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MANGROVE FOREST CONSERVATION IN SUNDARBAN

Sheikh Jasimuddin[1], Dr. Jyotirmoy Sen[2], Dr. SK Zakir Hossain[3]

[1] *Research Scholar, Seacom Skills University, Kendradangal, Bolpur, Birbhum 731236*

[2] *Seacom Skills University, Kendradangal, Bolpur, Birbhum 731236.*

[3] *Chakshanjadi G. M. Institution.Purba Bardhaman, 713124*

Abstract- Mangrove ecosystem, an unique, fragile, highly productive ecosystem in the sea- land interphase, is the conglomerations of plants, animals and microorganisms acclimatized in the fluctuating environment of tropical intertidal zone. This ecosystem is a highly valued ecosystem in terms of economy, environment and ecology. Mangrove ecosystem of Sundarbans, India, (between 210 32' – 220 40' north and between 880 85' – 890 00' east) a World Heritage Site, is a unique tidal wetland from the point of view of its biodiversity and ecology. This tidal dominated deltaic complex is the largest of its kind and covers an area of 1,000,000 ha of land and water, the major part (60%) of which is situated in Bangladesh while the remaining western portion (40%) lies within India. The mighty Indian river, the Ganges and its associated estuaries like Muriganga, Saptamukhi, Bidyadhari, Haribhanga, Matla, Thakuran etc open into the Bay of Bengal having a north – south direction of water flow. The silt and loam carried by these estuaries were deposited on the salt marsh eventually leading to the formation of mosaic of 102 deltaic islands of which 54 have been reclaimed for human habitation. A number of geomorphological and resultant hydrological changes have contributed for shapping and reshapping of this estuarine complex making it a very dynamic system. This ecosystem (representing worlds' one of the most productive ecosystem) harbours thousand of flora and fauna in its diversified habitats and niche. The biodiversity includes true mangrove plants (34 species) and their associate plant species (40), 150 species of algae,163 species of fungi, 32 species of lichen, 250 species of fishes, 7 species of amphibian, 59 species of reptiles, around 200 species of birds, 39 species of mammals, besides numerous species of phytoplankton, zooplankton, ichthyoplankton, benthos, soil inhabiting micro arthropods and mangrove plants dependant insects. Species composition, and their distributional pattern, population dynamics and community structure of different groups of fauna experience wide range of changes spatially and temporally because of the prevailing fluctuating environmental condition. Temperature, rainfall and tidal mixing mostly make this environment unstable with a wide range of variation of major ecological parameters like salinity, pH, dissolved oxygen, nutrients, turbidity etc. from east to west in different periods of year. This ecosystem maintains rural economy by providing timber, fuel wood, faunal resources like fishes, honey etc and protects coast from soil erosion, buffer cyclone, stormes etc, mitigates flood and maintain estuarine flow. However, the biodiversity and basic fabric of ecosystem functioning are being threatened because of several reasons like reclamation of deltaic island for human use, deforestation, erosion and unwanted accretion, salinity invasion, nonjudicious exploitation of fishes, floral and other faunal components, ecotourism, bioinvation and pollution. Further the impact of global climate change has aggreviated the problem. The paper discusses the biodiversity conservation strategies which are being adopted giving due importance to the success and failure of previous ones.

Keywords: *Mangrove Ecosystem, Sundarbans, Biodiversity, Deltaic Island, Conservation*

I INTRODUCTION

The term mangroves collectively refers to woody halophytic angiosperm trees that inhabit the intertidal zone of the tropical and subtropical coastal-estuarine regions, especially between 250 N and 250 S, where the temperature of the winter water remains not less than 200 C. With rising latitudes, mangrove abundance declines gradually (Connoly and Lee 2007). Mangrove habitats are one of the most active natural wetlands found in tropical and subtropical regions of the world in the intertidal zone (Chaudhuri and Choudhury,1994). This specialized ecosystem, dominated by halophytic halophytic vegetation that tolerates intertidal salt and enjoys the influences of two high and two low tides a day, provides a unique environment for the growth of bioresource on the one hand and preserves ecological balance on the other hand by protecting the coastal line (Chakraborty, 1995). This detritus-based coastal ecosystem is highly productive with a productivity around 20 times higher than the average ocean production (Goudha and Panigrahy, 1996). The value of the mangrove ecosystem has been widely recognized throughout the world for its potential for fisheries and aquaculture growth, primarily for two reasons: first, large amounts of energy in the form of mangr. Compared to such studies on some other coastal habitats, such as coral reefs, due to difficulties in accessing rigorous mangrove ecosystems, in-depth ecological study is minimal. Their geographical distribution, floral and faunal surveys and potential for fisheries, however, have led to more mangrove research in the last few decades (Ellison et al, 1999). This paper discusses the diversity, distribution, zoning, succession, ecological interactions of the mangrove flora and fauna of the Indian mangrove ecosystem of Sundarbans with specific focus on the various threats and conservation strategies of this ecosystem.

II PHYSIOGRAPHY OF SUNDARBANS MANGROVE ECOSYSTEM, INDIA

The Mangrove-dominated estuarine networks constitute the main characteristic of West Bengal's coastal climate. The 102 deltaic islands of the Indian Sundarban (42 virgin and 54 reclaimed) are clustered between 210 30' - 220 15' N & 880 10' - 890 10' E, mostly within the South 24- Parganas Districts of West Bengal State (Fig.-1). In terms of economy, biodiversity and climate, this largest tidal wetland and only mangrove tiger land on earth, designated 'World Heritage Site' by the IUCN in 1997, is a highly valued ecosystem. It includes a Tiger Reserve (2585 km2 , 1970), 3 wildlife sanctuaries (3,800 ha Lothian, 1948; 35,240 ha Sojnekhali, 1960 and 595 ha Holiday Island, 1976) and one National Park (1330 km2 ; 1972). The Indian Sundarban environment, however, has changed remarkably due to many natural and anthropological activities such as land reclamation, drainage control, sediment control, tidal flood management steps, neotectonic movement, international freshwater sharing arrangement, etc. over the past centuries. The combined effect of all these modifications has altered the ecosystem's physicochemical properties (salinity invasion, massive shoreline erosion coupled with unwanted accretion, shifting of mudflats and sand dunes, increased turbidity, temperature, tidal amplitude and decreased transparency, nutrients, pH etc). These changes have led to changes in the composition of the species of biotic ecosystems, leading to the decrease and loss of detritivores, herbivores and other carnivores dependent on mangroves.

III GLOBAL DISTRIBUTION OF MANGROVES

There is a worldwide circumtropical distribution of mangroves, with the highest concentration in the Indo Pacific zone. Nearly 1/4th of the world's tropical coastline is covered by mangroves. The gross mangrove area covering 30 countries, including nations of different islands, is approximately 1,00,000 km2 (Annon, 2003). Global mangrove distribution is determined by a variety of interlinked and interdependent factors such as edaphic factors (soil texture, nutrients and microbial load), geomorphological factors (sedimentation rate, flora and fauna stabilization of deposited sediments in the deltaic island formation process), physical factors (tidal amplitude and strength, micro and macrotidal cycles, cu (flora, fauna, and microbs). To date, 69 vascular plant species of mangroves have been recorded with many unique adaptations to survive well in the rigorous and complex marine estuarine coastal setting (Blasco, 1975; Chapman, 1976; Kathiresen and Bingham,2001). These mangroves and their associated plant species promote the life of other faunal components in a diversified form (crustaceans, molluscs, polychaetes, finfi, finfi) (Chaudhuri and Choudhury, 1994; Annon, 2003). Another 80 plant species, both herbaceous and woody, have been recorded to be recognized as mangrove associates (Cannolly and Lee, 2007) and do not have specific adaptations for intertidal living. In South and South East Asia, more than 41 per cent of the world's mangroves remain, of which Indonesia alone accounts for 23 per cent (Gopal and Chauhan, 2006). In Brazil, Australia and Nigeria, a further 20 percent of the total mangrove area is (Spalding et al 1997). In the Ganga-Brahmaputra-Meghna Deltaic system of Sunderbans, however, the largest chunk of the world's mangroves occur jointly shared by two countries - Bangladesh and India.

IV CLIMATE

In this coastal environment, seasons are well defined, each with a duration of four months- premonsoon (March to June) with the highest temperature (42oC) and almost no precipitation; monsoon (July to October) with high precipitation (2000 ml) and moderate temperature; and postmonsoon with the lowest temperature (10 oC) with occasional precipitation. Winds blow from south-east to south-west directions with higher intensity diving from May to September. Winds blow from the south and south-west during the early premonsoon phases (February to April). The postmonsoon (late October to January) experiences primarily clam cycles with north-west winds (Annon, 2003).

V BIODIVERSITY OF INDIAN SUNDARBANS

Due to the broad range of temporal and spatial variations of different ecological parameters (salinity, pH, temperature, rail, nutrients, etc.) and ecological processes (duration of tidal exposure and flooding, volume of water, fresh water inflow and salty water mixing, erosion and accretion, etc.) in various creeks and tributaries, salt marshes, sand and mudflats, Sundar bansmangmang

A. Diversity, distribution, zonation and succession of floral components

Mangroves are an ‘artificial assemblage’ of trees and shrubs i.e. species are not taxonomically related with one another, which demonstrate special adaptations for life in the intertidal zone (Tomlinson,1986).The adaptability of mangrove plants to thrive well in the stressful ecological condition is ensured by the possession of pneumetaphores and trap roots, sunken stomata, viviparous germination, thick lignin coating on leaves etc. 69 species of true mangroves belonging to 26 genera and 20 families have been recognized by Duke (1992) while Kathiresan and Bingham (2001) considered 65 species (22 genera and 16 families) as to be true mangroves. Another 80 species of plants, both herbaceous and woody showing no special adaptation for living in the intertidal environment have been recorded as mangrove associates and they bridge the gap between, mangroves and terrestrial vegetation (Duke, 1995). Sundarbans mangrove ecosystem harbours 34 true mangrove species, out of the above mentioned ones, a total of 163 species of fungi (Chaudhuri and Choudhury 1994), 150 species of algae (Naskar et al 2004) and 32 species of lichens(Santra 1998) 40 species of mangrove associate (Annon, 2003).

B. Diversity, distribution and zonation of faunal components

Highly productive Mangrove ecosystem supports a high abundance and diverse variety of faunal components (Ong, 1995). The faunal biodiversity includes 215 species of fishes, 7 species of amphibia, 59 species of reptiles, more than 200 species of birds, 39 species of mammals, besides numerous species of phytoplankton, zooplankton, ichthyoplankton, benthos, soil inhabiting and mangrove plants dependant insects (Chaudhuri and Choudhury, 1994; Annon, 2003). Species composition, and their distributional pattern, population dynamics and community structure of different groups of fauna experience wide range of changes spatially and temporally because of the prevailing fluctuating environmental condition.More distinct zonations have been revealed by different macrobenthic fauna especially brachyuran crabs, molluscs and polychaetes (Chakraborty and Choudhury, 1992). Mangrove ecosystem of Sundarbans supports a rich estuarine fauna in hundreds of creeks and tributaries, salt marshes, sandflats and mudflats in the form of plankton, benthos and nekton. Zooplankton, an important biotic component of mangrove aquatic subsystem, constitutes the secondary and tertiary trophic levels of mangrove food web (Fig-II and Table-III). The faunistic composition of zooplankton in this system includes copepods as principal component of the total zooplankton (67.8% to 15 90%). A total of 36 copepod species belonging to 19 families and 21 genera have been recorded (Sarkar et al, 1986). Other zooplanktonic forms are mysidacea, sergestidae, amphipoda, cladocera, ostracoda, cumacea, chaetognatha, hydromedusea etc (holoplankters) and polychaete larvae, nauplius, zoea, megalopa, fish eggs and larvae, echinoderm larvae etc (meroplankters) (Annon, 2003, Chakraborty et al.2009). Icthyoplankton, the juvenile stages of fin fisheses constitute an important planktonic group and include hundred of species under 29 families. The major families are Clupeidae, Megolopidae (Chakraborty et al, 2009). A hoard of benthic fauna, both infauna (sessile, semisessile and burrowing) and epifauna (crawlers and creepers) are the happy residents of these habitats which are subjected to various oscillatory exposures of hydrological parameters (Chakraborty et al, 1992; Chaudhury and Chaudhury, 1994). Most of the benthic organisms have evolved various behavioural and physiological adaptation to cope with the stress due to varying ecological conditions (Vernberg and Vernberg, 1972). Besides, benthic fauna are divisible into three broad groups based on their body sizes—macrobenthos, meiobenthos and microbenthos. There is a distinct zonation of different microbenthic species along the intertidal slope reflecting their adaptation to different prevailing ecological parameters (Chakraborty and Choudhury, 1985; Chakraborty and Choudhury, 1992). Among the intertidal macrobenthic fauna, brachyuran crabs constitute a dominant faunal component of ecological and economic significance. 26 species of brachyuran crabs belonging to 15 genera and 5 families have been recorded from the deltaic Sundarbans estuarine complex (Chakraborty et al, 1986). A total of 69 species of polychaetes under 45 genera and 25 families have been documented from this ecosystem (Misra,1986). Subba Rao et al, (1986) recorded 110 species of benthic mollusca from the intertidal zones of Sundarbans, India which are distributed under class gastropoda (59 species) and bivalvia (40 species). These salt marshes also harbour a rich abundance of benthic insects in its different categories of soils. A total of 24 dipteran species belonging to 5 families and 11 genera (Roy and Choudhury, 1989) and 14 coleopteran species (Poddar et al, 1990) have been reported. Phytophagus insects living on mangrove plants are noticed in abundances which include 2 species of hemiptera, 1 species of hymenoptera, 8 species of hemiptera, 1 species of homoptera, 16 species of coleopteran, and 30 species of diptera (Chakraborty and Naskar, 16 1988). Actiniarian, sipunculans, echiurans, hemichordates, globid fishes etc are other important benthic faunal groups. Dey et al, 2010 recorded 44 species of microarthopods belonging to six major taxonomic groups viz. Acarina, Collembola, Coleoptera, Diptera, Isoptera, and Hymenoptera. 80 species of nematodes belonging 26 families have been documented (Chaudhuri and Choudhury 1994). Rao and Misra,1983 studied meiofaunal abundance in Sagar Island, Sundarbans and found that nematodes constitute the most dominant group followed by copepoda, polychaeta, ostracoda etc. An ecological survey on the distribution of subtidal and intertidal foraminiferan faunal components revealed the occurrence of 58 species belonging to 31 genera under 21 families and 4 suborders from the coastal belts of West Bengal, especially in and around Sundarbans mangrove ecosystem (Majumder et al, 1996).

VI RELATED WORK

The trophic relationships between the various biotic components of the mangrove ecosystem indicate that three separate types of green plants (mangrove plants, benthic algae and phytoplankton) constitute the first trophic level as primary producers, which are taken up as food by primary consumers representing the secondary trophic level (insects, intertidal crabs, molluscs, deer, wild boars, birds, forests, etc. Ultimately, such energies flow through some other trophic levels, mostly represented by carnivores and omnivores (larger finfishes, dolphins, leopard cats, turtles, water monitors and various birds), ultimately ends at the highest trophic level, represented by top carnivores such as Royal Bengal tiger, crocodile, crocodile, etc.

The Sundarban's geological formation is of comparatively recent origin. The deposition of sediments in the Bengal Basin and creation of the Sundarban Delta resulted in several geomorphological changes since the Tertiary period that included tectonic movements in northwestern Punjab and the southeastern flow of the River Ganga (Wadia, 1961). It is worth noting that the Ganga and Brahmaputra together bring the largest sediment load in the world to the oceans (Coleman, 1969; Milliman and Meade, 1983; Milliman et al., 1995). In the Bengal Basin, neotectonic motions between the 12th and 15th centuries AD further resulted in an easterly tilt (Morgan and McIntire, 1959). The R. during the 16th century. Ganga has changed its course to travel east and join the Brahmaputra (Deb, 1956; Blasco, 1975; Snedaker, 1991). Later, the combined Ganga (now called Padma) and Brahmaputra tilted eastward again in the mid 18th century to empty into the R. About Meghna (Williams, 1919; Snedaker, 1991). Because of changes in the sedimentation patterns and the decline in freshwater inflows, this ongoing tectonic activity greatly affected the hydrology of the deltaic zone. Many rivers (distributaries) other than the Hooghly, which led to the creation of the Ganga Delta (from west to east: Muriganga, Saptamukhi, Thakuran, Matla, Gosaba and Bidya), have lost their original ties to the Ganga due to siltation (Fig. 1b), and the monsoonal runoff alone now retains their estuarine character (Fig. 1b) (Cole and Vaidyaraman, 1966). Therefore, in the west, the delta-building phase has almost ceased, but has accelerated in the eastern part. From the approximate rise in the land area by more than 800 km2 in 80 years between 1793 and 1870, the high rate of sediment deposition in the Sundarban can be understood (Richards, 1990). However, recent studies by Chakrabarti (1995) show that mangroves are the dominant geomorphic agent in the formation and accretion of tidal shoals to the main landmass.

Soils: The soil is formed primarily by tidal activity. The entire region is intersected by an intricate network of waterways, of which the larger channels (often 1.5 to 2.0 km wide) flow in a general north-south direction. At each tide of ebb, countless small khals (= creeks) drain the land. Rivers tend to be long and straight, a result of heavy tidal forces and erosion-resistant deposits of clay and silt. At the river mouths, easily eroded sands accumulate and form banks and chars, which are blown into dunes by the powerful southwest monsoon above the high-water mark. Finer silts are washed out into the Bay of Bengal, but on the leeward side of the dunes, where they are shielded from wave action, mud flats are formed. The sand from the dunes overlaps these mudflats, and they turn into grassy meadows. For as long as the area on the windward side is exposed to wave action, this phase of island construction continues. Silt starts to settle along the shore of the island with the creation of the next island farther out, and sand is blown or washed away (Seidensticker and Hai, 1983).

Climate: The climate of the region during the monsoon season is characterized by relatively high temperatures and humidity (>80%) throughout the year, and well distributed rainfall. During the monsoon, temperatures rise from a daily minimum of 2-4 ° C in winter to a maximum of around 43 ° C in March and can exceed 32 ° C. Latest reports say that air temperatures are steadily rising over the Sundarban and adjacent parts of the Bay of Bengal (Huq et al., 1999; Agrawala et al., 2003). The cold season stretches from about the middle of November to the end of February, followed by March to May in the summer. There is a six-month dry season during which precipitation is surpassed by evapotranspiration.

Hydrology and salinity regimes: The Sundarban hydrology is dominated by the freshwater flows from the Ganga, Brahmaputra and Meghna rivers, which display very high seasonal variation in their discharge, and tides varying from 2 to 5.94 m in height. Tidal impact spreads from the shoreline to more than 50 km inland, and surges increase dramatically during cyclonic storms.

Biodiversity: In hydrological regimes (both freshwater inflows and tides), the broad spatial and temporal variability, the topography and texture of the substratum, the salinity and their interactions result in very high heterogeneity of the environment in the habitats of mangroves, thus ensuring an equally diverse biodiversity. There has been some controversy about the distinctive mangrove plants and a distinction is generally made between the species of "true mangrove" and "mangrove associate." However, according to Gopal and Junk's definition of wetland species (2000, 2001), all those species that depend directly or indirectly on mangrove habitats or some other organism living in mangroves are considered as mangrove organisms here.

VII CONSERVATION

Conservation of the Sundarban mangrove was supposed to have started under the Indian Forest Act in 1878 with its declaration as a reserve forest, after Schlich (1875) raised concern about its conservation (Presler, 1991). As mentioned earlier, however, this did not aid conservation per se, but rather controlled the government's exploitation and conversion. India declared Lothian Island (3,800 ha) as a Wildlife Sanctury soon after independence, and later, in 1960, another 35,240 hectares were brought under the Sajnakhali Wildlife Sanctury. In 1970, after the IUCN listed the Bengal tiger (Pantheratigristigris) as an endangered species, the hunting of tigers was totally prohibited. The Government of India later created a Tiger Reserve in the Sundarban, covering 2,585 km2 in 1973, under Project Tiger (Fig. 4a). As a subsidiary wilderness area, another 241 km2 area was demarcated. The 1,330 km2 core area was later known as a National Park. To protect the spotted deer (Axis axis), wild boar (Susscrofa) and rhesus macaque (Macacamullata), which are dominant animals in a forest form consisting mainly of Ceriopsdecandra, another wildlife sanctuary was created on Haliday Island in 1976 (595 ha). Soon thereafter, in 1977, Bangladesh established three wildlife sanctuaries: the Sundarban West (71,502 ha), Sundarban East (31,226 ha); and Sundarban South (36,970 ha), under the Bangladesh Wildlife (Preservation) (Amendment) Act, 1974, protecting about 23.5 percent of the remaining Sundarban. In the Sundarban Forest Division of the Khulna District, near the border with India and just west of the main outflow of the Ganges, Brahmaputra and Meghna rivers, these sancturies (IUCN, 1997) lie on disjunct deltaic islands (Fig. 4b). Sundarban National Park in India was added to the World Heritage List in 1987 and parts of Sundarban in Bangladesh in 1997 (IUCN, 1997). The Sundarban Biosphere Reserve has also been designated as the entire Indian Sundarban area south of the Dampier-Hodges line (that demarcates the inward limit of tidal influence), including 5,366 km2 of reclaimed land. Several different zones have been recognized within the Biosphere Reserve: a Central Zone consisting of the National Park and the Tiger Reserve, a Manipulation Zone (2,400 km2 of mangrove forests), a Regeneration Zone covering 240 km2 of degraded forest and saline mud flats, and a Growth Zone containing much of the areas reclaimed. Only the Core Zone has stringent protection measures in place. Income-generating activities are permitted in the Manipulation Region, such as the collection of black tiger prawn seeds (Penaeusmonodon), the cultivation of oysters and crabs, mushroom cultivation and beekeeping for the production of honey. However, attempts are being made to rehabilitate some degraded areas by forestation as well. The estuarine crocodile and the Olive Ridley turtle are gaining some attention among faunal species by way of captive breeding. A specific sea turtle conservation program (http://www. wildbengal.com/sanctuaries/sunderban main.htm) has been launched by the Sundarban Tiger Reserve in India. The conservation approaches vary considerably between the Sundarbans of India and Bangladesh and this has been addressed at length by Seidensticker (1991). In small sanctuaries located in the larger forest tract, the Bangladesh Sundarban is managed as a refuge where biodiversity is protected by providing protection for the resource' hot-spots' necessary for the maintenance of wildlife populations. This strategy assumes that the survival of populations and species such as large mammals and birds dependent on resources such as food or nesting and roosting sites over wider areas can be assured by inviolating core areas surrounded by restricted-use buffer zones. In India, however, the Sundarbans conservation policy includes setting aside areas where a community's entire life-cycle needs can be met and the ecological needs of wildlife can be related to the overall management of the Sundarbans scheme.

VIII CONCLUSION

While significant steps have been taken to preserve the biodiversity of the Sundarbans, an integrated action plan, including the results and recommendations of multidimensional research carried out over the last four decades, is needed. Based on these, appropriate guidelines on this globally relevant environmental field should be framed for potential researchers so that Time Series Analysis and Long Trend Analysis on natural and anthropogenic stress factors can be made possible. These would promote the process of more clearly pointing out concerns and more productive remedial steps.

Two major factors will determine the future of the Sundarban mangroves and their biological diversity. First, as the human population continues to rise in both countries, demand for freshwater resources is bound to increase, resulting in the monsoon season being restricted to freshwater flows when extensive floods occur in the eastern parts of India and Bangladesh. The resulting rise in salinisation and accretion of sediments will change the vegetation's composition. Due both to the direct effects of salinity and indirectly to changes in the food chain induced by changes in the quality and quantity of detritus available in the mangrove environment, there may also be impacts on animal populations. Therefore, it is the human response to the spatial and temporal variability of precipitation and, ultimately, the availability of fresh water that will determine the availability of water to sustain the functions and values of mangroves. India's proposed plan for a river-linking program for inter-basin water transfer in India has already raised questions about the fate of the Sundarban and its rich biodiversity, as well as the millions of people who depend on it (Ahmed et al., 2004). Second, global climate change is expected to increase the surface temperature and spatio-temporal precipitation variability and cause sea-level rise (Ellison, 1994). The rise in variations in temperature and rainfall will put increased pressure on the supply of freshwater and thus alter the freshwater inflows to the mangroves. If rainfall falls in the Ganga-Brahmaputra basin, it will lead to a further decline in the delta region's freshwater supply. In certain climate change projections, an increased frequency of tropical cyclones and storm surges is also present, which may cause further changes in the interactions between freshwater and seawater and thus affect mangroves (Ali, 1995, 2003; Ali et al., 1997). In this case, large parts of the Sundarban along the coast are likely to be filled with sea water and the biotic composition would be influenced by the increased intrusion of landward salinity. Ultimately, the survival of the Sundarban mangroves depends on the effectiveness of the management of limited freshwater resources in order to satisfy both human and environmental needs, combined with efficient adaptive responses to the additional challenges posed by climate change.

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