

Major Estuarine systems of India and their Fisheries

Estuaries are the transitional zones between the rivers and sea and have specific ecological properties and biological composition. Estuaries offer immense biological wealth characterized by the diversified rich flora and fauna including fisheries. The term estuary may be defined as the tidal mouth of a great river, where the tide meets the current". It is a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with freshwater derived from land drainage. A more comprehensive definition that an estuary is an inlet of the sea reaching into a river valley as far as the upper limit of tidal rise near being divided into three sectors: (a) a marine or lower estuary, having free connos with the open sea, (b) a middle estuary subject to strong salt and freshwater mixing, and (c) an upper or fluvial estuary, characterized by freshwater but subject to daily tidal action. The limits between these sectors are variable and subject to constant changes in the river discharge. A new functional definition is an estuarine system is a coastal indentation that has a restricted connection to the ocean and remains open at least intermittently. The estuarine system can be subdivided into three regions: (a) a tidal zone, (b) a mixing zone - the estuary proper, and (c) a near shore turbid zone. This definition of estuaries includes the adjacent coastal waters. The salinity of the estuarine waters varies between 0.5 and 35‰. Estuarine water is extremely variable in its salinity, while marine and freshwater have distinctive stable salinities.

Classification of estuaries

Based on environment

There is a lack of uniformity among tropical estuaries in terms of size, depth, physical and chemical features and other environmental factors such as the nature of the adjacent marine and freshwater habitats. The tropical estuarine environment can be divided into four broad categories, viz. (1) open estuary, (ii) estuarine coastal waters, (iii) blind estuary, and (iv) coastal lake.

Open estuaries:

These estuaries are never isolated from the sea. The extensive delta of the Ganga river forms the countries largest estuarine system (Hooghly - Matlah) in the Indian Ocean. The tidal impact of the system is felt up to 200 km from the mouth, The Mahanadi and Godavari are also open type of estuaries.

Estuarine coastal waters:

The effect of the discharge from the Ganga (Hooghly) is felt more than 100 km in the Bay of Bengal. The shallow nature of such tropical coastal waters and their physical conditions of lowered salinity and high turbidity make them at least partly estuarine in character, particularly as regards their fish fauna.

Blind estuaries:

The estuaries in this category are usually relatively small, both in length and catchments areas. During summer these estuaries are temporarily closed by a sand bar across sea mouth and during this period there is no tidal range and thus no tidal currents. The mouth opens only during the rainy season and at that time a normal estuarine salinity gradient is established. A number of this type of estuaries are located in Tamil Nadu and Karnataka coasts.

Coastal lakes:

The coastal lakes have some form of connection to the sea and at the same time they receive freshwater through a river or number of rivers. Two of the best examples of coastal lakes in the country are Chilka (Odisha) and Pulicat (Andhra Pradesh) on the east coast. Both support important fisheries. The former is the largest brackishwater lake in India.

Based on the pattern of salinity distribution

Estuaries can be divided into three main groups based on the pattern of salinity distribution, viz. positive, negative, and neutral estuaries.

Positive estuary:

When the freshwater inflow exceeds evaporation, the estuary is defined as positive estuary. In positive estuary, the outgoing freshwater float on top of the saline water that has entered the estuary from the sea and water gradually mixes vertically from the bottom to the top.

Negative estuary:

When evaporation exceeds the freshwater inflow, the estuary is defined as negative. In a negative estuary the sea and freshwater both enter estuary on the surface and after evaporation they leave the estuary as an outgoing bottom current. Higher rate of evaporation increases the value of surface salinity

Neutral estuary:

Evaporation and freshwater inflow are in approximate equilibrium and in such situation a static salinity regime occurs. This category of estuaries are almost absent as evaporation and freshwater inflow are never equal.

Geomorphic classification

Based on geomorphology estuaries can be divided into four main groups.

Coastal plain estuaries (Drowned river valleys):

They are the most common types of estuaries and are formed by the lower reaches of river valleys and drowned river mouths. They are formed by a rise in sea level when river valleys became increasingly more flooded by melting glaciers. Estuaries of this type are generally elongated and shallow, branched and irregular in outline and at the upstream end all receive a river or a number of rivers. These estuaries are regarded as true estuaries. Most of the Indian estuaries belong to this category

Bar-built estuaries: The extensive development of sand bars parallel to coastline in the form of a chain of islands, may enclose a large shallow body of water receiving the freshwater discharge of a number of rivers. The enclosed shallow area may develop into a large estuary. Normally, this type of estuaries has narrow connection with the sea, e.g. Vellar estuary of Tamil Nadu.

Tectonically produced estuaries

The former is produced due to land subsidence or land slide or volcanic eruption.

Fjord type estuaries

Fjord is glacially over deepened valleys into which sea water penetrates.

Estuaries of East coast**Hooghly-Matlah estuarine**

The Hooghly-Matlah estuarine system located (latitude 21° 23'N and longitude 88°-89'E) in West Bengal is the largest among the estuaries on the Indian coast covering the Gangetic delta called Sundarbans which is the world's largest delta endowed with largest mangrove vegetation (4,264 km²) in India. The total area of the estuarine system is about 8,029 km². The Hooghly estuary (main channel) is a distributary of the river Ganga. The annual flow of freshwater in the Ganga is estimated at 142.6 billion m³ resulting from the melting of snow in the Himalayas during the spring, summer, and monsoon from June to September. The river Ganga has an annual runoff of 493 km and carries 616x10 tonnes of suspended solids to the Hooghly estuary. Whereas, the

annual flow rate is reported to be 67,200, 16,200 and 62,100 million cubic feet from the main Hooghly channel, Damodar and Rupnarayan rivers, respectively, and the latter two rivers are the main tributaries of the Hooghly. It is a positive estuary of mixohaline in nature exhibiting semi-diurnal type of tide. The active tidal regime is felt up to a distance of 200 km which was felt up to a distance of 300 km upstream during pre - Farakka barrage period. Tidal characteristics, spring and neap tide pattern at the mouth of the estuary is the highest for the east coast. Tidal high water elevation is 5.7 m on an average and the highest recorded is 7 m.

Texture of the bed soil and water quality:

The estuarine soil is alluvial and mostly silty clay loam in texture. The soil salinity is highest from April to May. The pH values range between 7.8 and 8.8. The texture of the estuary bed (sediment) contains 25.0 to 55.0% sand, 25 to 58% silt and 18 to 36% clay. After commissioning of Farakka barrage in 1975, the main Hooghly estuary is fed directly by the Ganga. The additional discharge of freshwater into the system has changed the ecology of the estuary. These changes significantly affect the biological and physico-chemical factors responsible for plankton, benthos and fish production.

Fisheries:

A total of 172 species of fishes are recorded from the estuary, of which 73 occupy the freshwater zone and 99, the higher saline (lower) zone. The impact of the fishery resources of the estuary after commissioning of barrage is the improvement of general habitat of certain prawn and fish resources. As a result, the annual average prawn and fish yield from the estuarine system increased from 3,204 tonnes during 1960-61 to 61,194 tonnes during 1998-99, and to 117,639 tonnes 2010-11 (CIFRI data) The average contribution of the fish species in this fishery were hilsa, *Tenualosa Harpadon nehereus* (11.3%), *Pama pama* (5.7%), *Setipinna* spp. (4.7%), *Trichurus* spp. (4.2%) and penaeid prawns (4.35%). Other important fish species were *Polynemus paradiseus*, *Polydactylus indicus*, *Eleutheronema tetradactylum*, *Lates calcarifer*, *Pangasius pangasius*, *Liza parsia*, *L. tade*, *Rhinomugil corsula*, *Pampus argenteus*, *Coilia dussumieri*, *Mystus* spp., *Johnius dussumieri*, *Sillaginopsis panijus* etc. Among prawn species, *Penaeus monodon*, *P. indicus*, *Metapenaeus brevicornis*, *M. monoceros*, *Parapenaeopsis sculptilis*, *P. stilifera*, *Macrobrachium* spp. were the most important. Declining trend in the availability of certain fish and prawn species, viz. *Liza* spp., *Lates calcarifer*, *Plotosus canius*, *Eleutheronema tetradactylum*, *Pangasius pangasius*, *Penaeus monodon*, *Metapenaeus dobsoni*, and *M. monoceros* in the estuary was

observed. Whereas certain freshwater fish, viz. *Eutropichthys vacha*, *Clupisoma garua*, *Wallago attu*, *Sperata seenghala*, *Ompok bimaculatus*, and *Rita rita*, made their appearance in freshwater stretch of the estuarine system. Size range, season of abundance, feeding habit, size at first maturity, recorded.

Mahanadi estuary

Odisha has several estuaries, of which Mahanadi estuary (latitude 20°18'N and longitude 86° 43'E) forms the important fishery. It is a medium type estuary, the total approximate area of this estuarine system is 30,000 ha, opens into the Bay of Bengal at Paradip along with two distributaries, viz. Devi and Looni. The tidal influence of this estuary is felt up to 42 km upstream from the sea face where mangroves occupy about 120 km-region. Odisha has rich mangroves in the Mahanadi deltaic region in Cuttack district. The tides are semi-diurnal in nature this estuary with considerable variation between spring and neap tides. The maximum tidal elevation in the estuary is 2.85 m. The annual flow rate is reported to be 66,640 million m³.

Texture of bed soil and water quality:

The texture of the estuary bed contains 79.70 to 92.00% sand, 1.30 to 7.7% clay silt and 4.3 to 12.6% clay. The predominantly sandy bed of the estuarine stretch appears to be very less productive. The soil reaction indicated neutral to alkaline and the pH varies from 6.8 to 8.3 (average 7.3). The salinity values in the upper freshwater (tidal) zone range between 0.04 and 0.08 g/ litre, while in the gradient (brackishwater) and lower marine zones the values vary from 0.04 to 7.61 g/litre and 0.20 to 31.61g/ litre respectively. In summer, the estuary hardly receives any significant amount of freshwater and the salinity at the estuary mouth varies between 16.99 and 31.61 g/ litre. The water temperature regime of the estuarine stretch varies between 28.5° and 30.8°C with minor fluctuations. The transparency of water range from 66.0 to 69.0 cm in the upper estuarine stretch, whereas the values were 35.6 to 47.0 cm in the lower estuarine stretch between Kujang and Paradip. The estuarine water maintains higher pH ranging from 8.04 to 8.25 dissolved oxygen content, 6.7 to 7.9 mg/lit.

Biotic communities:

The average net plankton abundance of the estuary varies between 60 and 280 numbers/liters. Plankton population is poor during monsoon in the estuary than pre-and post-monsoon. A sharp dominance of phytoplankton was observed over the entire estuarine stretch with highest percentage of Chlorophyceae 523 Myxophyceae 22.8 and Bacillariophyceae 14.8 in

abundance. Among zooplankton copepode (4.0%), rotifer (2.1%) and cladocera (0.4%) are the major groups. Macr benthic fauna of the estuary is principally represented by molluscs (gastropods and bivalves), annelid worms, and insects (dipterans).

Fishery:

A total of 134 fish species has been recorded from the entire estuarine stretch between Tirtal and Paradip. In earlier days, the annual yields of prawn and fish (dry and fresh) from the estuary varied between 651.0 and 802.2 tonnes from 1960-61 to 1963-64 with an average of 646.3 tonnes. While an improved Isevel of yield was observed (3, 674.7 tonnes) during 1996-97. However, the annual fish production has drastically declined to 110.0 tonnes during 2005-06. The fish and prawn fauna available during 1961-64 were hilsa (2.6 to 38.6%), other clupeids (13.7 to 47.3%), *Mugil cephalus* and *Liza* spp. (22.1 to 44.1%), prawns (12.4%), thread fins (5.4%), *Lates calcarifer* 3.7%, sciaenids (4.9%), catfishes (1.9%) and miscellaneous (10.6%). Presently, a total of 90 species of fish and prawn are recorded in the commercial fish landings and the fish composition mainly comprises of mullets, viz. *Mugil cephalus* and *Liza* spp. (18.2%), prawns (14.2%), *Harpodon nehereus* (10.9%) and others Presence of both adult and juvenile hilsa is recorded in the estuary during monsoon months. The post-larvae of *Penaeus monodon* were also encountered almost through out the year.

Fishing gears:

The main fisheing gears operated in the estuary are gill net (Chandijal), seine net (Ghaijal), bag net, drag nets, small drift nets (charajal), large seine (Berjal) and boat seine (Torania).

Godavari estuarine complex

The Godavari estuarine complex (18,000 ha in area) on the Andhra coast is the second largest estuarine system in the country. It is located between latitude 16° 51'N and longitude 82° 05'E). At the estuarine zone, Godavari divides itself into two distributaries, viz. Gautami and Vasistha, the latter is again divided into Vasistha proper and Vanatheyan to meet the Kakinada Bay. On the other hand, two branches of Goutami, viz. Coringa and Goderu, meet the sea through mangrove swamps (180 km²). Gautami is the main estuary of the system where tidal influence is felt up to 45 to 48 km from the sea face. The annual freshwater discharge of Godavari varies from 80,137 m³ /sec during monsoon months.

Texture of bed soil and water quality:

Soil texture of the system is predominantly sandy loam. The present texture of the estuarine bed from Yanam to Narsapur contains 77 to 81% sand, 8 to 11% silt, and 11 to 12% clay; and the soil pH of this stretch varies between 7.7 and 8.4. The surface water temperature fluctuates from 24.5° to 32.9 °C. As regards water transparency, a wide range from 10 to 120 cm is observed. The other important chemical parameters of the estuarine stretch are as follows, salinity 0.5 to 33.5 g/litre; DO 6.9 to 10.2 mg/litre; pH 7.5 to 8.2; nitrate 0.02 to 0.05 mg/litre; phosphate 0.01 to 0.015 mg/litre, and silicate 0.1 to 16.2 mg/ litre. The maximum rate of gross primary production, 1.619 g C/m²/day (av. 0.858g/C/m/day) indicates the higher productivity of the estuarine system.

Biotic communities:

Phyto- and zoo-plankton contribute 18.46 to 46.51% and 53.49 to 81.54%, respectively, in number of total plankton abundance in the estuarine stretch between Yanam and Narsapur. Major groups contributing phytoplankton were Bacillariophyceae, Chlorophyceae and Myxophyceae in abundance. Among zoo plankton, copepods, rotifers, dinophyceae and cladocerans are the main groups. The bottom macro-benthic fauna is characterised by poor diversity with only molluscs occurring in estuarine stretch. The macro-zoobenthic density ranged between 500 and 1,890 numbers/m², of these gastropods and bivalves contributed 72.15 and 27.30% respectively.

Fisheries:

Earlier studies during 1960s revealed that a total of 185 species of fish was recorded from the estuary among which 72% were euryhaline, 12.2% almost marine and 15% freshwater. Freshwater species were recorded only during flood season. The mullets, viz. *Mugil cephalus*, *Valamugil speigleri*, *Liza subviridis*, *L. macrolepis*, *L. oligolepis (melinoptera)*, *Valamugil seheli*, constituted one-third of the fish catch. Other important commercial fish species were *Pristipoma hasta (Pomadasy argenteus)*, *Leiognathus sp.*, *Gerres filamentosus*, *Caranx sp.*, *Sillago sihama*, *Gobius sp.*, *Sciaena (Daysciaena) albida*, *Platycephalus maculipinna*, *Lates calcarifer* etc. Total annual fish landings of the Godavari estuary along with the contribution made by its branches, viz. Vasistha-Vainathayan were 3,916.0 tonnes and 3,156.13 tonnes between 1963-64 and 1964-65 respectively. Among the contribution of different fish groups during 1963-64, prawns and crabs were dominant (57.8%) followed by Mugil Spp. (13.14%), shark and rays 8.9%, pomfrets (6.6%), mackerel (4.75%), clupeids (3.5%), ribbon fish (3.3%) and perches (1.7%). The most dominant species among the prawns were *Metapenaeus monoceros*, *Penaeus indicus*, *P. monodon*, *M.*

dobsoni, *M. affinis*, *M. brevicornis*, etc. Composition of fish and prawn species during 1964-65 was a bit different from 1963-64. During 1964-65, the major contributors were prawns 29.18%), clupeids (18.1%), *Trichurus* spp. (5.5%), *Mugil cephalus* (4.4%), pomfrets 3.5%), *Arius sona* (2.9%), *Scomberomorus guttatus* (1.5%) and miscellaneous fishes (23.08%). However, the annual yield of fish and prawn was found highest (5,000 Conne) during 1969. Species composition of prawns comprised *Macrobrachium malcolmsonii*, *Metapenaeus monoceros* (42.6%), *Penaeus indicus* (24.5%), *P. Monodon* 220 (10.9%), *M. dobsoni* (3.9%), *M. affinis* (3.6%), and *M. brevicornis* (2.0%). The average annual landings of fish and prawn from the estuary showed a decreasing trend. Presently the dominant species contributing the fishery in the estuarine stretch are *Mugil parsia* *M. cephalus*, *Lates calcarifer*, *Thryssa* spp., *Pseudosciaena coibor*, *Arius* spp. and *Gerres* spp. A total of 68 species of fishes belonging to 37 families and 12 orders was recorded from the estuarine system besides seven species of prawn and four species of crab. *Anadromous hilsa*, *Tenualosa ilisha* is one of the most dominant species in this estuary during monsoon months (September-November). Upstream migration of hilsa was restricted up to Dowleswaram anicut situated 97 km upstream from the estuary mouth.

Fishing gear:

A number of different types of gears are deployed in the estuarine system. The most important gears are drift gill net (Teluvala), bag net (Gidasavala). seine net etc.

Krishna estuarine system

Krishna is the second largest estuarine system (Latitude 16° 15'N and longitude 82° 05'E) in Andhra Pradesh. The entire system is estimated to be about 320 km. Before it (Krishna proper) meets the sea, it divides into three distributaries, namely Krishna proper in the west, Gollumuthapaya in the east, and Nadimeru in the middle. The tidal effect is felt up to 6 to 22 km from the mouth of the estuary depending on the month of the year. The tidal high water elevation is 2 to 3 m on an average. Inadequate freshwater influx into the estuarine system because of the construction of the barrages across the river has greatly affected the usual flow pattern of the system. A considerable increase in the salinity all over the estuary has been observed barring monsoon. On the whole, the ecology of estuary has undergone a major change.

Texture of the bed soil and water quality:

The bed soil of the estuarine stretch contains trace to 8.0% clay, nil to 62.54% silt and nil to 91.43% fine sands as well as 1.23 to 98.0% coarse sand. The soil reaction was slightly acidic

(6.32) to alkaline 8.57. Low values of pH were observed during summer while higher during monsoon and post-monsoon. The mean surface water temperature of the system varied between 29.16° and 31.67°C indicating extended summer in the area. The salinity value at Hamsala and Gollalamodha located at the lower zone of the estuary fluctuated between 18.4 and 35.6 g/litre. A wide fluctuation of dissolved oxygen values was observed in the estuarine system, which varied between 4.8 and 8.0 mg litre. while relatively lower DO values were observed in lower zone compared upper and gradient zones. The entire estuarine system maintained slightly higher ranging from 7.4 to 8.5. As regards phosphate, nitrate and silicate contents the values ranged from 0,02 to 0,36 mg/litre, 0.012 to 0.45 mg/litre and 0.7 to 13.3 mg/litre. respectively.

Primary production:

Gross primary production varies greatly depending upon climatic factors as well as turbidity of water. Gross and net primary production varies from 25 to 187.5 mg C/m/hr and 15 to 156.2 mg C/m/hr respectively. Maximum primary production is observed during monsoon and post monsoon months. Lower is zone more productive compared with upper zone of the estuary.

Biotic communities:

The annual production of plankton in the system varies from 249 to 503 nos/litre. Maximum density is observed during pre-monsoon and minimum in the monsoon. The bulk of plankton constituted by phytoplankton (69.3%), represented by Bacillariophyceae (68.23 to 90.08%), Dinophyceae (18.30 to 22.63%), Myxophyceae (3.56 to 6.25%), Chlorophyceae (2.89 to 3.11%) and Xanthophyceae (1.30 to 1.82%) are the principal groups in order of abundance. Zooplankton community (30.7%) is found to be represented by the copepods (45.0 to 62.12%), protozoans (16.15 to 23.0%), rotifers (6.23 to 8.15%) and cladocerans (3.98 to 5.64%) in order of abundance. The average density of macro-benthos varies from 1,091 to 1,217 nos/m². The density is maximum in the gradient and upper zones (67%) and minimum in the marine zone (33%). Gastropods 69.2%, bivalves (17.9%), insects (7.2%) and annelids 15.79) are the main forms. Benthic population did not show any marked seasonal variation.

Fisheries:

A total of 47 fish species belonging to 30 families and 40 genera are recorded from the estuary. The availability of freshwater and oligohaline species are meagre as hyper-saline condition is observed in the estuarine stretch almost throughout the year barring a short period of monsoon. Even then a wide variety of fish and prawn diversity was observed in this estuary. The

total fish and prawn yield from the estuary during 2004-05 was estimated as 496.1 tonnes. The dominant species contributing the fishery were *Mugil cephalus*, *Liza parsia*, *Liza macrolepis*, *clupeids* (*Tenuulosa ilisha*, and *Hilsa kelee*). *Chanos chanos*, *Lates calcarifer*, *Sillago sihama*, *Mystus vittatus*, *Scatophagus argus*, *Etroplus suratensis*, *Rhinomugil corsula*, *Polydactylus indicus*. *Valamugil cunnesius*, *Rastrelliger kanagurta*, *Caranx spp.*, *Therapon jarbua*, *Arius spp.*, and *Trichurus spp.* in the entire estuarine system. Among prawns, *Penaeus monodon*, *P. indicus*, *Metapenaeus monoceros*, *M. brevicornis*, *M. dobsoni* were available. Mulletts alone contributed to the tune of 80% of the total yield of the estuary of which the contribution of *Mugil cephalus*, *Liza parsia* and other *Liza Spp.* was 48, 21 and 11% respectively. Catfishes, perches, sciaenids, clupeids, penaeid prawns and crabs contributed the rest 20% of the total catch. Presently fishery activities are mainly confined in the lower stretch of the estuary. More than 173 small mechanized and 771 non-mechanized boats are actively engaged in the estuary. The most important Sears are gill net (gidasavala/ eduvala/ teluvala), drag net (laguduvala) and cast net (esuruvala).

Muthupet estuary

Muthupet estuary is situated in Nagai district (latitude 10° 20'N and longitude 79 35'E) of Tamil Nadu. Vennar canal of Cauveri dividing into five channels open to Muthupet estuary and ultimately opens into Palk Bay. The total water spread area of the estuary is estimated to be about 20.000 ha. The 73 species of fishes were recorded from this estuary and of these 2 species were freshwater, 31 species were resident and 40 species were migrants. Out of these, 60 species of fishes were of commercial importance. The annual fish and prawn yield from this estuarine system is about 31 tonnes. The fisheries mainly comprised *Teuualosa ilisha*, *Hilsa kelee*, *Elcualosa thoracata*, *Nematolosa nasus*, *Anguilla bicolor bicolor* *Chanos chanos*, *Plotosus canius*, *Mystus gulio*, *Strongylura strongylura*, *Platycephalus indicus*, *Lates calcarifer* *Arius maculatus*, *Leiognathus equula*, *Johnius belengari*, *Scatophagus argus*, *Pseudapocryptes lanceolatus*, *Glossogobius giuris* etc.

Other estuaries of east coast

Cauvery is another major estuary in Tamil Nadu, but very little is known about fishing potentials of this estuary. Besides Cauvery, east coast of India has innumerable minor estuaries. Some of them are very productive and form substantial fishery Information on landing data for these estuaries is available. The annual harvest of fish and prawn was recorded as 7.2 to 21.6 tonnes from Adayar; 72 tonnes from Kazhuveli (782 ha); 13 tonnes from Ponnaiyar (43 ha); 28 tonnes

from Gadilam-Paravanan (346 ha): 29 to 83 tonnes from Vellar (262 ha); 139 tonnes from Killai (1685 ha) and 90 tonnes from Coleroon (809 ha): 10 tonnes from Kottaikarai, Kottakudi and Malaltas estuaries and 25.5 tonnes from Vaigai during 1970s and 1980s. Manakudy estuary near Cape Comorin has an area of 14.5 ha. Salinity variation was in the order of 4.75 to 11.38%, dissolved oxygen 3.16 to 3.44 ml/litre, nitrate; 5.01 to 14.32 mg/litre; phosphate, 0.70 to 1.13 mg/litre and silicate 27.0 to 77.9 mg/litre. Species composition of these estuaries mostly comprised Mugil spp., prawn, Leiognathus spp., cat fishes etc. These estuaries were found to be potential sources of cultivable fish (mulletts and milk fish) and shrimp (penaeid) seeds.

Chilka lake:

Chilka lake is situated (latitudes 19° 28'-19° 54'N and longitudes 85 05'-85°38'E) on the east coast of India in Puri, Khurda and Ganjam districts of Odisha. It is a pear-shaped brackishwater lake connected with the sea through two openings, viz. the first is a natural feeder channel meets the sea through a single mouth at northern extremities of lake. The second one is a man-made artificial channel meets the sea (Palur Bay) near the confluence of Rasikullya estuary at southern extremity of the lake. Formation of sand bars in feeder channel mouth due to deposition of sediments reduces the width of feeder channel as well as tidal ingress into the lake. It has a water spread area of 906 km² in summer and 1,165 km in flood season. It has vast catchment area of about 3,200 km² and receives 200,000 to 275,000 cusecs monsoon runoff along with 10 to 13 million tonnes of silt annually through various distributaries of river Mahanadi. These distributaries are the main sources of freshwater to this lake. Studies during 1995-96 revealed that the depth of the lake varied from 0.45 to 1.44 m. 1.09 to 1.98 m and 1.00 to 3.47 m during pre-monsoon, monsoon and post-monsoon periods respectively.

Texture of the bed soil and water quality:

Bed soil (sediment) of the lake contains 44.1 to 97.9% sand, 0.31 to 57.1% silt and 1.0 to 40.8% clay. The pH of the bed s varies between 7.0 and 8.8. The water temperature fluctuates between 23.0 and 20.0 e 29.5 and 32.5°C and 29.0 and 31.5°C during post-monsoon, pre-monsoon and monsoon respectively. The salinity of the lake is greatly influenced by the river discharge in the monsoon as well as sea water influx during summer. The salinity value in the lake ranges between 4.9 and 35.4 mg/litre during pre-monsoon season, while monsoon and post-monsoon season the values varied from 0.7 to 14.8 mg/litre respectively, The highest salinity was observed at the areas around Arakhakuda, the confluence of the feeder channel with the lake. The pH of the

lake water range from 8.0 to 8.7. Dissolved oxygen was relatively high (4.2 to 9.1 mg/litre) during post-monsoon period due to violent wind action. Low values of phosphate were recorded throughout the year as 0.04 to 0.12 mg/litre, 0.04 to 0.08 mg/litre and 0.04 to 0.28 mg/litre during pre-monsoon, monsoon and post-monsoon seasons respectively. While moderate to high values of nitrate were found during pre-monsoon (0.28 to 2.52 mg/litre), monsoon (1.4 to 3.60 mg/litre), and post-monsoon (0.06 to 2.49 mg/litre). Primary production from 41.66 to 515.59 mgC/m³/hr, 41.60 to 135.40 mgC/m³/hr and 41.46 to 145.7 mgC/m³/hr during pre-monsoon, monsoon and post-monsoon periods respectively.

Biotic communities:

The plankton production of the lake varies between 35 and 180 nos/litre in pre-monsoon, 15 and 96 mg/litre in monsoon and 8 and 57 numbers/ litre in post-monsoon. The bulk of plankton constituted by phytoplankton and occupied 53.4 to 93.3% of the total population. Among phytoplanktons, Bacillariophyceae, Chlorophyceae and Myxophyceae were the principal groups while zooplankton was represented by the copepods, rotifers and protozoans. The density of macro-zoo benthos varied from 5 to 1,300/m². 7 to 136/m², and 3 to 533 /m² during pre-monsoon, monsoon and post-monsoon seasons respectively. The dominant groups were gastropods, bivalves and polychaetes.

Fisheries:

In Chilka lake, 217 fish species comprising 147 genera, 71 families and 15 orders were recorded. The annual fish and prawn yield from the lake varied from 1,269.8 to 5,461.9 tonnes during 1990-91 to 1995-96 with an average of 3,742.8 tonnes. While during 1957-65, the annual fish and prawn yield ranged from 2,603 to 4,455 tonnes with an average of 4,375.36 tonnes. The lowest annual catch of the lake was estimated as 1,594.6 tonnes and 1,269.8 tonnes during 1994-95 and 1995-96 respectively. During the period the commercially important fish species available in the lake were *Tenualosa ilisha*, *Mugil cephalus*, *Liza macrolepis*, *Lates calcarifer*, *Eleutheronema tetradactylum*, *Plotosus canius*, *Mystus gulio*, *Etroplus suratensis*, *Pseudosciaena coibor*, *Nematalosa nasus*, *Osteogeniosus militaris*, *Gerres setifer*, *Strongylura strongylura* etc. Among prawns, *Penaeus indicus*, *P. monodon*, *Metapeneaus monoceros*, *M. dobsoni*, and among crabs, *Scylla serrata* and *Portunus* sp. were most commercially important species. The maximum contributors of the fishery were prawns (16.9%), perches (16.6%), mullet (14.7%), clupeids (14.3%), cat fishes (8.4%), beloniformes (3.6%), threadfins (2.6%) and others (22%). Of late,

increase in tidal ingress is being observed in the lake through a new mouth, which has opened during 2000. The additional ingress of sea water into the lake has significantly improved the ecology as well as fishery. As a result, the annual fish yield has increased significantly from 1,432 tonnes during 1994-96 to about 9,000 tonnes during 2000-03. The Chilka lake is a potential source of commercially important prawn (*Peneaus monodon*, *P. indicus* and *P. semisulcatus*) and fish (*Mugil cephalus*, *Liza macrolepis*, and *Eleutheronema tetradactylum*) seed. The seeds were mostly available at the mouth of the outer channel around Arkhakuda and the Palur canal for almost throughout the year with two peaks, one in January to June and the other in August to September. Principal gears operated in the lake are gill net (panchijal, dobijal), and (bhektijal, khatijal), drag net (khadijal, janglajal), cast net (khap jal), sieve net (bada jal) etc.

Pulicat lake:

The Pulicat lake is one of the biggest brackishwater lakes on the east coast of India. Major portion of the lake located (latitude 13° 26' and 13° 43'N) and longitudes (80°03' and 80°18'E) in the Nellore district of Andhra Pradesh and the real portion in Chingleput district of Tamil Nadu, where it joins the Bay of Bengal by narrow mouth. The total area of the lake is 350 km². The lake receives freshwater through two seasonal rivulets and Kalangi river. The drainage area is about 440 km². Presently, the average depth ranged from 0.7 to 3.0 m, whereas, during 1970s the average depth was 1.5 m with maximum being 9m. Tidal effect is felt up to a distance of 6 to 10 km from the lake mouth and the tidal high water elevation is only 25 to 30 cm.

Water quality:

Water temperature fluctuation is medium in the lake and it varies from 20.5 to 30.0 °C. Water transparency ranges from 15 to 50 cm. Dissolved oxygen content is moderately high, which varies between 5.7 and 7.6 mg/ litre. Salinity fluctuates from 28.91 to 7.79 mg/litre and highest salinity observed near the Barmouth area (Tamil Nadu) and also at Sriharikota (Andhra Pradesh) being nearer to sea.

Biotic communities:

The overall plankton production in the lake during 1960s was high when compared with present studies; 59 species of phytoplankton and 23 species of zooplankton were recorded during 1960s. Myxophyceae, Chlorophyceae, Bacillariophyceae and Rhodophyceae were the major groups among the phytoplankton. Zooplankton population was mainly represented protozoans, annelids, copepods, ostracods, decapods etc. Further studies during 1980s revealed that the

primary peaks of phytoplankton and zooplankton occurred during May-July and April-May respectively. Higher zooplankton production in the southern sector than that of the northern sector was well reflected in the fish yield of the corresponding sectors of the lake. The average annual fish yield was estimated as 632.6 tonnes and 470.6 tonnes in southern and northern sectors respectively from 1965 to 1972. Presently, 43 species of phytoplanktons and 11 species of zooplankton were recorded from the lake. Among phytoplanktons, Bacillariophyceae, Dinophyceae, Myxophyceae and Euglenophyceae were the dominant groups. Copepods and rotifers were major dominant groups a zooplankton.

Fisheries:

A total of 65 species of the fishes were recorded from the lake. The annual fish landing during 1945-46 was reported to be 2,678 tonnes with 48.67 prawns. Thereafter a gradual decline in catch was observed in the lake. The annual average landings of fish and prawn varied from 926.9 (in 1968) to 1,371.4 (in 1972) during 1967 to 1972 with an average of 1,152.86 tonnes. Prawns dominated the catch and contributed about 380 to 635 tonnes. The most dominant prawn species were *P. indicus*, *P. semisulcatus*, *P. monodon* and *Metapeneus monoceros*, *M. dobsoni* etc. Mulletts form the next group with *M. cephalus* as the dominant species and their contribution varied between 194 and 382 tonnes/year. Other contributors were perches (82 to 135 tonnes), clupeids (72 to 126 tonnes), catfishes (20 to 57 tonnes), sciaenids (18 to 23 tonnes), beloniformes (14 to 30 tonnes), thread fins (9 to 29 tonnes), crab mainly *Scylla serrata* (23 to tonnes) and others (16 to 21 tonnes). During 1980s. The annual average catch was recorded at the highest peak of about 9,000 tonnes. which presently declined to 4,545 tonnes and 3,892 tonnes during 2007-08 and 2008 09 respectively. The dominant fish and prawn species, namely *Mugil cephalus*, *Liza tade*, *Liza parsia*, *Chanos chanos*, *Plotosus canius*, *Hilsa kelee*, *Penaeus indicus*, *P. monodon*, *M. dobsoni*, *M. monoceros*, *M. brevicornis*, in the lake during 1970s and 1980s have shown a sharp decline or total absence in the catch. Presently, the fishery of the lake is mainly dominated by *P. indicus* (50%) and mulletts, *Mugil cephalus*, *Liza fade*, *L. parsia* (20%) and others (30%). The main gears of the lake are stake nets (Suthuvalai and Kattuvalai) and drag net (badivalai) and peak fishing season is July to October.

Estuaries of the west coast

Vembanad lake

Kerala offers extensive backwaters at the coast of Arabian Sea. The backwaters contribute productive ecosystem and the total fish landings from Kerala backwaters vary from 14,000 to 17,000 tonnes/year. Besides about 88,000 tonnes of live clams and 0.17 million tonnes of dead molluscs shells are collected annually. Vembanad - Kol - Wetland System, one of the Ramsar sites in Kerala (declared in November 2002), is the largest estuarine system of the western coastal wetland systems (09° 00' - 10° 40' N latitude and 76° 00'-77° 30' E longitude), and is spread over the districts Alappuzha, Kottayam, Ernakulam and Thrissur in Kerala. The Vembanad Wetland is a complex aquatic system of 96 km long coastal backwaters, lagoons, marshes, mangroves and reclaimed lands, with intricate networks of natural channels and man-made canals extending from Kuttanad in the south to the Kol lands of Thrissur in the north. The total area of the wetland system is 1521.5 km², approximately 4% of the State's geographic area. The total area of lake is about 250 km and extending 80 km from Munambam in the north to Alleppey in the south. The width of the lake varies from 500 m to 4 km and depth from less than 1 to 12 m. The wetland is mostly Waterlogged with depths ranging from 0.6 m. A number of rivers, viz. Meenachil, Manimala, Pamba and Achenkovil carry, huge quantities of freshwater in to the lake south of Thanneermukkom barrage and Muvattupuzha river flows into the Cochin backwaters north of the said barrage. Drainage area of these five river basins is about 7392 km and freshwater flow during monsoon and lean period is estimated at 10,348 million m and 2,817 million m respectively. The Thanneermukkom barrage has divided the lake into two zones, namely a freshwater dominant southern zone (Vembanad Lake) and a salt water dominant northern zone. The barrage (1,252 m long) was constructed in 1975 to prevent the intrusion of saline water and also to promote double cropping of paddy in about 55,000 ha of low-lying areas around the lake (Planning Commission Report, Government of India, 2008). The Vembanad lake is important for its rich flora and fauna including fisheries. The lake serves as a habitat and nursery ground for a variety of fin and shell fishes. It is also famous for its clam resources and sub-fossil.

Meteorological feature:

Temperature at the lake area varies between 21°C and 36 C and the humidity of the air fluctuated from 80 to 95%. The average rainfall is 3,200 mm. Two distinct rainy seasons are observed, one during south-west monsoon and the other north-east monsoon. Bulk precipitation is

during south-west monsoon (60%) and rest during north-east monsoon (30%) and summer rains (10%).

Water quality:

Dissolved oxygen (6.0 to 7.2 mg/litre) levels were generally adequate in the lake except Punnamada where it was 3.16 mg/litre during pre-monsoon period and sometimes below detectable levels. Acidic range of pH (6.8) was observed during 1989 to 2002. Decline in salinity was observed from the average summer value of 18.47g/litre during pre-barrage period to 2.8 g/litre during post-barrage period. Mean salinity values recorded between 1971 and 2001 were 23 g/litre and 3.87 g/litre respectively and in recent years the averages DO and salinity values were recorded as 6.6 mg/litre and 1.2 g/litre respectively. The phosphate-phosphorus, nitrate-N and HS contents were recorded as 0.020 mg/litre, 0.087 mg/litre and 2.59 mg/litre respectively. The gross and net primary production was recorded 0.87 gC/m/day and 0.75 g/m/day respectively.

Biotic communities:

As regards plankton biomass, pre-monsoon showed highest mean value of 4.7 ml/m, followed by 4.4 ml/m and 3.4 ml/m during post-monsoon and monsoon seasons respectively. The abundance of benthic forms in the lake showed maximum mean density of 39 numbers /m² during the monsoon

Fishery:

A total of 104 species of fish, 9 species of shrimps and prawns and species of molluscs were recorded from the lake. *Etroplus suratensis*, *Channa striatus*, *C. diplogramme*, a few species of native catfishes, namely *Horabagrus brachysoma*, *Labeo dussumieri*, freshwater prawn (*Macrobrachium rosenbergii*, *M. idella*), *Wallago attu*, are the major species available in the lake. The total finfish landings from the lake are around 20 tonnes and freshwater prawn around 70 tonnes and that of shrimp from 110 tonnes. Among molluscs *Meretrix costa* and *Villorita cyprinoids* (black clam) were the most dominant species. The production level of black clam was found to be 31,431 tonnes during 2000. During 1960s and 1970s, the average annual finfish shellfish landings from the lake varied from 1,200 to 8,500 tonnes. The commercially important prawn and fish species of the lake are *Metapenaeus dobsoni*, *M. monoceras*, *Penaeus indicus*, *Mugil cephalus*, *Valamugil cunnesius*, *M. parsia*, *Etroplus suratensis*, *Horabagrus brachysoma*, *Labeo dussumieri*, *Lates calcarifer*, *Chanos chanas*, *Thrissocles sp.*, *Anchovilla sp.*, catfishes, thread fins, silver belies etc. However, the most abundant species are *Metapenaeus dobsoni*, and

Mugil cephalus contributing 60% and 11% of total catch respectively. *Etroplus suratensis* is available in maximum numbers from June to September, *L. calcarifer* from July to April, and *Chanos chanas* from November to June. The important fishing gears of the lake are stake net chinese net. The other nets, operational are, dragnets, cast nets, boat seine etc. At present the water holding capacity of the lake due to siltation has reduced to an abysmal 0.6 km from 2.4 km. Major fishing activities are restricted in the lake areas just below the Thanneermukkom barrage. According to Planning Commission Report, Government of India, 2008 many euryhaline migratory species are unable to contribute to the fishery of this lake because of the construction of barrage and breeding migration of *Macrobrachium rosenbergii* and *M. Idella* is also partly affected by the barrage.

Ashtamudi lake:

Ashtamudi lake, another Ramsar site located near the southern part of Kerala is known for its rich clam fishery resources. Due to high rate of fishery, a great reduction of clam *Paphia malabarica* was recorded that made the Kerala government to impose a ban on the fisheries. Salinity is high near the bar mouth-33 ppt which gets decreased to 5 ppt at the upper reach. Dissolved oxygen shows a variation from 1.17 to 2.79 ml/litre.

Estuaries of Karnataka

The Karnataka having a coastline of 300 km is enriched with 26 estuarine environments with a total area of 7,213.5 ha in the three coastal districts: Dakshina Kannada- 5 (1,140 ha), Udupi - 8 (1,885 ha) and Uttara Kannada- 13 with an area of 4,188 ha The important ones are Nethravati-Gurupur, Mulki, Coondapur, Pavenja, Gangoli, Kali, Aghanashin, Sharavati etc. The total estuarine area of the state is estimated to be about. Vast information on the hydro-biological parameters of some of the estuaries is available. Of these, ethravati-Gurupur, Mulki estuaries of south Kannada and Kali estuaries of north Kannada are the most important.

Nethravathi estuary:

The Nethravathi estuary (12°15'N: 74°50'E) is situated in the confluence of Nethravathi river with Arabian Sea. The tidal influence is felt up to 19 km upstream.

Water quality:

The water temperature fluctuates between 27.0°C in November and 33.9°C in May. The pH varies from 7.36 to 8.63. Dissolve oxygen ranges from 2.50 mg/litre at 0300 hr to 8.55 mg/litre at 1200 hr. The salinity values varies from 4.06 g/ litre in November to 35.81 mg/litre in April.

Low nitrate value was observed during pre-monsoon (L01 to 2.25 ug/litre and post-monsoon (1.42 to 1.92ug/litre when compared with moderate value during monsoon (6.56 to 8.95 pg/litre). Similarly, phosphate value was recorded as 0.79 to 1.26 ug-/litre 1.43 to 1.61 ug/litre and 1.01 to 1.20 µg/litre during pre-monsoon, monsoon and post-monsoon respectively. Silicon content was maximum (54.89 to 65.72 ug/litre) during monsoon and it was poor during pre-monsoon (13.37 to 21.06 ug/litre) and post-monsoon (30.44 to 42.55 ug/litre). Thus, seasonal distribution of nitrate, phosphate and silicate in the estuary indicated marked variations in nutrient concentration. High value of nutrient was recorded during monsoon season.

Biotic communities:

Phytoplankton production in this estuary shows a trimodal pattern of distribution during May, June, and November-December. The total density of phytoplankton varies from 1,132 to 65,514 cells/m³. The major group contributing to phytoplankton were Bacillariophyceae (35 species), Dinoflagellates (9 species), Chlorophyceae (8 species) and Myxophyceae (5 species). Zooplankton density of the estuary varies from 4 to 228/liters. Among zooplankton, copepods and their naupl were the dominant forms. Larval forms of polychaetes, fish and bivalve were the other common representatives of zooplankton.

Fishery:

Nethravathi estuary is rich in finfish and shell fishes. The common Shell fishes are *Sillago sihama*, *ThriSSocles mystax*, *Anadontostoma chacunda*, *Ilisha indica* Kawala coval, *Platycephalus scaber*, *Lutjanus fulviflamma*, *Gerres filamentosus* *Leiognathus spp.*, *Sphyraena sp.*, *Pristipoma sp.* *Mugil cephalus*, *Liza parsia* *Stelophorus indica*, *Etroplus suratensis*, *E. canarensis*. *Horabagrus brachysome* *Caranx carangus*, *Belone cancila*, *Tachysurus spp.*, *Pseudosciaena sp.*, *Gobius spp.* and *Mystus gulio*. Of these, *Mugil cephalus*, *Liza tade*, *Sillago sihama*, and *Tachysuru spp.* were available almost throughout the year, with the former two species were dominant in the catches. Average annual landing of grey mullets was estimated as 2,685 tonnes during 1981-97, for all estuaries of Karnataka. Among mullets, *M. cephalus*, *Liza tade*, *L. macrolepis*, *Valamugil seheli* and *V. speigleri* were the dominant species. The *Metapenaeus dobsoni*, *M. monoceros*, *Penaeus indicus* and *P. monodom* were the important species of shrimps. The clams, mussels and edible oysters form the important components of the estuaries of Karnataka. The total harvest of clam from the estuaries of Karnataka varied from 351 to 588 tonnes from 1976 to 1992. The total yield of edible oysters as well as clams and cockle were estimated to the tune of 197 tonnes and 2,184

tonnes, respectively, during 2002-03. The edible oysters were represented by *Crassostrea madrasensis* and *Saccostrea cucullata*. Among clams, *Villorita cyprinoids*, *Paphia malabarica*, *Meretrix casta* and *M. meretrix* were the most important species. The important fishing gears of the estuary of Karnataka are shore seines, gill nets, cast nets, hooks and lines. Nethravati estuary is a potential source of brackishwater shrimps (*P. indicus*, *P. merguensis*, *M. dobsoni* and *M. monoceros*) and fish (*Mugil sp.*, *C. chanos*, *L. calcarifer*, *M. cyprinoids*, *Scatophagus argus*, and *S. sihama*) seed. Shrimp seeds are mostly available in this estuary during November to May, while maximum number of seeds (1,136/m) occur during low tide irrespective of time of occurrence. Availability of seeds is more during day time compared to night.

Apart from having a rich fish and prawn fauna, the other estuaries of Karnataka are equally rich in brackishwater shrimp and fish seed resources. The seed of *C. chanos* were available in the Coondapur and Mulki estuaries for a restricted period during April-May, while seeds of mullets, *Sillago sihama*, *L. calcarifer* and *Scatophagus sp.* were available in number of estuaries. Important fish seeds are also available in the Kali estuary of North Kannada district. The composition of seeds were *M. monoceros* (68.18%), *M. dobsoni* (22.72%), *Penaeus merguensis* and *P. monodon* (each 4.55%) in order of abundance.

Mandovi-Zuari estuarine complex:

Goa has seven major rivers of which the Mandovi and Zuari with Camberjua canal (latitude 14°54'-15° 48' N and longitude 73° 00 -74° 20'E) form the largest estuarine complex. Both the estuaries open in the Arabian Sea through Aguada and Marmugao Bay. The total area covered by the estuaries in Goa including Mandovi-Zuari estuarine complex is approximately 12,000 ha. In Mandovi-Zuari the tides are of mixed semi-diurnal type and their maximum range is about 2 meter.

Texture of bed soil and water quality:

The bed soil of Mandovi is sandier as compared to Zuari contained 70.0 to 91.0% and 69.0 to 84.5% sand respectively. The pH of the bed soil varies from 7.51 to 7.72 in Mandovi and 7.17 to 7.93 in Cumberjua Zuari. The pH of water varies from 6.98 to 8.29. Very low values of phosphate and nitrate were recorded from both the estuaries. The phosphate value ranged from traces. to 0.008 mg/litre in Mandovi and traces. to 0.012 mg/litre in Zuari. The average nitrate content was found to be 0.109 to 0.141 mg/litre and 0.115 to 0.153 mg/litre in Mandovi and Zuari respectively. Silicate content was very poor in both, Mandovi (0.24 to 2.34 mg/litre and Zuari

(0.36 to 2.14 mg/litre) estuaries. The fluctuation of primary production in Zuari and Camberjua canal varied from 62.50 to 208.33 mgC/m⁻/hr and 93.75 to 187.0 mgC/m²/hr respectively.

Biotic communities:

In Mandovi-Cumberjua-Zuari estuarine complex, the total plankton density varies from 55/litre at Shiroda to 285/litre at Cortalim. In total plankton population, 58.93 to 68.47% and 30.18 to 39.28% by numbers were contributed by phyto-and zoo-plankton respectively. Bacillariophyceae was the dominant group of phytoplankton followed by Myxophyceae and Chlorophyceae. In earlier studies, diatom counts in Mandovi estuary were 474/litre and 61 to 352/litre during monsoon and post-monsoon respectively, while in Zuari the counts were 336/litre and 25 to 380/litre during the same corresponding periods respectively. The average density of macrobenthos varied from 716 (Candola) to 1,835/m² (Panaji) in Mandovi and 994 (Shiroda) to 1,378/m² (Cortalim) in Zuari estuaries respectively. The most dominant group was polychaetes (51.8 to 96.3%) followed by malacostraca and molluscs.

Fishery:

Mandovi-Zuari estuaries are potential sources of fin, shellfishes and their seeds. The fishery is contributed mainly by Harpodon nehereus. Polydactylus indicus, *Eleutheronema tetradactylum*, *Arius sp.*, *Coilia sp.*, *Etroplus suratensis*, mullets, anchovies, sciaenids and prawns. It is reported that the seeds (mostly mysis stage) of commercially important prawns were observed in surface and bottom zooplankton samples. These were *Metapenaeus dobsoni*, *M. affinis*, *M. monoceros*, *Parapeneopsis stylifera*, *Penaeus merguensis*, *P. indicus*, *P. monodon* and *P. semisulcatus* in order of abundance. Total ingress of penaeid prawn larvae in the Mandovi-Zuari was more during full moon and high tide compared to new moon and low tide periods. Principal gears operated in the Mandovi estuary were trawl nets, stake nets, gill nets, nets, bag nets etc. Seines and trawl nets contributed about 60% of the total catch of the estuary.

Damanganga estuary:

The Damanganga estuary (latitude 20° 25'N and longitude 81° 0'E) on the west coast is a minor estuary of Gujarat and opens into the Arabian Sea near Daman.

Texture of bed soil and water quality:

The pH of soil ranges from 7.29 to 7.74 and Sand content varies from 63.95 to 88.8%. Transparency of water and pH values fluctuate from 2.5 to 107.0 cm and 6.80 to 8.70 respectively. A wide range of fluctuation in dissolved oxygen (Traces-9.6 mg/litre) was observed in the estuary.

The salinity Varies from 0.11 to 31.17 g/litre, higher values observed in the stretch between Nani-Dama and Zari, the lower stretch of the estuary. Phosphate, nitrate and silicate values range from Tr. to 0.2 mg/litre, 0.03 - 4.54 mg/litre and 1.08 to 20.88 mg/litre respectively.

Fishery:

Presently 23 species of fishes are recorded from the estuarine system. Harpodon nehereus (48.75%) and Liza parsia (22.35%) contributed maximum to the fishery.

Tapi estuary:

Tapi (latitude 21° 20'N and longitude 74° 30'E) is regarded as one of the major estuaries on the west coast. It is the second largest among the estuaries of Gujarat and opens into the Arabian Sea in Surat. Once it was a potential source of fish production, but after the construction of Ukai dam and number of weirs across the river, the congenial estuarine environment has been adversely affected due to inadequate freshwater discharge from the upstream. Presently the tidal impact is felt up to a distance of 45 km. The total area of the estuarine system is about 14,250 ha. The average rainfall is 775 mm.

Texture of bed soil and water quality:

Sand content of bed soil range from 71.16 to 88.83% and pH varies from 7.30 to 8.12. The water temperature range between 22 and 31.0°C. Transparency fluctuate between 15.3 and 93.6 cm. Low transparency was recorded at lower stretch of the estuary, while it was high (74.0 to 93.6 cm) at freshwater stretch. The estuary maintained higher pH fluctuating from 7.3 to 8.6. Dissolved oxygen is fairly available in the freshwater stretch of the system, while in Chowpati stretch of lower estuary has very poor content of DO (average 0.75 mg/ litre). Nutrients, viz. phosphate, nitrate and silicate contents were recorded as 0.035 to 0.065 mg/litre, 0.643 to 0.063 mg/ litre and 4.46 to 9.70 mg/litre respectively. The low values of phosphate and nitrate indicated poor nutrient status of the estuary. In the freshwater stretch, the gross primary production ranged between 75.53 and 156.25 mgC/m²/hr and values of 7.82 to 62.5 mgC/m³/hr were recorded in the lower stretch of estuary.

Biotic community:

The plankton population in the system ranges between 7,469 nos/ litre, of which phytoplankton contributed 62 to 99%. Bacillariophyceae, Myxophyceae and Chlorophyceae were the principal groups in order of abundance. Zooplankton community was mainly formed by the protozoans, copepods and rotifers. Protozoans were most abundant in the lower estuarine zone,

while copepods and rotifers were in the upper freshwater zone. Average macrobenthic abundance of the estuary varies from 98 to 2, 239/m. Molluscs (61 to 90%) and annelids (52 to 93%) were most abundant groups at different locations of estuary. 12

Fishery:

Total annual fish yield from the Tapi estuarine system was estimated and 290 tonnes from 1995-96 to 1999-2000 with an average of 179.6 tonnes presently the most dominant species in the system is hilsa (75 tonnes; 25.86%), while prawns millets and crabs contribute to the tune of 31.0, 10.3 and 8.66% of the total catch. The hilsa catch of the estuary showed a gradual increasing trend from 10 metric tonnes in 1995-96 to 75 metric tonnes in 1999-2000, though the upstream migration of hilsa during monsoon is restricted to downstream of weir in the neighbourhood of Surat city.

Narmada estuary:

The Narmada is one of the major estuaries on the west coast of India. The estuarine system (latitude 20°40'N and longitude 80°45'E) extends from Rajpipla to Bharuch for a distance of about 135 km and opens into Arabian Sea through Gulf of Cambay in the district of Bharuch, Gujarat. The entire estuarine system is estimated to be about 14,250 ha. The usual flow of Narmada river is restricted by commissioning of a dam, as a result a considerable reduction in freshwater availability at the down stream including estuary has been observed. Moreover, the development of sand bars at the mouth of the estuary reduces the tidal ingress into the system.

Texture of bed soil and water availability:

The soil texture in the entire estuarine stretch is predominantly sandy soil with 84.5 to 98.76% sand, nil to 11.5% silt and 1.0 to 7.5% clay. The soil reaction indicated highly alkaline and the pH ranged between 7.88 and 9.12. Water temperature varies from 22.9 to 30.8°C. Transparency of water fluctuates seasonally as well as centre-wise. Low transparency was recorded in the lower estuarine stretch between Shakkarpura and Ambetha. The transparency of the estuarine stretch ranged from 5.3 to 52.0 cm. Dissolved oxygen was adequate in the stretch (5.3 to 8.5 mg/litre). This stretch maintained slightly higher water pH ranging from 7.8 to 8.61. Very low values of phosphate (traces to 0.055 mg/litre) were recorded, while moderate to high values nitrate (traces to 1.09 mg/litre) were observed in the entire estuarine system. However, silicate content was highest (4.8 to 24.3 mg/litre) in this stretch. The salinity in the estuary varied between 62.4 and 3189.0 mg/litre. As regard primary production, lower rate of gross (36.34 to 88.39 mgC/m/hr) and

net (6.24 to 60.4 mgC/m/hr) primary production were recorded. Minimum production was recorded during monsoon season.

Biotic community:

The plankton population in the system shows a wide range of fluctuation and variation in abundance with regards to its quality and quantity. The average total plankton density varied from 63 to 1,161 nos/litre. The contribution of phyto-and zoo-plankton was 70.42 to 98.70 nos/litre and 1.30 to 29.58 nos/litre respectively. The major groups contributing phytoplankton were Chlorophyceae (11.27 to 88.20%), Bacillariophyceae (4.82 to 52.11%) and Myxophyceae (5.68 to 22.22%). whereas, zooplankton was mostly shared by protozoans (0.52 to 14.61%), copepods (0.26 to 12.68%), rotifers (0.43 to 5.63%), ostracods (1.41 to 2.31%), cladocerans (0.09 to 1.41%) of the total plankton population. Macro-zoobenthic fauna was found to be principally represented by annelids (nil to 93.81%), molluscs (3.33 to 70.37%), malacostracans (0.52 to 12.96%), dipteran (1.70 to 2.86%) and ostracods (0.61 to 3.06%).

Fisheries:

Narmada estuarine system is very rich in fishery resources. The estimated average annual fish yield of the estuary during 1990s ranged between 11,000 and 14,000 tonnes. The fish catches in the estuary consisted of *Tenualosa ilisha* (hilsa), *Mugil cephalus*, *Liza parsia*, *L. macrolepis*, *Harpodon nehereus*, *Lates calcarifer*, *Chanos chanos*, *Eleutheronema tetradactylum*, *Arius arius*, *Polynemus indicus*, *Etroplus suratensis*, *E. maculatus*, etc, while prawn comprised mainly *Macrobrachium rosenbergii* and *Penaeus indicus*; and *M. rosenbergii* formed the prime fishery of the estuary. The *T. ilisha* alone contributed to the tune of 977.1 to 3,727 metric tonnes for 1974-75 to 1982-83. Highest catch of hilsa recorded as 15,319 tonnes during 1993-94, which presently declined to 4,866.0 tonnes during 2007-08.

Mahi estuary:

Along the west coast, Mahi estuary (latitude 20° 20'N and longitude 73° 05' E) is an important major estuary in Gujrat. The estuary opens into the Arabian sea.

Texture of bed soil and water availability:

The soil texture is predominantly sandy and pH varies from 6.73 to 7.69. The water temperature ranges between 18.5 and 37.0 °C and transparency fluctuates from 6.0 to 88.0 cm. The pH ranges from 7.83 to 8.16 and dissolved oxygen from 7.14 to 9.26 mg/litre. Inorganic

nutrients. viz. phosphate, nitrate and silicate fluctuates from 0.057 to 0.08 mg/litre, 0.48 to 0.65 mg to 36.0 g/litre, high and low values of salinity were observed in lower and upper stretches of the estuary respectively. The gross and net primary production varied from 25.0 to 37.5 mg/m/hr and 16.67 to 208.33 mgC/m³/hr respectively.

Biotic community:

The average total plankton population varies from 172 to 295 nos/litre. Phyto- and zoo-plankton contributed 83.14 to 97.84% and 2.16 to 16.27% respectively. The principal components of the phytoplankton are Bacillariophyceat, Myxophyceae and Chlorophyceae while copepods, rotifers, cladocerans and ostracods were the major groups of zooplankton, Macrobenthos density ranged from 71 to 877 nos/m² represented by annelids (10.91 to 95.75%), molluscs (12.68 to 58.97%), dipterans (30.45 to 46.84%), malacostracans (26.76%) and ostracods (9.97%) at different sites of the estuary.

Sabarmati estuary:

There are 82 rivers and streams passing through Gujarat. Out of these Narmada, Tapi, Mahi and Sabarmati are the important ones. Sabarmati estuary (latitude 22° 19N and longitude 72° 38'E) of the western India debouches in the Gulf of Khambhat of Arabian Sea.

Texture of bed soil and water availability:

The soil pattern is variable. The alluvial plains of the east in the south Gujarat region are known for their fertility on account of their deposits of the rivers like Sabarmati, Mahi, Narmada and Tapi. The soil reaction is alkaline throughout the stretch. The pH varies from 7.47 to 8.34. Sand (84.25 to 92.50%) was the major component of soil. Water temperature ranges between 18. and 33.5 °C. Transparency varies from 8.0 to 91.0 cm. Dissolved oxygen varies from traces to 10.2 mg/litre. Phosphate, nitrate and silicate contents of the estuarine water varied from 0.002 to 0.174 mg/litre, 0.18 to 0.41 mg/litre and 4.68 to 20.28 mg/litre respectively. The gross primary production of the estuarine system varied between 250 mgC/m/hr and the net production between nil and 187.5 mgC/m/hr. The physico-chemical characters, nutrient levels and productivity indicated that estuarine system is under environmental stress. It is also reported that the river at Gandhinagar receives some excessive pollution pressure owing to the construction of dam

Biotic community:

Annual plankton production in the estuary varies from 3,301 to 10,822 nos/litre. Phyto- and zoo-plankton contributed 78.33 to 98.42% and 1.58 to 21.67% respectively. The bulk of

phytoplankton was constituted by the members of Bacillariophyceae (46.88 to 81.75%) followed by Myxophyceae and Chlorophyceae. Among the zooplankton, rotifers, copepods and cladocerans were the major groups. The density of macrobenthos varied from 9 to 2,274 nos/m². Diptera (mostly chironomid larval forms), tubifex and molluscs (*Thiara* spp.) were the main groups in the order of abundance.

Fishery:

Information on fish and fisheries of the estuary is meagre. Fishery activities are fairly common in the estuarine system during monsoon. However, during post monsoon and winter, fishes, viz. *Labeo bata*, *L. rohita*, *Catla catla*, *Cirrhinus mrigala*, *Sparata seenghala*, *Salmophasia bacaila*, *Notopterus notopterus*, and *Osteobrama cotio*, are available from the freshwater stretch of the estuary. The principal fishing gears are the cast and gill nets.