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Biodiversity and Conservation of Estuaries in India – A Report on the Status, Threats and Challenges

Mohan Raj V.*, Sangeetha R. and Susan George

P.G. and Research Department of Zoology, Sir Theagaraya College, Chennai 600 021, Tamil Nadu, India

**Corresponding Author*

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Abstract: India has an enormous bounding coastline and vast stretches of estuaries and backwaters. Indian estuarine waters have number of classic research records, most of which are historically important. Estuaries provide critical habitat for species that are valued commercially, recreationally and culturally. Birds, fishes, amphibians, insects and other wildlife depend on estuaries to live, feed, nest and reproduce. Estuaries provide essential food, shelter, migratory corridors and breeding ground for many aquatic organisms and also livelihood for many fisherfolks. Many of these aquatic resources are poorly conserved and this has led to the loss of biodiversity. The health status and biological diversity of the Indian estuarine system are deteriorating day by day through multi various man-made activities including dumping of enormous quantities of sewage and effluents into the estuary. This has drastically reduced the population of the fishes, also caused considerable ecological imbalance and resulted in large-scale disappearance of flora and fauna. However, the belated development of estuarine biodiversity as a field of systematic research has been the outcome of growing concern about immense societal importance of these ecosystems. Due to obvious reasons, the estuaries need to draw focused attention on the issues like status evaluation and stress quantification of the individual system for conservation and protection against further deterioration in future. Cleaning up of the badly affected Indian estuaries and bringing them back to health will also need a legal framework to ensure that management plans are implemented to produce desired results. Hence, it will require suitable legislation which in turn will need public awareness of the problems that our estuaries are experiencing today. The present study on various aspects of biodiversity in estuaries at varied geographical regions of India provide detailed historical baselines and quantitative targets for ecosystem-based management and estuary conservation.

Keywords: Ecology, Environment, Biodiversity, Conservation, Ecosystem, Pollution

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Introduction

India has a coastline of about 8200 km. A total of 14 major, 44 medium and 162 minor rivers discharge about 1645 km^2 of freshwater every year into the marine environment. The major

rivers are Ganga, Mahanadi, Godavari, Krishna and Kaveri on the east coast and Narmada and Tapti on the west coast. These seven rivers discharge about 812 km^3 of freshwater and transport about 1194×106 tons of silt and clay into the marine waters every year (Jhingran, 1985). An estuarine region is a transitional zone between the fluvial and marine environments and is a focal point of the maritime activities. Estuaries are semi-enclosed water bodies and are the integral part of the coastal environment. Estuaries act as natural harbour for trade and commerce and are also used for industrial and recreational activities. Estuary acts as an effective nutrient trap and provide the vital source of living and non-living resources. The biodiversity in the dynamic estuarine habitat is very significant and support fin and shellfisheries. Such a dynamic environment provides many ecological niches for diverse biota. The health status and the biological diversity of many Indian estuarine ecosystems have been deteriorating in recent days due to anthropogenic activities (Mathumitha *et al*., 2021). The release of enormous quantity of sewage into the estuarine ecosystem has caused considerable ecological imbalance and resulted in large scale disappearance of estuarine flora and fauna.

Estuary:

The word estuary is derived from the Latin word aestuarium meaning tidal inlet of the sea, which, in turn is derived from the term aestus, meaning tide. An estuary is the point at which a river and the sea meet. Estuaries are, therefore, dynamic ecosystems where seawater is brought in by the tides but is diluted by freshwater flowing in from rivers and streams. The main difference between lagoons and estuaries is in the flow dynamics of the water bodies, in estuaries, the water flows fast and strong, while in lagoons the water is shallower and flows sluggishly. Estuaries are usually deeper than lagoons (Kjerfve, 1986). Generally, there are three zones in an estuary: the first is where the river begins to meet the saltwater - more freshwater than saltwater is found in this zone; the next zone, towards the sea, is where there is about an equal mix of fresh and saltwater; the last zone is the area where the water flows into the ocean and this zone is mostly saltwater.

Estuarine Ecosystem:

The environment of an estuary is unique as it harbours a unique ecosystem, where the temperature is warm, tidal onslaught is at low intensity, the soil is rich in nutrients, saline, muddy and the dominant component of the habitat is mangrove forest. It is followed by mud flat halophytes like *Sesuvium portulacastrum*, mangrove grass like *Aeluropus lagopoides*, sea grass like *Halophila beccarii*, and borderline salt-tolerant plants like *Clerodendrum inerme* and *Salvadora persica*. On the sandy shores *Spinifex squarrosus* and *Ipomoea pes-caprae* dominate (Joshi and Bhosale, 1982). The coastal and estuarine regions of Goa, Puducherry and West Bengal are rich beds of several species of gastropods and bivalves (Shampa *et al*., 2015). Estuaries also provide habitat for fishes, amphibians, water birds, semi aquatic animals and aquatic plants.

Estuaries serve as a dynamic habitat for a large number of marine fish species during a part of their life span, which are characterized by large fluctuations in environmental conditions as these are meeting places of freshwater from river and salt water from sea (Nicola *et al*., 2007; Sha *et al*., 2009). The biodiversity in the estuarine habitat is very significant consisting of diverse habitats such as mangroves, salt marshes, sea-grasses, mud flats and it provides a nursery and breeding grounds for commercially or ecologically important species, such as fishes, shrimps, oysters, mussels, and is a habitat for amphibians, water birds, semi aquatic animals and aquatic plants.

Many of these aquatic resources are poorly conserved and this has led to the loss of biodiversity. The health status and biological diversity of the Indian estuarine system are deteriorating day by day through multi various man-made activities including dumping of enormous quantities of sewage and effluents into

the estuary (Mathumitha *et al*., 2021a) This has drastically reduced the population of the fishes. It has also caused considerable ecological imbalance and resulted in large-scale disappearance of flora and fauna. In order to safeguard the biodiversity, it is essential to conserve the water resources and to maintain good quality water towards minimizing the loss of aquatic resources.

Estuaries of India:

Hooghly-Matlah estuary:

The Hooghly-Matlah estuarine system, located within the State of West Bengal, India span into 0.8 million ha (8029 km^2) is forming one of the largest and most productive estuarine systems in the world. The system lies with the geographical coordinates, 20° 35' to 23° 20' N and 87° 45' to 89° E, covering a network of many estuarine distributaries and creeks apart from the principal river. The Hooghly Matlah estuarine system known for its high faunistic richness forms the mainstay of the capture fisheries of West Bengal. It sustains a major multi-species commercial fishery providing a source of livelihood to several lakhs of fishermen and supporting a flourishing trade (Mitra *et al*., 1999). Now the faunistic richness is low which may be due to pollution, land development, dams, water quality degradation and over exploitation.

Rushikulya estuary:

Rushikulya estuaries, one of the major estuaries of Orissa, is a perennial river, one of the major rivers that drains into the Bay of Bengal. The river flows from the Daringbadi hill station in Kandhamal district and flows through the Ganjam district for a distance of 165 km with a total catchment area of 7,700 km^2 (lat 19°22' and 19°24' N; long. 85°02' and 85°05' E). As the catchment is rich in mineral wealth, there are about 3,360 numbers of small-scale industries of different categories, mainly food and allied, forest and wood based, rubber, plastic products, glass and ceramics. Domestic sewage also contributes a significant component of pollutant reaching the river. These industries and untreated sewage have directly or indirectly affected the river water quality (Subrat *et al*., 2020). The estuary accommodates and accounts for mass nesting of Olive Ridely Seaturtles and known as one of the world's major rookeries (arribada) in India (Panday *et al*., 1994).

Godavari estuary:

The Godavari estuary is a typical positive estuary with a mean width of 1.5 km and an average depth of 12 to 15 m. The river Godavari is India's second longest river after the Ganga. At Dowaleswaram (16°56'59.99" N 81°44'59.99" E) it branches into two main distributaries called Vasistha Godavari and Gowthami Godavari (Reddy *et al*., 1994). The two distributaries together constitute the second biggest river-estuarine system along the east coast of India. The Gautami-Godavari is again subdivided into Neelaveru and Vrudha. The Vasishta-Godavari is joined by a tributary called Vainateyam Godavari. The entire Godavari estuarine system covers an area of 330 km^2, extending upto Narsapur and Kakinada (Venkateswara Rao and Srinivas 2020). Vasistha Godavari estuary is the source of water for both inlet and outlet for aquaculture farms. Effluent discharges from shrimp farms are the major source of pollution.

Krishna estuary:

The Krishna River is the second largest eastward draining, Perennial River in the Peninsular India. The river Krishna drains an area of 258,948 km^2, which is nearly 8% of the total geo-graphical area of the country. The Krishna estuarine system covers an area of 320 km^2 with its three tributaries such as Nadimeru, Golumuttaapaya and Hamsaladevipaya. It is a mesotidal estuary with a tidal range of 2-3 m associated with strong currents of 1.2 m. Suspended matter concentration is highest during the southwest monsoon (Krishna *et al*., 2017). The variation of physio-chemical parameters mainly depends on monsoon rains and also other sources of freshwater. The fluctuations in physio-chemical parameters influence the biological activity and productivity of aquatic organisms. Water is the

basic need for the life sustenance and propagation of aquatic organisms especially larvae and juveniles. The continuous discharge of effluents to the estuarine ecosystem may directly or indirectly influence the benefit of Krishna estuarine region.

Pulicat Lake:

Rayala Vagu and Kalangi estuaries, popularly called as Pulicat lake is situated (lat. 13°24'-13°47' N; long. 80°2'-80°16' E) on the east coast and covers an area of 77,000 ha. is the second largest coastal lake in India located 40 km north of Chennai city, Tamil Nadu, India. The lake is about 60 km in length and 0.2 to 17.5 km in breadth and separated from the Bay of Bengal by an inland split called the Sriharikota Island. The main source of freshwater is land runoff through three small seasonal rivers that open into the lake viz., Arani, Kalangi and Swarnamukhi (Dhinamala *et al*., 2016). The Buckingham canal, which runs parallel to the Bay of Bengal, brings in the industrial and domestic wastes to the lake and eventually to the Bay of Bengal. The hydrology of the Pulicat lake is influenced by local climate, the regime of the inflowing rivers, the Buckingham canal that enters the lake, in addition to the effect of the neritic waters of the Bay of Bengal. Pulicat lake, harbours many euryhaline species and serves as a nursery for several marine species and a very few secondary freshwater fishes. The industries located around Pulicat lake are discharging effluents indirectly into the lake and the point sources of pollution mainly comes from North Chennai thermal power plant, Ennore port activities, Manali petrochemical industries, other nearby industries and untreated urban wastes from Chennai metropolitan city (Dhinamala *et al*., 2016).

Ashtamudi estuary:

Ashtamudi estuary situated in the Kollam district, part of a Southern Kerala. The lake is located between the latitudes of 8º 31'–9º 02' N and 76º 31'–76 º 41' E, respectively. It has near about of 32 km^2 water spread area and known as second largest estuarine system in Kerala. It is characterised by its palm shaped wider water body. It consists of eight prominent arms. The major source for fresh water discharging to the lake is the Kallads river. This fresh water river originates from Western Ghats with an annual discharge of 75 x109 m^3 of water. The lake meets with the Arabian Sea at the location called Neendakara. Some of the major and minor drainage channels loaded with waste products from municipal and industrial sources join the lake at the southern end (Sunitha *et al*., 2018).

Backwaters of Kerala:

The backwaters of Kerala comprise a system of inter-connected lagoons, bays and swamps penetrating the mainland. The total area of Kerala backwaters is estimated to be 500 km^2. A total of 41 rivers originates from the Western Ghats and drain into the Arabian Sea through the backwaters. Huge quantity of freshwater is brought in by the five rivers, viz, Achancoll, Pamba, Manimala, Meenachil and Mooruttupuzha which meet the backwaters south of Cochin. The tidal influx is greatly attenuated during the monsoon period when continuous ebb was observed. The tides at Cochin are mixed and is semidiurnal type with average amplitude of 0.9 m. The Vembanad, the largest among the Kerala backwaters, extends from Cranganore in the north to Alleppy in the south, a distance of 96.5 km. The total area of the water body is 256 sq. km (Nagaraj, 2018). The northern portion of the Cochin backwaters is called the Varapuzha lake, while southern is termed as the Vembanad lake. The upper reach of the Cochin backwaters connected to the Arabian Sea by a 450 m wide channel with 5-15 m deep and is marked with flushing of the estuary with ebb tides.

Amba estuary:

Amba is a minor river originates in the Western Ghats and opens in the Mumbai harbour at Rewas (Lat. 18°45' N and Long. 73°10' E). The Amba estuary is seawater dominated during the dry season and salinity reaches as high as 27 ppt. at Nagothana. The river discharge is very high during

monsoon and is completely flushed out and the salinity was as low as 0.05 ppt even during flood tides. The estuary is well mixed vertically during the dry season. However, occasional stratification was observed at the mouth during monsoon (Gajbhiye, 1995).

Bahuda estuary:

Bahuda estuary is situated between latitude 19°3' N-19°10' N and 84°E on the extreme southern part of the Odisha State, India. It originates from Mahendragiri hills, traverses the distance of 47 km, and opens in Bay of Bengal at Sonepur of Ganjam district (Odisha). The estuary covers an area of 15 km^2 within average depth of 2.6 meter and is connected with Bay of Bengal from the lagoon by a channel of about 3 km. The estuary shows shallowness except in the monsoon flux from land drainage system (Prabhat and Padhy, 2012). According to Durga *et al.* (2021), the type and magnitude of human activities in the estuarine and coastal area of the Bahuda estuary showed significant influence in the water quality parameters of the estuary.

Mahanadi estuary:

Mahanadi is one of the major rivers in India, the Mahanadi estuary is consisting of Devi and Mahanadi estuaries, the former flowing into the sea in the south-east region of the district and the latter formed by the northern branch of the main river which join together as they approach the sea and eventually empty into the Bay of Bengal under the name of parent stream. The main estuary has several mouths but the principal is the one which debouches through the shoals, south of False Point light house (lat. 20°18' N; long. 86°43' E) (Das *et al*., 1997). The costal and estuarine environment is under stress of municipal sewage and industrial effluent discharge by receiving huge water inputs of contaminants which could be hazardous to the living organisms. The organic sewage is reflected through the high BOD and lower DO in the Mahanadi estuary during low tide (Mukunda *et al*., 2012). Physical and biological parameter input alter the ecology of the costal environment that causes greatly affecting the overall biotic community of the ecosystem.

Chilika Estuary:

Chilika (lat. 19°28'; 19°54' N; long. 85°67'; 85°35' E), the largest brackish water lagoon in Asia, has been designated as a Ramsar site on the Ramsar Convention of Wetlands in 1981. The shallow water body (average depth 2 m) is about 65 km in length, spreading from northeast to southwest parallel to the coastline with a variable breadth reaching 20.1 km. The lagoon is spread over an area of 950 km^2 during summer, which swells up to 1165 km^2 during monsoon (Siddiqui and Rama, 1995). The lagoon has several hydrological influences. Important among them are (i) drainage from unregulated degraded catchment basin lying on the western and southern boundaries, (ii) silt borne fresh water discharges from the distributaries of Mahanadi River, and (iii) exchange of lagoon water with Bay of Bengal. Changes in the strength and nature of these hydrological connections can have drastic and potentially unexpected consequences for the lagoon. The spatial and temporal salinity gradients caused due to fresh water flow from the riverine systems and seawater intrusion under tidal influence gives it the characteristics of an estuarine ecosystem (Satyanarayan *et al*., 2007).

At present, the lagoon is severely threatened by problems like shrinkage of water spread and decrease in depth due to siltation, fall in salinity, macrophyte infestation, eutrophication and loss of biodiversity. Anthropogenic activities related to the processes influencing the quantity and quality of water of Chilika lagoon are agriculture drainage, river run off containing urban sewage and drainage from the agro based industries (prawn processing units). These types of inputs alter the ecology of the lagoon severely and also affecting the overall biotic community of the ecosystem. Accumulation of huge amount of silt gradually decreases the depth of the lagoon and helps intensification of macrophyte growth. The role of fresh water influx is critical in bringing salinity changes and cyclic growth and decomposition of

macrophytes in the lagoon (Satyanarayan *et al*., 2007).

Adyar estuary:

Adyar river (13° 05' N latitude, 80° 15' E longitude) is one of the three rivers that flowing in Chennai district. Two streams, one starting near Manimangalam village and the other starting near Guduvancheri join near Tambaram. It starts to appear as a river with well-defined banks only from the point and receives the surplus water from Chembarambakkam lake near Thiruneermalai. It flows through Kanchipuram, Tiruvallur and Chennai district for about 42.5 km before joining the Bay of Bengal in Adyar, Chennai. The river is dry most of the time and has free flow of water only when Chembarambakkam lake overflows. A lot of slums and industries are located along the banks of the river. It also receives run off and sewage outlets from the Chennai metropolitan city (Sasikumar *et al*., 2018).

Mahi estuary:

The Mahi estuary is a permanent tropical estuary and one of the major estuaries on the Gulf of Cambay, west coast of Gujarat in India. The estuary is situated at Latitude 22°17′ N and Longitude 72°13′ E. The Mahi River has a length of 800 kms and a total basin of 1,036,200 km^2. After traversing the Panch Mahal, Vadodara and Charotar plains, it joins the northern part of the Gulf of Khambhat near Camboi at Kavi, forming a broad estuarine stretch extending to Mohammadpura, approximately 50 km inland. Along its course, the river receives industrial effluents released from many chemical and fertilizer industries in and around the Vadodara industrial area. This is the major source of pollution into the estuary (Nirmal *et al*., 2013).

Uppanar estuary:

The Uppanar (latitude, 11º42'N; longitude, 79º 49' E) estuary is situated closely in the Southeast coast of India. In Uppanar estuary during the past few decades, industrial development has increased three times with many large and small-scale industries being established along the riverbank. These include production of fertilizers, dyes, chemicals and mineral processing plants, and metal-based industries (Ajmal *et al*., 2014). The effluents from the industries find their way into river Uppanar through small channels and pipelines.

Vellar estuary:

Vellar estuary, (lat.11º29'N; long.79º46"E) located in Parangipettaicoast, south east coast of India, which is relatively pristine in nature, is known to receive mostly agricultural run-off from nearby agricultural fields (Ajmal *et al*., 2014). The river Vellar originates in the Shervaroyan hills of Salem District in Tamil Nadu. After meandering through a distance of 480 km, it forms an estuarine system at Parangipettai (Porto Novo) before joining the Bay of Bengal.Vellar estuary having artificially developed mangroves within it and lying close to the Pitchavaram mangroves is a relatively clean estuary with no major sources of pollution other than sewage and agricultural run-off.

Kollidam estuary:

Kollidam estuary is located at Pazhaiyar in northernmost tip of Nagapattinam district of Tamil Nadu, SE coast of India. Kollidam (Coleroon) estuary which is formed by the river Coleroon and is a tributary of the river Cauvery and it joins with the Bay of Bengal at Pazhayaru (lat. 11° 29' N; long.79° 50' E) at Tamil Nadu (Ramesh *et al*., 2020). The Kollidam is the northern distributary of the Kaveri River as it flows through the delta of Thanjavur. The main water source of Cauvery River is rainfall of South West monsoon and it originate from Coorg, Karnataka.

Mandovi and Zuari estuary:

The Mandovi and Zuari estuaries (lat. 45°54'-5°48' N; long. 73°40'-74°20' E) forms an integral part of the Mandovi-Zuari–Cambarjua canal system on the central west coast and drains into the Arabian Sea at Goa. The Mandovi estuary is fringed with extensive mangroves and opens into the Arabian

Sea. A high runoff of relatively easily degradable organic matter and recalcitrant matter from the leaf litter and inorganic particles from terrestrial regions comes into the estuarine system during the southwest (SW) monsoon season. This input of litter may be retained in the estuary either by sinking or re-suspension. Thus, the Mandovi estuary receives autochthonous and large allochthonous inputs from different sources, i.e. riverine discharge (particulate and dissolved matter) and mangrove leachate (Maria *et al*., 2009).

Ennore estuary:

Ennore estuary receives major amount of untreated domestic sewage from north Chennai area and untreated or treated industrial effluents from Manali Industrial Belt, which houses many refineries and chemical industries. The dredging activities in Ennore area result in changes in the landscape, sediment transport and dust pollution to the coast by quarrying process. Southern arm of the creek is well developed with industries, utilities, suburban residential areas and fishing hamlets (Mohan *et al*., 2013a). Northern section of the creek is connected to the Pulicat lagoon and has two major developments -- North Chennai Thermal Power Station (NCTPS) and Ennore satellite port has chocked the mouth of the Ennore creek. Raw municipal sewage, industrial trade effluents and industrial cooling waters all of them make it through Buckingham canal, enters into Ennore estuary and eventually drains into the Bay of Bengal of Chennai coast (Mohan *et al*., 2013a) So long as the assimilating capacity of the water body is not exceeded, the ecosystem is able to recover from additional stresses without permanent damage.

Threats to estuary:

Throughout history estuaries have been favoured locations for human settlement for which a major attraction has been easy access to sea routes for trade. Ports have been located on estuaries because they provide sheltered anchorage. Shipyards too are located there for the same reason. Nowadays estuarine and coastal areas are favoured locations for power plants and petrochemical complexes because they use seawater as coolant. Chemicals and fertilizer industries have used estuaries and coastal areas for discharging effluents (Mohan *et al*., 2013b). In the absence of sufficient quality-controlled data on dissolved trace constituents such as heavy metals, pesticides and hydrocarbons, the environmental status of our estuaries with respect to these contaminants remains uncertain. It has been observed that the sediment in certain waters contains high levels of heavy metals like Cadmium, Copper, Zinc and Lead (Mathumitha *et al*., 2021). The mercury content in some of the marine organisms at certain places has been found to be higher than the normal which may alter the genetic makeup of species (Mohan *et al*., 2020). The fly ash deposits from thermal plants at certain places are on the increase and it changes the topography of the affected area and the chances of species depletion and replacements are inevitable.

Hence, estuaries in India have come under severe anthropogenic impact. In addition, the Climate Change threats loom on the horizon. While the Climate Change impacts are worrisome, greater concern today is from anthropogenic impacts on the estuaries arising from discharge of civil and industrial effluents. Three of India's largest cities, Mumbai, Chennai, and Kolkata, are located on the banks of an estuary. Discharge into these estuaries has led to problems that need immediate attention.

Conclusion

Gathering data on the large number of estuaries poses a challenge. Educational institutions, colleges, and university departments could be encouraged to take up study of estuaries located in their proximity. This would provide opportunities to faculty of educational institutions to participate in real world environmental data gathering and research. It would also offer students first-hand experience in environmental studies and enlarge their awareness of current environmental issues. Cleaning up of the badly affected Indian estuaries

and bringing them back to health will also need a legal framework to ensure that management plans are implemented to produce desired results. Hence, it will require suitable legislation which in turn will need public awareness of the problems that our estuaries are experiencing today.

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