CHAPTER 1

INTRODUCTION

1.1 General

Coastal lagoons are a focal point for a wide range of human activities of increasing social and economic importance. The semi-enclosed basin that forms the brackish water lake provides an area that is relatively sheltered, with a complex interplay of physical, chemical and biological processes, all of which are influenced by the marine environment and the surrounding catchments. Throughout the history mankind had settled and developed near the coastline and has effectively used the inland waterways for the effective way of transport and developments. As population grew there become a greater need for livelihood land and disposal sites for human waste. Thus as man's ingenuity has evolved, increasing pressures have been imposed on the natural brackish water ecosystems.

Anthropogenic effects are the major agent influencing the morphology of a lagoon ecosystem either directly by means of engineering works and/or indirectly modifying the physical, biological and chemical processes at work within the ecosystem. With growing pressures comes the increasing risk that the long recognized areas of natural conservation importance will be compromised and hence a much more proactive approach is being adopted towards positive management for future generations. Basic requisite of making management decisions within the lagoon environment is a sound understanding of its functioning. Hence an integrated approach was planned to look into the details of the multiple uses of the ecosystem with sustainability central to the management process.

The Lagoons provide nursery and breeding grounds for many species of marine fauna. Pulicat Lake, which is a backwater lagoon, serve as a nursery for fish and prawns

and supports commercial fishing with major fish landing centers at Pulicat and Arambakkam. Recently the lagoons of these types are experiencing an accelerated decline in water quality & siltation and the say has been the focus of an integrated approach for the cause and effects of this degradation. The lake is currently the focus of environmental concern, attributable to issues such as pollution of both the sediment and water column by trace metals and nutrients, increased turbidity, especially during high wind condition and shoaling of the shallow peripheral bays and stream mouths.

In recent years shallow coastal lagoons have been gradually differentiated from the general description of estuaries to become a separate group of inland marine waters based on their unique hydrodynamic, mixing and sediment characteristics (Nicholos and Allen, 1981; Kjerfve and Magile 1989). In shallow coastal lagoon wind become more important in driving the circulation and is causing mixture in water column (Smith 1990). In shallow lagoons interactions among the vertical mixing of horizontal salinity gradient, vertical stratifications and residual circulation are coupled often forming positive and negative feedback loops (Park and Koo, 1994). Their cause and effect relationships are not straightforward.

Coastal communities and industries find the coastal waters as convenient locations to dump their wastes. Beaches serve as natural buffers between the ocean and the land. The destruction and removal of these buffers leaves the coast exposed to the erosion effects of the waves. It is thus apparent that many potential uses of the beach and adjacent waters are mutually incompatible. As the beaches become more intensely utilized because of increasing population, we must establish priorities in the possible uses of our finest natural resources. Once destroyed, its repair is difficult if not impossible, and it is always costly.

One of the important aspects of a beach is its dynamic nature. The loose granular sediments continuously respond to the ever-changing waves and currents imposed from the adjacent body of water. The beach profile is important in that it can be viewed as an effective natural mechanism, which causes waves to break and dissipate their energy.

Main shift in beach profile will be observed between summer profile and winter profile. Summer profile is characterized by a wide berm, the flat shoreward portion of the profile and by a smooth offshore profile with no bars except in relatively deep water. In contrast winter profiles have almost no berm, the sand having shifted offshore to form a series of bars parallel to the shoreline. With repeated profiles, it is possible to trace the annual destruction and reappearance of the berm. Shifts in the profile correspond with the winter and summer. Offshore shift of sand from the berm to the bars takes place during storm condition of large wave activity. During smaller swell wave the reverse is true. Sand shifts back onshore and the berm groves. When breakwaters are constructed they upset the natural equilibrium between the sources of beach sediment and the littoral drift pattern. In response, the shoreline must change its configuration in an attempt to reach a new equilibrium.

1.2 STUDY AREA

1.2.1 North Chennai Coast

North Chennai coast extending from the fisheries harbour to Pulicat lake, is an emerging industrial belt with many coastal hamlets. In the past few decades, Tamil Nadu coast has witnessed an increase in industrial growth for exploration and exploitation of its marine resources, resulting in the migration of inland population towards coastal towns. Many new structures have been constructed to supplement the industrial requirements.

The geographical location of Chennai coast makes the region vulnerable for wave attack both during northeast and southwest monsoon seasons. This region can receive waves as high as 8m during the northeast monsoon and during southwest monsoon maximum wave height varies between 4 and 5m. A very important phenomenon associated with this coastal stretch is that a large quantum of sediment, about 0.5 million cubic metres per year, is transported alongshore by waves especially during southwest monsoon causing considerable modifications to the coastal characteristics (Mani, 1998). Though, northeast monsoon lasts for a few months in a year compared to the southwest monsoon, the coastal deformations produced due to the former are more damaging

compared to its counterpart. For example, coastal stretch of about 10 kms, north of fisheries harbour at North Chennai is repeatedly threatened during northeast monsoon and the process still continues. With the result, the existence of vital road link, i.e. Ennore Highway, is challenged by the fury of the waves.

It has been reported that an area of 260 hectares of land has been lost between the years 1893 and 1955 along the coastal region between Royapuram and Ennore. An area of about 30 hectares has been destroyed by the sea between the years 1980 and 1989. Overall loss has been estimated to be of the order of 350 hectares during 1893 to 1989, the cost of land alone, lost to the sea is of the order of 160 crores of rupees (IHH Report, 2000). Construction of another port, the Ennore satellite port, to make use of the coal for North Chennai Thermal Power Station and forthcoming petrochemical park, has further influence the coastal zone and its nearshore characteristics. Therefore, Chennai coast has become volatile in nature, warranting for immediate remedial measures for upkeep of the coastal region.

1.2.2 Pulicat Lake

India has four brackish water lakes namely, the Chilka in Orissa state, the Pulicat lake extending between Andhra Pradesh and Tamil Nadu states both located on the Coramandel coast of the Bay of Bengal and the Vembanad and Asthamudi lake in Kerala on the Arabian Sea coastline. These lakes in India are being altered because of the disruption of natural processes by urbanization, agriculture and pollution from the industries.

Pulicat lake is the second largest brackish water lake in India. It is located between 13º26’ and 13º43’N latitude and 80º03’ and 80º18’E longitudes, with its narrow opening into the Bay of Bengal through the south-eastern margin near the Pulicat town which is located 40 km north of Chennai city by sea. Pulicat lake is lying almost parallel to the Bay of Bengal. However, dried part of the lagoon extends upto 13º 60’ N latitude. Thus, the past and present margins of the Pulicat lagoon lie between the present

Swarnamukhi river and the Paleo Palar river delta. The Pulicat lake is extending over the Ponneri and Gummidipundi Taluk of Thiruvallur district in Tamilnadu and Sulurpet and Tada Mandals of Nellore district in Andhra Pradesh and covers an area of about 461 sq.km.

The lake extends to about 59 km from north to south direction with a maximum width of 19 km in east - west direction in the northern sector of the lake. The narrowest region of the lake is near Pazhaverkadu village measuring about 250 metres with a narrow channel part. The average depth of the lake is about 1.5 metres and the minimum and maximum depth varies between 0.5 to 6.0 metres respectively. The lake at its southern end, near north of Pulicat (Pazhaverkadu) town opens into the Bay of Bengal by a narrow pass (bar mouth) into the sea.

The Lagoons provide nursery and breeding grounds for many species of marine fauna. Pulicat Lake, which is a backwater lagoon, serve as a nursery for fish and prawns and supports commercial fishing with major fish landing centers at Pulicat and Arambakkam. Recently the lagoons of these types are experiencing an accelerated decline in water quality and siltation and the say has been the focus of an integrated approach for the cause and effects of this degradation. The lake is currently the focus of environmental concern, attributable to issues such as pollution of both the sediment and water column by trace metals and nutrients, increased turbidity, especially during high wind condition and shoaling of the shallow peripheral bays and stream mouths.

Pulicat Lake is evolved around 6000 years ago at the peak of Holocene sea level rise by the growth of coastal sand barrier across the eastern side of the captured river plain (Vaz and Banerjee, 1997). The hydrodynamic characteristics of this system are, restricted lagoon-ocean water exchange and seasonal positional switching of the entrance channel. Within the lagoon sediment may be transported by wind-induced waves and currents directed predominantly towards the northeast and west direction. The evaporation rate exceeds precipitation and runoff. Evaporation results in lowering of the water level in the lake. In recent years shallow coastal lagoons have been gradually

differentiated from the general description of estuaries to become a separate group of inland marine waters based on their unique hydrodynamic, mixing and sediment characteristics (Nichols and Allen, 1981; Kjerfve and Magile, 1989). In shallow coastal lagoon wind become more important in driving the circulation and is causing mixture in water column (Smith, 1990). In shallow lagoons interactions among the vertical mixing of horizontal salinity gradient, vertical stratifications and residual circulation are coupled often forming positive and negative feedback loops (Park and Koo, 1994). Their cause and effect relationships are not straightforward.

Pulicat Lake is a rich natural ecosystem but at the same time is very fragile and hence an integrated approach is necessary, to evolve a sustainable management strategy. The evolution of this lake should be viewed as an integration of long term trends and short term modifications by human and catastrophic elements. The management perspective therefore, requires a better understanding of the ecosystem processes and their responses to various anthropogenic and natural disturbances.

1.2.3 Chennai Port

Port is vital transport infrastructure for any maritime nation providing services to shipping and cargo handling. Port forms an important element in the economic and social development of virtually all countries. Not only a port is a gateway for trade, but also a port attracts commercial infrastructure in the form of banks, agencies and industrial activities. Port is very significant from the point of view of various trades- export of commodities which earn valuable foreign exchange, import of essential inputs required for industrial development of a country and for transportation by developing overseas and coastal shipping and inland water transport(Veeramuthumoni, 2000). Port development should not only concern the port itself, but also consider the wider economic, commercial, social and physical factors in determining the role of the port in the overall national and regional development plans.

The Chennai coastline was in dynamic equilibrium in the pre harbour period 1862-1876. The construction of the harbour, especially its southern breakwater has cut-off the sediment transport from the south resulting in accretion. Marina beach has been formed as a result of arresting the littoral drift by the breakwater. However there is erosion on northern side of the harbour due to the southern breakwater. Further on the introduction of eastern breakwater and establishing the outer harbour and the continuous working of sand pump(dredger) to maintain its entrance channel, the erosion on the northern side has been pronounced necessitating constant attention. The villages, the hutments and Ennore express highway connecting the Manali Refineries and Ennore Thermal Power Station to the Chennai are subjected to sea erosion due to both southwest and northeast monsoons every year. It has been assessed that about 865 acres (350 hectares) of land has been lost to the sea in this reach (IHH Report, 2000).

The Chennai port is dredging one million cubic metres of sand every year and emptying it in the east of harbour and they are reluctant to come nearer to the shore and empty due to shallow draft.

1.2.4 Ennore Creek

Creek is a coastal feature wherein the coastal water is spread into the inland water body for some distance. The Ennore Creek is unique feature which is a place where the river Kortalaiar joins into Bay of Bengal. The Ennore Creek is the estuary or the mouth of the river Kortalaiar, which is an outlet for the surplus water from the Poondi Reservoir, where water is being stored for the city (Chennai) water supply. The Ennore Creek flows west to east and open into the Bay of Bengal at Ennore. The Buckingham Canal flowing north to south parallel to the coast joins at Ennore Creek and flow further south.

The stretch of coast near Ennore creek, at a distance of about 13 km from Chennai harbour was spared from experiencing coastal erosion as this part of the coast was not in shallow zone of the Chennai harbour. Restoration of natural sediments along this coast by the waves caused the creek inlet with Bay of Bengal, to experience an universal problem

viz., formation of sand barrier as any other inlet would have. As the inlet is the only source of sea water supply to the creek, its maintenance became imperative for the survival of neighbouring power stations, such as Ennore Thermal Power Station and North Chennai Thermal Power Station and the local population. Thus dredging of the inlet is a daily routine and dredged spoil is being disposed in the neighbourhood.

1.2.5 Ennore Satellite Port

In order to meet the required coal to the two thermal power stations situated at Ennore, the Satellite harbour at Ennore has been constructed recently, as an unloading port, partly funded by the Asian Development Bank (ADB). This project has been developed in an area of 2600 acres of land, due to insufficient capacity at the existing Chennai Port for cargo handling. The estimated quantity of coal to be handled at the Ennore Port will be about 16.12 million tonnes (Kanakasabai, 1999) per year. The Ennore Satellite Port has started functioning in the year 2001. This has again aggravated the problem of erosion in the northern side of Ennore port and accretion in the southern side by creation of frequent closening of inlet of Ennore Creek from which the Ennore Thermal Power Station and North Chennai Thermal Power Station are drawing water for their coolant purposes. Now it has increased the burden of frequent dredging in the mouth of the creek and additional financial constraints to the power stations.

1.2.6 Morphology of North Chennai Coast

The North Chennai coast stretches in a North-Northeast direction. The North Chennai coast is oriented along 15º - 195º bearing. Ennore shoals are located about 5 kms North-Northeast direction of the Ennore creek at Latitude 13º 17’ N and Longitude 80º 22’E. The coastal area near Ennore is very flat and has vast expanse of backwater including salt pans. From the bathymetry charts, it is seen that depth contours are nearly parallel along the coast. 5 km and 10 km contours are about 250 m and 750 m away from the coast indicating a nearshore slope of 1:50 and offshore slope of 1:75.

1.2.7 Morphology of the Pulicat Lake

The Pulicat Lagoon is sited within the Palar Basin (Prabhakar and Zutshi, 1993). Around 1500 A.D. the lagoon stretched over 64 km between the town of Pulicat and the Swarnamukhi River. The records reveal that the lagoon was the center of a flourishing navigational activity and trade, like Venice, during sixteenth century (Banerjee, 1993) but the northern part of the lagoon had become too shallow for maritime traffic between 1803 A.D. and 1861 A.D. During the first half of the nineteenth century, course of the Kalangi River has changed (Vaz and Banerjee, 1997).

The western and eastern margins of the lagoon with sand ridges are more or less aligned parallel to the coast line. The lagoon is separated from the Bay of Bengal by a sand barrier spit complex known as Sriharokota island. Two sand barrier islands namely, Irakkam and Venadu, aligned north-south and lying at the central part of the lake, separate the lagoon into eastern and western sectors. The margins of the lagoon exhibit four different types of morphology (Farooqui and Vaz, 2000), that is northern margin is an irregular and elevated hard surface and the eastern margin(Sriharikota island) is a sand barrier complex with high and low dunes and traces of five older spit heads on the lagoon side. Its seaward margin is smooth and curvilinear. The southern margin, a low-lying, flat and wide plain, is a palaeo-deltaic lobe of the Palar river fringed by marine landforms along the coast. The western margin is occupied by a pediplain, older sand ridges and small scale fluvial plain built by ephemeral streams.

The border between the dry northern half and the present lagoon coincides with an ENE-WSW trending lineament extending between Sullurpet and Point Pudi (Vaz and Banerjee, 1997). In 16th century, with the advent of little Ice Age, there was a sea level fall that formed the Sriharikota island, reducing the navigability and affecting the port of this period, that flourished like that of Venice. Till this period, the area was fed by the Kalangi river. The sedimentary processes before this period perhaps initiated the seismogenic movement along the lineament, changing the course of the Kalangi river that

gradually led to the closure of the port during the nineteenth century (Farooqui and Vaz, 2000).

1.2.8 Drainage Pattern

The River Kalangi and River Kaleru drain from northwestern part of the lake and join the Pulicat Lake near Tadakuppam in Andhra Pradesh state. The Kalangi river debouches into the northwest corner of the lagoon at 13º 40’ N latitude. The river Arani flows west to east in the southern side of the lake and branches out into two distributaries, one joins at north of Pulicat town near Jameelabad and the other one joins at the southern side of the Pulicat town near Sattankuppam.

The Buckingham Canal (East Coast Canal) was built as a salt water navigation canal in 1806. It stretches for about 315 km north of Chennai and 103 km south of Chennai, parallel to the east coast between Kakinada (Andhra Pradesh) and Cuddalore (Tamil Nadu). Since the canal runs less than 1 km away from and parallel to the coast, there are numerous points where the backwaters from the sea flow into the canal (Appasamy and Lundqvist, 1993). The Buckingham canal runs parallel to lake right from the northern end towards south along the Sriharikota island in the eastern side which separated Bay of Bengal and the lake. Buckingham canal enters into the Pulicat at the Moosamani Lock and it is then confluent with the lake for about 1.5 km. At Kottaikuppam lock,it is emerges out from the lake and runs parallel to the coast towards south and cuts perpendicularly the Ennore Creek and proceeds further.

Rivers Kalangi, Kaleru and Arani and Buckingham canal bring in enormous quantity of flood waters and consequently the average water level increases by about 1.5 meters during good monsoon period. The mud flats around Pulicat lake, Annamalaicherry, Arangam, North of Tada, northeast of Venadu and low lying areas adjoining to the Buckingham canal get flooded during the monsoon period. Turbidity level is also high during the monsoon period. Generally high turbidity is observed on the

northeastern side of the lake due to stirring of the detritus particles but also by the prevailing winds.

1.2.9 Meteorological and Hydraulic Conditions

The annual rainfall is extremely variable. The total annual rainfall varies as much as from 500 to 1500 mm per year. More than 60% falls during the northeast monsoon. The average monthly air temperatures vary between 37º C in May and June to about 29º C during December and January. The average minimum monthly temperatures vary between 28º C in May and June and 21º C in January and February.

During the northeast monsoon the winds blow predominantly from the northeast, reaching a force of 7 on the Beaufort scale. During the southwest monsoon the winds blow predominantly from the southwest, reaching a force of 6 on the Beaufort scale. Thunderstorms occur throughout the year. From May to August they normally occur in the early evening and for the rest of the year they usually occur in the early morning or late at night. Some of the thunderstorms are accompanied by wind gusts of up to 130 km/hr.

Tropical depressions and cyclones are a recurrent phenomenon, usually occurring in the months of October and November. Cyclonic disturbances originating in the Bay of Bengal track westwards towards the Indian coastline. Wave heights associated with these cyclones can be as high as 5 to 8 m. The study area experiences a high humidity. The average maximum monthly values of the relative air humidity remain high of above 90% throughout the year. The average minimum monthly values are between 25% in May and 48% in November.

Visibility in the study area is generally very good and more than 20 km for the major part of the year. The average visibility is between 4 and 10 km on 40 days per year and less than 4 km on 4 days per year.

1.3 Tasks Identified

Pulicat Lake is a rich natural ecosystem but at the same time is very fragile and hence an integrated approach is necessary, to evolve a sustainable management strategy. The evolution of this lake should be viewed as an integration of long term trends and short term modifications by human and catastrophic elements. The management perspective therefore, requires a better understanding of the ecosystem processes and their responses to various anthropogenic and natural disturbances. This is study is first step in identifying "No Impact Zone" in such critical habitats that need conservation and protection.

Different tasks completed under the project are detailed below:

1.3.1 Tasks Completed during 1999-2000

1. Demarcation of study region into different zones according to the status of the activity in the Pulicat Lake and surrounding regions

2. Pre and Post monsoon sampling were carried out in Pulicat Lake and the adjoining coastal regions

3. In total 61 samples were collected from the lake and coastal regions

4. Samples were analyzed for nutrients and physicochemical parameters

5. Biodiversity assessment were done for the lake region in detail from phytoplankton’s to fishes and birds

6. Heavy metals in water and sediments were analysed using Atomic Absorption Spectrophotometer

7. Grain size for the core and bed sediments of the lake region were analysed using particle size analyser

8. Study area base maps were prepared from 1974 SOI toposheets for digitisation to study the land use changes

9. Satellite imageries for 1990 and 1998 of IRS 1D data were rectified and digitised for further landuse/landcover analyses using ERDAS and GIS software

10. Preliminary socioeconomic survey were conducted in the Pulicat Lake southern region

11. Input database were designed and the collected details were stored in the system using Oracle and Developer 2000

1.3.2 Tasks completed during 2000-2001

1. Analysed data of Physicochemical and biological parameters were processed according to the impact zones

2. Activity - Impact analyses were made by identifying 12 major activities in the study region

3. Decadal changes in the biodiversity status (Phytoplankton to Fishes) of Pulicat Lake was carried out

4. Spatial contours for the collected parameters with respect to the activity were made in GIS

5. Land use changes from three sets of maps of 1974, 1990 and 1998 were carried out

6. Bathymetry survey (pole method) inside the lake region were carried out

7. Socioeconomic survey was conducted in the northern and the island regions of the Pulicat lake
8. Socioeconomic problems of local population around Pulicat Lake were identified from the survey
9. Output database was designed for further analyses
10. First set of beach profiles survey and coastal measurements were carried out
11. Integration of the data were carried out in GIS to identify the No Impact Zones in Pulicat Lake

On the basis of the results from Activity - Impact analyses in Pulicat Lake ecosystem, it is observed that the Ennore satellite port will playing a major role in near future in relation to coastal erosion and accretion related problems. Pollution related problems are secondary importance.

Harbours, estuaries and coastal waters have been used as a means of navigation, disposal site for waste, fishing and many commercial and economic activities. One of the most important phenomena in these regions is the transport of sediment which may cause erosion and deposition, resulting in problems for marine economic developmental activities and coastal settlements. In the study region Ennore satellite port was constructed recently and commissioned in 2001. Since the study on impact of satellite port on coastal erosion and accretion are of primary importance in the study region, study on coastal processes with particular reference to shore line, environmental parameters (wave, current, tide, sediments etc) and bathymetry of the study region from the Ennore Creek to Pulicat mouth region have been carried out during 2001-2002 and 2002-2003. Various studies carried out during the project period are detailed below;

1.3.3 Tasks Completed during 2001 - 2002

1. Beach profile survey were carried out for the second set of measurement in the identified four transects

2. Simultaneously in four locations instruments were deployed for three days to know the wave, tide and current pattern in the coastal region north of Ennore creek

3. Bed sediments and suspended sediments were collected and analyzed to quantify the suspended and bed load transportation

4. Sediments size and concentration was measured using Particle size analyser

5. Bathymetry survey in the coastal tract were carried out using Echo sounder

6. Seasonal shoreline survey were carried out for the Entire coast from Pulicat mouth to fishing harbour using KGPS

7. Pulicat mouth were mapped during open and closed conditions using KGPS

8. Tide and current conditions between NCTPS and Pulicat Lake were studied by deploying the equipments for two days in the channel system

1.3.4 Tasks Completed during 2002 - 2003

1. Environmental parameters such as wave, tide and current data were processed for using in modeling studies

2. Shoreline were plotted in GIS platform and quantitative study on the shoreline changes due to the construction of satellite port is studied

3. Modeling Study on wave propagation have been carried out using MIKE21 PMS Module numerical modeling package

4. Sediment transport and shoreline changes modeling were completed using LITPACK software of MIKE21

5. Heavy metal analyses for the bio accumulation studies in Pulicat Lake

6. Report Writing

Various studies carried out under the project are reported in detail in the following chapters.