachygrapsus porpinquus* De Man, 1908	BW	MAB	Canning (De Man, 1908; Annandale, 1907); Kakdwip (Ghosh, 1995)
	Family **SESARMIDAE** Dana, 1851			
282.	*Clistocoeloma merguiense* De Man, 1888	BW	MAB	Sagar Is. (Ghosh, 1995)
283.	*Episesarma mederi* (H. Milne Edwards, 1853)	BW	MAB	Jhingakhali, Canning (Mandal & Misra, 1985); Sagar, Lothian, Prentice & Jambu Islands (Chakraborty *et al*., 1986); Chamta Block (Ghosh, 1995); Golabari, Chaltamunikhal, Patharprotima, Frasergunj, Netidhopani, Bidya River Bank, Tooshkhali, Jharkhali, Marichjhapi and Sajnakhali (present record)
284.	*Muradium tetragonum* (Fabricius, 1798)	BW	MAB	Sundarban (Ghosh, 1995); Bhagabatpur and Ukiler haat (present record)
285.	*Parasesarma pictum* (De Haan, 1835)	BW	MAB	Sagar Is. (Chakraborty *et al*., 1986)
286.	*Parasesarma plicatum* (Fabricius, 1798)	BW	MAB	Matla River; Uttarbhag (Ghosh, 1995)

Sl. No.	Group and Species	Habitat	F. G.*	Locality & References
287.	*Perisesarma bidens* (De Haan, 1835)	BW	MAB	Bakkhali, Kakdwip, Bidya river, Achipur, Nurpur, Diamond Harbour, Uttarbhag, Gosaba, Bhangaduni Is., Baghmara, Sajnakhal, Jhingakhali and Marichjhapi (Ghosh, 1995); Sagar, Lothian & Prentice Islands (Chakraborty *et al*., 1986)
288.	*Sesarmops impressum* (H. Milne Edwards, 1837)	BW	MAB	Jhingakhali (Mandal & Misra, 1985)
289.	*Sesarmops intermedium* (De Haan, 1835)	BW	MAB	Nurpur (Ghosh, 1998)
290.	*Sesarmoides longipes* (Krauss, 1843)	BW	MAB	Bhangonkhali Ghat (Ghosh, 1995); Sagar Is. (Chakraborty *et al*., 1986)
291.	*Sesarmoides kraussi* (De Man, 1888)	BW	MAB	Nurpur (Ghosh, 1995, 1998)
292.	*Pseudosesarma edwardsi* (De Man, 1887)	BW	MAB	Falta, Majherchar, Babugungehat and Ballykhal (Ghosh, 1995); Achipur, Nurpur, Kakdwip, Bakkhali, Gosaba, Bidya River, Bhangaduni Is., Baghmara, Sajnakhali, Jhingakhali, Sagar, Lothian & Prentice Islands
293.	*Neosarmatium smithi* (H. Milne Edwards, 1853)	BW	MAB	Baghmara Khal (Ghosh, 1995)
294.	*Metasesarma rousseauxii* h. Milne Edwards, 1853	BW	MAB	Sandheads (Ghosh, 1995)
	Family **VARUNIDAE** Alcock, 1900			
	Subfamily CYCLOGRAPSINAE H. Milne Ed - wards, 1853			
295.	*Metaplax crenulata* (Gerstecker, 1856)	BW	MAB	Sundarbans (Alcock, 1900); Prentice & Lothian Islands (Chakraborty *et al*., 1986); Canning (Ghosh, 1995); Fraser-gunj, Patibunia, Haldibari, Jhingakhali, Kishorimohanpur, Chamta Block, Sajnakhali and Bhangaduni Is. (Ghosh, 1998)
296.	*Metaplax dentipes* (Heller, 1865)	BW	MAB	Port Canning (Annandale, 1906; De Man, 1908); Jhingakhali (Man - dal & Misra, 1985); Canning, Ba-santi, Achipur,Nurpur; Kakdwip, Bhangonkhali Ghat, Belekhali and Marichjhapi (Ghosh, 1998)
297.	*Metaplax distincta* H. Milne Edwards, 1852	BW	MAB	Jhingakhali (Mandal & Misra, 1985); Kakdwip (Ghosh, 1995)
298.	*Metaplax indica* H. Milne Edwards, 1852	BW	MAB	Prentice & Lothian Islands (Chakraborty *et al*., 1986); Achipur (Ghosh, 1998)
299.	*Metaplax intermedia* De Man, 1888	BW	MAB	Jhingakhali (Mandal & Misra, 1985); Sagar, Lothian, Prentice & Jambu Islands (Chakraborty *et al*., 1986); Nurpur, Jharkhali and Chota Mollakhali (Ghosh, 1995); Canning, Basanti, Go - saba, Sajnakhali, and Kakdwip (Ghosh, 1998)
	Subfamily VARUNINAE H. Milne Edwards, 1853			
300.	*Ptychognathus dentatus* De Man, 1892	BW	MAB	Falta (Ghosh, 1995); Falta, Nurpur, Dia - mond Harbour, Bakkhali and Uttarbhag (Ghosh, 1998)

Sl. No.	Group and Species	Habitat	F. G.*	Locality & References
301.	*Ptychognathus onyx* Alcock, 1900	BW	MAB	Nurpur and Falta (Ghosh, 1998)
302.	*Pyxidognathus fluviatilis* Alcock, 1900	BW	MAB	Sundarban (Ghosh, 1995)
303.	*Varuna litterata* (Fabricius, 1798)	FW/BW/ CW	NB	Port Canning (Annandale, 1907; De Man, 1908); Sagar Island (Chakraborty *et al*., 1986); Jhingakhali and Canning (Mandal & Misra, 1985); Kachuberia, Namkhana, Kakdwip, Sapkhali, Bortala, Frasergunj, Lothian Is., Mandirtala, Sajnakhali, Gosaba,Chadalkhali, Sand - eshkhali, Kalinagar, Belakhali, Hatkhali, Bagna,Charamayadwip,Narantala, Gho - shpur and Gogeshgunj (present record)
	Superfamily OCYPODOIDEA Rafines ue, 1815			
	Family **DOTILLIDAE** Stimpson, 1858			
304.	*Dotilla blanfordi* Alcock, 1900	BW	MAB	Sagar Is., Lower Long & Prentice Islands (Chakraborty *et al*., 1986); Kak- dwip (Bairagi, 1995)
305.	*Dotilla intermedia* De Man, 1888	BW	MAB	Sagar Is. (Bairagi, 1995)
306.	*Dotillopsis brevitarsis* (De Man, 1888)	BW	MAB	Jharkhali and Canning (Mandal & Misra, 1985); Sagar, Prentice, Jambu and Lothian Islands (Chakraborty *et al*., 1986); Gosaba and Canning (Bairagi, 1995); Kakdwip (Deb, 1998); Namkha - na, Jhingakhali and Pargumti (present record)
307.	*Ilyoplax gangeticus* (Kemp, 1919)	BW	MAB	Port Canning (Chakraborty *et al*., 1986); Gosaba and Chhotomollakhali (Bairagi, 1995)
308.	*Ilyoplax stapletoni* (De Man, 1908)	BW	MAB	Port Canning (De Man, 1908; Annan - dale, 1909); Nurpur (Bairagi, 1995)
309.	*Scopimera globosa* De Haan, 1835	BW	MAB	Sundarban (Mandal & Misra, 1985; Deb, 1998); Sundarban Tiger Reserve Area (Bairagi, 1995)
310.	*Scopimera investigatoris* Alcock, 1900	BW	MAB	Sundarban Tiger Reserve Area (Bairagi, 1995)
311.	*Scopimera proxima* Kemp, 1919	BW	MAB	Sundarban (Deb, 1998)
	Family **MACROPHTHALMIDAE** Dana, 1851			
312.	*Macrophthalmus (Macrophthalmus) brevis* (Herbst, 1804)	BW	MAB	Harinbari; Sagar Is. (Bairagi, 1995)
313.	*Macrophthalmus (Macrophthalmus) crassipes* H. Milne Edwards, 1834	BW	MAB	Jharkhali (Bairagi, 1995)
314.	*Macrophthalmus (Macrophthalmus) transver - sus* (Latreille, 1817)	CW	MAB	Sandheads (Deb, 1998)
315.	*Macrophthalmus (Mareotis) depressus* Rüppell, 1830	BW	MAB	Gosaba; Sonakhali (Bairagi, 1995)
316.	*Macrophthalmus (Mareotis) pacificus* 1851	BW	MAB	Gosaba (Bairagi, 1995)
317.	*Macrophthalmus (Mareotis) teschi* Kemp, 1919	BW	MAB	Pargumti, Jharkhali and Gosaba (Bairagi, 1995); Port Canning (Deb, 1998); Sagar Is. (Chakraborty *et al*., 1986); Pargumti; Jharkhali; Gosaba (present record)

Sl. No.	Group and Species	Habitat	F. G.*	Locality & References
318.	*Macrophthalmus (Mareotis) tomentosus* Souleyet, 1841	BW	MAB	Sundarban (Dev Roy & Nandi, 2001)
319.	*Macrophthalmus (Paramareotis) erato* De Man, 1888	BW	MAB	Bakkhali; Sagar Is. (Bairagi, 1995)
320.	*Macrophthalmus (Venitus) dentipes* Lucas in Guérin-Méneville, 1838	BW	MAB	Jhingakhali (Mandal & Misra, 1985); Sagar Is. (Chakraborty *et al*., 1986)
	Family **OCYPODIDAE** Rafines ue, 1815			
	Subfamily OCYPODINAE Rafines ue, 1815			
321.	*Ocypode ceratophthalma* (Pallas, 1772)	BW	MAB	Sagar & Lower Long Islands (Chakraborty *et al*., 1986)
322.	*Ocypode macrocera* H. Milne Edwards, 1837	BW	MAB	Sagar Is, Lower Long Is & Lothian Is.; Bakkhali (Chakraborty *et al*., 1986); Jharkhali and Namkhana (Bairagi, 1995); Bhangaduni Is., Frasergunj, Hali - day Is., Jambu Is.and Kakdwip (present record)
323.	*Ocypode platytarsis* H. Milne Edwards, 1852	BW	MAB	Sundarban (Deb, 1998)
	Subfamily UCINAE Dana, 1851			
324.	*Uca dussumieri* (H. Milne Edwards, 1852)	BW	MAB	Sagar, Prentice and Lothian Islands (Chakraborty *et al*., 1986); Namkhana, Bakkhali and Jharkhali
325.	*Uca rosea* (Tweedie, 1937)	BW	MAB	Canning and Jhingakhali (Mandal & Misra, 1985); Sagar, Prentice, Lower Long, Lothian & Jambu Islands (Chakraborty *et al*., 1986); Jharkhali (Bairagi, 1995); Sajnakhali , Gosaba and Port Canning (present record)
326.	*Uca vocans* (Linnaeus, 1758)	BW	MAB	Sajnakhali; Sagar Is. (Chakraborty *et al*., 1986)
327.	*Uca lactea* (De Haan, 1835)	BW	MAB	Sagar Is and Lothian Is. (Chakraborty *et al*., 1986); Bakkhali (Bairagi, 1995); Saimari (present record)
328.	*Uca triangularis* (A. Milne Edwards, 1873)	BW	MAB	Jhingakhali, Sagar, Prentice and Lothian Islands (Chakraborty *et al*., 1986); Jharkhali and Bakkhali (Bairagi, 1995)
	Superfamily PINNOTHEROIDEA De Haan, 1833			
	Family **PINNOTHERIDAE** De Haan, 1833			
	Subfamily PINNOTHERINAE De Haan, 1833			
329.	*Pinnotheres mactricola* Alcock, 1900	CW	PA	Sandheads (Alcock, 1900)

* Abbreviations used:

FG= Functional Guild FW=Fresh water EW= Estuarine water

BW= Brackish water CW= Coastal water PL= Pelagic/Planktonic

NB= Nektobenthos MAB= Macrobenhos MEB= Meiobenthos SEP=Sedentary Epibenthos
PA= Parasitic WB= Wood-borer

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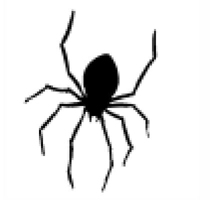
2.11 ARANEAE

Spiders are among the most omnipresent and numerous predators in both natural and agricultural ecosystems, averaging 50,000 individuals per acre in vegetated areas (Zahl 1971).

RATUL SAHA
Wildlife Biologist with specialization in Entomology



Mesothelae and Orthognatha consist of primitive spiders Labidognatha includes the more recent spiders

They are nature's master spinners of silken webs and are highly proficient predators (Wise 1993) and thereby, regulate insect populations. A quick glance at the biological diversity reveals that arthropods are the most diverse group of organisms. It has generated a very diverse group of arthropods and in particular, insects. Arthropods constitute 64.5 percent of the described species as compared to plants (14.3 percent), fungi (4.2 percent), and vertebrates (2.3 percent) (Global Biodiversity Assessment 1995). The arachnids constitute the second largest class (7 percent) of documented arthropods and it is estimated that 8.3 percent of arthropods are arachnids. Thus, arachnids rank second among arthropods. Currently, more than 39,000 species, 3,642 genera, and 111 families have been described. The order Araneae comprises three suborders: Mesothelae with one family of spiders the *Liphistiidae*; Mygalomorphae, the primitive spiders; and Araneomorphae, the modern spiders (Foelix 1996).

The class Arachnida comprises the orders Scorpiones (scorpions); Schizomida (schizomids) Amblypygi (tailless whip scorpions); Uropygi (uropygids or whip scorpions); Opiliones (opiliones, harvestmen, or daddy longlegs); Pseudoscorpiones (pseudo-scorpions or false scorpions); Palpigradi (palpigrades or micro whip scorpions); Solifugae (wind scorpions, sun spiders, or solifugids); Ricinulei (ricinuleids); Acari (mites and ticks); and Araneae (spiders).

Spiders belong to the class Arachnida of the phylum Arthropoda, animals that possess jointed appendages and a chitinous exoskeleton. The suborders Mesothelae and Orthognatha consist of primitive spiders, and the suborder Labidognatha includes the more recent spiders. The members of the class Arachnida are generally characterized by the two body regions, the cephalothorax having four pairs of segmented legs attached to it, and the abdomen. Unlike insects, arachnids do not have antennae.

Spiders can be clearly differentiated from other Arachnids by the presence of the pedicel, a narrow stalk that joins the cephalothorax (anterior body section) and the abdomen. In other arachnids, the two parts of the body are fused so that they appear as one. Spiders are unique as they possess spinnerets, situated near the hind end of the abdomen, which produce silk. Spiders range in size from the barely visible (Samoan moss spider, *Patu marplesi*, which measures only 0.017 inches) to many inches long, as in tropical mygalomorph spiders (the goliath tarantula, *Theraphosa blondihi*, with a body length of 3.5 inches and leg span of 11 inches).

It is known that spiders and insects have been able to spin silk for at least 380 million years. Orb-weaving spiders evolved about 120 million years ago and have developed silk for the specific purpose of trapping flying insects that are the spider's food source. Spider silk has tremendous economic value due to its extraordinary mechanical properties such as high tensile strength (stronger than steel), high extensibility comparable to rubber, and high capability and biodegradability of water uptake compared to wool (Sebastian et al. 2009).

OVERVIEW OF THE GROUP

The distribution and diversity of spiders and their importance in ecosystem dynamics has drawn the attention of field workers in different parts of the world. Taylor (1999) provides a good and well-illustrated account of the diversity, beauty, and intricacies of spiders.

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SPECIES RECORDED FROM INDIA

Platnick (2010) lists 41,719 spider species under 109 families and 3,802 genera globally. Tikader (1987) has listed 1,067 under 43 families. Siliwal et al. (2005) report 1,442 species belonging to 361 genera of 59 families from India. The predominant families are Lycosidae, Salticidae, Gnaphosidae, Thomisidae, and Araneidae.

Camaricus formosus

SYNOPTIC VIEW

Diversity

Although there are several published records on the spiders of the Indian Sunderbans (Tikader 1980a, b; Majumder and Tikader 1991; Biswas and Biswas 1992; Biswas 1995), very little work has been done on spiders' ecology and the role they play in ecosystem dynamics. Majumder (2004) in his monumental works on the Sundarban spider reported 108 species in 36 genera under 13 families (see annexure), namely Araneidae, Clubionidae, Erisidae, Gnaphosidae, Hersilidae, Heteropodidae, Lycosidae, Oxyopidae, Salticidae, Tetragnathidae, Theridiidae, Thomisidae, and Uloboridae from the Indian Sunderbans. Among them, 3 species have been recorded in this region as new: *Oxyooes reddyi* sp. nov. (Family: Oxyopidae); *Marpissa dayapurensis* sp. nov.; and *M. lakshmikantapurensis* sp. nov. (Family: Salticidae). Thirty-eight species are new records from this area. Majumder (2005) had also described another 4 species from the Indian Sundarbans.

114
SPECIES FROM SUNDARBANS

Out of the 361 genera recorded from the Indian region (Siliwal et al. 2005), 37 genera (table 1) are found in the Indian Sundarbans. Maximum generic diversity was found in Araneidae (11), Lycosidae (7), and Salticidae (4). The number of genera recorded here is higher than that of other major Indian spider studies, for example, in the Andaman and Nicobar Islands—33 genera (Tikader 1977).

Species Richness and Functional Groups

Of about 1,442 species of spiders that are reported from India (Siliwal et al. 2005), 114 species have been recorded from 19 blocks of the Indian Sundarbans (figure 2). This number is very high when compared with other regions like the Andaman and Nicobar Islands—65 species (Tikader 1977). Guild structure analysis (figure 1) of spiders at the Indian Sundarbans reveals eight functional guilds, namely orb web weavers, ground runners, foliage runners, foliage hunters, stalkers, ambushers, scattered line weavers, and social spiders. Ground runners, orb web weavers, and stalkers were the dominant functional guilds representing 39 percent, 28 percent, and 22 percent, respectively, of the total spiders found in the Sundarbans.

> 3 species recorded in Sundarbans are new to science
>
> 38 species are new record from this area

Distribution Pattern

From 19 blocks of the Indian Sundarbans, 114 species have been recorded (figure 2). Maximum species diversity was found from Gosaba (56), Hingalgunj (35), Patharpratima (33), and Sandeshkhali (24). Table 2 represents the species distribution pattern with reference to the functional guilds available at these four places representing high species diversity.

Table 1: Total number of families, genera, species composition and functional guilds of spiders.

Sr. No.	Family	No. of Genera	No. of Species	Guild
1	Araneidae	11	30	Orb web weavers
2	Clubionidae	3	8	Foliage hunters
3	Eresidae	1	1	Social Spider
4	Gnaphosidae	2	2	Ground runners
5	Hersilidae	1	1	Foliage hunters
6	Heteropodidae	2	4	Foliage runners
7	Lycosidae	7	42	Ground runners
8	Oxyopidae	2	9	Stalkers
9	Salticidae	4	13	Stalkers
10	Tetragnatha	1	1	Orb web weavers
11	Thomisidae	1	1	Ambushers
12	Theridiidae	1	1	Scattered line weavers
13	Uloboridae	1	1	Orb web weavers
	Total	**37**	**114**	

Fig 1: Functional Guild Structure of Spiders

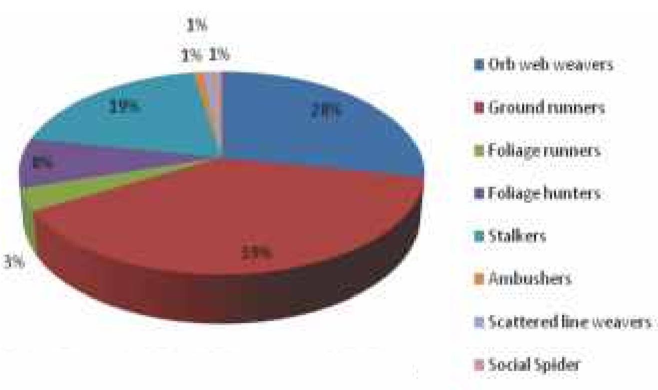


Fig 2: Distribution pattern of spiders in different blocks of Sunderban

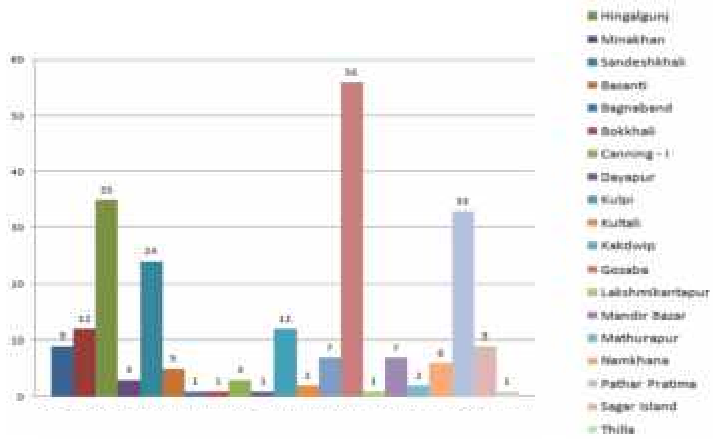


Table 2: Functional groups of spiders in 4 blocks of Indian Sundarbans.

Blocks	Functional groups					
	Orb web weavers	Foliage hunters	Foliage runners	Ground runners	Stalk-ers	Ambush-ers
Gosaba	+	+		+	+	+
Hingalgunj	+	+		+	+	
Patharpratima	+	+	+	+	+	+
Sandeshkhali	+			+		

Note: '+' means availability

Local Community Dependencies and Traditional Use

The healing of human ailments by using therapeutics based on medicines obtained from animals or ultimately derived from them is known as 'zootherapy' (Costa-Neto 2005). The use of animals for medicinal purposes is part of a body of traditional knowledge which is increasingly becoming more relevant to discussions on conservation biology, public health policies, and sustainable management of natural resources, biological prospection, and patents (Alves and Rosa 2005). Approximately 109 animals are reported in traditional medicine in different parts of India (Mahawar and Jaroli 2008).

Majumder and Dey (2005) reported drugs prepared from different species of spiders used successfully by the tribes at the Sundarbans as the remedy for various diseases. The Sundarbans hosts 81,000 tribal people. Fifty-seven medicinal applications have been reported from the Sundarbans, made from 14 species of spiders and 25 floral species (table 3).

The medicinal applications are used locally and some of them are taken orally for the cure of diseases. The applications are generally for the cure of toothache, paralysis of limbs, renal calculi, dysentery, burns, obesity, nasal obstruction, and so on.

Argiope pulchella

Table 3: Dependencies of Tribes on Aranae and flora for their ethnomedicinal usage.

Sr. No.	Name of Aranae Species	Name of the Flora	Local Name of the flora	Name of Tribe
1	*Argiope pulchella*	*Cynodon dactylon*	Durba *	S
		Blumea odorata	Kuksima	M
		Boerhaavia diffusa	Punarnaba *	O
		Acalypha indica	Muktajhuri	S
2	*Nephilia maculata*	*Ocimum sanctum*	Tulasi	O
		Nyctanthes arbor-tristis	Shephalika *	M
		Trichosanthes dioica	Patal	M
3	*Neoscona mukerjei*	*Luffa amara*	Titpolla *	S, M & O
		Hygrophilla spinosa	Kulekhara *	M
		Ocimum caryophyllatum	Dulai Tulasi	O
4	*Cyrtohora cicatrosa*	*Gentiana chirata*	Chirata	O
		Solanum lycopersicum	Tomato	S
		Hydrocotyle asiatica	Thankuni *	M

Sr. No.	Name of Aranae Species	Name of the Flora	Local Name of the flora	Name of Tribe
5	*Cheriacanthium melanostoma*	*Ficus bengalensis*	Bot *	M
		Achyranthes aspera	Apamarga	S
		Azadirachta indica	Nim *	O
6	*Cheriacanthium melanostoma*	*Calotropis gigantea*	Akanda *	S
		Nyctanthes arbor-tristis	Shephalika	M
		Azadirachta indica	Nim	M
7	*Pardosa birmanica*	*Musa sepientum*	Banana *	M & S
		Calotropis gigantea	Akanda	M
		Terminalia chrbula	Haritaki *	S
8	*Lycosa choudhuryi*	*Abroma radix*	Olat kambal root *	S
		Azadirachta indica	Nim	O
		Hygrophilla spinosa	Kulekhara	S
9	*Heteropoda venatoria*	*Azadirachta indica*	Nim	S
		Clerodendron infortunatum	Bhat *	S
		Boerhaavia diffusa	Punarnaba	M
		Hydrocotyle asiatica	Thankuni	O
10	*Spariolenus tigris*	*Musa sepientum*	Banana	M
		Cynodon dactylon	Durba	M
		Ficus bengalensis	Bot	M
		Hygrophilla spinosa	Kulekhara	S
		Tinospora cordifolia	Gulancha	M
11	*Phidippus bengalensis*	*Calotropis gigantea*	Akanda	O
		Terminalia chrbula	Haritaki	M
		Rauwolfia serpentina	Chandra	S
		Nyctanthes arbor-tristis	Shephalika	O
12	*Marpissa bengalensis*	*Abroma radix*	Olat kambal root	S
		Clerodendron infortunatum	Bhat	O
		Ocimum sanctum	Tulsi	S
		Nyctanthes arbor-tristis	Shephalika	S
13	*Crossoprhiza lyoni*	*Musa sepientum*	Banana	M
		Abroma radix	Olat kambal root	S
		Boerhaavia diffusa	Punarnaba	S
		Azadirachta indica	Nim	S
14	*Artema atlenta*	*Azadirachta indica*	Nim	M
		Solanum xanthocarpus	Kantikari	S
		Ficus religosa	Ashwattha	S
		Cynodon dactylon	Durba	O

Note:

- Name of the Tribe: S-Santhal; M-Munda; O-Oraon

- '*': multiple use of the flora with other Aranae species in different applications.
Source : (Majumder & Dey, 2005)

Ecological Importance and Need for Conservation

Spiders are among the oldest and most diverse groups of terrestrial organisms, with fossils dating back to the Devonian period. They stand out because of their ecological importance as the dominant predators of insects. Spiders are clearly an integral part of global biodiversity since they play many important roles in ecosystems as predators and sources of food for other creatures. Spiders are also used by ecologists in the form of conservation tools as ecological indicators of overall biodiversity in many terrestrial communities.

Large changes in moisture, such as those predicted by climate-change models, affect the sign of spider-induced cascades in the detrital web. Changes in rainfall affect ecosystem processes such as primary production and nutrient release from decomposing litter caused by the direct effects of altered rainfall on plants and primary decomposers. Change in rainfall also alters the trophic interactions, thus indirectly influencing ecosystem processes. In detritus-based food webs, predators have the potential to indirectly influence the amount of leaf litter through trophic interactions that affect the rates of decomposition. This chain of interactions as a trophic cascade is analogous to the classic cascade affecting living plants, thus altering net primary production. In the forest-floor food web, *Collembola* (Tomocerids and Entomobryids) affect litter disappearance directly by feeding on litter and indirectly through litter comminution, inoculation with microbes, and fungal grazing. Wandering spiders are clearly implicated as initiators of this trophic cascade. Lensing and Wise (2006) stated that in all trophic-cascade chains in forest leaf litter, it is primarily the Tomocerids or Entomobryids that increase in response to reduced densities of wandering spiders (Lycosidae). Decreased rainfall most likely changes the sign of the spider-initiated trophic cascade by altering the way in which these *Collembola* interact with fungi, a major resource of *Collembola* and an abundant primary decomposer in forest leaf litter.

Documenting spider diversity patterns in this mangrove ecosystem and given the impacts of climate change, the role spiders play in ecosystem dynamics can provide important information to justify the conservation of this unique ecosystem.

STATUS AND THREATS

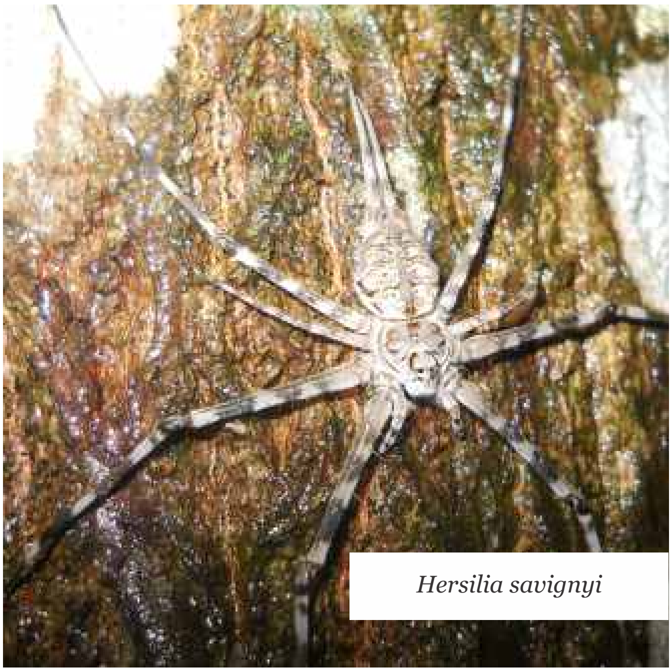
Sensitive to small changes in the habitat structure; including habitat complexity, litter depth and microclimate characteristics

Environmental factors are reported to affect species diversity (Rosenzweig 1995). The extensive leafy canopy of the mangrove forest provides a cool, stable, and shaded environment subjected to high humidity for faunal colonization (Sasekumar 1974; Ross and Underwood 1997). This is supported by Macnae (1968), who reported that mangroves are infested with mosquitoes and midges (often mistaken for sand flies), bees visiting mangrove flowers, and termite-infested deadwood together with cockroaches and beetles while canopy dwellers such as ants, spiders, and firefly aggregations take place during twilight. The canopy provides shelter for spider retreat, which would otherwise expose them to greater risk of desiccation.

The composition and properties of mangrove flora may affect the distribution and abundance of spiders analogous to faunal zonation, with possible dependent variables such as increasing distance from the seaward edge of the forest, height above low tidal level, orientation of the substratum, and biotic interaction such as competition or predatory relationships (Norma-Rashid 2009). Macnae (1968) stated that mangroves are limited to a few dominant groups and the widest zones in the mangroves are the forested area of *Bruguiera* which are separated from the sea by *Avicennia* or *Sonneratia* fringes. Here, the physical environment is potentially less severe due to the canopy of trees with extensive root growths and restricted movement of water (Ross and Underwood 1997). Maximum spider densities are found in such conditions in the middle zones of the mixed forest. In contrast, the open zones closest to the seaward edge have a harsh environment that is poor in fauna or flora. These areas with harsh environment do support a minimum spider community, especially the more hardy species of salticids, long-jawed, and web spiders (Berry 1972). Thus, there exists a clear spatial pattern of spiders in the mangrove forest.

A significant effect of habitat on the diversity of the spiders is evident from the eight functional guilds found in the Sundarbans. The web-building and foliage-running spiders rely on vegetation for some part of their lives, either for finding food,

Myrmarachne oreintalis



Hersilia savignyi

building retreats, or for web building. Studies have demonstrated that a correlation exists between the structural complexity of habitats and species diversity (Hawksworth and Kalin-Arroyo 1995). Diversity generally increases when a greater variety of habitat types are present (Ried and Miller 1989). Uetz et al. (1999) suggests that structurally more complex shrubs can support a more diverse spider community. Downie et al. (1999) and New (1999) have demonstrated that spiders are extremely sensitive to small changes in the habitat structure, including habitat complexity, litter depth, and microclimate characteristics. Spiders generally have humidity and temperature preferences that limit them to areas within the range of their 'physiological tolerances', which make them ideal candidates for land conservation studies (Riechert and Gillespie 1986). The structure of the vegetation is therefore expected to influence the diversity of spiders found in the Sundarbans.

Given the conservation and protection regime prevalent in India, spiders found in the Sundarbans do not find a place in the schedules of the Indian Wildlife (Protection) Act, 1972. This adds to the necessity of documenting the population diversity and relevant threats affecting their ecology and distribution.

ANNEXURE

List of Spiders reported from Indian Sundarbans and their economic importance

Family	Genera	Species Name	Common Name	Habitat	Economic Importance
Araneidae	*Araneus* Clerck	*Araneus mitifica* (Simon)	Orb-weaving spider	Mangrove & Semi-mangrove bushes	Controlling agent of various kind of harmful insect in crop field.
Araneidae	*Araneus* Clerck	*Araneus bitiberculata* (Walckenaer)	Orb-weaving spider	Mangrove & Semi-mangrove bushes	Predator of insect pest in the vegetable and flower garden.
Araneidae	*Araneus* Clerck	*Araneus anantnagensis* Tikader & Bal	Orb-weaving spider	Mangrove & Semi-mangrove bushes	Predator of insect pest in the vegetable and flower garden.
Araneidae	*Araneus* Clerck	*Araneus nympha* Simon	Orb-weaving spider	Mangrove & Semi-mangrove bushes	Controlling agent of various kind of harmful insect in crop field.
Araneidae	*Argiope* Audouin	*Argiope aemula* (Walckenaer)	Orb-weaving spider	Only Mangrove bushes	Controlling agent of various kind of harmful insect in crop field.
Araneidae	*Argiope* Audouin	*Argiope anasuja* Thorell	Signature Orb-weaving spider	Mangrove Herb & Small Trees	Predator of insect pest in the crop field.
Araneidae	*Argiope* Audouin	*Argiope arculata* Simon	Orb-weaving spider	True Mangrove and Semi-mangrove bushes	Predator of insect pest in the crop field.
Araneidae	*Argiope* Audouin	*Argiope kalimpongensis* Sinha	Orb-weaving spider	Mangrove & Semi-mangrove bushes & Small Trees	Controlling agent of insect pest in crop field.

Family	Genera	Species Name	Common Name	Habitat	Economic Importance
Araneidae	*Argiope* Audouin	*Argiope pulchella* Thorell	Orb-weaving spider	Mangrove & Semi mangrove forest	Medicinally Important
Araneidae	*Argiope* Audouin	*Argiope shillongensis* Sinha	Orb-weaving spider	Mangrove & Semi mangrove bushes	Medicinally Important
Araneidae	*Gasteracantha* Sundevall	*Gasteracantha hasseltii* C.L.Kochh	Orb-weaving spider	Mangrove & Semi mangrove bushes	Controlling agent of insect - pest in crop field.
Araneidae	*Neoscona* Simon	*Neoscona excelsus* (Simon)	Orb-weaving spider	Mangrove & Semi mangrove shurbs & bushes	Medicinally Important
Araneidae	*Neoscona* Simon	*Neoscona mukerjei* Tikader	Orb-weaving spider	Tall grasses, Mangrove & Semi mangrove bushes	Medicinally Important
Araneidae	*Neoscona* Simon	*Neoscona theis* (Walckenaer)	Orb-weaving spider	Mangrove & Semi mangrove areas	Medicinally Important
Araneidae	*Neoscona* Simon	*Neoscona shillongensis* Tikader & Bal	Orb-weaving spider	Mangrove & Semi mangrove bushes	Controlling agent of insect - pest in crop field.
Araneidae	*Neoscona* Simon	*Neoscona nautica* (L.Kocha)	Orb-weaving spider	Mangrove & Semi mangrove bushes	Controlling agent of insect - pest in crop field.
Araneidae	*Neoscona* Simon	*Neoscona pavida* (Simon)	Orb-weaving spider	Mangrove & Semi mangrove bushes	Predator of insect pest in the crop field.
Araneidae	*Neoscona* Simon	*Neoscona rumpfi* (Thorell)	Orb-weaving spider	Medium sized grass, mangrove and semi mangrove bushes and shrubs	Controlling agent of insect - pest in crop field.
Araneidae	*Neoscona* Simon	*Neoscona molemensis* Tikader & Bal	Orb-weaving spider	Mangrove & Semi mangrove bushes near paddy fields	Predator of insect pest in the crop field.
Araneidae	*Neoscona* Simon	*Neoscona elliptica* Tikader & Bal	Orb-weaving spider	Bushes & small trees	Medicinally Important
Araneidae	*Neoscona* Simon	*Neoscona lugubris* (Walckenaer)	Orb-weaving spider	Mangrove and Semi mangrove areas	Controlling agent of insect - pest in crop field.
Araneidae	*Larinia* Simon	*Larinia phtisica* (L. Koch)	Two tier orb-weaving spider	Mangrove and semi mangrove bushes and shrubs	Predator of insect pest in the crop field.

Family	Genera	Species Name	Common Name	Habitat	Economic Importance
Araneidae	*Parawixia* F.O.P. Cambridge	*Parawixia dehaanii* (Doleschall)	Orb-weaving spider	Mangrove forest	Predator of harmful insects in fruit garden
Araneidae	*Leucuage* White	*Leucuage decorata* (Blackwall)	Dome shaped Orb-weaving spider	Mangrove forest	Predator of harmful insects in the crop field.
Araneidae	*Leucuage* White	*Leucuage tessellata* (Thorell)	Dome shaped Orb-weaving spider	Bushes, shurb, herb of Mangrove and semi mangrove	Predator of harmful insects in the crop field.
Araneidae	Cyrtophora Simon	*Cyrtophora cicatrosa* (Stoliczka)	Dome shaped Orb-weaving spider	Mangrove and semi mangrove	Medicinally Important
Araneidae	Cyrtophora Simon	*Cyrtophora bidenta* Tikader	Dome shaped Orb-weaving spider	Mangrove and semi mangrove	Medicinally Important
Araneidae	Poltys Koch	*Poltys nagpurensis* Tikader	Orb-weaving spider	Mangrove and semi mangrove bushes	Predator of harmful insects
Araneidae	Zygeilla O.P. Cembrifge	*Zygeilla melanocrania* (Thorell)	Orb-weaving spider	Mangrove and semi mangrove	Predator of insects pest in fruit garden
Araneidae	*Singa* Koch	*Singa chota* Tikader	Orb-weaving spider	Mangrove and semi mangrove	Predator of harmful insects in the crop field.
Clubionidae	*Clubiona* Latreille	*Clubiona brassodes* Cambridge	Sac spider	Small tress or bushes & large grasses of mangrove & semi mangrove	Predator of harmful insects in the crop field.
Clubionidae	*Clubiona* Latreille	*Clubiona filicata* Cambridge	Sac spider	Shurb, herb or bushes near paddy field	Predator of harmful insects in the crop field.
Clubionidae	*Cheiracanthium* Koch	*Cheiracanthium trivialis* Thorell	Sac spider	Shurb, herb or bushes of Mangrove and semi mangrove	Medicinally Important
Clubionidae	*Cheiracanthium* Koch	*Cheiracanthium melanostoma* Thorell	Sac spider	Trees & Mangrove and semi mangrove bushes	Medicinally Important
Clubionidae	*Cheiracanthium* Koch	*Cheiracanthium himalayensis* Gravely	Sac spider	Shurb, herb or bushes near paddy field & Mangrove bushes	Medicinally Important

Family	Genera	Species Name	Common Name	Habitat	Economic Importance
Clubionidae	*Cheiracanthium* Koch	*Cheiracanthium mysorensis* Tikader & Majumdar	Sac spider	Trees, herb, shurb & bushes of Mangrove	Medicinally Important
Clubionidae	Castianeira Keyserling	*Castianeira himalayensis* Gravely	Mutilated Wasp Spider	Soil litters of Mangrove & Semi-Mangrove	-
Clubionidae	Castianeira Keyserling	*Castianeira tinae* Patel & Patel	Mutilated Wasp Spider	Forest litters of Mangrove	-
Eresidae	Stegodyphus Simon	*Stegodyphus sarasinorum* Karsch	Collonial Spider	Mangrove and semi mangrove	Controlling agent of harmful insect
Gnaphosidae	*Poecilochora* Westing	*Poecilochora barmani* Tikader	Two clawed nocturnal hunting spider	Forest litters in Mangrove & Semi Mangrove	-
Gnaphosidae	*Scopodes* Chamberlin	*Scopodes kuljitae* Tikader	Two clawed nocturnal hunting spider	Decaying logs & Forest litters in Mangrove & Semi Mangrove	-
Hersilidae	*Hersilia* Audouin	*Hersilia savignyi* Lucas	Arboreal Spider	Trunk of large trees	-
Heteropodidae	Heteropoda Latreille	*Heteropoda sikkimensis*	Giant Crab Spider	Rolled up dried leaves	Medicinally Important
Heteropodidae	Heteropoda Latreille	*Heteropoda venatoria* (Linnaeus)	Giant Crab Spider	Bushes of Mangrove and Semi Mangrove	Medicinally Important
Heteropodidae	*Spariolenus* Simon	*Spariolenus petricola* Gravely	Giant Crab Spider	Foliage of Bushes in Mangrove and Semi Mangrove	Medicinally Important
Heteropodidae	*Spariolenus* Simon	*Spariolenus tigris* Simon	Giant Crab Spider	Walls of old houses	Medicinally Important
Lycosidae	*Arctosa* Koch	*Arctosa mulani* (Dyal)	Wolf spider	Wet litters of Mangrove and Semi Mangrove forest	Predator of insect pest
Lycosidae	*Arctosa* Koch	*Arctosa indicus* Tikader & Malhotra	Wolf spider	Pond, Stream and river bed of Sundarban	Predator of insect pest
Lycosidae	*Arctosa* Koch	*Arctosa himalayensis* Tikader & Malhotra	Wolf spider	Pond, Stream and river bed of Sundarban	Predator of insect pest
Lycosidae	*Arctosa* Koch	*Arctosa khudiensis* (Sinha)	Wolf spider	Moist forest litters	Predator of insect pest

Family	Genera	Species Name	Common Name	Habitat	Economic Importance
Lycosidae	*Arctosa* Koch	*Arctosa sandeshkhaliensis* Majumder	Wolf spider	Marshy lands: paddy fields	Predator of insect pest
Lycosidae	*Hippasa* Simon	*Hippasa greenalliae (*Blackwall)	Funnel Orb-weaving spider	Mangrove and semi mangrove	Predator of insect pest
Lycosidae	*Hippasa* Simon	*Hippasa holmerae* Thorell	Funnel Orb-weaving spider	Marshy lands & Moist grassy lands	Predator of insect pest
Lycosidae	*Hippasa* Simon	*Hippasa partita* (Cambridge)	Funnel Orb-weaving spider	Mangrove and semi mangrove	Predator of insect pest
Lycosidae	*Hippasa* Simon	*Hippasa olivacea* Thorell	Funnel Orb-weaving spider	Mangrove and semi mangrove	Predator of insect pest
Lycosidae	*Trochosa* Koch	*Trochosa punctipes* (Gravely)	Trap Door spider	Mangrove and semi mangrove	Predator of insect pest
Lycosidae	*Flanona* Simon	*Flonona puellula* Simon	Three clawed hunting spider	Open Vegetation	Predator of insect pest
Lycosidae	Ocyale Audouin	*Ocyale atalanta* Audouin	Three clawed hunting spider	Soil liters and foliage of Mangrove & Semi-Mangrove	Predator of insect pest
Lycosidae	Lycosa Latreille	*Lycosa chaperi* Simon	Wolf spider	Ground Dwellers & Forest litters of Mangrove & Semi-mangrove	Medicinally Important
Lycosidae	Lycosa Latreille	*Lycosa kempi* Gravely	Wolf spider	Pond, Stream and river bed of Sundarban	Predator of insect pest
Lycosidae	Lycosa Latreille	*Lycosa choudhuryi* Tikader & Malhotra	Wolf spider	Ground dwellers & Forest litters of Mangrove & Semi-mangrove	Medicinally Important
Lycosidae	Lycosa Latreille	*Lycosa poonaensis* Tikader & Malhotra	Wolf spider	Pond, Stream and river bed of Sundarban	Medicinally Important
Lycosidae	Lycosa Latreille	*Lycosa masteri* Pocock	Wolf spider	Ground dwellers of Mangrove & Semi-mangrove	Predator of insect pest

Family	Genera	Species Name	Common Name	Habitat	Economic Importance
Lycosidae	*Lycosa* Latreille	*Lycosa mackenjei* Gravely	Wolf spider	Wet litters of Mangrove and Semi Mangrove forest	Predator of insect pest
Lycosidae	*Lycosa* Latreille	*Lycosa mahabaleshwarensis* Tikader & Malhotra	Wolf spider	Wet grassy land of Mangrove and Semi Mangrove forest	Predator of insect pest
Lycosidae	*Lycosa* Latreille	*Lycosa himalayaensis* Gravely	Wolf spider	Ground dwellers of Mangrove & Semi-mangrove	Medicinally Important
Lycosidae	*Lycosa* Latreille	*Lycosa pictula* Pocock	Wolf spider	Wet litters of Mangrove and Semi Mangrove forest	Predator of insect pest
Lycosidae	*Lycosa* Latreille	*Lycosa tista* Tikader	Wolf spider	Wet litters of Mangrove and Semi Mangrove forest	Predator of insect pest
Lycosidae	*Lycosa* Latreille	*Lycosa shillongensis* Tikader & Malhotra	Wolf spider	Ground dwellers of Mangrove & Semi-mangrove	Predator of insect pest
Lycosidae	*Pardosa* Koch	*Pardosa annandalei* (Gravely)	Wolf spider	Mangrove and semi mangrove	Predator of insect pest
Lycosidae	*Pardosa* Koch	*Pardosa birmanica* Simon	Wolf spider	Pond, Stream and river bed of Mangrove and semi mangrove	Medicinally Important
Lycosidae	*Pardosa* Koch	*Pardosa burasatiensis* Tikader & Malhotra	Wolf spider	Ground dwellers of Mangrove & Semi-mangrove	Medicinally Important
Lycosidae	*Pardosa* Koch	*Pardosa chambaensis* Tikader & Malhotra	Wolf spider	Wet litters of Mangrove and Semi Mangrove forest	Predator of insect pest
Lycosidae	*Pardosa* Koch	*Pardosa heterophthalmus* Simon	Wolf spider	Wet litters of Mangrove and Semi Mangrove forest	Medicinally Important

Family	Genera	Species Name	Common Name	Habitat	Economic Importance
Lycosidae	*Pardosa* Koch	*Pardosa kupupa* (Tikader)	Wolf spider	Pond, Stream and river bed of Mangrove and semi mangrove	Predator of insect pest
Lycosidae	*Pardosa* Koch	*Pardosa leucopalpis* Gravely	Wolf spider	Ground dwellers of Mangrove & Semi-mangrove	Predator of insect pest
Lycosidae	*Pardosa* Koch	*Pardosa minutus* Tikader & Malhotra	Wolf spider	Mangrove and semi mangrove	Predator of insect pest
Lycosidae	*Pardosa* Koch	*Pardosa oakleyi* Gravely	Wolf spider	Pond, Stream and river bed of Mangrove and semi mangrove	Predator of insect pest
Lycosidae	*Pardosa* Koch	*Pardosa rhenockensis* (Tikader)	Wolf spider	Pond, Stream and river bed of Mangrove and semi mangrove	Predator of insect pest
Lycosidae	*Pardosa* Koch	*Pardosa songosa* Tikader & Malhotra	Wolf spider	Wet litters of Mangrove and semi mangrove forest	Predator of insect pest
Lycosidae	*Pardosa* Koch	*Pardosa shyamae* Tikader	Wolf spider	Mangrove and semi mangrove	Predator of insect pest
Lycosidae	*Pardosa* Koch	*Pardosa sumatrana* (Thorell)	Wolf spider	Mangrove and semi mangrove	Medicinally Important
Lycosidae	*Pardosa* Koch	*Pardosa alii* Tikader	Wolf spider	Mangrove and semi mangrove	Predator of insect pest
Lycosidae	*Pardosa* Koch	*Pardosa mysorensis* (Tikader & Malhotra)	Wolf spider	Mangrove and semi mangrove	Medicinally Important
Lycosidae	*Pardosa* Koch	*Pardosa sutherlandi* (Gravely)	Wolf spider	Ground dwellers of Mangrove & Semi-mangrove	Predator of insect pest
Lycosidae	*Pardosa* Koch	*Pardosa amkhasensis* Tikader & Malhotra	Wolf spider	Mangrove and semi mangrove	Predator of insect pest
Lycosidae	*Pardosa* Koch	*Pardosa suchismitae* Majumder	Wolf spider	Pond, Stream and river bed of Mangrove and semi mangrove	Predator of insect pest

Family	Genera	Species Name	Common Name	Habitat	Economic Importance
Lycosidae	*Pardosa* Koch	*Pardosa debolinae* Majumder	Wolf spider	Pond, Stream and river bed of Mangrove and semi mangrove	Predator of insect pest
Oxyopidae	*Oxyopes* Latreille	*Oxyopes sakuntalae* Tikader	Lynx Spider	Mangrove and semi mangrove	Predator of insect pest
Oxyopidae	*Oxyopes* Latreille	*Oxyopes shweta* Tikader	Lynx Spider	Mangrove and semi mangrove	Predator of insect pest
Oxyopidae	*Oxyopes* Latreille	*Oxyopes sitae* Tikader	Lynx Spider	Foliage of Bushes in Mangrove and Semi Mangrove	Predator of insect pest
Oxyopidae	*Oxyopes* Latreille	*Oxyopes redyii* Majumder	Lynx Spider	Pond, Stream and river bed of Mangrove and semi mangrove	Predator of insect pest
Oxyopidae	*Oxyopes* Latreille	*Oxyopes ratnae* Tikader	Lynx Spider	Shurb, herb or bushes near ponds & rivers	Predator of insect pest
Oxyopidae	*Oxyopes* Latreille	*Oxyopes sunandae* Tikader	Lynx Spider	Shurb, herb or bushes near ponds & rivers	Predator of insect pest
Oxyopidae	*Oxyopes* Latreille	*Oxyopes sikkimensis* Tikader	Lynx Spider	Bushes of Mangrove and Semi Mangrove	Predator of insect pest
Oxyopidae	*Oxyopes* Latreille	*Oxyopes pandae* Tikader	Lynx Spider	Bushes of Mangrove and Semi Mangrove	Predator of insect pest
Oxyopidae	*Peucetia* Thorell	*Peucetia latikae* Tikader	Lynx Spider	Mangrove and semi mangrove	Predator of insect pest
Salticidae	*Marpissa* Kochh	*Marpissa calcuttaensis* Tikader	Jumping Spider	Shurb, herb or bushes of Mangrove and semi mangrove	Predator of insect pest
Salticidae	*Marpissa* Kochh	*Marpissa bengalensis* Tikader	Jumping Spider	Arboreal & Ground Dwellers	Medicinally Important
Salticidae	*Marpissa* Kochh	*Marpissa decorata* Tikader	Jumping Spider	Foliage of Bushes in Mangrove and Semi Mangrove	Medicinally Important
Salticidae	*Marpissa* Kochh	*Marpissa dhakuriensis* Tikader	Jumping Spider	Bushes near the paddy field	Predator of insect pest

Family	Genera	Species Name	Common Name	Habitat	Economic Importance
Salticidae	*Marpissa* Kochh	*Marpissa dyapurensis* Majumder	Jumping Spider	Foliage of Bushes in Mangrove and Semi Mangrove	Predator of insect pest
Salticidae	*Marpissa* Kochh	*Marpissa lakshmikantapurensis* Majumder	Jumping Spider	Foliage of Bushes in Mangrove and Semi Mangrove	Predator of insect pest
Salticidae	*Marpissa* Kochh	*Marpissa andamanensis* Tikader	Jumping Spider	Foliage of Bushes in Mangrove and Semi Mangrove	Predator of insect pest
Salticidae	*Marpissa* Kochh	*Marpissa gangasagerensis* Majumder	Jumping Spider	Foliage of Bushes in Mangrove and Semi Mangrove	Predator of insect pest
Salticidae	*Phidippus* Koch	*Phidippus* bengalensis Tikader	Jumping Spider	Foliage of Bushes in Mangrove and Semi Mangrove	Medicinally Important
Salticidae	*Phidippus* Koch	*Phidippus pateli* Tikader	Jumping Spider	Foliage of Bushes in Mangrove and Semi Mangrove	Medicinally Important
Salticidae	*Phidippus* Koch	*Phidippus indicus* Tikader	Jumping Spider	Foliage of Bushes in Mangrove and Semi Mangrove	Medicinally Important
Salticidae	*Plexippus* Kochh	*Plexippus paykulii*	Jumping Spider	Foliage of Bushes in Mangrove and Semi Mangrove	Predator of insect pest
Salticidae	*Myrmarachne* Mac Leay	*Myrmarachne orientalis* Tikader	Ant Spider	Ground dwellers of Mangrove & Semi-mangrove	Predator of insect pest
Tetragnatha	*Tetragnatha* Latreille	*Tetragnatha anadamanensis* Latreille	Long jawed spider	Shurb, herb or bushes near ponds & rivers	Predator of insect pest
Thomisidae	*Camaricus* Thorell	*Camaricus formosus* Thorell	Crab Spider	Ground dwellers of Mangrove & Semi-mangrove	Predator of insect pest
Theridiidae	*Theridion* Walckenaer	*Theridiidae* indica Tikader	Irregular orb-weaving spider	Ground dwellers of Mangrove & Semi-mangrove	Predator of insect pest
Uloboridae	*Uloborus* Latrille	*Uloborus danolius* Tikader	Triangular Orb-weaving spider	Shurb, herb or bushes near ponds & rivers	Predator of insect pest

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2.12 ACARINA

Phylum Arthopoda also includes a group of animals which, unlike insects or myriapoda, have neither antennae nor mandibles. These animals comprise the group known as Chelicerata, of which the largest group is the class Arachnida.

ASOK KANTI SANYAL
Acarologist

Highest population densities and species richness of free-living mites occur in the organic strata of soils

The class Arachnida was named by Chevalier De Lamark in 1815, splitting the Linnaeus heterogeneous group Insecta into three classes. Lamark's class Arachnida included scorpions, spiders, and mites together with the Myriapoda and Thysanura. At present, the living members of Arachnida are grouped into nine subclasses, namely Scorpionida, Pedipalpida, Microthelyphonida, Solifugae, Ricinulei, Opiliones, Pseudo-scorpionida, Acari, and Araneae. The subclasses Microthelyiphonida and Ricinulei are not recorded so far from India. The earliest record of arachnids from India was made as far back as 1758, when Linnaeus described ticks from India.

The arachnids are characterized by a number of features like two divisions of body—cephalothorax or prosoma and abdomen or opisthosoma—and absence of antenna. Arachnids have four pairs of legs each having seven segments and have eight simple eyes. One of the striking characteristic features of Arachnida is the absence of true jaws. Sexes are separate and remarkable sexual dimorphism is found in some cases.

The subclass Acarina comprising ticks and mites was first recorded in India by Peal (1868) through the discovery of the red-spider mite on tea in Assam. The size of mites ranges from 1.5 mm to 16 mm and ticks vary in size from 1.7 mm to 12.7 mm. Engorged individual ticks may attain 20–30 mm. Ticks differ from mites by the presence of hypostome with retrose teeth and the sensory setal field, Haller's organ on the tarsus-I of the leg. Most of the acarines are oviparous. Almost all mites complete several generations in a year. The ticks usually have a generation of several months and some may have an annual life cycle.

Many acarine groups have evolved far beyond the primitive habit of predation. Some are exclusively phytophagous and others have a parasitic relationship with invertebrate and vertebrate animals. Many acarine species are beneficial to human society as predators and decomposers.

Both the acarine groups, ticks and mites, live in diverse environments, including severe desert and tundra situations, mountain tops, deep soil layer, wetlands, subterranean caves, hot springs, and ocean floors. They live in almost every terrestrial, marine, and freshwater habitat. The highest population densities and species richness of free-living mites occur in the organic strata of soils where they form the numerically dominant component of the arthropod macrofauna and may contribute up to 7 percent of the total weight of the invertebrate fauna. The role of acarines is significant because of their manifold beneficial as well as harmful effects on agriculture, medical and veterinary sciences, public health, poultry, and apiaries.

Ticks are more capable of transmitting pathogens to man and domesticated animals than any other group of bloodsucking arthropods. Many of these agents cause zoonoses, that is, diseases that are transmitted from animal to man under natural conditions. Pathogens transmitted include viruses, spirochaetes, rickettsiae, anaplasmas, bacteria, piroplasmas, and filariae. There are a number of routes like saliva, regurgitation, coxal fluid, and faeces through which pathogens are transmitted from ticks to their vertebrate hosts.

Many family members of mites infest stored grains and other stored products. They are serious pests of crops and also act as vectors of viral diseases. They live as ectoparasites of man and domestic animals and suck blood from the host body or feed on the tissue material. They cause severe mange in cattle, dogs, cats, pigs, and horses. Oribatid mites act as vectors of anoplocephaline cestodes in cattle and cause various helminth diseases. The tiny creatures are also responsible for various human diseases such as scabies, tumors, nodules, thickening of the skin and other allergic dermatitis, loss of hair, anemia, pneumonia, scrub typhus, and respiratory allergies, including bronchial asthma and rhinitis to man.

Many species of mites are beneficial mainly for their ecological services. A number of species are efficient predators of plant-feeding mites and also of harmful soil nematodes. Some are used as biotic agents for control of the housefly and other insect and plant pests. The soil mites also facilitate the process of decomposition and humification of organic matter, resulting in increase of soil fertility and ultimately soil formation. Decomposition of litter occurs through physical and chemical changes. The presence of the soil fauna is necessary for the establishment of vigorous populations of these microorganisms. Mites are one of these soil fauna and live as detritivore in soil. They disintegrate plant and animal tissue and provide suitable substrate for invasion by microflora. They selectively decompose and chemically change litter, mix the organic matter thoroughly, transform plant residues into humic substances, and form a complex aggregate of organic matter with the mineral part of soil.

OVERVIEW OF THE GROUP

The fossil evidence of Arachnida in general or of the Acari in particular indicates that a major adaptive breakthrough occurred in Acari during the late Mesozoic and early Cenozoic era. Most of the acarologists opine that the Acari evolved from some primitive arachnid stock and branched into two separate entities as Acariformes and Parasitiformes. The enormous diversity in morphology, habit, and distribution in Acarina attracted the attention of Linnaeus (1758) and thousands of workers in the world. The existence of mites was referred to as early as 850 B.C. by Homer. The first consolidated list of mites was given in the book *Systema Naturae* by Linnaeus (1758). Alfred et al. (1998) presented a detailed account of the status of Acarina in India compared with the world.

Though no attempt has been made by anyone to estimate the total number of species from the world, it is presumed that the total acarine species known from the world is not less than 30,000 (Krantz 1978). Halliday et al. (2000) recorded 48,200 species of acari in the world, of which ticks share around 900 species. The total number of acarine species known so far from India is estimated as 2,186, distributed over 643 genera and 207 families (Alfred et al. 1998). Nearly 45 percent of the species known so far from India are described as new to science. The major families known from India include more than 20 species. Some of them are very rich in the number of species, for example, Ixodidae (107), Eriophyidae (270), Phytoseiidae (140), Tetranychidae (100), Tenuipalpidae (75), Scheloribatidae (50), and Gulumnidae (42).

SYNOPTIC VIEW

Diversity

45%
OF THE SPECIES SO FAR KNOWN FROM INDIA ARE DESCRIBED AS NEW TO SCIENCE

The work on Indian Acarina was initiated by Linnaeus (1758) and later by Peal (1868). The study of ticks in the Sundarbans was first attempted by Sharif (1928). While studying the collection of tick specimens present in the Indian Museum, he reported only two species. After a gap of about 60 years, Basu (1989) made a good collection of ticks from domestic cattle and buffalo in the Sundarbans and those were identified into two species. Nandi and De (1984) reported a case of tick infestation in humans. Thus, altogether four species under three genera, namely *Haemaphysalis, Hyalomma,* and *Rhipicephalus*, under one family Ixodidae are known from the Sundarbans. There is no record of argasid ticks from the area (see annexure). No new taxa of ticks was described from the area. This very poor representation was only due to lack of serious studies on ticks in the Sundarbans. No generic diversity in ticks was observed in the Sundarbans.

2186
ACARINE SPECIES KNOWN FROM INDIA

The number of genera recorded here is very low when considering the generic diversity of ticks in Gujarat (in general) - 7 genera (Sanyal and De 2004) and the Andaman and Nicobar Islands - 28 genera (De and Sanyal 1984).

Out of the 643 genera recorded from India (Alfred et al. 1998), 67 genera (table 1 and annexure) are found in the Indian Sundarbans. Maximum generic diversity was recorded in Phytoseiidae (7), Tetranychidae (6), Eriophyidae (5), and Tydeidae (4). As much more studies were undertaken in the Sundarbans than the other mangrove regions in India like Gujarat and the Andaman and Nicobar Islands, the number of genera is higher than that of Gujarat - 14 (Gupta 1985) and the Andaman and Nicobar Islands - 25 (Sanyal, forthcoming).

Table 1 : Diversity (Families, genera and species) of Acarina in Indian Sundarbans

Sl. No.	Family	No. of genera	No. of species
	METASTIGMATA		
1	Ixodidae	3	4
	CRYPTOSTIGMATA		
2	Hypochthoniidae	1	1
3	Mesoplophoridae	1	1
4	Cosmochthoniidae	2	2
5	Haplochthoniidae	1	1
6	Phthiracaridae	2	2
7	Euphthiracaridae	1	1
8	Lohmaniidae	2	2
9	Epilohmanniidae	1	1
10	Trhyhypochthoniidae	1	1
11	Malaconothridae	1	1
12	Basilobelbidae	1	1
13	Carabodidae	1	1
14	Tectocepheidae	1	1
15	Otocepheidae	1	2
16	Oppiidae	3	6
17	Chaunoproctidae	1	1
18	Xylobatidae	1	1
19	Haplozetidae	3	3
20	Scheloribatidae	2	6
21	Austrachipteridae	2	2
22	Galumnidae	1	3
	PROSTIGMATA		
23	Tetranychidae	6	18
24	Tenuipalpidae	3	7
25	Eriophyidae	5	8
26	Tarsonemidae	1	1
27	Stigmaeidae	1	2
28	Bdellidae	2	2
29	Tydeidae	4	7
30	Cunaxidae	1	3
31	Eupodidae	1	1
32	Cheyletidae	1	1
33	Erythraeidae	1	1
	MESOSTIGMATA		
34	Phytoseiidae	7	22
35	Ascidae	2	2
36	Rhodacaridae	1	1
37	Uropodidae	1	1

Species Richness and Functional Groups

121
SPECIES FROM INDIAN SUNDARBANS

Of the 2,186 acarine species known from India (Alfred et al. 1998), 121 species have been recorded from eight blocks of the Indian Sundarbans. This number is very high when compared to the number of mite species in Gujarat - 25 (Gupta 1992; Sanyal and Basak 2004) and the Andaman and Nicobar Islands - 45 (Gupta 1992). Though there is no definite functional group in ticks and mites, the acarine species in the Sundarbans may be divided into three major groups such as animal parasites, plant inhabiting forms, and soil dwelling forms, comprising 3.3 percent, 61.2 percent, and 35.5 percent, respectively, of the total acarines found in the Sundarbans.

Distribution Pattern

Of the 121 species known from eight blocks of the Indian Sundarbans, maximum species diversity was recorded from Sagar (56). The other major blocks in order of species richness were Namkhana (43), Pirkhali (28), Kakdwip (26), Canning (20), Gosaba (18), Patharpratima (8), and Basanti (4).

Local Community Dependency and Traditional Use

As ticks and mites are mostly harmful to humans and animals, livelihood of the local community is not directly dependent upon the acarines. They are, however, indirectly affected by acarine fauna due to their parasitic and pest habits which cause financial and health problems to the local community and domestic animals.

Ecological Importance and Need for Conservation

Soil inhabiting forms are of great ecological significance

Mites, especially the soil-inhabiting forms, are of great ecological significance. They constitute an integral part of the ecosystem as pest, predator, and decomposer and an active constituent of nutrient cycling in the ecological system. The unique habitat of the Sundarbans, having mangrove vegetation and partly shaded areas, exerts a direct and indirect influence on the distribution and abundance of soil- and plant-inhabiting mites (Macfadyen 1952) through its effect on soil cavity size, litter formation, and soil moisture. There might be a moderate correlation between plant community and mite population in the sense that the intensity of vegetation might directly or indirectly influence the faunal makeup. The analysis of the studies done so far in the Sundarbans clearly showed that the specimens were mostly collected from the middle zones in the forested areas where the physical environment was potentially less harsh due to tall trees, with a well-developed canopy and well-settled root system which checks frequent inundation.

Rainfall, soil temperature, moisture, and organic carbon were found to be positively correlated with the mite population and affect the trophic cascade in the detrital web. All the energy entering the soil community ultimately dispersed as heat energy due to the metabolic activities of soil organisms, including mites which constitute the bulk of the soil arthropod community. This heat is not cycled but the inorganic nutrients continually circulate through the plant or soil system.

The litter, together with the faeces and corpses of animals living above the soil surface, forms the energy base on which the mites operate along with other detritivorous animals and microfloral decomposers in the soil. The feeding activities of soil organisms and mites chemically degrade the energy-rich plant debris, resulting in liberation of energy and nutrients which cycle.

Mites play an important role in nutrient cycling in the soil ecosystem. The bulk of the atmospheric carbon which enters the soil through vegetation is assimilated into the bodies of detritivores and decomposers. This assimilated carbon travels through the soil community and is ultimately released to the atmospheric pool. The cycling nitrogen, phosphorous, and sulphur and more important nutrients of the plant or soil system emphasize the considerable importance of bacteria and fungi. The activities of soil fauna are of secondary importance.

The plant-inhabiting mites, particularly the predators, play a vital role in maintaining ecological balance through their habit of predation on the mites of plant pests. The above discussion clearly indicates that mites are the most important ecological component, needing proper conservation for sustenance of life in the Sundarban mangrove ecosystem. Formulation of strategies for conservation of some taxa is a priority. Conservation can be successfully carried out through management of the habitat of the beneficial acarina and judicious and restricted use of poisonous chemicals.

Economically important mites are indeed an important resource in management of mite pests and soil. The rational and meaningful exploitation of these mites needs mass culture and release of the mites in fields as biological control agents to act as decomposers.

THREATS

However, the question of threat arises in the case of economically important species, particularly predatory and soil-inhabiting mites. Pollution coupled with habitat degradation kills the soil mites, thus gradually transforming nutrient-enriched soil to wasteland. Further, excessive and indiscriminate use of chemical pesticides and fertilizers, wrong agricultural practices, and introduction of alien species cause the loss of predatory mites and mites of economic importance.

1. *Haemaphysalis bispinosa* 2. and 3. *Rhipicephalus haemaphysaloides* 4. *Scheloriates albialatus*
5. *Dolicheremaeus bengalensis*

ANNEXURE

List of Acarine species described and recorded from Indian Sundarbans

	Family	Genus	Species name	Host / Habitat	Economic Importance	Distribution
METASTIGMATA	Ixodidae	*Haemaphysalis* Koch	*H. indica* Warburton	Mongoose	Ectoparasitic	Alampur village, Raiganj
		Haemaphysalis Koch	*H. bispinosa* Neumann	Cattle	Ectoparasitic	Basanti Village
		Hyalomma Koch	H. *anatolicum* Koch	Cattle	Ectoparasitic	Canning, Kakdwip
		Rhipicephalus Koch	*R. haemaphysaloides* Supino	Unknown	Ectoparasitic	Basanti
CRYPTOSTIGMATA	Hypochthoniidae	*Hypochthonius* Koch	*Hypochthonius* sp.	Soil and litter	Decomposer	Bakkhali, Frazerganj
	Mesoplophoridae	*Mesoplophora* Berlese	*M. pectinata* Mahunka	Soil and litter	Decomposer	Namkhana, Sagar Island, Bakkhali
	Cosmochthoniidae	*Cosmochthonius* Berlese	*C. bengalensis* Chakrabarti *et. al.*	Soil and litter	Decomposer	Frazerganj, Kakdwip, Namkhana
		Phyllozetes Gordeeva	*P. heterotrichus* Sanyal and Bhaduri	Soil and litter	Decomposer	Sagar Island, Frazerganj, Namkhana
	Haplochthoniidae	*Haplochthonius* Willmann	*H. intermedius* Chakrabarti *et. al.*	Soil and litter	Decomposer	Kakdwip, Bakkhali, Canning
	Phthiracaridae	*Atropacarus* Ewing	*A.(Hoplophorella) scapellata* (Aoki)	Soil and litter	Decomposer	Sagar Island, Frazerganj, Kakdwip, Canning
		Atropacarus Ewing	*A.(Hoplophorella) sundarbanensis* Sanyal and Bhaduri	Soil and litter	Decomposer	Sagar Island, Bakkhali, Namkhana
	Euphthiracaridae	*Rhysotritia* Markel and Meyer	*R. ardua* var. *otahitensis* Hammer	Soil and litter	Decomposer	Kakdwip, Sagar Island, Bakkhali
	Lohmaniidae	*Cryptacarus* Grandjean	*C.tuberculatus* Csiszar	Soil and litter	Decomposer	Sagar Island, Frazerganj
		Haplacarus Wallwork	*H. foliates bengalensis* Bhattacharya *et al.*	Soil and litter	Decomposer	Bakkhali, Kakdwip
	Epilohmanniidae	*Epilohmannia* Berlese	*E. pallida pacifica* Aoki	Soil and litter	Decomposer	Sagar Island, Frazerganj, Namkhana

Family	Genus	Species name	Host / Habitat	Economic Importance	Distribution
Trhypoch-thoniidae	*Allonothrus* Hammen	*A.indicus* Bhaduri and Raychaudhuri	Soil and litter	Decomposer	Namkhana, Frazerganj
Malacono-thridae	*Malaconothrus* Berlese	*M. geminus* Hammer	Soil and litter	Decomposer	Namkhana
Basilobelbi-dae	*Basilobelba* Balogh	*B. indica* Bhaduri *et al.*	Soil and litter	Decomposer	Frazerganj, Kakdwip
Carabodi-dae	*Carabodes* Koch	*C. peniculatus* Ham-mer	Soil and litter	Decomposer	Sagar Island, Kakdwip, Frazergunj
Tectocep-heidae	*Tectocepheus* Berlese	*T. velatus velatus* (Michael)	Soil and litter	Decomposer	Frazergunj, Sagar Island, Canning
Otocephei-dae	*Dolicher-emaeus* Jacot	*D. bengalensis* Sanyal	Soil and litter	Decomposer	Namkhana
		D. coronarius Chakra-barti *et al.*	Soil and litter	Decomposer	Kakdwip, Sagar Island
Oppiidae	*Brachioppia* Hammer	*B. ananthakrishni* Sanyal and Bhaduri	Soil and litter	Decomposer	Kakdwip
	Multioppia Hammer	*M. simplitricha* Sanyal and Bhaduri	Soil and litter	Decomposer	Kakdwip, Frazergunj, Namkhana
	Oppia Koch	*O. orientalis* Sanyal and Bhaduri	Soil and litter	Decomposer	Bakkhali
		O. ramisetosa Sanyal and Bhaduri	Soil and litter	Decomposer	Kakdwip
		O. yodai Aoki	Soil and litter	Decomposer	Bakkhali, Namkhana, Can-ning
		Oppia sp.	Soil and litter	Decomposer	Canning
Chauno-proctidae	*Chaunoproctus* Pearce	*C. abalai* Bhaduri *et al.*	Soil and litter	Decomposer	Kakdwip, Frazergunj
Xylobatidae	*Xylobates* Jacot	*X. seminudus*	Soil and litter	Decomposer	Sagar Island, Bakkhali
Haplozeti-dae	*Haplozetes* Willmann	*Haplozetes* sp.	Soil and litter	Decomposer	Kakdwip, Frazergunj, Sagar Isalnd, Canning
	Lauritzenia Hammer	*L. longipluma* Ham-mer	Soil and litter	Decomposer	Frazergunj
	Rostrozetes Sellnick	*R. foveolatus* Sellnick	Soil and litter	Decomposer	Canning
Schelorib-atidae	*Euschelorib-ates* Kunst	*E.samsinaki* Kunst	Soil and litter	Decomposer	Namkhana
	Scheloribates Berlese	*S. albialatus* Hammer	Soil and litter	Decomposer	Canning
		S. bhadurii Sanyal	Soil and litter	Decomposer	Namkhana, Sagar Island

	Family	Genus	Species name	Host / Habitat	Economic Importance	Distribution
			S. indicus Sanyal	Soil and litter	Decomposer	Namkhana
			S. natalensis Hammer	Soil and litter	Decomposer	Sagar Island, Frazergunj, Bakkhali, Canning
			S. rakhali Sanyal	Soil and litter	Decomposer	Frazergunj, Sagar Island, Kakdwip
	Austrachip-teriidae	*Lamellobates* Hammer	*L. palustris* Hammer	Soil and litter	Decomposer	Sagar Island, Kakdwip, Canning
		Paralamello-bates Bhaduri and Raychaud-huri	*P. bengalensis* Bhaduri and Raychaudhuri	Soil and litter	Decomposer	Sagar Island, Namkhana
	Galumnidae	*Galumna* von Heyden	*G. crenata* Deb and Raychaudhuri	Soil and litter	Decomposer	Namkhana, Bakkhali
			G. flabellifera orienta-lis Aoki	Soil and litter	Decomposer	Kakdwip, Namkhana, Frazergunj
			Galumna sp.	Soil and litter	Decomposer	Canning
PROSTIGMATA	Tetranychi-dae	*Eutetranychus* Oudemans	*E. orientalis* (Klein)	Plant	Pest	Kakdwip, Sagar Island
		Eotetranychus Oudemans	*E. hicoriae* McGregor)	Plant	Pest	Sagar Island
			Eotetranychus sp.	Plant	Pest	Bakkhali
		Oligonychus Berlese	*O. magniferus* (Rah-man and Sapra)	Plant	Pest	Bakkhali, Lothian Island
			Oligonychus sp.	Plant	Pest	Sudhanyakhali
			O. indicus (Hirst)	Plant	Pest	Sagar Island, Chemaguri, Gosaba
			O. oryzae (Hirst)	Plant	Pest	Chandanpiri
			O. sacchari (McGregor)	Plant	Pest	Bhagabatpur
		Panonychus Yokoyama	*P. citri* (McGreger)	Plant	Pest	Gosaba
		Schizotetra-nychus Tra-gardh	*S. baltazari* Rimando	Plant	Pest	Kakdwip
	Tetranychi-dae	*Schizotetra-nychus* Tra-gardh	*S. hindustanicus* (Hirst)	Plant	Pest	Sagar Island
			Schizotetranychus sp.	Plant	Pest	Sajnakhali, Sagar Island

Family	Genus	Species name	Host / Habitat	Economic Importance	Distribution
	Tetranychus Dufour	*T. neocalidonicus* Andre	Plant	Pest	Sagar Island
		T. urticae Koch	Plant	Pest	Bakkhali, Sagar Island
		T. fijiensis Hirst	Plant	Pest	Sagar Island Lothian Island
		T. ludeni Zacher	Plant	Pest	
		T. macfarlanei Baker and Pritchard	Plant	Pest	Lothian Island
		Tetranychus sp.	Plant	Pest	Sajnakhali, Sagar Island
Tenuipalpi-dae	*Brevipalpus* Donnadieu	*B. essigi* Baker	Plant	Pest	Sagar Island, Gosaba
		B. phoenicis (Geij.)	Plant	Pest	Sagar Island
		B. rugolosus Chaudhuri *et al.*	Plant	Pest	Sajnakhali, Gosaba
	Raoiella Hirst	*R. indica* Hirst	Plant	Pest	Sajnakhali
	Tenuipalpus Donnadieu	*T. micheli* Lawrence	Plant	Pest	Sajnakhali
		T. perrieis Chaudhuri *et al.*	Plant	Pest	Bhagabatpur
		Tenuipalpus sp.	Plant	Pest	Sagar Island
Eriophyidae	*Aceria* Keifer	*A. litchi* (Keifer)	Plant	Pest	Sajnakhali
		A. guerreronis	Plant	Pest	Gosaba
		A. saccharini Wang	Plant	Pest	Gosaba
	Phyllocoptes Nalepa	*P. oleivora* (Ashmead)	Plant	Pest	Gosaba
	Aculops Keifer	*A. abutiloni* Mondal and Chakrabarti	Plant	Pest	Sajnakhali
		A. excoecaria Mondal and Chakrabarti	Plant	Pest	Sajnakhali
	Bakeriella Chakrabarti and Mondal	*B ocimis* Chakrabarti and Mondal	Plant	Pest	Kakdwip
	Tegolophus Keifer	*T. spondialfus* Mondal and Chakrabarti	Plant	Pest	Kakdwip
Tarsonemi-dae	*Polyphagotar-sonemus*	*P. latus* Banks	Plant	Pest	Sajnakhali

	Family	Genus	Species name	Host / Habitat	Economic Importance	Distribution
	Stigmaeidae	*Agistemus* Summers	*A.fleschneri* Summers	Plant	Pest	Kakdwip
			A.industani Gaonzalez Rodriguez	Plant	Pest	Sagar Island
	Bdellidae	*Bdella* Latreille	*B.maldahensis* Gupta	Plant	Pest	Sagar Island, Lothian Island, Chemaguri
		Bdellodes Oudemans	*B.(Hoploscirus)* sp.	Plant	Pest	Sajnakhali
	Tydeidae	*Parapronematus* Baker	*Parapronematus* sp.	Plant	Pest	Sagar Island, Chandanpiri
		Pronematus Canestrini	*P. fleschneri* Baker	Plant	Pest	Sagar Island
			Pronematus sp.	Plant	Pest	Sajankhali, Chandanpiri
		Paralorryia Baker	*P. fodder* Gupta	Plant	Pest	Gosaba
		Tydeus Koch	*T. gossabaensis* Gupta	Plant	Pest	Gosaba
			T. cumini Gupta	Plant	Pest	Gosaba
			Tydeus sp.	Plant	Pest	Sagar Island, Canning
	Cunaxidae	*Cunaxa* Von Heyden	*C.cynodonae* Gupta and Ghosh	Plant	Pest	Sajnakhali
			C. setirostris (Hermann)	Plant	Pest	Gosaba, Sagar Island, Lothian Island
			Cunaxa sp.	Plant	Pest	Canning
	Upodidae	*Eupodes* Koch	*E.sigmoidensis* Strandtmann and Goff	Plant	Pest	Sagar Island
	Cheylelidae	*Cheletogenes* Oudemans	*C.ornatus* (Canestrini and Fanzago)	Plant	Pest	Sajnakhali
	Erythraeidae	*Sphaerolophus* Berlese	*S. gigas* Khat	Plant	Pest	Sajnakhali
MESOSTIGMATA	*Phytoseiidae* Berlese	*Amblyseius* Berlese	*A.largoensis* (Muma)	Plant	Pest	Sajnakhali, Sagar Island, Gosaba, Kakdwip, Chemaguri, Bhagabat-pur
			A. alstoniae Gupta	Plant	Pest	Basanti, Sagar Island, Bhagabatpur
			A. coccineae Gupta	Plant	Pest	Kakdwip, Sagr Island, Namkhana
			A. finlandicus (Ondemans)	Plant	Pest	Namkhana, Gosaba, Kakdwip

Family	Genus	Species name	Host / Habitat	Economic Importance	Distribution
		A. ovalis Evans	Plant	Pest	Kakdwip, Sagar Island, Namkhana, Chandanpiri
		A. pruni Gupta	Plant	Pest	Gosaba, Sagar Island
		A. fallacies Garman	Plant	Pest	Sagar Island,Bhagabatpur, Chandanpiri
		A. multidentatus (Swirski and Shechter)	Plant	Pest	Gosaba, Sagar Island, Sajnakhali, Gosaba
		A. paspalivorus (De Leon)	Plant	Pest	Basanti
	Indoseiulus Ehara	*I. ricini* (Ghai and Menon)	Plant	Pest	Sajnakhali
Blattisoci-dae	*Blattisocius* Keegan	*B. keegani* Fox	Plant	Pest	Sajnakhali
	Iphiseius Berlese	*I. andamanicus* Gupta	Plant	Pest	Sajnakhali, Sudhanyakhali, Sagar Island, Lothian Island
	Phytoseius Ribaga	*P. kapuri* Gupta	Plant	Pest	Gosaba, Sagar Island, Che-manguri, Chandanpiri
		P. cornigera Wainstein	Plant	Pest	Sagar Island
		P. indicus Bhattacha-ryya	Plant	Pest	Sagar Island, Bhagabatpur
		P. macropilis (Banks)	Plant	Pest	Sagar Island
		Phytoseius sp.	Plant	Pest	Chemaguri
	Typhlodromus Scheuten	*T. communis* Gupta	Plant	Pest	Sagar Island, Bhagabatpur
		T. homalii Gupta	Plant	Pest	Sajnakhali
Ascidae	*Asca* von Hey-den	*Asca* sp.	Soil and litter	Decomposer	Canning
	Lasioseius Berlese	*L. megregori* Chant *L. parberlesei* Bhat-tacharyya *L. reticulates* Bhat-tacharyya	Soil and litter	Decomposer	Canning
	Ololaelaps Berlese	*Ololaelaps* sp.	Soil and litter	Decomposer	Canning
	Proctolaelaps Berlese	*Proctolaelaps* sp.	Plant	Pest	Sajnakhali
Rhodacari-dae	*Gamasiphis* Berlese	*Gamasiphis bengalen-sis* Bhattacharyya	Soil and litter	Decomposer	Canning
Uropodidae	*Uroobovella* Berlese	*U. villosella* Berlese	Soil and litter	Decomposer	Canning

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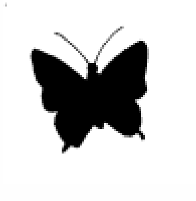
2.13 INSECTS

Insects comprise the largest number of species in the animal kingdom. A quick glance at the biological diversity reveals that arthropods, to which insects belong, are the most diverse group of organisms.

RATUL SAHA
Wildlife Biologist with specialization in Entomology



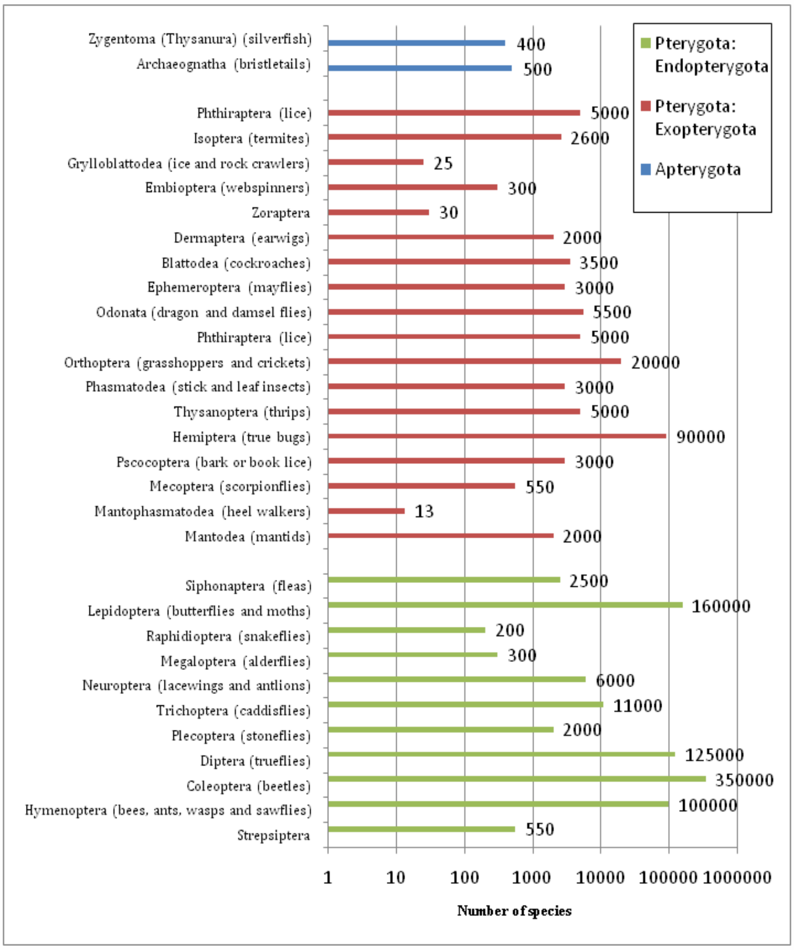
The Zoological Survey of India database (2007) lists 861696 and 61151 insect species in world & India respectively

The phylum Arthropoda contains roughly three-quarters of the species of animals on earth. The class Insecta alone accounts for about two-thirds of the animal species (Hammond 1992) and belongs within the superclass Hexapoda (true or six-legged insects) (Gullan and Cranston 2005).

The class Insecta comprises Aptery- gota (wingless insects): the Zygen-toma (silverfish), the Archaeog-natha (bristletails), and the Pterygote group (winged insects). This is in turn divided into the Exopterygota (also known as the Hemi-metabola), whose wings develop gradually through several nymphal instars, and the Endopterygota (also known as the Holometabola), which usually have a distinct larval stage separated from the adult by a pupa. Figure 1 summarizes the classification of insects and roughly indicates the number of species described so far from each order. With extensive survey in hitherto inaccessible areas, a large number of new species of insects are being described by scientists, especially from the humid, tropical forest areas of the Southern Hemisphere. Gaston and Hudson (1994) estimate that global insect species are likely to be around 10 million based on biogeographic patterns of diversity of well- or better-documented taxa. The Zoological Survey of India (2007) database lists 861,696 and 61,151 insect species in the world and India, respectively.

Asian giant honey bee (Apis dorsata)

Figure 1: Numbers of described species in world within the orders of insect. (From Gullan & Cranston, 2005.)



Source: Gullan and Cranston 2005

Insects have evolved a highly technologically efficient set of specialized body parts and appendages. The three basic sections (called tagmata) of an insect's body are admirably adapted for different purposes. The head specializes in sensory reception and food gathering, the thorax in locomotion, and the abdomen in digestion and reproduction. All but a minimum number of appendages have been lost when compared with ancestors, leaving a set of highly adapted mouth parts and a pair of immensely stable tripods, the legs (Gullan and Cranston 2005).

Insects are believed to constitute a significant portion of the fauna in many mangrove communities. They may be permanent residents of the mangroves or only transient visitors. In either case, they often play important roles in the ecology of the system and contribute to the unique character of these habitats (Kathiresan and Bingham 2001). Surveys of mangrove insects reveal complex assemblages of species filling a wide variety of niches. Many of the insects being temporary visitors and representing a wide array of habitat types provide linkages between the mangroves and other environments (Ananda Rao et al. 1998). Mangroves provide a habitat that supports a number of insects at different trophic levels. These insects bear inputs into the mangrove ecosystem and play a vital role in pollination, as a food resource, in nutrient cycling in forests, and in other important dynamics of the ecosystem.

Being dominated by trees, mangroves forests are similar to terrestrial forests in many ways, especially so for canopy fauna such as insects. Among the insects, ants play an important ecological role. They are important actors in ecosystem functioning due to their high abundance and the multitude of interactions they are engaged in. (Cannicci et al. 2008). It is evident from terrestrial studies that ants are able to protect plants against herbivores through their predatory and territorial behavior (Bronstein 1998).

OVERVIEW OF THE GROUP

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SPECIES OF INSECTS FROM DIFFERENT MANGROVE ECOSYSTEM OF INDIA

Insects have been reported to have a significant impact on tree growth rate and form, survivorship, reproductive output, and forest ecology in virtually all forest ecosystems (Crawley 1989; Schowalter 1986). However, the impact of insects on mangroves has been considered of minor importance compared to other types of forests (Macnae 1968).

Mangrove insects and other terrestrial arthropods avoid harsh conditions of strong sunlight, high temperatures, and desiccation by emerging only at night or by living entirely within the plants. Wood-boring moths and beetles in *mangals* (mangroves) of Belize, South America have been reported to excavate tunnels through the mangroves. The tunnels then become habitat to more than 70 other species of ants, spiders, mites, moths, roaches, termites, and scorpions (Feller and Mathis 1997; Rützler and Feller 1996). A number of organisms (including isopods, amphipods, myriapods, and spiders in addition to insects) escape high temperatures and desiccation by living in the intertidal portions of the *mangals* (mangroves). During periods of high tide, these organisms retreat to air-filled cavities where they remain until they are again exposed by the falling water level (Murphy 1990a).

The global distribution of mangroves has been divided into two biogeographical hemispheres, the Indo-West Pacific and the Atlantic-East Pacific (Duke 1992). The former ranges from the east coast of Africa to Asia, Australia, and the western Pacific Islands, while the latter includes the eastern Pacific Islands, the coasts of the American continent, and the African west coast. Insect diversity in the mangroves of the Indo-West Pacific is thought to be higher than in the Atlantic-East Pacific as a result of higher plant diversity in the former although, to some extent, the dearth of insect species in the latter reflects gaps in our knowledge rather than low species diversity (Macintosh and Ashton 2002). Of about 711 species of insects reported from different mangrove ecosystems of India (Kathiresan and Rajendran 2005), 497 species of insects are reported from the Indian Sundarbans. This number is very high when compared with other mangroves of India (table 1) such as the Andaman and Nicobar Islands - 276, Pichavaram - 101, and Muthupet - 113.

Table 1: Total number of insect species in mangrove ecosystem of different regions.

Sr. no.	Name of the region	No. of Species	Reference
1	Indo Malaysia	500	Spadling *et. al.,* 1997
2	Australasia	72	Spadling *et. al.,* 1997
3	India *(all mangroves inclusive)*	711	Kathiresan *et. al.,* 2005
4	Sundarbans, India	497	Ghosh, 1992 – 2001
5	Andaman & Nicobar Islands, India	276	Veenakumari *et al.* (1997)
6	Pichavaram, India	101	Senthil and Varadharajan (1995)
7	Muthupet, India	113	Rahaman, (2002)

SYNOPTIC VIEW

Diversity

497 SPECIES IN 344 GENERA UNDER 107 FAMILIES IN SUNDARBANS

Although there are several published records on the insects of the Indian Sundarbans, little effort has been spent to make all those records available as a compendium. To add to this, very little work has been done on insect ecology and the role of insects in the Sundarbans mangrove ecosystem dynamics.

The present review of available records (Ghosh 1992–2001; Mitra and Mitra, 2009) reports 497 species in 344 genera under 107 families (table 2 and figure 2). The insects are classified into 15 orders (see annexure): Thysanura, Collembola, Isoptera, Dermaptera, Blataria, Odonata, Orthoptera, thysanoptera, Hemiptera, Homoptera, Lepidoptera, Neuroptera, Diptera, Coleoptera, and Hymenoptera. Maximum generic diversity was found in Orthoptera (36), Hemiptera (46), Lepidoptera (59), Diptera (52), Coleoptera (69), and Hymenoptera (28). The number of genera recorded in the Sundarbans is higher than that of other major Indian mangrove insect studies—the Pichavaram mangrove hosts 9 orders and 42 families (Senthil and Varadharajan 1995) and the Muthupet mangrove hosts 8 orders and 53 families (Rahaman 2002).

The maximum number of 100 species was found in the order Coleoptera, followed by Diptera - 93 species, Lepidoptera - 77 species, Hemiptera - 72 species, Orthoptera - 45 species, Hymenoptera - 45 species, and Odonata - 26 species. Among

Lady Bird Beetle(Coccinella sp.)

Pygmy dartlet (pygmaea)

them, *Mahathala ameria ameria* (Hewitson), family Lycaenidae (order Lepidoptera) is a single species recorded in India, from West Bengal. *Mixomicromus lampus* (Ghosh), family Hemerobiidae (order Lepidoptera) is new to science and *Mantispa femoralis* (Banks), family Mantispidae (order Neuroptera) is a new record from this area.

Honey bees produce significant quantities of honey from the mangroves of the Sundarbans and are an important food resource for humans. *Apis dorsata* and *Apis mellifera* are the honey bees that are reported from the Sundarbans (Naskar and Guhabakshi 1987). The dominant bee species (*Apis dorsata*) may travel hundreds of miles to forage in the mangrove forests during periods of peak blooming (March and July). They build honeycombs on several mangrove species but prefers *Excoecaria* (Krishnamurthy 1990). Twenty-two ant species are reported from here. *Camponotus, Leptogenys*, and *Diacamma* are the most common genera. The carpenter ant *Componotus* sp. and thief ant *Solenopsis* sp. found in the Sundarbans are reported to construct their nests preferably in rotten and decaying *Exoecaria* woods.

Beehive

Holes in the mangrove trees (particularly the *Avicennia* species) and crab burrows provide ideal sites for mosquito breeding (Thangam 1990). Mosquitoes are often incredibly numerous and the degree of abundance is exceptional (Macnae 1968); many act as vectors for diseases of vertebrates. Populations are often dense and species diversity can be high; 21 species of the Culicidae family (Diptera) are recorded from the Sundarbans area. Culicine mosquitoes are reported to find breeding places in pools at ground level, in water collecting at the bases of the leaves of *Nypa*, in rot holes in trees, and in the burrows of crabs. Macnae (1968) also reported that mosquitoes settle on the back of the head of the mudskipping goby; *Boleophthalmus sp. Anopheles sundaicus* breeds exclusively in brackish water of chlorinity 4.8–13 percent (Hodgkin 1956). The breeding pools are, as a rule, found at the limits of tidal rise, where the tide reaches once or twice per month. Rain and seepage water dilute the dammed-up seawater to a point that is suitable for the mosquito to breed

Feeding Guilds

Mangroves provide a habitat that supports a large number of insects at different trophic levels. The primary trophic groups are (a) herbivorous insects that feed on leaves and other plant parts, (b) saproxylic and saprophagous insects that feed on dead and decaying organic matter, and (c) parasitic and predatory insects that feed or prey on other animals.

Mixomicromus lampus Ghosh, Family Hemerobiidae (Order Lepidoptera) is new to science

Herbivorous insects. The Feeding Guild structure analysis (Southwood 1973) of insects in the Indian Sundarbans reveals herbivory as the dominant feeding guild represented by the orders Orthoptera, Hemiptera, Homoptera, Lepidoptera, Diptera, Coleoptera, and Hymenoptera. They feed in all stages

White Tiger - (Danaus melanippus)

Vespa sp. feeding on a caterpillar

while larval dipterans are gall farming, leaf mining, and flower and fruit boring insects (Murphy 1990b). Insects are reported to feed on a wide range of mangrove plant parts, including leaves, shoots, flowers, fruits, and stems. Butterflies are known to be host specific and a few species are entirely restricted to mangroves (Corbet and Pendlebury 1992). However, some butterfly species such as Burma Tree Nymph (*Idea agamarschana*) are recorded from the tidal creeks of the Sundarbans and are associated with flora of secondary growth.

Saproxylic and saprophagous insects. Saproxylic insects consist of termites and wood borers (usually the larvae of beetles or moths), which form a relatively characteristic assemblage in mangroves. The relative abundance of a limited number of tree species provides an abundant and stable food source for this group of insects. In the intertidal zone, periodic or continuous flooding makes mangroves uninhabitable for many termite species that forage from the ground. However, species that nest above the ground thrive in this habitat in the absence of competing fauna and in the presence of abundant food resources. Termite groups that readily colonize the mangrove habitat are *Coptotermes* (Kirton 1995), which are able to nest in moist wood with no ground contact, and species that build arboreal carton nests on tree trunks and branches, such as *Microcerotermes* spp. *Coccotrypes nepheli*, a scolytid beetle, is reported to be the primary wood-boring beetle in mangroves, including in the Sundarbans. The beetles feed on dead branches that have yet to dry completely and burrow under the bark or into the wood and culture fungi on which their brood feeds. However, some are seed or prop-root feeders (Ng and Sivasothi 2002), and others may cause the death of branches and trees through girdling and hollowing of stems and twigs. The dung beetle (Scarabidae) communities are excellent models to evaluate and to monitor the extent to which the changes in the vegetation alter the animal communities (Halffter and Favila 1993). *Onthophagus quadridentatus* (dung beetle) is also recorded from this area. Ground-dwelling saprophagous insects are also found in the Sundarbans, and many have specialized adaptations for survival in the intertidal zone. Springtails (Collembola) are diverse among the roots of mangrove plants and in the leaf litter that accumulates on the ground (Murphy 1965; Roque 2007), where they feed on a range of organic material, including detritus and fungi.

Parasitic and predatory insects.

A wide range of predatory and parasitic insects, with a great diversity of host and habit, occur in mangrove habitats. These include predatory larvae and adult insects that prey on other organisms, parasitoids that feed within a single host and eventually kill it, hyperparasitoids that parasitize parasitoids, and blood-sucking parasites of vertebrates. They occur throughout the mangroves, from the soil to the water surface and on mangrove plants, where they exert a restraining influence on populations of herbivorous and saprophagous organisms. Ants (Formicidae) are important predators in mangroves (Nagelkerken et al. 2008).

Many other predatory insects live and feed on the ground, sheltering under plant debris during high tides and emerging to feed on springtails, copepods, protozoa, and nematodes when the tides recede (Ng and Sivasothi 2002). In the Sundarbans, the more common predatory insects are hemipterans. On the water surface of mangrove tidal pools in Singapore, water skaters (Veliidae) are reported to prey on smaller insects that fall or land on the water (Ng and Sivasothi 2002). Female mosquitoes (Culicidae) and other small biting flies (Ceratopogonidae and Phlebotominae) that inhabit mangroves take a blood meal from vertebrate hosts, before reproduction. Biting midges breed in the mud in mangroves and mosquitoes breed in stagnant pools as well as rot holes in trees (Nagelkerken et al. 2008).

Local Community Dependencies and Traditional Use

Natural honey from *Apis dorsata,* cultured (apiary) honey from *Apis indica*, and bee wax are among the Non Timber Forest Products (NTFP) collected by the local community from the Sundarbans. Singh et al. (2010) report that honey and wax

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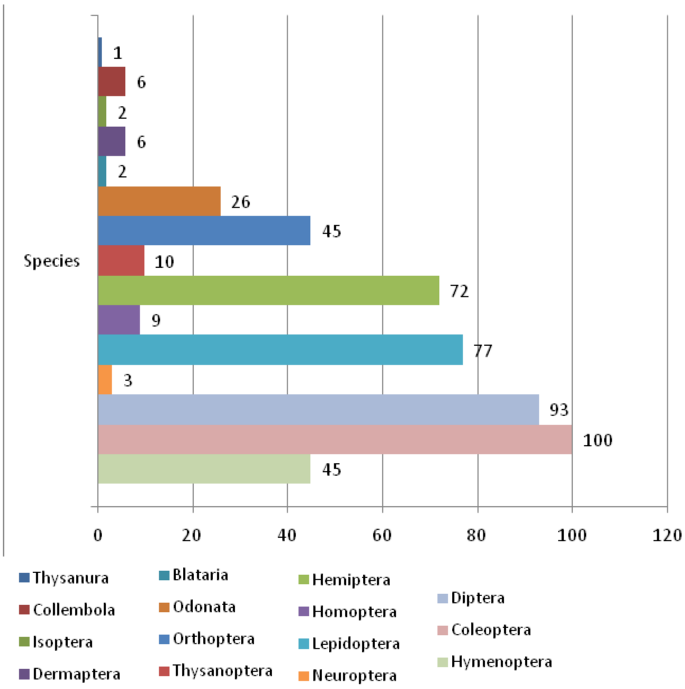
MEDICINAL APPLICATIONS FROM 24 INSECT SPECIES

Table 2: Total number of families, genera, species composition of Insects in Sundarbans

Sr. No.	Order	Family	Genus	Species
1	Thysanura	1	1	1
2	Collembola	2	3	6
3	Isoptera	2	2	2
4	Dermaptera	4	6	6
5	Blataria	1	1	2
6	Odonata	3	24	26
7	Orthoptera	8	36	45
8	Thysanoptera	2	6	10
9	Hemiptera	19	46	72
10	Homoptera	4	8	9
11	Lepidoptera	15	59	77
12	Neuroptera	3	3	3
13	Diptera	20	52	93
14	Coleoptera	17	69	100
15	Hymenoptera	6	28	45
	Total	**107**	**344**	**497**

Fig 2: Diversity of Insect species in Sundarbans.



collection from the forest is one of the livelihood activities of Sundarban dwellers even though it is not a high income-yielding activity. About 1,000 honey collectors are given permits from West Bengal Forest Development to collect honey at a fixed tariff per kg.

Majumder and Dey (2005) reported a drug prepared from different species of entomofauna by the tribes (Santhal, Oraon, and Munda) at the Sundarbans for the treatment of various diseases. Ninety-three medicinal applications made from 24 insect species have been reported from the Sundarbans. The insect species were Coleoptera (6 species), Hymenoptera (10 species), Hemiptera (4 species), Orthoptera (1 species), Diptera (2 species), and Odonata (1 species). The medicinal applications are used locally and the oral applications are for the cure of hydrophobia, nerve disability, hemoptysis, dysmeno-rrhoea, obesity, gallstone, and nasal obstruction.

Ecological Importance and Need for Conservation

Mangrove forests consists of tree species occurring in monoculture stands or a mixture of tree species. Very rarely, under storey plants exist and even the canopy of the existing trees has limited vertical stratification. This further simplifies the structural and floristic diversity of the mangrove ecosystem. Herbivore insects are widely accepted as playing a significant role in the ecology of forest ecosystems (Burrows 2003). Herbivore insects have a significant impact on tree growth and form, survivorship curve, reproductive output, and forest ecology (Crawley 1989; Schowalter 1986).

> Components of several biogeochemical cycles as well as mediators of energy transformation

Insect herbivores can cause changes in nutrient cycles and nutrient availability in soils (Hunter 2001b); they deposit significant quantities of fecal material onto litter and soil. Nutrients returned to soils in insect cadavers are more easily decomposed than those in leaf litter (Schowalter 1986) and can stimulate the decomposition of litter during defoliator outbreaks (Seastedt and Crossley 1984; Swank et al. 1981). Insect defoliation changes the nutrient content of precipitation as it passes through plant canopies. Herbivory can change the quantity of leaf litter that falls from plant canopies to the soil and also affect the utilization of soil nutrients by the new community (Kielland et al. 1997). Herbivory may influence root exudates or interactions between roots and their symbionts (Bardgett et al. 1998), both of which are known to influence nutrient dynamics. Changes in soil microclimate, which result from insect herbivory, can alter the cycling of nutrients (Mulder 1999). Similarly, herbivore-induced changes in light availability may influence litter quality through effects on leaf chemistry (Hunter and Forkner 1999) or plant productivity and diversity (van der Wal et al. 2000).

Insects are important components of several biogeochemical cycles as well as mediators of energy transformation. Some of the carbon captured by plants is consumed by primary consumers such as insect herbivores and, in turn, by predators that eat herbivores. At each trophic level, carbon that was originally captured by plants is returned to the atmosphere by the respiration of organisms at that trophic level. Leaf shredding insects like Diptera select leaf litter tissue that has been colonized and partially decomposed (or 'conditioned') by fungi and bacteria (Cummins and Klug 1979). Shredders also ingest attached algae and bacteria along with litter tissue (Merritt and Cummins 1984), and it seems likely that they gain some of their energy and nutrient requirements from the microbes rather than the litter itself. The leaf shredders possess the ability to turn the coarse particulate organic matter (CPOM) of litter into fine particulate organic matter (FPOM) and dissolved organic matter (DOM) (Wallace et al. 1982). Most of the litter passes through their gut, emerging as fine particles or dissolved fractions in the faeces. FPOM and DOM are major sources of nutrition for gatherers; filter feeders (for example, blackfly larvae in the dipteran family Simulidae); and microbes in streams (Cummins et al. 1973; Short and Maslin 1977; Wotton 1994). Insect shredders also promote wood decomposition by scraping, gouging, and tunneling into the woody debris (twigs, branches, and stems) that fall into streams. Freshly gouged surfaces act as sites for microbial activity and subsequent decomposition (Anderson et al. 1984).

Insects play a major role in the carbon cycle during the decomposition process. Blowflies and flesh flies (Diptera: Calliphoridae and Sarcophagidae, respectively) are well-known insect decomposers whose larvae often feed within carrion or excrement. The gut symbionts of various termite groups include both flagellate protozoans (Yoshimura et al. 1993) and bacteria (Basaglia et al. 1992). As an aside, it has been reported that some spirochetes that live symbiotically in termite guts are able to fix atmospheric nitrogen and may contribute this nitrogen to termite nutrition (Lilburn et al. 2001). Large amounts of ammonia (NH_3) build up in the nests of certain termite species, possibly to levels 300 times higher than in the surrounding soil (Ji and Brune 2006). One crucial feature of termites relevant to the carbon cycle is the occurrence of anaerobic microsites in termite guts. Termites therefore have the potential to recycle significant amounts of carbon to the atmosphere in two gaseous forms.

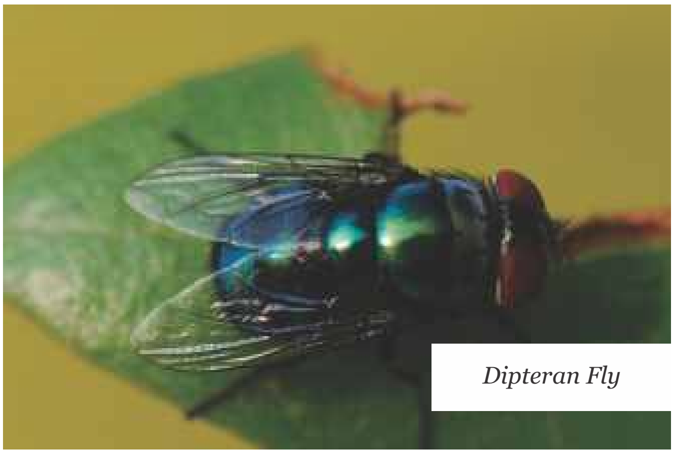
Besides wind, birds, and, in some instances, bats, insects also play a major role in pollination in most mangrove species. In the absence of bats, hawkmoths become the primary night-time pollinators of *Sonneratia* (Hockey and de Baar 1991). Two lycaenid butterflies are reported to be important in the

Honey collection

pollination of mangroves in Brisbane, Australia, where their abundance is directly correlated with the abundance of mangrove flowers (Hill 1992). Bees are also reported to regularly visit and pollinate species of *Avicennia, Acanthus, Excoecaria, Rhizophora, Scyphiphora*, and *Xylocarpus*. Some wasps and flies are highly dependent on mangroves for nesting and are particularly important pollinators of *Bruguiera* sp., *Ceriops decandra*, *Kandelia candel*, and *Lumnitzera racemosa* (Tomlinson 1986).

STATUS AND THREATS

Given the conservation and protection regime prevalent in India, of the total insect fauna recorded in the Sundarbans, only 4 insect species (Lepidoptera) (table 3) has been included in the Indian Wildlife (Protection) Act, 1972.



Dipteran Fly

Table 3: Protection regime of Lepidopteran Species

Sr No.	Order	Family	Scientific Name	Schedule*
1	Lepidoptera	Lycaenidae	*Euchrysops cnejus* (Fabricius)	II
2	Lepidoptera	Lycaenidae	*Lampides boeticus* (Linnaeus)	II
3	Lepidoptera	Nymphalidae	*Hypolimnas misippus* (Linnaeus)	II
4	Lepidoptera	Lycaenidae	*Mahathala ameria ameria* (Hewitson)	II

Note : * Schedules of Indian Wildlife (Protection) Act, 1972

ANNEXURE

Insect fauna of Sundarbans

Sr. No.	Order	Family	Genus	Species
1	Thysanura	Lepismatidae	*Ctenolepisma* Escherich	*Ctenolepisma longicaudata*
2	Collembola	Entomobryidae	*Lepidocyrtus* Bourlet	*Lepidocyrtus (Acrocyrtus) scaber*
3	Collembola	Entomobryidae	*Lepidocyrtus* Bourlet	*Lepidocyrtus (Acrocyrtus) heterolepis*
4	Collembola	Entomobryidae	*Lepidocyrtus* Bourlet	*Lepidocyrtus (Lepidocyrtus) medius*
5	Collembola	Entomobryidae	*Cyphoderus* Nicolet	*Cyphoderus javanus*
6	Collembola	Entomobryidae	*Cyphoderus* Nicolet	*Cyphoderus albinus*
7	Collembola	Neamuridae	*Lobelia* Burner	*Lobella (Lobella) maxillaris*
8	Isoptera	Rhinotermitidae	*Coptotermes*	*Coptotermes heimi* (Wasmann)
9	Isoptera	Termitidae	*Microcerotermes*	*Microcerotermes cameroni* Snyder
10	Dermaptera	Pygidicranidae	*Pradiplatys*	*Pradiplatys gladiator* (Burr)
11	Dermaptera	Pygidicranidae	*Diplatys*	*Diplatys sinuatus* Hincks
12	Dermaptera	Anisolabididae	*Euborellia*	*Euborellia annulipes* (Lucas)
13	Dermaptera	Labiduridae	*Nala*	*Nala lividipes* (Dufour)
14	Dermaptera	Labiduridae	*Labidura*	*Labidura riparia* (Pallas)
15	Dermaptera	Spongiphoridae	*Pralabella*	*Pralabella curvicauda* (Motschulsky)
16	Blataria	Blattelidae	*Blattella*	*Blattella humbertiana* (Sauss.)
17	Blataria	Blattelidae	*Blattella*	*Blattella germanica* (Linnaeus)
18	Odonata	Coenagrionidae	*Ceriagrion*	*Ceriagrion cerinorubellum* (Brauer, 1865)
19	Odonata	Coenagrionidae	*Ceriagrion*	*Ceriagrion coromandelianum* (Fabricius, 1798)
20	Odonata	Coenagrionidae	*Pseudagrion*	*Pseudagrion australasiae* Selys, 1876
21	Odonata	Coenagrionidae	*Pseudagrion*	*Pseudagrion decorum* (Rambur, 1842)

Sr. No.	Order	Family	Genus	Species
22	Odonata	Coenagrionidae	*Cercion*	*Cercion malayanum* (Selys, 1870)
23	Odonata	Coenagrionidae	*Ischnura*	*Ischnura senegalensis* (Rambur, 1842)
24	Odonata	Coenagrionidae	*Ischnura*	*Ischnura aurora aurora* (Brauer, 1865)
25	Odonata	Coenagrionidae	*Agriocnemis*	*Agriocnemis pygmaea* (Rambur, 1842)
26	Odonata	Coenagrionidae	*Onychargia*	*Onychargia atrocyana* Selys, 1865
27	Odonata	Gomomphidae	*Ictinogomphus*	*Ictinogomphus rapax* (Rambur, 1842)
28	Odonata	Libellulidae	*Brachydiplax*	*Brachydiplax sobrina* (Rambur, 1842)
29	Odonata	Libellulidae	*Lathrecista*	*Lathrecista asiatica asiatica* (Fabricius, 1798)
30	Odonata	Libellulidae	*Orthetrum*	*Orthetrum sabina sabina* (Drury, 1770)
31	Odonata	Libellulidae	*Acisoma*	*Acisoma panorpoides panorpoides* (Rambur, 1842)
32	Odonata	Libellulidae	*Brachythemis*	*Brachythemis contaminata* (Fabricius, 1798)
33	Odonata	Libellulidae	*Bradinopyga*	*Bradinopyga geminata* (Rambur, 1842)
34	Odonata	Libellulidae	*Crocothemis*	*Crocothemis servilia servilia* (Drury, 1770)
35	Odonata	Libellulidae	*Diplacodes*	*Diplacodes trivialis* (Rambur, 1842)
36	Odonata	Libellulidae	*Neurothemis*	*Neurothemis tullia tullia* (Drury, 1773)
37	Odonata	Libellulidae	*Trithemis*	*Trithemis pallidinervis* (Kirby, 1889)
38	Odonata	Libellulidae	*Rhyothemis*	*Rhyothemis variegata variegata* (Linnaeus, 1763)
39	Odonata	Libellulidae	*Pantala*	*Pantala flavescens* (Fabricius, 1798)
40	Odonata	Libellulidae	*Tramea*	*Tramea virginia* (Rambur, 1842)
41	Odonata	Libellulidae	*Tholymis*	*Tholymis tillarga* (Fabricius, 1798)
42	Odonata	Libellulidae	*Macrodiplax*	*Macrodiplax cora* (Brauer, 1867)
43	Odonata	Libellulidae	*Urothemis*	*Urothemis signata signata* (Rambur, 1842)
44	Orthoptera	Tetrigidae	*Thoradonta*	*Thoradonta apiculata*
45	Orthoptera	Tetrigidae	*Thoradonta*	*Thoradonta pruthii*
46	Orthoptera	Tetrigidae	*Coptotettix*	*Coptotettix annandalei*
47	Orthoptera	Tetrigidae	*Ergatettix*	*Ergatettix dorsifera*
48	Orthoptera	Tetrigidae	*Ergatettix*	*Ergatettix guntheri*
49	Orthoptera	Tetrigidae	*Euparatettix*	*Euparatettix histricus*
50	Orthoptera	Tetrigidae	*Euparatettix*	*Euparatettix personatus*
51	Orthoptera	Tetrigidae	*Hedotettix*	*Hedotettix gracilis*
52	Orthoptera	Gryllidae	*Gryllotalpa*	*Gryllotalpa africana*
53	Orthoptera	Gryllidae	*Modicogryllus*	*Modicogryllus confirmatus*
54	Orthoptera	Gryllidae	*Plebeiogryllus*	*Plebeiogryllus guttiventris*
55	Orthoptera	Gryllidae	*Pteronemobius*	*Pteronemobius concolor*
56	Orthoptera	Gryllidae	*Pteronemobius*	*Pteronemobius fascipes*
57	Orthoptera	Gryllidae	*Pteronemobius*	*Pteronemobius taprobanensis*
58	Orthoptera	Scleropteridae	*Scleropterus*	*Scleropterus variolosus*
59	Orthoptera	Trigonidiidae	*Trigonidium*	*Trigonidium humbertianum*

Sr. No.	Order	Family	Genus	Species
60	Orthoptera	Eneopteridae	*Euscyrtus*	*Euscyrtus hemelytrus*
61	Orthoptera	Pyrginirogudae	*Atractomorpha*	*Atractomorpha crenulata* (Fabr.)
62	Orthoptera	Pyrginirogudae	*Chrotogonus*	*Chrotogonus trachypterus*
63	Orthoptera	Acrididae	*Dnopherula*	*Dnopherula physopoda*
64	Orthoptera	Acrididae	*Acrida*	*Acrida exalata* (Walker)
65	Orthoptera	Acrididae	*Aiolopus*	*Aiolopus thalassinus tamulus* Fabricius
66	Orthoptera	Acrididae	*Dittopternis*	*Dittopternis venusta* Walker
67	Orthoptera	Acrididae	*Oedaleus*	*Oedaleus senegalensi*s (Krauss)
68	Orthoptera	Acrididae	*Phlaeoba*	*Phlaeoba infumata* Brunner
69	Orthoptera	Acrididae	*Trilophidia*	*Trilophidia annulata* (Thunberg)
70	Orthoptera	Acrididae	*Gesonula*	*Gesonula punctifrons* Stal
71	Orthoptera	Acrididae	*Hieroglyphus*	*Hieroglyphus banian* Fabricius
72	Orthoptera	Acrididae	*Spathosternum*	*Spathosternum prasiniferum prasiniferum* (Walker)
73	Orthoptera	Acrididae	*Oxya*	*Oxya fuscobittata (* Marschall)
74	Orthoptera	Acrididae	*Oxya*	*Oxya hyla hyla* Serville
75	Orthoptera	Acrididae	*Oxya*	*Oxya nitidula*
76	Orthoptera	Acrididae	*Epistaurus*	*Epistaurus sinetyi* Bolivar
77	Orthoptera	Acrididae	*Tristria*	*Tristria pulvinata* (Uvarov)
78	Orthoptera	Acrididae	*Eupreponotus*	*Eupreponotus inflatus* Uvarov
79	Orthoptera	Acrididae	*Heteracris*	*Heteracris pulchra* (Bolivar)
80	Orthoptera	Tettigoniidae	*Meroncidius*	*Meroncidius ochraceous*
81	Orthoptera	Tettigoniidae	*Phisispectinata*	*Phisispectinata* sp.
82	Orthoptera	Tettigoniidae	*Elimaea*	*Elimaea securigera*
83	Orthoptera	Tettigoniidae	*Sathrothyllia*	*Sathrothyllia femorata*
84	Orthoptera	Tettigoniidae	*Onomarchus*	*Onomarchus leuconatus*
85	Orthoptera	Tettigoniidae	*Acanthoprion*	*Acanthoprion suspectum*
86	Orthoptera	Tettigoniidae	*Euconocephalus*	*Euconocephalus incertus*
87	Orthoptera	Tettigoniidae	*Euconocephalus*	*Euconocephalus pallidu*
88	Orthoptera	Tettigoniidae	*Xiphidiopsis*	*Xiphidiopsis straminnula*
89	Thysanoptera	Thripidae	*Retithrips*	*Retithrips syriacus* (Mayet)
90	Thysanoptera	Thripidae	*Selenothrips*	*Selenothrips rubrocinetus* (giard)
91	Thysanoptera	Thripidae	*Thrips*	*Thrips hawaiiensis* (Morgan)
92	Thysanoptera	Thripidae	*Thrips*	*Thrips flavus* Schrank
93	Thysanoptera	Thripidae	*Thrips*	*Thrips orientalis* (Baganall)
94	Thysanoptera	Phlaeothripidae	*Elaphrothrips*	*Elaphrothrips procer* (Schmutz)
95	Thysanoptera	Phlaeothripidae	*Haplothrips*	*Haplothrips ceylonicus* Schumutz
96	Thysanoptera	Phlaeothripidae	*Haplothrips*	*Haplothrips clarisetis* Priesner
97	Thysanoptera	Phlaeothripidae	*Haplothrips*	*Haplothrips gangalbaueri* Schmutz
98	Thysanoptera	Phlaeothripidae	*Podothrips*	*Podothrips lucasseni* (Kruger)

Sr. No.	Order	Family	Genus	Species
99	Hemiptera	Cercopidae	*Clovia*	*Clovia bipunctata* Kirby
100	Hemiptera	Cicadellidae	*Amitodus*	*Amitodus atkinsoni* (Lethierry)
101	Hemiptera	Membracidae	*Oxyrhachis*	*Oxyrhachis lefroi* Distant
102	Hemiptera	Membracidae	*Oxyrhachis*	*Oxyrhachis rufescens* Walker
103	Hemiptera	Membracidae	*Oxyrhachis*	*Oxyrhachis tarandus* (Fabricius)
104	Hemiptera	Membracidae	*Tricentrus*	*Tricentrus cinereus* Anathasubrananian
105	Hemiptera	Membracidae	*Tricentrus*	*Tricentrus cornutus* Anathasubrananian
106	Hemiptera	Psyllidae	*Trioza*	*Trioza fletcheri* Crawford
107	Hemiptera	Psyllidae	*Trioza*	*Trioza* sp. *Probably fletcheri*
108	Hemiptera	Aphididae	*Aphis*	*Aphis citricola* Patch
109	Hemiptera	Aphididae	*Aphis*	*Aphis craccivora* Koch
110	Hemiptera	Aphididae	*Aphis*	*Aphis fabae* Scopoli
111	Hemiptera	Aphididae	*Aphis*	*Aphis gossyp*i iGlover
112	Hemiptera	Aphididae	*Aphis*	*Aphis nasturtii* Kaltenbach
113	Hemiptera	Aphididae	*Aphis*	*Aphis nerii* Boyer de Fonscolombe
114	Hemiptera	Aphididae	*Toxoptera*	*Toxoptera aurantii* Boyer de Fonscolombe
115	Hemiptera	Aphididae	*Toxoptera*	*Toxoptera citricidus* (Kirkaldy)
116	Hemiptera	Aphididae	*Toxoptera*	*Toxoptera odinae* (van der Goot)
117	Hemiptera	Aphididae	*Hysteroneura*	*Hysteroneura setariae* (Thomas)
118	Hemiptera	Aphididae	*Melanaphis*	*Melanaphis sacchari* (Zehnter)
119	Hemiptera	Aphididae	*Rhopalosiphum*	*Rhopalosiphum maidis* (Fitch)
120	Hemiptera	Aphididae	*Rhopalosiphum*	*Rhopalosiphum rufiabdominalis* (Sasaki)
121	Hemiptera	Aphididae	*Acyrthosiphon*	*Acyrthosiphon pisum* (Harris)
122	Hemiptera	Aphididae	*Aulacorthum*	*Aulacorthum solani* (Kaltenbach)
123	Hemiptera	Aphididae	*Bachycaudus*	*Bachycaudus helichrysi* (Kaltenbach)
124	Hemiptera	Aphididae	*Brevicoryne*	*Brevicoryne brassicae* (Linnaeus)
125	Hemiptera	Aphididae	*Hyadaphis*	*Hyadaphis coriandri* (Das)
126	Hemiptera	Aphididae	*Lipaphis*	*Lipaphis erysimi* (Kaltenbach)
127	Hemiptera	Aphididae	*Macrosiphoniella*	*Macrosiphoniella sanborni* Gillette
128	Hemiptera	Aphididae	*Macrosiphum*	*Macrosiphum rosaeformis* (Das)
129	Hemiptera	Aphididae	*Myzus*	*Myzus ornatus* Laing
130	Hemiptera	Aphididae	*Myzus*	*Myzus persicae* Laing
131	Hemiptera	Aphididae	*Neomyzus*	*Neomyzus circumflexus* (Buckton)
132	Hemiptera	Aphididae	*Petalonia*	*Petalonia nigronervosa* Coquerel
133	Hemiptera	Reduviidae	*Conorhinus*	*Conorhinus rubrofasciatus de* Geer
134	Hemiptera	Lygaeidae	*Spilostetethus*	*Spilostetethus hospes*
135	Hemiptera	Lygaeidae	*Pseudopachybra-chius*	*Pseudopachybrachius guttus*
136	Hemiptera	Alydidae	*Leptocorisa*	*Leptocorisa acuta* Thumb
137	Hemiptera	Plataspidae	*Coptosoma*	*Coptosoma siamicum*
138	Hemiptera	Plataspidae	*Coptosoma*	*Coptosoma cribrariun*

Sr. No.	Order	Family	Genus	Species
139	Hemiptera	Scutelleridae	*Fitha*	*Fitha ardens*
140	Hemiptera	Scutelleridae	*Chrysocoris*	*Chrysocoris stollii*
141	Hemiptera	Pentatomidae	*Eysarcoris*	*Eysarcoris montivagus*
142	Hemiptera	Pentatomidae	*Eysarcoris*	*Eysarcoris ventralis*
143	Hemiptera	Pentatomidae	*Eysarcoris*	*Eysarcoris guttiger*
144	Hemiptera	Mesoveliidae	*Mesovelia*	*Mesovelia vittigera*
145	Hemiptera	Hydrometridae	*Hydrometra*	*Hydrometra vittata*
146	Hemiptera	Veliidae	*Microvelia*	*Microvelia annandalei*
147	Hemiptera	Veliidae	*Microvelia*	*Microvelia albomaculata*
148	Hemiptera	Gerridae	*Rhagadotarsus*	*Rhagadotarsus kraepelini*
149	Hemiptera	Gerridae	*Naboandelus*	*Naboandelus signatus*
150	Hemiptera	Gerridae	*Halobates*	*Halobates flaviventris*
151	Hemiptera	Gerridae	*Asclepios*	*Asclepios annandalei*
152	Hemiptera	Gerridae	*Limlometra*	*Limlometra anadyomene*
153	Hemiptera	Gerridae	*Limlometra*	*Limlometra fluviorum*
154	Hemiptera	Gerridae	*Limlometra*	*Limlometra nitidus*
155	Hemiptera	Gerridae	*Limlometra*	*Limlometra fossarum*
156	Hemiptera	Gerridae	*Limlometra*	*Limlometra parvulus*
157	Hemiptera	Gerridae	*Gerris*	*Gerris spiolae*
158	Hemiptera	Belostomatidae	*Sphaerodema*	*Sphaerodema annulatum*
159	Hemiptera	Belostomatidae	*Sphaerodema*	*Sphaerodema rusticum*
160	Hemiptera	Belostomatidae	*Sphaerodema*	*Sphaerodema molestum*
161	Hemiptera	Belostomatidae	*Lethocerus*	*Lethocerus indicus*
162	Hemiptera	Nepidae	*Laccotrephes*	*Laccotrephes ruber*
163	Hemiptera	Nepidae	*Laccotrephes*	*Laccotrephes griseus*
164	Hemiptera	Nepidae	*Ranatra*	*Ranatra filiformis*
165	Hemiptera	Nepidae	*Ranatra*	*Ranatra sordidula*
166	Hemiptera	Nepidae	*Ranatra*	*Ranatra varipes*
167	Hemiptera	Notonectidae	*Anisops*	*Anisops sardea*
168	Hemiptera	Notonectidae	*Anisops*	*Anisops breddini*
169	Hemiptera	Notonectidae	*Nychia*	*Nychia marshalli*
170	Hemiptera	Pleidae	*Plea*	*Plea liturata*
171	Homoptera	Tachardiidae	*Kerria*	*Kerria fici fici* (Green)
172	Homoptera	Pseudococcidae	*Birendracoccus*	*Birendracoccus saccharifolii* (Green)
173	Homoptera	Pseudococcidae	*Brevennia*	*Brevennia rehi* Lindiger
174	Homoptera	Pseudococcidae	*Rastrococcus*	*Rastrococcus iceryoides* (Green)
175	Homoptera	Cerococcidae	*Ceroccus*	*Ceroccus indicus* (Maskell)
176	Homoptera	Diaspididae	*Aonidiella*	*Aonidiella aurantii* (Maskell)
177	Homoptera	Diaspididae	*Aonidiella*	*Aonidiella orientalis* (Newstead)
178	Homoptera	Diaspididae	*Lopholeucaspis*	*Lopholeucaspis exoecariae* Borchsenius

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179	Homoptera	Diaspididae	*Pinnaspis*	*Pinnaspis strachan*i (Cooley)
180	Lepidoptera	Danaidae	*Danus*	*Danus melanippus* (Cramer)
181	Lepidoptera	Noctuidae	*Ophiusa*	*Ophiusa coronata* (Fabricius)
182	Lepidoptera	Noctuidae	*Polydesma*	*Polydesma inangulata* (Gwen)
183	Lepidoptera	Sphingidae	*Hippotion*	*Hippotion celerio* (Linnaeus)
184	Lepidoptera	Zygaenidae	*Thyrassia*	*Thyrassia subcordata subcordata* (Walker)
185	Lepidoptera	Arctiidae	*Ansacta*	*Ansacta lineola*
186	Lepidoptera	Arctiidae	*Creatonotos*	*Creatonotos gangis* (Linnaeus)
187	Lepidoptera	Arctiidae	*Spilaretia*	*Spilaretia obliqua* (Walker)
188	Lepidoptera	Arctiidae	*Utetheisa*	*Utetheisa pulchella* (Linnaeus)
189	Lepidoptera	Arctiidae	*Agylla*	*Agylla ramelana* (Moore)
190	Lepidoptera	Arctiidae	*Asura*	*Asura undulosa*(Walker)
191	Lepidoptera	Hesperiidae	*Parnara*	*Parnara naso bada* (Moore)
192	Lepidoptera	Hesperiidae	*Parnara*	*Parnara naso* (Fabricius)
193	Lepidoptera	Hesperiidae	*Pelopidas*	*Pelopidas mathias mathias* (Fabricius)
194	Lepidoptera	Hesperiidae	*Pelopidas*	*Pelopidas mathias* (Fabricius)
195	Lepidoptera	Hesperiidae	*Telicota*	*Telicota ancilla bambusae* (Moore)
196	Lepidoptera	Hesperiidae	*Telicota*	*Telicota ancilla* (Herrich-Schaffer)
197	Lepidoptera	Hesperiidae	*Suastus*	*Suastus gremius* (Fabricius)
198	Lepidoptera	Pyralidae	*Scirpophaga*	*Scirpophaga bisignata* (Swinhoe)
199	Lepidoptera	Pyralidae	*Scirpophaga*	*Scirpophaga adjurellus* (Walker)
200	Lepidoptera	Pyralidae	*Scirpophaga*	*Scirpophaga bipunctifer* (Walker)
201	Lepidoptera	Pyralidae	*Tryporyza*	*Tryporyza incertulas* (Walker)
202	Lepidoptera	Pyralidae	*Epicrocis*	*Epicrocis aegnusalis* (Walker)
203	Lepidoptera	Pyralidae	*Nymphula*	*Nymphula diminutalis* (Snella)
204	Lepidoptera	Pyralidae	*Nymphula*	*Nymphula fluctuosalis zeller* (Snella)
205	Lepidoptera	Pyralidae	*Cnaphalocrocis*	*Cnaphalocrocis medinalis* (Guenee)
206	Lepidoptera	Pyralidae	*Syngamia*	*Syngamia abruptalis* (Walker)
207	Lepidoptera	Pyralidae	*Diaphania*	*Diaphania indica* (Saunbers)
208	Lepidoptera	Pyralidae	*Sameodes*	*Sameodes cancellalis* (Zeller)
209	Lepidoptera	Saturniidae	*Actias*	*Actias selene* (Huebner)
210	Lepidoptera	Saturniidae	*Antheraea*	*Antheraea paphia* (Linnaeus)
211	Lepidoptera	Lycaenidae	*Euchrysops*	*Euchrysops cnejus* (Fabricius)
212	Lepidoptera	Lycaenidae	*Euchrysops*	*Euchrysops pandava pandava* (Horsfield)
213	Lepidoptera	Lycaenidae	*Zizeeria*	*Zizeeria maha* (Kollar)
214	Lepidoptera	Lycaenidae	*Anthene*	*Anthene lycaenoids lycambes* (Hewitson)
215	Lepidoptera	Lycaenidae	*Catochrysops*	*Catochrysops strabo strabo* (Fabricius)
216	Lepidoptera	Lycaenidae	*Lampides*	*Lampides boeticus* (Linnaeus)
217	Lepidoptera	Lycaenidae	*Curetis*	*Curetis thetis thetis* (Drury)
218	Lepidoptera	Lycaenidae	*Mahathala*	*Mahathala ameria ameria* (Hewitson)

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259	Neuroptera	Chrysopidae	*Ankylopteryx*	*Ankylopteryx octopunctata* (Fabricius)
260	Diptera	Tipulidae	*Limonia*	*Limonia (Geranomyia) circipunctata* (Brunetti)
261	Diptera	Tipulidae	*Limonia*	*Limonia (Geranomyia) flavicosta* (Brunetti)
262	Diptera	Tipulidae	*Limonia*	*Limonia (Geranomyia) tridens* (Brynetti)
263	Diptera	Tipulidae	*Trentopohlia*	*Trentopohlia (Trentepohlia) trentepohlii* (Wiedemann)
264	Diptera	Psychodidae	*Psychodu*	*Psychodu alternata* Say
265	Diptera	Psychodidae	*Psychoda*	*Psychoda nigripennis* Brunetti
266	Diptera	Psychodidae	*Phlebotomus*	*Phlebotomus (Euphlebotomus) argentipes* Annadale & Brunetti
267	Diptera	Psychodidae	*Phlebotomus*	*Phlebotomus montana* Rondani
268	Diptera	Psychodidae	*Sergentomyia*	*Sergentomyia (Parrotomyia) babu* (Annadale)
269	Diptera	Ceratopgonidae	*Culicoides*	*Culicoides* (Oecacta) *schultzei* (Enderlein)
270	Diptera	Ceratopgonidae	*Culicoides*	*Culicoides peliliouensis Tokunaga (Unplaced species)*
271	Diptera	Ceratopgonidae	*Culicoides*	*Culicoides similis* Carter, Ingram & Macfie
272	Diptera	Ceratopgonidae	*Alluaudomyia*	*Alluaudomyia formosana* Okada
273	Diptera	Ceratopgonidae	*Alluaudomyia*	*Alluaudomyia maculosipennis* Tokunaga
274	Diptera	Culicidae	*Anopheles*	*Anopheles (Anopheles) peditaeniatus* (Leicester)
275	Diptera	Culicidae	*Anopheles*	*Anopheles (Cellia) annularis* vander Wulp
276	Diptera	Culicidae	*Anopheles*	*Anopheles (Cellia) pseudojamesi* Strickland & Chowdhury
277	Diptera	Culicidae	*Anopheles*	*Anopheles (Cellia) ramsayi* Covell
278	Diptera	Culicidae	*Anopheles*	*Anopheles (Cellia) subpictus* Grassi
279	Diptera	Culicidae	*Anopheles*	*Anopheles (Cellia) sundaicus* (Rodenwaldt)
280	Diptera	Culicidae	*Anopheles*	*Anopheles (Cellia) vagus* Donitz
281	Diptera	Culicidae	*Aedeomyia*	*Aedeomyia (Aedeomyia) catasticta* Knab
282	Diptera	Culicidae	*Lorrainea*	*Lorrainea fumida* Edwards
283	Diptera	Culicidae	*Stegomyia*	*Stegomyia albopictus* (Skuse)
284	Diptera	Culicidae	*Armigers*	*Armigers (Armigeres) kuchingensis* Edwards
285	Diptera	Culicidae	*Armigers*	*Armigers (Armigeres) subalbatus* (Coquillett)
286	Diptera	Culicidae	*Culex*	*Culex (Culex) quinquefasciatus* Say
287	Diptera	Culicidae	*Culex*	*Culex (Culex) pseudovishnui* Colless
288	Diptera	Culicidae	*Culex*	*Culex (Culex) tritaeniorhynchus* Giles
289	Diptera	Culicidae	*Culex*	*Culex (Culex) vishnui* Theobald
290	Diptera	Culicidae	*Culex*	*Culex (Culiciomyia) sitiens* Wiedemann
291	Diptera	Culicidae	*Culex*	*Culex (Eumelanomyia) malayi* (Leicester)
292	Diptera	Culicidae	*Mansonia*	*Mansonia (Mansonoides) annulifera* Theobald
293	Diptera	Culicidae	*Mansonia*	*Mansonia (Mansonoides) indiana* Edwards
294	Diptera	Culicidae	*Mansonia*	*Mansonia (Mansonoides) uniformis* (Theobald)

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219	Lepidoptera	Lycaenidae	*Narathura*	*Narathura atrax* (Hewitson)
220	Lepidoptera	Lycaenidae	*Spindasis*	*Spindasis vulcanus vulcanus* (Fabricius)
221	Lepidoptera	Lycaenidae	*Spindasis*	*Spindasis ictis ictis* (Hewitson)
222	Lepidoptera	Lycaenidae	*Spindasis*	*Spindasis elima elima* (Moore)
223	Lepidoptera	Lycaenidae	*Tajuria*	*Tajuria jehana* Moore
224	Lepidoptera	Geometridae	*Agathia*	*Agathia lycaenaria* (Kollar, 1844)
225	Lepidoptera	Nymphalidae	*Ariadne*	*Ariadne ariadne indica* (Moore)
226	Lepidoptera	Nymphalidae	*Hypolimnas*	*Hypolimnas misippus* (Linnaeus)
227	Lepidoptera	Nymphalidae	*Cirrochroa*	*Cirrochroa tyche mithila* Moore
228	Lepidoptera	Nymphalidae	*Precis*	*Precis atlites* (Linnaeus)
229	Lepidoptera	Nymphalidae	*Precis*	*Precis lemonis lemonis* (Linnaeus)
230	Lepidoptera	Nymphalidae	*Precis*	*Precis almana almana* (Linnaeus)
231	Lepidoptera	Nymphalidae	*Neptis*	*Neptis jumbah jumbah* Moore
232	Lepidoptera	Ctenuchidae	*Ceryx*	*Ceryx godartii* (Boisduval)
233	Lepidoptera	Ctenuchidae	*Syntomis*	*Syntomis diaphana*
234	Lepidoptera	Ctenuchidae	*Syntomis*	*Syntomis passalis fabricius*
235	Lepidoptera	Ctenuchidae	*Syntomis*	*Syntomis cyssea* (Stoll)
236	Lepidoptera	Pieridae	*Eurema*	*Eurema hecabe contubernalis* (Moore)
237	Lepidoptera	Pieridae	*Valeria*	*Valeria valeria hippia* (Fabricius)
238	Lepidoptera	Pieridae	*Delias*	*Delias eucharis* (Drury)
239	Lepidoptera	Pieridae	*Leptosia*	*Leptosia nina nina* (Fabricius)
240	Lepidoptera	Pieridae	*Ixias*	*Ixias marianne* (Cramer)
241	Lepidoptera	Pieridae	*Cepora*	*Cepora nerissa phryner* (Fabricius)
242	Lepidoptera	Pieridae	*Catopsilia*	*Catopsilia pyranthe pyranthe* (Linnaeus)
243	Lepidoptera	Pieridae	*Catopsilia*	*Catopsilia florella gnoma* (Fabricius)
244	Lepidoptera	Satyridae	*Mycalesis*	*Mycalesis perseus blasius* (Fabricius)
245	Lepidoptera	Satyridae	*Ypthima*	*Ypthima ceylonica hubneri* Kirby
246	Lepidoptera	Satyridae	*Melanitis*	*Melanitis leda ismene* (Cramer)
247	Lepidoptera	Papilionidae	*Pachliopta*	*Pachliopta hector* (Linnaeus)
248	Lepidoptera	Papilionidae	*Princeps*	*Princeps polytes* (Linnaeus, 1758)
249	Lepidoptera	Papilionidae	*Princeps*	*Princeps demoleus* (Linnaeus, 1758)
250	Lepidoptera	Nymphalidae	*Trirumala*	*Trirumala limniace* (Cramer, 1775)
251	Lepidoptera	Nymphalidae	*Danaus*	*Danaus genutia* (Cramer, 1779)
252	Lepidoptera	Nymphalidae	*Danaus*	*Danaus melanippus* (Cramer, 1777)
253	Lepidoptera	Nymphalidae	*Danaus*	*Danaus chrysippus* (Linnaeus, 1758)
254	Lepidoptera	Nymphalidae	*Euploea*	*Euploea core* (Cramer, 1780)
255	Lepidoptera	Nymphalidae	*Euploea*	*Euploea crameri* Lucas (1853)
256	Lepidoptera	Nymphalidae	*Idea*	*Idea agamarschana* (C. & R. Felder, 1865)
257	Neuroptera	Mantispidae	*Mantispa*	*Mantispa femoralis* Banks
258	Neuroptera	Hemerobiidae	*Mixomicromus*	*Mixomicromus lampus* Ghosh

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295	Diptera	Chironomidae	*Chironomus*	*Chironomus barbatitarsis*
296	Diptera	Cecidomyiidae	*Stephaniola*	*Stephaniola bengalensis* Mani
297	Diptera	Stratiomyidae	*Odontomyia*	*Odontomyia dorsoangulata* Brunetti
298	Diptera	Stratiomyidae	*Oplodontha*	*Oplodontha rubrithorax* (Macquart)
299	Diptera	Tabanidae	*Chrysops*	*Chrysops dispar* (Fabricius)
300	Diptera	Tabanidae	*Atylotus*	*Atylotus agrestis* (Wiedemann)
301	Diptera	Tabanidae	*Tabanus*	*Tabanus (Tabanus) striatus* Fabricius
302	Diptera	Tabanidae	*Haematopota*	*Haematopota javana* Wiedemann
303	Diptera	Asilidae	*Philodicus*	*Philodicus femoralis* Ricardo
304	Diptera	Asilidae	*Philodicus*	*Philodicus javanus* (Wiedemann)
305	Diptera	Empidaidae	*Drapetis*	*Drapetis (Elaphropeza) ferruginea* Brunetti
306	Diptera	Dolichopodidae	*Medetera*	*Medetera grisescens* de Meijere
307	Diptera	Phoridae	*Megaselia*	*Megaselia (Megaselia) scalaris* Loew
308	Diptera	Pipunculidae	*Pipunculus*	*Pipunculus (Eudorylus) biroi* Kertesz
309	Diptera	Syrphidae	*Ischiodon*	*Ischiodon scutellaris* (Fabricius)
310	Diptera	Syrphidae	*Paragus*	*Paragus* (Paragus) *serratus* (Fabricius)
311	Diptera	Syrphidae	*Eristalinus*	*Eristalinus (Eristalinus) obscuritarsis* (de Meijere)
312	Diptera	Syrphidae	*Mesembrius*	*Mesembrius quadrivittatus* (Wiedemann)
313	Diptera	Syrphidae	*Syritta*	*Syritta indica* (Wiedemann)
314	Diptera	Syrphidae	*Syritta*	*Syritta orientalis* Macquart
315	Diptera	Syrphidae	*Baccha*	*Baccha (Allobaccha) apicalis* Loew.
316	Diptera	Ephydridae	*Drachydeutera*	*Drachydeutera longipes* Hendel
317	Diptera	Tephritidae	*Platensina*	*Platensina acrostacta* (Wiedemann)
318	Diptera	Sepsidae	*Sepsis*	*Sepsis indica* Wiedemann
319	Diptera	Muscidae	*Musca*	*Musca (Byomya) conducens* Walker
320	Diptera	Muscidae	*Musca*	*Musca (Byomya) confiscata* Speiser
321	Diptera	Muscidae	*Musca*	*Musca (Byomya) endeni* Nandi & Sinha
322	Diptera	Muscidae	*Musca*	*Musca (Byomya) pattoni* Austen
323	Diptera	Muscidae	*Musca*	*Musca (Byomya) sorbens* Wiedemann
324	Diptera	Muscidae	*Musca*	*Musca (Byomya) ventrosa* Wiedemann
325	Diptera	Muscidae	*Musca*	*Musca (Eumusca) hervei* Villeneuve
326	Diptera	Muscidae	*Musca*	*Musca (Eumusca) seniorwhitei* Patton
327	Diptera	Muscidae	*Musca*	*Musca (Musca) domestica* Linnaeus
328	Diptera	Muscidae	*Musca*	*Musca (Philaematomyia) crassirostris* Stein
329	Diptera	Muscidae	*Orthellia*	*Orthellia indica* (Robineau-Desvoidy)
330	Diptera	Muscidae	*Orthellia*	*Orthellia lauta* (Wiedemann)
331	Diptera	Muscidae	*Orthellia*	*Orthellia timorensis* (Robineau- Desvoidy)
332	Diptera	Muscidae	*Muscina*	*Muscina stabulans* (Fallen)
333	Diptera	Muscidae	*Ophyra*	*Ophyra leucostoma* (Wiedemann)

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334	Diptera	Muscidae	*Synthesiomyia*	*Synthesiomyia nudiseta* (Van der Wulp)
335	Diptera	Muscidae	*Gymnodia*	*Gymnodia tonitrui* (Wiedemann)
336	Diptera	Muscidae	*Lispe*	*Lispe pumila* (Wiedemann)
337	Diptera	Muscidae	*Haematobia*	*Haematobia irritans exigua* de Mejire Sagar
338	Diptera	Muscidae	*Stomoxys*	*Stomoxys calcitrans* (Linnaeus)
339	Diptera	Muscidae	*Stomoxys*	*Stomoxys indica* Picard
340	Diptera	Caliphoridae	*Hemipyrellia*	*Hemipyrellia ligurriens* (Wiedemann)
341	Diptera	Caliphoridae	*Hemipyrellia*	*Hemipyrellia pulchra* (Wiedemann)
342	Diptera	Caliphoridae	*Calliphora*	*Calliphora (Calliphora) vicina* Robineau-Desvoidy
343	Diptera	Caliphoridae	*Chrysomya*	*Chrysomyia bezziana* Villeneuve
344	Diptera	Caliphoridae	*Chrysomya*	*Chrysomya megacephala* (Fabricius)
345	Diptera	Caliphoridae	*Idiella*	*Idiella mandarina* (Wiedemann)
346	Diptera	Sarcophagidae	*Parasarcophaga*	*Parasarcophaga (Liopygia) ruficornis* (Fabricius)
347	Diptera	Sarcophagidae	*Parasarcophaga*	*Parasarcophaga (Liosarcophaga) choudhuryi* Sinha & Nandi,
348	Diptera	Sarcophagidae	*Parasarcophaga*	*Parasarcophaga (Liosarcophaga) dux* (Thomson)
349	Diptera	Sarcophagidae	*Parasarcophaga*	*Parasarcophaga (Parasarcophaga) albiceps* (Meigen)
350	Diptera	Sarcophagidae	*Parasarcophaga*	*Parasarcophaga (Parasarcophaga) misera* (Walker)
351	Diptera	Sarcophagidae	*Liproctia*	*Liproctia lothianensis* Sinha & Nandi
352	Diptera	Sarcophagidae	*Leucomyia*	*Leucomyia cinerea* (Fabricius)
353	Coleoptera	Carabidae	*Pheropsophus*	*Pheropsophus cetorei*
354	Coleoptera	Carabidae	*Pachytrachelus*	*Pachytrachelus oblongus* (Dejean)
355	Coleoptera	Cerambycidae	*Xystrocera* Serville	*Xystrocera globosa* Olivier
356	Coleoptera	Cerambycidae	*Ceresium* Newmann	*Ceresium zeylanicum* White
357	Coleoptera	Cerambycidae	*Diorthus*	*Diorthus emeritus* Whiti
358	Coleoptera	Cerambycidae	*Derolus*	*Derolus discicollis* Gahan
359	Coleoptera	Cerambycidae	*Macrotoma* Serville	*Macrotoma plagiata*
360	Coleoptera	Cerambycidae	*Gelonaetha*	*Gelonaetha hirta* Fairmine
361	Coleoptera	Cicindelidae	*Cicindela*	*Cicindela erudata* Wiedemann
362	Coleoptera	Cicindelidae	*Cicindela*	*Cicindela biromasa* Fabricius
363	Coleoptera	Cicindelidae	*Cicindela*	*Cicindela quadrilineata* Fabricius
364	Coleoptera	Cicindelidae	*Cicindela*	*Cicindela sexpunctata* Fabricius
365	Coleoptera	Cicindelidae	*Cicindela*	*Cicindela haemorrhoidalis* Wied
366	Coleoptera	Dytiscidae	*Hydrocoptus*	*Hydrocoptus subvittulus* Mots.
367	Coleoptera	Dytiscidae	*Canthydrus*	*Canthydrus flavus* (Motschulsky)

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368	Coleoptera	Dytiscidae	*Canthydrus*	*Canthydrus morsbachi* (Wehncke)
369	Coleoptera	Dytiscidae	*Laccophilus*	*Laccophilus anticatus* Sharp
370	Coleoptera	Dytiscidae	*Laccophilus*	*Laccophilus basalis* Motscholsky
371	Coleoptera	Dytiscidae	*Laccophilus*	*Laccophilus chinensis inefficiens* Walker
372	Coleoptera	Dytiscidae	*Laccophilus*	*Laccophilus parvulus* Aube
373	Coleoptera	Dytiscidae	*Hydrovatus*	*Hydrovatus bonvouloiri* Sharp
374	Coleoptera	Dytiscidae	*Hydrovatus*	*Hydrovatus fusculus* Sharp
375	Coleoptera	Dytiscidae	*Hydrovatus*	*Hyphoporus aper* Sharp
376	Coleoptera	Dytiscidae	*Peschetius*	*Peschetius quadricostatus* Aube
377	Coleoptera	Dytiscidae	*Fretes*	*Fretes sticticus* (Linnaeus)
378	Coleoptera	Dytiscidae	*Hydaticus*	*Hydaticus (G.) fabricii* Macleay
379	Coleoptera	Dytiscidae	*Hydaticus*	*Hydaticus (G.) luzonicus* Aube
380	Coleoptera	Dytiscidae	*Cybister*	*Cybister (M.) confusus* Sharp
381	Coleoptera	Dytiscidae	*Cybister*	*Cybister (M.) guerini* Aube
382	Coleoptera	Dytiscidae	*Cybister*	*Cybister (M.) limbatus* (Fabricius)
383	Coleoptera	Dytiscidae	*Cybister*	*Cybister (M.) ventralis* Sharp
384	Coleoptera	Gyrinidae	*Orectochilus*	*Orectochilus similis* Ochs
385	Coleoptera	Gyrinidae	*Orectochilus*	*Orectochilus haemorrhous* Regimbart
386	Coleoptera	Gyrinidae	*Orectochilus*	*Orectochilus ribeiroi* Vazirani
387	Coleoptera	Hydrophilidae	*Sternolophus*	*Sternolophus rufipes* (Fabricius)
388	Coleoptera	Hydrophilidae	*Spercheus*	*Spercheus gibbus* Champion
389	Coleoptera	Hydrophilidae	*Sphaeridiun*	*Sphaeridiun cameroni* d'Orchymond
390	Coleoptera	Hydrophilidae	*Helochares*	*Helochares luntus* Sharp
391	Coleoptera	Silvanidae	*Oryzaephilus*	*Oryzaephilus mercator* (Fauvel)
392	Coleoptera	Scarabaeidae	*Adoretus*	*Adoretus lacustris* Arrow
393	Coleoptera	Scarabaeidae	*Adoretus*	*Adoretus gemmifer* Arrow
394	Coleoptera	Scarabaeidae	*Glycosia*	*Glycosia tricolor* Oliver
395	Coleoptera	Scarabaeidae	*Heliocopris*	*Heliocopris gigas* (Linnaeus)
396	Coleoptera	Scarabaeidae	*Heterorychus*	*Heterorychus lioderes* Retd.
397	Coleoptera	Scarabaeidae	*Onthophagus*	*Onthophagus quadridentatus* (Fabricius)
398	Coleoptera	Scarabaeidae	*Phyllognathus*	*Phyllognathus dionysius* (Fabricius)
399	Coleoptera	Bostrichidae	*Heterobostrichus*	*Heterobostrichus aequalis* Watson
400	Coleoptera	Bostrichidae	*Rhizopertha*	*Rhizopertha dominica* (Fabricius)
401	Coleoptera	Tenebrionidae	*Alphitobius*	*Alphitobius diaperinus* (Panz.)
402	Coleoptera	Chrysomelidae	*Dicladispa*	*Dicladispa armigera* (Olivier)
403	Coleoptera	Chrysomelidae	*Dactylispa*	*Dactylispa armigera* (Fabricius)
404	Coleoptera	Curculionidae	*Tanymecus*	*Tanymecus albomarginatus* Gyl.
405	Coleoptera	Curculionidae	*Tanymeans*	*Tanymeans albomarginatus* Gyl.
406	Coleoptera	Curculionidae	*Platypus*	*Platypus maritimus* Schedl
407	Coleoptera	Curculionidae	*Xyleborus* Eich-hoff	*Xyleborus cognatus* Blanford

Sr. No.	Order	Family	Genus	Species
408	Coleoptera	Scolytidae	*Coccotrypes* Eichhoff	*Coccotrypes nepheli* (Eggers)
409	Coleoptera	Coccinellidae	*Brumus*	*Brumus suturalis* (Fab.)
410	Coleoptera	Coccinellidae	*Pseudaspidi-merus*	*Pseudaspidimerus circumflexa* var. testaceus (Weise)
411	Coleoptera	Coccinellidae	*Rodolia*	*R. fumida var. roseipennis* Muls.
412	Coleoptera	Coccinellidae	*Coccinella*	*Coccinella transversalis* Fab
413	Coleoptera	Coccinellidae	*Menochilus*	*Menochilus sexmaculatus* (Fab.)
414	Coleoptera	Coccinellidae	*Oenopia*	*Oenopia luteopustulata* Mulsant
415	Coleoptera	Coccinellidae	*Micraspis*	*Micraspis discolor* (Fab.)
416	Coleoptera	Coccinellidae	*Afidenta*	*Afidenta mimetica ssp. simplex* Dieke
417	Coleoptera	Coccinellidae	*Epilachna*	*Epilachna dodecastigma* (Weidmann)
418	Coleoptera	Coccinellidae	*Epilachna*	*Epilachna septima* Dieke
419	Coleoptera	Coccinellidae	*Epilachna*	*Epilachna viginitioctopunctata* (Fab.)
420	Coleoptera	Meloidae	*Mylabris*	*Mylabris cichorii* (Linnaeus)
421	Coleoptera	Meloidae	*Mylabris*	*Mylabris phalerata* (Pallas)
422	Coleoptera	Meloidae	*Mylabris*	*Mylabris thunbergi* Billbarg
423	Coleoptera	Tenebrionidae	*Gonocephalum*	*Gonocephalum depressum*
424	Coleoptera	Tenebrionidae	*Anthracius*	*Anthracius punctipennis*
425	Coleoptera	Tenebrionidae	*Stenosis*	*Stenosis medinipurensis n* .sp.
426	Coleoptera	Chrysomelidae	*Lema*	*Lema lacertosa* Lacord
427	Coleoptera	Chrysomelidae	*Diapromorpha*	*Diapromorpha pallens* (Fabricius)
428	Coleoptera	Chrysomelidae	*Cryptocephalus*	*Cryptocephalus sehestedti* Fabricius
429	Coleoptera	Chrysomelidae	*Pachnephorus*	*Pachnephorus lewisii* Baly
430	Coleoptera	Chrysomelidae	*Platycorynus*	*Platycorynus pyrophorus* (Parry)
431	Coleoptera	Chrysomelidae	*Chrysolina*	*Chrysolina conglomerata* Maulik
432	Coleoptera	Chrysomelidae	*Gallerucella*	*Gallerucella placida* Baly
433	Coleoptera	Chrysomelidae	*Oides*	*Oides maculata* (Olivier)
434	Coleoptera	Chrysomelidae	*Oides*	*Oides flava* (Olivier)
435	Coleoptera	Chrysomelidae	*Hoplasoma*	*Hoplasoma unicolor* (Illiger)
436	Coleoptera	Chrysomelidae	*Aulacophora*	*Aulacophora foveicollis* (Lucas)
437	Coleoptera	Chrysomelidae	*Aulacophora*	*Aulacophora excavata* Baly
438	Coleoptera	Chrysomelidae	*Aulacophora*	*Aulacophora lewisii* Baly
439	Coleoptera	Chrysomelidae	*Medythia*	*Medythia nigrobilineata* (Mots.)
440	Coleoptera	Chrysomelidae	*Monolepta*	*Monolepta orientalis* Jacoby
441	Coleoptera	Chrysomelidae	*Monolepta*	*Monolepta bifasciata* (Hornst.)
442	Coleoptera	Chrysomelidae	*Monolepta*	*Monolepta signata* (Oliv.)
443	Coleoptera	Chrysomelidae	*Monolepta*	*Monolepta limbata* (Oliv.)
444	Coleoptera	Chrysomelidae	*Sphenoraia*	*Sphenoraia bicolor* (Hope)
445	Coleoptera	Chrysomelidae	*Aspidomorpha*	*Aspidomorpha indica* Boh.
446	Coleoptera	Chrysomelidae	*Aspidomorpha*	*Aspidomorpha furcata* (Thunberg)

Sr. No.	Order	Family	Genus	Species
447	Coleoptera	Chrysomelidae	*Aspidomorpha*	*Aspidomorpha miliaris* (F.)
448	Coleoptera	Chrysomelidae	*Laccoptera*	*Laccoptera quadrimaculata* (Thun.)
449	Coleoptera	Chrysomelidae	*Oocassida*	*Oocassida obscura* (F.)
450	Coleoptera	Chrysomelidae	*Chiridopsis*	*Chiridopsis bipunctata* (Linn.)
451	Coleoptera	Chrysomelidae	*Cassida*	*Cassida enervis* Boh.
452	Coleoptera	Chrysomelidae	*Cassida*	*Cassida circumdata* Herbst
453	Hymenoptera	Apidae	*Apis*	*Apis dorsata*
454	Hymenoptera	Apidae	*Apis*	*Apis mellifera*
455	Hymenoptera	Vespidae	*Polistes*	*Polistes olivaceus* (De Geer, 1773)
456	Hymenoptera	Vespidae	*Polistes*	*Polistes rothneyi rothneyi* Cameroon, 1900
457	Hymenoptera	Vespidae	*Polistes*	*Polistes nigritarsis* Cameroon, 1900
458	Hymenoptera	Vespidae	*Polistes*	*Polistes stigma tamula* (Fabricius, 1798)
459	Hymenoptera	Vespidae	*Polistes*	*Polistes sagittarius* Saussure,1853
460	Hymenoptera	Vespidae	*Ropalidia*	*Ropalidia marginata marginata* (Lepele-tier,1836)
461	Hymenoptera	Vespidae	*Ropalidia*	*Ropalidia artifex artifex* (Saussure, 1853)
462	Hymenoptera	Vespidae	*Ropalidia*	*Ropalidia stigma stigma* (Smith, 1858)
463	Hymenoptera	Vespidae	*Parapolybia*	*Parapolybia varia* (Fabricius, 1787)
464	Hymenoptera	Vespidae	*Vespa*	*Vespa basilis* Smith,1852
465	Hymenoptera	Vespidae	*Vespa*	*Vespa tropica tropica* (Linnaeus, 1758)
466	Hymenoptera	Vespidae	*Vespa*	*Vespa tropica leefmansi* van der Vecht, 1959
467	Hymenoptera	Scoliidae	*Campsomeriella*	*Campsomeriella collaris collaris* (Fabricius)
468	Hymenoptera	Scoliidae	*Scolia*	*Scolia cianipennis* Fabricius
469	Hymenoptera	Scoliidae	*Scolia*	*Scolia affinis* Guerin
470	Hymenoptera	Formicidae	*Aenictus*	*Aenictus clavitibia* Forel
471	Hymenoptera	Formicidae	*Bothroponera*	*Bothroponera tesserinoda* (Emery)
472	Hymenoptera	Formicidae	*Diacamma*	*Diacamma rugosum* var. *sculptum* (Jerdon)
473	Hymenoptera	Formicidae	*Diacamma*	*Diacamma vagans* (Smith)
474	Hymenoptera	Formicidae	*Leptogenys*	*Leptogenys chinensis* (Forel)
475	Hymenoptera	Formicidae	*Leptogenys*	*Leptogenys kitteli* Forel
476	Hymenoptera	Formicidae	*Ponera*	*Ponera* sp.
477	Hymenoptera	Formicidae	*Tertaponera*	*Tertaponera rufonigira* (Jerdon)
478	Hymenoptera	Formicidae	*Meranoplus*	*Meranoplus rothneyi* Forel
479	Hymenoptera	Formicidae	*Messor*	*Messor barbarus* Linnaeus
480	Hymenoptera	Formicidae	*Oligomyrmex*	*Oligomyrmex rothneyi* Forel
481	Hymenoptera	Formicidae	*Pheidole*	*Pheidole spathifera* Forel
482	Hymenoptera	Formicidae	*Solenopsis*	*Solenopsis geminata* (Fabricius)
483	Hymenoptera	Formicidae	*Camponotus*	*Camponotus angustata* (Mayr)
484	Hymenoptera	Formicidae	*Camponotus*	*Camponotus compressus* (Fabricius)
485	Hymenoptera	Formicidae	*Camponotus*	*Camponotus oblongus* (Smith)

Sr. No.	Order	Family	Genus	Species
486	Hymenoptera	Formicidae	*Camponotus*	*Camponotus rothneyi* (Forel)
487	Hymenoptera	Formicidae	*Camponotus*	*Camponotus rufoglaucus dolenda* (Forel)
488	Hymenoptera	Formicidae	*Camponotus*	*Camponotus sericeus* (Fabricius)
489	Hymenoptera	Formicidae	*Polyrhachis*	*Polyrhachis tubericeps* Forel
490	Hymenoptera	Formicidae	*Acantholepis*	*Acantholepis frauenfeldi* (Mayr)
491	Hymenoptera	Formicidae	*Plagiolepis*	*Plagiolepis dichroa* Forel
492	Hymenoptera	Ichneumonidae	*Echthromorpha*	*Echthromorpha agrestoria notulatoria* (Fabricius)
493	Hymenoptera	Ichneumonidae	*Xanthopimpla*	*Xanthopimpla sikkimensis* Cameron
494	Hymenoptera	Ichneumonidae	*Leptobatopsis*	*Leptobatopsis indica* (Cameron)
495	Hymenoptera	Ichneumonidae	*Menaforia*	*Menaforia indica* Gupta & Saxena
496	Hymenoptera	Braconidae	*Chelonus*	*Chelonus heliope* Gupta
497	Hymenoptera	Braconidae	*Bracon*	*Bracon famulus* Bingham

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2.14 COASTAL FISHES

The Sundarbans have numerous rivers, creeks, and channels which form important fish resources.

TAPAN KUMAR CHATTERJEE
Ichthyologist with specialization in brackish water fish culture

32500
extant fishes

It is bounded on the west by the Hooghly River and on the east by the Saptamukhi River. From east of Calcutta flows the Bidyadhari, which along with other streams forms the river Matla. The Kankalmari River joins Matla downstream. The other main rivers are Gosaba and the Harinbhanga. The Raimangal River flows along the Indo-Bangladesh boundary. Such an environment provides an ideal environment for fish diversity (figure 1).

The term 'fish' precisely descri- bes any non-tetrapod craniate (that is, an animal with a skull and, in most cases, a backbone) that has gills throughout life and whose limbs, if any, are in the shape of fins (Nelson 2006). Unlike groupings such as birds or mammals, fish are not a single clade but a paraphyletic collection of taxa, including hagfishes, lampreys, sharks and rays, ray-finned fishes, coelacanths, and lungfishes (Helfman et al. 1997).

Fish come in many shapes and sizes. Tuna, swordfish, and some species of sharks show some warm-blooded adaptations; they can heat their bodies significantly above ambient water temperature. Streamlining and swimming performance varies from fish such as tuna, salmon, and jacks that can cover 10–20 body-lengths per second to species such as eels and rays that swim no more than 0.5 body-lengths per second. Many groups of freshwater fish extract oxygen from the air as well as from the water using a variety of different structures. Lungfish have paired lungs similar to those of tetrapods; gouramis have a structure called the labyrinth organ that performs a similar function, while many catfish such as *Corydoras* extract oxygen through the intestine or stomach (Moyle and Cech 2003). Body shape and the arrangement of the fins are highly variable, covering such seemingly un-fishlike forms as seahorses, pufferfish, anglerfish, and gulpers. Similarly, the surface of the skin may be naked (as in moray eels) or covered with scales of different types, usually defined as placoid (typical of sharks and rays); cosmoid (fossil lungfishes and coelacanths); ganoid (various fossil fishes but also living gars and bichirs); cycloid; and ctenoid (these last two are found on most bony fish). There are even fishes that live mostly on land, for example, mudskippers. They feed and interact with one another on mudflats and go underwater to hide in their burrows (Froese et al. 2006).

The living fishes belong to class Infraphylum Gnathostomata (jawed vertebrates); the cartilaginous fishes belong to class Chondrichthyes; and the bony fishes belong to class Actinopterygii (ray-finned fish) and class Sarcopterygii (lobe-finned fish), under the superclass Osteichthyes (Nelson 2006). There are almost 28,000 known extant species, of which almost 27,000 are bony fish, with 970 sharks, rays, and chimeras and about 108 hagfishes and lampreys. About 64 families are monotypic, containing only one species. The total of extant species may grow to exceed 32,500 (Nelson 2006).

OVERVIEW

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SPECIES RECORDED FROM INDIA

Nelson (2006) estimated 27,977 valid species of fishes world over under 62 orders, 515 families, and 4,494 genera, and the eventual number of extant fish species is projected to be close to 32,500. About 11,952 species or 42.72 percent normally live in freshwater lakes and rivers that cover only 1 percent of the earth's surface and account for a little less than 0.01 percent of its water. The secondary freshwater species numbers 12,457 and the remaining 3,568 species are exclusively marine.

The Indian subcontinent harbors rich ichthyofaunal diversity, comprising about 2,500 species (Talwar 1991), of which 930 species are freshwater inhabitants and 1,570 are marine. The Indian species represent about 11.72 percent of the known fish species of the world (Lakra et. al. 2010).

Species composition and community structure vary from east to west and along the hydrological and salinity gradients (Gopal and Chauhan 2006). Jhingran (1977) recorded a total of 172 species from a variety of sources and also mentioned that the diversity of the Hooghly-Matlah estuary increases along an increasing salinity gradient. Numerous species (estimated to be 400) are known to use mangrove swamps in India as nursery grounds (Gundermann and Popper 1984; McConnell 1987). The number of fish species in the world, India, and the Sundarbans is shown in table 1.

Table-1: Comparison between the Number of Fish Species in World, India and the Sundarbans:

Group	No. of available species				
	World	India	Percentage	Sundar-bans	Percentage
Fishes	29977 (Nelson, 2006)	2500 (Talwar, 1991)	About 11.72% of world spe-cies (Lakra et. al., (2010)	364	About 14.56 % of Indian species About 1.21% of World spe-cies

The Indian Sundarbans at the apex of the Bay of Bengal (between 21°40′ N, 88°03′ E and 22°40′ N, 89°07′ E) located on the southern fringe of West Bengal, on the northeast coast of India, is a dynamic environment with a complex of features and biogeochemical properties. The aquatic biodiversity in the Sundarbans delta is largely controlled by freshwater flux, nutrient inputs, and changing environmental conditions such as salinity and temperature. Plankton communities are generally well studied in the deltaic ecosystem over a time scale encompassing more than three decades and show patterns or trends similar to those found in other man -grove ecosystems at a regional and global scale.

SUMMARY

Diversity

The dynamics of the fish communities of the Sundarbans are poorly understood (Rainboth, 1990). Although there are many published works on the fish fauna of different states of India including that of West Bengal, there is no comprehensive account of the fishes recorded from the Sundarbans. However, the works of Talwar et al. (1992); Mukherjee (1995); Das and Nandi (1999); and Gopal and Chauhan (2006) report the fish diversity of the Sundarbans. Compilations of the species listed in these works reveal that 364 species distributed under 215 genera are available in the Sundarbans as against 4,494 genera world over.

364 SPECIES
ARE DISTRIBUTED
UNDER 215 GENERA

It was hypothesized that fish assemblages would vary between mangroves and mudflats and that species richness and abundance would decrease with increasing distance from the mangrove forest. Patterns were expected to be species specific, that is, some species are found in higher numbers in mangroves and others are more abundant in mudflat habitats (Payne and Gillanders 2009).

Species Richness and Functional Groups

Functional type classification is a contemporary topic at the forefront of ecology throughout the world. The species guild is frequently cited as an ecological entity but lacks any formal or testable definition (Adams 1985). A review of literatures worldwide shows that functional groups in fishes have been formed on the basis of diet similarity, namely piscivores, benthivores, planktivores, and so on. Functional guilds of the species representing their families are listed in the annexure.

Gopal and Chauhan (2006) reported 250 fish species from the Indian Sundarbans. Among fin fish, the highly priced Hilsa (*Hilsa ilisha*), Bhetki (*Lates calcarifer*), Bhangon (*Liza tade*), and Mullets (*Liza parsia*) form a lucrative fishery of this region. About 400 fish species (pelagic and demersal) are reportedly available in the combined Sundarbans (India and Bangladesh). The largest fishing ground in the Bay of Bengal is close to the Sundarbans.

A list of the fish species recorded from the Indian Sundarbans is given in the annexure. Table 2 lists the fish families recorded from the Sundarbans together with the number of species under each of them.

Table-2: List of the fish families recorded from the Sundarbans together with the number of species

Sl. No.	Family	No. of Sp.	Sl. No.	Family	No. of Sp.
1	Hemiscyllidae	2	41	Rachycentridae	1
2	Stegostomatidae	1	42	Carangidae	19
3	Rhincodontidae	1	43	Coryphaenidae	1
4	Proscylliidae	1	44	Parastromateidae	1
5	Carcharhinidae	9	45	Leiognathidae	10
6	Sphyrnidae	1	46	Lutjanidae	4
7	Pristidae	3	47	Lobotidae	1
8	Torpedinidae	4	48	Gerreidae	4
9	Rhinobatidae	6	49	Haemulidae	4
10	Dasyatidae	7	50	Sparidae	3
11	Gymnuridae	2	51	Nemipterydae	3
12	Myliobatidae	2	52	Sciaenidae	25
13	Elopidae	1	53	Mullidae	2
14	Megalopidae	1	54	Toxotidae	1
15	Anguillidae	2	55	Ephippididae	4
16	Moriguidae	2	56	Scatophagidae	1
17	Muraenidae	10	57	Mugilidae	11
18	Muraenesocidae	4	58	Sphyraenidae	2
19	Ophichthidae	3	59	Polynemidae	7
20	Clupeidae	12	60	Uranoscopidae	1
21	Pristigasteridae	8	61	Callionymidae	5
22	Engraulidae	16	62	Blennidae	2
23	Chirocentridae	1	63	Eleotridae	8
24	Ariidae	15	64	Gobiidae	47
25	Harpadontidae	1	65	Kurtidae	1
26	Synodontidae	1	66	Siganidae	2
27	Bregmaceroti-dae	1	67	Trichiuridae	6
28	Antennariidae	1	68	Scombridae	3
29	Hemiramphidae	7	69	Stromateidae	2
30	Belonidae	3	70	Psettodidae	1
31	Fistulariidae	1	71	Citharidae	1
32	Syngnathidae	1	72	Bothidae	5
33	Synanceiidae	2	73	Cynoglossidae	9
34	Platycephalidae	1	74	Soleidae	6
35	Ambassidae	2	75	Triacanthidae	3
36	Centropomidae	1	76	Balistidae	1
37	Serranidae	3	77	Ostraciidae	1
38	Teraponidae	3	78	Tetraodontidae	11
39	Sillaginidae	2			
40	Lactaridae	1			

Distribution and Local Community Dependencies

The Sundarbans at present has an estimated water area of 27,085.39 ha under fishing and 19,390.73 ha under aquaculture in its northern and southern parts, respectively (Das 2009). The estimated total number of inland fisherfolk families in the 24-Parganas South District is 52,917 and 50,897 in the 24-Parganas North District (Government of West Bengal 2005). The 24-

Parganas South District has a marine fisherfolk population of 269,565, with an active fisher population of 70,750, located in 237 villages (CMFRI 2005). Some of the popular commercial fishes are listed in table 3.

Table 3: Commercially important fishes

Scientific name	Common Name	Local name
Lates calcarifer	Sea perches	Bhetki
Johnius spp.	Croakers	Bhola
Mugil cephalus	Mullets	Parse
Polynemus spp.	Threadfins	Tapse
Pampus spp.	Pomfrets	Pomfret
Hilsa ilisha	Hilsa	Ilish
Trichiurus spp.	Ribbonfishes	Rupabati, Patia
Harpadon nehereus	Bombay duck	Nehara, Lote
Cynoglossus spp.	Tongue soles	Pata machh
Arius spp.	Sea cat fishes	Kanta
Mystus spp.	Cat fishes	Tangra
Parastromateus niger	Black pomfret	Baul
Setipinna phasa	Anchovies	Phyasa, Tapra
Coilia dussumieri	Anchovies	Ruli

During winter, a large number of fishermen migrate in groups from different areas of the Hoogly-Matla estuary to practice traditional fishing. They move to suitable areas near the sea or in lower zones to establish fishing camps and remain engaged in bag net fishing till early February. Traditional fishers use rowboats or boats with small diesel engines while fishing in rivers and creeks. Estimation of the number of fishing boats in the region is very difficult as the smaller boats require no registration or license except when fishing within the protected area (Danda 2007).

Sarkar (2009) highlights the processes and procedures of the indigenous fishing communities through time and space to grapple with the eco-environmental setting in making their living through uninterrupted fishing operations. Around 2,069 km^2 inside the SBR is considered ideal for riverine fishing using traditional methods (Mukherjee 2007). The Sundarbans being the nursery for nearly 90 percent of the aquatic species of the eastern coast, the coastal fishery of eastern India is dependent upon the Sundarbans (Chandra et al. 2003). Since fishes are active swimmers, they are not confined to particular blocks; all riverine fishes are distributed in all blocks of South 24-Parganas and North 24-Parganas parts of the Sundarbans and coastal fishes are distributed in all blocks of South 24-Parganas. Brackish-water fish farms (*bheries*) are predominant in North 24-Parganas District. Block-wise distribution of important fish landing centers, fishing harbors, and *bheries* are shown in table 4.

Table-4: Distribution of important fish landing centers, fishing harbours and 'bheries'

Blocks	Important Fish Landing Centers	Fishing harbours	Large scale 'Bheries'
Sagar	-	+	-
Namkhana	+	+	-
Patharpra-tima	+	+	-
Mathurapur-I	-	-	-
Mathurapur-II	+	-	-
Canning-II	+	-	-
Kakdwip	+	+	-
Sandesh-khali-I	-	-	+
Sandesh-khali-II	-	-	+
Haroa	-	-	+
Mina-khan	-	-	+

Note: '+' denotes predominant

The main areas of traditional fishing (migratory bag net fishery) are Sagar Island, Frasergunj, Bakkhali, and Kalisthan. The significant inland fish landing centers in the Sundarbans include Canning, Herobhanga, and Gosaba. Other landing centers deemed important by the Fisheries Department, where traditional fishing is predominant, are Kakdwip, Frazerganj, Buroburir tath, Bakkhali, Namkhana, Jambu Island, Chemaguri, Hatipitha, Maragoli, Haribhanga, Sagar, Shikarpur, Gobindapur, Bankimpur, Boatkhali, Roydighi, Domkhal, Sitarampur, and Kakramari.

Block-wise location of traditional fishing zones and important fish landing centers are shown in figure 1. Sorting of commercial catches and some fish and prawns are shown in figures 2 and 3. Different types of traditional gears used in the inland waters of Sundarbans (Mukherjee 2007) are shown in figure 4. In 2005–06, West Bengal recorded the highest fish production in India of 1.2 million tons, of which 1.09 million tons were from inland resources (Government of India 2006).

Fig.1: Rivers and location of important inland fish landing centers and traditional inland fishing zones in Sundarban Biosphere Reserve

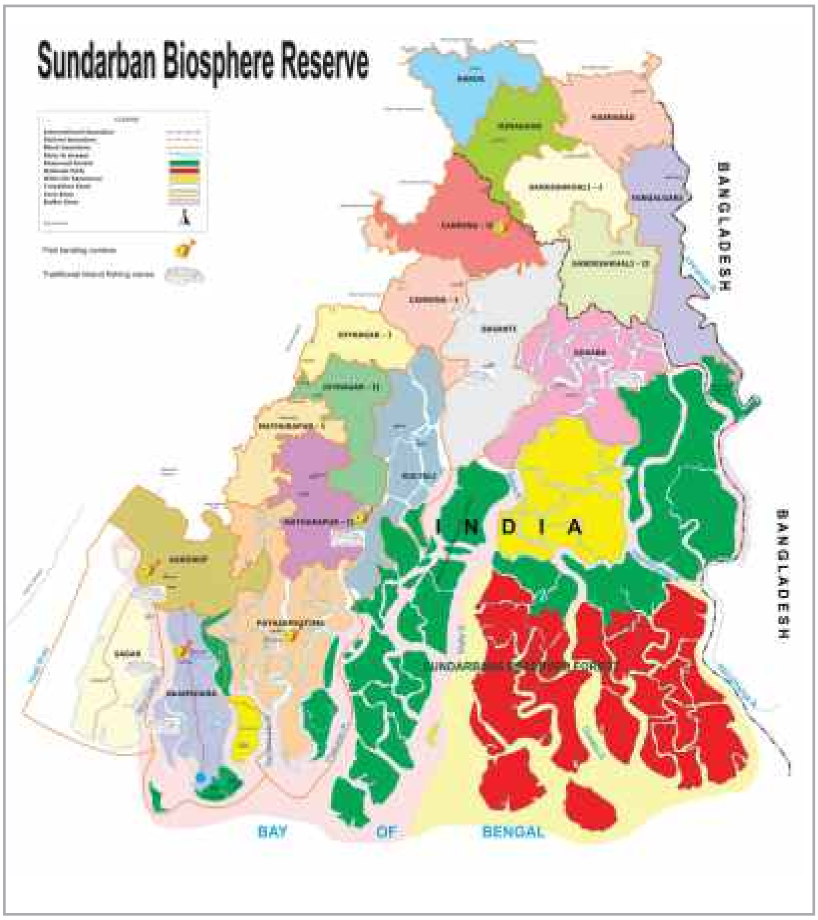
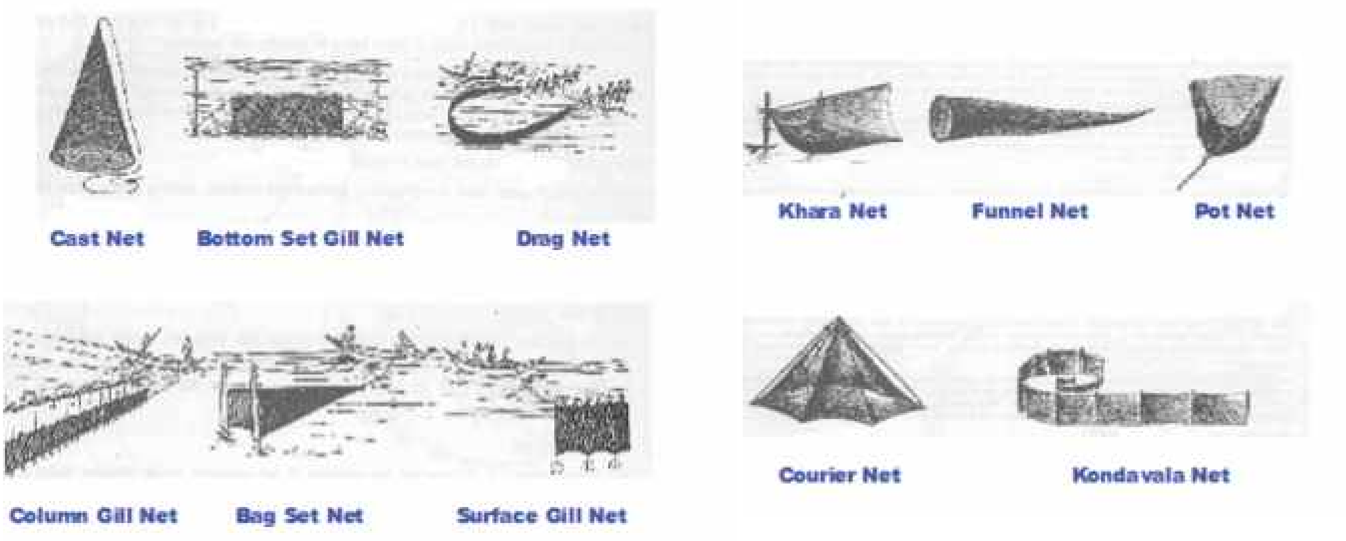


Fig.2 - Sorting of fishes

Fig.3 - A collection of prawn

Fig.4: Traditional fishing nets (after Mukherjee, 2007)



A large section of the poor tribal population of the Sundarbans, especially the females and minors living far below subsistence level, are engaged in the practice of spawn collection of *Penaeus monodon* and *Penaeus indicus* during daily tides using unscientific gears like mosquito nets (figure 5). A number of individual groups of commercial fishermen and multinational companies are collecting large-scale commercial catch from the vast coastal, estuarine, and deep-sea zone of the Sundarbans throughout the year. The fish-landing stations at Canning, Raidighi, Diamond Harbour, Kakdwip, and Namkhana are for the latest fishing crafts and gears like big bull trawlers; mechanized boats; and polyvinyl chloride (PVC) trawl, gill, and bag nets. Built-in slaughting-washing units and artificial units are collectively helping in profitable export-based fishing economy as well as in degrading the sensitive aqua-mangrove ecosystem of the Sundarbans (Das 2009).

Fisheries in the Sundarbans are based on both inland and marine fisheries' resources. West Bengal is the highest fish-producing state of India and in 2002–03, 11.20 lakhs metric tons of fish were exported earning 5331.34 million of rupees. In this coastal terrain, there is vast scope for shrimp-based polyculture. Fisheries extension programs need to be strengthened through the active involvement of fisherfolk working in inland, brackish-water, and marine sectors; industrialists; end users; the Fisheries Department; universities; research institutes; and nongovernmental organizations. The new infrastructural facilities, such as six new fishing harbors, are being set up by the Fisheries Department, complete with cold storage facilities, packaging centers, and modern fish markets at Frazerganj, Diamond Harbour, Kakdwip, Sagar, and Patharpratima. Construction works have already been completed at Frazerganj and Diamond Harbour. These harbors together will provide export opportunities to fish farmers and fish sellers (*Fish Biz Bonanza to Boost State* 2003).

STATUS AND THREATS

Six fish species of the Sundarbans are under the Indian Wildlife (Protection) Act, 1972. Schedule-I Part 2 (A) Fishes (Lakra et al. 2010). According to the IUCN Red List of all life forms, 16,928 species are threatened globally and of these, 1,275 species are fishes. Further, out of 659 globally threatened Indian fauna, 42 species belong to fishes according to the IUCN classification under different categories. Eight fish species from the Sundarbans are in this list. The Convention on International Trade in Endangered Species (CITES) Appendices II includes two species of fishes common to the Sundarbans, namely *Pristis microdon* and *Rhincodon typus* (table 5).

Table- 5: Protection regime of Fish in Sundarbans.

Sr. No.	Name	Schedules of Wildlife (Protection) Act 1972	IUCN Red Data Book	CITES appendices
1	*Anoxypristis cuspidata* : (Knifetooth Sawfish)	I	Critically Endangered	-
2	*Aetomylaeus nichofii* (Banded Eagle Ray)	-	Vulnerable	-
3	*Carcharhinus hemiodon* (Pondicherry Shark)	-	Critically Endangered	-
4	*Glyphis gangeticus* (Ganges Shark)	I	Critically Endangered	-
5	*Himantura fluviatilis* (Ganges Stingray)	I	Endangered	-
6	*Pristis pectinata* (Wide Sawfish)	-	Critically Endangered	-
7	*Pristis microdon* (Largetooth Sawfish)	I	Critically Endangered	II
8	*Rhincodon typus* (Whale Shark)	I	Vulnerable	II
9	*Rhina ancylostoma* (Bowmouth Guitarfish)	-	Vulnerable	-
10	*Rhinobatos obtusus* (Widenose Guitarfish)	-	Vulnerable	-
11	*Rhynchobatus djiddensis* (Whitespotted Wedgefish)	I	Vulnerable	-

Limited extraction of mangroves for fuelwood and poles is an old practice. However, in the revenue areas, the destruction of mangroves is conspicuous and at places the area has been reclaimed for agriculture as well as for settlement. The extent and condition of the crop and the threat to such mangrove areas need to be assessed. The problems of marine and estuarine fisheries in the Sundarbans can be categorized into the following groups:

- **Indiscriminate seed collection and bycatch.** Thousands of untrained workers who collect shrimp fry from the sea, channels, and rivers cause significant losses to the fry of other fishes. Frequently, collectors discard non-shrimp fry, perhaps one of the main causes of a gradually declining supply of different natural fish (Baer 2001). In a study in the SBR, it was found that to catch 1 tiger prawn seed in the Sundarbans, collectors destroyed juveniles of 161 other prawns, 7 fishes, 30 crabs, 1 mollusc, and 8 unidentified meroplanktons (Das and Nandi 1999).
- **Lack of post-harvest and other infrastructure.** Proper storage, preservation, and prompt disposal or transport service are essential (Yadava 2004).
- **Water pollution.** The current environmental status of the Sundarbans water systems is relatively poor. A mixture of domestic sewage and industrial waste is discharged into the canal systems of Kolkata and these waters eventually reach the Sundarbans and are responsible for the accumulation of heavy metals and the presence of organic pollutants in the tissue of fish (ADB 2003). The river channels of the Sundarbans have experienced high rates of deterioration largely due to this sewage discharge. Choudhury and Choudhury (1994) note that the Bidhadhari and Piali Rivers have been transformed into dead water bodies and these waters have experienced the knock-on impact of affecting the Matla River. The same review notes the steady degradation of fisheries resources in the Ichhamati, Bidyadhari, Kalagachia, Matla, Moni, Satumukhi, and Hataniadoania waterways. Agricultural runoff and effluents from fish farms are thought to be responsible for increased levels of eutrophication in the Indian Sundarbans and are also thought to be the cause of dinoflagellate blooms that are now a common phenomenon in the coastal waters of West Bengal (Mukherjee et al. 2007).
- **Impact of coastal aquaculture (*bheri* fishing).** Local fishermen have converted many coastal swamps into *bheries*, that is, artificial enclosures for taking the tidal saline water in and out through sluices from nearby rivers for commercial pisciculture. Sinha (1998) reports that 1,392 *bheries* covering 43,000 ha are operative in the Sundarbans.

Fig.5 - Collection of prawn seeds

Table 6: Magnitude of commercial coastal fishing in southern Sundarbans

Police Station	Total production in Kgs (1997-'98)	No. of Vessels	Distance of Fishing trips	No. of Trips/ months	Capacity Of Vessels
Canning	50,40, 000	Trawlers-10 Mechanized Boats-12	60 kms (monsoon), 100 kms (winter).	7 days x 4 trips(mon soon), 15 days x 2 trips (winter).	8000 kgs.
Diamond Harbour	151,60,000	Trawler-100 Mechanized boats-60	25 kms. (monsoon), 180 kms (winter).	7 days x 4 trips (monsoon), 10 days x 3 trips(winter).	18,000 kgs.
Kakdwip	435,40,000	Trawlers-100 Mechanized boats-2000.	80 kms. (monsoon) 180 kms (winter)	7 days x 4 trips (monsoon), 15 Days x 2 trips (winter).	12,000 kgs.
Roydighi	62,22,400	Trawlers-200 Mechanized boats-600	100 kms (monsoon), 180 kms (winter)	7 days x 4 trips (monsoon) 15 days x 2 trips(winter).	8000 kgs
Namkhana	1,49,200,00	Trawler-200 Mechanized boat-500	70 kms (monsoon), 200 kms (winter).	10 days x 4 trips (monsoon), 15 days x 2 trips(winter).	8000 kgs.

Source: Primary data from field survey at Namkhana, Kakdwip, Diamond Harbour, Roydighi & Canning on 30.4.99, 25.4.99, 23.4.99, 1.4.99 & 14.4.99 respectively (Das, 2009).

ANNEXURE

Family/ Species	Common name	Habitat
CLASS CHONDRICHTHYES		
ORDER ORECTOLOBIFORMES		
Family Hemiscyllidae	**Bamboo sharks**	**Pelagic**
Chiloscyllium indicum (Gmelin)		
Chiloscyllium griseum Muller and Henle		
Family Stegostomatidae	**Zebra sharks**	**Pelagic**
Stegostoma fasciatum (Hermann)		
Family Rhincodontidae	**Whale sharks**	**Pelagic**
Rhincodon typus Smith		
Order Carcharhiniformes		
Family Proscylliidae	**Finback catsharks**	**Pelagic**
Eridancis radcliffei Smith		
Family Carcharhinidae	**Requim sharks**	**Oceanic/Pelagic/semi pelagic/ littoral**
Carcharhinus dussumieri (Valenciennes)		
Carcharhinus hemiodon (Valenciennes)		
Carcharhinus leucas (Valenciennes)		
Carcharhinus melanopterus (Quoy and Gaimard)		
Carcharhinus limbatus (Valenciennes)		
Glyphis gangeticus (Muller and Henle)		
Lamiopsis temmincki (Muller and Henle)		
Rhizoprionodon acutus (Ruppell)		
Scoliodon laticaudus (Muller and Henle)		
Family Sphyrnidae	**Hammerhead sharks**	**Semi pelagic and littoral**
Eusphyrna blochii (Cuvier)		
Order Rajiformes		
Family Pristidae	**Sawfishes**	**Demersal**
Anoxypristes cuspidata (Latham)		
Pristis microdon Latham		
Pristis pectinata Latham		
Family Torpedinidae	**Electric Rays**	**Benthic and semi pelagic**
Bengalichthyes impennis Annandale		

Family/ Species	Common name	Habitat
Narke dipterygia (Schneider)		
Narcine timlei (Schneider)		
Narcine brunnea Annandale		
Family Rhinobatidae	**Guitar fishes**	**Demersal**
Rhina ancylostoma Schneider		
Rhina grannulatus Cuvier		
Rhina lionotus Norman		
Rhinobatos obtusus Muller and Henle		
Rhinobatos annandalei Norman		
Rhynchobatus djeddensis (Forsskal)		
Family Dasyatidae	**Sting Rays**	**Demersal**
Dasyatis microps (Annandale)		
Himantura bleekeri (Blyth)		
Himantura fluviatilis (Hamilton-Buchanan)		
Himantura marginata (Blyth)		
Dasyatus zugei (Muller and Henle)		
Himantura imbricata (Schneider)		
Himantura uarnak (Forsskal)		
Family Gymnuridae	**Butterfly Rays**	**Demersal**
Aetoplatea tentaculata (Valenciennes)		
Gymnura (Gymnura) poecilura (Shaw)		
Family Myliobatidae	**Eagle Rays**	**Benthic littoral and semi pelagic**
Aetobatus narinari (Blainville)		
Aetomylaeus nichofii (Schneider)		
CLASS: ACTINOPTERYGII		
Family Elopidae	**Lady fishes**	**Pelagic**
Elops machnata (Forsskal)		
Family Megalopidae	**Tarpons**	**Demersal/Pelagic**
Megalops cyprinoides (Broussonet)		
Family Anguillidae	**Freshwater Eels**	**Demersal**
Anguilla bengalensis bengalensis (Gray)		
Angilla bicolor bicolor Mc Clelland		
Family Moriguidae	**Worm Eels**	**Demersal**

Family/ Species	Common name	Habitat
Moringua arundinacea (Mc Clelland)		
Moringua raitaborua (Hamilton-Buchanan)		
Family Muraenidae	**Moray Eels**	**Demersal**
Sideria picta (Ahl)		
Thyrsoidea macrura (Bleeker)		
Uropterygius tigrinus (Lesson)		
Echidna nebulosa (Ahl)		
Echidna zebra (Shaw)		
Gymnothorax meleagris (Shaw and Nodder)		
Gynothorax sathete (Hamilton-Buchanan)		
Gymnothorax tile (Hamilton-Buchanan)		
Leptocephalus milnei Southwell and Prasad		
Leptocephalus vermicularis Southwell and Prasad		
Family Muraenesocidae	**Pike Congers**	**Demersal**
Congresox talabon (Cuvier)		
Congresox talabonoides (Bleeker)		
Muraenesox bagio (Hamilton-Buchanan)		
Muraenesox cinerius (Forsskal)		
Family Ophichthidae	**Snake Eels**	**Demersal**
Neenchelys buitendijki Weber and de Beaufort		
Pisodonophis boro (Hamilton-Buchanan)		
Lamnostoma orientalis (McClelland)		
Order Clupeiformes		
Family Clupeidae	**Herrings, Sardines, Sprats, Gizzard shads**	**Pelagic**
Hilsa (Hilsa) kelee (Cuvier)		
Hilsa (Tenualosa) ilisha (Hamilton-Buchanan)		
Hilsa (Tenualosa) toli (Valenciennes)		
Escualosa thoracata (Valenciennes)		
Herklotsichthys quadrimaculatus (Ruppell)		
Sardinella brachysoma Bleeker		
Sardinella fimbriata (Valenciennes)		
Sardinella gibbosa (Bleeker)		
Anodostoma chacunda (Hamilton-Buchanan)		

Family/ Species	Common name	Habitat
Anodostoma thailandiae Wongratana		
Nematalosa nasus (Bloch)		
Corica soborna Hamilton-Buchanan		
Family Pristigasteridae	**Ilishas, Pellonas**	**Pelagic**
Ilisha filigera (Valenciennes)		
Ilisha kampeni Weber and De Beaufort		
Ilisha megaloptera (Swainson)		
Ilisha melastoma (Schneider)		
Opisthopterus tardoore (Cuvier)		
Opisthopterus valenciennesi Bleeker		
Pellona ditchela Valenciennes		
Raconda russeliana Gray		
Family Engraulidae	**Anchovies**	**Pelagic**
Coilia dussumieri Valenciennes		
Coilia neglecta Whitehead		
Coilia ramcarati Hamilton-Buchanan		
Coilia reynaldi Valenciennes		
Setipinna brevifilis (Valenciennes)		
Setipinna phasa (Hamilton-Buchanan)		
Setipinna taty (Valenciennes)		
Setipinna tenuifilis Valenciennes		
Stolephorus baganensis Hardenberg		
Stolephorus commersonii Lacepede		
Stolephorus heterolobus (Rupell)		
Stolephorus indicus (van Hasselt)		
Thryssa dussumieri (Valenciennes)		
Thryssa hamiltonii (Gray)		
Thryssa malabarica (Bloch)		
Thryssa purava (Hamilton-Buchanan)		
Family Chirocentridae	**Wolf Herring**	**Pelagic**
Chirocentrus nudus Swainson		
ORDER SILURIFORMES		
Family Ariidae	**Sea catfishes**	**Demersal**
Arius arius (Hamilton-Buchanan)		

Family/ Species	Common name	Habitat
Arius caelatus Valenciennes		
Arius dussumieri Valenciennes		
Arius gagora Hamilton-Buchanan		
Arius jella Day		
Arius maculatus (Thunberg)		
Arius parvipinnis Day		
Arius platystomus Day		
Arius sagor (Hamilton-Buchanan)		
Arius sona (Hamilton-Buchanan)		
Arius tenuispinnis Day		
Arius thalassinus (Ruppell)		
Batrachocephalus mino (Hamilton-Buchanan)		
Hemipimelodus jatius (Hamilton-Buchanan)		
Osteogeniosus militaris (Linnaeus)		
ORDER AULOPIFORMES		
Family Harpadontidae	**Bombay Duck**	**Pelagic**
Harpadon neherius (Hamilton-Buchanan)		
Family Synodontidae	**Lizard fishes**	**Demersal**
Saurida tumbil (Bloch)		
ORDER GADIFORMES		
Family Bregmacerotidae	**Codlets**	**Demersal**
Bregmaceros macclellandi Thompson		
ORDER LOPHIFORMES		
Family Antennariidae	**Frog fishes**	**Demersal**
Antennarius hispidus (Bloch and Schneider)		
ORDER CYPRINODONTIFORMES		
Family Hemiramphidae	**Halfbeaks**	**Demersal**
Dermogenys brachynopterus (Bleeker)		
Hemiramphus far (Forsskal)		
ORDER SYNGNATHIFORMES		
Family Fistulariidae	**Cornet fishes**	**Pelagic**
Fistularia petimba Lacepede		
Family Syngnathidae	**Pipe fishes and Sea horses**	**Shallow coastal waters and estuaries**

Family/ Species	Common name	Habitat
Ichtyocampus carce (Hamilton-Buchanan)		
ORDER SCORPAENIFORMES		
Family Synanceiidae	**Minous**	**Pelagic**
Minous coccineus (Alcock)		
Trachicephalus uranoscopus (Bloch and Schneider)		
Family Platycephalidae	**Spiny flatheads**	**Benthic**
Platycephalus indicus (Linnaeus)		
ORDER PERCIFORMES		
Family Ambassidae	**Perchlets**	**Near river mouths**
Ambassis nalua (Hamilton-Buchanan)		
Ambassis kopsii Bleeker		
Family Centropomidae	**Sea Perches, Sea bass, Barramundi**	**Demersal and bottom dwelling**
Lates calcarfer (Bloch)		
Family Serranidae	**Groupers**	**Pelagic**
Epinephelus malabaricus (Schneider)		
Epinephelus tauvina (Forsskal)		
Promicrops lanceolatus (Bloch)		
Family Teraponidae	**Tiger perches**	**Pelagic**
Terapon jarbua (Forsskal)		
Terapon puta (Cuvier)		
Terapon theraps (Cuvier)		
Family Sillaginidae	**Whitings**	**Sandy shores and estuarine waters**
Sillago sihama (Forsskal)		
Sillaginopsis panijus (Hamilton-Buchanan)		
Family Lactaridae	**False trevallis**	**Waters shallower than 100m**
Lactarius lactarius (Schneider)		
Family Rachycentridae	**Cobia**	**Pelagic**
Rachycentron canadum (Linnaeus)		
Family Carangidae	**Jacks, Scads**	**Pelagic**
Alectis ciliaris (Bloch)		
Alectis indicus ((Ruppell)		
Alepes djedaba (Forsskal)		

Family/ Species	Common name	Habitat
Atropus atropus (Schneider)		
Atule mate (Cuvier)		
Carangoides chrysophrys (Cuvier)		
Carangoides malabaricus (Bloch and Scneider)		
Caranx carangus (Bloch)		
Caranx ignobilis (Forsskal)		
Caranx sexfasciatus Quoy and Gaimard		
Decapterus russelli (Ruppell)		
Elagatis bipinnulata (Quoy and Gaimard)		
Megalaspis cordyla (Linnaeus)		
Scomberoides commersonianus Lacepede		
Scomberoides lysan (Forsskal)		
Scomberoides tala (Cuvier)		
Selar crumenopthalmus (Bloch)		
Trachynotus blochii (Lacepede)		
Uraspis uraspis (Gunther)		
Family Coryphaenidae	**Dolphin fish**	**Pelagic**
Coryphaena hippurus Linnaeus		
Family Parastromateidae	**Black Pomfret**	**Deep coastal waters**
Parastromateus niger (Bloch)		
Family Leiognathidae	**Slipmouths**	**Pelagic**
Gazza minuta (Bloch)		
Leiognathus blochii (Valenciennes)		
Leiognathus brevirostris (Valenciennes)		
Leiognathus daura (Cuvier)		
Leiognathus dussumieri (Valenciennes)		
Leiognathus equulus (Forsskal)		
Leiognathus fasciatus (Lacepede)		
Leiognathus splendens (Cuvier)		
Secutor insidiator (Bloch)		
Secutor ruconius (Hamilton-Buchanan)		
Family Lutjanidae	**Snappers**	**Deep coastal waters**
Lutjanus argentimaculatus (Forsskal)		
Lutjanus bengalensis (Bloch)		

Family/ Species	Common name	Habitat
Lutjanus johnii (Bloch)		
Lutjanus russelli (Bleeker)		
Family Lobotidae	**Tripletails**	**Brackish waters and large river mouths**
Datnioides quadrifasciatus (Sevastianov)		
Family Gerreidae	**Mojarras**	**Sandy shores**
Gerres (Gerres) oyena (Forsskal)		
Gerres (Gerres) poieti Cuvier		
Gerres (Pertica) filamentosus Cuvier		
Gerreomorpha setifer (Hamilton-Buchanan)		
Family Haemulidae	**Grunts**	**Demersal**
Pomadasys argenteus (Forsskal)		
Pomadasys argyreus (Valenciennes)		
Pomadasys furcatus (Schneider)		
Pomadasys maculatum (Bloch)		
Family Sparidae	**Seabreams**	**Demersal**
Acanthopagrus berda (Forsskal)		
Acanthopagrus latus (Houttuyn)		
Rhabdosargus sarba (Forssal)		
Family Nemipterydae	**Threadfin Breams**	**Pelagic and Demersal**
Nemipterus bipunctatus (Ehrenberg)		
Nemipterus japonicus (Bloch)		
Nemipterus tolu (Valenciennes)		
Family Sciaenidae	**Croakers**	**Demersal**
Bahaba chaptis (Hamilton-Buchanan)		
Chrysochir aureus (Richardson)		
Daysciaena albida (Cuvier)		
Dendrophysa russelli (Cuvier)		
Johnius (Blythsciaena) macropterus (Bleeker)		
Johnius (Johnieops) dussumieri (Cuvier)		
Johnius (Johnieops) sina (Cuvier)		
Johnius (Johnieops) vogleri (Bleeker)		
Johnius (Johnius) belangerii (Cuvier)		
Johnius (Johnius) carutta Bloch		
Johnius (Johnius) coitor (Hamilton-Buchanan)		

Family/ Species	Common name	Habitat
Johnius (Johnius) macrorhynus (Mohan)		
Nibea maculata (Schneider)		
Nibea soldado (Lacepede)		
Macrospinosa cuja (Hamilton-Buchanan)		
Otolithoides biauritus (Cuvier)		
Otolithes cavieri Trewavas		
Otolithes ruber (Schneider)		
Pama pama (Hamilton-Buchanan)		
Panna microdon (Bleeker)		
Panna heterolepis Trewavas		
Pennahia macrocephalus (Tang)		
Pennahia macrophthalmus (Bleeker)		
Protonibea diacanthus (Lacepede)		
Pterotolithus maculatus (Kuhl and van Hasselt)		
Family Mullidae	**Goat fishes**	**Benthic predator**
Parupeneus indicus (Shaw)		
Upeneus vittatus (Forsskal)		
Family Toxotidae	**Archer fishes**	**Demersal**
Toxotes chatareus (Hamilton-Buchanan)		
Family Ephippididae	**Space-fishes**	**Pelagic and often enters estuaries**
Depane longimana (Bloch and Schneider)		
Drepane punctata (Linnaeus)		
Ephippus orbis (Bloch)		
Platax pinnatus (Linnaeus)		
Family Scatophagidae	**Scats**	**Shallow brackish waters**
Scatophagus argus (Bloch)		
Family Mugilidae	**Mullets**	**Coastal waters and estuaries**
Liza macrolepis (Smith)		
Liza parsia (Hamilton-Buchanan)		
Liza subviridis (Valenciennes)		
Liza tade (Forsskal)		
Liza vaigiensis (Quoy and Gaimard)		

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

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

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

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

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

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2.15 HERPETOFAUNA

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

KAUSHIK DEUTI
Herpetologist

Fuels detrital food chains in mangrove ecosystems

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

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

Both reptiles and amphibians are often referred to as cold blooded although at certain times their body or blood temperature is actually hotter than that of most birds and mammals. It is therefore better to refer to them as poikilothermous (as their body temperature varies with that of the environment in which they live). Thermoregulation in reptiles is a behavior function and is achieved by a judicious use of available sunlight. By basking in the sun or absorbing heat through a hot substratum when heat is required and moving away from the sun when heat is not needed, reptiles are able to maintain the ideal temperature within their body, which is more or less the air temperature of their habitat. The hot summer is spent by aestivating in burrows and hiding among thick vegetation, while in winter, they need to bask in the sunshine for some time before they become active. In the Sundarbans, which hardly has a proper winter, they are therefore active throughout the year.

Monocled Cobra (Naja kaouthia)

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

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

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

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

OVERVIEW OF THE GROUP

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

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

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

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

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

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

River Terrapin (Batagur baska)

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

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

Note: Sauria and Serpentes are suborders

SYNOPTIC VIEW

Diversity

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

Water Monitor Lizard (Varanus salvator)

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

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

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

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

Functional Guild Structure of Herpetofauna Distribution

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

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

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

Local Community Dependencies and Traditional Use

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

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

Ecological Importance and Need for Conservation

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

> 80 MEDICINAL APPLICATIONS FROM 7 HERPETOFAUNAL SPECIES

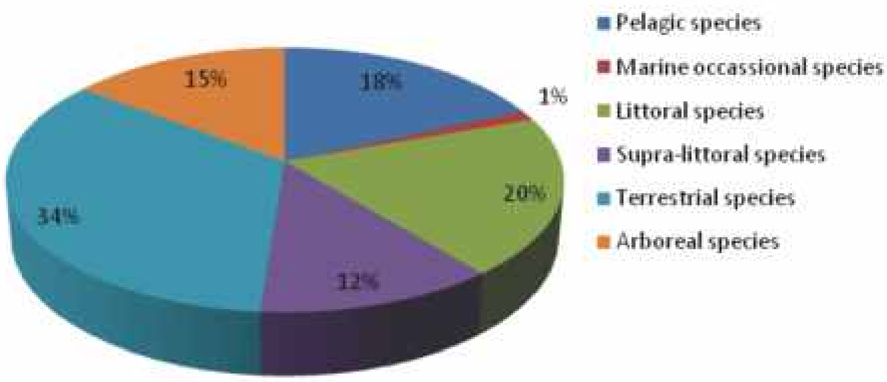


Fig 1: Functional Guild Structure of Herpetofauna Distribution

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

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

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

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

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

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

STATUS AND THREATS

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

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

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

Estuarine Crocodile (Crocodylus porosus)

Reed Frog (Hylarana tytleri)

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

Sr No.	Common English Name	Scientific Name	IUCN Red List Status	Indian Wildlife (Ptotection)Act, 1972 (Schedule)	Appendix of CITES
01.	Leatherback Sea Turtle	*Dermochelys coriacea*	CE	I	I
02.	Hawksbill Sea Turtle	*Eretmochelys imbricata*	CE	I	I
03.	Olive Ridley Sea Turtle	*Lepidochelys olivacea*	V	I	I
04.	River Terrapin	*Batagur baska*	CE	I	I
05.	Three-striped Roofed Turtle	*Batagur dhongoka*	E	-	II
06.	Red-crowned Roofed Turtle	*Batagur kachuga*	CE	I	I
07.	Spotted Pond Turtle	*Geoclemys hamiltonii*	V	I	I
08.	Crowned River Turtle	*Hardella thurjii*	V	-	-
09.	Indian Roofed Turtle	*Pangshura tecta*	LC	I	I
10.	Narrow-headed Softshell Turtle	*Chitra indica*	E	IV	II
11.	Asian Giant Softshell Turtle	*Pelochelys cantorii*	E	I	-
12.	Indian Flapshell Turtle	*Lissemys punctata*	LC	I	II
13.	Indian Softshell Turtle	*Nilssonia gangetica*	V	I	I
14.	Indian Peacock Softshell Turtle	*Nilssonia hurum*	V	I	I

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

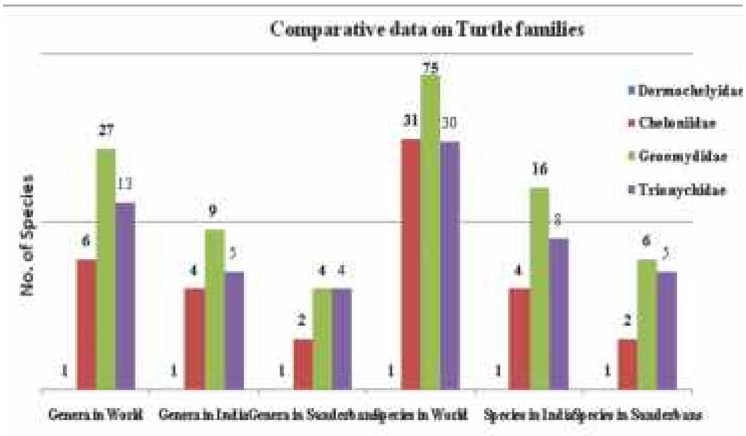
Table 5: Species of Snakes in the Sunderbans and their Protection Status

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

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

Note: NT-Not Threatenend; V-Vulnerable

Fig 2: Comparitive data on Turtle Families found in Sundarbans



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

Fig 3: Comparitive data on Crocodile Families found in Sundarbans

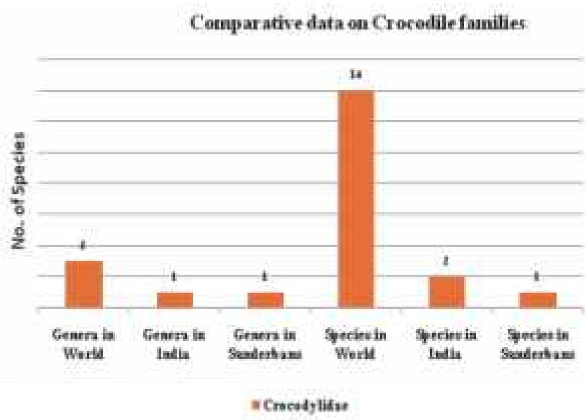


Fig 4: Comparitive data on Lizard Families found in Sundarbans

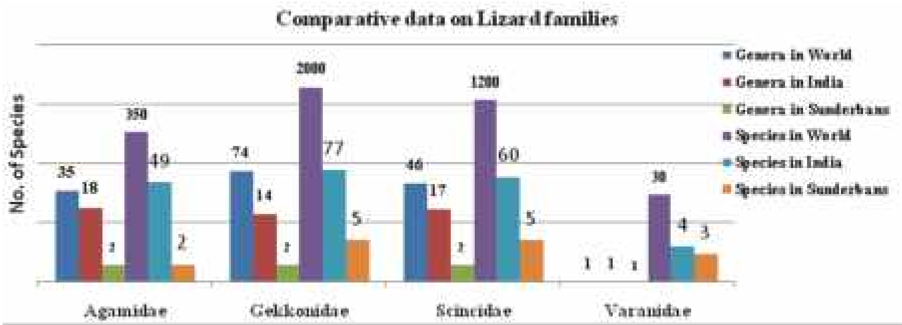


Fig 5: Comparitive data on Snake Families found in Sundarbans

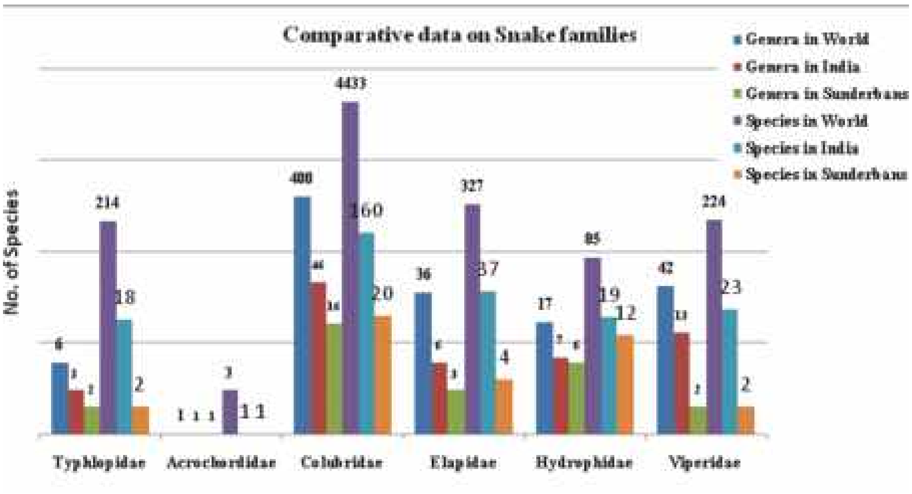
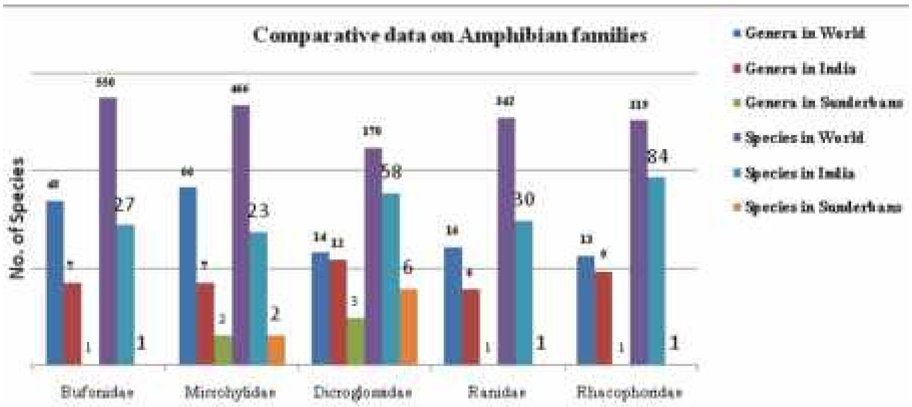


Fig 6: Comparitive data on Aphibian Families found in Sundarbans



ANNEXURE

Herpetofaunal Species in the Indian Sundarbans:

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

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

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

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

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

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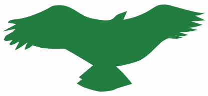
2.16 AVES

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

KUSHAL MOOKHERJEE
Wildlife consultant with specialization in Avifauna



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

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

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

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

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

Mangroves consist of a succession of monospecific stands located along tropical and subtropical coasts. Their local distribution is not directly associated with terrestrial climatic factors such as rainfall, humidity, or air temperature (Elhaï 1968) but rather with hydrographic factors such as water temperature (Rodriguez 1975), wave intensity, marine currents,

Common Red Shank (Tringa totanus)

and water salinity (Blasco 1984; Chapman 1977; West 1977). Accordingly, mangroves are distributed in isolated forest patches of varying sizes. Despite their often similar plant composition and structure, these mangrove patches frequently experience different climatic conditions (Jiménez 1992; Oliver 1982). Botanical studies have shown that timing of flowering and leaf production (Duke 1990; López-Portillo and Ezcurra 1985), as well as intensity of vegetative growth (Lugo and Snedaker 1974), is influenced by flooding, seasonality, and underground salinity. Since these factors depend mostly on rainfall and tide (Por 1984), mangrove phenology is likely to vary geographically (Duke 1990). The extent to which these variations affect the invertebrate community and their prey, especially the bird fauna, is unknown.

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

Little cormorants (Phalacrocorax niger)

Great egret (Ardea alba)

Little Tern
(Sterna albifrons)

Collared Kingfisher
(Todriamphus chloris)

Overview of the Group

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

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

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

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

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

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

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

SYNOPTIC VIEW

Diversity

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

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

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

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

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

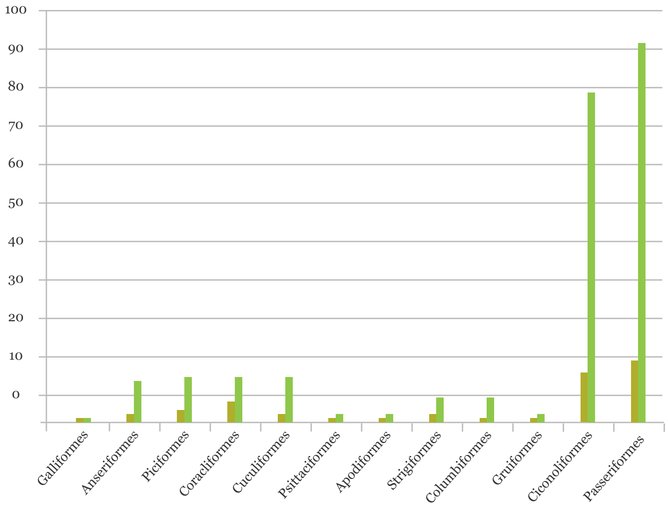
The Red Jungle Fowl (*Gallus gallus*) is common on the forest floor. Rufous Woodpecker *(Celeus brachyurus)*; Fulvous-breasted Woodpecker *(Dendrocopos macei)*; and Streak-throated Woodpecker *(Picusxanthopy- gaeus)* seek insect larvae in the older trees of the landward fringes. The Rose-ringed Parakeet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

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

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

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

Fig 1: Family and Species composition of Avifauna in Sundarbans



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

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

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

Distribution

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

Brown-winged kingfisher (Halcyon amauroptera)

White bellied sea eagle (Haliaeetus leucogaster)

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

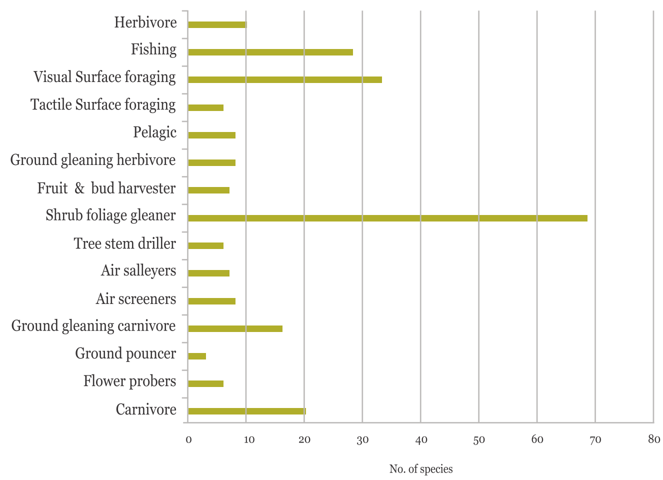
Order	Status		Total	Feeding Guilds														
	R	M		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Galliformes	1		1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Anseriformes	3	7	10	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Piciformes	9	2	11	-	-	-	-	-	-	3	-	6	-	-	2	-	-	-
Coraciiformes	11		11	-	8	-	-	-	-	-	-	-	2	-	-	1	-	-
Cuculiformes	7	4	11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

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

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

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

Fig 2: Functional guild structure of Avifauna in Sundarbans



Local Community Dependencies and Traditional Use

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

100
MEDICINAL APPLICATIONS HAVE BEEN REPORTED FROM SUNDARBANS.


Lesser Adjutant, (Leptoptilos javanicus)


Red Jungle fowl (Gallus gallus)

Ecological Importance and Need for Conservation

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

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

Owing to their great mobility, birds are also especially important in nutrient transport to or from the ecosystem (Morales and Pacheco 1986). Gonzalez-Jimenez and Escobar (1977) reported that top carnivores are nutrient accumulators by themselves. Their nutrient levels exceed those of water, soil (Bulla et al. 1980), and plant tissues. Morales and Pacheco (1986) reported that nutrient flow through birds may mobilize large amounts of nutrients, primarily nitrogen, phosphorus, and calcium and might be viewed as biological indicators of the aquatic productivity. The enrichment of a red mangrove stand by bird guano stimulates plant growth and results in higher nitrogen concentrations of some parts in comparison to a nearby stand with no enrichment (Onuf et al. 1977). As top consumers, they can provide information on the major changes in the pattern of the flow of energy and nutrients of the entire system.

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

STATUS AND THREATS

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


Congregation of gulls (Chroicocephalus brunnicephalus)

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

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

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

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

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

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

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

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

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

ANNEXURE

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

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

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

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

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

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

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

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

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

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

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

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

Status : (R) Resident (M) Migrant

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

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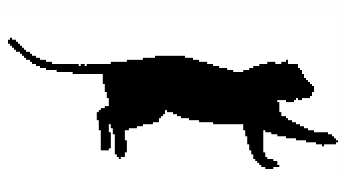
2.17 MEGA-FAUNA

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

SUBRAT MUKHERJEE
Protected Area Manager with specialization in mangrove conservation



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

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

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

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

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

OVERVIEW OF THE GROUP

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

401 SPECIES UNDER 45 FAMILIES INCLUDING 45 SPECIES ENDEMIC TO INDIA

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

Royal Bengal Tiger (Panthera tigris)

Table – 1: Diversity & Endemicity of Indian Mammals

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

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

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

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

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

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

SYNOPTIC VIEW

Diversity

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

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

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


Indo-Pacific Humpbacked Dolphin (Sotalia plumbea)

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

Ecological Importance and Need for Conservation

Influence ecosystem function and biodiversity as ecological landscapers

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

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

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

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

Table – 2. Account of mega fauna in Indian Sundarbans

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

Source: Mandal & Nandi, (1989)

STATUS AND THREATS

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

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

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

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

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

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

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

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

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

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

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

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

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

1. Indian wild boar (*Sus scrofa*) **2.** Rhesus macaque (*Macaca mulatta*) **3.** Golden Jackal (*Canis aureus*) **4.** Chital (*Axis axis*) **5.** Fishing cat (*Prionailurus viverrinus*) **6.** Jungle cat (*Felis chaus*)

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2.18 SMALL MAMMALS

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

SUJIT CHAKRABORTY
Mammalogist

RINA CHAKRABORTY
Mammalogist

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

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

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

Leopard cat (Prionailurus bengalensis)

OVERVIEW

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

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

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

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

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

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

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

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

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

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

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

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

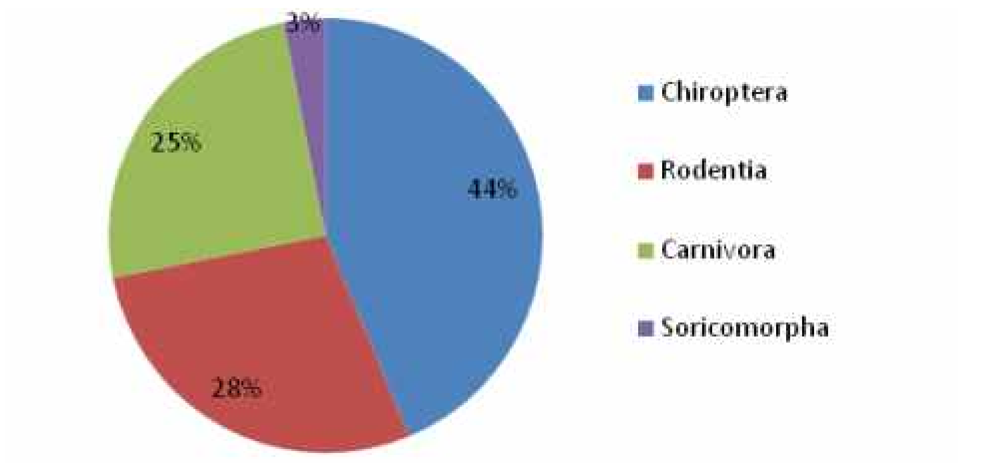
SYNOPTIC VIEW

Diversity

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

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

Fig. 1. Diversity in species of small mammals



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

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

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

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

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

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

Ecological Importance

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

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

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

Indian Flying Fox (Pteropus giganteus)

STATUS AND THREATS

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

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

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

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

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

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

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

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

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

ANNEXURE

Small mammals of Sundarbans and their Protection/ Conservation Status

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

Small mammals of Sundarbans and their Protection/ Conservation Status

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

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

LC = Least Concern; VU= Vulnerable

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3 ONGOING AND PREDICTED IMPACTS ON BIODIVERSITY

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

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

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

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

Table 1: Sundarbans Threat Matrix

Threat Category	Ecosystems	Large Fauna	Small Fauna (including aquatic)	Vegetation	Microbes
Population & poverty					
Resource extraction	--	Disturbance	Population decline	Partial damage to vegetated habitats	--
Wildlife harvesting	--	Endangered populations	Local extinctions	--	--
Encroachment/ land use change	Loss of ecosystems	Impact on breeding	Restricted distribution; local extinctions	Loss of carbon sequestration potential	Local extinctions
Sea level rise					
Sea Level Rise	Loss of Coastal mangroves	Inward/Upland Migration	Local Extinctions	Loss of vegetated habitats	Local Extinctions
Salinisation					
Reduced freshwater inflow	Alteration of ecological patterns and processes	Aquatic fauna may change its range	Local Extinctions	Changes in mangrove composition and distribution	--
Climate Change					
High intensity weather event	Damage to ecosystems	Migration	Migration	Partial loss to vegetation	Population decline
Increased Atmospheric CO2	Fertilization effect	--	Depletion in fish stocks	Changes in community structure and composition; reduced primary productivity	Life cycle changes/ local extinctions
Key	(red)	Severe Impact			
	(orange)	Moderate Impact			
	(yellow)	Low Impact			

3.1 INCREASING POPULATION AND GRINDING POVERTY

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.2 SEA LEVEL RISE

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

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

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

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

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

Fig 2: Eroded and vulnerable islands

3.3 SALINISATION AND REDUCED FRESH WATER FLOW

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

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

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

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

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

Table 3: Salinity Trends in the Sundarbans

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

3.4 CLIMATE CHANGE

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

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

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

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

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

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

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

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

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

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4 THE WAY FORWARD

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

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

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

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

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

4.1 THE STATE OF BIODIVERSITY IN THE SUNDARBANS

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

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

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

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

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

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

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

4.2 CHALLENGES FACED BY THE SUNDARBANS

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

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

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

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

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

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

4.3 KNOWLEDGE GAPS

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

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

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

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

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

Table 4: Possible research and management interventions

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

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

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

4.4 POLICY OPTIONS FOR MANAGEMENT OF THE SUNDARBANS

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

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

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

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

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

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

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

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

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

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

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

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

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ANNEXURE

Human-wildlife Conflicts in the Sundarbans

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

CHANDAN SURABHI DAS
Biogeographer

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

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

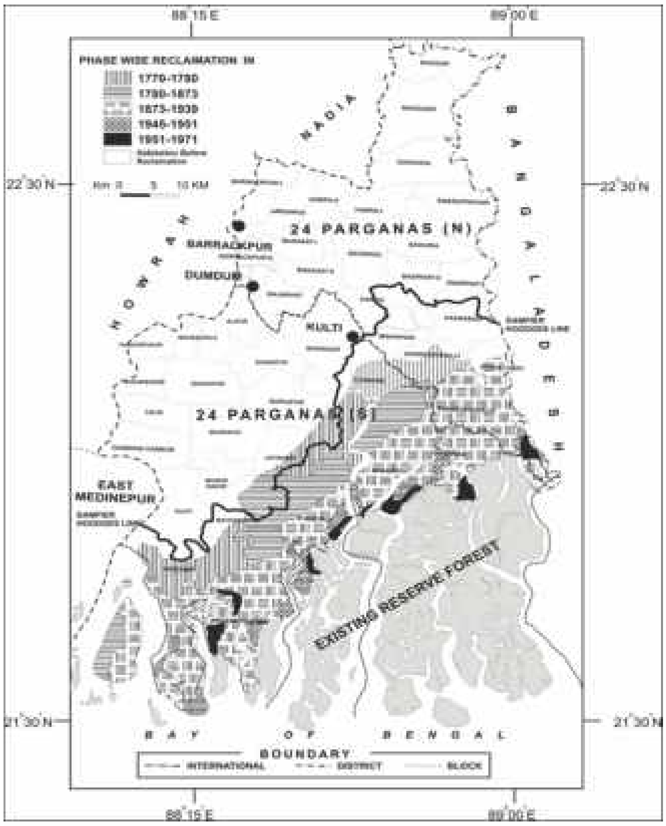
Reclamation of the Sundarban mangrove wetlands in the lower Ganga Brahmaputra delta was started from 1770 (Pargiter 1934). During the next two centuries, some 5,364 km^2 of the former tidal forests were converted to farmlands in 19 police station areas in the North and South 24-Parganas Districts of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

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

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

A single crop of paddy cannot cater to the needs of the people residing in the Sundarbans, and to eke out a living, they take to fishing, crab collection, honey collection, and woodcutting inside the mangrove forests. Increasing population pressure and dire poverty urge the people to take the risk of facing natural

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



hazards as well as attacks from wild animals as they venture into the jungle. Trespassers take undue advantage of this human presence in the zone for pilferage of forest produce and poaching of wild animals. It is also not uncommon for the animals to stray into human habitations and cause dep - redations. All these lead to conflict between humans and animals—the root cause of which is socioeconomic.

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

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

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

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

HUMAN-TIGER CONFLICT

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

Habits and Habitat

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


Royal Bengal Tiger-(Panthera tigris)

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

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

Study on Attack on Humans

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

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

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

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


Biodiversity Based Livelihood

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

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

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

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

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

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

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

Probable Reasons for Attacks on Humans

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

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

It is evident from figure 2 that tigers are found to attack the honey collectors, crab collectors, and fishermen who enter the deep forest in the early mornings and afternoons, mostly because they intrude into the tigers' habitat and disturb the animal by their activities, which typically is lighting fires and/or creating smoke for honey collection. During these periods of the day, these groups of workers are caught unaware by the tiger, which makes them more prone to tiger attack. The tigers are not known to attack groups of more than 4 people and when the groups are well connected. In a span of 24 years (1985–2009), a total of 789 victims (666 dead and

Crab collectors

Human face masks as a protective device against tiger attacks

123 injured) have been reported from the Sundarbans (Das 2009). The honey collectors are more vulnerable to tiger attack than the fishermen community as the honey season lasts only for two months in a year. A total of 108 cases (92 dead and 16 injured) have been reported for the period 1986–2009.

Measures to Reduce Conflict in the Tiger Territor

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

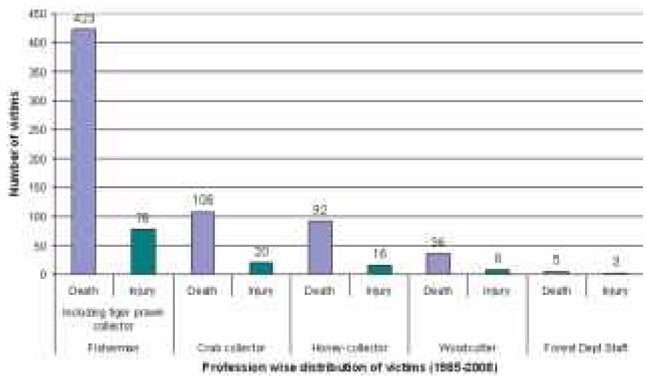
The clay models represented fishermen, woodcutters, and honey collectors. In all, six models were made, two for each profession, irrespective of the profession-wise pattern of tiger attacks (Sanyal 1987). These six models were set up in the Netidhopani, Pirkhali Panchamukhani, and Jhilla forest blocks.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

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

Patterns of Tiger Straying

On the other hand, during the period 1986–2009, a total of 279

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



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

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

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

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

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

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

A narrow creek dividing protected area and Samsernagar village of Sundarban

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

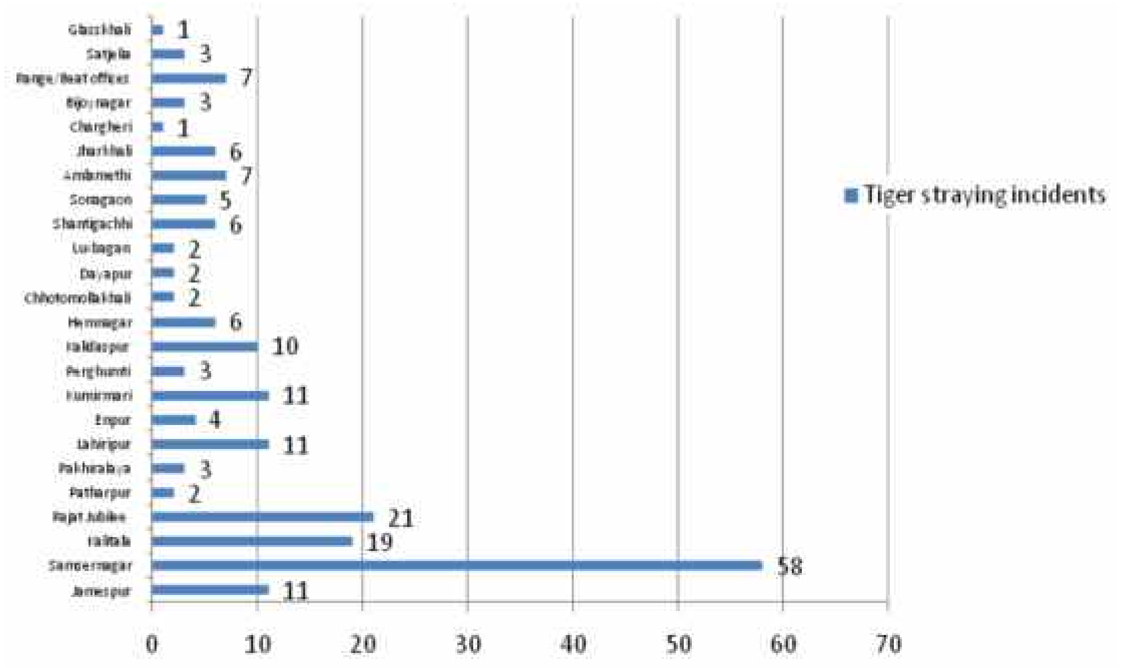


Fig 3: Tiger straying incidents in villages of Sundarbans(1986-2005)

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

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

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

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

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

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

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

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

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

Measures to Reduce Conflict from Tiger Straying

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

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

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

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

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

Source: STR & SBR

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

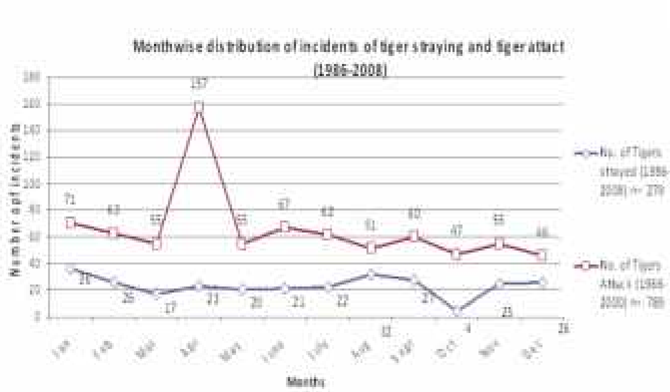
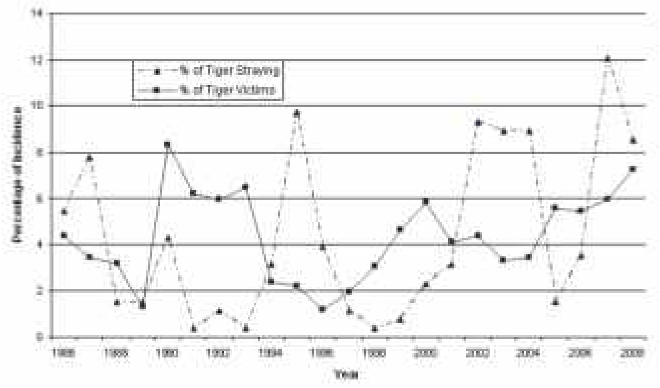


Fig 5: Percentage Distribution of Tiger Attacks and Tiger Straying by Years Which Shows a Weak Negative Correlation between Them



HUMAN-SNAKE CONFLICT

Habit and Habitat

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

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

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

Pattern of Snakebite

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

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

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

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

Russell's Viper (Vipera russellic)

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

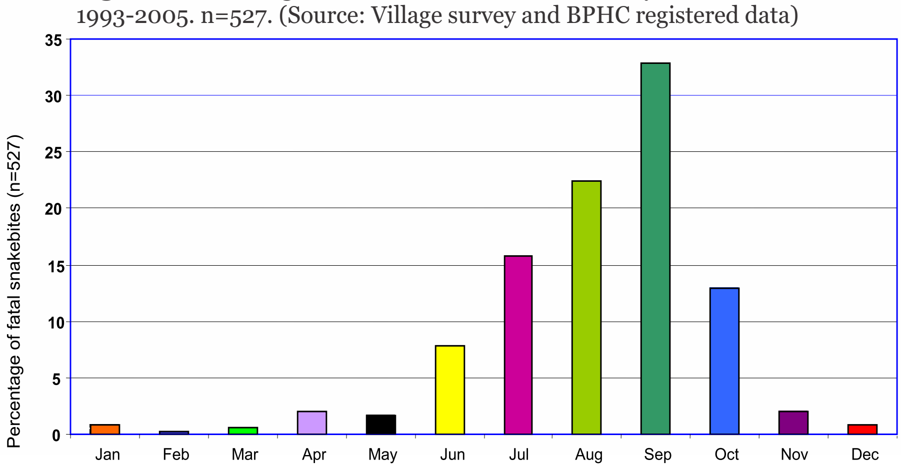


Table 5: Distribution of mortality from snakebites by blocks: 1993–2005

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

SOURCE: Village survey and BPHC-registered data

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

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

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

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

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

Measures to Mitigate Conflict with Snakes

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

ATTACK BY CROCODILES AND SHARKS

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

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

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

Prawn seed collection

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

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

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

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

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

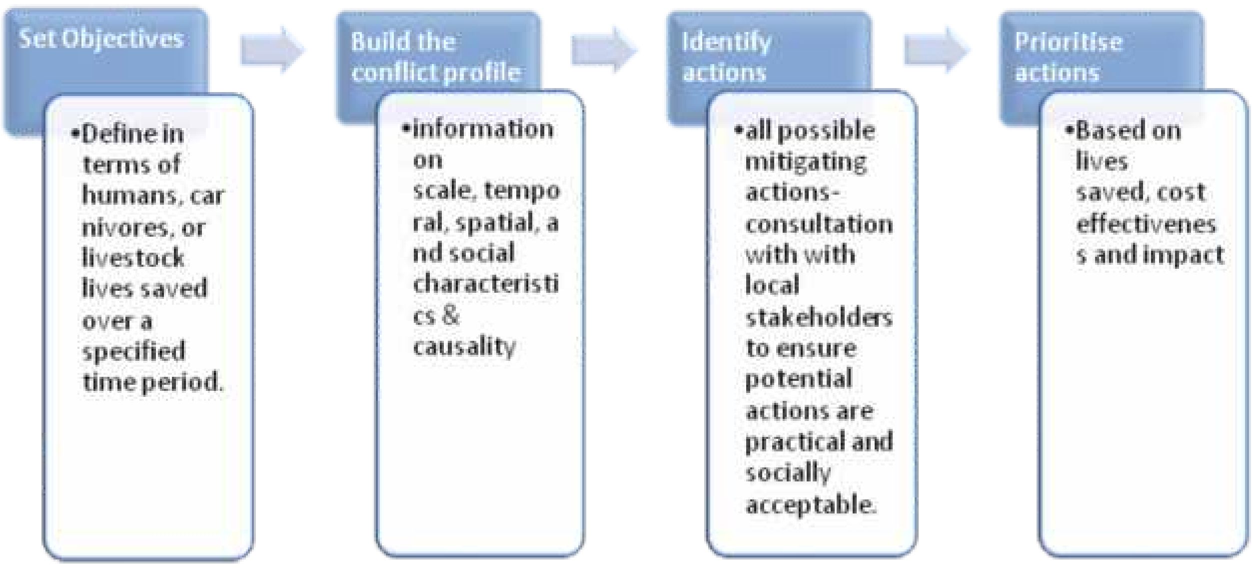
CONFLICT RESOLUTION FRAMEWORK

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

The present review builds the conflict profiles using the Action-Selection Framework (Barlow et al. 2010) (figure 8) of the three most important fauna inhabiting the supra-littoral forests, intertidal mud flats, and estuaries of the Sundarbans, namely the Royal Bengal Tiger (*Panthera tigris tigris*) and venomous snakes. The profiles contain a general description of the circumstances in which the conflict takes place and specific information on the severity of the conflict and its spatial, temporal, and social characteristics. The severity of the conflict

would reveal the relative size of each aspect of the conflict and help the concerned administrative bodies estimate the potential impact and costs of actions (Graham et al. 2005). Spatial information on the conflict would help in focusing actions in areas where they can be most effective. Information on temporal characteristics may help in identifying the seasonal variations and ideal time to implement the actions. Understanding social characteristics would help identify target groups (Barlow et al. 2010). The conflict profile would also highlight the gaps that require further research to identify and prioritize the actions for conflict resolution.

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



OUTLOOK

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

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

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

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

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

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

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

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

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

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

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

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