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REVIEWS

A review on the ichthyofaunal diversity in mangrove based estuary of Sundarbans

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Abstract The two great rivers of India the Ganga and the Brahmaputra form their estuary at the lower part of West Bengal and most of the part of this estuarine system is surrounded by Sundarban mangrove forest. This mangrove based estuarine ecosystem harbors a large number of fin fishes i.e. more or less 267 species of fishes which belong under 81 families. Estuary's own ecological characters and mangrove's all beneficial features support this high species diversity here. But due to continuously increasing natural and anthropogenic stresses, nowadays this entire species community faces a tremendous problem of extinction. 82 species under 24 families loss their juveniles in a significant number regularly due to wild harvest of lucrative prawn seeds. The present article aims to review the roles of estuary and mangroves in enrichment of finfish diversity and the possible threats causing harm to the same.

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Introduction

An estuary is a semi-enclosed coastal body of water with a free connection with the open sea within which sea water is measurably diluted by fresh water from land drainage (Pritchard 1967).varying quantum of fresh water discharge from rivers in different seasons and tidal changes during a year may cause considerable fluctuations in salinity and other physico-chemical conditions resulting in significant changes in estuarine ecosystem. The estuaries are the most productive natural ecosystems because of regular active interaction between fresh water discharge and tides from sea. The estuaries of rivers and connected mangroves, backwaters and brackish water lagoons constitute important fishery resources of the country. The Ganga–Brahmaputra estuary has horse-shoe shaped sandbars at the river mouth forming several small islands called 'Deltas'. One of the most important characteristics of this estuary is the presence of mangrove forest at the deltaic region of the river mouth. This unique vegetation has a significant role in promoting fish diversity as it protects the coastal deltaic lands, estuarine mouths and shallow bays besides providing the ideal dwelling place, natural food items, and ideal nursery and breeding grounds for

a good number of offshore and estuarine shellfish and finfish (Dutta and Homechaudhuri 2004).

Origin and physiography

Regarding some geological evidences about the origin of Sundarban, the whole of 'Lower Bengal' was originally an estuary. The tidal swamp was extended up to the Rajmahal Hill in the past. It was filled up in later part of Tertiary period (35 million years) by the drainage from the folded mountains of the north. Pascoe (1962) was of the opinion that during the early Pleistocene shallow marine water condition prevailed in this part of Bengal Basin, it was only the late Pleistocene the sea receded completely from this area. Older sediments began to be covered with thick river borne alluvium. The occasional presence of sandy ridges and sandy silty marine terraces along the coast line mark an old sea coast, the bed of which been elevated in later periods not continuously or uniformly but at intervals. Very precisely Oldham (1893) states, the whole of area including Sundarban, lying between the river Hooghly on the west and the Meghna in the east, is only the delta caused by the deposition of debris carried down by the rivers Ganga, Brahmaputra and their tributaries. The soil of Sundarbans can very well be differentiated into three major divisions such as Fine silty clay in northern most part; Peaty deposits in the middle and swampy areas towards the sea face along with the sandy clay and sand dunes (Mandal and Ghosh, 1989). The deltaic Sundarbans of India characterized by low flat alluvial plains covered with mangrove swamps and marshes and are intersected by an intricate network of several riverine systems—river Hooghly, Mooriganga, Saptamukhi, Thakuran, Matla, Bidyadhari, Bidya, Gosaba, Harinbhanga, Raimangal etc. and other salt water courses. This network of drainage system encloses a large number of islands of variable shapes and sizes and acts as avenues for upland discharge and tidal flows. Total area of Sundarbans is 4,366.6 km^2 out of which water area is 1,781 km^2 and actual forest area is about 2,333 km^2 (Adhikari et al. 1987). The rivers of the western Sundarbans in comparison to those of the eastern portion are more saline because in all estuaries of northern estuaries outward flowing fresh water and inward flowing sea water are deflected to the east due to Earth's rotation.(Smith and Smith 2001).

Geographical status

The Indian Sundarban based estuary at the apex of the Bay of Bengal (between 21°13′N and 22°40′N latitude and 88°03′E–89°07′E) is located on the southern fringe of the state of West Bengal, covering the major portions of the South and North 24 Parganas districts. The region is bordered by Bangladesh in the east, the Hooghly River in the west, 'Dampier and Hodges line' in the north and the Bay of Bengal in the south (Fig. 1). The intensity and magnitude of tidal impulses is not same in all the areas of this estuary. Tides cause an ingression of saline waters from the Bay of Bengal and hence the areas in upstream regions are often less saline and riverine zone in comparison to areas situated in the down stream regions where the degree of marine characteristics is very important. On the basis of salinity, the entire deltaic complex of Indian Sundarbans has been divided into three distinct zones viz. high saline, medium saline and low saline zones (Mitra et al. 2005) (Fig. 1).

Hydro-ecological status

In coastal West Bengal, the seasonal variation of surface water temperature is not so drastic between premonsoon and monsoon seasons. The premonsoon period (March to mid June) is characterized by a mean surface water temperature around 34 °C. The monsoon period (mid June to October) shows a surface water temperature around 32 °C and post monsoon period (November–February) is characterized by cold weather with a mean surface water temperature around 23 °C (Mitra 2000).

Rainfall is usually maximum during the month of August/September and the monsoon period lasts from July to October. The south west wind triggers the precipitation in the monsoon period with an average rainfall of about 165 mm. The post monsoon period is characterized by negligible rainfall and the premonsoon period is basically dry, but occasionally accompanied by rains and thunder storms.

Sea waves in this region rarely become destructive except during cyclonic storms. During Nor-wasters, the wind speed rise above 100 km/h and is usually accompanied by huge tidal waves. Turbidity is highest in the aquatic phase during monsoon due to run-off from adjacent landmasses, as, turbidity in the coastal

and estuarine waters is the effect of suspended particulate matters (David 1956). Unique seasonal oscillation of salinity, pH and nutrients is observed in this ecosystem. The premonsoon period is characterized by high surface water salinity, relatively high pH and low nutrient load. The picture is totally opposite during monsoon season (Bose 1956; Mitra et al. 2005).

Fishes are the natives of Sundarbans

Among all the group of animal species available in Sundarbans, fishes are most important because of their abundance, diversity and above all economic importance. It was estimated that as many as 1,300 varieties of marine fishes are available around Indian Ocean and among them about 267 varieties are available in estuaries in some stage of their life cycle. Most of the fishes found in estuaries, of course, are found in transient period at some stages of their life cycle. The wonderful physiological adaptability of these fishes to be at ease in marine, estuarine and fresh water habitats, is really noteworthy. It has been found that the Perciformes is the most dominating Order in respect of Family diversity and species diversity both (Figs. 2 and 3). A few species of fishes have developed some special morphological characters as in Gobiid fish and some others lack eyes, which are adaptation for living in the muddy substratum of this ecotonal zone. The mudskippers are found hopping on the mudflats along with the oscillation of the tidal water. The rise of water level during high tide may push the mud skippers high over the trees, some of them remain there during low tide and exhibit a false idea about the strange habit of tree climbing (Mandal and Ghosh 1989).

Finfish diversity of the estuary

Considerable research has been undertaken in many aspects of fish biology in the Sundarbans. Notable works (Hamilton-Buchanan 1822; Kemp 1917; Annandale 1922; Hora 1933, 1934; Pantulu 1966 and Shetty et al. 1961; Talwar and Joglekar 1970) have contributed to the study of fish fauna of Hooghly–Matlah estuary. Gopalkrishnan (1968, 1971, 1973), Sen (1975), Naskar and Guha Bakshi (1987), Mandal and Nandi (1989), Chaudhuri and Choudhury (1994), Bose et al. (1999), Sanyal (1999), Debnath (2001), Khan (2003), Naskar (2004) have reported on the fish

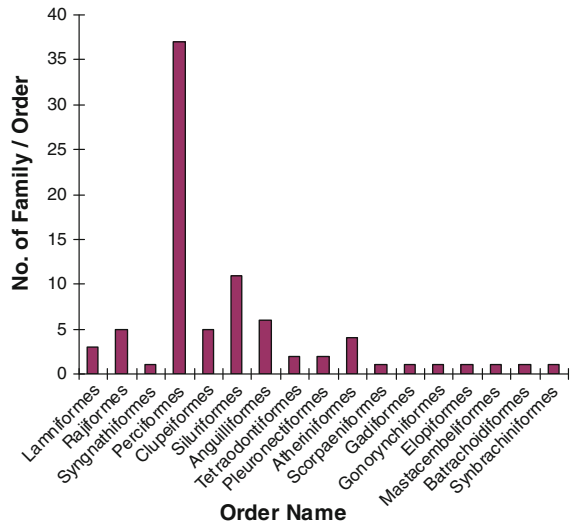

Fig. 1 Diversity of finfish family of Sundarbans belonging to different orders

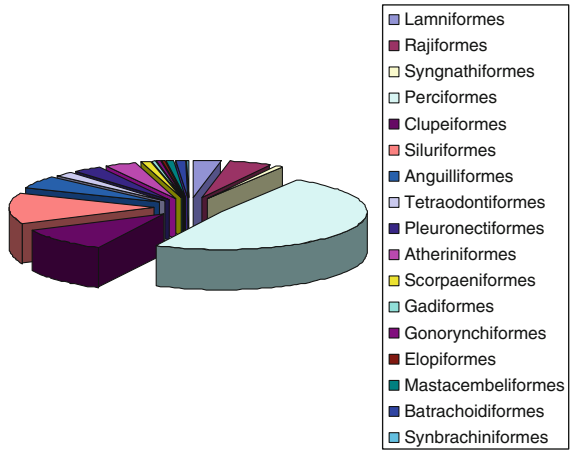

Fig. 2 Finfish Species diversity of Sundarban Mangrove ecosystem belonging to different orders

and fishery resources of the Sundarban mangrove based estuary.

Sen (1975) reported 61 finfish sp., Naskar and Guha Bakshi (1987) 92 sp., Mandal and Nandi (1989) documented 141 species under 100 genera, Chaudhuri and Choudhury (1994) reported 150 species of class Pisces under the umbrella of 96 genera, Bose et al. (1999) reported 74 sp., Sanyal (1999) reported 134 sp., Debnath (2001) documented 91 sp., Khan (2003) reported (2003) documented 106 sp. and Naskar (2004) reported 139 sp. of fish. A total of about 267 fish sp. have been recorded as a total with their respective 81 Families and 17 Orders.

Estuary's high fish diversity: background reasons

Ecological profiles of the estuary, excellent supports from the mangrove forests and rich availability of all essential nutrients for entire trophic levels of this ecosystem, allow the finfish communities to gather here.

Ecological principles governing diversity

As this estuary evolved long back, a large number of species had got the opportunity to invade, share and join this community leading to species diversity here. The primary productivity of this ecosystem is very rich causing fish species to utilize the feeds without competition.

Community structure of the system is complex, thus providing more niches that are easily occupied by the different fishes according to their ecological position, food habits, shelter etc. Estuarine habitat is sometimes termed as the Fundamental niche of sp. because here the species are free from the interference of another species, although a large number of species live together in a wide range of varying environmental conditions. These large numbers of environmental factors both biotic and abiotic affect the population. The estuarine niche is therefore multidimensional in nature. The several fin fish species found in abundance in this region indicate that the niches occupied by them are overlapping on each other within a wide range and thus a very little competition exits between them. This estuary provides resource in such a way that the niche becomes available for different species at different stages and time become different. As a result a large number of species can stay at same place utilizing the food and shelter at different times of a day or at different stages of their life cycle.

This estuarine habitat is considered as microhabitat. Thus the particular niche that can be occupied by a particular species is determined by the physical features of microhabitat viz. substratum, space and microclimates. Huge size of the habitat affects the number of species. Special patchiness in this microhabitat allows different fin fishes with different requirements to live together. The estuarine environment changes cyclically and periodically permitting several fish species to utilize the niche at different range of period. The tidal system does not cause any harshness of habitat. It helps in proper gradation and mixing of fresh water with sea water which ultimately provides a dwelling place for different species with different salinity tolerance range. The tidal flow and other possible disturbances prevent all competitive species from dominating a community, so the species that might otherwise disappear are able to survive. Both types of stratification (viz. vertical and horizontal) are found in estuary. The vertical stratification of water layer due to penetration of sunlight, atmospheric temperature etc. helps to niche differentiation, less competition and higher species diversity in estuary. The horizontal stratification highlights the issues like ecotonal community and edge species that also indicate towards the more species diversity (Dutta and Homechaudhuri 2004). The maximum concentration of fish species is noticed in the Thakuran River which lies in the western part of Indian Sundarbans. The Thakuran River significantly abound more in fish species rather than those in other rivers/creeks appeared in the sample (Chakravarty 1991).

Role of mangroves to maximize diversity

Mangrove forests are among the world's most productive sites, producing organic carbon well in excess of the ecosystem requirements and thus contributing significantly to the global carbon cycle. The complexity of mangrove forest habitat increases the residence time which assists in the assimilation of inorganic nutrients and trapping the suspended particulate matter (Mitra et al. 2004).The mangrove dominated ecosystem forms an ideal ecological asset due to production of leaf litter and detritus matters from plants fulfill the massive nutritional demands of juveniles and adults of maximum fishes in this region. According to Mumby et al. (2004) mangrove ecosystem is recognized as world's most potential nursery and the mangrove nursery may increase the survival rates of young fish. High levels of water turbidity that increases the survival chance of fish juveniles through reduced perception distance of their predators; increased primary and secondary productivity due to nutrient trapping, tidal mixing and fresh water inflow; the physical and structural complexity of the habitat, niche segregation leads to less and less competition are the principle factors why it is a nursery with maximum potentiality (Mitra et al. 2004). *Plotosus canius* and *Pangasius pangasius* fish have been found to feed themselves passionately on the fruits of Keora

(*Sonneratia apetala*) and Baen (*Avicennia* sp.). During the month of August, September and October tones and tones of fruits fall on water when these fishes concentrate near bank and devour them. One *P. pangasius* was found to weigh 12 kgs and it was found to have stuffed its belly with about 1 kg of *Avicennia* fruits. This fish had layers of yellow fat deposition. The growth of fish and fat contents indicate that these vegetable foodstuffs are responsible for (1) fat deposition and (2) growth. The Baen leaves are heavily infested with insects and pests. The defoliation is likely to affect flower and fruit production which in turn seriously affects the migration of *P. pangasius* and *P. canius* (Chakravarty 1991). Mangroves often act as bio-purifier or bio-filter. Bioaccumulation of heavy metals like Zn, Cu, Pb, Hg by certain mangrove species (viz. *Avicennia alba*, *Avicennia marina*, *Excoecaria agallocaha*, *Acanthus ilicifolius*) are unique and combat heavy metal contaminated wastes to purify the estuarine water (Mitra et al. 2004).

Profuse nutrients for maintaining diversity

The estuarine food webs are spun with the energy of plankton. Phytoplanktons form the foundation stone of world fishery. The secondary production of estuary is contributed by zooplankton and these are important linkers between primary and tertiary productions. Phytoplankton is the primary producers of pelagic system. The pelagic system around the coastal zone is highly productive due to considerable concentration of nutrients derived from anthropogenic origin, run-off from the adjacent landmasses, litters and detritus of mangrove vegetation etc. In Indian Sundarbans, 102 species of marine and estuarine phytoplankton has been documented. Though, preliminary investigations have shown the presence of about 50 species of Diatoms, 30 species of green algae and about 18 species of blue green algae in the eastern Sundarban region (Chakravarty, 1991). The upwelling zones of the oceans exhibit highest primary production due to presence of nutrients. The primary production in the marine and estuarine ecosystems is basically regulated by light, nutrients and temperature and ocean currents. In Indian Sundarbans, high degree of spatial and temporal heterogeneity of phytoplankton is observed and this is basically due to drastic regionalism in water characteristics (Mitra et al. 2005). Sarkar et al. (1986) reported that copepods constitute 61.0–96.4 percent of the total zooplankton counts in different parts of Sundarbans. Among the species of diatoms, *Fragilaria oceanica* and *Hemidiscus hardmannianus* have been recorded to indicate the abundance of clupeid fish, *Hilsa* in the Hooghly estuary (Mitra et al. 2004). One *Coelathrum* sp. and one *Ulva* sp. are very abundant in the supply of the pneumatophores and trunks of mangrove plants. These two algae have been found in stomachs of *Periopthalmus* and *Boleopthalmus* (mud-skippers), *P. pangasius*, *Pampus chinensis*, *Mugil tade* and several other fish species (Chakravarty 1991). Diversity alone cannot be responsible for abundance of animal. Higher productivity (in dry weight) has been found to have correlation with animal species diversity. High productivity is derived from stem, leaves, flowers and fruits. But caloric concentration which is of prime importance for animal species may or may not be consistent with high productivity. Caloric production is more directly involved in animal nutrition rather than in dry weight production. Since animals depend on leaves and fruits, more the leaf production, the more is the expectation of animals (Chakravarty 1991).

Fish uses estuarine corridors for migration

Some marine fishes which travel upstream through estuaries to breed in fresh water form a group such as, *Hilsa*, *Pama*, *Sillaginopsis*, *Polynemus* etc. The marine fishes which enter the estuaries to breed also form another group. They are *Arius* sp., *Osteogeniosus* sp., *Polydactylus* sp. and *Eleutheronema* sp. etc. The fresh water forms which migrate to estuaries for breeding are also classified as a group. They are *Pangasius* sp., different types of eel etc. Amongst eel, *Anguilla bicolor*, *Moringua raitaborua*, partly migrant *Pisidonophis boro* (Borofish), Pike eel, *Muraenesox cinereus* had been reported from this place (Mandal and Ghosh 1989; Chaudhuri and Choudhury 1994).

Threats for the estuarine fishes

Overexploitation of bioresources (fish), continuous increment of anthropogenic pressures, problems of ichthyoplankton loss during the time of wild harvesting of shrimp seeds and increasing global temperature

with sea level rise are the major causes for the destruction of finfish diversity in this estuary.

Overexploitation of fish from Indian Sundarbans

Surveys conducted in the Sundarbans indicate a total annual catch of fish of 25,000 MT. On an average, 4,000 individuals daily engage in fishing, with an average catch per fisherman of 1.5 kg fish per day. Mitra and Karmakar (1992) reported that the lower region has higher productive fishing grounds in lower Sundarbans, contributing to the major portion (about 90 %) of the total fish catch of the estuary. The period from September to February accounts for almost 70 % of the annual fish harvest. There has been a sharp decline in fish catches from the Sundarban estuaries in recent years. This has been caused by a combination of a number of factors. A steady increase in the number of fisherman has resulted in sharp competition, leading to over- exploitation. This, in turn, has led to a decline in numbers of adult fish reaching breeding condition, which are needed to replenish stocks. The fishermen also catch fingerlings and immature fish in their nets. Salinity level has increased in all the rivers and creeks which are detrimental to fish breeding (Chaudhuri and Choudhury 1994).

The study in Sundarbans mangroves inhabits higher caloric concentrations and record significantly high biomass productivity with low generic and specific diversity, generally both for flora and fauna. The balance of poor floral and faunal diversity in Sundarban mangroves is practically compensated by lesser biotic interference so with proper forest management, Sundarbans hold bright future for a natural ecosystem (Chakravarty 1991).

Steady decline in fish catch in the Sundarban estuary is mainly due to:

- Competition is keen among fishermen for catching fish and the number having risen 8 times since 1962 (500 fishermen). Such competition induces over catching of fish which, in a biological sense, is a condition of the stock in which, due to irrational catches, the number of individuals are incapable of reproducing under the optimal conditions and therefore can not ensure the maintenance of the stock.
- The faster rate of siltation has made rivers/creeks rather shallow and difficult for fishing.
- Percentage of salinity has shown a steady rise is all the rivers/creeks which are detrimental for fish breeding.
- Catch of brood and immature fish in the estuaries (Chakravarty 1991).

Anthropogenic stresses can harm fishes

The antifouling paints used for conditioning fishing vessels and trawlers also contribute appreciable amount of zinc, copper and lead to the ambient environment which may pose severe threat to this free floating microscopic drifting community. Several workers also pointed out that the lower stretch of Hooghly estuary receives an annual sewage of 396×10^6 m^3. This causes estuarine system to remain under saturated with respect to dissolved oxygen almost throughout the year indicating unhealthy condition of the estuary. Light limitation to use the available resources, predator pressure, tide induced turbulent motion, short flushing time along with pollution load have put the phytoplankton community in the present study area under several stress. The alteration in salinity has high probability to disrupt the phytoplankton community (Mitra et al. 2005).

The salinity of the zone is also showing an increasing trend since the last few decades because of excessive siltation and gradual tilting of the Bengal Basin eastward since 12th century due to neotectonic movements (Chakravarty 1991).

Ecological crop loss

The root of this ecologically adverse practice is basically related to high demand for prawn seeds by coastal shrimp culture firms and absence of tiger prawn hatchery in the entire state of West Bengal. During the collection of prawn seeds several non target species (juveniles of several finfishes) are trapped in net, thrown away and wasted. The extent of icthyoplankton waste varied from 2.019 kg to 9.101 kg/net/day/haul (Mitra et al. 1999, 2000, 2006; Banerjee et al. 2005a, b; Sasmal et al. 2009). This may pose an adverse impact on the pelagic and demersal fish reservoir in ecosystem (De and Sinha 1997). From different studies (Trivedi et al. 1994; Mukherjee and Mandal 2007, MOEF Project, Sanction No. J-22014/11/93-CSC(M)) it has been found that more or less 82

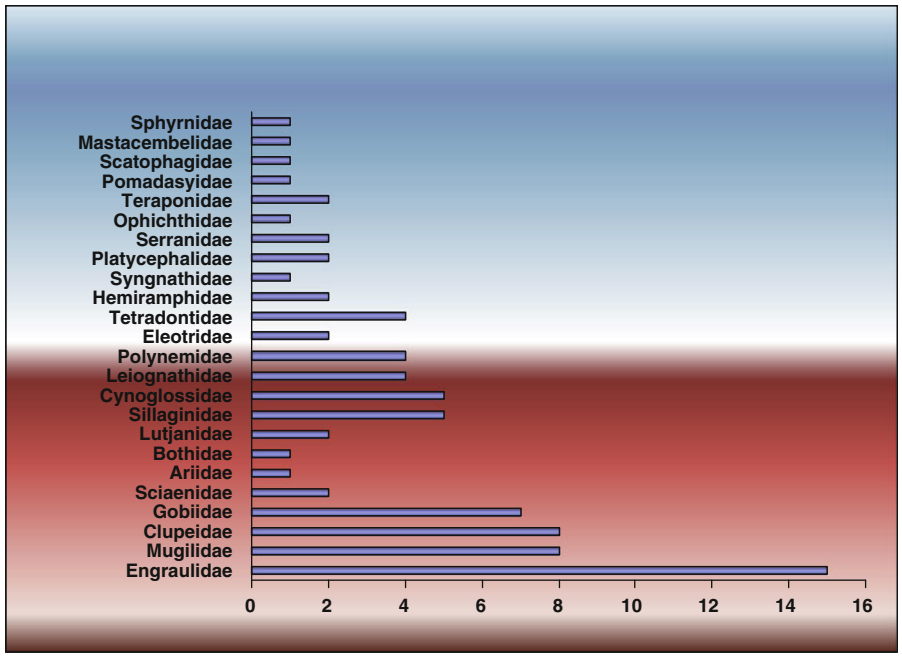

Fig. 3 Number of species/family faces most bycatch problem in Indian sundarbans

fin fish species are wasted in this region at a regular basis (Fig. 4).

Global warming gives ultimate threats

The pulse of climate change has also been felt in the domain of estuarine biodiversity of Indian Sundarbans. Few case studies reflected that there is a drastic alteration occurred in the species composition of phytoplankton and ichthyoplankton. The physical and chemical characters of water have altered with respect to water temperature, turbidity, pigment concentration and pH which may have the serious impacts on the species existing in this dynamic mangrove dominated gene pool of the tropics (Mitra et al. 2004).

Concluding remarks

The Sundarban estuary is rightly considered as goldmine of fishes. Its rivers, rivulets and creeks with tidal saline waters and flushing fresh waters provide the ideal ecotonal zone for the development and propagation of many populations of various fish species. As this estuary harbors Sundarban mangrove forest along side of its intermingled water paths, mangrove forest shares all of its positive characters with this estuary. Mangrove gives filtered water to the system, as the few species of mangrove forest have ability to purify heavy metals containing waste waters come from nearby industries and fishing trawlers of the estuary. Mangrove produces a large amount of detritus matters that fall in estuarine waters and break down into primary nutrients by highly propagated decomposer matrix of the water bodies. Presence of very low number of terrestrial grazers also increases the chances of detritus decomposition. Estuarine system function on plankton based and detritus based food webs. The producer component, particularly in middle and lower estuary, consist of Dinoflagellates and diatoms. The latter convert some of the carbon intake to high caloric fats and lipids, rather than the low energy carbohydrate. This fat provides the high energy food base for higher trophic levels (Smith and Smith 2001). The estuarine saline soup generally contains a great amounts of phytoplankton and zooplankton species which in turn benefited by continuous supply of nutrients from the adjacent rural and urban areas. Mangrove's intricate root system provides a hospitable environment for fishes to breed there and juvenile caring. Both of these important functions of fish again benefited from the

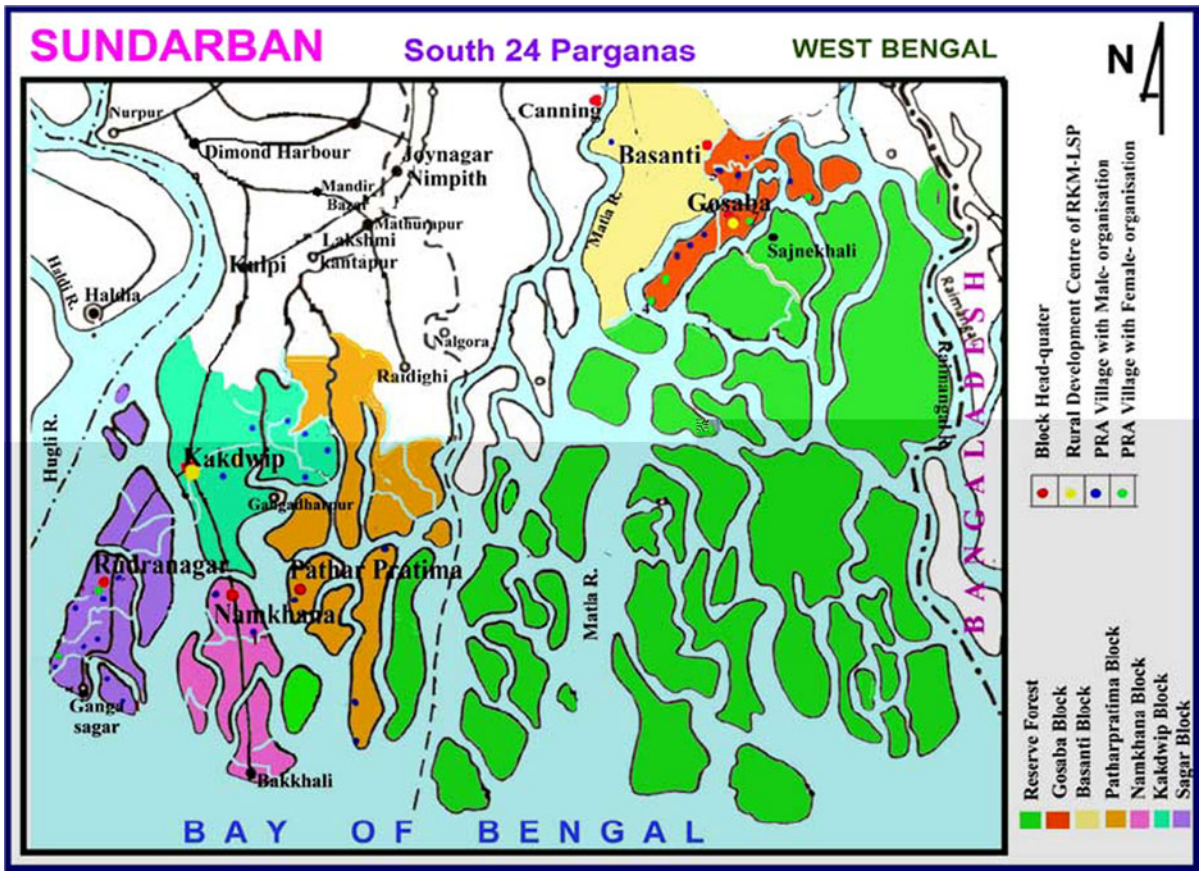

Fig. 4 Map of Indian Sundarbans

fact like avoidance of predations due to presence of root made shelters of the mangrove plants.

But today, these entire diverse communities are facing a great threat due to the few factors like, human settlements in malignant fashion and the continuous changes in the arena of the global climate. Actually this mangrove dominated estuarine ecosystem is encountered from the north and south sides of the regions by indiscriminately growing population settlements and ever increasing earth's temperature related sea level rise, respectively. Deforestation due to increment of anthropogenic pressure damages the ecological balance of the system; on the other hand, increment of salinity due to sea level rise may change the aquatic characters of the estuarine system which again leads to alter the population structures of the various fish communities. Global warming often blocks the migration of anadromous and catadromous fishes, warming of water temperature may affect predator prey relationships, as predator species expand their niche breadth and start to predate on few unexpected prey. The event of species replacement may also occur due to sea level rise, as natural adaptation process favours more and more euryhaline species rather than stenohaline ones.

Extinction of a species is not unnatural thing, but the fears are gathered in cloud when the rate of extinction events is more than the natural rate of extinction of the particular species. In Indian Sundarbans, many fin fish species are facing this excessive extinction pressures due to fishing of adults, semi adults, brooders etc. in unsustainable manner and loss of varieties of juvenile fin fishes during wild harvest of prawn seeds (Fig. 3). In this estuary loss of spawn, fry, fingerling and juveniles of fin fishes literally occur in an every second of a day, as large numbers of prawn seed collectors, irrespective of their age and sex are performing this lethal work in maximum hours of a

day. Huge catch of different shark species for the export related commercial purpose surely impose a very bad impacts on the basic food chain in this region. Often excess tourism and release of untreated industrial waste creates pollutional hazards and minimize the survival chances of different fin fish species.

Still the maximum fish species thrives with the problems. Mangrove forest minimizes most of the adverse effects and saves them from all the odds. But how long they thrives this extinction pressure, if, the causes behind the destruction will persist continuously? The fin fishes don't know, but we, the most prestigious organism in the world know this well, the fact, that, a part of global diversity is in extreme danger and we have to do something to save it, just not for themselves but specially for future of ourselves. So, impede deforestation, stop more anthropogenic settlements, prevent unsustainable exploitation of the resources should be our goals from the time, that will start now.

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