ANNEXURE - I

# ADDITIONAL EIA STUDIES FOR THE IMPACT ON MARINE BIODIVERSITY FOR THE CONSTRUCTION OF FISH LANDING CENTRE WITH PROTECTION STRUCTURE AS GROYNE FIELD AT KOVALAM VILLAGE, KOVALAM TALUK, KANCHEEPURAM DISTRICT, TAMIL NADU

**Prepared by**

**Department of Geology, University of Madras, Guindy Campus, Chennai-600 025.**

# CONTENTS

**Page No.**

# LIST OF TABLES

# LIST OF FIGURES

## 1.0 BACKGROUND

The Chennai Coast is characterized by sandy beaches, estuaries, creeks and backwaters with fishing settlements, casuarinas and coconut groves. Eventhough the Chennai coastal stretch is short; it is the most widely populated coast in the state. The beaches in the southern Chennai are broad with very high human intervention due to dense population and urbanization. Hence it becomes necessarily important for the Government of Tamil Nadu to maintain the balance between urbanization and conservation of coastal ecosystem. Hence any developments in the Chennai Coast need to address the ecosystem problems if any. Under these circumstances, the Department of Fisheries (DoF), Government of Tamil Nadu, Chennai has requested Department of Geology, University of Madras, Guindy Campus, Chennai to undertake a revised EIA studies for the Impact on Marine Biodiversity for the construction of Fish Landing Centre with protection structure as Groyne field at Kovalam Village, Kovalam Taluk, Kancheepuram District, Tamil Nadu. This report deals with the ecological aspects of the concerned project area within 10km radius, existing conditions prevailing in the concerned site and likely impact which may be a hindrance to the environment due to the implementation of this work

### 1.1 General

The Department of Fisheries (DoF) of Government of Tamil Nadu is a leading department endowed with rich fishery resources from Marine, Inland and Coastal Aquaculture. Tamil Nadu has a coastal length of 1076 km (13% of the country's coast line) 0.19 million sq.km of EEZ (9.4% of the India's EEZ) and a continental shelf of about 41,412 sq.km. Tamil Nadu is one of the leading state in marine fish production.

Historically, the east Coastline of 1100 Km of Tamil Nadu is known to have more locations for boat landing, atleast 3-5 in each of the 13 coastal districts. With changes in the shoreline profile, continued vulnerability of many locations for erosion and human interference and more specifically, the ever increasing fishing activities of 1.1 million strong fisherman community, upgrading or augmenting of such locations which are natural choice for places to park fishing vessels on shore, along shore and as well off shore .None the less, there are locations known for its accretion with significant numbers of sand dunes and bars. However, in the last one decade of time, erosion in the coastline has become evident with loss of beach and eroding shorelines. The human settlement and coastal community, which is largely fishermen, has become vulnerable to erosion resulting in loss of life and property. The interface of land and sea has also become fragile for its specific biological community threatened with these changes in the coastline.

### 1.2 Brief SiteDescription

The location is Kovalam Village, Thiruporur Taluk in Kancheepuram district.Kovalam is a fishing village in Thiruporur Block in Kanchipuram District of Tamil Nadu State, India. It is located 69 KM towards East from District headquarters Kanchipuram, 14 KM from Thiruporur and 35 KM from State capital Chennai.The project extent of coastline is 2.16 Km. The geological location of the area is 12° 47' 24.30" to 12° 48' 24.90" N Latitude and 80° 15' 00.80" to 80° 15' 13.30" E Longitude in the Coromandal Coast, in Kovalam, Thiruporur Taluk, Kancheepuram District, Tamil Nadu(Figure.1). The area of interest is likely to start from the Narasimha temple near the existing beach upto 300 m north of the mouth of Muttukadu Back water .The project line is falling under intertidal and it is classified as Zone–I under CRZ Notification, 2011. The buildings which are proposed towards FLC is learnt to fall under Category Zone-IV. Kancheepuram District is located the north east part of Tamil Nadu. The district spreads over an area of 4432 Sq.km, with the population of 39, 98,252(2011 census). The project location is about 50 km from the district head quarters, Kancheepuram. The coastal length of the district is 57 km in Kovalam (Project Location) and Thiruporur CD blocks. There are about 19 fish landing places with about 5900 active fisherman. The Population is largely fisherman in the coastline of the district. The fisherman population is 90,000, the second highest district in the state. There are 60 listed fishing villages and the fish production in 80,900T per annum, the highest in the state. The coastal community of the district is very significant with it's over all activities.

## 1.3 Geology

The geology of the study area is represented by the basement Archean charnockite rocks which are overlain by a thick mantle of quaternary alluvium and these in turn overlain by the Holocene tidal flat deposit and coastal dunes. The coastal beach area is characterized by salt marsh and barrier dunes forming paleoshorelines and a spit. A spit of sand protects the low lying marshy land at Muttukadu (Achyuthan 2009). Granite stones are found along the banks of the southern side.

## 1.4 Soil Environment

The predominant soil found in the project location is clayey and sand. Thiruporur Taluk region is, in general, covered by sand and brown clayey soil. The project location is largely barren and unused. There are no significant agricultural activities in the project lands.

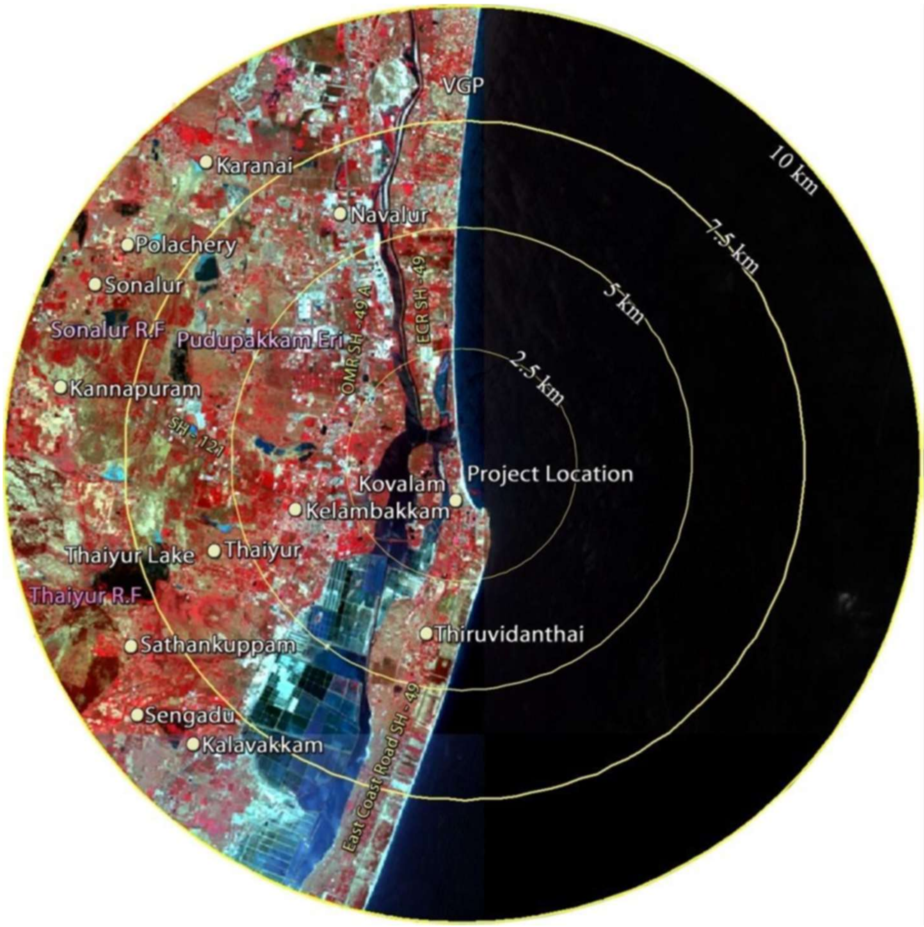



*Figure: 1 Study area location with the limit of the area falling in 10 kmradius*

### 1.5 Water quality - Coastal waters

The area has high traffic of seagoing vessels, boats and trawlers from the nearby coastal stretches. This stretch of the coastal waters receives raw sewage from domestic and trade effluent from industries. The Marina, Muttukudu, Kovalam beaches are most hot tourism spots. Southern Chennai region is very popular for tourism and resorts. Several theme parksand other recreational activities are more in this region. These kinds of activities are polluting the coastal zone and altering its nature. Besides, industrial and municipal wastes, port related operations such as continuous movement of marine vessels at Chennai including oil transport as also the wastes of aquaculture and agriculture farms (near Kovalam) are increasingly posing threats to the coastal water quality and to the biodiversity(C. Venkatraman and K. Venkataraman, 2012).Salt production along Kovalam stretch also imparts coastal/ marine pollution(Prof. Dr. R. Rameshet al,2008). Kovalam beach, the southern tip of the Chennai coastal region is connected with a fishing village located about 40 km south of Chennai which is slightly clean and has various recreational boating and surfing activities, are presently polluting the coastal region(Kottaivedu Jayaraman Sharmila and Ramanathan Narayanan, 2017).

### 1.6Physical Setting of Muttukadu Backwaters

Muttukadu Backwater form a complex system of shallow estuarine network spread over an area of 0.87 $km^2$ meant for fishing and boating activities. The backwater extends to north and south for about 15 km and opens into the Bay of Bengal at its eastern end. The width of the estuary ranges from 800m to 1050m. The estuary is shallow, the maximum depth being 2 m, in the middle of the channel, while in most of the areas; it is 1m or less. Depth varied throughout the year depending on rainfall and outflow of water from the sea during high tide period. Owing to extreme shallowness, the backwater is highly influenced by the wind turbulence. Due of the shallowness, the wind induced currents dominate the tidal currents. The seawater exchange is predominantly by tide which is semi-diurnal in nature. The evaporative outflow was assumed to be insignificant, and the freshwater inflow ($2.1 \times 10^6$ $m^3$ /d) is calculated by sum of groundwater flow, other flow volume, precipitation volume and evaporation volume. Inflow includes runoff, direct precipitation, ground water seepage, etc. and removal includes evaporation. There was zero precipitation during the period of survey and ground water seepage is assumed to be negligible, as the soil is sandy clay (Elango et al 2011). The mixing flux is calculated as $2.98 \times 10^6$ $m^3$/d, of about 77% of the total fresh water inputs, apparently indicating that backwater is dominated by freshwater discharge and its characteristics when the mouth is open. Both residual and mixing fluxes are negative indicating that their direction towards the Bay of Bengal. The water exchange time for Muttukadu Backwaters is 2.4 days when the mouth is open and it is negative when the mouth is closed. The water budget of the backwater is apparently controlled by both fresh water inputs and exchange rates by the tidal action. When the mouth is closed it is seen that residual salinity in the system is high which is due higher rate of evaporation and lack of freshwater discharge.

### 1.7 Oceanographic parameters

The seasonal circulation in the Bay of Bengal influences currents in the coastal waters off Kovalam/Chennai. Currents along the coast move towards the North from March to October and southwards from November to February. This phenomenon is also responsible for the sediment transport/littoral drift, which results in net sedimentation on the southern side of most structures built on the coast.

### 1.8 Land Environment

The area of Kovalam is dominated by agriculture,crop land followed by agriculture and plantations.The area Kovalam is barren salt marsh with little or no vegetation. Cultivation is generally dependent upon monsoon. The landuse distribution consists of Builtup-Rural , Builtup-Urban, Wetlands/Water bodies, Reservoirs/Lakes, Ponds, River/Streams/Canals, Salt Pan, Barren/Uncultivable/Wastelands, Scrub Land, Agriculture, Plantation ,Crop Land.The land environment of impact area of project site is predominantly agriculture activities.The predominant soil found in the project location is clayey and sand. The project location is largely barren and unused. There are no significant agricultural activities in the project lands.

# 2.0 PROJECT DESCRIPTION

## 2.1 Need for the Project

The coastal stretch of Tamil Nadu is characterized by sandy beaches, mangroves, estuaries, creeks and backwaters with fishing settlements, casuarinas and coconut groves. Various communities rely on the marine biology for their livelihood. Therefore it becomes absolutely necessary to maintain a clean and usable waterfront. Environmental Management is essential for sustainable use of the coastal ecosystem to preserve its rich biodiversity.

Kovalam is a coastal village where the fisherman community of not less than 10 000 lives, require augmenting the landing area as Fish Landing Centre. The location, especially the northern side is facing the threat of the loss of their coastline to erosion. Their life and property will become more vulnerable to erosion for 2.16 km stretch. The Kovalam shore is subjected to seasonal erosion since 1986 and, during the last decade, there was heavy erosion observed which resulted in loss of over 150 coconut and palm trees. About 13 houses were destroyed in due course of time. The livelihood of the fishermen in the villages is severely affected. The shoreline has advanced towards the village rapidly about 130m since 2002 to till date. Department of fisheries has approached Department of Ocean Engineering, I.I.T Madras for a consultancy proposal to protect the shore of Kovalam village. I.I.T Madras in turn accepted the consultancy proposal and conducted bathymetry survey and shore line analysis during 21-05-2015 and 22-05-2015, to study the shoreline behavior and its effect over the years. The local villagers welcomed the decision of shore protection using groynes and extended full support and cooperation for the team during survey. On the study of various factors influencing the erosion, it has been finalized to construct six short groynes and two training walls along the shore starting from the Narasimha temple on the south to North covering1860m length of shore. The layout of groynes are designed so as to form accretion in between these groynes and hence, to win over the eroded areas.

The proposed fishery structures are to cover Kovalam shoreline which is vulnerable to erosion of its shoreline. The project line is envisaged to safe guard the village from loss of life and property. This proposed coastal fishery infrastructures augmenting the shoreline of Kovalam as FISH LANDING CENTRE with required Groyne Field (11 numbers of groynes) in 2.16 km stretch of coastal line will eventually safeguard the proposed FLC and more valued tourism spots and also more than 10000 fisherman community.

Groyne Field :The location is observed to experience significant erosion in the recent past and hence protection to the shoreline and as well to the proposed FLC is important. A series of Groynes (11 numbers) as Groyne Field is envisaged as Fishery Infrastructures to provide safe landing for fishing boats and place for handling and marketing of fish. The SPS is required to contain the erosion and sea inundation in the coastline of about 2.16 Km. The proposed structures will prevent loss of valuable land, cultivable land stretches, fisherman habitations and vegetation in the project location of 1.5 to 3 km long shore stretch of Thiruporur Taluk in Kancheepuram district. Groynes as a field is envisaged as rock structures which have the advantage of simple construction, long-term durability and ability to absorb some wave energy due to their semi permeable nature. The integrated project of FLC with SPS for shoreline protection for 2.16 Km is unique as this is the first of its kind that erosion protection of project coastline is envisaged with hard structures integrated with sand nourishment so that the erosion on Northern side will be fully prevented

According to the report on "Protection Measures for Tamil Nadu Coast- Submitted to Public Works Department, Government of Tamil Nadu by Prof. V. Sundar & Prof. R. Sundaravadivelu" Department of Ocean Engineering Indian Institute of Technology Madras, Chennai - 600 036 March 2005, the Kovalam (N 12° 48'24.9" E 80" 15'12.1") coastal stretch upto Chinnakuppam (N 12° 26'54.8" E 80° 08'37.4") is a bay like formation from north of the above location has formed and this formation as per the local public appears to be quite stable. This bay formation is likely due to the outcrops on its south acting as a natural littoral barrier. As regard to the coastal protection, it is suggested to 'do nothing'. This bay could be thought of developing as a fishing harbour at a later stage if funds are available. A perfect road is also available up to this beach, which may be quite suitable for the development of a fishing harbor. However, this needs further assessment as regard to the Cost - Benefit analysis. A significant stretch of coast south of Kovalam has a wide beach conducive for plantations as a long-term measure for protecting the coast.This growth must be achieved while protecting the environment surrounding the proposed site. It is important to thoroughly examine the existing environmental status and analyze the possible impacts which pose a threat to human health and the marine environment.

## 2.2 Objectives

The primary objective of the project is to review the current status of the environmental quality of the project site and its surroundings. Therefore a study was conducted (January 2018) in the Kovalam area, by the Department of Geology, University of Madras, Guindy Campus, Chennai. This would enable the proponents to identify sensitive environmental issues and take appropriate action for maintaining ecological balance along with development of the project.

The primary objectives of the study are:

- Review the current status of the environmental quality of the project site and its surroundings
- Determine the range of physical, chemical and biological parameters in the coastal waters in and around the project area within 10 km radius using grids ( 1km$^2$) following the limits prescribed by the Central Pollution Control Board (CPCB)
- Survey of coral reef, gorgonian bed, sea weeds, sea grass, salt marsh and mangroves in and around the project locality.

## 3.0 BASELINE ENVIRONMENT

Baseline data defines the present quality of the environment at the site. Objective of the baseline study is to understand the system behavior, i.e., analysis of response of environment to changes, causes for change and to thereby establish trends for future. The baseline study requirements are based on screening of possible impacts of the project. As the proposed project is a construction of Fish Landing Centre with protection structure as Groyne field, the environmental quality of various parameters like marine water quality and marine sediment quality should be regularly monitored by the proposed authorities.

### 3.1 Water Quality Standards for Coastal Waters

In a coastal segment, marine water is subjected to several types of uses. Depending on the types of uses and activities, water quality standards have been specified to determine its suitability for a particular purpose. Among the various types of uses there is one use that demands highest level of water quality/purity and that is termed a "designated best use" in that stretch of the coastal segment. Based on this, primary water quality has been specified for five designated best uses as follows. (As per amendment to Schedule-1, serial no. 86 of Environment Protection Rules, 1986 dated 22nd December, 1998.Table 1 and 2(a,b) describes the classification of Sea and Primary water quality criteria for class SW – I & II waters.

**Table.1 Classification of Sea**

| | |
|---|---|
| **SW-I** | Saltpans, shell fishing, mariculture and Ecologically Sensitive |
| **SW-II** | Bathing, contact water sports and commercial fishing |
| **SW-III** | Industrial cooling, recreation (non-contact) and aesthetics |
| **SW-IV** | Harbour |
| **SW-V** | Navigational and controlled waste disposal |

**Table.2aPRIMARY WATER QUALITY CRITERIA FOR CLASS SW-1 WATERS (For Salt pans, Shell fishing, Mariculture and Ecologically Sensitive Zone)**

| S.No | Parameter | Standards | Rationale/Remarks |
|---|---|---|---|
| **1.** | **pH range** | 6.5---8.5 | General broad range, conductive for propagation of aquatic lives is given. Value largely dependent upon soil-water interaction. |
| **2.** | **Dissolved Oxygen** | 5.0 mg/l or 60 per cent saturation value whichever is higher | Not less than 3.5 mg/l at any time of the year for protection of aquatic lives. |
| **3.** | **Color and Odor** | No noticeable color or offensive odor | Specially caused by chemical compound like creosols, phenols, naptha pyridine benzene, toluene etc. causing visible colouration of salt crystal and fainting fish flesh. |
| **4.** | **Floating Matters** | Nothing obnoxious or detrimertal for use purpose | Surfactants should not exceed an upper limit of 1.0 mg/l and the concentratic not to cause any visible foam. |
| **5.** | **Suspended Solids** | None from sewage or industrial waste origin | Settleable innert matters not in such concentration that would impair any usages specially assigned to this class. |
| **6.** | **Oil and Grease (including** | 0.1 mg/l | Concentration should not exceed 0.1 mg/l as because it has effect on fish eggs |

| S.No | Parameter | Standards | Rationale/Remarks |
|---|---|---|---|
| | **Petroleum Products)** | | and larvae. |
| 7. | **Heavy Metals : Mercury (as Hg) Lead (as Pb) Cadmium (as Cd)** | 0.001 mg/l<br>0.001 mg/l<br>0.01 mg/l] | Values depend on: (i) Concentration in salt,fish and shell fish. (ii) Average per capita consumption per day. (iii)Minimum ingestion rate that induces symptoms of resulting diseases. |

**Table.2bPRIMARY WATER QUALITY CRITERIA FOR CLASS SW-II WATERS (For Bathing, Contact Water Sports and Commercial Fishing)**

| S.No | Parameter | Standards | Rationale/Remarks |
|---|---|---|---|
| 1. | **pH range** | 6.5---8.5 | Range does not cause skin or eye irritation and is also conducive for propagation of aquatic lives. |
| 2. | **Dissolved Oxygen** | 4.0 mg/l or 50 per cent saturation value whichever is higher. | Not less than 3.5 mg/l at any time of the year for protection of aquatic lives. |
| 3. | **Color and Odor** | No noticeable color or offensive odor | Specially caused by chemical compound like creosols phenols, naptha, benzene, pyridine toluene etc. causing visible colouration of water and tainting of and odour in fish flesh. |
| 4. | **Floating Matters** | Nothing obnoxious or detrimental for use purpose | None in such concentration that would impair usages specially assigned to this class. |

| S.No | Parameter | Standards | Rationale/Remarks |
|---|---|---|---|
| 5. | **Turbidity** | 30 NTU (Nephelo Turbidity Unit) | Measured at 0.9 depth |
| 6. | **Fecal Coliform** | 100/100 ml(MPN) | The average value not exceeding 200/100 ml in 20 per cent of samples in the year and in 3 consecutive samples in monsoon months. |
| 7. | **Biochemical Oxygen Demand (BOD) (3 days at 27oC)** | 3 mg/l | Values depend on: (i) Concentration in salt, fish and shell fish. (ii) Average per capita consumption per day. (iii)Minimum ingestion rate that induces symptoms of resulting diseases. |

### 3.2 Baseline study - Survey by Department of Geology, UNOM, GC

A team of Scientists from Department of Geology, University of Madras (UNOM), Guindy Campus(GC), Chennai undertook field surveys in the Kovalam coastal area during January 2018.Marine sampling was conducted in and around the proposed project area(Figure.2).Water and sediment samples were collected at pre-determined locations.

### 3.2.1 Methodology

**WATER**

Thewatersampleswerecollectedusingsuitablesamplersand*Insitu*oronboard measurementsweremadeusingamultiprobe,aftercalibrationwith appropriate standards. The samples were stored in one-litrepre- cleaned acid washed polyethylene bottles and were preserved underdryice, in an icebox, and stored in the cold room at 4°C in the laboratoryuntilfurther analysis. The water samples were filtered through a 0.45 umMilliporefilter and were analyzed for nutrients and metals followingstandard procedures and methods (APHA, $22^{nd}$edition, 2012) using AtomicAbsorptionSpectrometer. Apart from these parameters such as

BOD,volatilehydrocarbon, total and faecal coliforms which play a crucial role in thequality of water were also analyzed. Based on the results, the Water QualityCriteria (WQC) were calculated (NSF, 2000) for the quality of surface*waters.Based on the results, the WaterQuality Criteria (WQC) were calculated (NSF, 2000) for the quality of s u r f a c e waters.*

**SEDIMENT**

Sediment samples were collected from the seabed using a VanVeenSediment Grab sampler. Sediments were oven dried at 60°C forfurtheranalysis. The sediment samples were analyzed for the heavy metalcontentusing Atomic Absorption Spectrophotometer and for texturalparameters.

**BIOTA**

Plankton were collected from each stations using plankton net No.20 (100 mmeshsize).Theorganismswererinsedfromthecollectionbucketintosampling bottles and preserved with neutralized formaldehyde. Inthelaboratory,theconcentratedplanktonsamplewereplacedinashallow covereddish,counted,andidentifiedusingastereoscopicmicroscope.Theke ys of Edmonson and Pennak were used foridentifications.

Seabottombiotai.e.benthos,weresampled,ateachsamplinglocationby lowering a Vanveen Grab having penetration depth of 10 cms. Forbenthos,thesedimentsamples were sievedthrough0.5mmstainlesssteelmesh,onboard the vessel, and the material retained on the sieve were usedforbenthic studies. Benthic organisms were preserved in 5%neutralized formaldehyde solution after being stained in 0.01% rose Bengalstain.

Primary data of water, sediment quality and biological characteristics of the project environs were obtained from field data collection during January 2018. The boundaries were fixed considering the extent of impacts of the proposed project activities. Locations and classification of the marine sampling sites are given in Table. 3.

**3.3 Water Quality**

Determination of the physico-chemical characteristics of seawater is important in environmental monitoring. The pollutants if any released into the marine environment due to anthropogenic activity, first enter the aquatic system by direct discharge and through atmospheric inputs and get incorporated into the environment.

***Table: 3 Sampling Locations for the proposed study***

| S.No | Sample ID | Latitude(E) | Longitude (N) |
|---|---|---|---|
| **1** | **S 1** | 12°44'43.58"N | 80°15'30.27"E |
| **2** | **S 2** | 12°44'45.47"N | 80°16'34.13"E |
| **3** | **S 3** | 12°44'48.25"N | 80°17'39.65"E |
| **4** | **S 4** | 12°44'49.14"N | 80°18'40.19"E |
| **5** | **S 5** | 12°44'49.13"N | 80°19'38.58"E |
| **6** | **S 6** | 12°46'4.61"N | 80°19'39.89"E |
| **7** | **S 7** | 12°45'52.35"N | 80°18'37.29"E |
| **8** | **S 8** | 12°45'52.20"N | 80°17'36.51"E |
| **9** | **S 9** | 12°45'46.24"N | 80°16'31.99"E |
| **10** | **S10** | 12°45'40.37"N | 80°15'29.17"E |
| **11** | **S 11** | 12°46'56.42"N | 80°15'43.59"E |
| **12** | **S 12** | 12°46'57.07"N | 80°16'38.52"E |
| **13** | **S 13** | 12°46'58.70"N | 80°17'36.73"E |
| **14** | **S 14** | 12°46'58.42"N | 80°18'29.34"E |
| **15** | **S 15** | 12°47'1.02"N | 80°19'30.85"E |
| **16** | **S 16** | 12°48'2.65"N | 80°19'28.91"E |
| **17** | **S 17** | 12°47'55.99"N | 80°18'26.81"E |
| **18** | **S 18** | 12°47'53.81"N | 80°17'33.51"E |
| **19** | **S 19** | 12°47'45.72"N | 80°16'34.85"E |
| **20** | **S 20** | 12°47'46.60"N | 80°15'39.00"E |
| **21** | **S 21** | 12°48'46.49"N | 80°15'36.30"E |
| **22** | **S 22** | 12°48'46.48"N | 80°16'32.93"E |
| **23** | **S 23** | 12°48'46.46"N | 80°17'29.60"E |
| **24** | **S 24** | 12°48'50.42"N | 80°18'26.08"E |
| **25** | **S 25** | 12°48'54.30"N | 80°19'20.96"E |
| **26** | **S 26** | 12°49'47.90"N | 80°19'19.45"E |
| **27** | **S 27** | 12°49'42.01"N | 80°18'17.31"E |
| **28** | **S 28** | 12°49'36.62"N | 80°17'24.21"E |
| **29** | **S 29** | 12°49'35.13"N | 80°16'29.26"E |

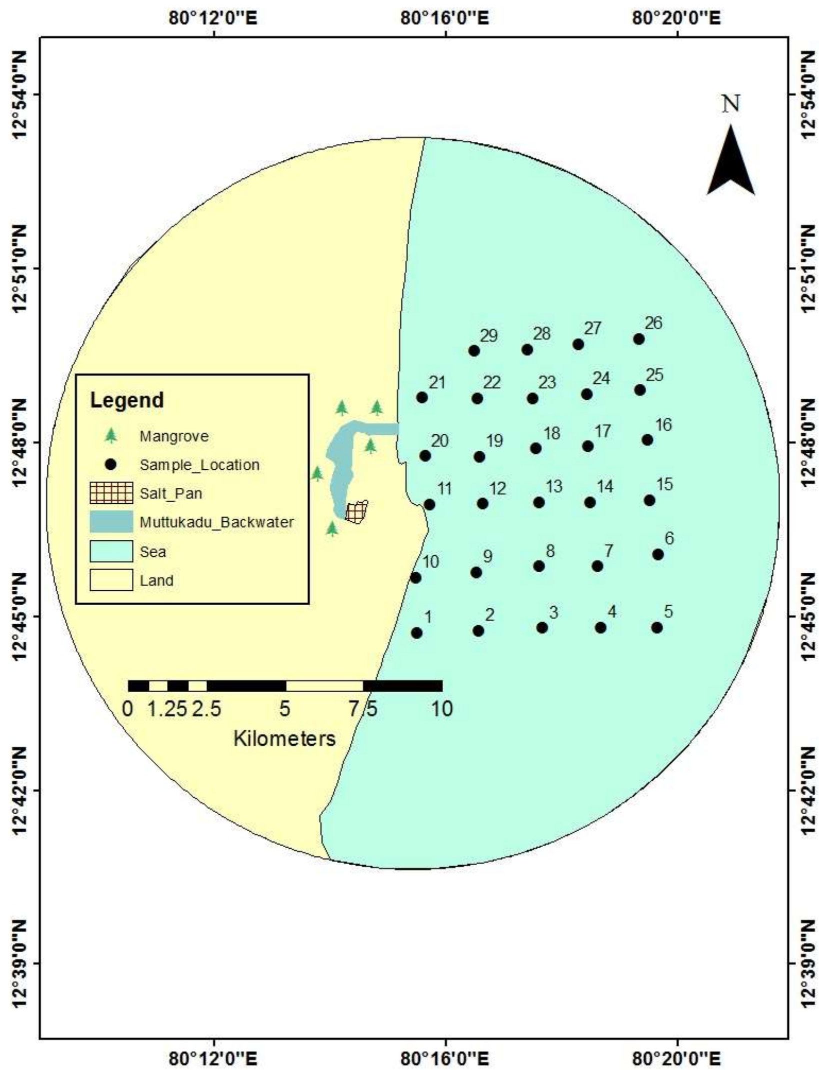
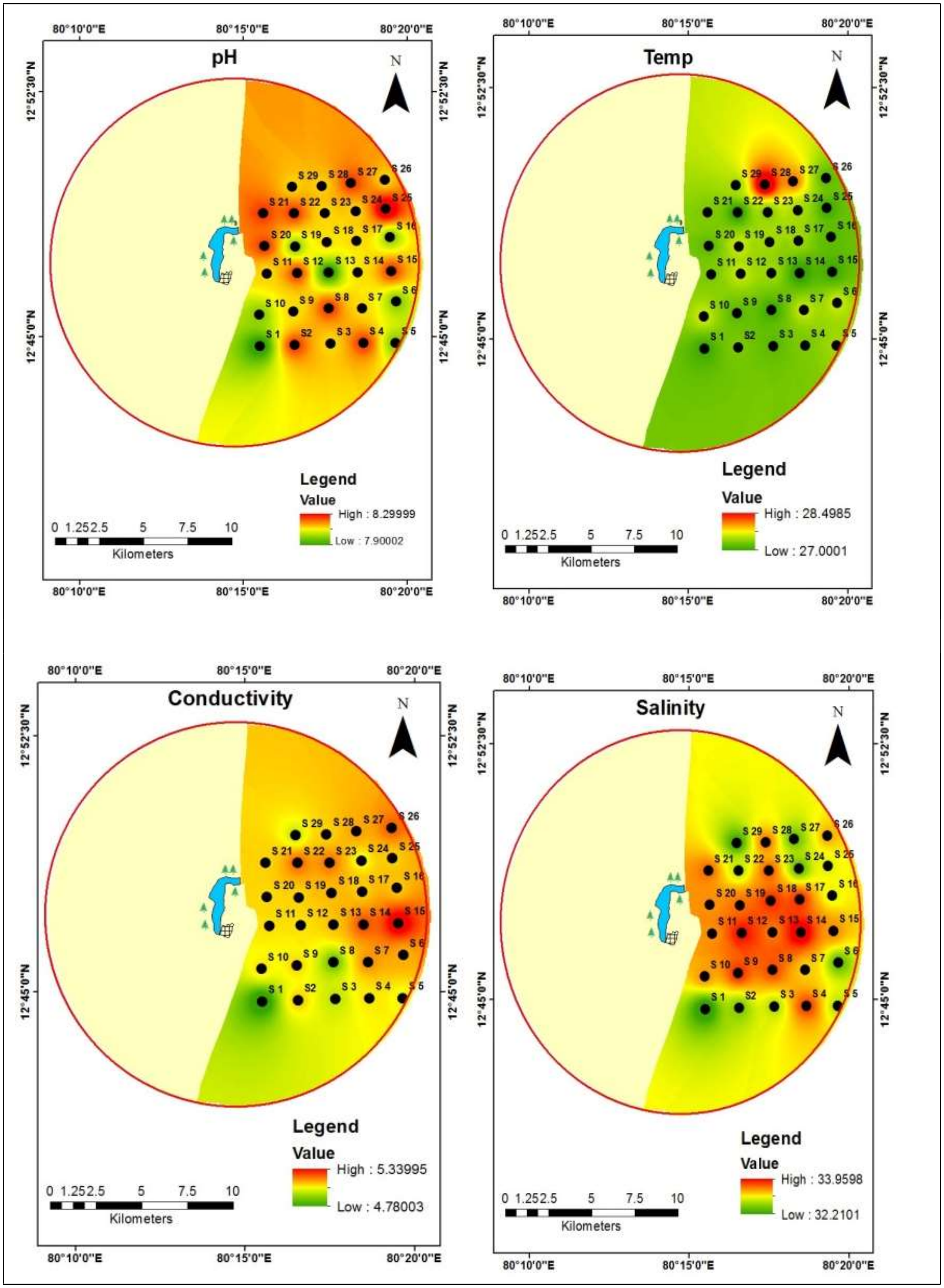


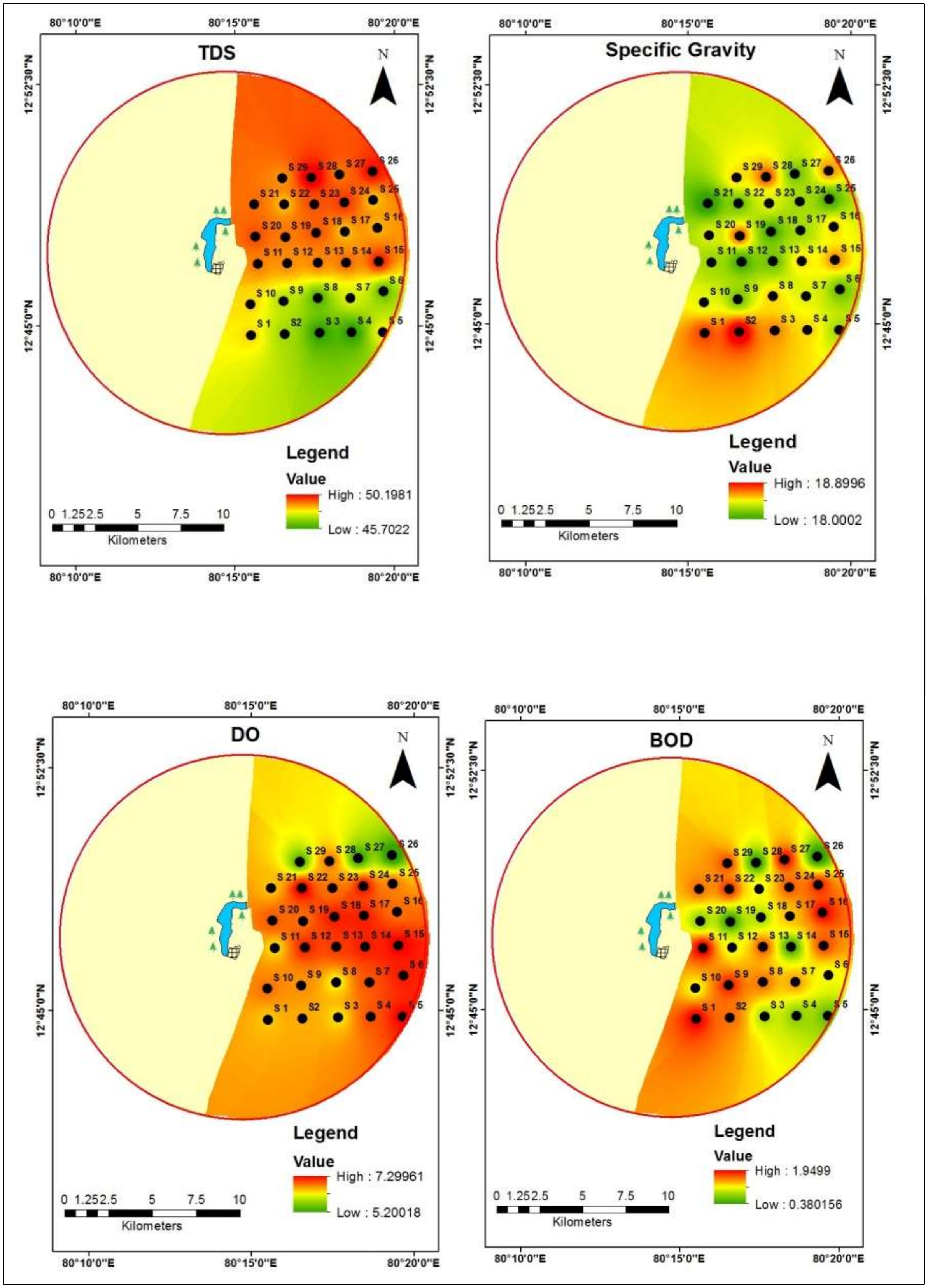

***Figure: 2 Marine water, sediment and biological sampling locations***

The water quality parameters measured were pH, temperature, conductivity,salinity, DO, BOD, TDS, Specific Gravity, Nutrients, PHC, E.coli, faecal coliforms and total coliforms. Results of the in situ water quality parameters measured during the survey are potrayed in Table .4 and depicted in Figure.3, and the values represent the quality of the existing baseline. In addition to this, baseline studies help us to understand the behaviour of the system, which is essential for establishing trends for predicting future conditions with the proposed development.

## *Table 4: Physico-Chemical parameters of Marine Waters of the Study Area*

| S.No | Sample ID | pH | Temp (°C) | Conductivity (mS) | Salinity (ppt) | TDS(g/L) | Specific Gravity | DO (mg/l) | BOD (mg/l) | PHC (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | **S 1** | 7.9 | 27.1 | 4.78 | 32.21 | 48.10 | 18.7 | 6.5 | 1.87 | 0.055 |
| **2** | **S2** | 8.2 | 27.3 | 5.1 | 32.67 | 47.10 | 18.9 | 6.6 | 1.57 | 0.043 |
| **3** | **S 3** | 8.1 | 27.2 | 5 | 32.84 | 45.80 | 18.6 | 6.4 | 0.98 | 0.073 |
| **4** | **S 4** | 8.2 | 27.3 | 5.07 | 33.58 | 45.70 | 18.5 | 6.9 | 0.86 | 0.089 |
| **5** | **S 5** | 8 | 27.4 | 5.04 | 32.88 | 47.80 | 18.3 | 7.2 | 0.74 | 0.059 |
| **6** | **S 6** | 8 | 27.5 | 5.12 | 32.56 | 46.50 | 18.2 | 7.1 | 1.16 | 0.078 |
| **7** | **S 7** | 8.1 | 27.5 | 5.15 | 33.17 | 47.60 | 18.4 | 6.9 | 1.46 | 0.045 |
| **8** | **S 8** | 8.2 | 27.1 | 4.91 | 33.54 | 46.30 | 18.5 | 6.3 | 1.57 | 0.032 |
| **9** | **S 9** | 8.1 | 27.2 | 5.09 | 33.64 | 47.20 | 18.2 | 6.7 | 1.77 | 0.042 |
| **10** | **S 10** | 8 | 27.5 | 5.08 | 33.34 | 48.10 | 18.4 | 6.8 | 1.18 | 0.077 |
| **11** | **S 11** | 8.1 | 27.3 | 5.08 | 33.33 | 48.80 | 18.3 | 6.4 | 1.95 | 0.082 |
| **12** | **S 12** | 8.2 | 27.5 | 5.074 | 33.72 | 48.70 | 18.1 | 7.1 | 1.16 | 0.019 |
| **13** | **S 13** | 7.9 | 27.4 | 5.104 | 33.37 | 48.80 | 18.2 | 7 | 1.66 | 0.044 |
| **14** | **S 14** | 8.1 | 27 | 5.21 | 33.96 | 49.00 | 18.5 | 7.1 | 0.56 | 0.029 |
| **15** | **S 15** | 8.2 | 27.1 | 5.34 | 33.35 | 49.60 | 18.6 | 7.2 | 1.67 | 0.046 |
| **16** | **S 16** | 8 | 27.2 | 5.094 | 32.99 | 48.40 | 18.5 | 6.8 | 1.87 | 0.012 |
| **17** | **S 17** | 8.1 | 27.4 | 5.09 | 33.64 | 48.20 | 18.3 | 7.1 | 1.36 | 0.05 |
| **18** | **S 18** | 8.1 | 27.4 | 5.11 | 33.63 | 49.10 | 18.1 | 7.1 | 0.96 | 0.025 |
| **19** | **S 19** | 8 | 27.5 | 5.088 | 33.44 | 48.80 | 18.7 | 6.8 | 0.49 | 0.083 |
| **20** | **S 20** | 8.2 | 27.2 | 5.082 | 33.34 | 49.20 | 18.4 | 6.9 | 0.86 | 0.092 |
| **21** | **S 21** | 8.2 | 27.3 | 5.09 | 33.46 | 48.90 | 18 | 6.5 | 1.57 | 0.084 |
| **22** | **S 22** | 8.2 | 27 | 5.19 | 32.86 | 48.20 | 18.2 | 7.3 | 1.77 | 0.075 |
| **23** | **S 23** | 8.1 | 27.3 | 5.18 | 33.52 | 49.10 | 18.4 | 6.8 | 1.18 | 0.047 |
| **24** | **S 24** | 8.1 | 27.4 | 5.04 | 32.53 | 49.40 | 18.3 | 7.2 | 1.65 | 0.064 |
| **25** | **S 25** | 8.3 | 27.1 | 5.09 | 32.99 | 48.20 | 18.1 | 6.8 | 1.77 | 0.021 |
| **26** | **S 26** | 8.1 | 27.2 | 5.192 | 33.28 | 49.70 | 18.6 | 5.2 | 0.38 | 0.052 |
| **27** | **S 27** | 8.2 | 27.9 | 5.134 | 32.6 | 48.80 | 18.2 | 5.4 | 1.87 | 0.053 |
| **28** | **S 28** | 8.1 | 28.5 | 5.088 | 33.44 | 50.20 | 18.7 | 6.8 | 0.49 | 0.043 |
| **29** | **S 29** | 8.1 | 27.4 | 5.004 | 32.38 | 48.60 | 18.5 | 5.6 | 1.66 | 0.066 |
| **MIN** | | **7.90** | **27.00** | **4.78** | **32.21** | **45.70** | **18.00** | **5.20** | **0.38** | **0.012** |
| **MAX** | | **8.30** | **28.50** | **5.34** | **33.96** | **50.20** | **18.90** | **7.30** | **1.95** | **0.092** |
| **AVG** | | **8.11** | **27.38** | **5.09** | **33.18** | **48.25** | **18.40** | **6.68** | **1.30** | **0.054** |


pH
Temp
Conductivity
Salinity
N
80°10'0"E
80°15'0"E
80°20'0"E
12°52'30"N
12°45'0"N
S 1
S2
S 3
S 4
S 5
S 6
S 7
S 8
S 9
S 10
S 11
S 12
S 13
S 14
S 15
S 16
S 17
S 18
S 19
S 20
S 21
S 22
S 23
S 24
S 25
S 26
S 27
S 28
S 29
Legend
Value
High : 8.29999
Low : 7.90002
High : 28.4985
Low : 27.0001
High : 5.33995
Low : 4.78003
High : 33.9598
Low : 32.2101
0 1.252.5 5 7.5 10
Kilometers


TDS
N
80°10'0"E
80°15'0"E
80°20'0"E
12°52'30"N
12°45'0"N
S 1
S2
S 3
S 4
S 5
S 6
S 7
S 8
S 9
S 10
S 11
S 12
S 13
S 14
S 15
S 16
S 17
S 18
S 19
S 20
S 21
S 22
S 23
S 24
S 25
S 26
S 27
S 28
S 29
Legend
Value
High : 50.1981
Low : 45.7022
0 1.252.5 5 7.5 10
Kilometers
Specific Gravity
Legend
Value
High : 18.8996
Low : 18.0002
DO
Legend
Value
High : 7.29961
Low : 5.20018
BOD
Legend
Value
High : 1.9499
Low : 0.380156

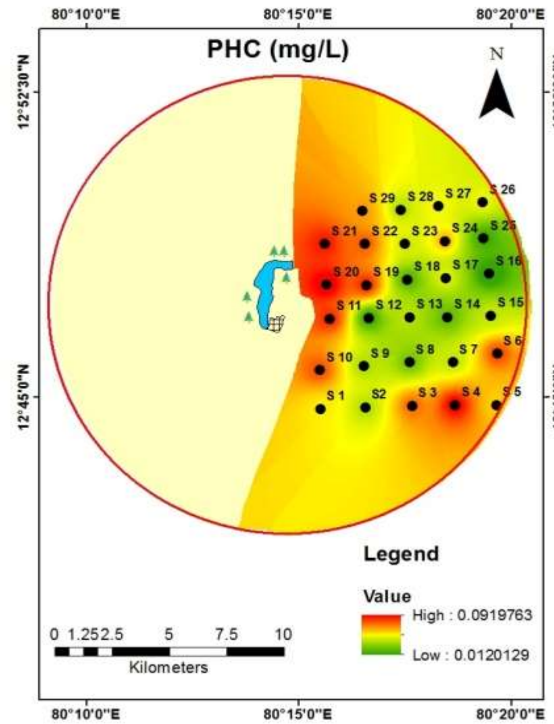



***Figure:3Physico-Chemical parameters of Marine Waters of the Study Area***

### 3.3.1 Temperature & Salinity

Temperature of the surface waters collected in the coastal waters ranged from 27.0°C to 28.50°C. Temperatures affect the kinetics of dissolved oxygen, photosynthesis, metabolic processes and other chemical and physical processes and thus control the water quality characteristics. We observed a homogenous salinity regime in all the sampling locations, with the maximum at location 28 and minimum at sampling location14 and 22(Table.4).

### 3.3.2 pH

The pH of an aqueous solution is controlled by interrelated chemical reactions that produce or consume hydrogen ions (Hem, 1989). pH did not exhibit significant variation ranged from 7.9 - 8.3and is within the range prescribed by CPCB (pH 6.5 –8.5). The range in pH is in agreement with the values reported from the other areas in the Bay of Bengal. This suggests that the primary productivity and nutrient levels are not excessive. The pH is also within the ranges specified for SW I and SW II.

### 3.3.3 Total Dissolved Solids (TDS)

The TDS varied between 45.7 - 50.2 mg/L, with an average of 48.25 mg/l. In general TDS values are found to be normal indicating not much turbulence experienced inside the break waters.

### 3.3.4 Dissolved Oxygen (DO)

Dissolved oxygen is a measure of the ability of surface waters to support aquatic life. DO is the most important factor regulating microbiological processes in marine waters and sediments, processes which alter the physico-chemical nature of the near shore waters. Dissolved oxygen in water depends on several factors, some of which are the salinity, temperature, reaeration, organic matter, productivity and the presence of pollutants. Dissolved oxygen measured in the marine waters showed concentrations ranging from 5.2 to 7.3 mg $l^{-1}$, with an average concentration of 6.68mg $l^{-1}$ (Figure 3). These values are higher than that prescribed National Standards for primary water quality criteria for class SW I & II waters. The data indicates that the DO levels are not affected by any anthropogenic activity.

### 3.3.5 Biological Oxygen Demand

BOD in sea water is generally less compared with river waters, as river waters will have high organic matter due to sewage pollution. The BOD values measured in Kovalam waters were very low, ranging between 0.38 to 1.95 mg $l^{-1}$, (average: 1.30 mg $l^{-1}$) (Figure 3) indicating minimal pollution. In general, when BOD levels are high, there is a decline in DO levels. In general, BOD values in marine waters tend to be low (below the detection limit of 2 mg/L) due to the high dilution. Figure 3 depicts the petroleum hydrocarbon concentrations along the coastal stretch of Kovalam coastal waters.

### 3.3.6 Nutrients

The elements, which are essential for biota, are classified as nutrients. Under this category, nitrate, nitrite, ammonia and phosphate are included. These elements are food for micro-organisms such as the diatoms, dianoflagellates, phytoplankton, etc., the growth of which are necessary as they are important for the food for higher order biota. In general, nutrient concentrations in the seawater are very low, which increases or decreases altering primary productivity. The nutrient content in the marine environment is controlled by the input from terrestrial sources and hence, in the open ocean waters nutrients are low. In addition to natural sources, agricultural source, sewage and industrial effluents released into the sea directly or through rivers contribute to the nutrient content of the sea. Very high concentrations can result in eutrophication, resulting in DO and nuisance problems. Nitrogen exists in nature in many different forms and there are reactions commonly that go both to and from the different forms. Nitrification, the oxidation of ammonia and nitrite to nitrate, consumes oxygen in the water column and streambed. Ammonia and nitrate are also important nutrients for the growth of algae and other plants.

In general in near shore estuarine waters inorganic nitrogen ($NO_2^-$, $NO_3^-$, NH4+) forms and phosphorus have a significant effect on macrophyte community structure and macrophyte biomass. $NO_2^-$ ranged from 0.04 - 0.2(µm/l), whereas $NO3^-$concentrations ranged between 0.18–1.12(µm/l) [1]. $NH_4$+ and $PO4^{3-}$concentrations were in the range from 0.3 - 10(µm/l) and 0.02 – 0.2 (µm/l) respectively (Table. 5 &Figure.4) The recommended level of total phosphorus in estuaries and coastal ecosystems to avoid algal blooms is 0.01 to 0.1 mg/l and 0.1 to 1 mg $l^{-1}$ of nitrogen (a 10:1 ratio of N:P). The higher concentrations support less diversity

## Table :5 Nutrients in Marine Waters of the Study Area

| S.No | Sample ID | $NO_2^-$(µm/l) | $NO_3^-$(µm/l) | $NH_4^+$(µm/l) | $PO4^{3-}$(µm/l) |
|---|---|---|---|---|---|
| 1 | S 1 | 0.05 | 0.77 | 7.34 | 0.17 |
| 2 | S2 | 0.04 | 0.79 | 5.52 | 0.2 |
| 3 | S 3 | 0.16 | 0.76 | 10 | 0.14 |
| 4 | S 4 | 0.04 | 0.68 | 8.22 | 0.02 |
| 5 | S 5 | 0.11 | 0.72 | 7.83 | 0.05 |
| 6 | S 6 | 0.07 | 0.56 | 0.3 | 0.03 |
| 7 | S 7 | 0.1 | 0.45 | 7.42 | 0.11 |
| 8 | S 8 | 0.12 | 0.69 | 6.9 | 0.04 |
| 9 | S 9 | 0.11 | 0.72 | 4.83 | 0.13 |
| 10 | S 10 | 0.15 | 0.78 | 7.23 | 0.16 |
| 11 | S 11 | 0.17 | 0.68 | 5.31 | 0.18 |
| 12 | S 12 | 0.07 | 0.71 | 2.41 | 0.2 |
| 13 | S 13 | 0.07 | 0.48 | 3.26 | 0.13 |
| 14 | S 14 | 0.06 | 0.18 | 3.62 | 0.07 |
| 15 | S 15 | 0.08 | 0.64 | 5.11 | 0.05 |
| 16 | S 16 | 0.08 | 0.91 | 4.21 | 0.03 |
| 17 | S 17 | 0.07 | 0.78 | 6.63 | 0.12 |
| 18 | S 18 | 0.09 | 0.86 | 5.91 | 0.11 |
| 19 | S 19 | 0.22 | 1.03 | 4.82 | 0.18 |
| 20 | S 20 | 0.16 | 1.12 | 5.93 | 0.09 |
| 21 | S 21 | 0.14 | 0.99 | 5.86 | 0.11 |
| 22 | S 22 | 0.23 | 1.11 | 4.22 | 0.12 |
| 23 | S 23 | 0.06 | 1.06 | 2.36 | 0.11 |
| 24 | S 24 | 0.13 | 0.86 | 2.05 | 0.04 |
| 25 | S 25 | 0.06 | 0.85 | 5.62 | 0.08 |
| 26 | S 26 | 0.04 | 0.91 | 7.13 | 0.06 |
| 27 | S 27 | 0.04 | 0.81 | 1.84 | 0.04 |
| 28 | S 28 | 0.14 | 1.1 | 3.07 | 0.15 |
| 29 | S 29 | 0.07 | 0.87 | 8.32 | 0.12 |
| **MIN** | | **0.04** | **0.18** | **0.3** | **0.02** |
| **MAX** | | **0.23** | **1.12** | **10** | **0.2** |
| **AVG** | | **0.10** | **0.78** | **5.28** | **0.11** |

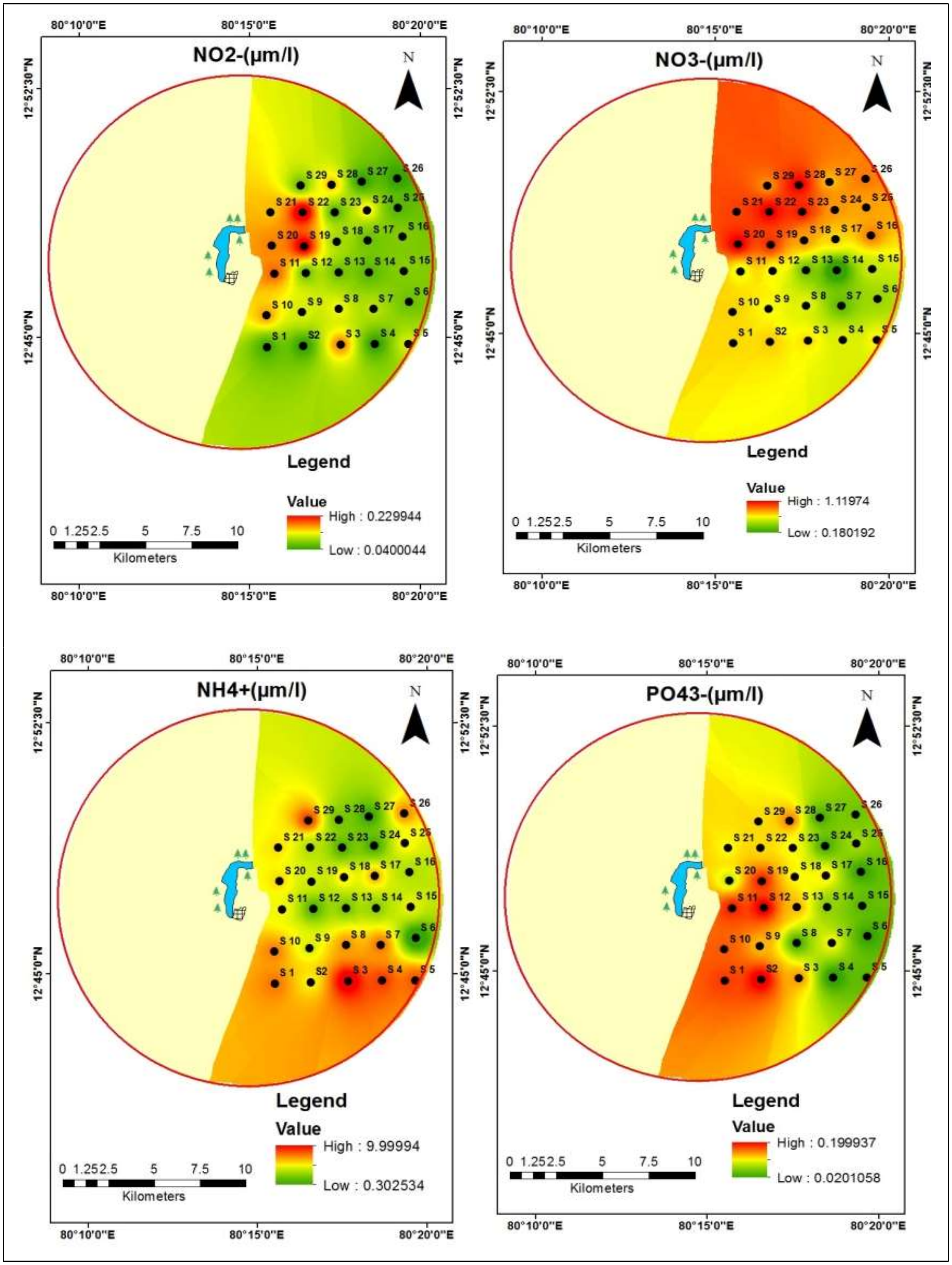



*Figure: 4 Nutrients in Marine Waters of the Study Area*

### 3.3.7 Microbiology

Bacteria are the most primitive forms of microorganisms but are composed of a great variety of simple and complex molecules and are able to carry out a wide range of chemical transformations. From the present survey it was observed that the total, faecal coliforms and E.Coli are shown in Table.6 &Figure. 5 were within the limits stipulated for primary water quality criteria for Class SW I & SW II waters by CPCB (100/100 ml CFU). Faecal coliforms are indicators of pathogenic organisms and were measured at the water quality stations.

***Table: 6 Total, Faecal Coliforms and E.coli in Coastal waters of the Study Area***

| S.No | Sample ID | E.Coli | F.Coli | Total Coliforms |
|---|---|---|---|---|
| **1** | **S 1** | 88 | 92 | 180 |
| **2** | **S 2** | 81 | 92 | 173 |
| **3** | **S 3** | 68 | 76 | 144 |
| **4** | **S 4** | 75 | 95 | 170 |
| **5** | **S 5** | 85 | 91 | 176 |
| **6** | **S 6** | 59 | 89 | 148 |
| **7** | **S 7** | 74 | 89 | 163 |
| **8** | **S 8** | 70 | 95 | 165 |
| **9** | **S 9** | 82 | 98 | 180 |
| **10** | **S 10** | 66 | 87 | 153 |
| **11** | **S 11** | 71 | 92 | 163 |
| **12** | **S 12** | 68 | 74 | 142 |
| **13** | **S 13** | 66 | 69 | 135 |
| **14** | **S 14** | 65 | 83 | 148 |
| **15** | **S 15** | 83 | 87 | 170 |
| **16** | **S 16** | 78 | 80 | 158 |
| **17** | **S 17** | 85 | 89 | 174 |
| **18** | **S 18** | 80 | 92 | 172 |
| **19** | **S 19** | 83 | 89 | 172 |
| **20** | **S 20** | 79 | 84 | 163 |
| **21** | **S 21** | 85 | 91 | 176 |
| **22** | **S 22** | 69 | 79 | 148 |
| **23** | **S 23** | 92 | 96 | 188 |
| **24** | **S 24** | 77 | 81 | 158 |
| **25** | **S 25** | 96 | 98 | 194 |
| **26** | **S 26** | 74 | 80 | 154 |
| **27** | **S 27** | 90 | 92 | 182 |
| **28** | **S 28** | 69 | 86 | 155 |
| **29** | **S 29** | 85 | 91 | 176 |
| **MIN** | | **59** | **69** | **135** |
| **MAX** | | **96** | **98** | **194** |
| **AVG** | | **77.35** | **87.23** | **164.81** |

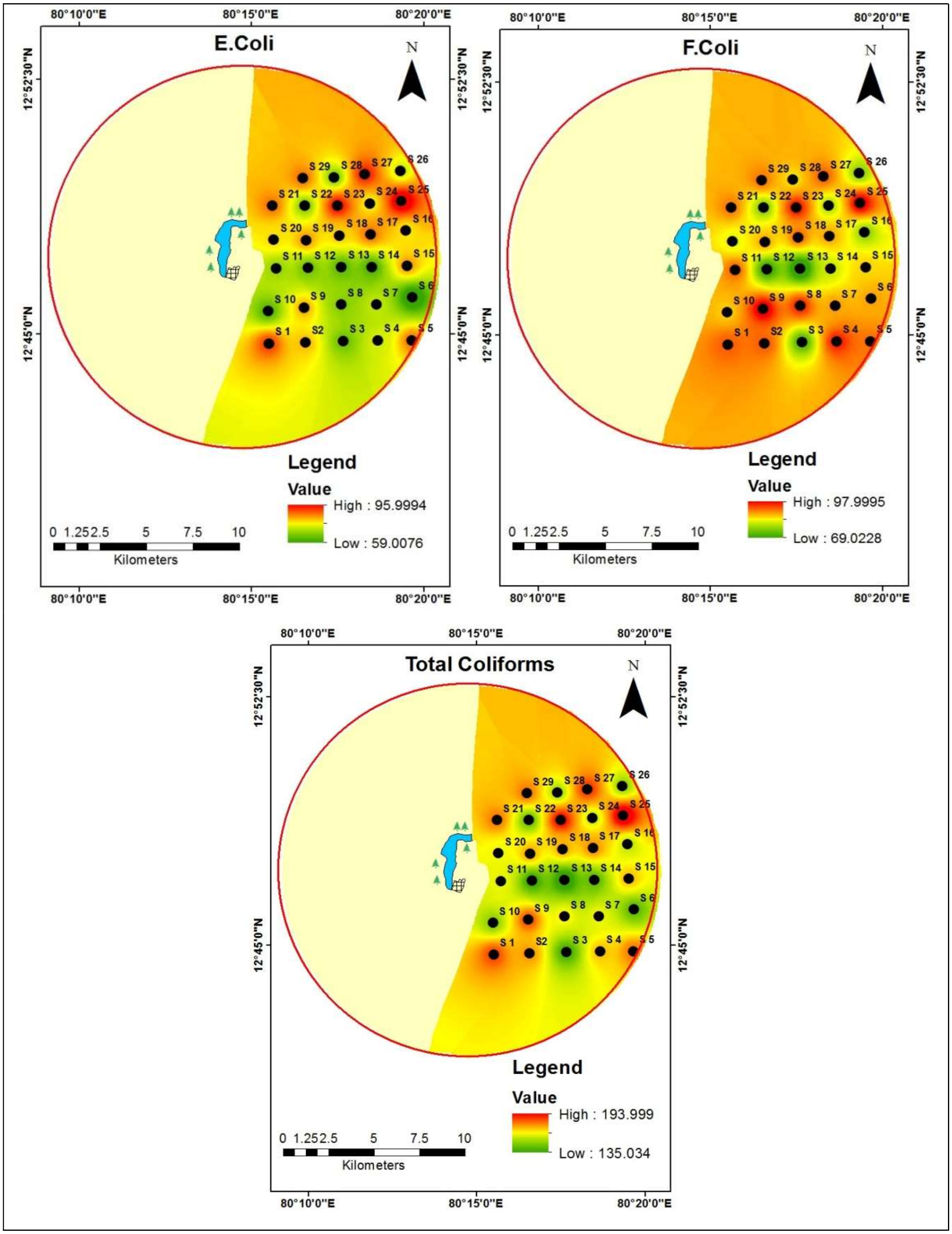



***Figure: 5 Total, Faecal Coliforms and E.Coli in Coastal waters of the Study Area.***

### 3.3.8 Heavy Metals

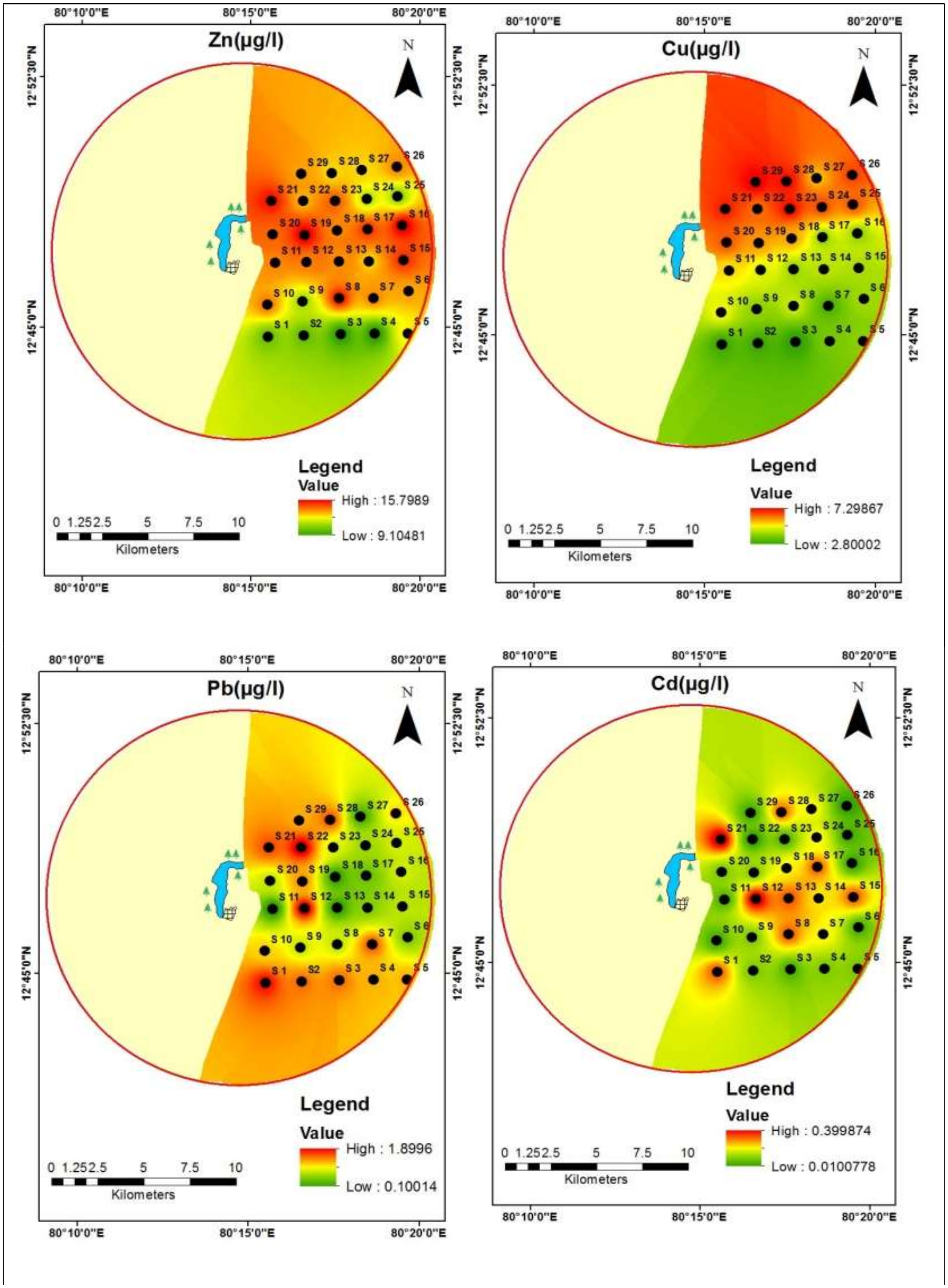
Trace elements, and especially the so-called heavy metals, are one of the serious pollutants in our natural environment because of their toxicity, persistence and bioaccumulation problems, and their happening in waters and biota point out the presence of natural or anthropogenic sources. Heavy metals tend to be trapped in the aquatic environment and accumulate in sediments and may be 1) directly available to benthic fauna or 2) released to the water column through sediment resuspension, adsorption-desorption reactions, reduction-oxidation reactions and degrading organisms. Such processes enhance the dissolved concentration of trace metals in the environment and threaten the ecosystem. Thus heavy metals introduced into the aquatic environment by anthropogenic activities can have a detrimental effect on organisms in that environment.

These elements, although naturally occurring in the environment, are not usually present in high concentrations in sediments unless they are introduced via anthropogenic inputs. Other than industrial dumping of metals into the ocean, many heavy metals have been introduced into the aquatic environment through the use of anti-fouling paints on ship hulls. Zinc is introduced into the environment through its use in the bottom paints of boats but mostly through its use as the sacrificial anode on boat motors. Copper is introduced into the aquatic environment through sewage sludge disposal, anti-fouling paint and pressure treated wood, which also contains chromium. Modern contaminant lead (Pb) has had a unique, predominant source as a product of combustion of leaded gasoline. Anthropogenic Cd-sources include primarily non-ferrous metal industry and waste incineration. Natural sources contribute far less than the anthropogenic sources.

Heavy metals presence in the water column is usually the result of recent inputs. The concentration of heavy metals Zinc and Copper in the seawater samples collected in the various stations are given in Table 7. The concentration of the essential heavy metals is found to be less in the surface waters. The concentration of heavy metals in seawater is strongly influenced by the dissolution of resuspended sediment particles. The concentration of Zn is found to range from 9.1–15.8 ug/l and the concentration of Cu is found to range from 2.80 -7.30 ug/l in the surface waters. High concentrations of copper in water cause detectable inhibition of photosynthesis.

***Table: 7 Concentration of heavy metals (µg/l) in the Coastal waters of the StudyArea***

| S.No | Sample ID | Zn(µg/l) | Cu(µg/l) | Pb(µg/l) | Cd(µg/l) | Cr(µg/l) | Ni(µg/l) | Co(µg/l) |
|---|---|---|---|---|---|---|---|---|
| **1** | **S 1** | 10.5 | 3.1 | 1.7 | 0.3 | 3.2 | 3.8 | 0.6 |
| **2** | **S2** | 10.4 | 3.1 | 1.4 | 0.1 | 2.9 | 3.3 | 0.3 |
| **3** | **S 3** | 9.2 | 2.8 | 1.4 | 0.05 | 3.5 | 3.2 | 0.4 |
| **4** | **S 4** | 9.1 | 3.9 | 1.2 | 0.1 | 2.3 | 3.1 | 0.1 |
| **5** | **S 5** | 12.7 | 4.1 | 1.2 | 0.1 | 2.3 | 3.1 | 0.3 |
| **6** | **S 6** | 13.5 | 4.3 | 0.6 | 0.05 | 2.2 | 29 | 0.6 |
| **7** | **S 7** | 13.9 | 3.3 | 1.5 | 0.2 | 2.1 | 2.9 | 0.5 |
| **8** | **S 8** | 15.4 | 4.8 | 0.8 | 0.3 | 2.1 | 3.9 | 0.8 |
| **9** | **S 9** | 11.3 | 4.1 | 0.8 | 0.1 | 2.4 | 3.8 | 0.4 |
| **10** | **S 10** | 14.1 | 5.1 | 1.1 | 0.04 | 2.4 | 41 | 0.5 |
| **11** | **S 11** | 13.8 | 5.3 | 0.1 | 0.05 | 1.5 | 3.1 | 0.7 |
| **12** | **S 12** | 13.9 | 4.8 | 1.9 | 0.4 | 1.3 | 3.7 | 0.5 |
| **13** | **S 13** | 13.7 | 4.2 | 0.2 | 0.3 | 1.9 | 3.5 | 0.3 |
| **14** | **S 14** | 12.8 | 4.5 | 0.6 | 0.2 | 2.2 | 3.5 | 0.2 |
| **15** | **S 15** | 14.9 | 4.4 | 0.8 | 0.3 | 2.1 | 2.7 | 0.5 |
| **16** | **S 16** | 15.8 | 4.1 | 0.9 | 0.03 | 1.4 | 3.8 | 0.4 |
| **17** | **S 17** | 14.9 | 4.1 | 0.5 | 0.3 | 1.3 | 3.4 | 0.6 |
| **18** | **S 18** | 13.8 | 5.8 | 0.2 | 0.2 | 2.1 | 3.3 | 0.5 |
| **19** | **S 19** | 15.8 | 5.9 | 1.3 | 0.1 | 1.2 | 3.1 | 0.2 |
| **20** | **S 20** | 14.2 | 6.5 | 0.8 | 0.1 | 2.3 | 3.3 | 0.4 |
| **21** | **S 21** | 15.3 | 6.9 | 1.5 | 0.4 | 2.7 | 3.5 | 0.1 |
| **22** | **S 22** | 13.2 | 6.2 | 1.9 | 0.01 | 1.2 | 2.9 | 0.5 |
| **23** | **S 23** | 14.5 | 7.2 | 0.9 | 0.05 | 1.9 | 1.5 | 0.3 |
| **24** | **S 24** | 11.4 | 6.6 | 0.7 | 0.2 | 1.2 | 2.4 | 0.4 |
| **25** | **S 25** | 10.9 | 6.5 | 0.9 | 0.04 | 1.5 | 2.9 | 0.5 |
| **26** | **S 26** | 13.9 | 6.6 | 1.1 | 0.02 | 1.1 | 2.5 | 0.3 |
| **27** | **S 27** | 12.9 | 5.5 | 0.3 | 0.2 | 1.1 | 2.5 | 0.4 |
| **28** | **S 28** | 12.8 | 7.1 | 1.5 | 0.3 | 1.3 | 2.2 | 0.3 |
| **29** | **S 29** | 13.5 | 7.3 | 1.2 | 0.04 | 0.3 | 2.5 | 0.5 |
| **MIN** | | **9.1** | **2.8** | **0.1** | **0.01** | **0.3** | **1.5** | **0.1** |
| **MAX** | | **15.8** | **7.3** | **1.9** | **0.4** | **3.5** | **41** | **0.8** |
| **AVG** | | **13.176** | **5.1032** | **1** | **0.161** | **1.8968** | **6.3194** | **0.4194** |
| **Safety Levels *** | | 100 | 25 | 100 | 10 | NA | 70 | NA |
| **Unpolluted Seawater** | | 10 | 3 | 0.03 | 0.11 | | 0.7-7 | |



Zn(µg/l)
Legend
Value
High : 15.7989
Low : 9.10481
Cu(µg/l)
Legend
Value
High : 7.29867
Low : 2.80002
Pb(µg/l)
Legend
Value
High : 1.8996
Low : 0.10014
Cd(µg/l)
Legend
Value
High : 0.399874
Low : 0.0100778
Kilometers

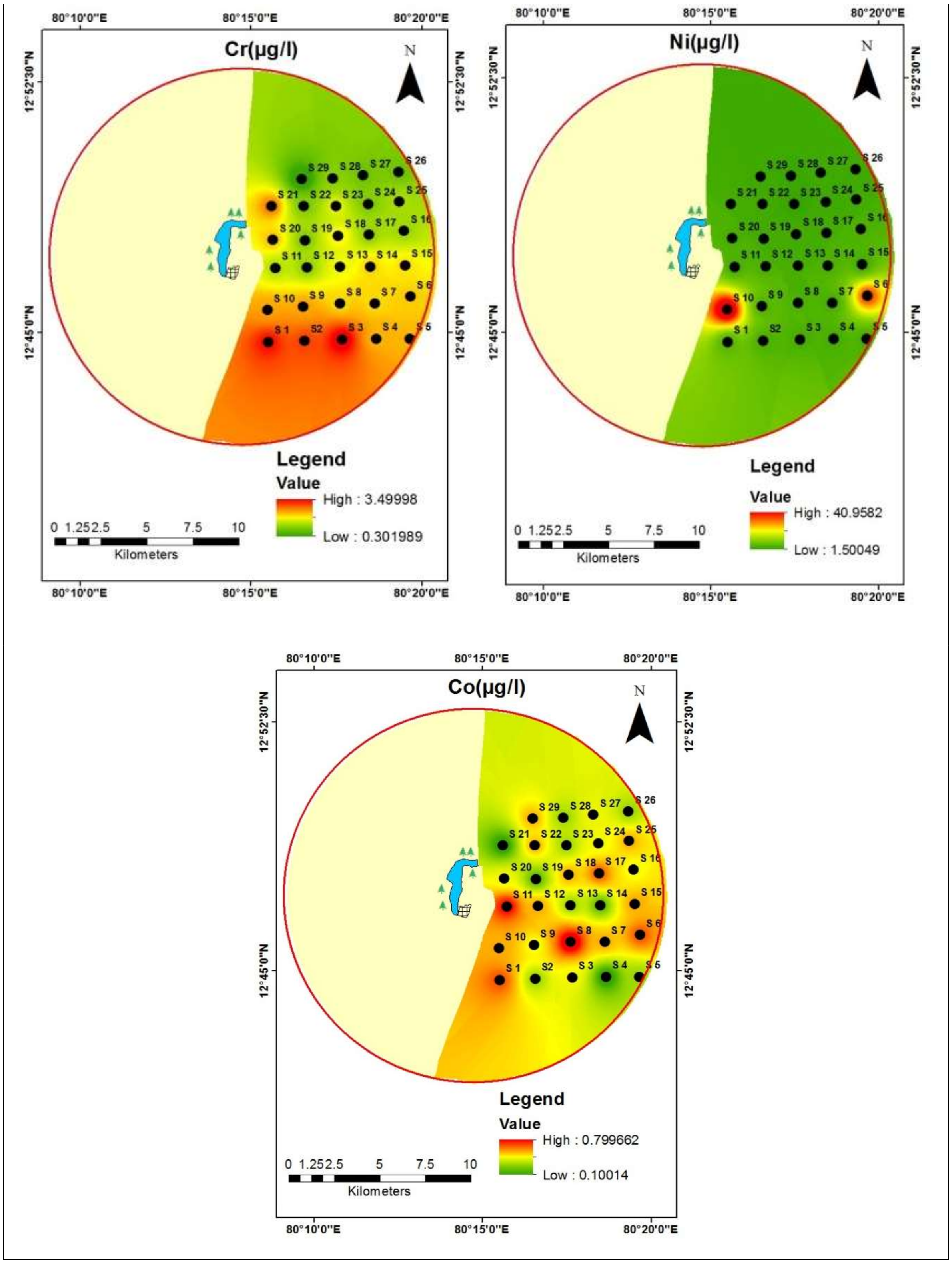



*Figure: 6 Concentration of heavy metals (µg/l) in the Coastal waters of the Study Area*

Metals like Pb, Cd, Hg, Cr, Co and Ni are considered as toxic heavy metals and may affect the marine life if present in higher concentration. The concentration of these metals in the organisms, which serve as food for higher order life, may undergo bio-magnification in the food chain. Hence, monitoring the level of these metals becomes important. The concentrations of these toxic heavy metals analyzed in the water samples examined are presented in Table 7 & Figure 6. The surface waters are found to have lesser concentration of the toxic heavy metals. The concentration pattern of the toxic heavy metals is Zn> Ni>Cu >Cr >Pb >Co >Cd >Hg in the Kovalam waters.

### 3.4 Sediment quality

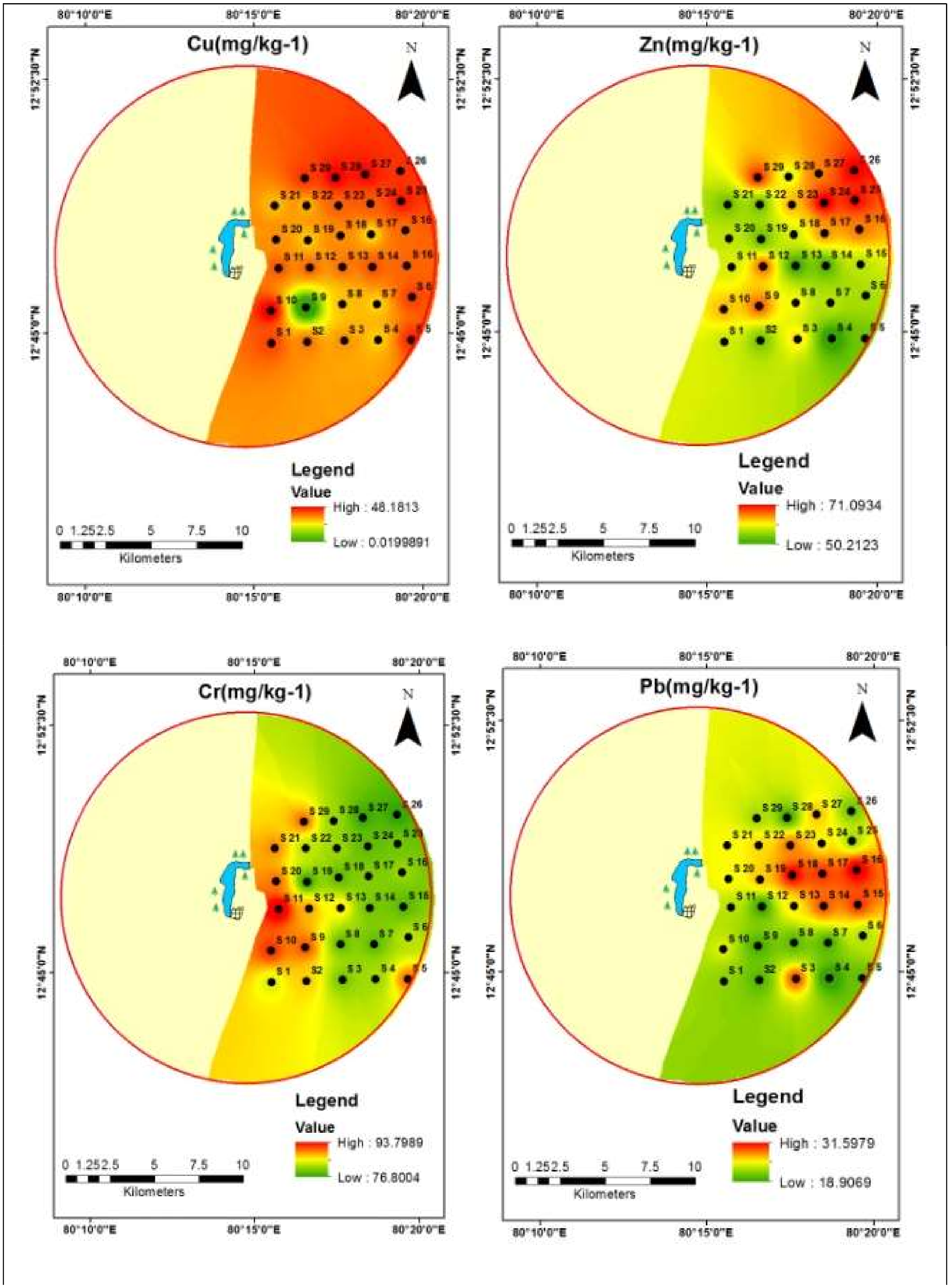
Coastal sediments constitute a reservoir of trace metals in aquatic environments and the distribution of metals among specific components in sediment largely determines the fate of sediment bound metals. Sediments serve as a sink for several trace metals through a process of hydrolysis and adsorption by suspended particles. High metal concentrations in sediments would also release these metals into the dissolved phase when in suspension. In addition, pore water concentrations can reach harmful levels and eventually get biomagnified as it moves up the food chain through feeders like molluscs and crustaceans. Thus, sediment quality was assessed for presence of heavy metals such as Copper, Cadmium, Chromium, Cobalt, Lead, Nickel, Zinc and Mercury.

In general, heavy metal concentrations in the sediments were found to be low, the concentration pattern of the heavy metals are Cr > Zn >Cu>Ni> Pb > Co > Cd > Hg in the marine sediments and are depicted in Table.8 and Figure 7.

**Table: 8 Heavy Metal concentrations (mg/kg-1) in Marine Sediments**

| S.No | Sample ID | Cu | Zn | Pb | Cr | Co | Hg | Cd | Ni |
|---|---|---|---|---|---|---|---|---|---|
| **1** | **S 1** | 41.8 | 59.2 | 22.7 | 83 | 8.56 | BDL | 0.2 | 33.5 |
| **2** | **S2** | 38.6 | 55.6 | 21 | 85.6 | 8.81 | BDL | 0.3 | 38.2 |
| **3** | **S 3** | 36.5 | 62.3 | 29.3 | 79.8 | 7.9 | BDL | 0.1 | 37.9 |
| **4** | **S 4** | 32.1 | 50.2 | 18.9 | 81.3 | 8.1 | BDL | 0.5 | 33.5 |
| **5** | **S 5** | 43.5 | 55.6 | 21.5 | 88.2 | 8.6 | BDL | 0.41 | 41.2 |
| **6** | **S 6** | 42.1 | 58.1 | 23.6 | 82.3 | 8.3 | BDL | 0.2 | 40.2 |
| **7** | **S 7** | 31.6 | 58.8 | 20.5 | 78.9 | 7.9 | BDL | 0.1 | 43.8 |
| **8** | **S 8** | 33.5 | 61.2 | 21.1 | 79.1 | 12.5 | BDL | 0.2 | 35.6 |
| **9** | **S 9** | 33..6 | 66.8 | 20.6 | 89.2 | 11.9 | BDL | 0.3 | 33.5 |
| **10** | **S 10** | 48.2 | 63.5 | 24.6 | 90.1 | 16.8 | BDL | 0.2 | 31.2 |
| **11** | **S 11** | 40.5 | 59.6 | 23.8 | 93.8 | 13.5 | BDL | 0.1 | 30.8 |
| **12** | **S 12** | 39.8 | 66.6 | 19.8 | 86.6 | 14.2 | BDL | 0.5 | 32.2 |
| **13** | **S 13** | 39.1 | 52.2 | 25.6 | 85.4 | 15.2 | BDL | 0.1 | 31.6 |
| **14** | **S 14** | 40.6 | 53.6 | 28.9 | 79.7 | 18.9 | BDL | 0.3 | 33.3 |
| **15** | **S 15** | 39.6 | 58.6 | 29.5 | 78.6 | 9.8 | BDL | 0.2 | 31.2 |
| **16** | **S 16** | 38.8 | 65.8 | 31.6 | 81.2 | 12.3 | BDL | 0.1 | 36.8 |
| **17** | **S 17** | 30.6 | 64.7 | 29.5 | 80.5 | 13.5 | BDL | 0.1 | 42.2 |
| **18** | **S 18** | 36.5 | 59.8 | 31.2 | 78.8 | 15.6 | BDL | 0.4 | 45.6 |
| **19** | **S 19** | 32.2 | 54.9 | 26.5 | 76.9 | 12.9 | BDL | 0.2 | 39.5 |
| **20** | **S 20** | 36.5 | 58.8 | 25.4 | 88.3 | 11.8 | BDL | 0.1 | 35.2 |
| **21** | **S 21** | 33.3 | 55.4 | 25.2 | 87.5 | 11.1 | BDL | 0.3 | 32.6 |
| **22** | **S 22** | 33.8 | 54.9 | 26.1 | 82.2 | 10.9 | BDL | 0.6 | 33.6 |
| **23** | **S 23** | 39.2 | 63.5 | 28.2 | 81.3 | 10.5 | BDL | 0.1 | 31.3 |
| **24** | **S 24** | 39.8 | 71.1 | 25.3 | 78.9 | 14.6 | BDL | 0.2 | 38.6 |
| **25** | **S 25** | 44.6 | 69.8 | 22.9 | 79.8 | 15.3 | BDL | 0.3 | 36.5 |
| **26** | **S 26** | 42.6 | 70.3 | 21.8 | 76.8 | 15.1 | BDL | 0.2 | 31.1 |
| **27** | **S 27** | 45.8 | 65.5 | 26.6 | 77.2 | 17.6 | BDL | 0.1 | 41.2 |
| **28** | **S 28** | 47.2 | 59.8 | 20.1 | 81.2 | 18.1 | BDL | 0.2 | 40.4 |
| **29** | **S 29** | 42.8 | 68.7 | 23.1 | 88.6 | 17.5 | BDL | 0.3 | 38.6 |
| **MIN** | | **30.6** | **50.2** | **18.9** | **76.8** | **7.9** | | **0.1** | **30.8** |
| **MAX** | | **48.2** | **71.1** | **31.6** | **93.8** | **18.9** | | **0.6** | **45.6** |
| **AVG** | | **39** | **60.845** | **24.69** | **82.948** | **12.728** | | **0.2455** | **36.365** |

BDL - Below Detection Limit



Cu(mg/kg-1)
Legend
Value
High : 48.1813
Low : 0.0199891
Zn(mg/kg-1)
Legend
Value
High : 71.0934
Low : 50.2123
Cr(mg/kg-1)
Legend
Value
High : 93.7989
Low : 76.8004
Pb(mg/kg-1)
Legend
Value
High : 31.5979
Low : 18.9069
0 1.252.5 5 7.5 10
Kilometers
80°10'0"E
80°15'0"E
80°20'0"E
12°52'30"N
12°45'0"N
N

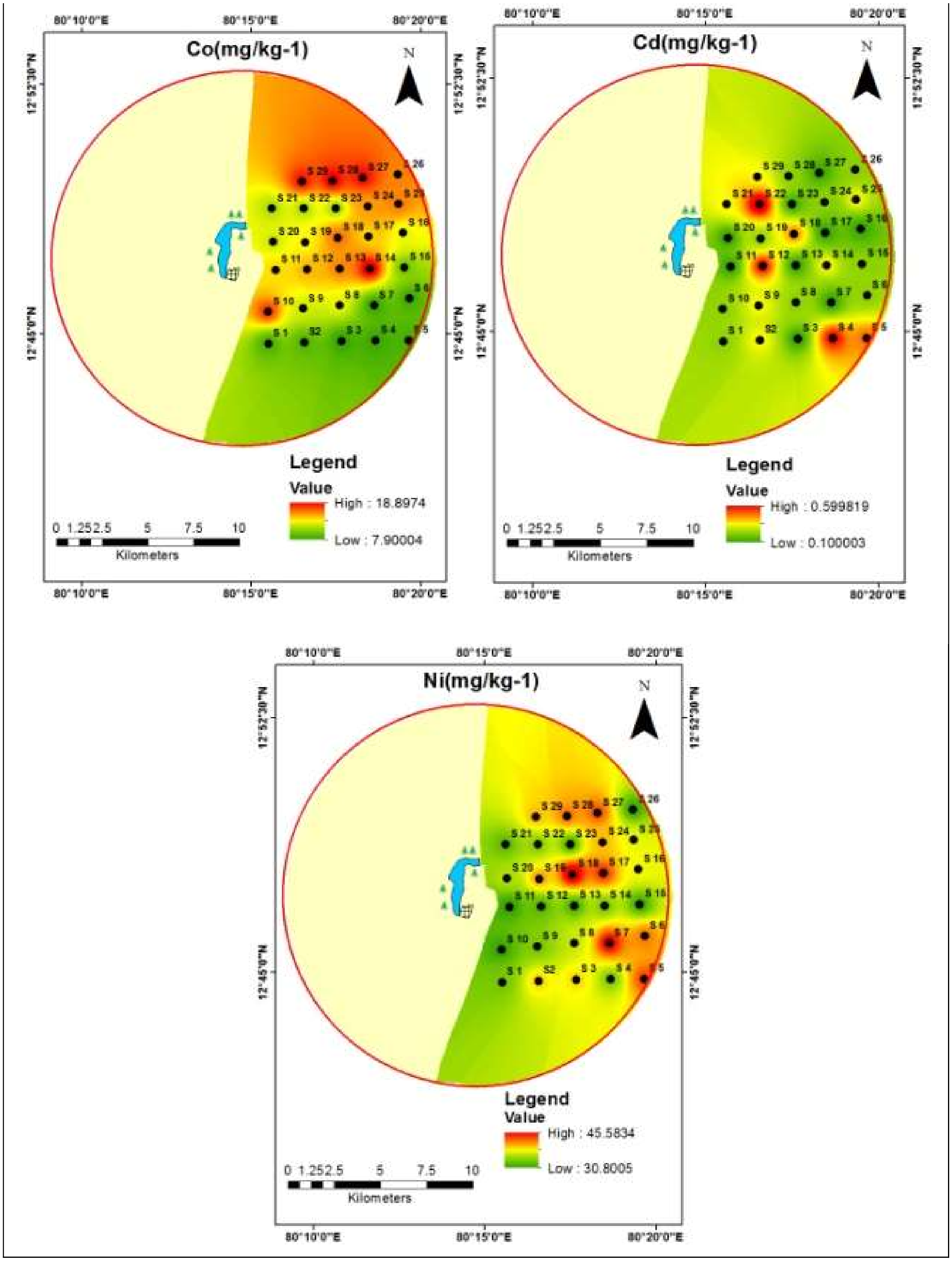



*Figure: 7 Heavy Metal concentrations (mg/kg-1) in Marine Sediments*

### 3.4.1 Sediment Classification

The sediment characters mainly focuses on the results of spatial and vertical distributions of sand, silt, clay, Sediment accumulation in a marine environment is mainly dependent on the type and rate of input.

***Table :9 Textural Parameters in Marine Sediments of the Study Area***

| S.No | Sample ID | Sand % | Clay % | Silt % |
|---|---|---|---|---|
| **1** | **S 1** | 70.96 | 3.82 | 25.22 |
| **2** | **S2** | 69.44 | 3.85 | 26.71 |
| **3** | **S 3** | 65.72 | 2.85 | 31.43 |
| **4** | **S 4** | 56.22 | 2.7 | 41.08 |
| **5** | **S 5** | 83.21 | 3.65 | 13.14 |
| **6** | **S 6** | 76.11 | 2.7 | 21.19 |
| **7** | **S 7** | 87.3 | 2.3 | 10.4 |
| **8** | **S 8** | 95.74 | 2.5 | 1.76 |
| **9** | **S 9** | 12.05 | 3.4 | 84.55 |
| **10** | **S 10** | 29.86 | 2.65 | 67.49 |
| **11** | **S 11** | 12.84 | 2.8 | 84.36 |
| **12** | **S 12** | 76.43 | 3.35 | 20.22 |
| **13** | **S 13** | 79.43 | 3.25 | 17.32 |
| **14** | **S 14** | 86.71 | 2.55 | 10.74 |
| **15** | **S 15** | 96.49 | 0.65 | 2.86 |
| **16** | **S 16** | 82.75 | 2.65 | 14.6 |
| **17** | **S 17** | 81.21 | 1.55 | 17.24 |
| **18** | **S 18** | 83.15 | 1.45 | 15.4 |
| **19** | **S 19** | 86.53 | 1.4 | 12.07 |
| **20** | **S 20** | 77.64 | 1.5 | 20.86 |
| **21** | **S 21** | 79.3 | 1.2 | 19.5 |
| **22** | **S 22** | 92.04 | 0.4 | 7.56 |
| **23** | **S 23** | 75.64 | 2.5 | 21.86 |
| **24** | **S 24** | 75.64 | 2.15 | 22.21 |
| **25** | **S 25** | 88.83 | 1.1 | 10.07 |
| **26** | **S 26** | 79.98 | 1.75 | 18.27 |
| **27** | **S 27** | 78.15 | 1.4 | 20.45 |
| **28** | **S 28** | 89.84 | 1.6 | 8.56 |
| **29** | **S 29** | 92.96 | 1.4 | 5.64 |
| **MIN** | | **12.05** | **0.4** | **1.76** |
| **MAX** | | **96.49** | **3.85** | **84.55** |
| **AVG** | | **73.2487** | **2.23613** | **24.4861** |

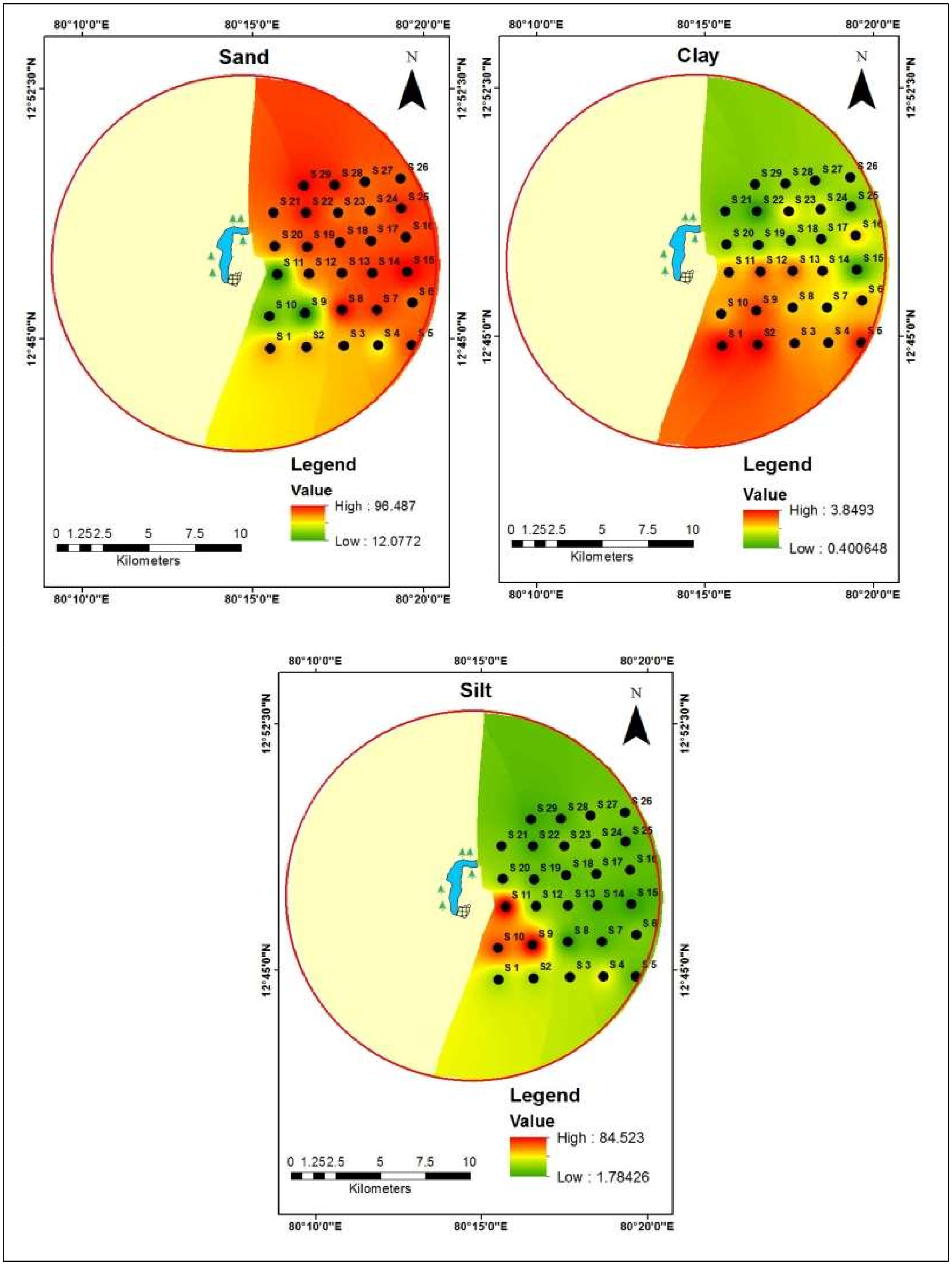



*Figure: 8 Textural Parameters in Marine Sediments of the Study Area*

Grain size also has a significant effect on the heavy metal geochemistry of sediment. To understand the distribution of sediment types and textural characteristics, detailed studies were carried out and the results obtained have been discussed.

Sediment samples were analyzed for the particle size distribution. Sieve analysis and hydrometer analysis were carried out depending on the material passing 75-micron sieve. Classifications are based on IS 1498. In general the sediments in Kovalam area are poor in clay fraction, which displays a range between 0.40- 3.85 %. Sand is found to range from 12.05 - 96.49% and silt display a range of 1.76 - 84.55 % and are pictured in Table 9 and Figure 8.

## 3.5 Marine biology

### 3.5.1 Analysis of biological samples:

Samples for plankton studies were collected from 29 locations along the Kovalam coastal stretch using the standard methods, Phytoplankton samples were collected from the surface water by horizontal towing a conical net bag (0.35 m mouth diameter), made up of bolting silk cloth (cloth No. 30; mesh size 48 µm) for thirty minutes at each sampling site. The plankton concentrate was then transferred into the sampling bottles and preserved with 5 % buffered formalin solution. In the laboratory, the concentrated plankton sample was taken in aliquots of known volumes and identified and enumerated using a LEICA - DM 1000 LED inverted microscope. The identification keys by Newell and Newell were followed for sample identification, up to the generic and in many cases up to the species level. Shannon–Weaver index was used as a tool to measure the overall biodiversity of the study site. The advantage of this index is that it takes into account the number of species and the evenness of the species.

### 3.5.2 Phytoplankton diversity and distribution:

Phytoplankton recorded from the 29 locations of the coast, composed of 25 species from four Major groups namely

1. Bacillariophyceae -56%
2. Dinophyceae -28%
3. Cyanophyceae -8%
4. Mediophyceae -8%

Total of 25 species were recorded from the sampling sites. Of which 14 species belonged to Bacillariophyceae (diatoms), 7 species of the family Dinophyceae (dinoflagellates) and 2 species belonged to Cyanophyceae (blue green alga) and two species from Mediophyceae. Bacillariophyceae constituted 56 % of the mass biomass of the phytoplankton population (Figure 9).

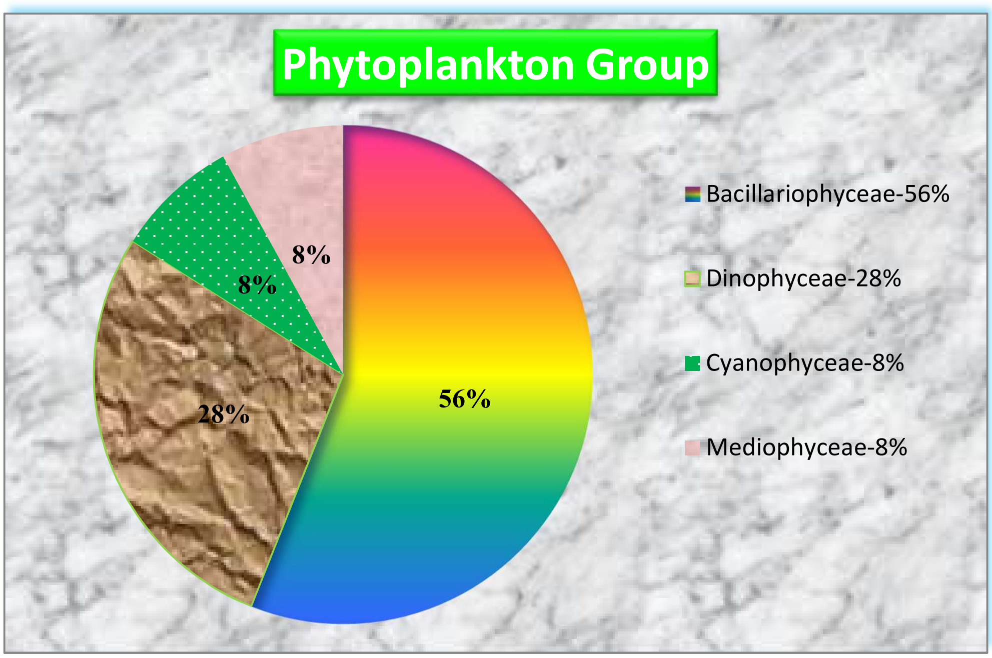



*Figure: 9 Abundance of phytoplankton groups*

The overall biomass recorded from all station shows *Tricodesmium erytheaum* with the high range from 29853.6 cells/l

### 3.5.2.1 Diversity Indices

The diversity indices calculated for 29 station along the Kovalam coastal stretch indicate species diversity (Shannon-weiner index ) ranging from 4.598 to 2.78; Species richness fluctuated between 5.061 to 1.983 and is depicted in Table.10 with the diversity indices portrayed in Figure.10.Figure: 11 depicts the dominant phytoplankton species observed in the sampling sites at Kovalam.

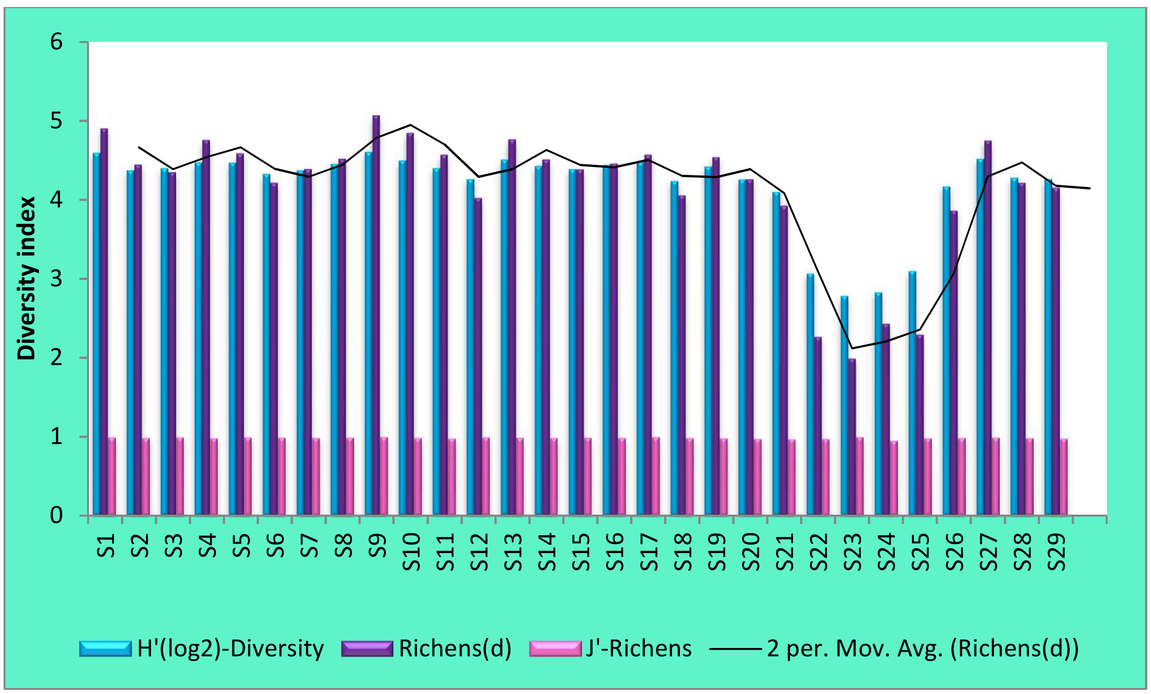



***Figure: 10 Shannon-weiner index for phytoplankton***

***Table: 10 Diversity indices for phytoplankton in various stations***

| Stations | S | N | D(Richens) | J' | H'(log2) Diversity | 1-Lambda' |
|---|---|---|---|---|---|---|
| **S1** | 25 | 135 | 4.895 | 0.9877 | 4.587 | 0.9637 |
| **S2** | 22 | 114 | 4.437 | 0.9783 | 4.363 | 0.9561 |
| **S3** | 22 | 126 | 4.341 | 0.9848 | 4.392 | 0.9578 |
| **S4** | 24 | 127 | 4.748 | 0.974 | 4.466 | 0.9584 |
| **S5** | 23 | 122 | 4.578 | 0.9867 | 4.463 | 0.9605 |
| **S6** | 21 | 116 | 4.205 | 0.9835 | 4.32 | 0.9553 |
| **S7** | 22 | 121 | 4.381 | 0.9785 | 4.364 | 0.9564 |
| **S8** | 23 | 131 | 4.512 | 0.9833 | 4.448 | 0.9591 |
| **S9** | 25 | 115 | 5.061 | 0.9901 | 4.598 | 0.9656 |
| **S10** | 24 | 116 | 4.837 | 0.979 | 4.489 | 0.9592 |
| **S11** | 23 | 124 | 4.563 | 0.9708 | 4.392 | 0.9553 |
| **S12** | 20 | 113 | 4.018 | 0.9847 | 4.256 | 0.9535 |
| **S13** | 24 | 126 | 4.759 | 0.9819 | 4.502 | 0.9609 |
| **S14** | 23 | 133 | 4.502 | 0.9779 | 4.423 | 0.9574 |
| **S15** | 22 | 121 | 4.379 | 0.9823 | 4.38 | 0.9567 |
| **S16** | 23 | 140 | 4.452 | 0.98 | 4.433 | 0.9572 |
| **S17** | 23 | 124 | 4.562 | 0.9888 | 4.473 | 0.9611 |
| **S18** | 20 | 109 | 4.047 | 0.9791 | 4.231 | 0.951 |
| **S19** | 23 | 129 | 4.53 | 0.9753 | 4.412 | 0.9563 |
| **S20** | 21 | 110 | 4.252 | 0.9679 | 4.251 | 0.9512 |
| **S21** | 19 | 99 | 3.918 | 0.9639 | 4.095 | 0.9455 |
| **S22** | 9 | 35 | 2.257 | 0.9655 | 3.061 | 0.899 |
| **S23** | 7 | 21 | 1.983 | 0.9904 | 2.78 | 0.8952 |
| **S24** | 8 | 18 | 2.426 | 0.9418 | 2.825 | 0.8942 |
| **S25** | 9 | 33 | 2.287 | 0.9753 | 3.092 | 0.9056 |
| **S26** | 19 | 107 | 3.853 | 0.9794 | 4.161 | 0.9497 |
| **S27** | 24 | 128 | 4.743 | 0.984 | 4.512 | 0.9615 |
| **S28** | 21 | 116 | 4.209 | 0.9724 | 4.271 | 0.9531 |
| **S29** | 21 | 124 | 4.148 | 0.9687 | 4.255 | 0.9504 |

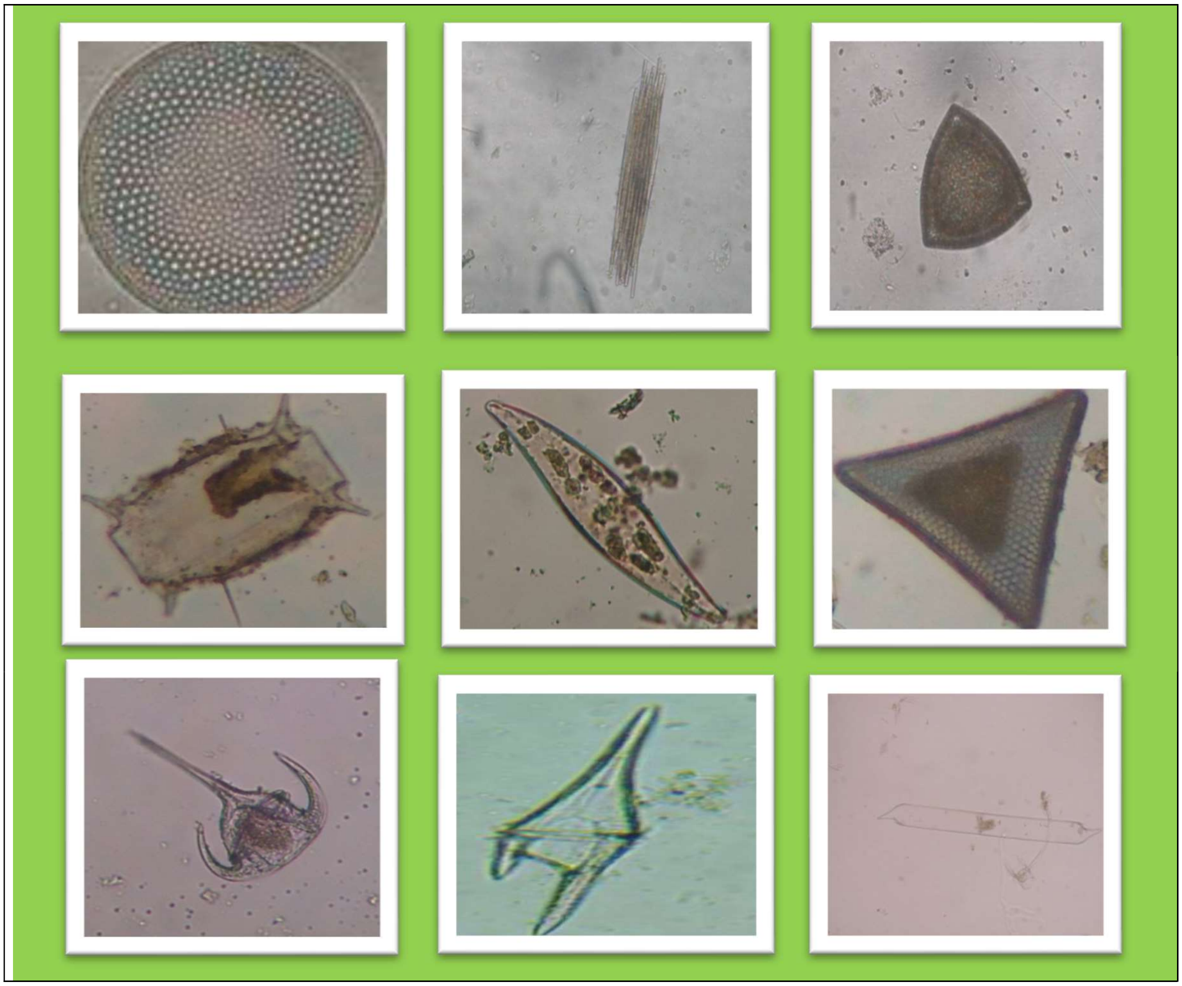


*Figure: 11 Dominant phytoplankton species observed in the sampling sites at Kovalam*

### 3.5.3 Zooplankton diversity and distribution

Zooplankton recorded from the 29 locations of the Kovalam coast, composed of 22 species from four major groups namely Copepoda, Oligotrichea, Appendicularia, Oligotrichea, and eggs and larvae (Figure.12).Copepods formed the major component of the zooplankton population and contributed to 50 % of the biomass. Among the copepods, the genera *Microsetella norvegica* species dominated the population, and second level staged by larval forms (32%) and the next two positions occupied by Oligotrichea and Appendicularia. The sampling sites were moderately rich in its biodiversity.

Major groups namely

1. Copepoda-50%
2. Appendicularia 5%
3. Oligotrichea - 9%
4. Larval Forms-32%

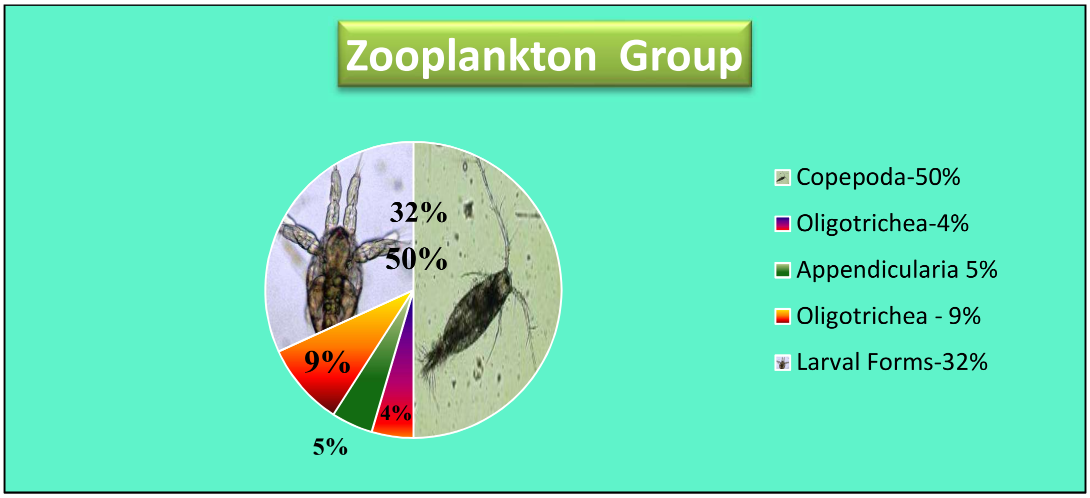



*Figure :12Abundance of zooplankton groups*

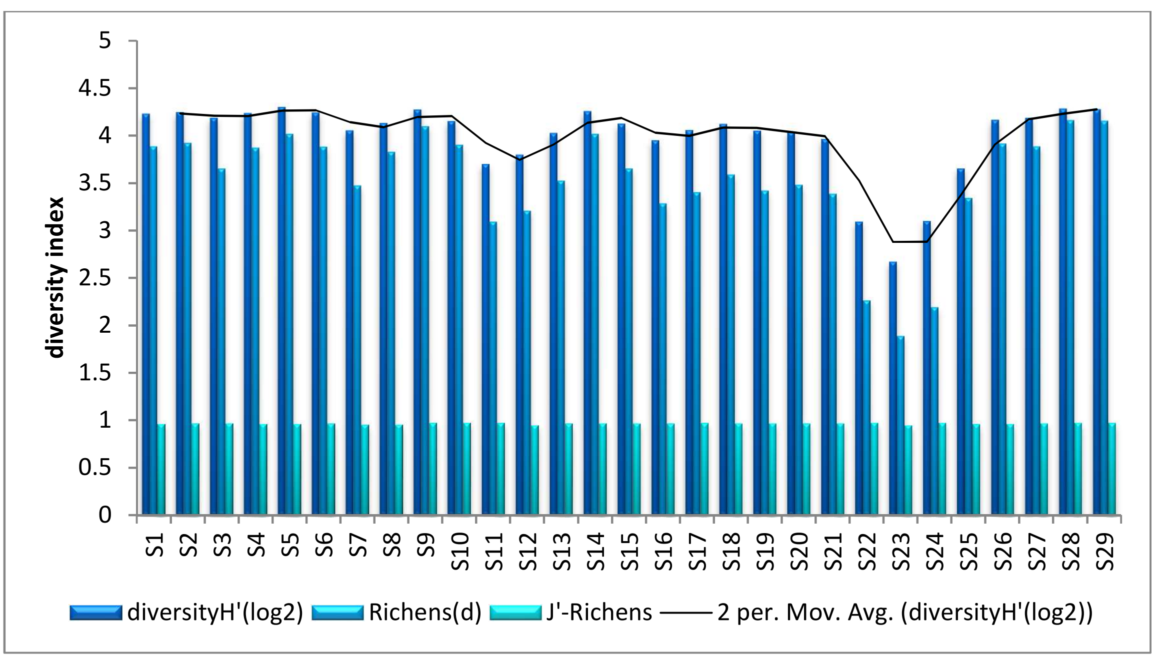



*Figure: 13 Shannon-weiner index for zooplankton*

### 3.5.3.1 Diversity Indices

The diversity indices calculated for 29 station of Kovalam coast were depicted in Table.11 which points species diversity (Shannon-weiner index) ranging from 4.598 to 2.78, species richness fluctuating between 5.061 to 1.983. Figure.13 potrays diversity indices. Figure: 14 depict the dominant zooplankton species observed in the sampling sites at Kovalam.

***Table: 11 Diversity indices for zooplankton in various stations***

| Station | S | N | d | J' | H'(log2) | 1-Lambda' |
|---|---|---|---|---|---|---|
| **S1** | 21 | 173 | 3.881 | 0.9618 | 4.224 | 0.9475 |
| **S2** | 21 | 165 | 3.918 | 0.9655 | 4.241 | 0.9496 |
| **S3** | 20 | 183 | 3.649 | 0.9678 | 4.183 | 0.9465 |
| **S4** | 21 | 176 | 3.87 | 0.9638 | 4.233 | 0.9485 |
| **S5** | 22 | 187 | 4.013 | 0.9637 | 4.298 | 0.9499 |
| **S6** | 21 | 174 | 3.877 | 0.9653 | 4.24 | 0.9482 |
| **S7** | 19 | 179 | 3.471 | 0.9533 | 4.049 | 0.9378 |
| **S8** | 20 | 144 | 3.825 | 0.9552 | 4.128 | 0.9439 |
| **S9** | 21 | 133 | 4.093 | 0.9719 | 4.269 | 0.9511 |
| **S10** | 19 | 101 | 3.899 | 0.9764 | 4.148 | 0.9489 |
| **S11** | 14 | 67 | 3.091 | 0.9712 | 3.698 | 0.9314 |
| **S12** | 16 | 108 | 3.205 | 0.9484 | 3.794 | 0.929 |
| **S13** | 18 | 125 | 3.521 | 0.9645 | 4.022 | 0.9404 |
| **S14** | 21 | 146 | 4.012 | 0.9678 | 4.251 | 0.9492 |
| **S15** | 19 | 139 | 3.649 | 0.9702 | 4.121 | 0.9449 |
| **S16** | 17 | 131 | 3.281 | 0.9652 | 3.945 | 0.9366 |
| **S17** | 18 | 148 | 3.401 | 0.972 | 4.053 | 0.9419 |
| **S18** | 19 | 152 | 3.584 | 0.9691 | 4.117 | 0.944 |
| **S19** | 18 | 145 | 3.416 | 0.9703 | 4.046 | 0.9411 |
| **S20** | 18 | 133 | 3.477 | 0.9673 | 4.033 | 0.9411 |
| **S21** | 17 | 113 | 3.384 | 0.9685 | 3.959 | 0.9383 |
| **S22** | 9 | 34 | 2.262 | 0.9752 | 3.091 | 0.904 |
| **S23** | 7 | 24 | 1.887 | 0.9503 | 2.668 | 0.8665 |
| **S24** | 9 | 39 | 2.19 | 0.9769 | 3.097 | 0.9017 |
| **S25** | 14 | 49 | 3.339 | 0.9587 | 3.65 | 0.933 |
| **S26** | 20 | 129 | 3.911 | 0.9632 | 4.163 | 0.9455 |
| **S27** | 20 | 134 | 3.882 | 0.9678 | 4.183 | 0.947 |
| **S28** | 21 | 123 | 4.159 | 0.9747 | 4.281 | 0.9522 |
| **S29** | 17 | 113 | 3.384 | 0.9685 | 3.959 | 0.9383 |

*Figure: 14 Dominant zooplankton species observed in the sampling sites at Kovalam*

### 3.6 Benthos

Benthic organisms represent a major component within the marine environment. Thus the benthos should play a major part in the strategy of biodiversity conservation. The use of benthos in aquatic ecological research, and particularly in evaluating marine pollution, is especially effective in assessing long-term changes and detecting input from diffuse sources. The benthos reflects the effects of pollutants or organic enrichment by responding through detectable changes in population dynamics on a time scale of weeks to years. Macro invertebrate community responses to environmental perturbations are useful in assessing the impact of municipal, industrial, oil and agricultural wastes and impacts from other land uses on surface water bodies. There is no rare or endangered species recorded in the studied region.

### 3.6.1 Benthic Diversity in Kovalam Coastal Region.

Totally benthos was analyzed in 29 stations.Among the29 samples analysed, 31 species and fivegroupswere recorded during the study period. Among the five groups recorded, polychates (68%) group stands out with maximum (Figure.15).

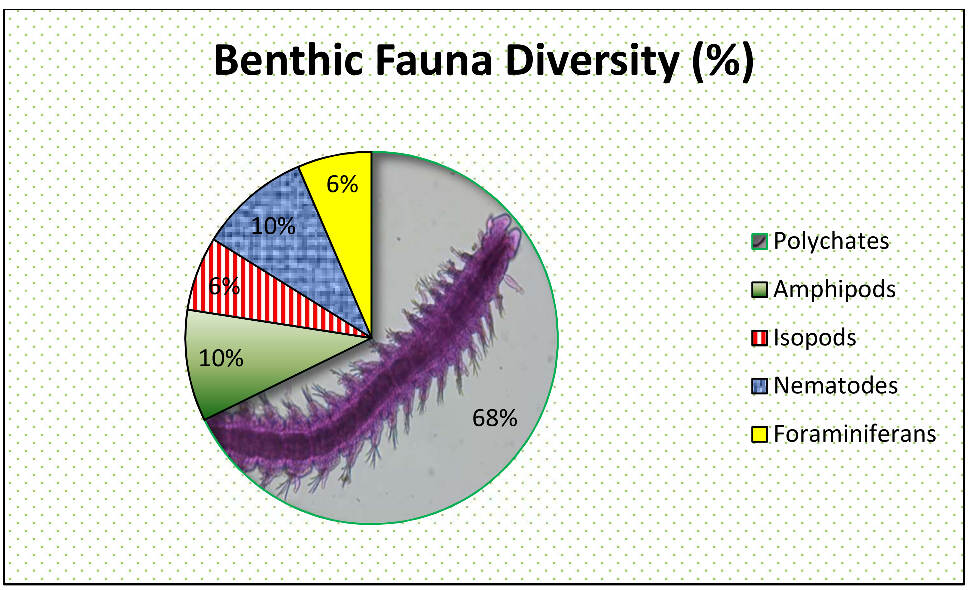



*Figure 15 Benthic diversity indicating abundance in Polychates*

***Table: 12 Benthos distributions in the proposed Study Area***

| Group | Sl. No. | Species | Stations | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| Polychaetes | 1 | Cirratulus sp. | - | + | - | + | + | + | - | + | - | - | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | - | + | + | + |
| | 2 | Lumbreneris sp. | + | + | + | + | + | + | + | + | + | + | - | + | + | + | + | + | + | + | + | + | + | + | + | - | - | - | - | - | + |
| | 3 | Sternaspis scutata | + | + | + | + | + | + | + | - | + | + | + | - | + | + | + | + | + | + | + | - | - | + | - | + | - | - | - | - | - |
| | 4 | Syllis gracilis | - | - | + | + | + | - | - | - | - | - | + | + | + | + | - | - | + | - | + | - | - | - | - | + | - | - | - | - | - |
| | 5 | Syllis sp. | - | + | + | + | + | + | - | - | + | + | + | + | + | + | + | + | + | + | + | + | + | - | + | + | + | + | - | - | - |
| | 6 | Terebella sp. | - | - | - | - | + | - | - | + | + | + | + | + | + | + | + | + | - | + | - | + | + | - | + | + | + | + | - | + | + |
| | 7 | Amphiglena mediterranea | + | + | - | + | - | + | + | - | - | + | - | - | + | + | + | + | + | - | + | - | - | - | - | - | - | - | + | + | - |
| | 8 | Paralacydonia paradoxa | - | + | - | + | + | + | - | - | + | + | + | - | + | + | - | - | + | + | + | - | - | + | - | + | - | - | - | - | - |
| | 9 | Eurythoe sp. | - | + | - | - | + | - | - | + | + | + | - | + | + | + | + | - | - | + | - | + | + | - | - | - | + | + | - | - | - |
| | 10 | Capitella capitata | + | + | + | + | + | - | + | - | + | - | + | + | - | - | - | + | + | + | + | - | - | + | + | + | - | - | + | + | + |
| | 11 | Dorvillea sp | - | - | - | - | + | - | - | + | + | - | + | + | + | + | + | + | - | + | - | + | - | + | - | + | - | - | - | - | - |
| | 12 | Dorvillea neglecta | + | - | + | + | + | - | + | - | - | - | + | - | + | + | + | - | + | - | + | + | - | + | - | - | - | - | - | - | - |
| | 13 | Eunice vittata | - | - | + | + | + | + | - | + | - | - | + | + | + | + | + | - | + | + | + | + | - | - | + | + | - | - | - | - | - |
| | 14 | Eunice sp. | + | + | + | + | + | + | + | + | + | + | - | - | - | - | + | - | + | + | + | - | - | + | - | + | - | - | - | - | - |
| | 15 | Lumbrinereis megalhaensis | + | + | - | + | + | + | + | + | + | + | - | - | - | - | + | + | + | + | + | - | + | + | + | + | - | - | - | - | - |
| | 16 | Onuphids erimita | - | - | + | - | + | + | - | + | - | + | - | + | + | + | - | - | - | - | - | + | + | - | + | - | - | - | - | - | - |
| | 17 | Prionospio pinnata | - | - | + | + | + | - | - | + | + | + | + | - | + | + | + | + | + | - | + | + | + | + | + | + | + | + | - | + | + |

| Group | Sl. No. | Species | Stations | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| | 19 | Megalomma quadrioculatum | + | + | + | + | + | - | + | + | + | - | + | + | + | + | + | + | + | + | + | - | - | + | + | + | + | - | - | + | + |
| | 20 | Terebella sp | + | - | + | + | + | - | + | - | + | - | - | - | - | + | + | + | + | + | + | - | - | + | - | + | + | + | - | + | + |
| | 21 | Pseudonereism varigata | + | - | - | + | + | + | + | + | + | - | - | + | + | - | - | - | + | + | - | + | + | - | - | - | + | + | - | + | + |
| | 22 | Scolelepis sp | - | - | - | + | + | + | - | - | - | - | + | + | + | + | + | + | + | + | + | + | + | + | - | - | - | - | - | - | - |
| **Amphipods** | 23 | Ampithoe gammaroides | - | - | - | - | + | + | - | + | - | + | - | + | + | + | + | + | - | - | + | - | - | - | + | + | - | + | - | - | - |
| | 24 | Gammarus sp. | - | + | + | + | - | + | - | + | - | - | - | - | - | - | + | + | + | + | + | - | - | + | + | + | - | + | - | + | + |
| | 25 | Corophium madrasensis | + | - | - | + | + | + | + | + | + | + | - | + | - | + | - | - | + | + | - | + | + | + | - | + | - | - | + | + | - |
| **Isopods** | 26 | Grandidierella sp. | + | - | - | - | + | - | + | + | + | + | - | - | + | + | + | - | - | + | + | - | - | + | - | - | - | - | - | - | - |
| | 27 | Cymodoce sp | - | + | + | + | + | - | - | - | - | + | + | - | + | + | - | + | + | - | - | + | - | + | - | + | + | + | - | - | - |
| **Nematodes** | 28 | Sphaeroma sp | - | - | - | - | + | - | - | - | - | + | - | - | + | + | + | + | - | - | + | + | - | - | - | - | + | - | + | + | + |
| | 29 | Daptonema conicum | + | + | + | + | + | - | + | - | + | + | + | + | + | - | + | - | + | + | + | + | - | + | + | - | + | - | - | - | - |
| **Foraminifera's** | 30 | Siplophorella | - | - | - | + | + | + | - | + | - | - | + | + | + | + | + | - | + | + | + | - | - | + | + | + | - | + | - | + | + |
| | 31 | Macrosetella | - | + | + | + | + | - | - | + | - | - | - | + | + | + | + | - | + | + | + | - | + | + | - | + | - | - | + | + | - |

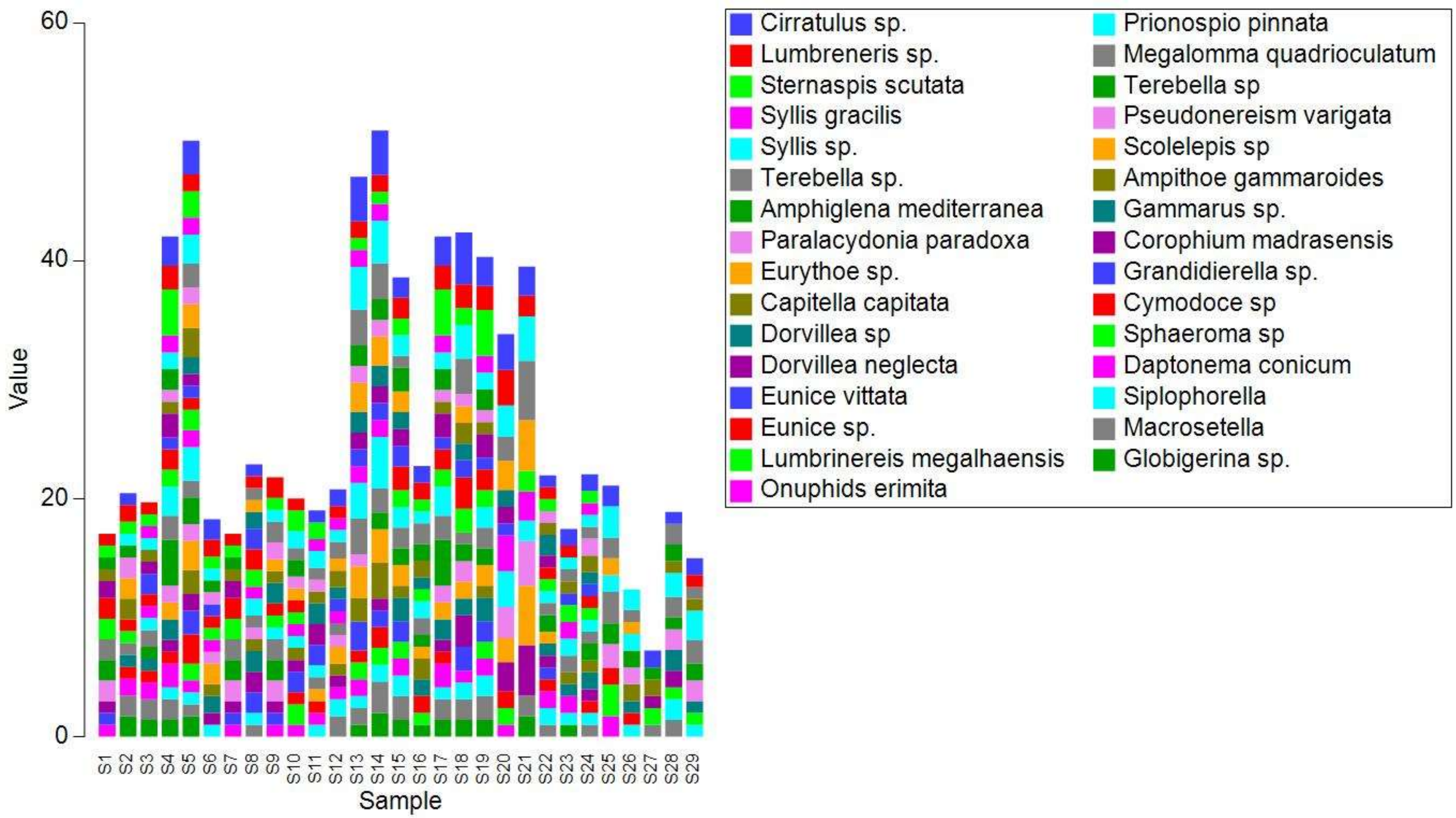



*Figure: 16 Graph representing the total number of taxa at different stations of Kovalam*

Totally31 species of macrobenthos were recorded at Kovalam in the present observation with five groups Polychaetes, Amphipods, Isopods, Nematodes and Foraminiferans (Table.12 &Figure. 16)

### 3.6.2 Diversity Results

The range of diversity indices are species diversity (Shannon-Wiener index) (2.563 to 4.563), species richness( 3.279 to 7.153), species evenness (Pielous's evenness)( 0.966 to 0.995)and Simpson index ( 0.962 to 0.993)depicted in Table 13 andFigure. 17.

***Table 13. Diversity indices calculated for the stations 1 to 29***

| S.No | S | N | d | J' | H'(log2) | Simpson Index |
|---|---|---|---|---|---|---|
| **1** | 13 | 17.074 | 4.229 | 0.986 | 3.650 | 0.975 |
| **2** | 16 | 20.489 | 4.967 | 0.988 | 3.953 | 0.981 |
| **3** | 17 | 19.707 | 5.367 | 0.992 | 4.054 | 0.988 |
| **4** | 24 | 42.058 | 6.151 | 0.973 | 4.462 | 0.973 |
| **5** | 29 | 50.119 | 7.153 | 0.984 | 4.780 | 0.981 |
| **6** | 16 | 18.293 | 5.161 | 0.991 | 3.966 | 0.988 |
| **7** | 13 | 17.074 | 4.229 | 0.986 | 3.650 | 0.975 |
| **8** | 18 | 22.903 | 5.429 | 0.989 | 4.125 | 0.984 |
| **9** | 17 | 21.807 | 5.191 | 0.988 | 4.037 | 0.982 |
| **10** | 17 | 20.025 | 5.339 | 0.990 | 4.047 | 0.987 |
| **11** | 16 | 19.025 | 5.092 | 0.990 | 3.959 | 0.985 |
| **12** | 18 | 20.803 | 5.601 | 0.993 | 4.143 | 0.990 |
| **13** | 25 | 47.084 | 6.231 | 0.972 | 4.512 | 0.973 |
| **14** | 25 | 50.968 | 6.105 | 0.973 | 4.516 | 0.971 |
| **15** | 24 | 38.634 | 6.294 | 0.992 | 4.563 | 0.983 |
| **16** | 18 | 22.778 | 5.439 | 0.993 | 4.141 | 0.985 |
| **17** | 24 | 42.058 | 6.151 | 0.973 | 4.462 | 0.973 |
| **18** | 23 | 42.403 | 5.871 | 0.975 | 4.412 | 0.972 |
| **19** | 24 | 40.346 | 6.220 | 0.983 | 4.509 | 0.978 |
| **20** | 16 | 33.847 | 4.259 | 0.978 | 3.911 | 0.958 |
| **21** | 13 | 39.528 | 3.264 | 0.966 | 3.576 | 0.931 |
| **22** | 20 | 21.975 | 6.149 | 0.991 | 4.299 | 0.993 |
| **23** | 15 | 17.485 | 4.893 | 0.995 | 3.885 | 0.988 |
| **24** | 20 | 22.071 | 6.140 | 0.996 | 4.304 | 0.994 |
| **25** | 11 | 21.108 | 3.279 | 0.988 | 3.417 | 0.948 |
| **26** | 10 | 12.389 | 3.576 | 0.991 | 3.292 | 0.974 |
| **27** | 6 | 7.243 | 2.525 | 0.992 | 2.564 | 0.961 |
| **28** | 13 | 18.903 | 4.083 | 0.989 | 3.659 | 0.970 |
| **29** | 11 | 15.010 | 3.692 | 0.976 | 3.378 | 0.962 |

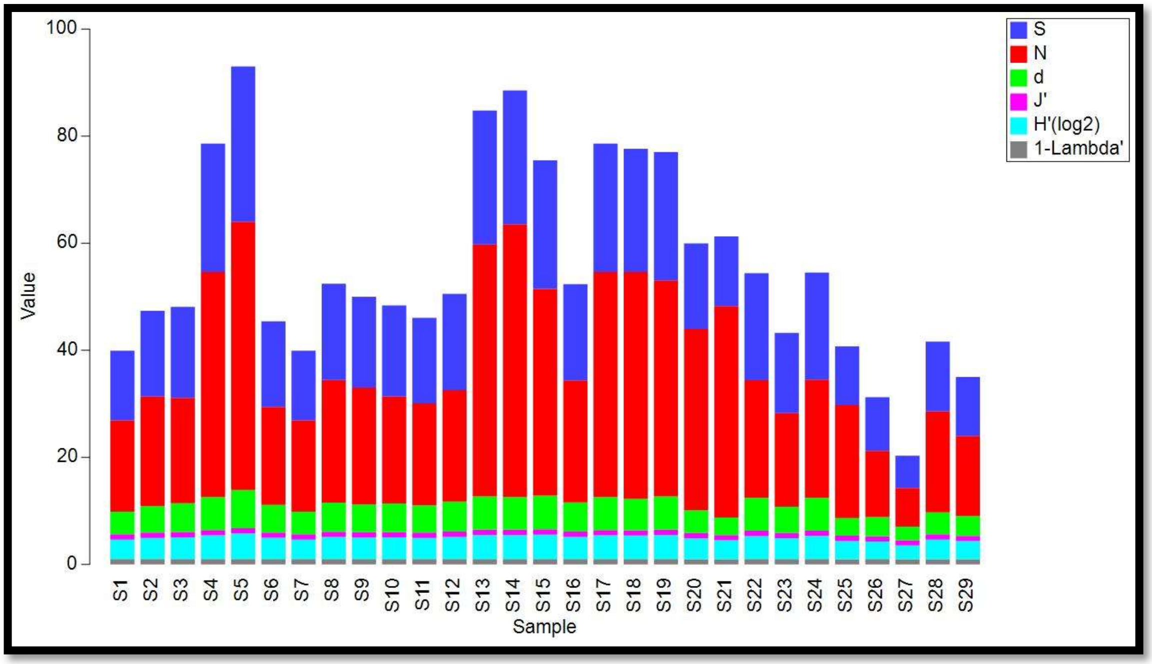



*Figure: 17 Diversity indices for Kovalam*

### 3.6.3 Graphical technique

The K- dominance plot drawn clearly demonstrated the diversity pattern in 29 stations. Conforming to the trend observed in diversity indices, curves of stations 15 and 5 which lies on the lower side extends further and rises slowly due to the presence of more number of species. As the percentage contribution of each species is added, the curve extends horizontally (species number is evident in the X- axis) before reaching the cumulative 100%. As the curve for the station 27 had to accommodate only a few species, it rises quickly. Hence it lies above the curves of stations 15 and 5. This plot also amply proved the rich diversity in the stations 15 and 5 compared to station 27 (Figure. 18).

Besides this, to study the similarity/dissimilarity, the data of three different zones were also approached to cluster analysis and MDS ordination. To achieve this, duplicate samples were collected in all the stations and the data were approached to cluster analysis and MDS ordination.

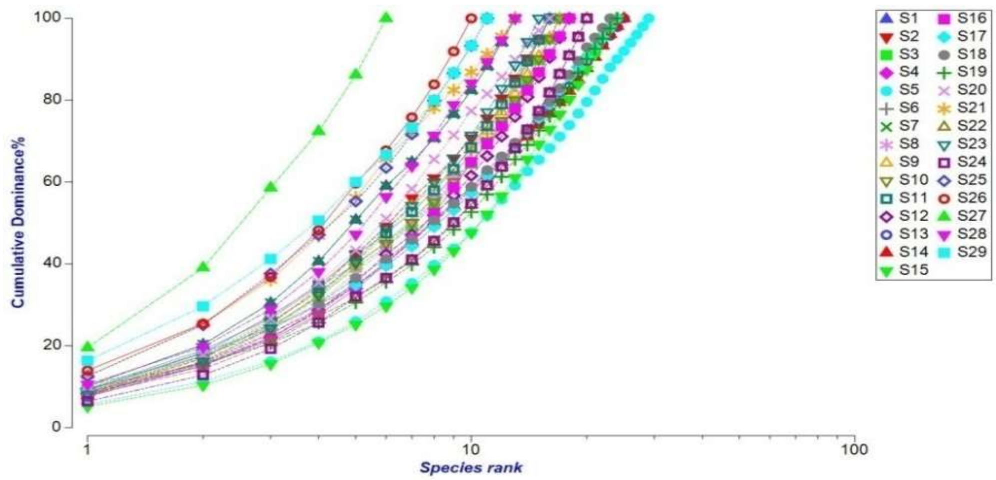



***Figure : 18 K- dominance curve drawn for macrofauna of the stations 1-29.***

The dendrogram derived clearly indicated that the duplicate samples of 29 stations got grouped together indicating the variations in species composition. Among the stations, station 4 and 17 got grouped at the highest level of similarity (100%) followed by stations of 13 and 14 (88%) and stations 19 (83%). Further, station 22 were formed a single cluster at the next level of similarity (22%) (Figure. 19).

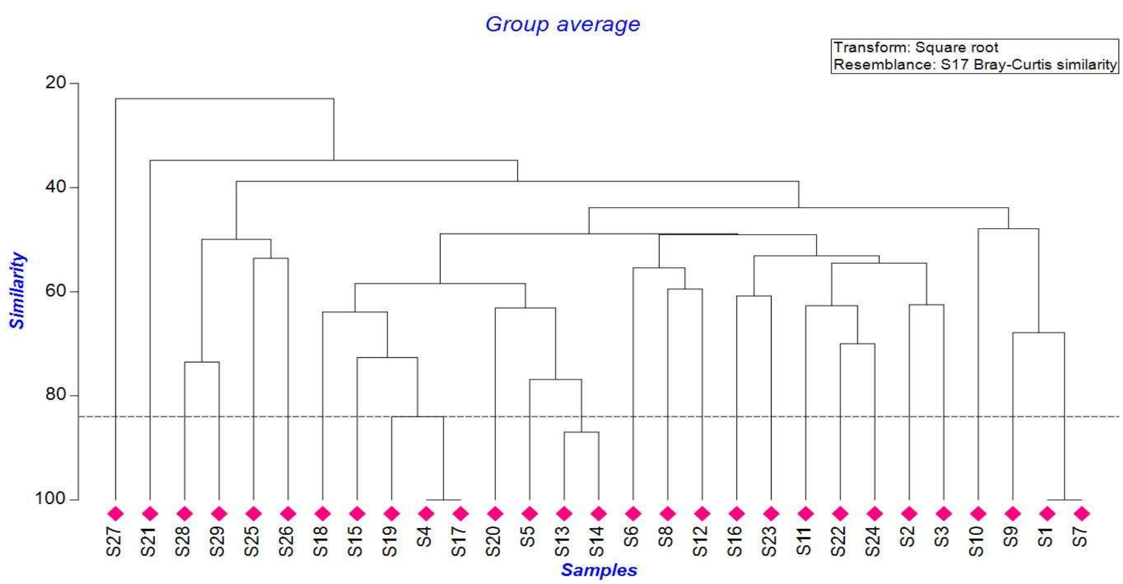



***Figure: 19Dendrogram for hierarchical clustering of the macrofauna in stations 1-29***

To confirm this pattern of grouping, the data were also given as input to MDS (non-metric Multi Dimensional Scaling). The plot revealed that the groupings recognized in the cluster were quite evident here also. The stress value, which overlie on the top right corner of the plot, is also very minimum (0.22) signaling the good ordination pattern of species in stations of various regions (Figure. 20).

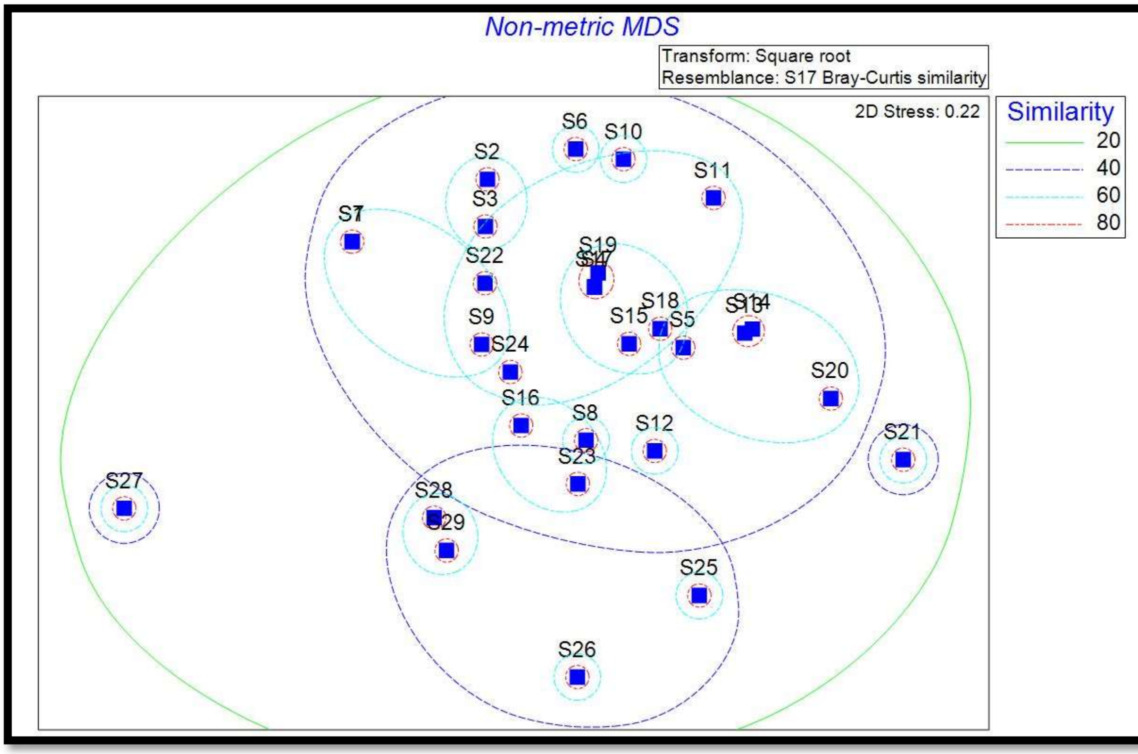



*Figure : 20 MDS ordination generated for the macrofauna in stations 1-29.*

### 3.7 Ecologically Sensitive Areas

### 3.7.1 Mangroves

Considering the mangroves we could pointout patches of mangrove dispersed here and there within the CIBA work are extension campus (prawn culture) which dwells approximately 400 to 600meters from the shore (Figure.21).

*Figure : 21 Availability of mangroves in the adjacent Location.*

### 3.7.2 Backwaters:

Muttukadu backwaters also mark a role inbetween the project site and one or two mangroves were noticed along this stretch (Figure.22).

*Figure : 22 Muttukadu backwaters*

### 3.7.3 Saltpans

Approximately 2 to 2.5km from the sea, salt pans were identified in the opposite side towards Kelambakkam road which lies in the landward region (Figure.23). Several salt pans dot the entire stretch from Kelambakkam to Kovalam on Old Mahabalipuram Road. Interestingly, in recent times, more number of birds have started thronging Chennai water bodies.Some of the factors attributed to the sudden spurt of birds in these salt pans are that human movement is limited, they are always filled with shallow water and above all because of the approachingnorth east monsoon(https://www.dtnext.in/News/City/2016/09/17232249/Kelambakkam-salt-pans-birds-new-home.vpf). According to Santhiya et al,2010, Salt pan areas are observed in declining trend that, 2.67% in 1976, 2.58% in 1999 and 0.85% in 2007 due to the inter tidal areas are present from Ennore and Kovalam creek.

*Figure: 23Availability of saltpans in the adjacent Location.*

### 3.7.4 Gorgonian Beds

Accounting the gorgonian beds, we could identify some gorgonians attached with the fishing nets of the local fisherman community during our survey along the marine environment (Figure.24).some remnants of gorgonians were noticed with the grab samples from 7 to 12mts depth. These gorgonians are also known as sea fans and sea whips and are similar to the sea pen, a soft coral. Gorgonians are closely related to coral. Individual tiny polyps form colonies that are normally erect, flattened, branching, and reminiscent of a fan. Others may be whiplike, bushy, or even encrusting. The colonyof these gorgonians can be several feet high and across but only a few inches thick. They may be brightly coloured, often purple, red, or yellow. Mostly these photosynthetic gorgonians can be successfully kept in captive reef aquariums. There are also species which encrust like coral. Most of Holaxonia and Sclerazonia, however, do not attach themselves to a hard substrate.


*Figure : 24 Presence of gorgonian beds in the Study Area*

Instead, they anchor themselves in mud or sand. Gorgonians are found primarily in shallow waters, though some have been found at depths of several thousand feet. The size, shape, and appearance of gorgonians can be correlated with their location. The more fan-shaped and flexible gorgonians tend to populate shallower areas with strong currents, while the taller, thinner, and stiffer gorgonians can be found in deeper, calmer waters.( https://en.wikipedia.org/wiki/Gorgonian)

### 3.8 Field Photos

## 4.0 SUMMARY AND CONCLUSIONS

The primary objective of the project is to develop a fishery structures to cover Kovalam shoreline which is vulnerable to erosion and is envisaged to safe guard the village from loss of life and property. This proposed coastal fishery infrastructures augmenting the shoreline of Kovalam as Fish Landing Centre with required Groyne Field (11 numbers of groynes) in 2.16 km stretch of coastal line will eventually safeguard the proposed FLC and more valued tourism spots and also more than 10000 fisherman community.The project is important in view of protecting the eroding shoreline, livelihood security of the dwelling fisherman community and will also contribute to the socio economic development in the region. Baseline studies on water quality, sediment quality including heavy metal concentrations, marine ecology including biological observations were carried out during January 2018, around Kovalam coastal stretch and adjoining areas. The data was evaluated against known standards and criteria, and have not identified any parameter that violates environmental standards mandated by the MoEF&CC. Though the adjoining areas are pointed with ecological sensitivity,the concerned coastal fishery infrastructure doesn't pose any threats to the marine environment. The essential heavy metal concentration pattern with reference to the data from other areas shows lesser concentrations. The toxic heavy metals are found to be well within the safety limits and as such do not pose any problem to the marine environment.

*****

ANNEXURE - II

## ESTIMATION OF MARINE FISH PRODUCTION 2016-2017 – SPECIESWISE & DISTRICT WISE(QUANTITY IN TONNES)

| S. No | Name of the Species | Chennai | Thiruvallur | Kanchee puram | Villupuram | Cudda lore | Nagapattina m | Thanjavur | Tiruvarur | Pudu kottai | Ramanathap uram | Thoothu-kudi | Tiru nelveli | Kanyaku mari | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 1 | Sharks | 145.41 | 212.00 | 111.71 | 0.00 | 0.00 | 985.45 | 330.40 | 30.40 | 33.00 | 1000.21 | 1202.00 | 38.50 | 436.51 | 4525.59 |
| 2 | Skates & Rays | 185.03 | 145.00 | 155.00 | 75.10 | 346.00 | 2467.79 | 311.70 | 40.00 | 54.00 | 1379.03 | 1143.00 | 85.00 | 600.89 | 6987.54 |
| 3 | Cat fishes | 189.45 | 400.00 | 136.98 | 170.55 | 242.00 | 1008.84 | 272.00 | 36.80 | 65.00 | 5441.71 | 590.00 | 0.00 | 539.20 | 9092.53 |
| 4 | Chirocentrus | 390.68 | 417.03 | 297.67 | 51.55 | 0.00 | 1736.68 | 246.50 | 20.80 | 750.00 | 0.00 | 2145.00 | 104.00 | 877.22 | 7037.13 |
| 5 | Lesser Sardines | 2065.38 | 450.00 | 1293.68 | 529.66 | 7800.00 | 2823.03 | 1646.80 | 732.80 | 15255.00 | 4277.28 | 2500.00 | 969.00 | 2135.36 | 42477.99 |
| 6 | Silver bellies | 1702.24 | 485.67 | 1058.67 | 549.20 | 5100.00 | 4597.64 | 838.40 | 161.60 | 2600.00 | 2801.07 | 4512.00 | 37.00 | 1452.40 | 25895.89 |
| 7 | Anchovy | 1322.71 | 420.78 | 840.96 | 136.92 | 4525.00 | 2987.38 | 945.50 | 136.00 | 2250.00 | 3203.84 | 2317.00 | 302.00 | 1203.05 | 20591.14 |
| 8 | Thrissocles | 16.48 | 389.70 | 12.58 | 406.70 | 64.50 | 985.51 | 210.80 | 17.60 | 12.00 | 434.00 | 645.00 | 26.50 | 560.70 | 3782.07 |
| 9 | Clupeids | 1229.62 | 410.34 | 854.84 | 22.30 | 0.00 | 2356.43 | 1207.00 | 179.20 | 5640.00 | 191.16 | 2725.00 | 512.00 | 2812.69 | 18140.58 |
| 10 | Saurida & | 121.70 | 324.00 | 91.40 | 0.50 | 44.00 | 311.51 | 93.50 | 14.40 | 8.00 | 401.21 | 158.00 | 12.00 | 98.10 | 1678.32 |
| 11 | Nemipterus | 171.90 | 450.89 | 0.00 | 810.51 | 0.00 | 1278.65 | 416.50 | 22.40 | 550.50 | 5122.33 | 345.00 | 5.50 | 732.80 | 9906.98 |
| 12 | Flying fish | 189.81 | 728.00 | 144.07 | 563.15 | 283.00 | 3640.20 | 263.50 | 33.60 | 0.32 | 0.00 | 560.00 | 0.00 | 607.10 | 7012.75 |
| 13 | Perches | 2552.54 | 320.67 | 1995.96 | 77.21 | 323.00 | 4125.98 | 1717.00 | 347.20 | 3850.00 | 2427.23 | 3700.00 | 308.00 | 2910.06 | 24654.85 |
| 14 | Red Mullets | 1537.30 | 700.45 | 1236.82 | 30.34 | 48.00 | 2036.45 | 987.70 | 155.20 | 6.78 | 320.87 | 2001.00 | 238.00 | 1880.50 | 11179.41 |
| 15 | Polynemids | 428.61 | 430.36 | 336.78 | 15.50 | 26.00 | 356.98 | 144.50 | 19.20 | 350.00 | 2170.96 | 265.00 | 114.00 | 902.43 | 5560.32 |
| 16 | Sciaenids | 570.30 | 117.54 | 387.28 | 199.54 | 53.00 | 2884.70 | 889.10 | 65.60 | 3400.00 | 579.11 | 1790.00 | 229.50 | 1373.10 | 12538.77 |
| 17 | Ribbon fish | 432.45 | 530.00 | 370.14 | 0.00 | 109.00 | 1099.07 | 263.50 | 33.60 | 2500.00 | 2328.51 | 475.00 | 159.00 | 1770.70 | 10070.97 |
| 18 | Caranx | 698.07 | 467.89 | 527.53 | 406.23 | 172.00 | 2671.48 | 873.80 | 36.80 | 4002.00 | 11018.08 | 1918.00 | 231.50 | 1998.80 | 25022.18 |
| 19 | Chironemus | 196.65 | 232.96 | 142.71 | 0.00 | 84.00 | 764.65 | 22.10 | 0.80 | 2.57 | 0.00 | 245.00 | 17.00 | 27.10 | 1735.54 |
| 20 | Trachynotus | 12.49 | 231.80 | 7.52 | 0.20 | 85.00 | 541.28 | 300.50 | 33.60 | 3.87 | 0.00 | 140.00 | 149.00 | 36.68 | 1541.94 |
| 21 | Ceryph aena | 0.48 | 237.48 | 0.00 | 0.09 | 66.50 | 424.74 | 27.50 | 4.80 | 1.01 | 0.00 | 0.00 | 11.00 | 18.50 | 792.10 |
| 22 | Oil Sardines | 5730.89 | 786.00 | 5219.82 | 0.00 | 7374.00 | 8849.92 | 1110.00 | 792.00 | 6543.00 | 54.61 | 4100.00 | 591.00 | 3802.05 | 44953.29 |
| 23 | Lactarius | 238.37 | 130.00 | 174.93 | 19.00 | 0.00 | 678.36 | 29.75 | 6.88 | 14.67 | 0.00 | 25.00 | 115.00 | 220.26 | 1652.22 |
| 24 | Pomfrets | 209.02 | 564.00 | 127.21 | 77.27 | 93.50 | 912.38 | 147.90 | 27.20 | 5467.00 | 4187.17 | 295.00 | 193.50 | 126.20 | 12427.35 |
| 25 | Mackerel | 1058.92 | 657.00 | 670.40 | 670.60 | 1290.00 | 3553.03 | 807.50 | 51.20 | 4213.00 | 1857.46 | 1690.00 | 287.00 | 2698.29 | 19504.40 |
| 26 | Seerfish | 707.25 | 684.88 | 486.85 | 558.63 | 421.00 | 2679.65 | 700.40 | 36.80 | 1345.56 | 366.67 | 1695.00 | 287.00 | 2908.73 | 12878.42 |
| 27 | Tunnies | 317.04 | 628.00 | 316.80 | 93.27 | 721.00 | 1458.49 | 453.90 | 67.20 | 15.00 | 1090.01 | 1700.00 | 444.50 | 1170.77 | 8475.98 |
| 28 | Sphyreana | 215.90 | 476.76 | 148.21 | 10.93 | 1347.00 | 720.87 | 40.80 | 0.64 | 1123.00 | 4054.00 | 970.00 | 210.00 | 988.25 | 10306.36 |
| 29 | Mullets | 78.73 | 326.98 | 60.25 | 39.47 | 28.00 | 2265.75 | 161.50 | 19.20 | 3937.00 | 0.00 | 370.00 | 21.50 | 90.40 | 7398.78 |
| 30 | Soles | 296.29 | 410.45 | 257.97 | 217.48 | 28.00 | 2874.36 | 467.50 | 97.60 | 240.00 | 1900.40 | 1010.00 | 38.00 | 814.20 | 8652.25 |

24311

ORIGINAL

भारत सरकार
Government of India
सूक्ष्म लघु एवं मध्यम उद्यम मंत्रालय
Ministry of Micro, Small and Medium Enterprises
MSME Testing Station
(Formerly Field Testing Station)
Puducherry - 605 009
पुदुच्चेरी - 605 009

सूक्ष्म लघु एवं मध्यम उद्यम

Page No. 1 | Total No. of Pages : 1

# TEST REPORT

**Date:10/03/2016**

1 . Issued to : The Executive Engineer
Fishing Harbour Project Divison,
Chennai

2 . Ref Your Letter No. : EMJAY-HO/Kovalam.001/ Dt.07/03/2016

3 . Sample Details : HBG Stone

4 . Name of Work : Providing Shore protection along the Coastal stretch of Kovalam in Kancheepuram District

5 . Sample Received on : 7/3/2016

**RESULTS**

| Sl.No. | Name of Test | Observed Values |
|---|---|---|
| 1 | Specific Gravity | **2.682** |
| 2 | Abrasion in % by mass | **19.24** |
| 3 | Crushing Strength in $kg/cm^2$ | **1960** |

Note: Above tests have been Conducted as per IS:2386

(C.SIVA SUDHAKAR)
Assistant Director, I/C.

This report refers *ONLY* to the particular samples submitted for test.

C. SIVA SUDHAKAR
Assistant Director
MSME Testing Station
Puducherry - 605 009.

## Table 11.1 Summary table for shoreline management plan

| S.No | Latitude | | Indicative nearby places | Average Erosion (in m/year) | Average Accretion (in m/year) | Vulnerability Scale | Priority | Extreme events ranking | Scope for fisheries proposal | Training wall priority |
|---|---|---|---|---|---|---|---|---|---|---|
| | From | To | | | | | | | | |
| 1 | 13° 26' 42.00" N | 13° 24' 00.00" N | Pulicat | 0.8 | 0.4 | 3 | I | | | I |
| 2 | 13° 23' 42.00" N | 13° 21' 10.80" N | 1 5km Karungali | 1 | 1.4 | 3 | | | | |
| 3 | 13° 21' 10.80" N | 13° 18' 28.80" N | North of Kattupalli | 8.1 | 0 | 1 | I | I | | |
| 4 | 13° 18' 28.80" N | 13° 15' 45.00" N | South of Kattupalli | 0 | 13.7 | 3 | | | | |
| 5 | 13° 15' 45.00" N | 13° 12' 36.00" N | Puzhithivakkam | 4.4 | 3.7 | 2 | I | I | | I |
| 6 | 13° 12' 36.00" N | 13° 09' 54.00" N | Bharath Nagar | 0.8 | 0.9 | 3 | I | I | ✓ | |
| 7 | 13° 09' 54.00" N | 13° 07' 48.00" N | North of Port | 0.9 | 1.9 | 3 | I | II | ✓ | |
| 8 | 13° 07' 48.00" N | 13° 05' 13.20" N | South of Port | 0.7 | 1.2 | 3 | | | | |
| 9 | 13° 05' 13.20" N | 13° 02' 20.40" N | Triplicane | 0.5 | 1.5 | 3 | | II | ✓ | I |
| 10 | 13° 02' 20.40" N | 12° 56' 52.80" N | Adyar | 0.9 | 1.1 | 3 | | III | ✓ | I |
| 11 | 12° 58' 58.80" N | 12° 56' 27.60" N | Adyar to Karapakkam | 0.2 | 0.8 | 3 | | | ✓ | |
| 12 | 12° 56' 27.60" N | 12° 53' 49.20" N | Karapakkam to Kanathur | 0.5 | 0.8 | 3 | | | ✓ | |
| 13 | 12° 53' 49.20" N | 12° 51' 18.00" N | Kanathur to Kanathur Reddikuppam | 0.4 | 0.7 | 3 | | | ✓ | |
| 14 | 12° 51' 18.00" N | 12° 48' 18.00" N | Kanathur Reddikuppam to Muthukadu | 0.3 | 1.5 | 3 | | | ✓ | |
| 15 | 12° 48' 18.00" N | 12° 45' 39.60" N | Muthukadu to Kovalam | 2.1 | 1.9 | 2 | I | II | ✓ | I |
| 16 | 12° 45' 39.60" N | 12° 43' 04.80" N | Vadanemmeli to Perur | 0.6 | 0.5 | 3 | | | ✓ | |
| 17 | 12° 43' 04.80" N | 12° 40' 30.00" N | Perur to Pattipulam | 1.5 | 0.9 | 3 | II | | ✓ | |
| 18 | 12° 40' 30.00" N | 12° 37' 55.20" N | Pattipulam to Mahabalipuram | 0.7 | 0.1 | 3 | | I | ✓ | |
| 19 | 12° 37' 55.20" N | 12° 35' 16.80" N | Mahabalipuram to Kokilamedu | 1.1 | 0.3 | 3 | | III | ✓ | |
| 20 | 12° 35' 16.80" N | 12° 33' 07.20" N | Kokilamedu to Edaiyur | 2.6 | 1.1 | 2 | II | | ✓ | I |
| 21 | 12° 33' 07.20" N | 12° 30' 14.40" N | Edaiyur to Kalpakkam | 0.6 | 0.6 | 3 | | I | ✓ | III |