| 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<br>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, insecti-cidal, 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 oc-casionally |
| 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 gonor-rhoea & syphilis |
| 43 | *Cerbera odollam* | Dabur | Medicinally used as purga-tive, narcotive & poisonous & in hydrophobia |
| 44 | *Pandanus tectorius* | Keya kanta | Fibres used in cordage, leaves as vegetable/ medi-cine |
| 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 sealevel 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<br>August-September | September-November |
| 4. | *Heritiera fomes* (Sundari) | January-April<br>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<br>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<br>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. |

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|---|---|---|
| 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. |

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|---|---|---|
| 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.

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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

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

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

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.

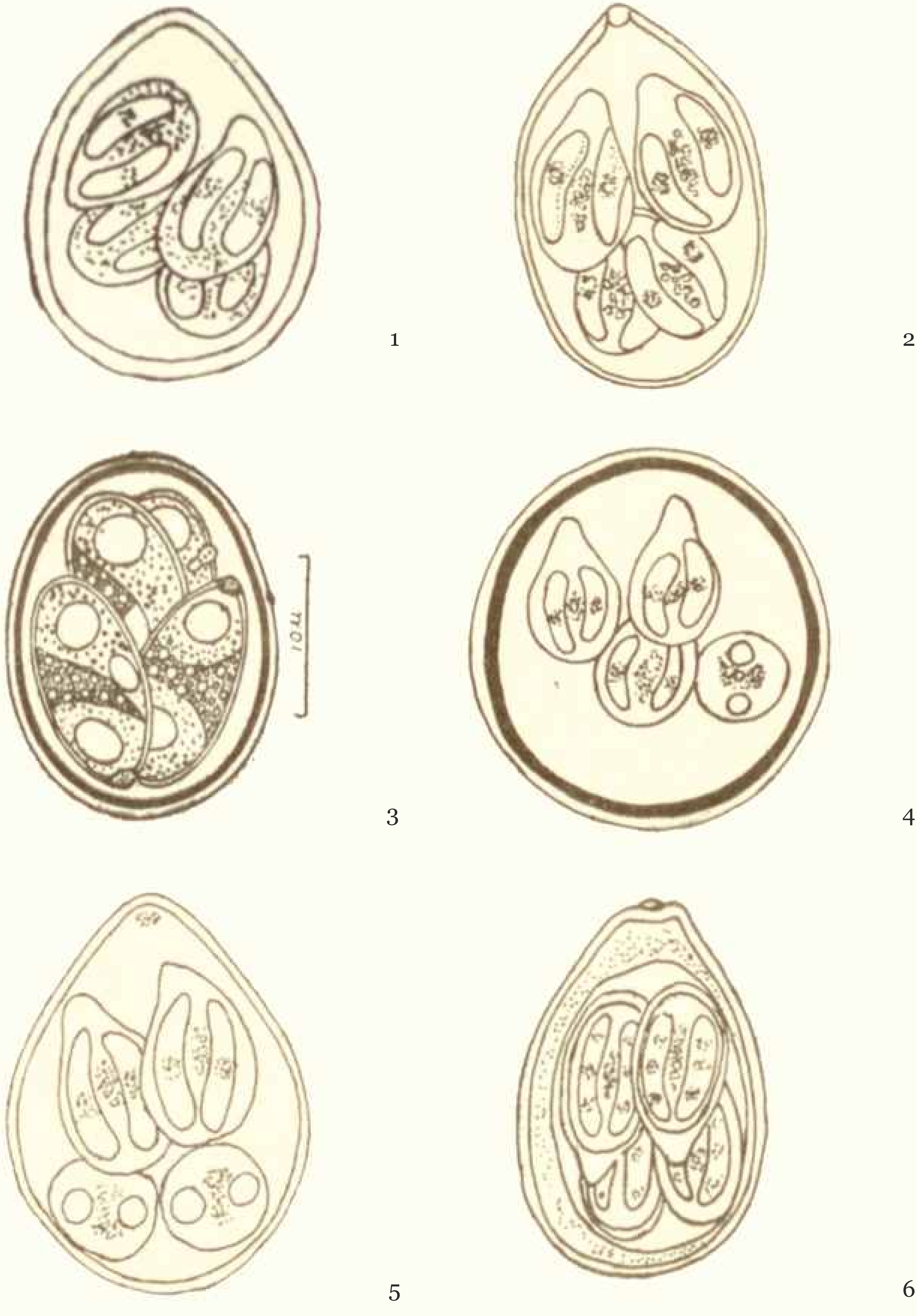
In India as well as at the global level, despite reports of the disease being caused by protozoan species, studies dealing with pathology in fishes, shellfish, and wild animals are very few and fragmented. Though the exact nature of many of these protozoan parasites of man and his domesticated animals 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.

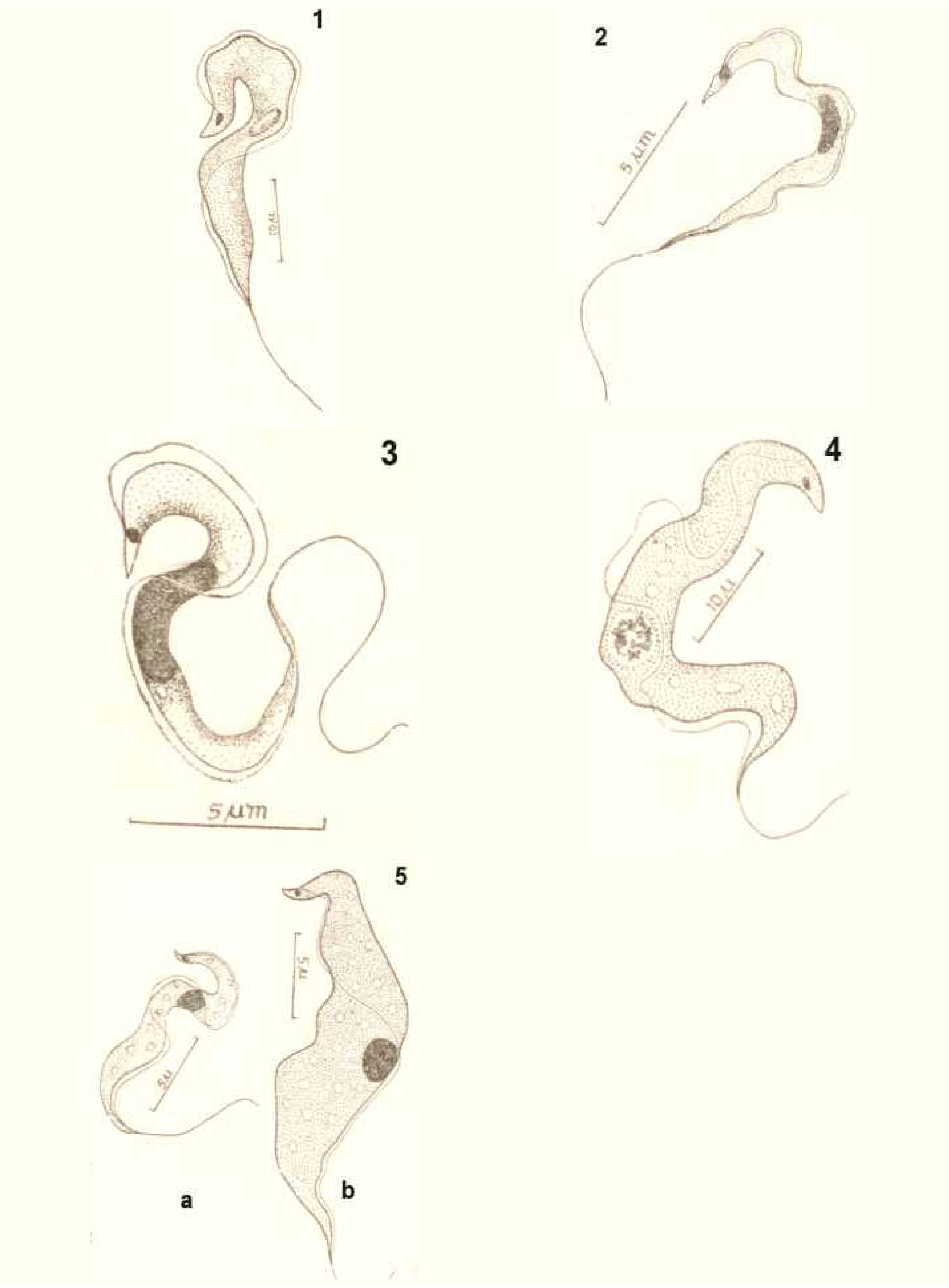
**STATUS AND THREATS**

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.

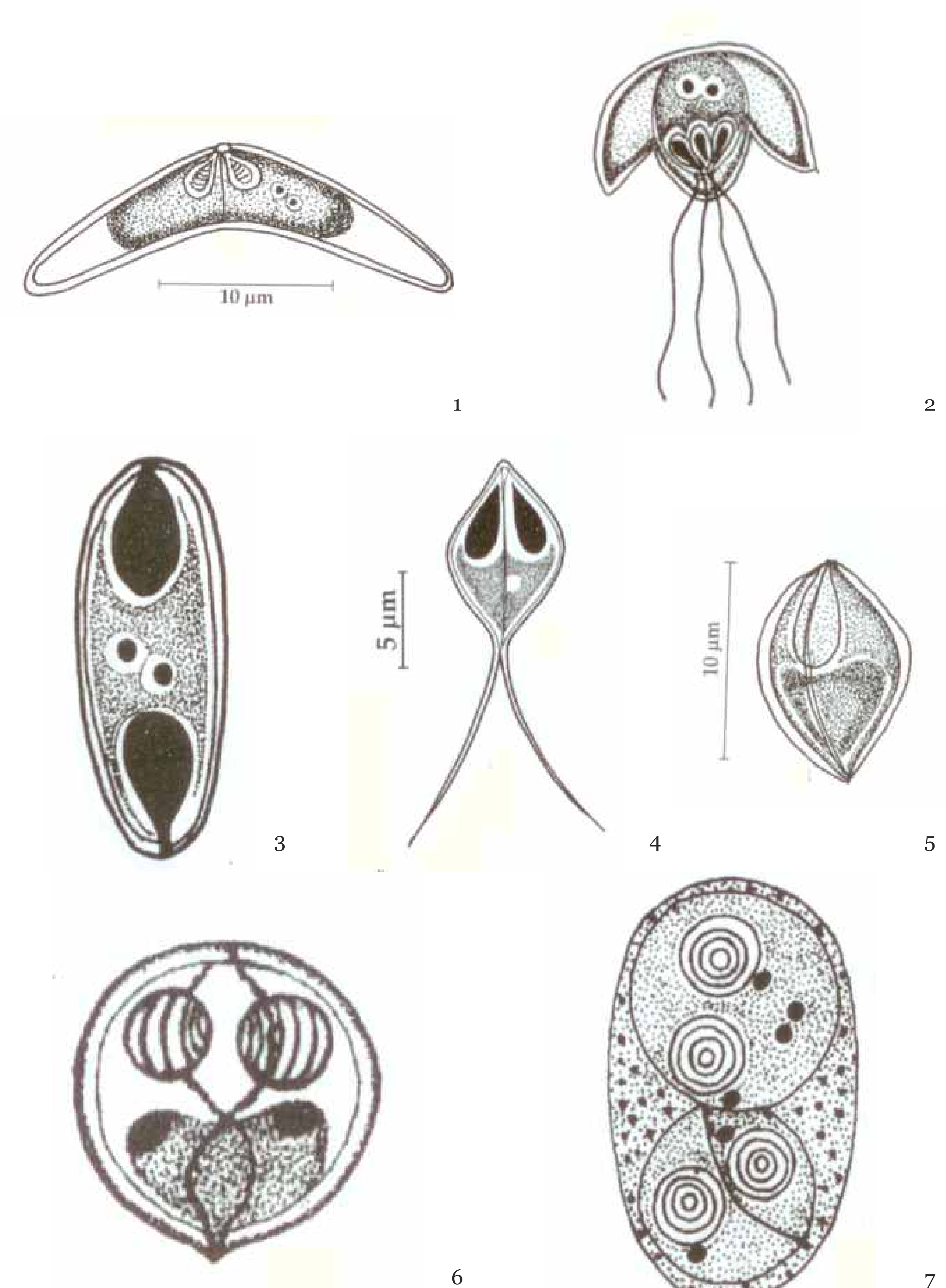
**PLATES**



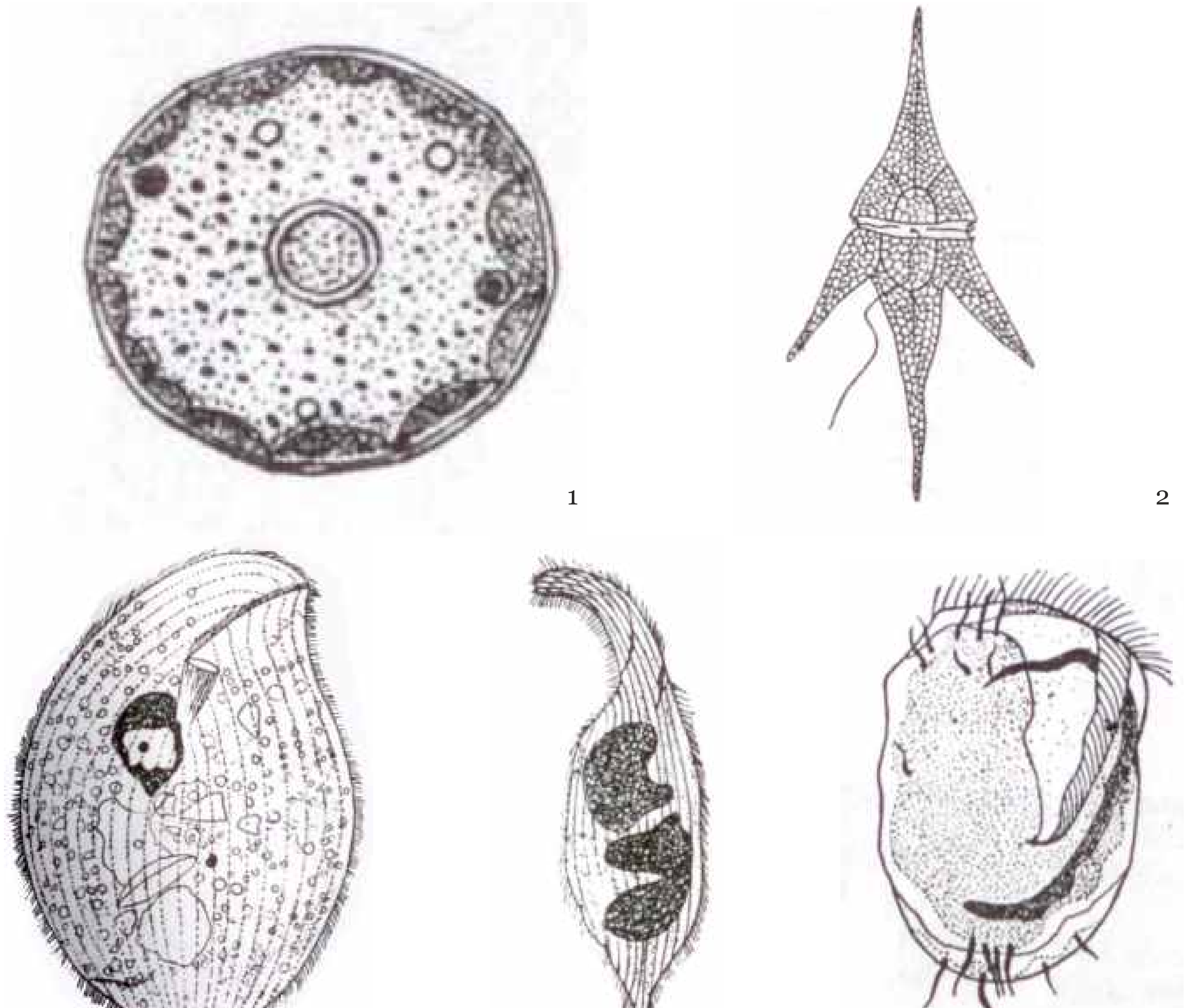

Coccidian parasites of wild animals - 1. *Eimeria charadrii* 2. *Eimeria gallinagoi* 3. *Eimeria neodebliecki* 4. *Eimeria numeni* 5. *Eimeria rocoviensis pluviana* 6. *Eimeria vanelli*




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 intermedia* | Kakdwip |
| 98. | *H. oryzivorae* Anschutz., 1909 | *Turdoides striatus* | Sagar Island |
| 99. | *H. pastoris* de Mello, 1935 | *Sturnus malabaricus* | Sagar Island |
| 100. | *H.* sp. | *Acrocephalus dumetorum* | 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 fungal 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 respectively |

| 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*<br>*L. melanostoma* | Sagar Island<br>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*<br>*Rhacophorus maculatus* | Nalgora<br>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)<br>Freshwater algal mass | Datta river<br>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<br>Mangrove fungal mass<br>Mud scum | Kalas<br>Rajat jubilee<br>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, 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);

## 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.

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

**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 |

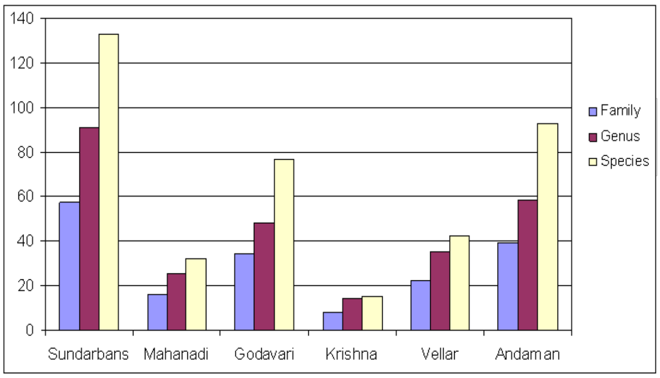
Mahanadi 32 (1.46 percent); Godavari 77 (3.53 percent); Krishna 15 (0.68 percent); Vellar 42 (1.92 percent); and Andamans 93 (4.26 percent) (table 2 and figure 1). The sheltered marine mangroves support a rich diversity of the malacofauna in the Andaman Islands.

**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.*

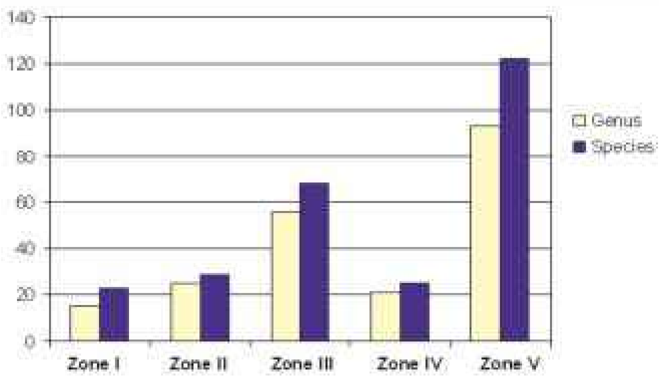
*Nerita articulata*

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<br>Subclass Gymnomorpha<br>Order Soleolifera<br>Family Veronicellidae<br>Genus *Filicaulis* Simroth | *Filicaulis (Eleuthero-caulis) alte* (Ferussac) | Slug | Inhabitant of cultivated gardens. | - |
| Subclass Pulmonata<br>Order Stylommatophora<br>Family Pupillidae<br>Genus *Pupilla* Leach | *Pupilla barrackpo-rensis* Gude | Snail | Under fallen leaves, stems, wooden logs in dump shady areas. | - |
| Family Vertiginidae<br>Genus *Pupisoma* Stoliczka | *Pupisoma orcula* (Benson) | Snail | Occurs on trunks, leaves and bark of large trees | - |
| Family Cerastuidae<br>Genus *Rachis* Albers | *Rachis bengalensis* (Lamarck) | Snail | Occurs on stems, branches or leaves of trees. | - |
| Family Subulinidae<br>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<br>Genus *Achatina* Lamarck | *Achatina fulica fulica* (Bowdich) | Shamuk/ Snail | Dump shady areas of kitchen gardens with vegetable plants. | Agri-horticultural pest |
| Family Succineidae<br>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<br>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<br>Subclass Prosobranchia<br>Order Archaeogastropoda<br>Family Neritidae<br>Genus *Septaria* Ferussac | *Septaria lineata* (Lamarck) | - | Coastal freshwater bodies with some tidal influence<br>. | - |
| Order Mesogastropoda<br>Family Viviparidae<br>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<br>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<br>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<br>Genus *Iravadia* Blanford | *Iravadia ornata* Blanford | - | Occurs under crecks. | - |
| Family Assimineidae<br>Genus *Assiminea* Fleming | *Assiminea francessi* (Wood) | Snail | Occurs in ponds, canals link with river Hugli; and muddy substratum of river. | - |
| Family Thiaridae<br>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<br>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<br>Order Basommatophora<br>Family Lymnaeidae<br>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<br>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<br>Genus *Indoplanorbis* Annandale & Prashad | *Indoplanorbis exustus* (Deshayes) | Snail | Water bodies with abundant vegetations. | Intermediate host for number of trematodes. |
| Class Bivalvia<br>Subclass Pteriomorphia<br>Order Arcoida<br>Family Arcidae<br>Genus *Scaphula* Benson | *Scaphula deltae* Blanford | - | Found in water bodies connected with river Hugli. | - |
| Subclass Paleoheterodonta<br>Order Unionoida<br>Family Unionidae<br>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<br>Order Veneroida<br>Family Corbiculidae<br>Genus *Corbicula* Megerle von Müehlfeld | *Corbicula striatella* Deshayes | Jhinuk | Sand dwellers | - |
| Genus *Polymesoda* Rafinesque | *Polymesoda (Geloina) bengalensis* (Lamarck) | Jhinuk | Mud dwellers | Commercial |
| Family Pisidiidae<br>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<br>Subclass Prosobranchia<br>Order Archaeogastropoda<br>Family Lottiidae<br>Genus *Potamacmaea* Peile | *Potamacmaea fluviatilis* (Blanford) | True Limpet | Stem of mangrove plants, crevices, algal coated bricks and dykes. | - |
| Family Trochidae<br>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<br>Genus *Tubiola* A. Adams | *Tubiola microscopica* (Nevill) | - | Mud and sand mixed muddy area | - |
| Family Neritidae<br>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<br>Family Littorinidae<br>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<br>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<br>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<br>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<br>Genus *Xenophora* Fischer | *Xenophora solaris* (Linnaeus) | Carrier Shells | | - |
| Family Naticidae<br>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<br>Genus *Tonna* Bruennich | *Tonna dolium* (Linnaeus) | Tun shell | Sand dweller | - do - |
| | *Tonna sulcosa* (Born) | Banded Tun | Sand dweller | - do - |
| Family Ficidae<br>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<br>Genus *Phalium* Link | *Phalium bisculcatum* (Schubert and Wagner) | Japanese Bonnet | Sand dweller | - |
| Family Ranellidae<br>Genus *Gyrineum* Link | *Gyrineum natator* (Roeding) | Triton shell | Sand or mud dweller | Used in shell craft. |
| Family Bursidae<br>Genus *Bursa* Roeding | *Bursa spinosa* (Lamarck) | Frog shell | Sand dweller | - do - |
| Family Epitoniidae<br>Genus *Amaea* H.&A. Adams | *Amaea (Acrilla) acuminata* (Sowerby) | Wentle trap | Mud and sand mixed muddy area | - do - |
| Order Neogastropoda<br>Family Muricidae<br>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<br>Genus *Pseudanachis* Theile | *Pseudanachis duclosiana* (Sowerby) | Mangrove dove shell | Attached to pneumatophores and in clusters in bricks crevices, decomposed mangroves. | - |
| Family Nassariidae<br>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<br>Genus *Pugilina* Schumacher | *Pugilina (Hemifusus) cochlidium* (Linnaeus) | Spiral Melongena | Mud or sand dweller | Medicinal and commercial |
| Family Olividae<br>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<br>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<br>Order Cephalaspidea<br>Family Architectonicidae<br>Genus *Architectonica* Roeding | *Architectonica perspectiva* (Linnaeus) | Clear Sundial | Mud or sand dweller | Used in shell craft. |
| Subclass Opisthobranchia<br>Order Cephalaspidea<br>Family Hamineidae<br>Genus *Haminoea* Turton & Kingston | *Haminoea crocata* Pease | Bubble Shell | Mud and sand mixed muddy area | - |
| Subclass Gymnomorpha<br>Order Systellommatophora<br>Family Onchidiidae<br>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<br>Order Archaeopulmonata<br>Family Ellobiidae<br>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<br>Genus *Salinator* Hedley | *Salinator burmana* (Blanford) | - | Muddy or sandy substratum of mangrove areas. | - |
| Class Cephalopoda<br>Subclass Coleoidea<br>Order Sepiida<br>Family Sepiidae<br>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<br>Family Loliginidae<br>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<br>Family Octopodidae<br>Genus *Octopus* Lamarck | *Octopus macropus* Risso | Octopus | Offshore and free swimming | - do - |
| | *Octopus rugosus* (Bosc) | Octopus | Offshore and free swimming | - do - |
| Class Bivalvia<br>Subclass Protobranchia<br>Order Nuculoida<br>Family Nuculidae<br>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<br>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<br>Family Arcidae<br>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<br>Genus *Striarca* Conard | *Striarca lactea* (Linnaeus) | Ark Clam | Mud and sand mixed muddy area | - |
| Order Mytiloida<br>Family Mytilidae<br>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<br>Family Pinnidae<br>Genus *Atrina* Gray | *Atrina pectinata pectinata* (Linnaeus) | Pecten | Sandy bottom, in meso-littoral zone. | - |
| Order Ostreoida<br>Family Ostreidae<br>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<br>Genus *Enigmonia* Iredale | *Enigmonia aenigmatica* (Holten) | Saddle Oyster | On the mangrove plants. | - |
| Family Placunidae<br>Genus *Placuna* Solander | *Placuna placenta* (Linnaeus) | Windopane Oyster | Mud and sand mixed muddy area | Used for door hanging. |
| Subclass Heterodonta<br>Order Veneroida<br>Family Lucinidae<br>Genus *Eamesiella* Chavan | *Eamesiella philippinarum* (Hanley) | Lucina clam | Mud and sand mixed muddy area | - |
| Family Cardiidae<br>Genus *Trachycardium* Moerch | *Trachycardium asiaticum* (Bruguiere) | Asiatic Cockle | In shallow water, near low tide, on sandy shore. | - |
| Family Mactridae<br>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<br>Genus *Solen* Linnaeus | *Solen brevis* Gray | Jack knife clam | Mud and sand mixed muddy area | - |
| Family Cultellidae<br>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<br>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<br>Genus *Theora* H. & A. Adams | *Theora opalina* (Hinds) | - | Mud and sand mixed muddy area | - |
| Family Psammobiidae<br>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<br>Genus *Trapezium* Megerle | *Trapezium sublaevigatum* (Lamarck) | Trapezium shell | Attached to hole of the pneumatophores in the vicinity of mangoves. | - |
| Family Veneridae<br>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<br>Genus *Glauconome* Gray | *Glauconome sculpta* (Sowerby) | - | In hard mud of littoral zone. | - |
| Order Myoida<br>Family Myidae<br>Genus *Sphenia* Turton | *Sphenia perversa* Blanford | - | Nestling in crevices, lower shore. | - |
| Family Corbulidae<br>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<br>Genus *Barnea* Leach | *Barnea candida* (Linnaeus) | Pholad/<br>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<br>Genus *Bactronophorus* Tapparone-Canefri | *Bactronophorus thoracites* (Gould) | Shipworm/<br>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<br>Order Pholadomyoida<br>Family Laternulidae<br>Genus *Laternula* Roeding | *Laternula truncata* (Lamarck) | - | In mud and muddy sand, intertidal flats and offshore. | - |
| Family Cuspidariidae<br>Genus *Cuspadaria* Nardo | *Cuspadaria chilkaensis* (Preston) | - | In mud, deep water. | - |
| Class Scaphopoda<br>Order Dentaliida<br>Family Dentaliidae<br>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.

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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) |

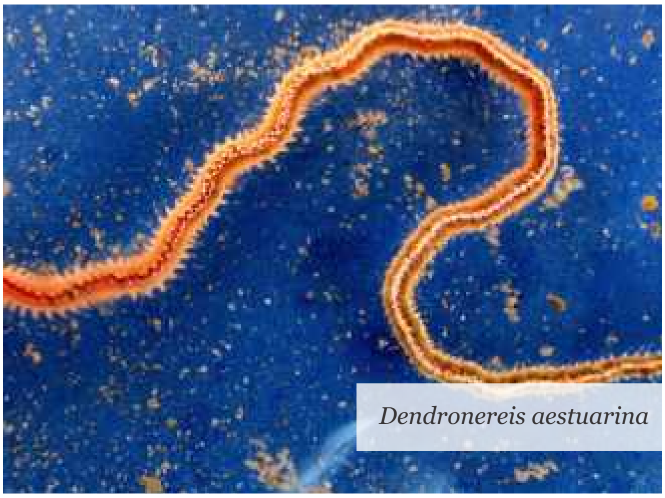
*Ceratonereis burmensis*

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

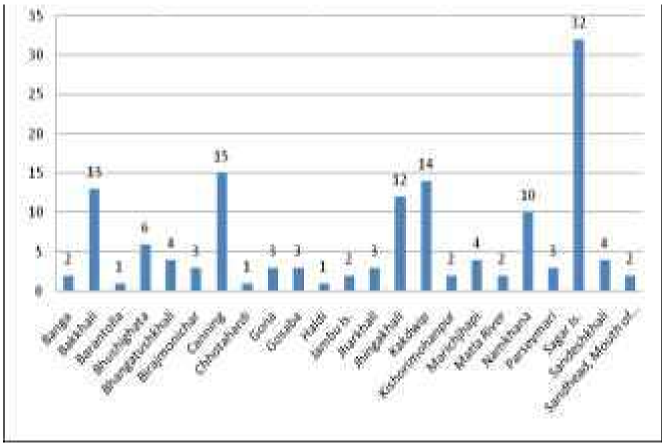


*Dendronereis aestuarina*

**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

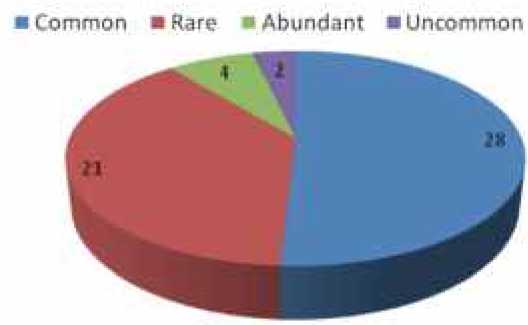
Among polychaetes, most of the species have a short life-span which involves secondary production and act as an important link for marine food webs and feed for many demersal fishes. In aquaculture practices, some species of polychaetes were used in the diet of shrimp's brood stock and in the treatment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

**Fig 2:** Local Status of Polychaetes in Sundarbans




represented in figure 2.

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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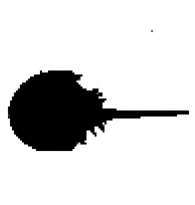
# 2.9 XIPHOSURA

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

*Carcinoscorpius rotundicauda & Tachypleus gigas* are represented in Indian Sundarbans

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).

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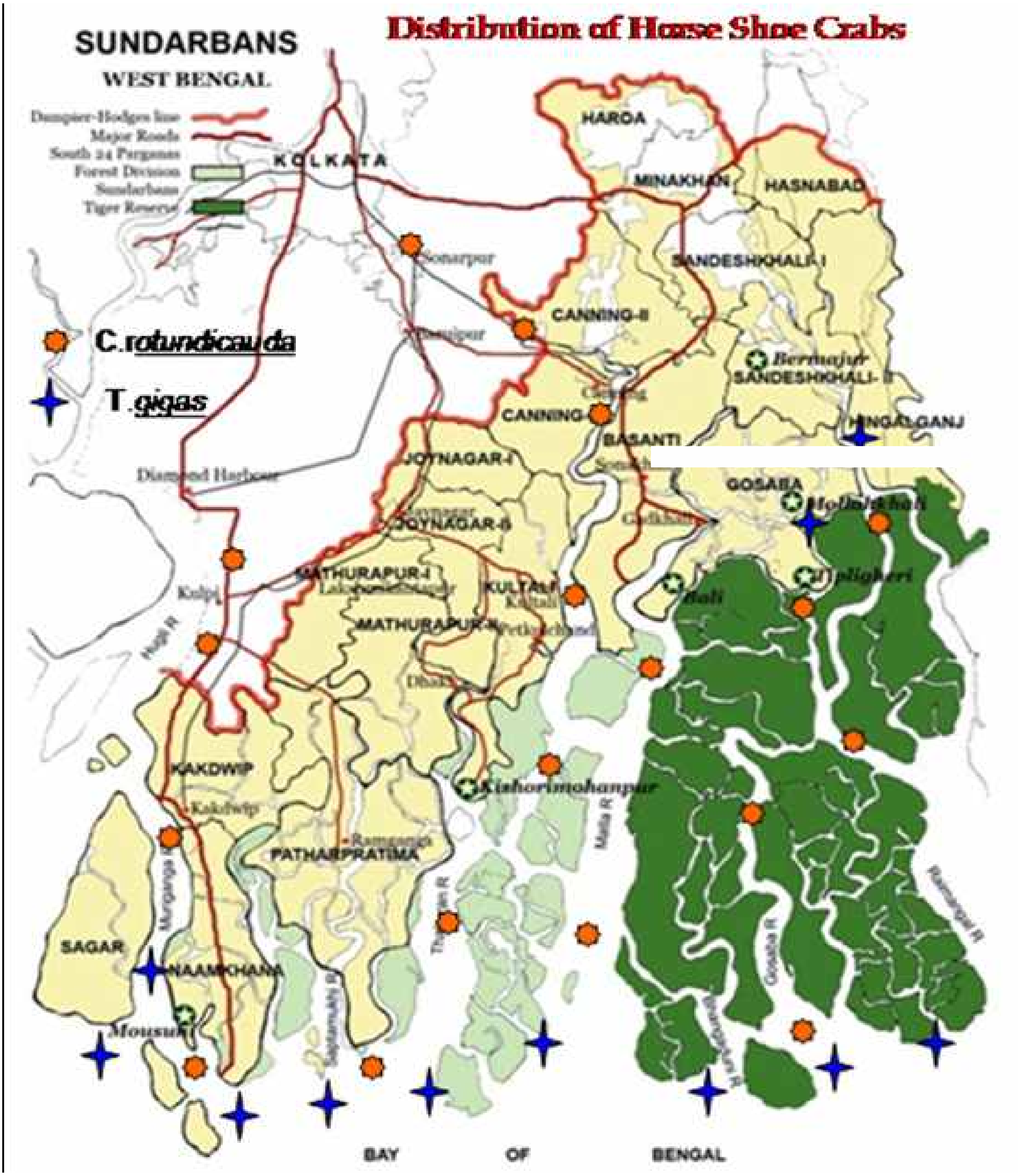
[1]ERDG (The Ecological Research and Development Group). 2010. “Ecological Importance of Horseshoe Crabs” (accessed September 18, 2010). http://www.horseshoecrab.org/con/con.html#bio.

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)

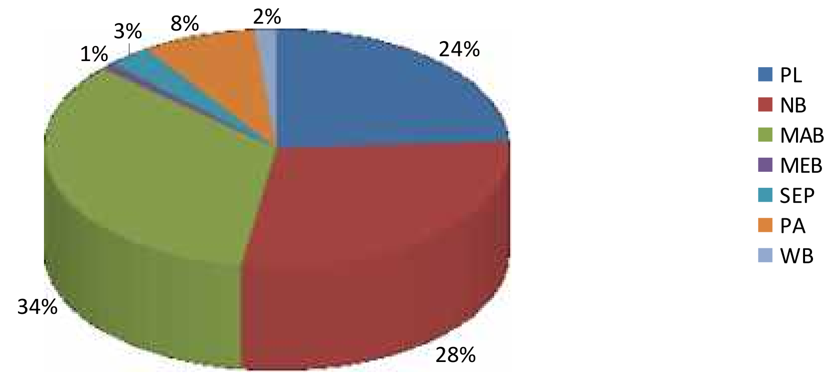
**Table 4.** Species richness and ecological groups of crustacean fauna of Sundarbans

| 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.

*Mud crab (Scylla seratta)*

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.*

*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

*Varunid crab (Varuna litterata)*

*Ghost crab (Ocypode macrocera)*

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.

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.