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06

The Ecological Baseline Assessment of the Palk Bay

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SACON

Indo-German Biodiversity Programme
Conservation and Sustainable Management of Coastal and Marine Protected Areas

CMPA Technical Report Series No. 06
The Ecological Baseline Assessment of the Palk Bay

Authors
Azeez P.A., Goldin Quadros, Mahendiran M.,
Shirish Manchi S., Akshaya M. Mane, K.A. Nishadh
V.J. Jins, M.P. Swathi

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Indo-German Biodiversity Programme (IGBP),
GIZ-India, A-2/18, Safdarjung Enclave,
New Delhi - 110029, India
E-Mail: biodiv.india@giz.de
Web: www.giz.de

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Responsible
Dr Konrad Uebelhör, Director,

Photo Credit
Akshaya M. Mane

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Commons Collective, Bangalore
shibipeter@gmail.com

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Dr. Azeez P.A., Dr. Goldin Quadros, Dr. Mahendiran M.,
Dr. Shirish Manchi S., Akshaya M. Mane, K.A. Nishadh
V.J. Jins, M.P. Swathi

(Sálim Ali Centre for Ornithology and Natural History)

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Acknowledgement

Palk Bay is an ecosystem that has held our attention since the time we have known about its biodiversity and maritime importance. When we were given the opportunity to conduct the "Ecological baseline assessment for Palk Bay" we felt blessed with the chance to learn more about this unique ecosystem. This study was possible due to efforts of the scientific team from GIZ, New Delhi and the PCCF, Tamil Nadu Forest Department. We thank them for giving us this opportunity to be a part of the larger goal of Conservation of Palk Bay.

The present study involved interactions with a number of research institutions, educational institutions, NGO's and the community, all of whom were cooperative in sharing information and helped us in various ways. Most important was the cooperation of librarians from all the institutions who went out of their way to help our literature survey. In the field we were immensely helped by Mr. Raju from Devipattinam who always spared time for the study, the dedication and concern he showed for the conservation is contagious. We also thank Dr. Deepak Bilgi, DFO and Mr. Gyanapazhalam RFO, Ramanathapuram and their field staff for assistance during the study. The support from various sources helped in gathering diverse perceptives on the bay.

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P.A.Azeez
Goldin Quadros
Mahendiran Mylswamy
Shrish S. Manchi
Akshaya M. Mane
K.A. Nishadh
V.J. Jins
M.P. Swathi

Executive Summary

Marine coastal areas are among the world's most productive ecosystems. In the course of time, the world over these coastal ecosystems are increasingly coming under immense pressure from various human activities. In India, coastal habitats sustain the livelihoods of over 20 million people. India has a long coastline, which is under tremendous developmental pressure. In this context, the present study was undertaken to consolidate baseline ecological information on the Palk Bay in the southeastern coast of India. The present scientific literature available on the Palk Bay is relatively limited compared with that of the Gulf of Mannar. This study was undertaken on the request of GIZ and their sponsorship. The overall objective of the GIZ in sponsoring the project is 'to contribute to the improvement of the conservation and sustainable use of biodiversity in the pilot protected areas, while taking into consideration the economic circumstances of the local population'. The objective set for this specific study was to conduct a rapid ecological baseline survey for Palk Bay (off the Ramanathapuram coast), Tamil Nadu. The work was taken up based on the "Conceptual Framework for a Baseline Study on the Ecological Status of the Pilot Sites for the CMPA Project by the Leibniz Center for Tropical Marine Ecology, Bremen, Germany", but contextualized for Palk Bay, the selected pilot site in Tamil Nadu. The present study explored water quality and sediment quality across the Palk Bays along specific transects, various habitats in the coastal ecosystem (focusing on mangroves, seagrass and corals), and issues related to aquaculture farms in the area and their interactions with the local fishers.

The study (based on the Terms of Reference provided by GIZ) focused only on the coastal stretch of the Palk Bay along the Ramanathapuram District. A quick literature survey, rapid field surveys and laboratory

analyses were undertaken to generate data mainly on habitat features of various ecosystems and the flora and fauna within. The perceptions of the fishing communities on the same especially on the ecological changes happening in the area. Grids of 1 x 1 km^2 size were laid on the study covering the full 126 km of the Ramanathapuram coast of the Palk Bay. In total 269 grids were marked covering at least 800 m seawards and 200 m landwards from the high tide line. From the bay so far 392 species, which includes only one floral endemic species were reported. The mangroves in the study area currently are in fragmented patches. Natural forest growth is seen only in a very minor scale. Mangroves with marshland are the highest in proportion, followed by patches where mangrove restoration is attempted by adopting the common fishbone techniques.

A total of 7,405 birds belonging to 130 species representing 46 families were recorded from the area during our survey. Of the 130 species, the birds belonging to the family Laridae and the familiy Scolopacidae were higher in number. Opportunistic observations during the survey recorded six lizards, two snakes and one turtle species. In total, 27 species of insect and 5 species of Arachnid were recorded from the mangrove patches along the coast. Lepidopterans were the most observed group with 12 species, followed by seven species of Odonata.

The benthos studies revealed the dominance of gastropoda followed by bivalves and polychaeta. The gastropods were represented by 41 species while bivalves had a representation of 15 species and five species of crabs were observed. However, we observed that the benthos number and composition were mainly governed by the organic enrichment in the entire Palk Bay. The benthos also differed with the habitats as the mangrove ecosystem were dominated by polychaetes whereas the offshore habitat had the influence of seagrass and corals that influenced the faunal distribution and occurrence.

The water and sediment quality surveys did not indicate serious changes. In some locations, oil and grease levels were found to be high, due to local boating activities and anchorage. In Palk Bay, the sediment texture is mainly sandy and at certain locations more clay and silt were found based on, depth and currents. During the present study, organic carbon varying between 1.37% and 8.11% (average 3.46%) were recorded. The organic carbon content can be attributed to several factors including the abiogenic inputs of nutrients and organic matter. The salinity within the mangrove swamps was higher than the offshore locations, which is characteristic of mangrove ecosystems. The mangrove sediment is mostly silty-clay rather than the sandy substratum from the offshore regions.

To elicit the perceptions of local inhabitants on the local ecology and changes, mainly active fishers, we interviewed randomly selected people who gave their informed consent for the interview using a structured questionnaire with open and close-ended questions. Fishing being their primary occupation, the income of the respondents varied between INR 2,500 and 10,000 per month. A large proportions of the respondents reported fell much below the poverty line. The survey also provided valuable information on habitat-wise occurrence of species and the reason for their disappearance from the area etc.

The findings from the questionnaire survey gave a clearer picture of the ground reality with respect to the coastal ecosystem in the Palk Bay. These results present a picture of the environment and the apparent resource conflicts with different fishery techniques including aquaculture. Generally, fishers tend to be anxious about the resource depletion and conflict in the sea rather than that in the land. Respondents were furious while answering questions about trawlers. Though aware of the ill effects of aquafarms, fishing communities were more bothered about the impacts of mechanised fishing.

Availability of potable water appears to be one of the major issues faced by the fishing community of the area. Most of them depend on the informal water sector in the area. No one pointed out the seepage and associated impact of aquaculture farms on quality of local water. The expressed changes were about the direct impact of aquaculture farm drainage to their fishing grounds. The discharges is said to keep the fishes away from the coast and at times lead to death of fishes.

The traditional practice of resource sharing is in vogue among the traditional fishing community. The trawlers are forcing changes in the practices. The capital-intensive bottom trawling and aquaculture farms are making the life of the traditional fishing community increasingly difficult. The interactions indicate the need for an extensive work investigating the resource conflicts between fishers from local and elsewhere and bigger investors having access to more effective but most times damaging the natural resource base.

Chapter 1

Introduction

Marine coastal areas are among the world's most productive ecosystems. In the course of time, these coastal ecosystems are increasingly coming under immense pressure from various human activities. In India, they sustain the livelihoods of over 20 million people. India has a 7500 km long coastline. It is under tremendous developmental pressure, including several port project that could change the ecosystem of the area. In many regions, they have reached a critical condition, with insufficient conservation measures in place to counter the increasingly serious challenges. Meanwhile, the adverse impact of climate change on these ecosystems is expected to grow. It is therefore, necessary to establish and support protected areas and improve measures for the conservation of numerous species, and the overall ecological goods and services offered by these greatly valuable ecosystems.

Of the coastal ecosystem in the country, mangroves have significant ecological, economical and societal functions (Duke, 1992; Jordan and Chandra 2011). They are important in terms of carbon fixation (Jennerjahn and Ittekkot, 2002), litter-fall-based detritus food chain (Nammalwar & Muniyandi 2000,). The soils in these ecosystems sequentially go through inundated and drained cycles based on the tidal cycles. Plants growing in these regions are adaptive with traits such as salt excreting leaves, exposed breathing systems with viviparous propagation (Jordan and Chandra 2011).

Mangrove habitats have high capacity for long-term carbon sequestration due to its high sediment accumulation and low sedimental respiration (Simard *et al*., 2006). This makes mangrove stands one of the important component in global carbon cycling and economically viable carbon trading stocks for various global level initiatives for carbon emission reduction (Zhu *et. al.,* 2015). Mangroves also provide effective protection against coastal erosion. Apart from Mangroves, corals and seagrass beds are also high in biodiversity. These biotopes function as protective cover and detritus food sources, which forms important nurturing ground for various fish species and prawns. However, over fishing, fishery related activities and also other

developmental pressures have resulted in serious habitat destruction and biodiversity loss.

In this context, the present study was undertaken to consolidate information on the Palk Bay in the southeastern coast of India. The present scientific literature available on the Palk Bay is relatively limited compared to that of the Gulf of Mannar.

Objectives

The objective of this specific study was to conduct a rapid ecological baseline survey for the Palk Bay off the coast of Ramanathapuram district, Tamil Nadu. This work was taken up based on the "Conceptual Framework for a Baseline Study on the Ecological Status of the Pilot Sites for the CMPA Project by the Leibniz Center for Tropical Marine Ecology, Bremen, Germany" but contextualized for Palk Bay.

Under the general objectives, we identified sub-objectives as listed below.

1. Explore the water quality and sediment quality parameters across the Palk Bay along specific transects;
2. Explore the various habitats in the coastal ecosystem of the Palk Bay focussing on mangroves, seagrass and corals
3. Explore areal expansion of aquaculture farms in the last thirteen years (from 2002 to 2015), interaction between aquaculture farms and fishers, and analyse the impact of aquaculture farms on fisherfolk.

Study Area

Palk Bay in Tamil Nadu is among the ecologically significant regions along the mainland coast of India. It is situated between latitudes 9° 55'N - 10° 45' N and longitudes 78° 58' E - 79° 55' E. The north-eastern part of the coastline of Ramanathapuram district, Tamil Nadu, converges with the Palk Bay. The Palk Bay is connected on its south with the Gulf of Mannar through a 1.2 km wide and 3 to 5 m deep passage called Pamban Strait. The Pamban strait also separates the Island of Rameswaram from the mainland. The Palk Bay has a width ranging from 64 to 137 km. The Palk Bay waters join the Bay of Bengal in the northeast and the Gulf of Mannar in the south. The Palk Strait is just 35 km long and is narrower than the English Channel. It separates the northern coast of Sri Lanka and southeast coast of India. Consequently, the international boundary line is adjacent to the shores of both the countries. The international boundary is only 6.9 km away from Dhanushkodi, 11.5 km away from Rameswaram and 24.5 km away from Thondi, a major coastal township and business centre in the area.

The Palk Bay is adjacent to the Gulf of Mannar Marine Biosphere Reserve, India's first marine protected area. The bay harbours rich biodiversity that sustains a large number of people in terms of livelihood, besides marvelous and diverse ecosystems. It supports three important ecosystems, namely seagrass ecosystem, coral-reef ecosystem and mangrove ecosystem in close association with each other. These marine ecosystems are characterized by high diversity of species including large number of unique and threatened ones. A total of 186 birds, 16 mangroves, 9 seagrass and more than 344 animals from different taxa are reported in various studies (Bhatt *et al*., 2012). The Palk Bay is among the three locations in India, where the endangered marine mammal Dugong (*Dugong dugon*) has been reported.

The Palk Bay is blessed with both southwest and northeast monsoons, of which the latter is more important in terms of annual rainfall contribution. The southwest monsoon contributes much to the annual rainfall of the area. Rainfall is sufficient to heavy in October to mid December with sporadic storms. The annual rainfall varies from 762 mm to 1,270 mm. The monthly atmospheric average temperature fluctuates from 25°C to 31°C with the maximum and minimum seen in the months of May and January respectively. The average water temperature in the Palk Bay varies from 24.6°C to 29.1°C. The surface salinity of the water depends on surface evaporation, winds and humidity gradients and mixing of water masses

brought into the region by currents causing turbulent exchange. The marine environment and geographical features of the region show contrasting seasonal changes in wind velocity, direction and wave action.

The Palk Bay is shallow and reaches a maximum depth of 13 m. The land adjacent to the bay of streams/rivers consists of alluvium with charnockite, pink and grey granites, amphibolite, garnets, illimanite, gneiss, khondalite, pyroxenite and biotite schists lying on the northwest and southern parts of the alluvium.

The Palk Bay is one of the important fishing grounds in India. The annual average fish production is ≈ 70,000 tones. The district is home to one of the largest fisher population, highest number of fish landing sites and fishing villages of Tamil Nadu. The discharge from the Vaigai and Cauvery rivers, the saline water and the muddy bedrock together with seasonal rains create conducive prolific breeding grounds for a variety of pelagic and demersal fishes. The major fishing season in the area starts in October and lasts until February; the peak season is during winter i.e., December to January. The mangrove, seagrass and coral habitats in the area sustain the fishery industry in this area. The area, rich in biological diversity, has a long history of human settlement dependent on the local biological resources.

All the seaweed-based industries in the country mostly depend on the seaweed harvested from the southeast coast of Tamil Nadu from Mandapam to Kanyakumari. Vegetative propagation method using long line coir-rope nets, and coir rope frames is used to cultivate the agar-yielding seaweed (Khan and Satam, 2003; Krishnan and Kumar, 2010).

The Palk Bay contain diversified and productive ecosystems such as estuaries, salt marshes, coral beds, seagrass beds and mangroves that are sensitive to human activities. The backwater system of the bay sustains lush growth of mangrove forests, which harbour a diversity of native and seasonally migratory birds. The backwaters act as breeding and feeding grounds for a wide-ranging variety of fishes. Dolphins, whales and turtles are frequently seen in this bay region.

Chapter 2

METHODOLOGY

The study focused along coastal length of Palk Bay side of Ramanathapuram. A quick literature survey was conducted to appreciate the already existing knowledge base on the area. This was followed by a rapid survey yielding primary data on various ecosystems and associated fauna and flora. The perception of the dependent communities (primarily fishing communities) were also gathered.

Transect walks were done to understand the physical features of the study area, fishing hamlets, aquaculture farms etc.

Area Mapping

Area mapping was undertaken before finalizing the strategy for the fieldwork. Grids of 1 km^2 size were laid on the study area, along the coastal boundary (stretching 126 km) of Ramanathapuram district, along the coast of the Palk Bay. Thus, in total 269 grids were marked covering 800 m towards offshore and 200 m towards land from the high tide line (Figure 1). Maps with important towns, fish landing points, main roads and approach roads to mangrove patches were overlaid on satellite imagery of the study area.

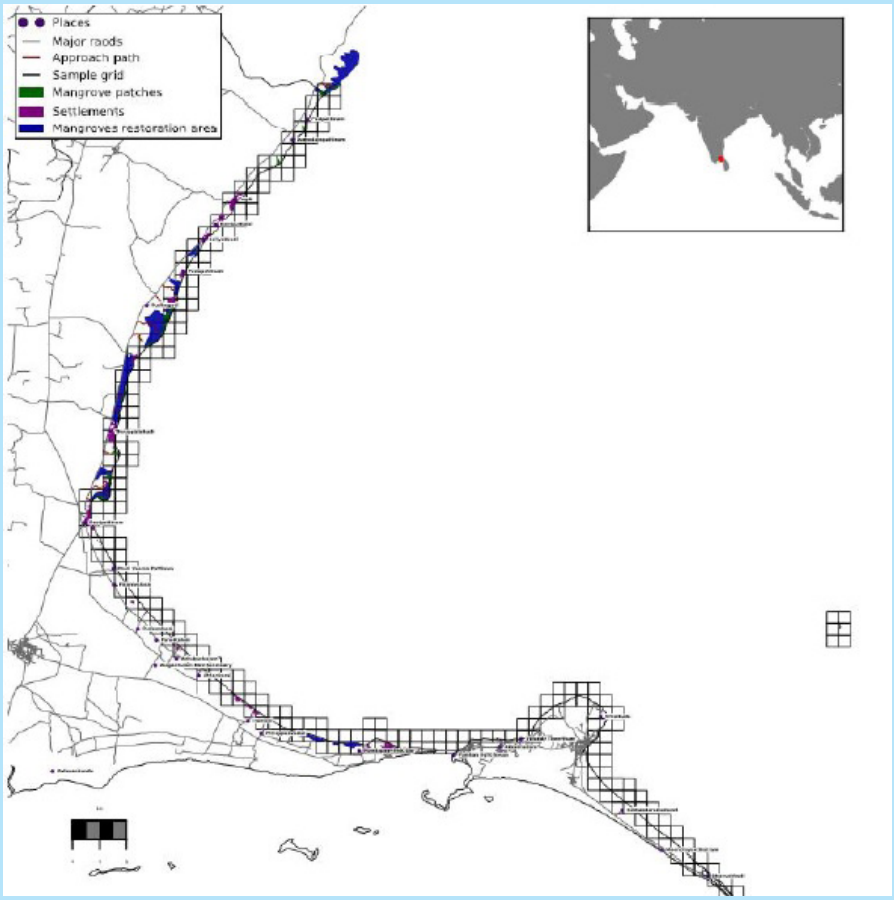
Habitat and Taxa Surveys

For sampling major habitat quadrat method was employed keeping the tidal phase in mind. The mangroves were enumerated in 92 grids by plotting 10 m quadrats. The birds were surveyed using the point count method (Bibby *et al.*, 1993) at 62 sampling locations along the entire coast. Based on the vegetation and the geographical setting we demarcated nine different habitat types for the avian study. Opportunistic sampling was used to record insects and reptiles.

Water and Soil Quality Surveys

The water and soil quality in the Palk Bay and landward habitats such as mangroves were also studied. Standard methods (APHA, 2012) for each parameter were used for analysis of the water and soil / sediment and that is briefed below (Table 1).

Figure 1
Grids Laid in the Study Area



People's Perception

Personal contact and survey, with customized questionnaires, were adopted to elicit the perception of the fishers regarding i) the ecology, habitats, and fishery techniques in the Palk Bay, and ii) and the aqua-farms in the area. While surveying for aqua-farms, details regarding dominant vegetation, land use pattern, soil type, infrastructure, and nature of settlements were also recorded to identify explicit commonalities of those areas where aquaculture farms are flourishing.

The structured questionnaire had both open-ended and close-ended question (Mellenbergh, 2008) meant for collecting data from the fishers, aqua-farm labours, aqua-farm owners and fish sellers. Close-ended questions helped to quantify the changes in ecosystem and the response of fisherfolk to the change. Open-ended questions were designed to bring forth the perceptions of the fisherfolk on the recent changes in the ecosystem and how they respond to those changes. Market survey, again using a structured questionnaire, was done to check whether there is any domestic market linkage with the local aqua-farms.

Mapping of aquaculture farms was carried out using Google Earth and QGIS software (Karakassis *et al.*, 2002). The land area expansion of aquaculture farms at an interval of three years, from the year 2002 to 2015 were taken. The temporal change in land use was plotted with the help of Google Earth and QGIS.

Table 1
Parameters Investigated During the Study

Sl. No.	Parameter	Method
Habitat studies		
1	Mangroves	Quadrats
2	Seagrass	Diving and Point intersect method along transects
3	Corals	Diving and transects
4	Benthos	Grab sampling along transects
5	Aquaculture	QGIS and questionnaire survey
Water and sediment		
1	Temperature	Digital thermometer
2	Light Penetration (LP)	Sechi disc
3	Total Suspended Solids (TSP)	Gravimetric
4	Salinity	Titration using Silver Nitrate
5	Dissolved Oxygen (DO)	Winkler's method
6	Phosphate- Phosphorus	Spectophotometric
7	Nitrate Nitrogen	Spectophotometric
8	N: P ratio	Computation
9	Oil and Grease	Spectophotometric
10	Chlorophyll pigments	Spectophotometric
11	Chlorophyll a	Spectophotometric
12	Sediment studies of Palk Bay	Gravimetric
13	Water Content	Gravimetric
14	Sediment texture	Sieves and Gravimetric
15	Sand	Sieves and Gravimetric
16	Silt	Gravimetric
17	Clay	Gravimetric
18	Organic Carbon (OC) and Organic Matter (OM)	Titrimetric, Walkley - Black method

Chapter 3

Results and Discussions

Species Richness as per Literature

A preliminary stock taking of the flora, fauna, the physical characteristics and social aspects of Palk Bay was done through literature survey and is summarised in Table 2.

The literature survey revealed a higher faunal richness compared to floral richness. (Figure 2). This could be due to either the low richness of the flora in the area or more probably the investigators' bias towards faunal studies that are more crucial for the local livelihood. The literature also reveals 392 endemic species, with only one floral specie (Figure 3).

Mangrove Patches

The mangroves in the study area are fragmented patches. Natural forest growth is seen only in a very minor scale. Mangroves with marshland are the highest in proportion followed by patches of mangrove restoration by the commonly adopted fishbone techniques. Primary digitization of the mangrove patches in the study area was done using Google Earth imagery. Then Bhuvan web application, ISRO's land use land cover classification for the year 2011-2012 were used for digitizing mangroves and coastal swamps. Mangrove patches restored by fishbone method were marked separately. The analysis reveals the mangrove cover to vary between 7.5% to 22% in the three different habitats at Palk bay.

Along the entire coast in the Palk bay, the reconnaissance survey showed that mangroves were found to be mostly in the northern part of the Palk Bay. To represent the most important

Table 2
Summary of Literature on the Palk Bay Examined

Seagrass and Corals	Water studies	Mangroves studies	Social studies
54	140	60	21

Figure 2
Reported Faunal and Floral Diversity in the Study Area

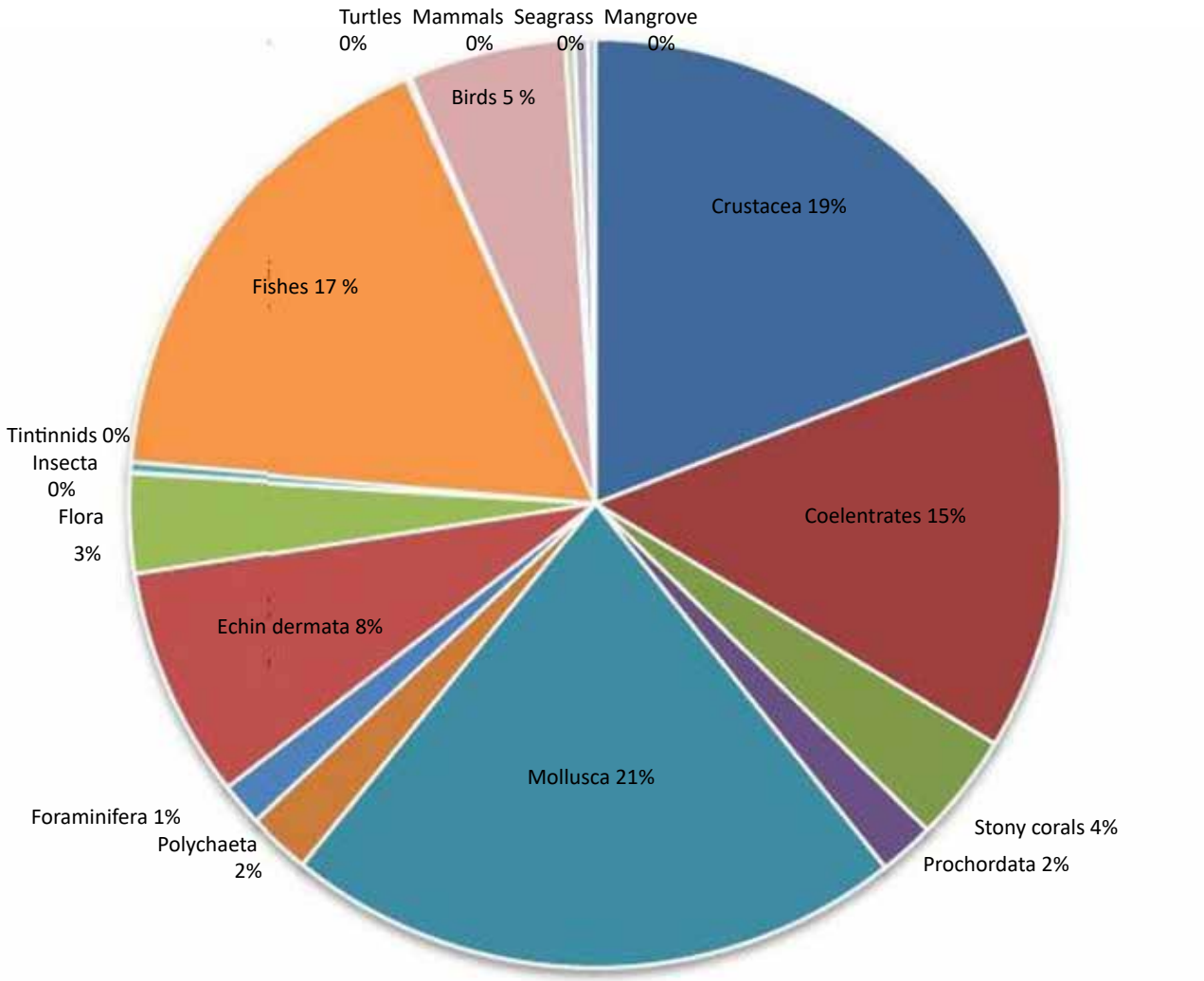


Figure 3
Endemic Species Reported from Palk Bay

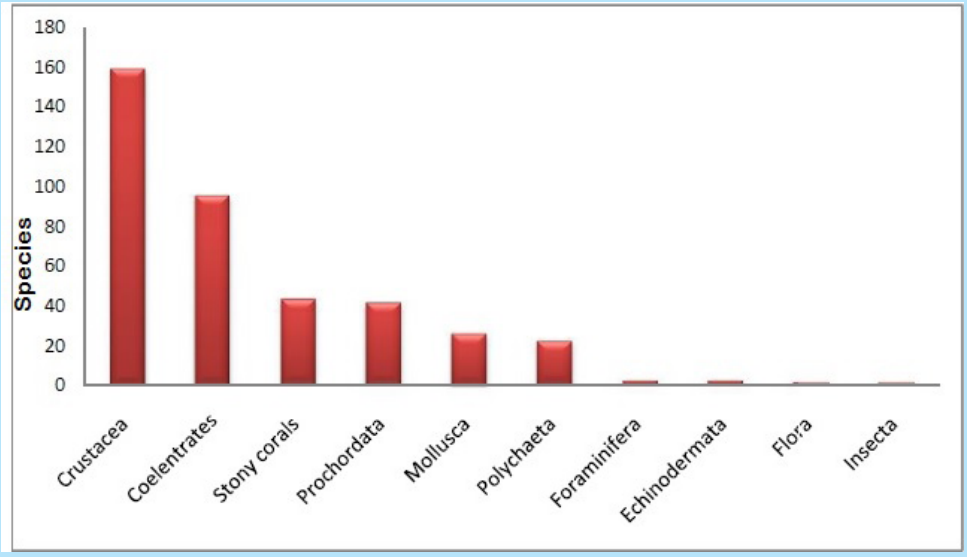
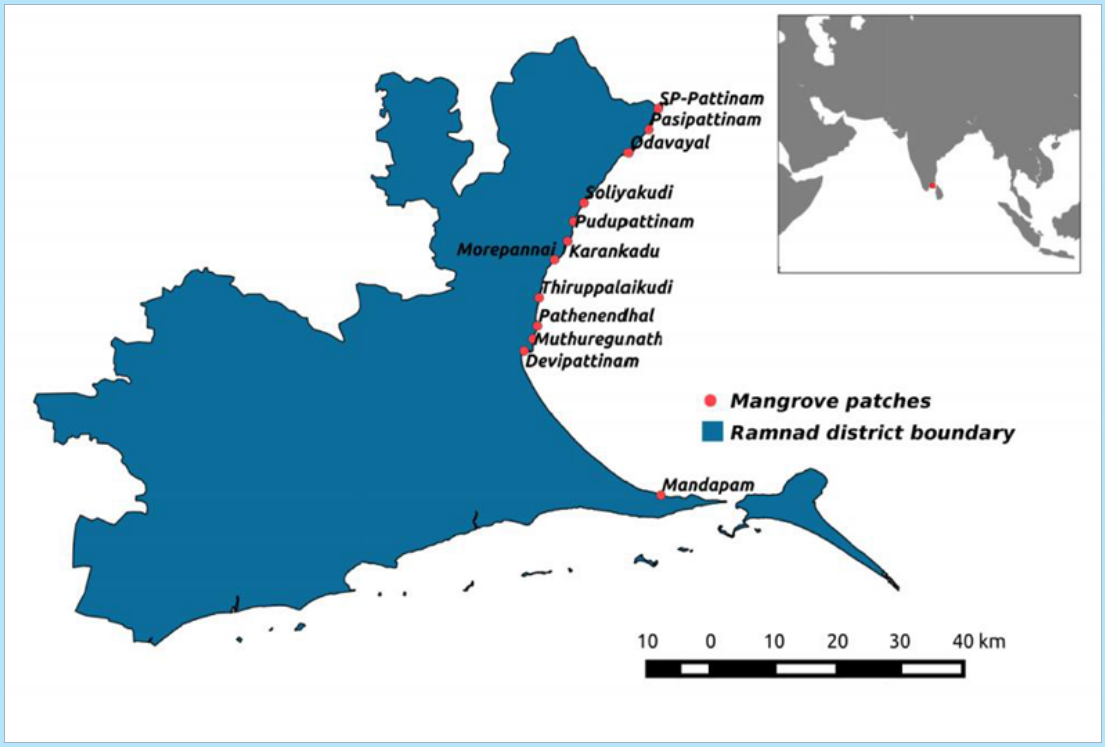


Table 3
Mangrove Study Site Statistics

	Habitat type	Grids Number	Area (km²)
1	Total grids covering the study area	269	269.0
2	Mangroves (natural forest growth)	20	0.769
3	Mangroves with Marshland	60	45.33
4	Mangroves Restoration (Fishbone method)	36	14.42

Figure 4
Mangrove Habitats Studied During the Present Study in Palk Bay



mangroves patches 12 locations were identified and extensively studied for the mangrove diversity and biomass. The map (Figure 4) shows the mangrove patches sampled in the study.

Important variables related to mangrove trees sampled are given in Table 4 and Table 5. A total of 92 quadrats of 10 m were accessed at 12 locations in total 26 mangrove and mangrove- associate species were recorded. Of the mangroves, *Avicennia marina* was found dominant. In total from the 92 plots, 1601 trees were sampled. The highest density of tree stands were observed in Odavyal (63 trees /10x10 m) and SP-Pattinam (60 trees/10x10 m) mangrove patches (Figure 5).

Seagrass

These are specialized marine flowering plants adapted to a near-shore environment. Seagrass form extensive meadows supporting high biodiversity (Connolly *et al*, 1999; Thayer *et al*, 1975) in shallow coastal waters with sandy or muddy bottoms. It serves as feeding and nursery habitats for endangered species like the dugongs, turtles and many commercial and recreationally important fishes and other organisms.

In terms of ecological services, seagrass regulate dissolved oxygen, reduce suspended sediments and nutrients in the water column (Stevenson, 1988; Short and Short, 1984) and thereby modify

Table 4
Mangrove Tree Density in Each of the Study Plots

Mangrove patches	No. of plots sampled	No. of Low tide plots	No. of High tide plots	Tree counts per plot
Devipattinam	13	7	6	2.0-23.0
Karankadu	14	7	7	9.0-56.0
Mandapam	2	2	0	0
Morepannai	8	5	3	14.0-32.0
Muthuregunathapuram	10	6	4	3.0-20.0
Odavayal	6	4	2	2.0-63.0
Pasipattinam	2	2	0	2.0-2.0
Pathenendhal	6	2	4	9.0-34.0
Pudupattinam	2	1	1	16.0-16.0
SP-Pattinam	17	10	7	1.0-60.0
Soliyakudi	3	1	2	21.0-25.0
Thiruppalaikudi	9	8	1	15.0-30.0

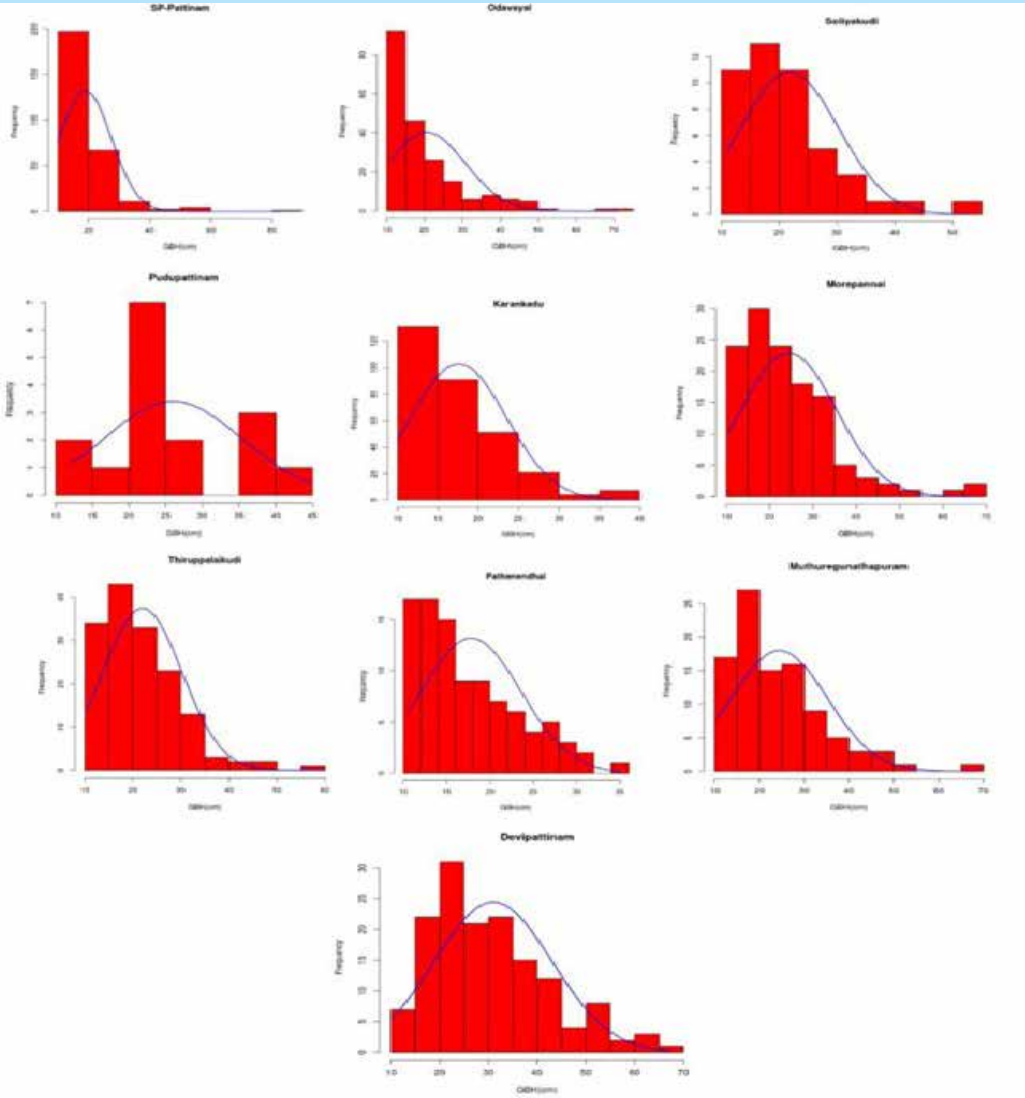
Table 5
Range of Values for Mangrove Tree Related Variables in Each Sampled Patches

Mangrove patches	GBH range(cm)	Average tree height (M)	Canopy cover (%)	Pneumatophore height (cm)
Devipattinam	10.0-67.0	2.5-9.0	10-70	18.5-40.0
Karankadu	10.0-40.0	2.0-6.5	20-45	21.75-42.5
Mandapam				20.75-22.25
Morepannai	10.5-67.0	4.0-7.5	20-70	18.75-38.75
Muthuregunathapuram	10.5-69.0	2.5-10.0	25-70	16.25-42.75
Odavayal	11.0-71.0	2.5-8.0	25-60	24.25-44.0
Pasipattinam	17.0-21.0	2.0-2.0	5-5	24.0-30.5
Pathenendhal	10.5-35.0	2.5-4.0	15-80	21.0-32.0
Pudupattinam	12.0-45.0	6.0-6.0	30-30	22.75-37.375
SP-Pattinam	10.0-84.0	2.0-7.0	1-60	7.125-52.5
Soliyakudi	11.0-53.0	6.0-8.0	25-65	14.75-37.75
Thiruppalaikudi	10.5-60.0	3.0-6.0	20-55	22.0-37.5

physical and chemical environments. Seagrass beds also prevent coastal erosion thereby offering natural shoreline protection. Seagrass are important in the production of organic carbon in the oceans (Duarte *et al*, 2002).

During our study at Palk Bay to determine the distribution and diversity of seagrass we employed the point intercept method (Tripathy *et al.*, 2015) involving divers to get first hand information on the occurrence and diversity of seagrass along the five stations and the four transect lines. However, during our field visit there was a bloom of jellyfish making conditions unfavourable for diving and sampling. Hence, in order to get a better realistic picture of the seagrass in Palk bay we also complemented the sampling strategy using the Van-veen grab (Tripathy *et al.*, 2015) along 89 locations spread at regular intervals of 500 meters from the shore bank up to the 5.5 km transect line. Along the five stations we recorded seagrass along 8 transect points during the dives and obtained seagrass in 21 grab samples out of the 89 locations. Mostly all the seagrass patches were located along the northern limits of the Palk Bay (Figure 6, Figure 7 and Figure 8).

Figure 5
Graphs Showing the Tree Density along the Different Sampling Points



During the study, we recorded 6 species of seagrass although there are reports of 14 species from the Palk Bay. The species recorded now were *Halophila ovalis, Halophila pinifolia, Cymodocea rotundata, Cymodocea serrulata, Syringodium isoettifolium,* and *Enhalus acoroides*. Of these six *Halophila ovalis, Halophila pinifolia, Cymodocea rotundata* only along the Nothern transects of Palk Bay, while *Enhalus acoroides* was observed only along the southern parts. The seagrass varied in density from 0 to 700 no/m^2 with a maximum of four species at a location.

In addition to seagrass, we also observed Green, Red and Brown algae that were either associated or competed with the seagrass. In the southern end of the Palk Bay, we recorded the occurrence of algae along the shore bank as well as at the 0.5 km transect. The most common species we recorded are given in the Table 6 below.

Corals

Corals are the major reef-building organisms maintaining the structure, function and stability of reef ecosystems (Moberg and Folk, 1999). Although they are ecologically (structurally and functionally) very important in marine system, corals are threatened alarmingly by numerous factors such as climate change, diseases, ocean acidification, coastal erosion, storms

Figure 6
Map Showing the Locations where the Grab Sampling was Undertaken for Seagrasses and Corals

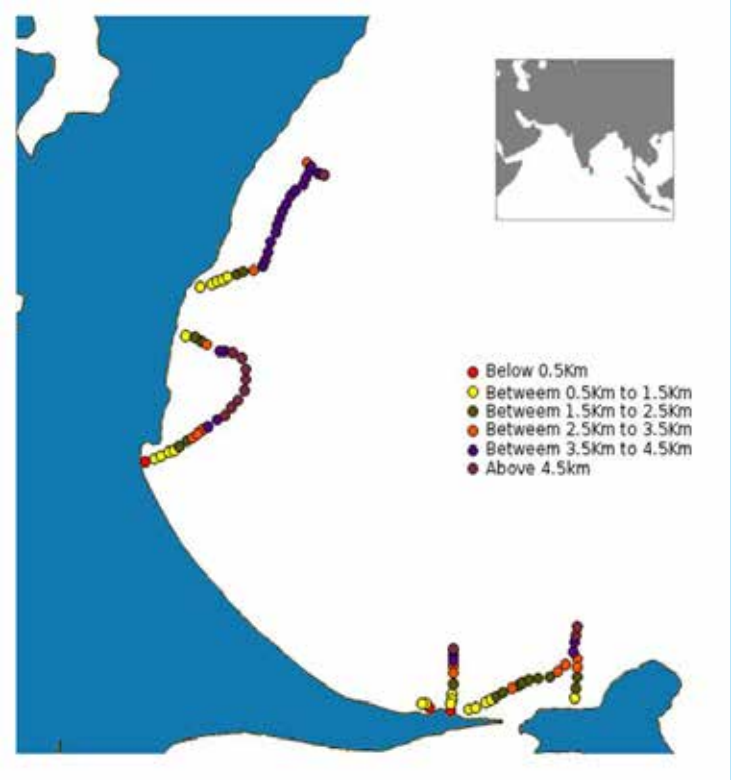


Figure 7
Map Showing the Transects along the Palk Bay Where the Study is Undertaken

Figure 8
Distribution and Density of Seagrass in Palk Bay

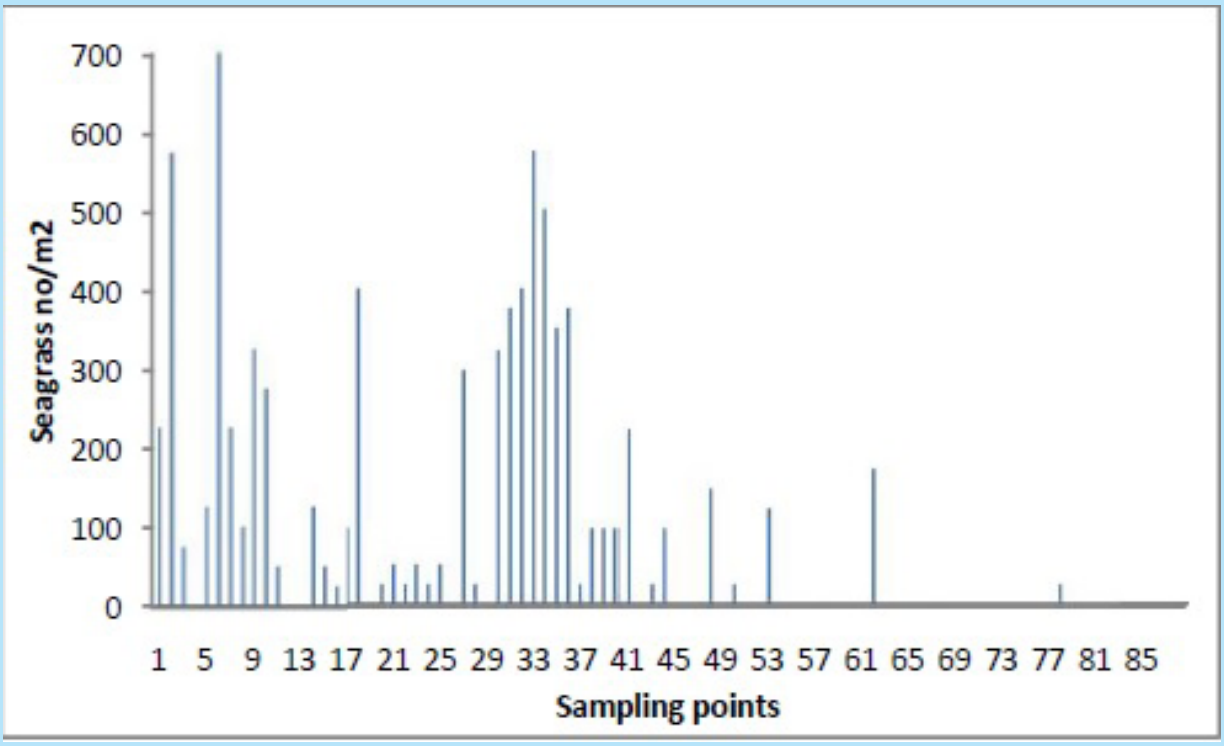
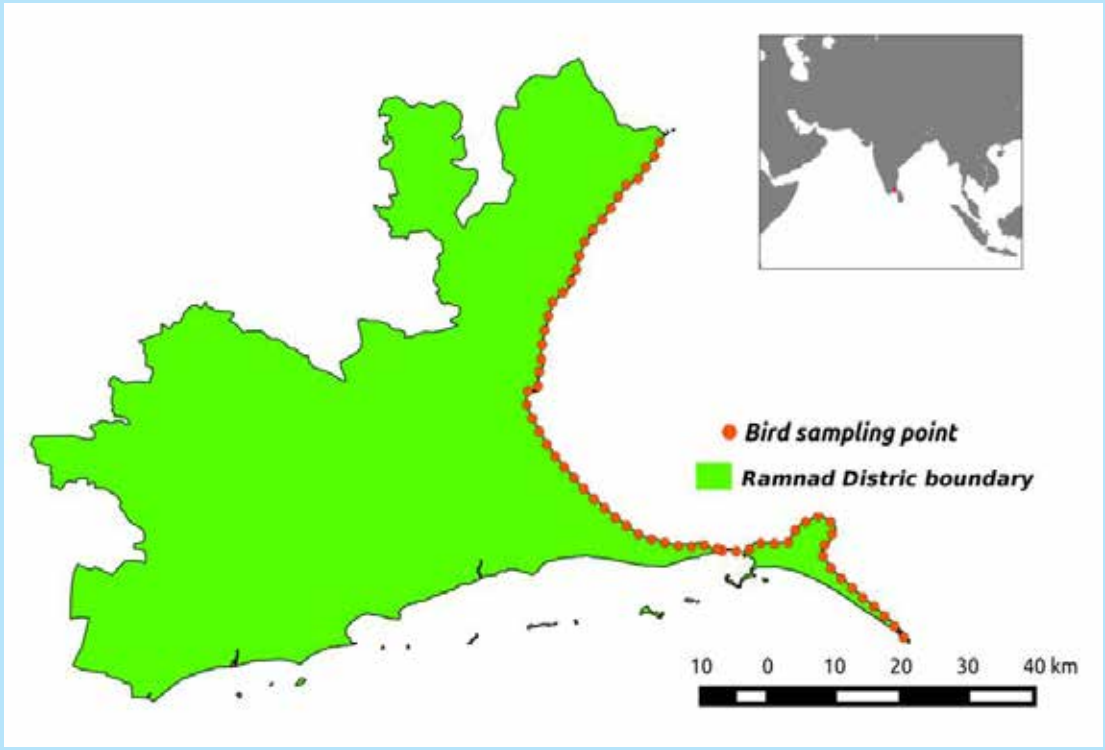


Table 6
Algae Species Observed in Palk Bay

Chlorophyceae (Green algae)	
1	*Enteromorpha compressa*
2	*Ulva lactuca*
3	*Ulva reticulata*
4	*Chaetomorpha spp.*
5	*Caulerpa serrulata*
6	*Caulerpa racemosa*
7	*Caulerpa peltata*
8	*Caulerpa taxifolia*
9	*Caulerpa sertularioides*
Rhodophyceae (Red algae)	
10	*Gracilaria corticata*
11	*Acanthophora muscoides*
12	*Gracilaria edulis*
Phaeophyceae (Brown algae)	
13	*Padina tetrastromatica*
14	*Sargassum wightii*

Figure 9
Sampling Locations for Birds During the Present Study in Palk Bay



and several anthropogenic activities including tourism. Coral reef ecosystems are the most sensitive ecosystems that respond rapidly to environmental stressors. In the recent couple of years there was wide report of coral bleaching, functionally the death of coral. However, corals show capability to recover from bleaching when environmental conditions turn favorable. Coral bleaching was observed during 1998 and 2002 in Palk Bay. Deposition of sediment over the bleached corals and live corals kill the coral polyps by smothering them (Ravindran *et al*., 1999)

In the Palk Bay, there is a fringing reef of approximately 25 to 30 km stretching from Mandapam to Rameshwaram with a width of 300 m. During our study, we undertook diving to record the coral diversity and distribution along the entire Palk Bay. However, we could find very few insignificant patches of corals in the northern side of the Palk Bay that were either bleached or smothered from sedimentation and anthropogenic activities like trawl dredging.

From our dives, we could observe the corals only along the 0.5 km transect line along the stations 4 and 5. At station 3, there were very few sporadic intermittently spread pieces of *Porites* sp. and *Goniopora* sp. The corals that we observed at stations 4 and 5 include *Porites lutea, Porites lichen, Goniastra pectinata, Goniopora minor, Cyphastrea serailia, Favia pallida, Acropora corymbosa, Favia sp.* and *Acropora sp.* Along with the corals we also observed star fish, sea anemones, brittle star, cuttlefish, sea urchin, sponges, ophistobranchs and coral fishes. Although *Cyphastrea serailia* corals were recorded, they were not continuous contrary to the earlier reports and were distributed in patches.

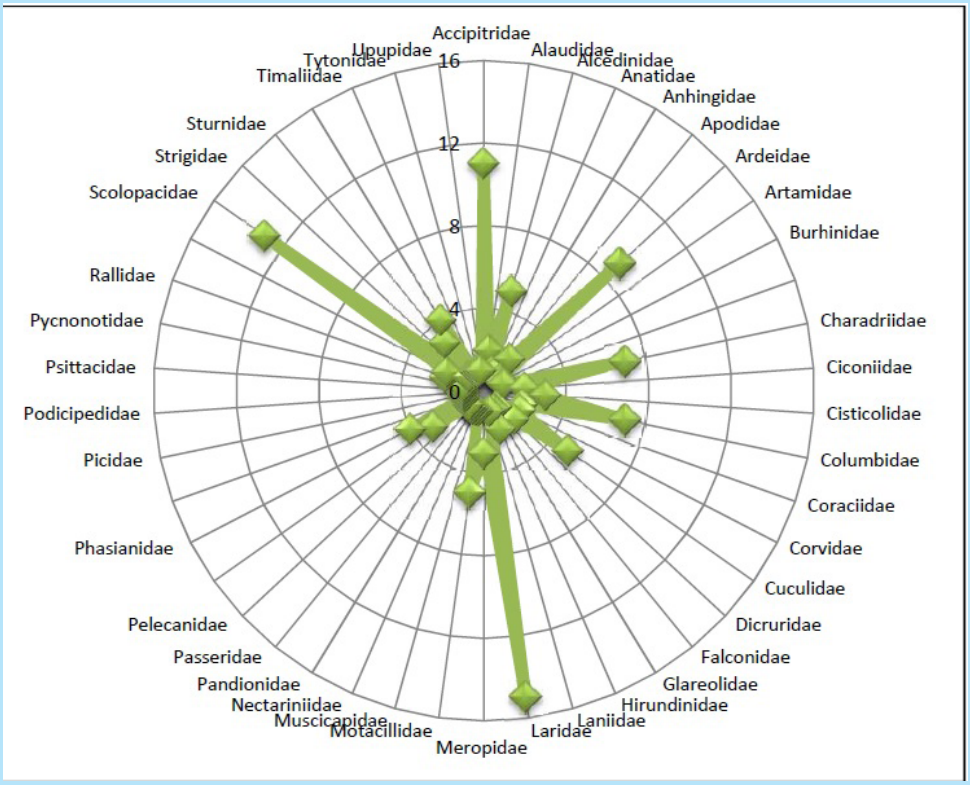
Avifauna

The survey points for birds are shown below (Figure 9). A total of 7,405 birds belonging to 130 species representing 46 families were recorded from the area during our survey. Of the 130 species, the birds belonging to family Laridae and family Scolopacidae were higher

Table 7
Avian Species Sighted During the Survey in Different Habitats

Habitat type		Habitat	Species sighted
1	Natural Mangrove Forest	1	35
2	Fishbone Mangrove Cultivation	2	30
3	Family of Arecace e	3	30
4	Urban Fishing Point	4	33
5	Plants of Family Fabaceae	5	44
6	Aquaculture Pond	6	32
7	Palm Plantation and Casuarinas	7	8
8	Plants of Family Casuarinaceae	8	12
9	Sandbar	9	23

Figure 10
Avian Taxa and the Respective Number of Species Sighted During the Survey



in number (Figure 10). Comparison of the nine habitats shows that two species were common in eight habitats (Table 7) while five species were common in seven habitats and the others were not very common throughout (Figure 11). Only six species were commonly sighted along the entire coastal length.

Reptiles

Opportunistic observations were made during the ecological assessment survey from January –March 2016 to record reptiles along the coast. In total nine species were recorded during the survey which included six lizards, two snakes and one turtle species (Table 8).

Figure 11
Birds Commonly Sighted in the Area

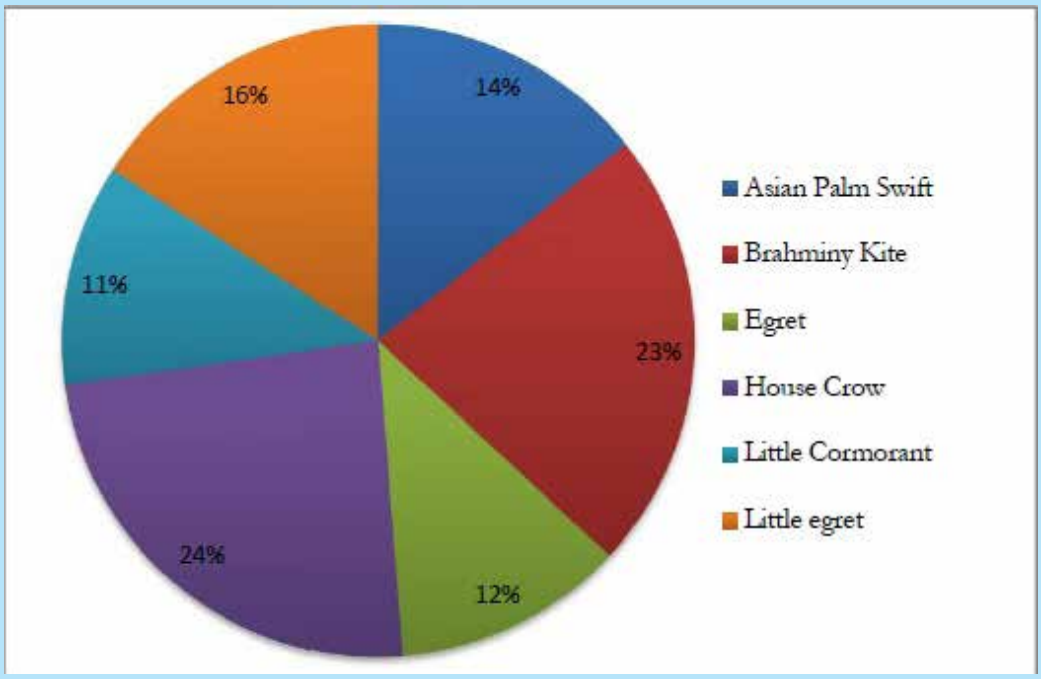


Table 8
Reptile Species Recorded During the Survey

	Scientific name	Common Name	IUCN status
1	*Lepidochelys olivacea*	Olive Ridely sea turtle	VU
2	*Hemidactylus sp.1*	House gecko sp.1	-
3	*Hemidactylus sp.2*	House gecko sp.2	-
4	*Calotes versicolor*	Oriental Garden Lizard	Not assessed
5	*Sitana ponticeriana*	Fan throated lizard	LC
6	*Eutropis carinata*	Keeled grass skink	LC
7	*Eutropis bibronii*	Bibron's Skink	LC
8	*Eryx johnii*	Red sand Boa	Not assessed
9	*Dryocalamus nympha*	Common Bridal snake	Not assessed

VU- Vulnerable; LC Least Concern

Insects and Arachnids in the Mangrove Patches

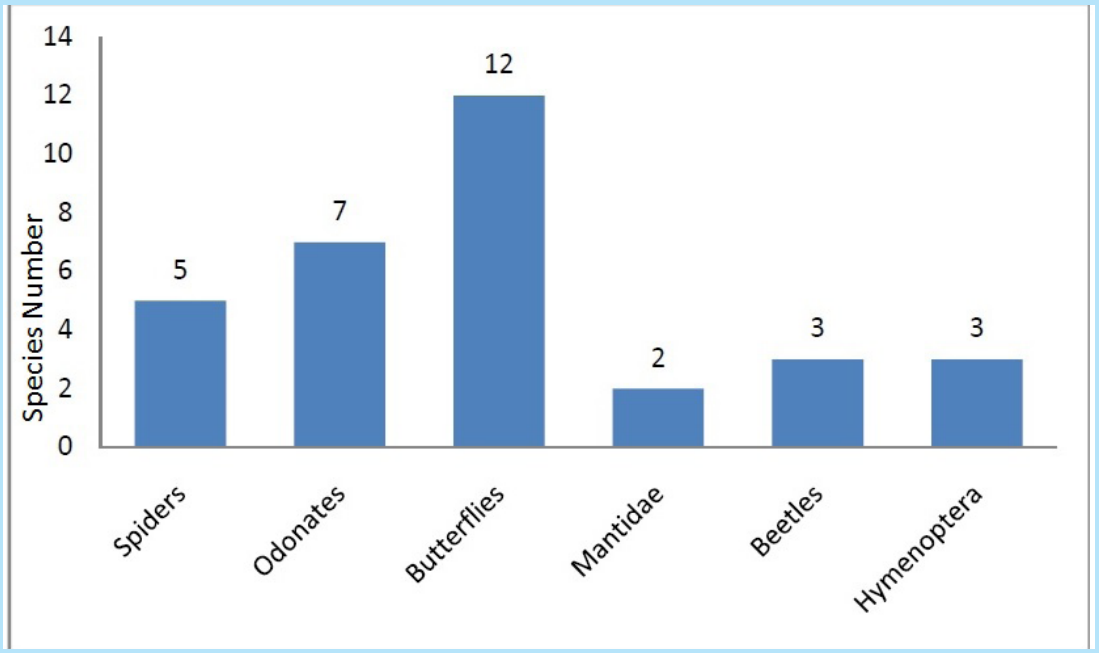
While studying the mangroves, insects and arachnids were recorded opportunistically. In total, 27 species of insects and five species of Arachnids were recorded from the patches along the Ramanathapuram coast.

The arachnids comprised of five species of spiders, while the insects included the Lepidopterans, Mantids, Odonates, Hymenopterans and Beetles. Lepidopterans were the most observed group with 12 species, followed by seven species of Odonates (Figure 12).

Benthos

The ocean bottoms are generally heavily populated with invertebrate species, and the organisms that live within sediments (infauna), on the bottom (epifauna) or that associated with the aquatic sediments (phytal) are called benthos and their mode of life as benthic. This bottom fauna according to Ziegelmeier (1972) is involved in recycling materials in the marine ecosystem playing crucial role in food chains as the plankton do in the pelagic zone. Studies on the benthic

Figure 12
Insects and Arachnids Commonly Sighted in the Area



fauna are important from the context of assessing production (Srinivasarao and Ramasarma, 1983). Further, Athalye (1988) is of the opinion that the coastal sediments lined with diverse littoral mangrove swamps contribute significantly to the total productivity by harbouring a great variety of organisms, by producing a large amount of detritus and providing food to demersal fishery, thus emphasizing the importance of benthos in the food chain. Analysis of benthic macrofauna, according to Bilyard (1987), is a key element of many marine and estuarine monitoring programmes. Benthos are superior to other biological groups in indicating pollution stress because they are sedentary and are under compulsion that either they must adapt to environmental stress or perish. Benthos can indicate the magnitude and as well as spatial and temporal distribution of pollution in the environment (Hartley, 1982).

The polychaetes are among the common and important benthic organisms in marine system. They form an important group as a descriptor of environmental conditions (Simboura et al., 2000). Polychaetes play a key role in the macrobenthic secondary production and form the most abundant food in the diet of commercially important demersal fishes and large epibenthic invertebrates. The growth of polychaetes, according to Ansari *et al* (1986), is enhanced due to sewage release. They are considerably the most tolerant group of animals and dominate in number in polluted zones.

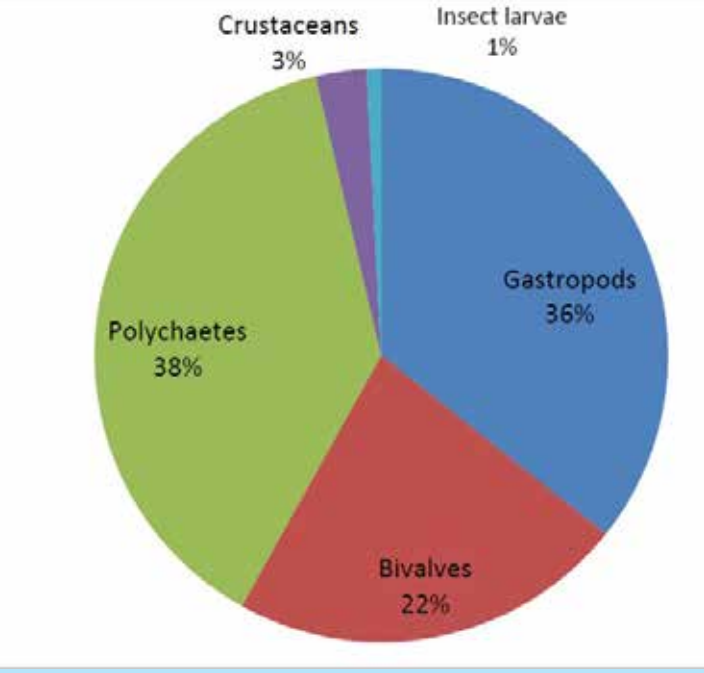
During our study at Palk Bay, we recorded benthos from the mangrove mudflats (Figure 13), benthos from the offshore transects (Figure 7) and benthos associated with the seagrass (Figure 6).

Benthos in Mangroves

The mangrove mudflats were sampled at five different locations where the water and soil were studied. The macrobenthos mainly comprised of five groups i.e Polychaetes, Gastropods, Bivalves, Crabs and Insect Larvae (Figure 14) the total density of which varied between 129/m^2 to 334/m^2 (Average 258/m^2). The M3 sampling station had marginally higher number of benthic organisms followed by M1, M2, M4 and

Figure 13
Map Showing the Mangrove Benthos Sampling Locations

Figure 14
Overall Macrobenthos (%) Recorded from the Mangroves along Palk Bay



M5 (Figure 15). Polychaetes were the dominant fauna along all the sampling stations and they ranged in number from 25 /m^2 to 150 m^2 (average 85/m^2); the M3 station had a higher proportion of polychaetes followed by M1, M2, M4 and M5 (Figure 16). The dominance of polychaetes can be attributed to the organic enrichment from the mangroves, creeks and other shoreward sources.

The distribution and abundance of gastropods according to Kashinath and Shanmugam (1988) are controlled by environmental conditions. Gastropods contributed 36 % to the total

Figure 15
Distribution of Macrobenthos (no/m²) at the Mangroves Sampling Points in Palk Bay

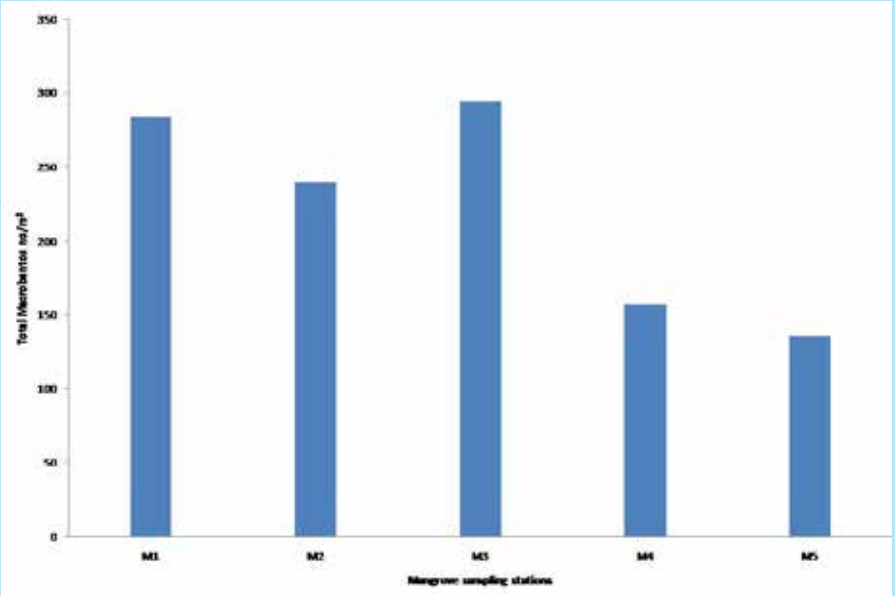


Figure 16
Composition of Faunal Groups (%) at the Mangrove Sampling Stations in Palk Bay

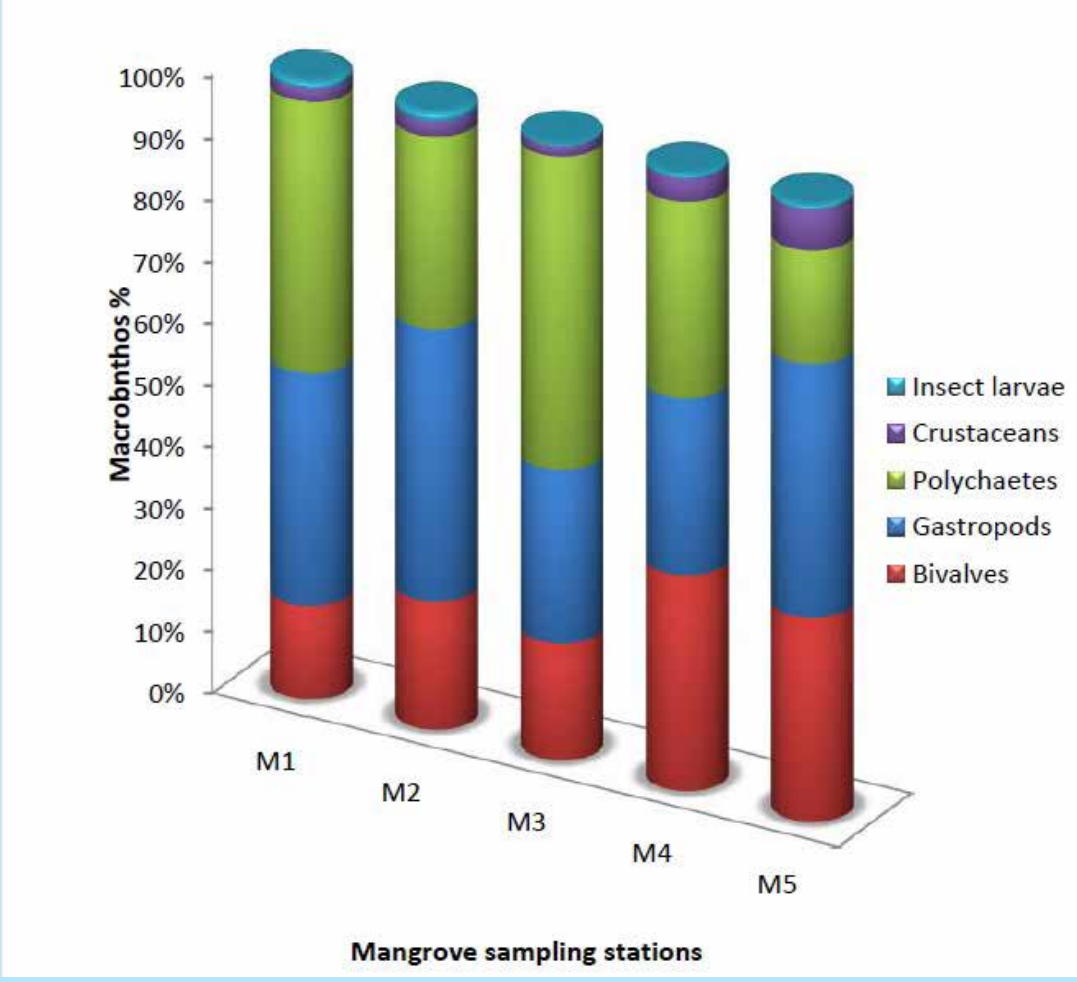


Figure 17
Distribution of Gastropods (no/m²) at the Mangrove Sampling Stations in Palk Bay

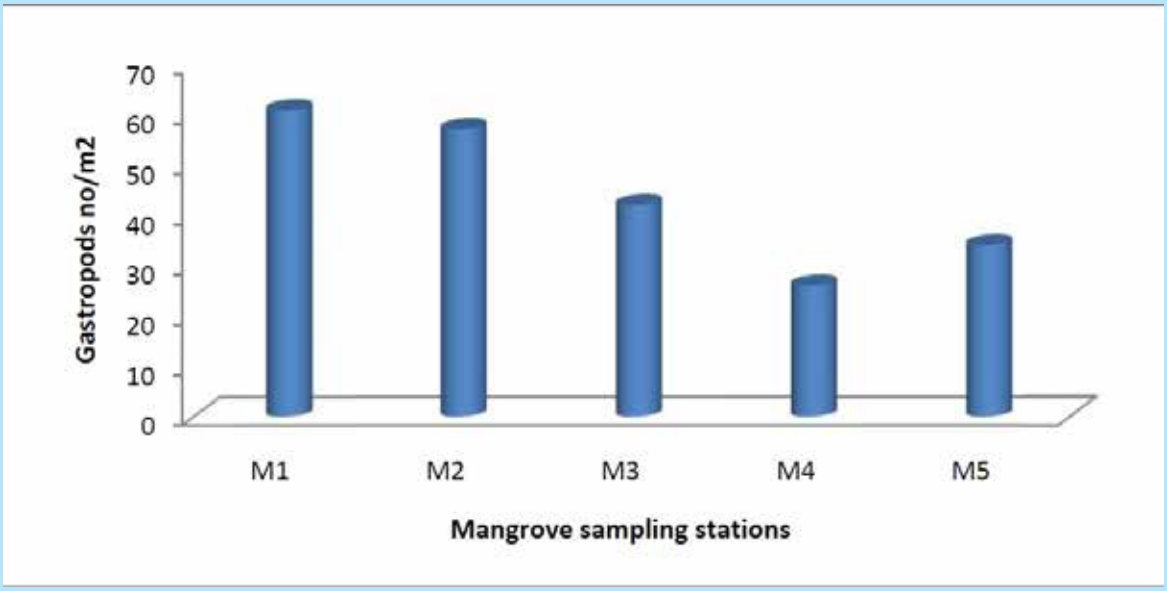
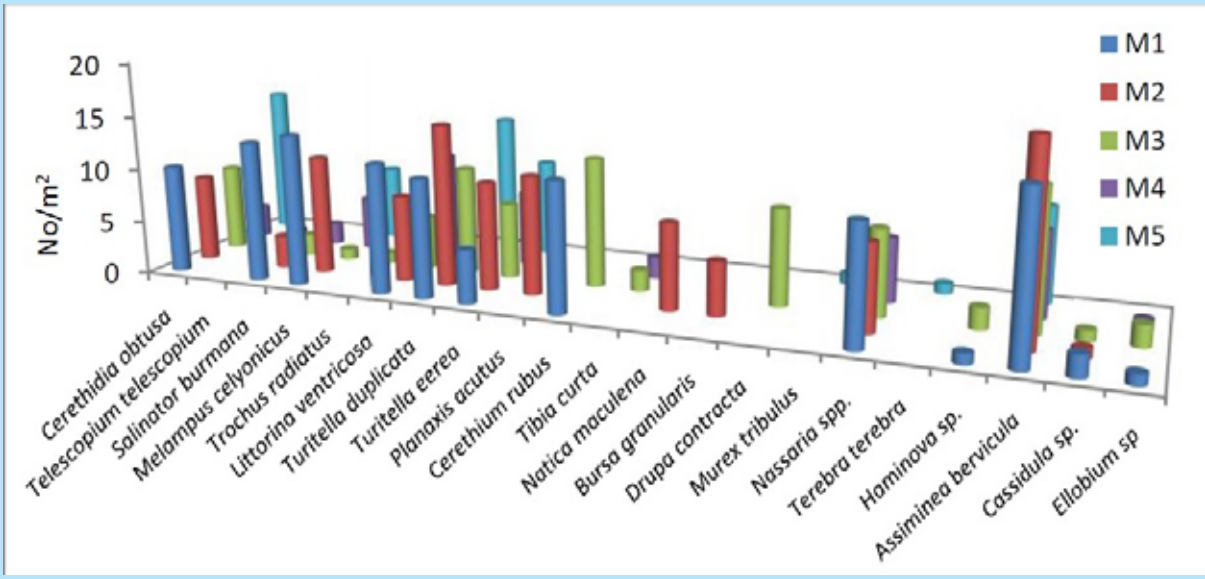


Figure 18
Gastropod Species (no/m²) at the Mangrove Sampling Stations in Palk Bay



number of macrobenthos in the mangrove mudflats of the Palk Bay. They varied in number between 45 /m² and 107 /m² (average 79/m²) with highest number observed at the sampling station M1 followed by M2, M3, M5 and M4 stations (Figure 17). Twenty-one species of gastropods were recorded from the mangroves. Of these only four species (i.e. *Cerethidia obtusa, Melampus celyonicus, Turitella eerea, Assiminea brevicula*) were present at all the sampling stations, indicating their resilience to different environmental conditions. The occurrence of the different species of gastropod is given in Figure 18; the M3 sampling station had the highest gastropod species (15) while the lowest was recorded at M5 with nine species.

Bivalves are filter feeders and are known to concentrate more pollutants in their body than other organisms. Hence, they are less tolerant

Figure 19
Distribution of Bivalve Species (no/m²) at the Mangrove Sampling Stations in Palk Bay

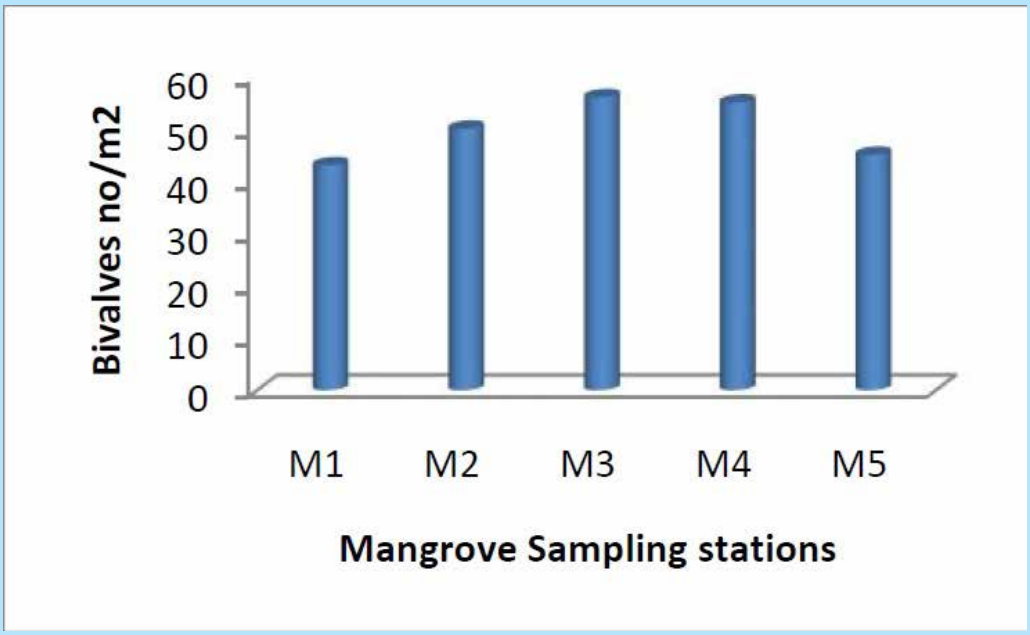
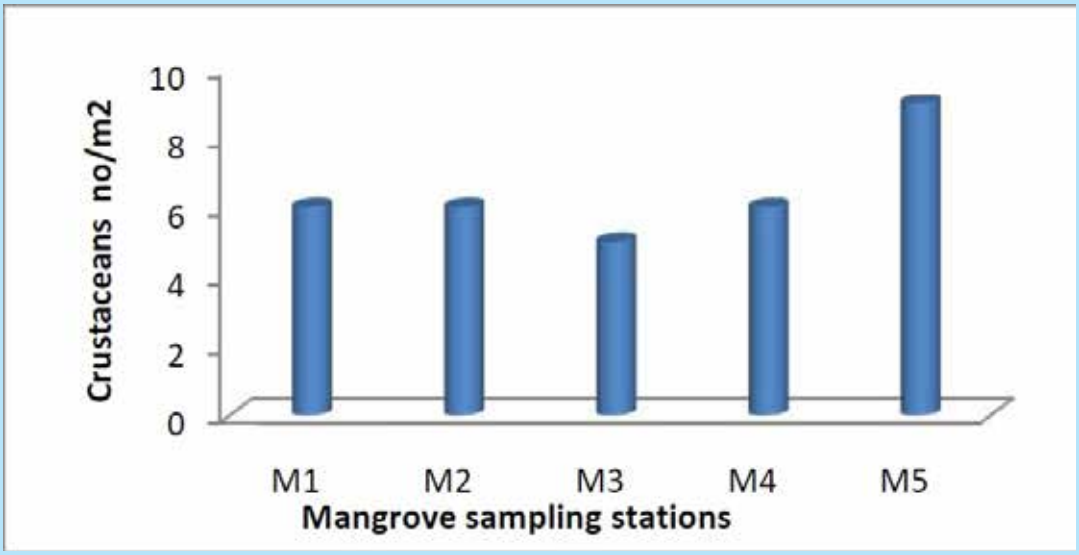


Figure 20
Crustaceans (no/m²) at the Mangrove Sampling Stations in Palk Bay



to pollution and beyond a level decrease in numbers or disappear. In the Palk Bay five species of bivalves were recorded from the mangroves ranging in number from 43/m² to 56/m² (average 50/m²). Of the five species, three (i.e. *Dosinia pubescens, Galuconome cerea* and *Cuspidaria cochinensis*) were recorded from all the five locations. The bivalve number was highest at M3 followed by M4, M2, M5 and M1 (Figure 19).

Crustaceans have heterotrophic feeding habits and can consume polluted detritus available and result in accelerated growth rate (Unnithan *et al*., (1975). However, accumulation of pollutants beyond the level of tolerance affects the survival of species and consequent reduction in numbers. In the Palk Bay, the crustacean population comprised of the Brachyuran crabs *Scylla serrata, Varuna sp., Sesarma sp., Uca*

Figure 21
Composition of Macrobenthos (%) at the Offshore Stations in Palk Bay

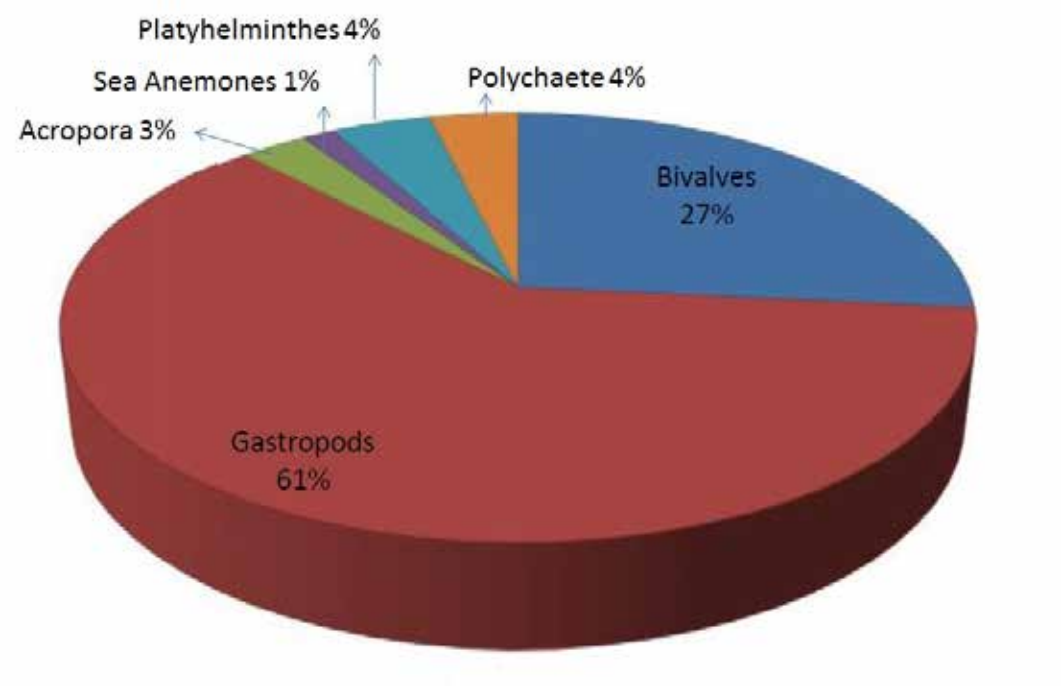
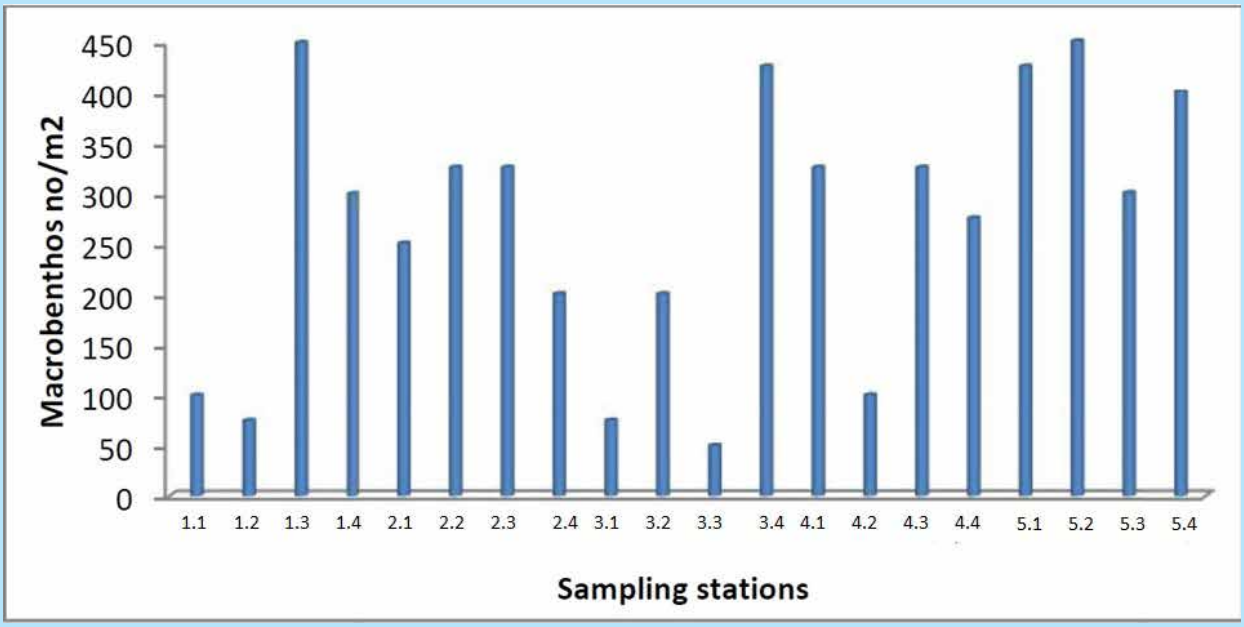


Figure 22
Macrobenthos (%) Recorded from the Different Sampling Stations along Palk Bay

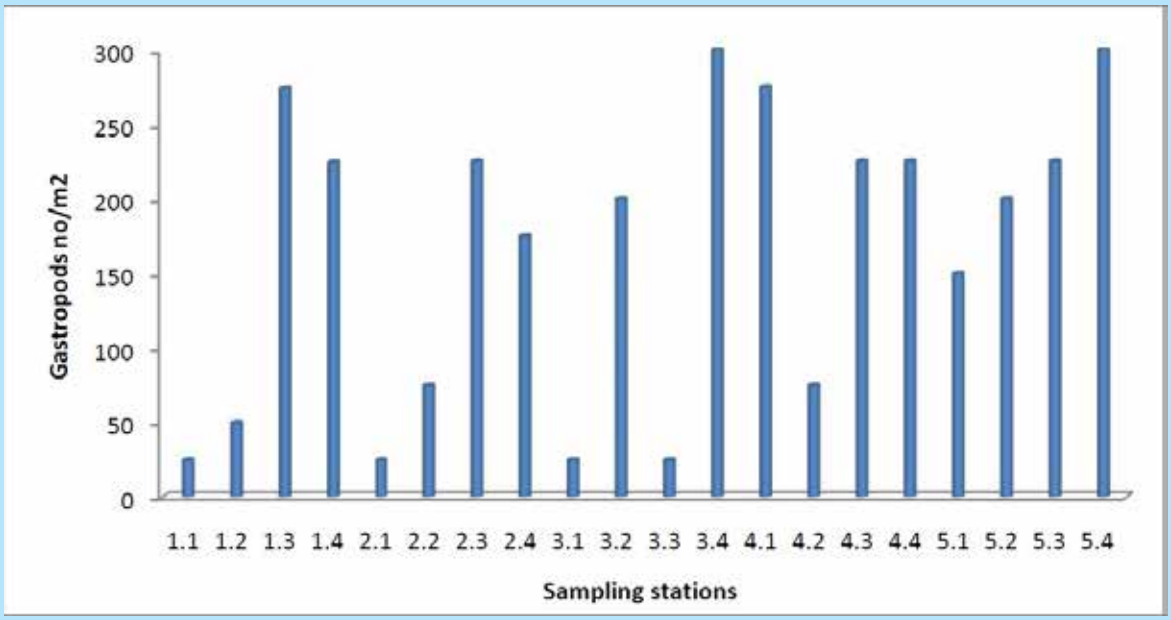


annulipes and Uca sp., the Anumoran Hermit crab and the Amphipod gammarid species. The numbers varied from 5 to 9/m^2 (Average 1.8/m^2) with the highest number and diversity seen at M5 location (Figure 20).

Benthos Along the Offshore Transects

The benthos along the open offshore transects was surveyed using the Van-Veen grab of 0.04 m^2 area. In the Palk Bay, the benthos was dominated by gastropods followed by bivalves,

Figure 23
Distribution of Gastropods (No/m²) at the Sampling Stations in Palk Bay



platyhelminthes, coral and sea anemones (Figure 21). The total number varied from 50/m² to 450/m² (average 269/m²). The highest number benthos was recorded along the 0.5 km transect line at station one, while the lowest number was recorded from station three on the 0.5 km transect line. The macrobenthos was more along station 5 followed by stations 2, 4, 1 and 3 (Figure 22). As per the transects, the benthos seemed to decrease from the shore bank up to the 5.5 km transect line.

The Gastropods were represented by 19 species, of which only *Rissoina bertholleti* was most widespread. All the other gastropods had a restricted distribution. Highest number of gastropods was recorded along the station 5 at all the transect points (Figure 23). Among the transects the shore bank transect had the greatest species richness of 12 species followed by the 3.0 km transect (10 species). Along the 0.5 km and the 5.5 km transects nine species each were reported. The number of gastropods in Palk Bay varied between 25/m² and 300 /m² (average 165/m²).

The bivalves in the sediment of the open waters varied in number from none to 250/m² (average 71/m²) and were represented by eight different species. *Arca avellana* and *Soletellina sp.* were wide spread although they could be found at all the sampling stations. The bivalves were more in number at stations 1 to 3 while the stations 4 and 5 were less in number (Figure 24). The species diversity was more along the shore bank followed by the 0.5 km transect.

A comparison of the mollusc species shows that the gastropods were more abundant along the southern stretch while the bivalves were more along the northern part of the Palk Bay, probably acting as indicators of the environmental conditions in the region. Among the other faunal groups recorded, the platyhelminthes were the more prominent group followed by the sporadic occurrence of coral species, sea anemones and polychaetes. All these groups were more concentrated towards the southern end of the Palk Bay.

Benthos Associated with Seagrass

In addition to the mangroves and the fixed transect points we also assessed the seagrass along the Palk Bay at intervals of 500 m from

Figure 24
Bivalves (No./m²) at the Sampling Stations Along the Transect Points of Palk Bay

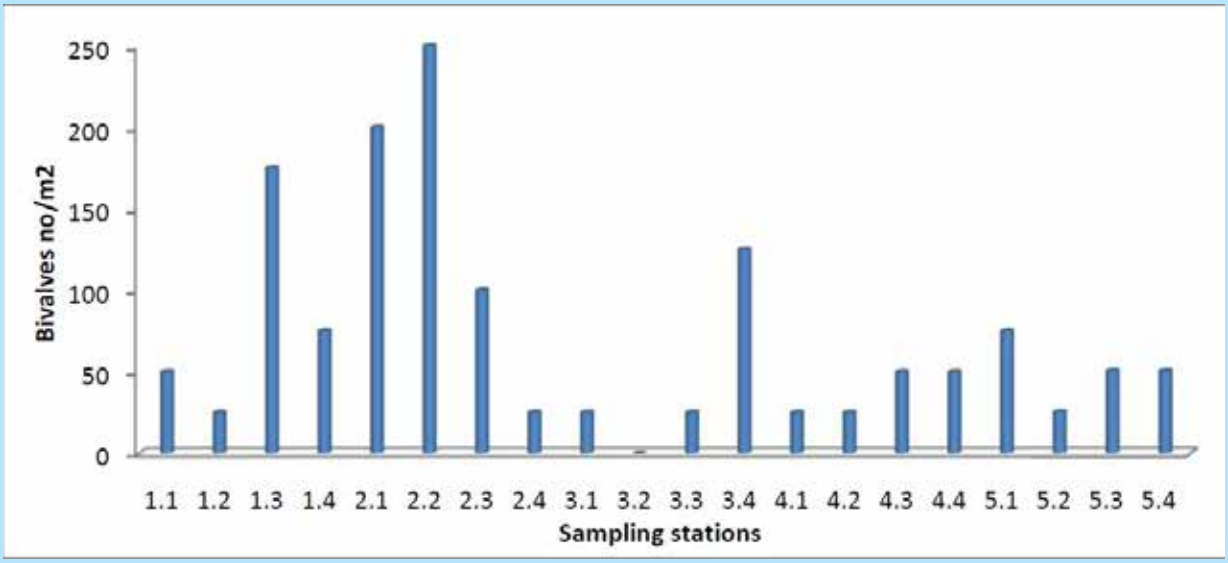
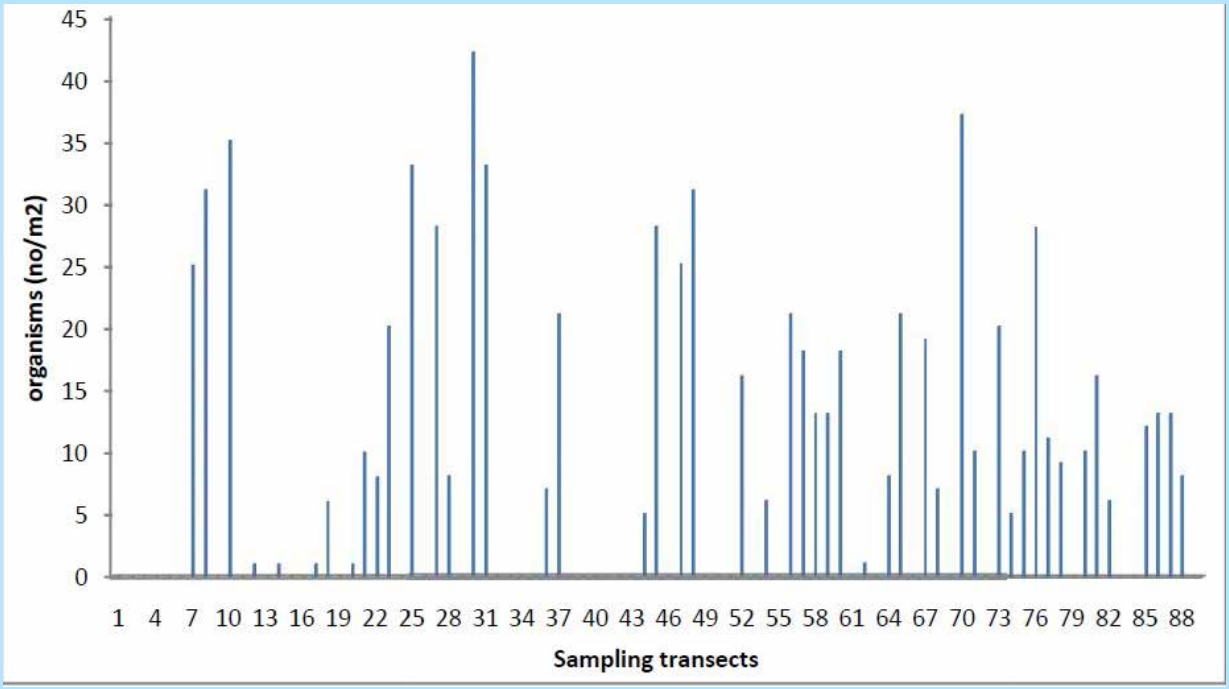


Figure 25
Benthic Organisms (no/m²) at 89 Locations Sampled in Palk Bay



the shore bank transect to the 5.5 km transect line along four stations i.e. 1, 2, 4 and 5. In all, 89 locations were sampled using the Van-veen grab to know the benthos associated with the seagrass; these samplings were undertaken in addition to the 20 locations sampled for benthos, making it a total of 109 grab samples. From the grab samples, we could get benthos at 69 different locations (Figure 25), while the remaining 40 locations had only clay, sand and silt and seagrass. From the 69 benthos grabs, only 29 had seagrass samples. The stations 1 to

Figure 26
Composition of Benthic Fauna from the 89 Grab Samples Collected from Palk Bay

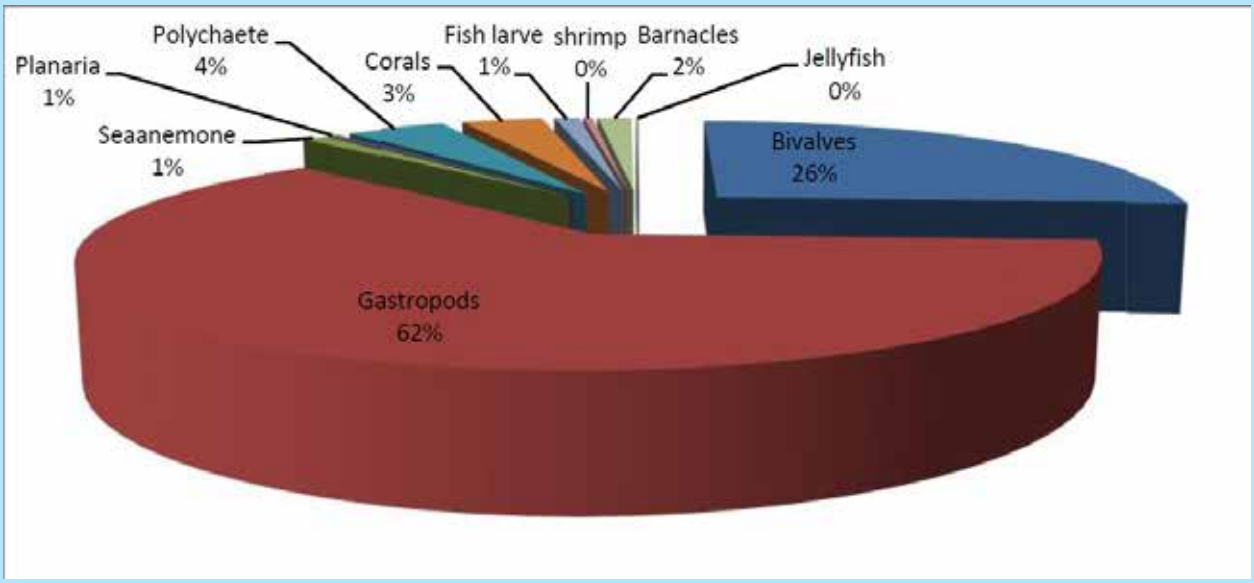
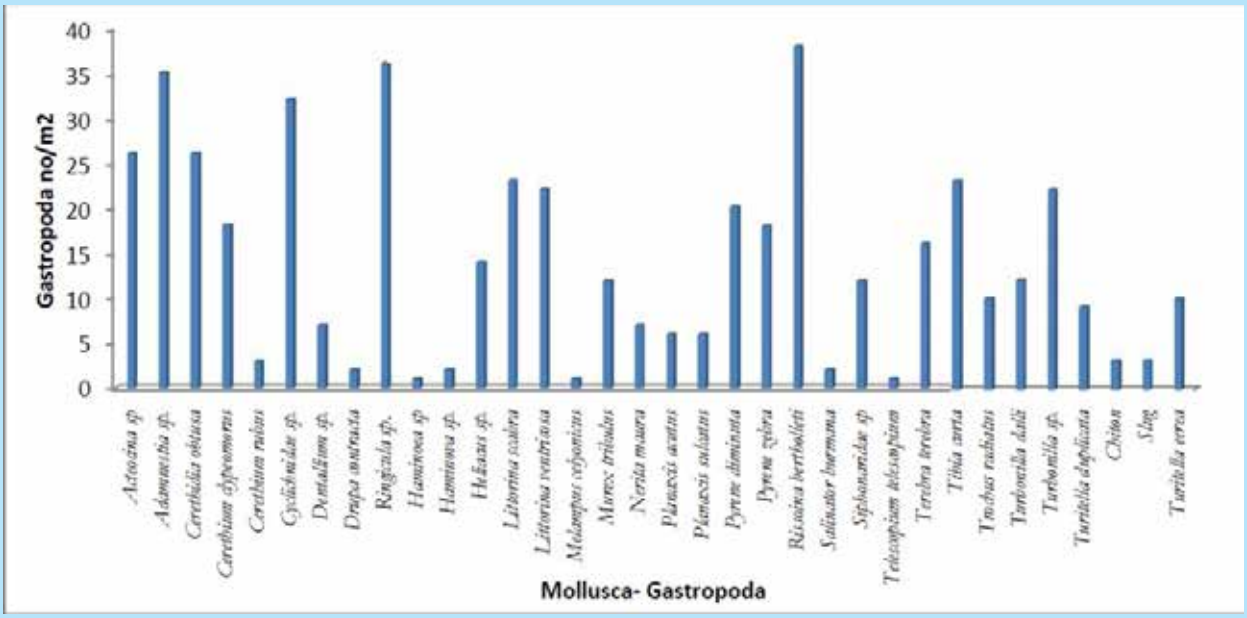


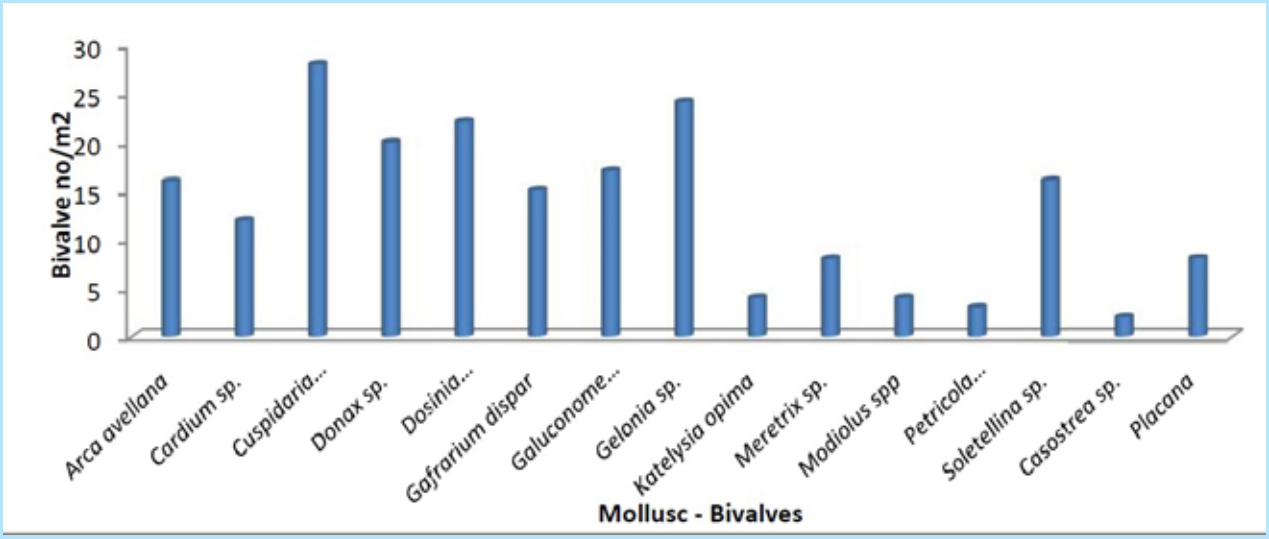
Figure 27
Abundance of Gastropods Recorded from the 89 Grab Samples Collected from Palk Bay



3 had the highest number of seagrass associated organisms compared with the southern stations 4 and 5. Overall the benthic fauna comprised of astropods (33 species), Bivalves (15 species), polychaetes, sea anemones, corals, platyhelminthes, coelenterates (Jellyfish), barnacles, Fish larvae and shrimps (Figure 26).

Among the 33 gastropods recorded (Figure 27), *Rissoina bertholleti, Ringicula sp.* and *Adamnestia sp.* were widely distributed and were more in number throughout the Bay. The bivalves (Figure 28) were dominated by *Cuspidaria cochinensis, Gelonia sp., Donax sp.* and *Dosinia pubescens* and were widespread evenly throughout the Palk Bay. There was no particular pattern in the distribution of the other faunal groups. Although we observed significant association

Figure 28
Abundance of Bivalves Recorded from the 89 Grab Samples Collected from Palk Bay



of gastropods with seagrass, the benthic fauna was more diverse and abundant in the southern stations where the seagrass was not obtained in the grab.

Water Quality in the Palk Bay

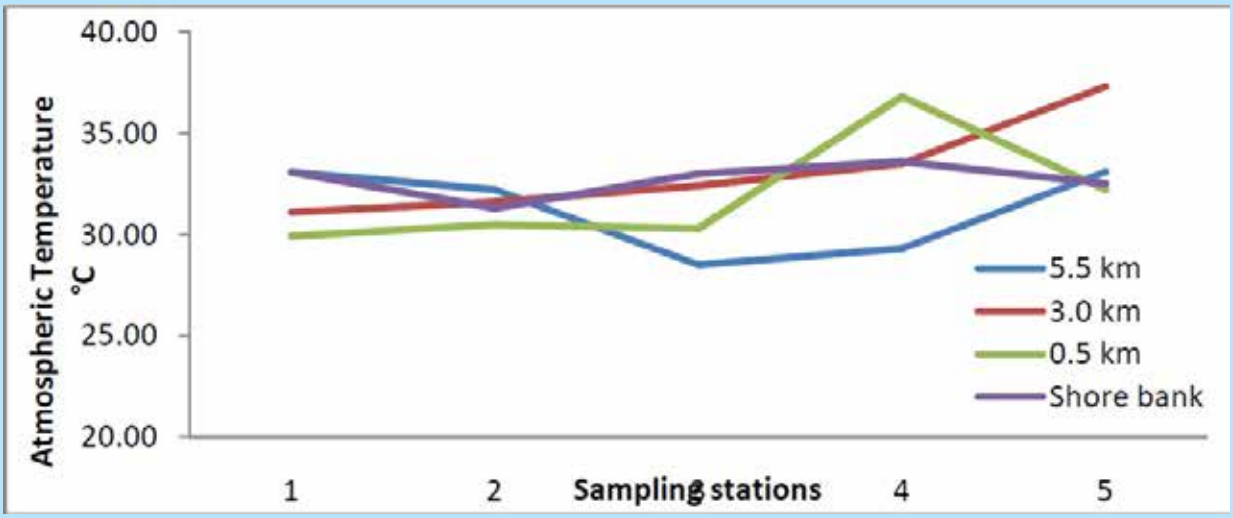
Water is the most vital resource for all forms of life. However with growing population and indiscriminate use of this resource has led to several kinds of pollution affecting the ecology of the water bodies. This is especially true in the case of the marine system, which is the ultimate universal receptor for almost all anthropogenic wastes. Marine system is abundant with all types of waste starting with the invisible micro-plastics to explicitly repulsive macro-plastics. The coastal areas are the first to face anthropogenic pressures and numerous types of waste, effluents and debris. Of the several subcategories of coastal ecosystem, mangroves are one of the most vulnerable. Although mangroves serve very vital roles and the ecosystem services, they are vanishing at a fast pace all across our coastline. Hence, the management of coastal waters and mangrove ecosystems has now become a key factor in sustaining developments and livelihoods, not just to those directly draw their sustenance from them, but also to a much larger segment living inland. The water quality in the coastal area is a critical feature that determines the health of the coastal ecosystem. Hence, hydro-chemical studies are important in assessment of aquatic ecosystems as they can be a window to the metabolic processes taking place in the water body that significantly influence the aquatic life.

Assessment of water quality being one of the objectives of the present study, the Palk Bay region along the coasts of Ramanathapuram district, both the bay as well as the waters entering the mangrove areas, was explored using indicative parameters.

Temperature

Temperature is one among the critical environmental parameters, which directly and radically affects or even determines the presence, physiology, growth and reproduction of aquatic organisms, both plants and animals. During our study in June 2016, we recorded the air temperature in the Palk Bay waters. It was found to vary between 28.5°C and 37.3°C (average 32.26°C) in the region (Figure 29). The fluctuations in air temperature were produced by factors, such as time of the sampling, wind

Figure 29
Atmospheric Temperatures at the Sampling Stations along the Transects in Palk Bay



and cloud cover. The sampling process in the present case extended from 6.00 hours to 15.00 hours each day. The 3 km transect line showed the highest average temperatures, which can be attributed to the time of sampling that was mainly around noon.

The water temperature was mostly governed by the air temperature, the depth of the water body and the currents. Any other intense physical activity in the area also can modify the water temperature. The Palk Bay is known to have a maximum depth of 12 m at its farthest from the shoreline, i.e. beyond 6 km from the shore. During our study, we covered a distance of up to 5.5 km from the shore hence was reaching to a depth of less than 12 m throughout. The water temperature varied between 29.5°C and 34.2°C (Average 31.49°C) in the study region (Figure 30). The water temperature close to the shore was higher than the remaining three transects. This can be attributed to the shallowness, the waves and the mixing of the waters near the coast resulting in high values. The temperature was more or less decreasing towards the farthest sampling point, roughly in agreement with water depth. The sampling points on the transects varied in temperature for the local modifying factors.

Light Penetration

A measure of transparency of water provides information on the clarity of water, growth and decay of plankton and suspended detritus in the media (Alam 1992). It is generally affected by the sun's position in the sky, the angle of incident light, cloudiness, visibility, water currents, water surface conditions and abundance of phytoplankton and zooplankton. It is also influenced by turbulence and nature of suspended material (Ramana *et al*., 1991). During the study, we recorded 0.00 to 810.26 cm (average 326.29 cm) light penetration in the region (Figure 31). The minimum light penetration observed along the transect close to the shore was primarily due to the disturbance by waves and churning of the sediments with the organic debris accumulated along the coast. According to Chandran and Ramamoorthi (1984), re-suspension of sediments caused by turbulence of tidal currents is a major factor influencing transparency, corroborating our observation.

A comparison of stations (Figure 1) shows that the minimum variation in light penetration is seen at station 5 i.e. closer to Rameswaram. This station is under high human activity including

Figure 30
Water Temperatures at Different Sampling Stations along the Transects in Palk Bay

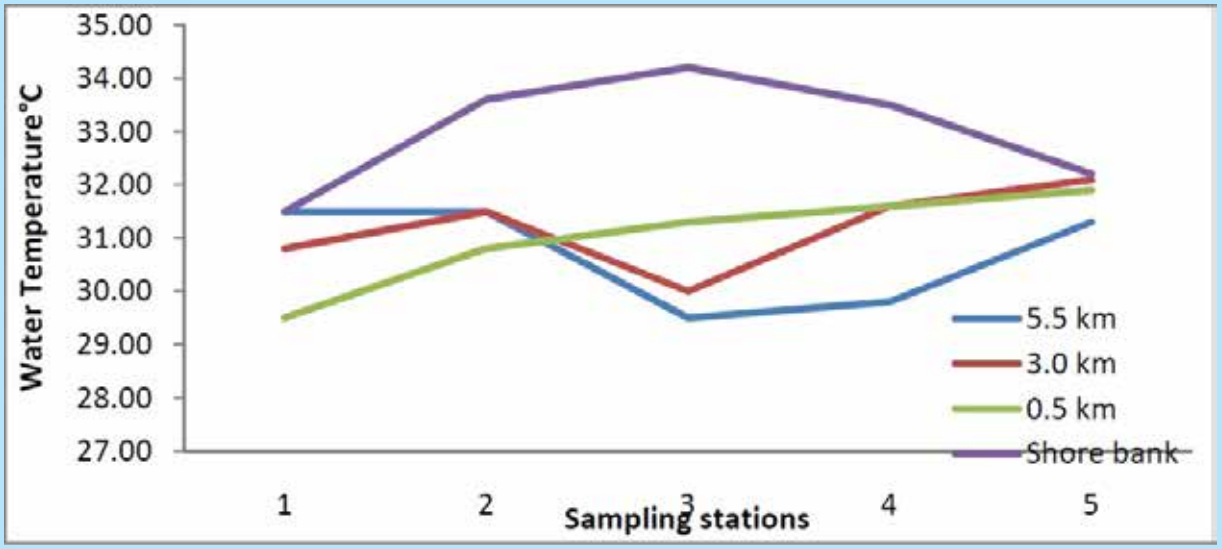
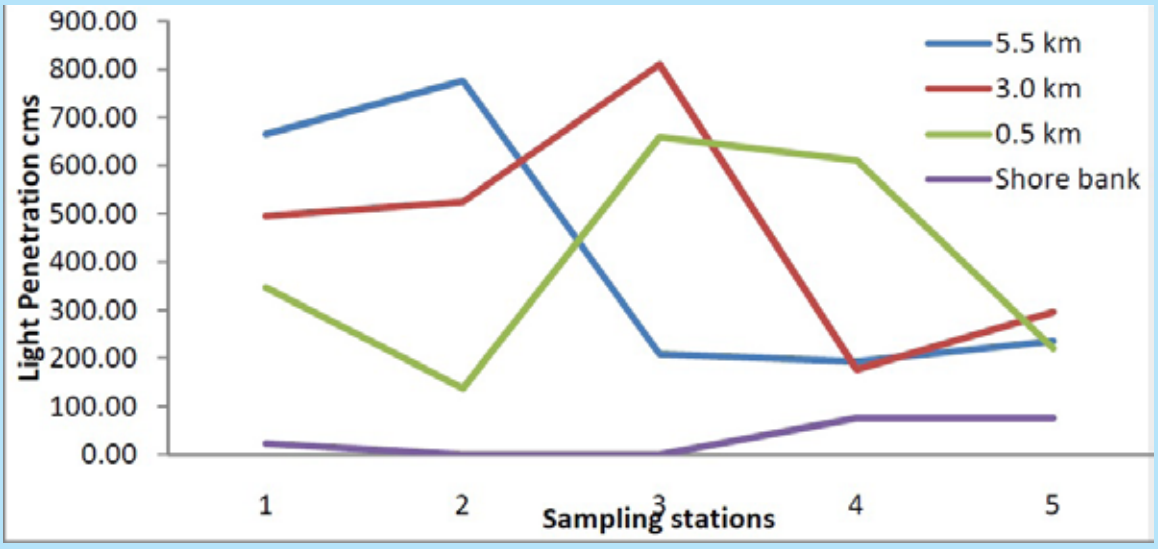


Figure 31
Light Penetration (cm) at Different Sampling Stations along the Transects in Palk Bay

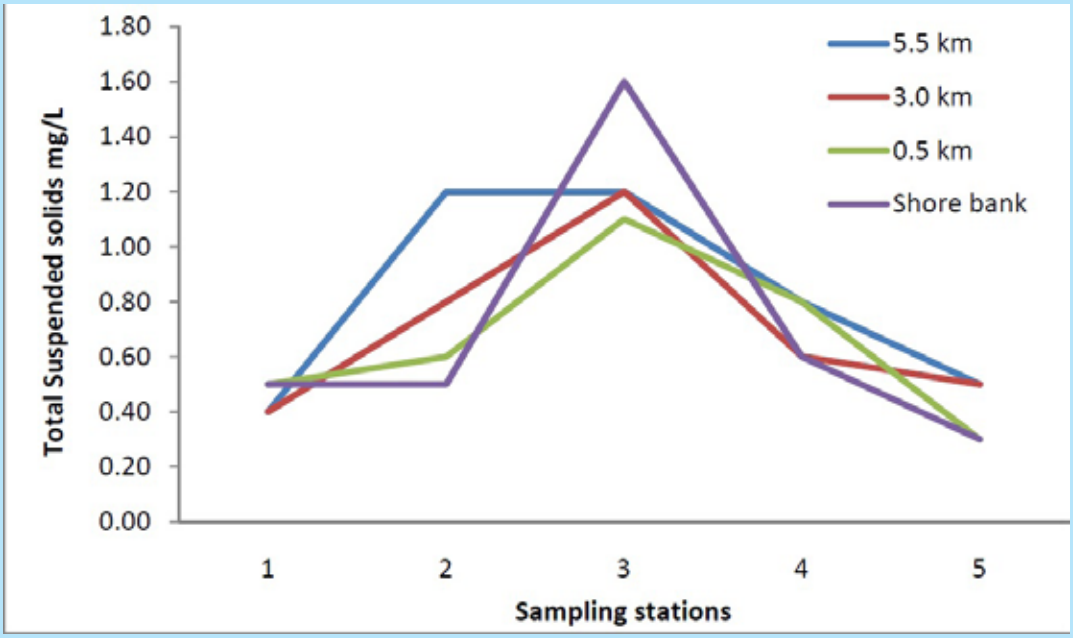


fishing boat traffic. Moreover, the region is subject to substantial influence of the Gulf of Mannar that brings about mixing of the waters from the Palk Bay and Gulf of Mannar along with suspended material. The station 4 also shows a similar situation although the 0.5 km sampling point showed higher light penetration. A comparison between the transects reveals that the 3 km transect as having the highest light penetration followed by the 5.5 km, then 0.5 km and the least light penetration seen at the shore.

Total Suspended Solids (TSP)

Suspended solids in aquatic bodies are in the form of silt and clay particles, suspended debris and phytoplankton and zooplankton. High level of suspended solids thus may be due to highly eutrophic conditions, due to other non-living suspended matter or even with incoming effluents that would react to generate suspended precipitates. In any case, high level of suspended solids obstructs light penetration in water and hence can adversely affect the productivity. In

Figure 32
Total Suspended Solids (mg/L) at Different Sampling Stations along the Transects in Palk Bay



general, high level of suspended solids can be indicating unhealthy polluted state of waters. Nair *et al*., (1987) states that the distribution of suspended solids is a natural tracer that can reveal the concentration and dispersion of a pollutant, and also the impact of the pollutant on the ecosystem.

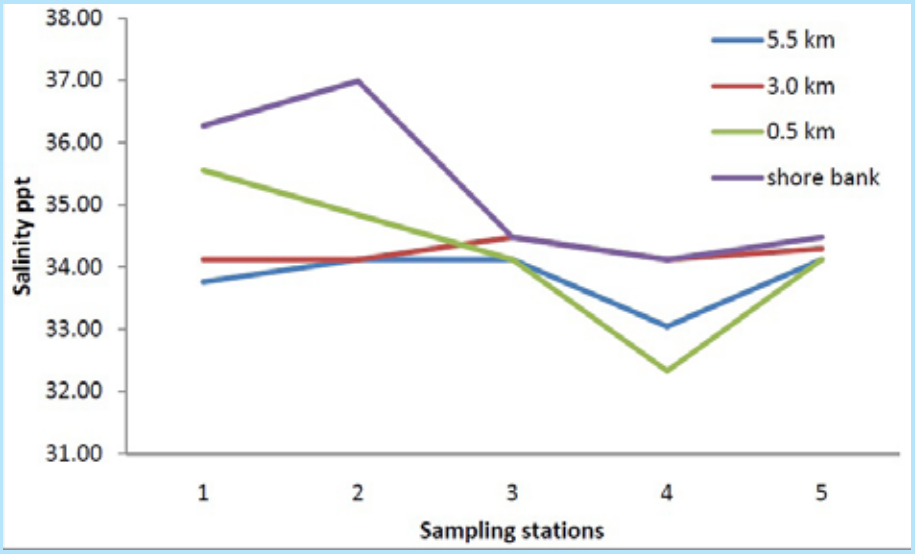
Overall, the total suspended solids (TSP) varied between 0.30 and 1.6 mg/L (average 72 mg/L) in the region during the study. The TSP in Palk Bay were observed to be highest at the sampling station 3 along all transect points, followed by stations 2, 4 and 1; the lowest was recorded at station 5 (Figure 32). On the whole, the 5.5 km transect had the highest total suspended solids, while the lowest was on the 0.5 km transect. The temperature is known to play significant role in the settling of suspended solids (Piper, 1942), provided there is no other overwhelming factor. During our study, we observed the temperature along the 5.5 km transect to be lower than the other transects and could be one of the probable reasons for the higher values. However, other possible more powerful factors in determining the level cannot be ignored.

Salinity

Salinity is an important factor according to Levinton (1982) that causes physiological stress to animals influencing their occurrence and distribution. Salinity has profound effect on biotic and abiotic components as it not only influences organisms but also affects precipitation of suspended solids, adsorption, precipitation and leaching of nutrients and toxic metals.

The salinity recorded at Palk Bay varied marginally between 32.33 and 36.99 ppt (average 34.38 ppt). A comparison between the transects reveals higher salinity near the shore bank that can be attributed to the evapo-transpiration and the higher water temperatures near the shore. The lowest values were recorded along the 5.5 km transect at all the stations (Figure 33). A comparison across the stations revealed the salinity showing narrow variations at station 3 and 5 that could be attributed to the topography of the bay while the wide variations at stations 1 and 2 were due to the prevalent fishing activities and other anthropogenic pressures from the villages in the area.

Figure 33
Salinity (ppt) at Different Sampling Stations along the Transects in Palk Bay



Dissolved Oxygen

Life in water depends on dissolved oxygen (DO) available for all aquatic flora and fauna. The respiratory processes, which release energy by oxidation of food, consume DO whereas photosynthetic processes release oxygen to water. Hence, DO level in water reveals much about the metabolism of water and it is widely used as an index of water quality, primary productivity and pollution. According to Laponite and Clark (1992), low DO is critical in determining quality of waters and their ability to sustain biologically diverse habitats. Metcalf and Eddy (1979) recommend 4 mg/L DO as optimum for estuarine and coastal waters. During our study, we recorded high DO varying between 5.49 mg/L and 11.18 mg/L (Average 6.90 mg/L). The levels were more or less uniform along the three coastal transects while at the one close to the shore, the DO was higher and that can be attributed to the wave action leading to oxygenation of the waters (Figure 34). Among the stations the widest fluctuations were recorded at station 2 could be due to the higher photosynthetic activity by the abundant seagrass occurring in the waters along the transect.

Phosphate - Phosphorus

In aquatic ecosystems, phosphorus occurs as dissolved inorganic phosphorus, dissolved organic phosphorus and particulate phosphorus. The dissolved inorganic phosphorus is utilized by the primary producers and converted to dissolved and particulate phosphorus (Lemasson and Pages, 1981). According to Fisher *et al*., (1988), phosphorus is added to the aquatic bodies due to industrialization, urbanization and use of fertilizers washed down with runoff water getting into aquatic ecosystems. Being an important nutrient element, the study of phosphorus helps in determining the state of primary production in aquatic ecosystems (Ketchum, 1967).

During our study, we recorded PO_4-P varying from 0.5 mg/L to 1.64 mg/L (Average 1.04 mg/L). The lowest value was at station 3 and the highest at station 1 (Figure 35). These high phosphorous can be attributed to the anthropogenic activities like the agriculture and aquaculture activities. The PO_4-P limit for unpolluted waters is 0.09 mg/L according to Yentsch and Ryther (1957); however, at Palk Bay the lowest value was much higher than the stipulated value. This indicated to the external source of phosphorus.

Nitrate Nitrogen

Like phosphorous, nitrogen significantly affects phytoplankton growth in natural waters. Shortage of nitrogen can stop phytoplankton

Figure 34
Dissolved Oxygen (mg/L) at Different Sampling Stations along the Transects in Palk Bay

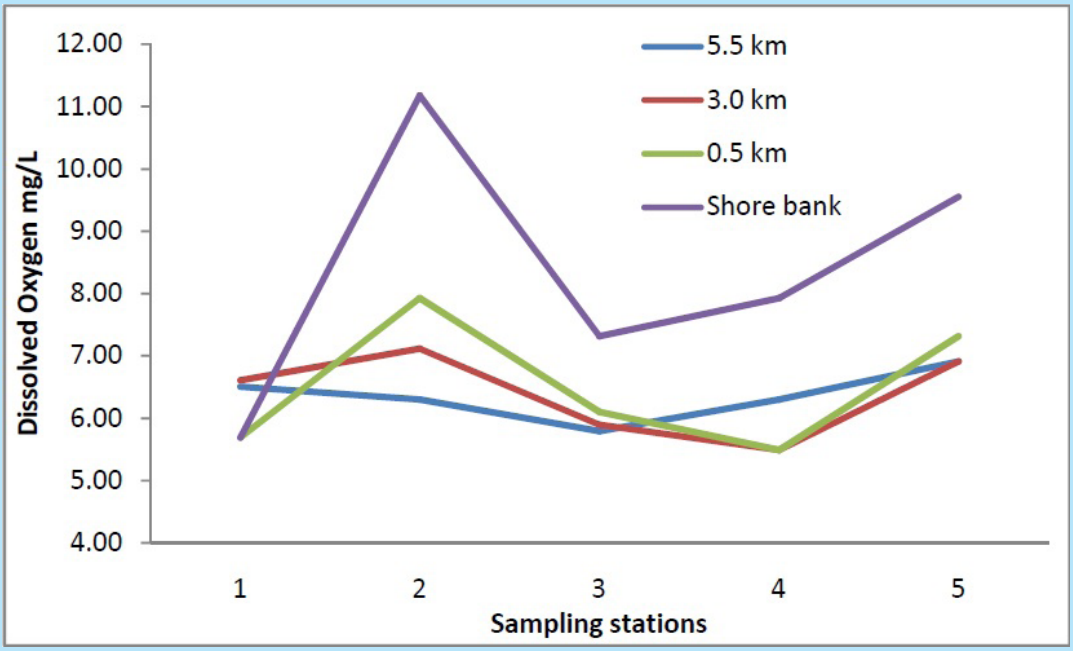
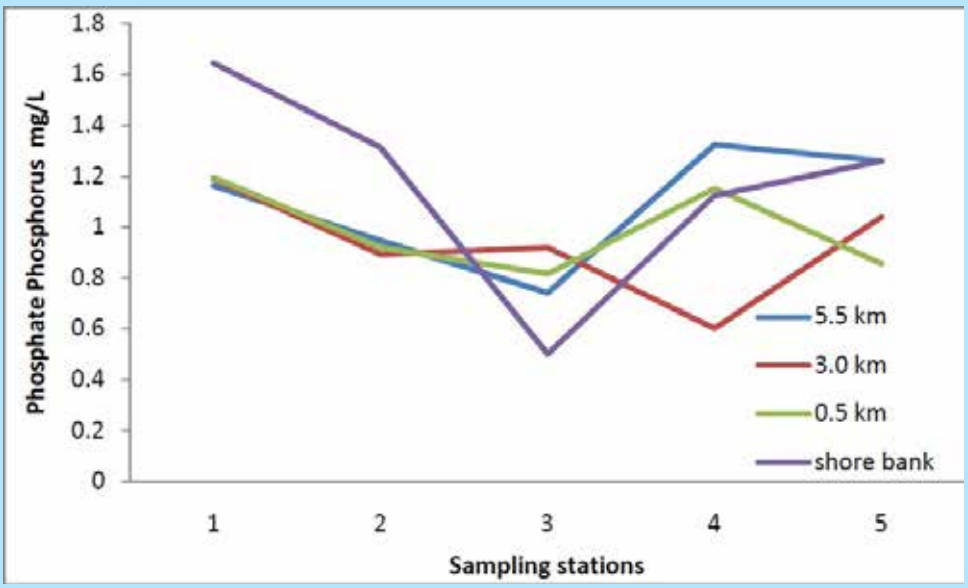


Figure 35
Phosphate Phosphorus (mg/L) at Different Sampling Stations along the Transects in Palk Bay



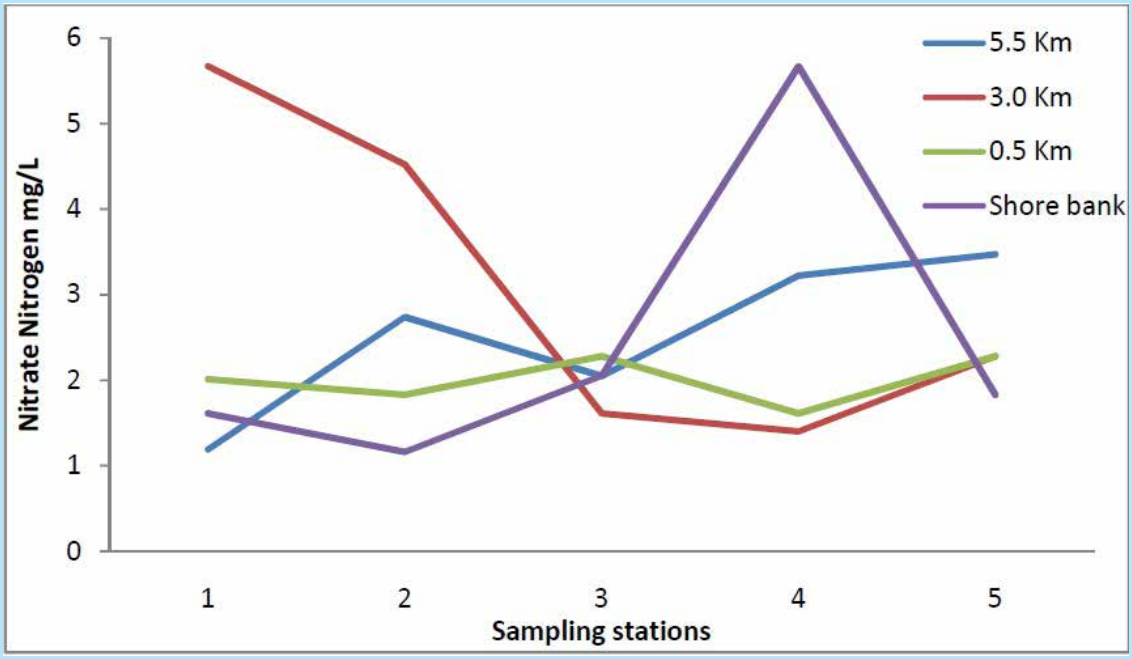
growth (Strickland, 1965), while high amounts of nitrogen can cause serious disturbances such as eutrophication, changed phytoplankton structure and release of nitrous oxide (Jickells, 1998).

During the present study, the Nitrate Nitrogen varied between 1.16 and 5.67 mg/L (Average 2.52 mg/L). Except for the station 3 the values showed fluctuations among the transects at all the sampling stations (Figure 36). The nitrogen showed an inverse relation with the DO indicating biological utilization of NO_3-N for phytoplankton growth (Upadhyay 1988).

N: P Ratio

N:P ratio is an important measure, for an ecosystem. Harvey (1926) noted the growth of phytoplankton because of concurrent depletion

Figure 36
Nitrate Nitrogen (mg/L) at Different Sampling Stations along the Transects in Palk Bay



of nitrogen and phosphorus, which according to Redfield *et al*.(1963) are available in ocean waters in very nearly the proportion required by phytoplankton. This proportion (N: P = 16:1) is known as the Redfield ratio. N:P between 8 and 30 indicates that both N and P limit phytoplankton growth, N limits phytoplankton production in the medium when the ratio is less than 8, while P is the limiting nutrient when the ratio is over 30 (Minghui *et al*., 1990).

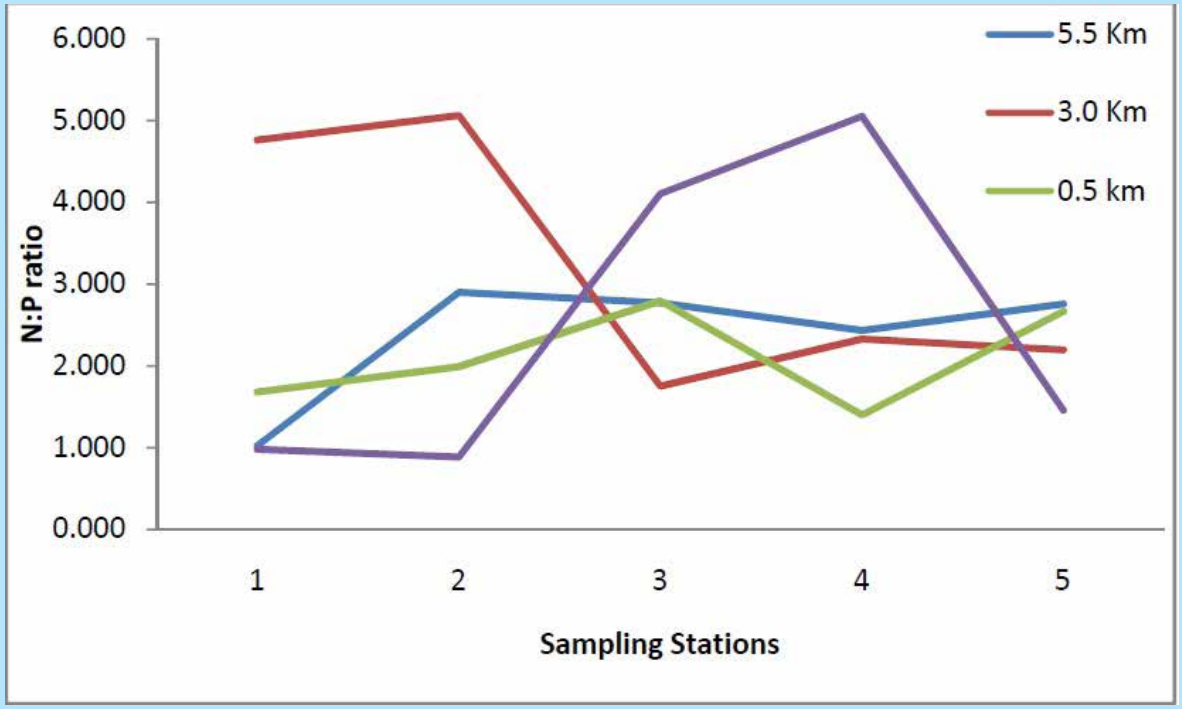
During the present study, we recorded ratios between 0.883 and 5.062 (average 2.548) indicating that nitrogen is the major nutrient that is controlling phytoplankton production in the Palk Bay. A comparison across the stations shows wide variations along all the transects, except at station 5 where the margin is narrow (Figure 37). Further, it is also observed that at stations 1 and 2 phosphorus has a major role compared to other stations along the 3.0 km transect line. Moreover, this can be attributed to quick utilization of nitrogen that corresponds with the abundance of aquatic flora and fauna. Similarly, at stations 3 and 4 along the transect close to the shore indicates a higher influence of phosphorus obtained from abiogenic origins as compared to nitrogen. In general, all the ratios seen are within the pollution limits.

Oil and Grease

Oil and Grease enter aquatic ecosystems through industrial effluents and through accidental leakage from tankers carrying petroleum products. It can also enter through use in transport systems. Oil and grease are insoluble in water and lighter than water, and hence floats on water forming a film on the surface. The layer of oil and grease can prove detrimental to aquatic flora and fauna as it hinders the natural processes and creates pollution. Many species from microbes, to birds to marine mammals gets seriously affected with oil and grease pollution in water.

During the present study , oil and gas in water were recorded from all the stations (Figure 38) in substantial quantities ranging between 30 mg/L and 710 mg/L (average 111.50 mg/L). The high values were obtained at stations where the boating activities were high. This may be due to oil spills or due to water oozed near engine from the anchored boats.

Figure 37
N:p Ratio at Different Sampling Stations Along the Transects in Palk Bay



Chlorophyll Pigments

Aquatic plants use chlorophyll in photosynthesis to convert inorganic material into organic compounds to store energy for growth and reproduction. Oceanic productivity mostly refers to the production of organic matter from the inorganic matter by "phytoplankton", most of which are single-celled. The presence of chlorophyll pigments is of paramount importance in the ecology of any aquatic biotope. In biological oceanography, chemical indicators like chlorophyll a or other pigments are used to describe the phytoplankton population density and growth rates are consequently expressed as the rate of change of these indicators.

Chlorophyll-a

The pigment Chlorophyll-a (Chl-a) found in phytoplankton is known to produce systematic variations in the colour of the ocean and is responsible for the primary production of the marine ecosystem and fishery productivity (Yapa, 2000). Chl-a is the main photosynthetic pigment and an indicator reflecting the amount of phytoplankton biomass. It is an important parameter for assessing the primary productivity of the sea, and carbon storage in the sea the biogeochemical cycles. It is also an important indicator to locate potential fishing grounds in any marine ecosystem.

During our study, we recorded high Chl-a values (Figure 39) varying from 0.36 to 13.34 mg/m^3 (Average 5.29 mg/m^3). Similar values were also reported throughout the year by Yapa (2000) during their earlier studies on Palk bay. The chlorophyll a values conformed with the N: P ratio and showed positive correlation with nitrates and phosphates along all the transects indicating the productivity of phytoplankton.

Sediment Quality in the Palk Bay

In aquatic ecosystems, sediments act as reservoirs of nutrients in water. They function as both sink as well as source, depending on the situation; they replenish nutrients in times of need and also remove them from water facilitating the biological cycle in the system.

Figure 38
Oil and Grease (mg/L) at Different Sampling Stations along the Transects in Palk Bay

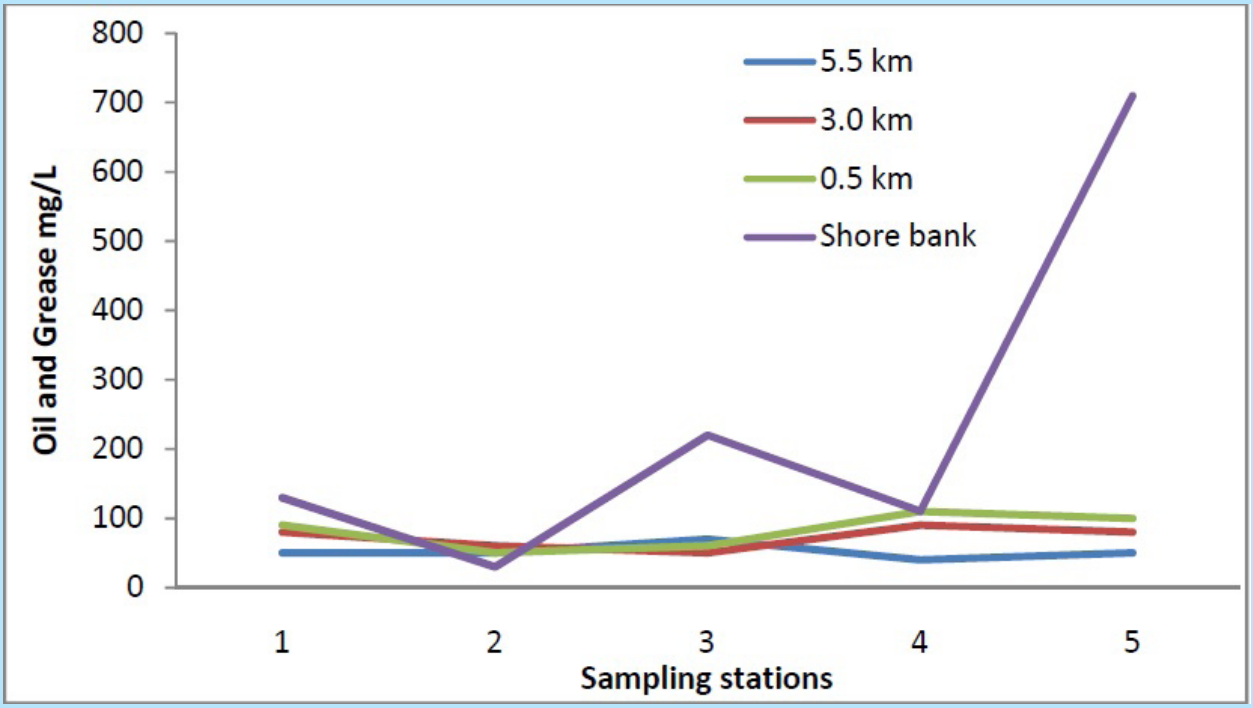
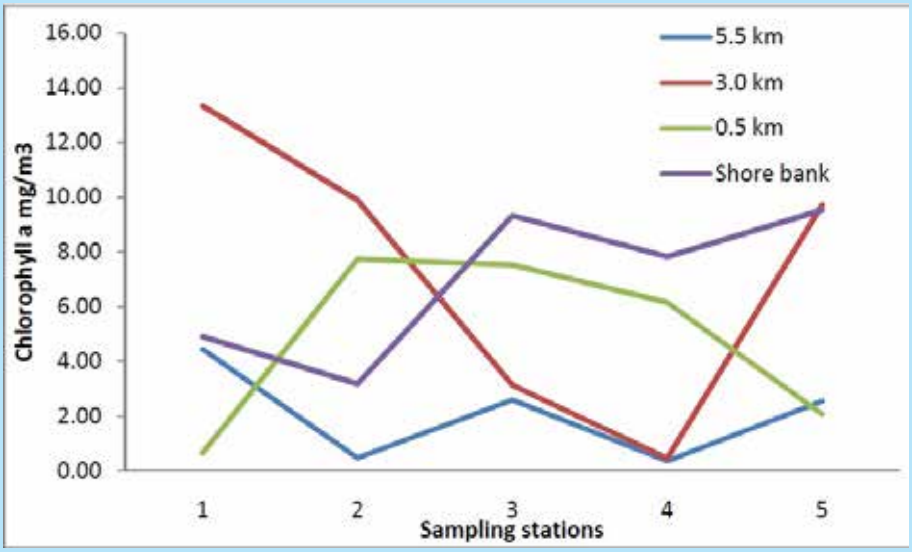
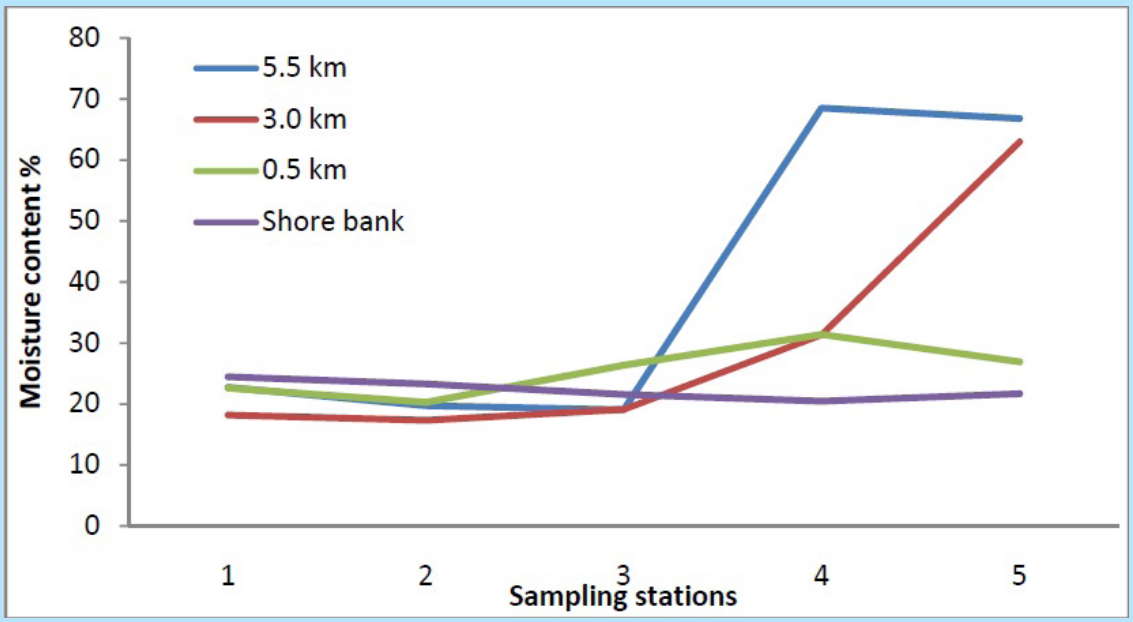


Figure 39
Chlorophyll-a (mg/m³) at Different Sampling Stations along the Transects in Palk Bay



The sediments play an important role in immobilization of pollutants through adsorption on to their ion exchange sites, binding to organic matter, incorporation into lattice structures and precipitation into insoluble compounds (Dunbabin and Bowmer, 1992). They also at times play a mobilization role depending on the local micro-level chemistry. According to De Bustamante (1990), all these processes are affected by the biological, chemical and physical properties of soil such as soil texture and nutrient levels. Hence, sediment studies are important in assessment of environmental pollution.

Figure 40
Water Content (%) at Different Sampling Stations along the Transects in Palk Bay



Soil / Sediment Water Content

In soil / bottom sediment / substrate, the presence of clay is known to increase the water holding capacity, whereas sandy substrates hold less moisture. Features such as presence of high organic content also influence the soil water content. According to Robinson (1936), clay fraction is of colloidal character having high holding capacity for water and organic carbon. The moisture content also depends on the pore space. The presence of organic matter reduces the compactness of the soil and increases the porosity.

During our study, we recorded water content (Figure 40) varying between 17.37 % and 68.52% (average 29.26 %) for the study area. The water holding capacity was low at stations 1 to 3 while at stations 4 and 5 it was higher moisture content along the 5.5 km and the 3.0 km transects due to the higher content of clay and organic matter.

Sediment Texture

Sediment grain size or texture decides the nature of the substratum, which has the greatest influence on the distribution and abundance of benthic population (Sanders, 1958). The clay and silt substratum can hold more water and organic matter as opposed to sandy soil. Hopkinson *et al* (1999) reported that in aquatic systems sediments play important role in degrading organic matter and in nutrient recycling. In the Palk Bay, the sediment texture is mainly sandy (Figure 41).

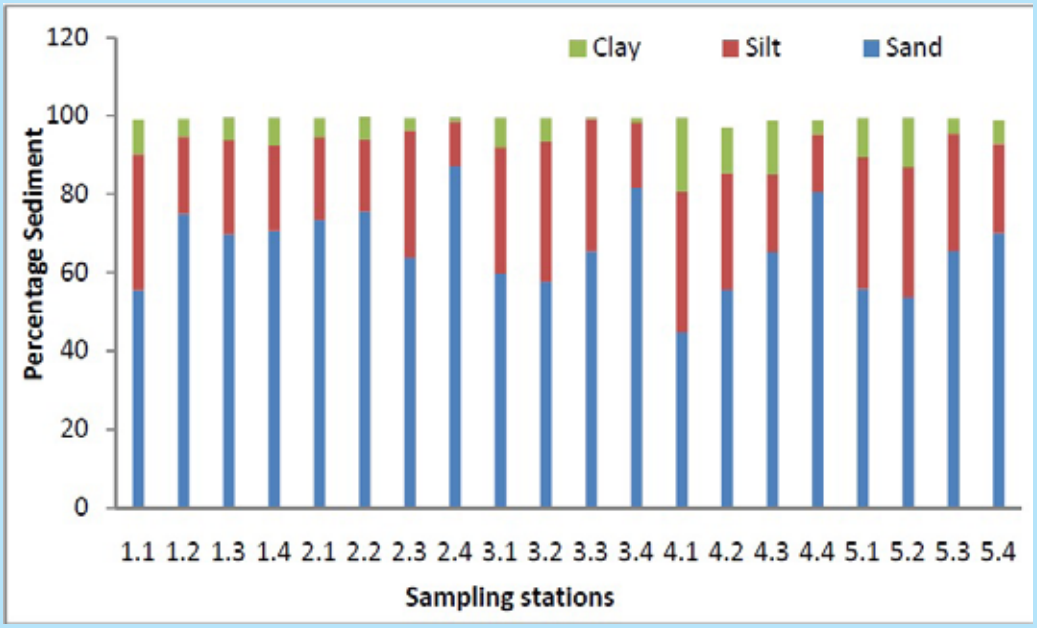
Sand

The substratum in the Palk Bay was mostly sandy and the percentage of sand varied between 44.80% and 87.20 % (Average 66.34 %). A comparison across transects shows the one close to the shore having higher proportions of sand as opposed to the 5.5 km transect at all the sampling stations (Figure 42). Although the substratum is sandy overall, the proportion of sand shows a decreasing trend from station 1 to 5.

Silt

The silt comprises of the finer grains that vary between 62 um to 250 um in size. Silt component varied between 11.30 % and 35.80 % (average 26.08 %) in the Palk Bay samples. Higher proportion of silt was seen along the 5.5

Figure 41
Sediment Texture (Clay, Silt and Sand in %) at Different Sampling Stations along the Transects in Palk Bay



km transect followed by the 3 km transect (Figure 43). The transect close to the shore had the lowest silt component.

Clay

Clay is finer than silt and hence when suspended in water it takes longer time to settle. High amounts of clay in the sediment makes the substratum harder, and is suitable for egg laying by animals such as prawns and fishes, whereas high silt level makes the substratum soft, loose and sinking, and the eggs or attached organisms can die due to siltation. Hence, clay is considered better compared to silt for organisms.

During the present study, the clay component varied (Figure 44) between 0.50% and 18.90% (Average 6.82 %). The clay component was higher at stations 4 and 5 and the 5.5 km transect showed the maximum percentage of clay.

Organic Carbon and Organic Matter

Organic carbon in the sediment is directly related to organic matter and acts as food source for detritus feeding organisms and microbes. Therefore, it indicates the nutritional status of the sediment or soil. However, very high level of organic carbon / matter can also be an indicator of organic pollution from sewage. Organic carbon in sediments can be from plant and animal matter brought in through land runoff and deposition from overlying waters (Sankaranarayanan and Punampunnayil, 1979). Ergin (1993) attributed organic matter in the marine environment to be a function of the rate of primary productivity, water depth, DO content in water column, sedimentation rate, biological activity and sediment stability.

In the present study, we recorded organic carbon levels varying (Figure 45) between 1.37% and 8.11% (Average 3.46%). The organic carbon is seen increasing from station 1 to 5. The variations were higher v at station 4 and 5 and that can be attributed to several factors including the abiogenic inputs of nutrients and organic matter. As expected the same trend was seen in the case of organic matter (Figure 46).

Water and Soil Quality in the Mangroves

In addition to the studies on seawater and soil at offshore and near-shore locations, we also analysed water and soil collected from five parallel mangrove locations. The water depth at each of the locations was less than 0.5m. The results of

Figure 42
Sand (%) at the Different Sampling Stations along the Transects in Palk Bay

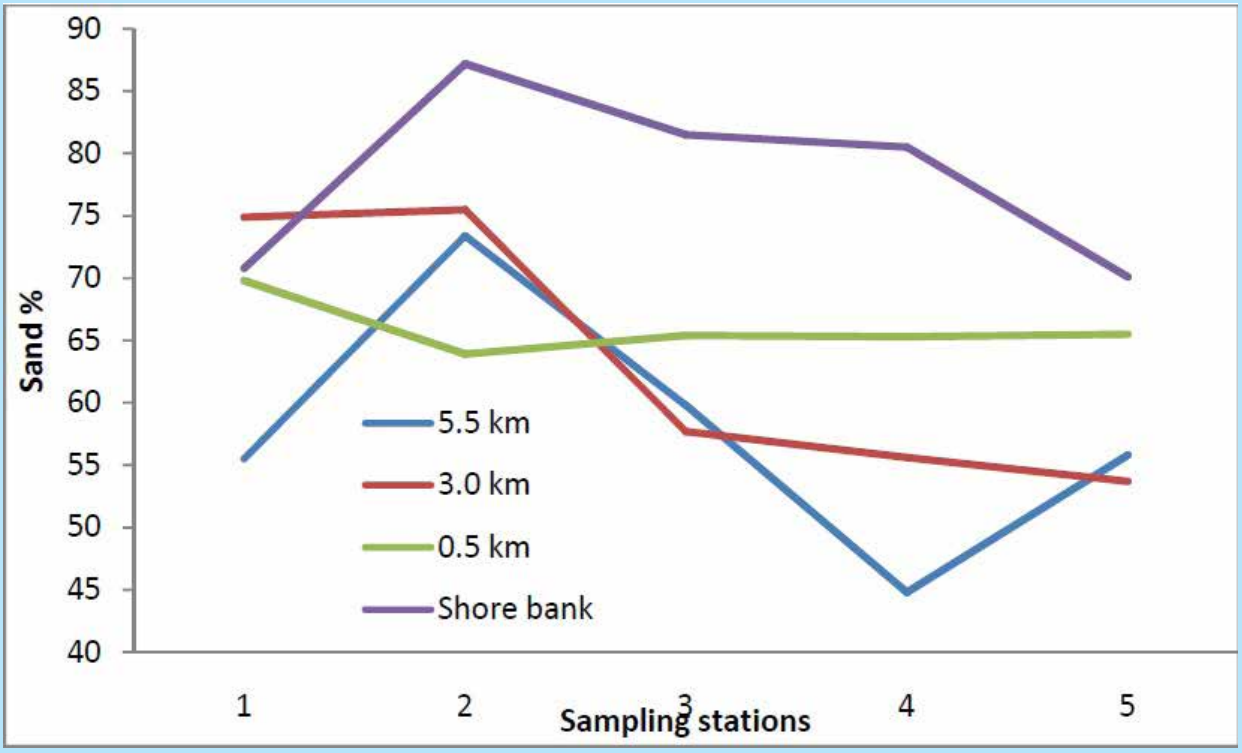


Figure 43
Silt (%) at the Different Sampling Stations along the Transects in Palk Bay

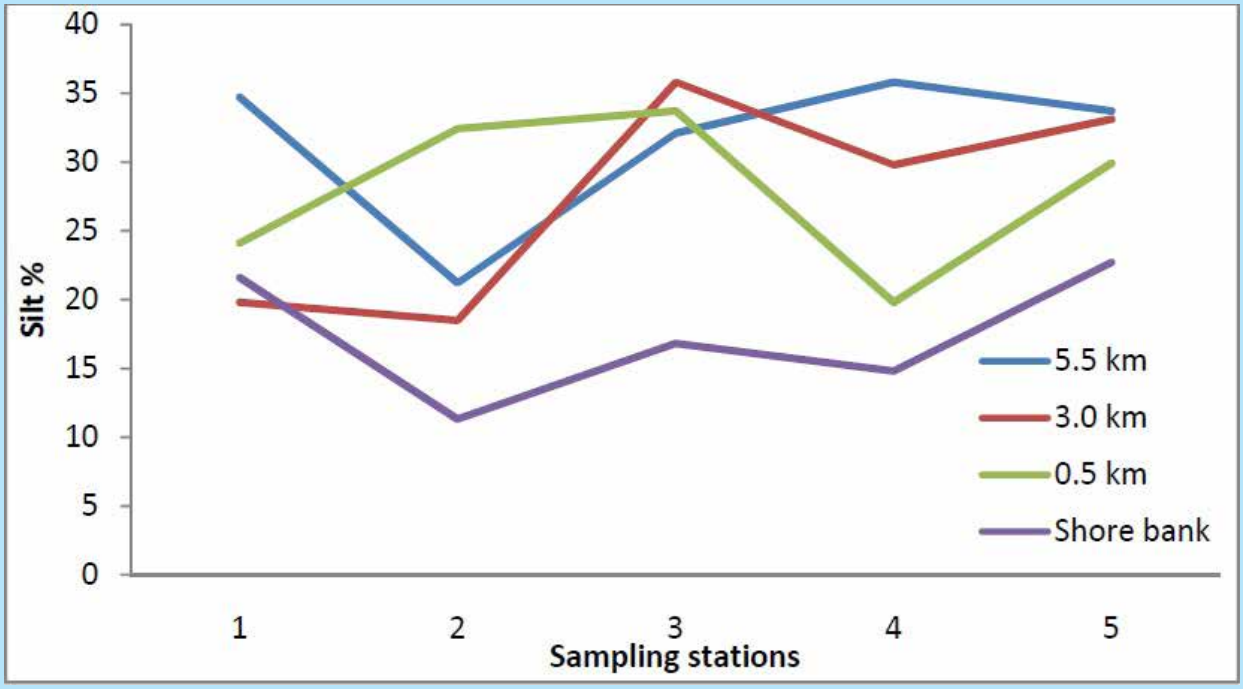


Figure 44
Clay (%) at the Different Sampling Stations along the Transects in Palk Bay

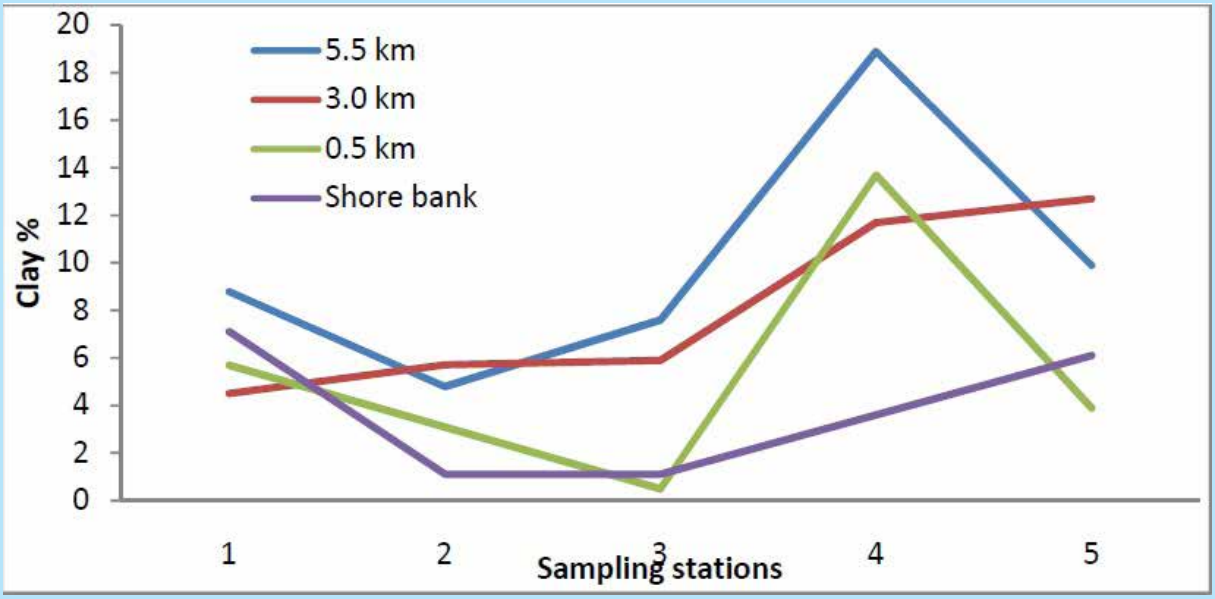


Figure 45
Organic Carbon (%) at the Different Sampling Stations along the Transects in Palk Bay

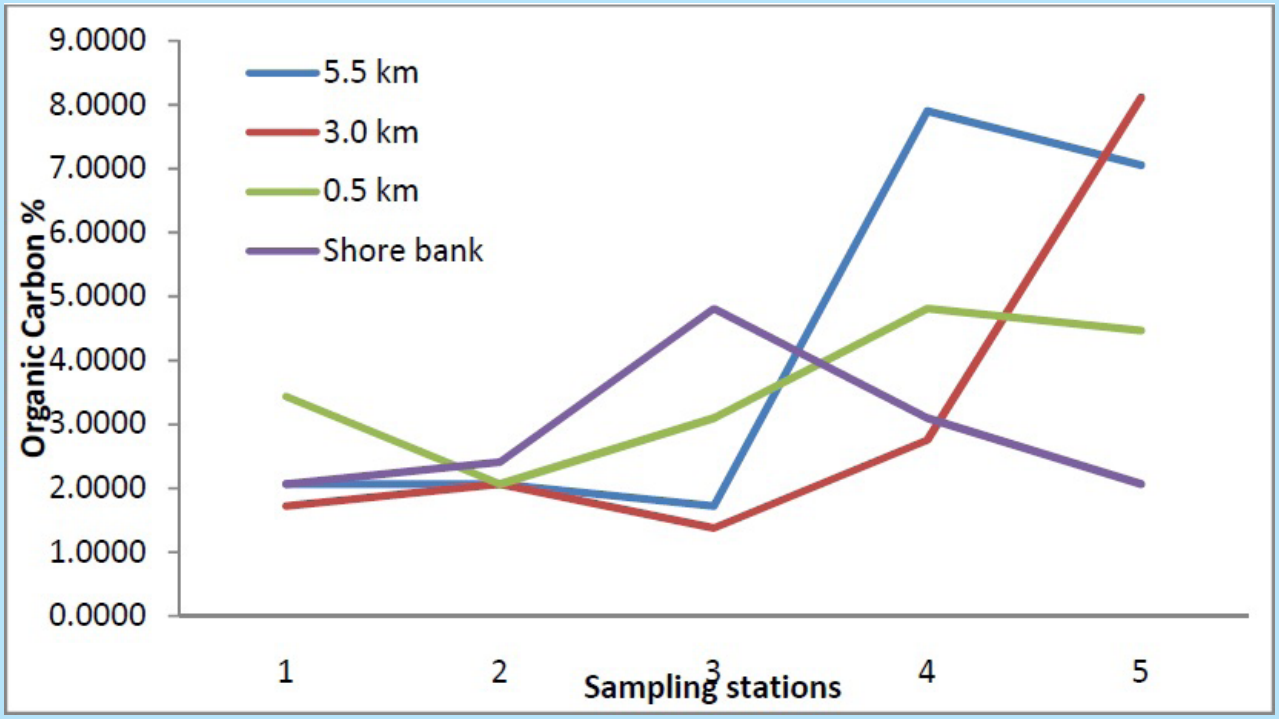
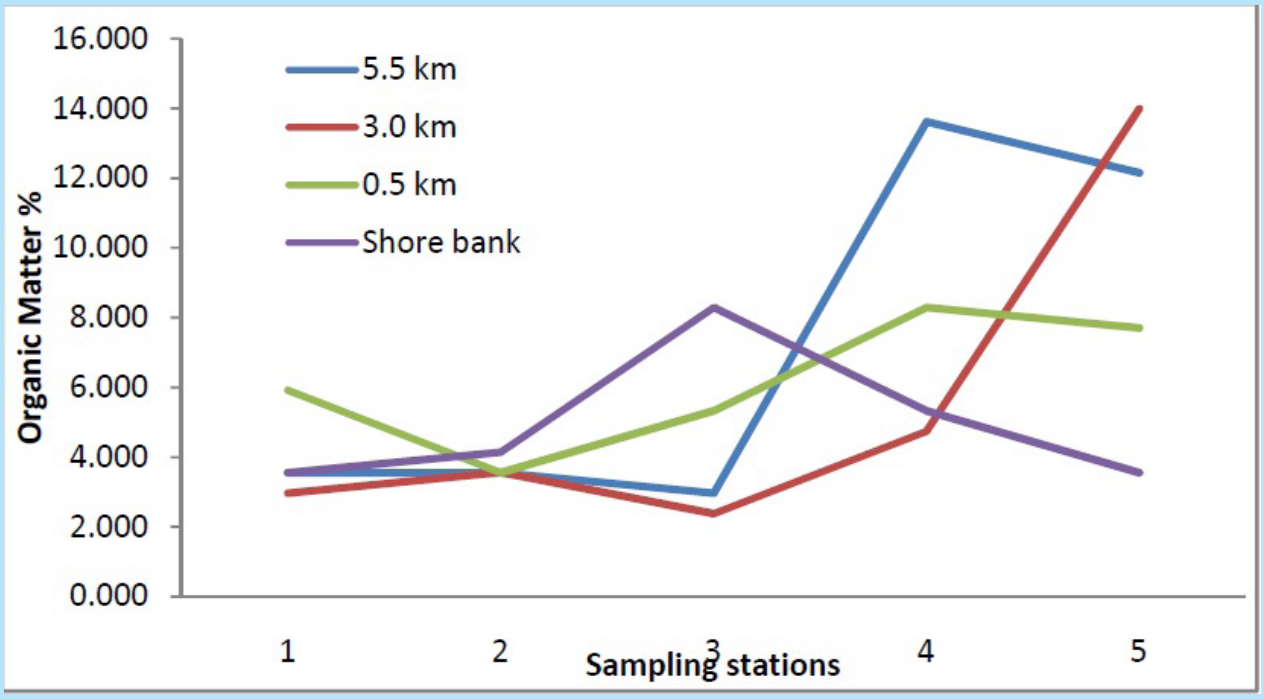


Figure 46
Organic Matter (%) at the Different Sampling Stations along the Transects in Palk Bay

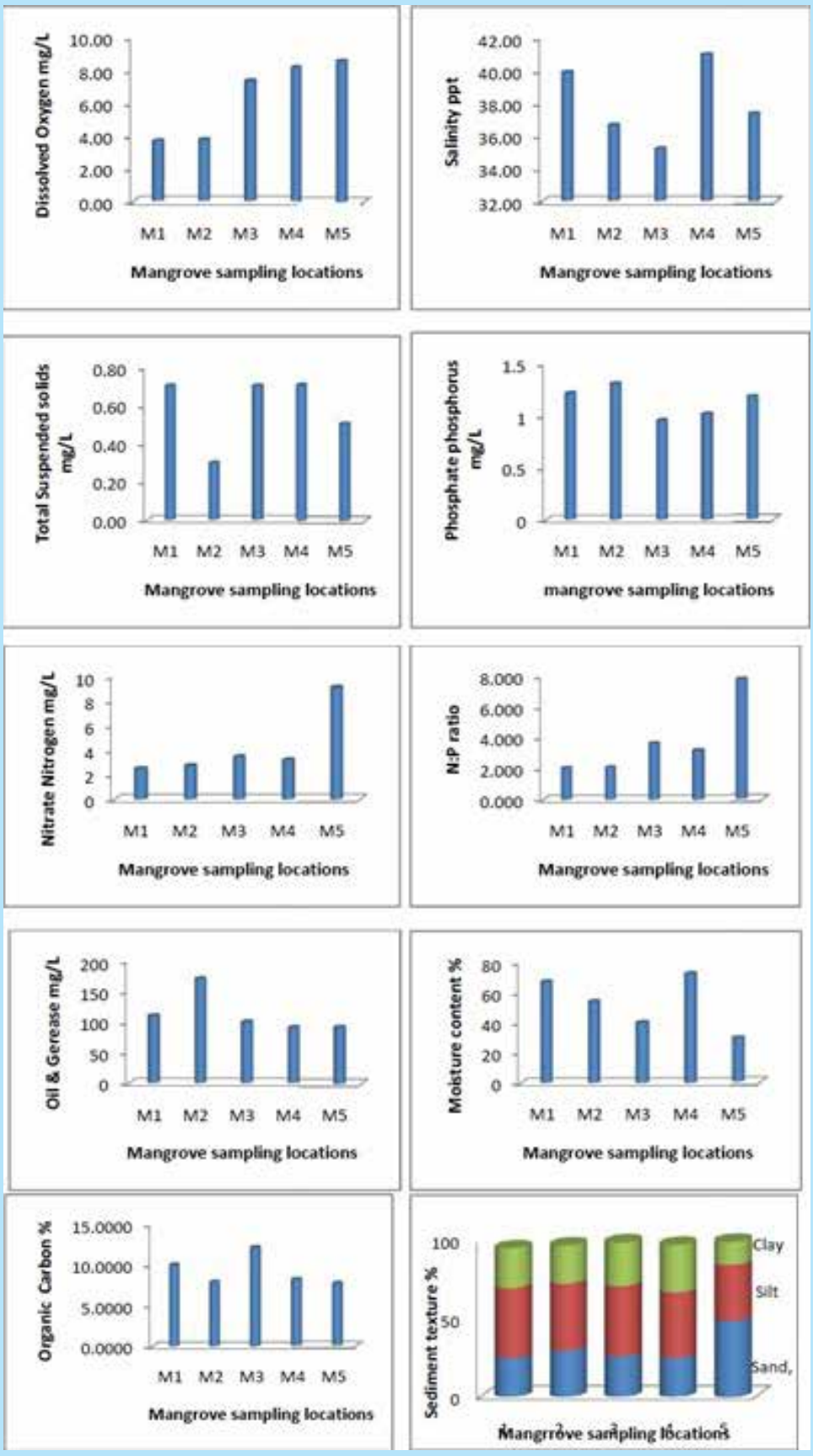


the water and soil analyses are as below (Figure 47).

The Total Suspended Solids (TSP) in the water in the mangroves varied from 0.30 to 0.70 mg/L. Seawater incursion and debris surrounding the mangrove swamps influenced the water quality. The salinity within the mangrove swamps was higher than the offshore locations and that ranged from 35.20 to 40.94 ppt. It is characteristic of mangrove ecosystems where it is known to have slightly higher salinity due to higher evapo-transpiration and limited inflows. The DO within the mangroves was lower than the offshore waters; it varied between 3.66 and 8.54 mg/L. The DO showed an increasing trend from the Stations 1 to 5. Among the nutrients, the PO_4-P values varied from 0.947 to 1.304 mg/L, the variations mainly governed by anthropogenic influences; stations 1, 2 and 4, were fairly closer to human habitations. The overall nitrate values ranged from 2.5 to 9.14 mg/L and increased from station 1 to 5. N:P ratio showed a similar trend with the values ranging from 2.064 to 7.759 mg/L; the ratio was highest at station 5 where there was dominance of phosphorus in productivity. The chlorophyll-a values ranged from 2.53 to 25.72 mg/m^3 and it corroborated with the nutrient values and the utilization of nutrients by planktons. The Oil and grease in mangroves is mainly due to the influx from the shore waters and it is seen to form layer over the mangroves within the concentration varied from 90 to 170 mg/L.

The mangrove sediment is mostly silty-clay rather than the sandy substratum from the offshore regions. The sand content varies from 24.9 to 47.8%, silt ranges from 35.8 to 44.8 % while clay comprises of 14.6 to 30.2%. The water content follows the sediment texture and varies between 29.29 to 72.2%. The high water content is due to the larger clay component in the sediment as well as the presence of organic matter. The organic carbon is found to be high in the mangroves and follows a similar pattern as that of organic carbon from the offshore areas. The organic carbon recorded in the mangroves ranged from 7.56 to 12.02 % and was mostly governed by the rich mangrove litter fall that enriched the soil nutrition.

Figure 47
Water Quality Parameters in the Mangroves in Palk Bay



Chapter 4

Fishers' Perception on Ecological Habitats of the Palk Bay

We interviewed in total 101 fishers. Then their responses were analyzed by grouping them into those from the north and the south of the study area based on the locality of the respondents' village and on the ecological habitat availability. The northern part is dominated by mangroves and seagrass whereas the southern part is dominated by corals and seagrass. In total 32 villages were surveyed, of which 20 villages were from the southern part and 12 villages are from the northern part (Figure 48). The details of the respondent are given below (Table 9).

During the survey, we could interact predominantly with male members except for five females (one from North and four from South) who obliged to our request. Most of the respondents (53%) were between 45 and 65 years of age. The average fishing experience of the respondents was 25 years with a higher average among the northern fishers (average 28.7 years) while for southern fishers the average was 21.7 years. Education does not seem to be a priority for the fishers as 53% respondents did not have primary education. The proportion of uneducated fishers is higher in the southern part than in the northern part. Fishing being the primary occupation, the income of the respondents varied between INR 2500 to 10,000 per month. The fishers existing below the stipulated poverty line (INR 35 per day income, categorized in less than INR 2500. income per month) is prevalent in the north compared to the south. The major fish caught and sold is given in (Figure 49, Table 10, 11 and 12).

Fishing is undertaken using appropriate craft and gear. The most commonly used by the respondents were the 9 HP fibre boats (59) followed by row or sail boats (23), while only a very small proportion of the fishers had boats of 90 HP capacity, i.e. trawler boats (10), and 20 HP capacity boats (3). Most of the respondents (67) owned a boat, 5 respondents had 2 boats and 3 respondents had 3 or 4 boats. Of the respondents, 21 were employed by other fishers.

Group fishing or community fishing comprising of 3-4 people in each fishing visit was the most preferred fishing practice as informed by

Table 9
General Characteristics of the Respondents to the Survey

Particulars	North	South
Gender (%)		
Male	46.53	48.51
Female	0.99	3.96
Age in years (%)		
<20	0.00	1.98
20-45	19.80	19.80
46-65	26.73	25.74
>65	2.97	2.97
Education (%)		
Fifth grade and below	12.87	17.82
Tenth grade and below	5.94	4.95
Twelve grade and below	2.97	2.97
Graduation and below	1.98	0.99
None	9.90	12.87
Not questioned	13.86	12.87
Not responded	0	0
Income (INR) per month (%)		
<2500	2.97	12.87
<5000	11.88	10.89
<10,000	7.92	7.92
<20,000	0.99	3.96
>20,000	0.00	0.00
Not questioned	21.78	7.92
Not responded	1.98	8.91
Fishing Method (%)		
Motorized bottom trawling	8.91	4.95
Gill net	33.66	29.70
Hook	5.94	2.97
Row/wind boat trawling	12.87	4.95
On foot trawling	4.95	10.89
Time spent at sea per fishing visit (hours)		
05 to 12	31.68	34.65
12 to 24	7.92	4.95
12 to 48	4.95	4.95
Not questioned	0	0
Not responded	2.97	8.91
Fishing experience (years)		
Mean	21.70	28.70
Range	04 - 57	0-70
Income from fishing		
Primary	44.55	45.54
Secondary	0.00	2.97
Not questioned	0	0
Not responded	2.97	3.96

Figure 48
Fishing Villages in the Study Area Visited for Interviews to Elicit Peoples' Perception

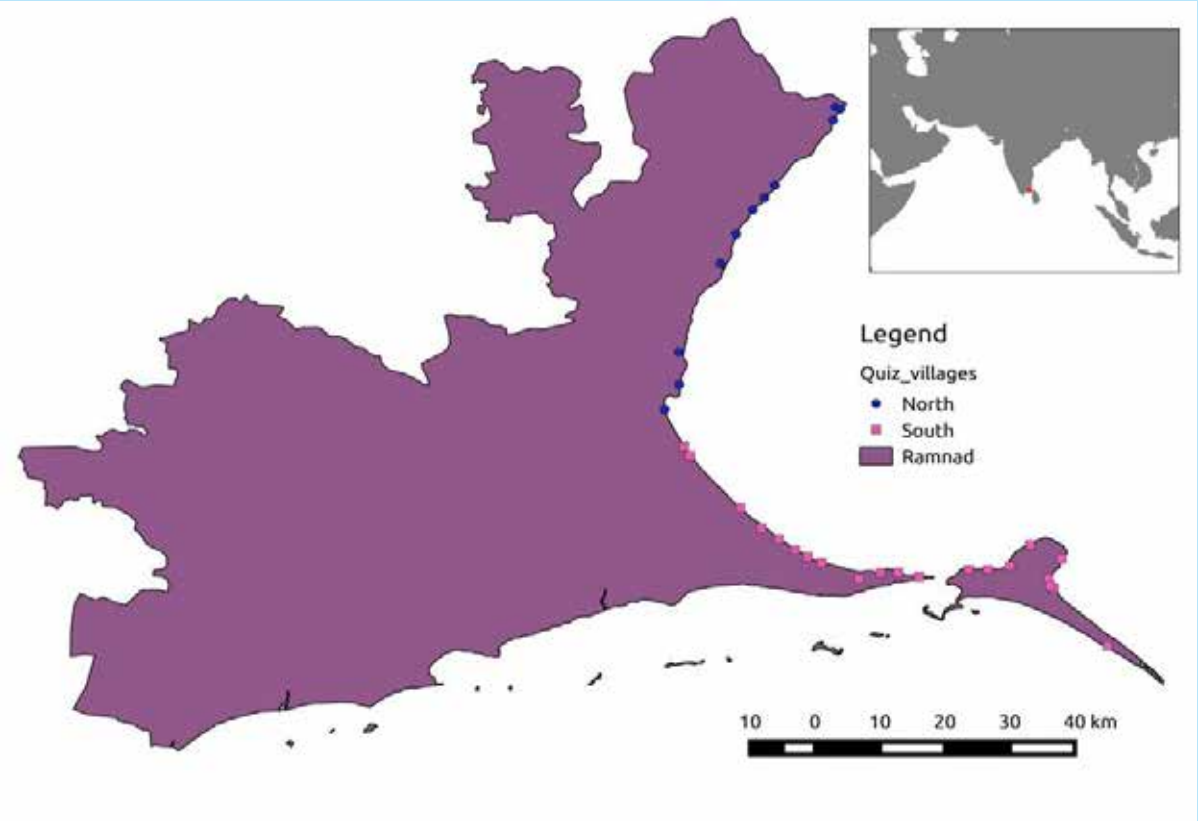


Figure 49
Common Fishes in the Market

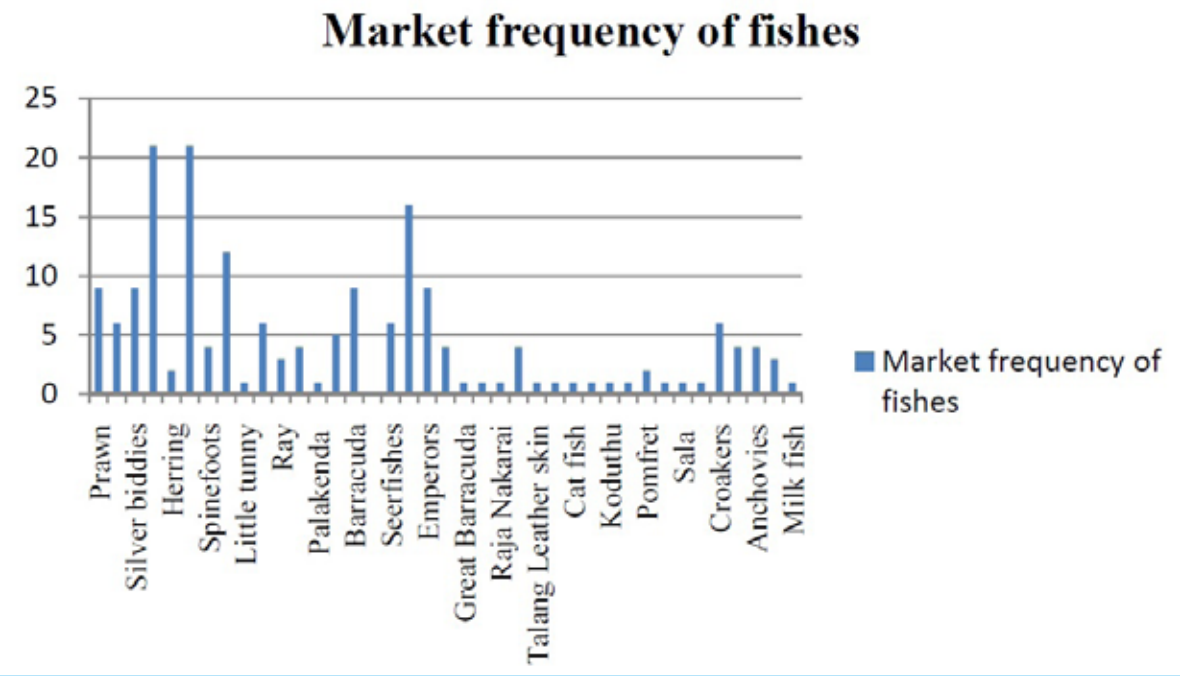


Table 10
Commercially Important Crustaceans Caught in Palk bay

Local Name	Common Name	Scientific Name
Singi (2)	Pointed spiny lobster	*Panulirus versicolor*
Vellara (8)	Indian White prawn	*Fenneropenaeus indicus*
Poochieral (1)	Prawn	*Metapenaeus monoceros*
Pasieral (4)	Green tiger prawn	*Penaeus semisulcatus*
Kan Nandu (7)	Spotted crab	*Portunus sanguinolentus*
Kazhi nandu (5)	Green mud crab	*Scylla serrata*
Para/Olakkal Nandu (12)	Reticulate crab	*Portunus pelagicus*
Siluvai Nandu (3)	Cross crab	*Charybdis cruciata*

Results of perception surveys. The numbers in parenthesis indicate number of respondents

Table 11
Commercially Important Cephalopods Caught by Fishers in Palk bay

Local Name	Common Name	Scientific Name
Olaikanava (4)	Siboga squid	*Doryteuthis sibogae*
Oosikanava (14)	Indian squid	*Loligo duvaucel*
Ottukanava (23)	Needle cuttlefish	*Sepia aculeate*
Palk Bay squid (4)	Palk Bay squid	*Sepioteuthis lessoniana*
Peikanava (5)	Spineless cuttle-fish	*Sepiella inermis*

Results of perception surveys. The numbers in parenthesis indicate number of respondents

Table 12
Commercially Important Fishes Caught by Fishers in Palk Bay

Local Name	Common Name	Scientific Name
Vezha (19)	Saw fish	*Pristis spp.*
Thirukkai (4)	Rays	
Colour (5)	Five spot herring	*Hilsa keele*
Venkannai (4)	Indian pellona	*Pellona ditchela*
Thondan (1)	Rainbow sardine	*Dussumieria acuta*
Pei chalai (8)	Indian oil sardine	*Sardinella albella*
Vazhai (10)	Wolf herring	*Chirocentrus spp.*
Palmeen (1)	Milk fish	*Chanos chanos*
Anjalai (1)	leopard Moray	*Gymnothorax undulates*
Valaya mural (1)	Square tailed alligator gar	*Strongylura leiura*

38 individuals. The next prevalent practice is individual fishing (15) and then fishing in a pair (15). The fishers during the year mostly caught finfish followed by crabs, squids and prawns (Table 10 to 16). The respondents rarely travel a distance beyond 12 km from the coast and most of them restrict themselves to a 2-5 km distance from the shore for fishing. They usually spend around 5 to 12 hours during a fishing bout. The fishing was mostly based on past and traditional experience, while a few fishers have started to depend on the community messages for wind

Table 12 (*Cntd...*)
Commercially Important Fishes Caught by Fishers in Palk Bay

Local Name	Common Name	Scientific Name
Selva mural (4)	Full/Half beaks	
Mural (12)	Full/Half beaks	
Kozhya mural (1)	Fork tail alligator gar	*Strongylura crocodiles*
Ooli (1)	Barracuda	*Sphyraena spp.*
Soorai (2)	Tunny fish	*Thynnus spp.*
Panna (3)	Croaker	*Otolithus spp.*
Koduva (1)	Cockup	*Lates calcarifer*
Chenganni (9)	Waigen sea perch	*Psammoperca waigiensis*
Keeli (1)	Tiger perches	*Therapon spp.*
Paarai (15)	Trevally/Scad	
Katta (2)	Deep queen fishes	*Scomberoides tala*
Karal (3)	Silverbellies	*Leiognathus spp.*
Udagam (28)	Mojarras	*Gerres spp.*
Navarai (20)	Goat fishes	*Upeneus spp.*
Kizhi meen (1)	parrot fish	*Callyodon spp.*
Ora meen (11)	Spine foots	*Siganus spp.*
Choorai (1)	Tuna	
Kumla (7)	Mackerel	*Rastreliiger kanagurta*
Seela (8)	Seer fishes	*Cybium guttatum*
Vaval (1)	Pomfret	*Stromateus spp*
Kilathi (5)	Tripod fishes	

Results of perception surveys. The numbers in parenthesis indicate number of respondents

Table 13
Major Animal Species Observed in Seagrass Habitat of Palk Bay

Local Name	Common Name	Scientific Name
Vezha (19)	Saw fish	*Pristis spp.*
Thirukkai (3)	Rays	
Colour (3)	Five spot herring	*Hilsa keele*
Schungan keliru (1)	Catfish	*Plotosus canius*
Mural (5)	Full/Half beaks	
Selva mural (1)	Full/Half beaks	
Kadal kuthirai (5)	Sea horse	*Hippocampus kuda*
Ooli (3)	Barracuda	*Sphyraena spp.*
Vannathi meen (1)	Spade fishes	*Platax spp.*
Koduva (1)	Cockup	*Lates calcarifer*
Chenganni (27)	Waigen sea perch	*Psammoperca waigiensis*
Keeli (11)	Tiger perches	*Therapon*
Paarai (2)	Trevally/Scad	
Karal (1)	Silverbellies	*Leiognathus spp.*

Table 13 (*Cntd...*)
Major Animal Species Observed in Seagrass Habitat of Palk Bay

Local Name	Common Name	Scientific Name
Udagam (9)	Mojarras	*Gerres spp.*
Navarai (20)	Goat fishes	*Upeneus spp.*
Ora meen (16)	Spine foots	*Siganus spp.*
Seela (5)	Seer fishes	*Cybium guttatum*
Choorai (1)	Tuna	
Kilathi (5)	Tripod fishes	
Pethai (2)	Puffer fishes	
Aamai (1)	Turtles	
Avuria/Kadal pasu (1)	Sea cow	*Dugong dugon*

Results of perception surveys. The numbers in parenthesis indicate number of respondents

Table 14
Major Species Observed in Mangrove Habitats of Palk bay

Local Name	Common Name	Scientific Name
Uluva (1)	Skates	
Palmeen (1)	Milk fish	*Chanos chanos*
Koduva (1)	Cockup	*Lates calcarifer*
Vanchiram (1)	Narrow barred seer fish	*Scomberomerus commerson*
Karuvandu Iral (1)	Prawns	
Manalai (3)	Mullets	

Results of perception surveys. The numbers in parenthesis indicate number of respondents

Table 15
Major Fishes Observed in Coral Habitats of Palk bay

Local Name	Common Name	Scientific Name
Vezha (3)	Saw fish	*Pristis spp.*
Anjalai (1)	leopard Moray	*Gymnothorax undulatus*
Kalava (4)	Reef cods	*Epinephelus spp.*
Keeli (2)	Tiger perches	*Therapon spp.*
Paarai (1)	Trevally/Scad	
Udagam (1)	Mojarras	*Gerres spp.*
Kizhi meen (6)	parrot fish	*Callyodon spp.*
Ora meen (4)	Spine foots	*Siganus spp.*
Singi (1)	Pointed spiny lobster,	*Panulirus versicolor*
Madavai (1)	Mullets	

Results of perception surveys. The numbers in parenthesis indicate number of respondents

Table 16
Organisms that have Become Rare/ Very Rare in Palk Bay During Last 12 years

Local Name	Common Name	Scientific Name
Pal sorrah (1)	Grey dog shark	*Rhizoprionodon acutus*
Uluva (3)	Skates	
Vezha (8)	Saw fish	*Pristis spp.*
	Indian pellona	*Pellona ditchela*
	Rainbow sardine	*Dussumieria acuta*
Aadaa thirukkai (1)	Sting ray	*Trygon sephen*
Thirukkai (14)	Rays	
Pei chalai (8)	Indian oil sardine	*Sardinella albella*
Matta konthan (1)	White sardine	*Escualosa thoracata*
colour (5)	Five spot herring	*Hilsa keele*
Nethili (3)	Anchovies	
Vazhai (6)	Wolf herring	*Chirocentrus spp.*
Mural (1)	Full/Half beaks	
Kadal kuthirai (1)	Sea horse	*Hippocampus kuda*
Chemmeen (1)	Red squirrel fish	*Holocentrus rubrum*
Ooli (1)	Barracuda	*Sphyraena spp.*
Kaala (3)	Thread fins	*Dussumeria acuta*
Tholan (2)	Perch	*Diagramma griseum*
Soorai (1)	Tunny fish	*Thynnus spp*
Panna (3)	Croaker	*Otolithus spp.*
Koduva (4)	Cockup	*Lates calcarifer*
Chenganni (5)	Waigen sea perch	*Psammoperca waigiensis*
Kalava (3)	Reef cods	*Epinephelus spp.*
Paarai (13)	Trevally/Scad	
Perum parai (1)	Thread fin trevally	*Alectis ciliaris*
Katta (8)	Deep queen fishes	*Scomberoides tala*
Karal (1)	Silverbellies	*Leiognathus spp.*
Udagam (2)	Mojarras	*Gerres spp.*
Mathanam (1)	Sweetlips	*Gaterin spp.*
Seraiah (2)	Grunter	*Pomadasys spp.*
Navarai (1)	Goat fishes	*Upeneus spp.*
Ora meen (3)	Spine foots	*Siganus spp.*
Choorai (2)	Tuna	
Kumla (9)	Mackerel	*Rastreliiger kanagurta*
Seela (10)	Seer fishes	*Cybium guttatum*
Ayilai (1)	Indian mackerel	*Rastrelliger kanagurta*
Vaval (3)	Pomfret	*Stromateus spp*
Kilathi (5)	Tripod fishes	
Pethai (1)	Puffer fishes	
Kuthippu (1)	White fish	*Lactarius lactarius*
Thalai Iral/Pasi Iral (1)	Green tiger prawn	*Penaeus semisulcatus*

Table 16 (*Cntd...*)
Organisms that have Become Rare/ Very Rare in Palk Bay During Last 12 years

Local Name	Common Name	Scientific Name
Singi (5)	Pointed spiny lobster,	*Panulirus versicolor*
Siluvai Nandu (2)	Cross crab	*Charybdis cruciata*
Ongole or odan (2)	Bottle nose dolphin	*Tursiops truncatus*
Avuria/Kadal pasu (2)	Sea cow	*Dugong dugon*

Results of perception surveys. The numbers in parenthesis indicate number of respondents

direction and fish availability. The fishers would avoid fishing because of high wind velocity (71 respondents), weather services information (33 respondents) and cloudy weather conditions. The marketing of the fish catch was either by direct selling (44) or through intermediaries (43) (usually the fishers' creditor) to whom the fisher is on credit. The region being close to the international border many of the respondents indicated the probable hassles of crossing over the line and emphasized the need for caution while going for fishing in that area. There were 7 respondents who faced intimidation, manhandling to bullet firing upon crossing the line.

The major species that were reported by the respondents from seagrass, mangroves and coral habitats are listed in Table 13 to 15. Majority of respondents agree that the ecological habitat comprising of seagrass (65) and corals (33) is important for fishery. At the same time, a small proportion of respondents did not perceive mangroves (17) and corals (19) as important for the fishery or ecosystem. There was a general agreement that there is a reduction in variety and catch size in the case of prawns, crabs, finfish and squids during last decade. Fish and other organisms that reduced during the same period as per the fishers are given in Table 16. Habitat destruction through dredging and over-fishing are said to be major causative factors for fish catch reduction.

We also enquired with the fishers regarding sightings of dugongs, dolphins, sharks and turtles. The responses varied greatly, only 10% of the respondents reported sightings of Dugongs, 21% of Dolphins and 4% of Sharks. They reported high number of turtle sightings (57%), as they are caught in fishing nets. The turtles also damage fishing nets, however lesser in comparison to the damage caused by molluscs and corals damage caused by mollusk (42%) and seagrass (65%) that cause higher economic and time loss.

Chapter 5

Co-Existing Sectors Of Fishery In Palk Bay

In a populous developing country like India, fisheries holds great importance both economically and nutritionally. India is one among the leading producers in fisheries; it stands third in production of fish and second in aquaculture production. In addition, the share of fisheries to Gross Domestic Product (GDP) is increasing steadily (Sathiadhas et al., 2014). The huge size of dependent population adds importance to fisheries beyond mere economic benefits derived from this sector. According to UNESCO, 771 million people across the globe are dependent on fisheries for a living. Out of that, 381 million people are from South- East Asia. In India, 14 million people are associated with fisheries and allied sectors, and of that, 90 lakhs are in subsistence fisheries (Anusha and Fleming, 2014).

Generally, very low literacy rate is observed among communities engaged in fishing (Sathiadhas *et al*., 2014), is a factor that hinders progress in the community. Geographic marginalization along with low literacy rate increased the depth of social marginalization of fishing community. The extent of the fisheries is diverse in India; it ranges from subsistence fisheries to the multi-crore mechanized fishing industry. However, in recent years, a decline in the diversity as well as in per capita area available for fishers is observed. The range of income along with decline in per capita area available for fishers indicated overfishing and thereby declining resources.

Besides diverse practices, uneven dissemination of technology is also prevailing in the Indian coast. Western Coast have more mechanized crafts than East Coast; only 58 % of the fishing crafts are mechanized in westcoast, while in the eastcoast 78 % fishing crafts are motorized. The fishery output also shows a parallel with the extent of mechanization. The eastcoast contributes only 33 % of the fish harvest (Sathianandan, 2012). An increase in fishing efforts happened over time in the tropics where it is predominantly multispecies fishing. The stock abundance found to vary from season to and season (Vivekanandan and Jayasankar, 2008). Like other primary sectors fishery is also dependent on climatic factors. It is facing serious threats from changes in climate

and environmental factors, over-exploitation, habitat loss and anthropogenic activities as well (Sathiadhas *et al*., 2014). Palk Bay is home to fisheries and aquaculture. The interactions between these two occupations as well as their social linkages were analysed during the study.

Growth and Importance of Aquaculture

Aquaculture gained importance when production from marine capture fisheries dropped. India has immense potential for aquaculture, almost 1.2 million ha is found to be suitable for land based aquaculture; however, only 13% is utilized for aquaculture (Mariculture). In India aquaculture boomed from 1970. It saw an expansion of 126% with respect to trade and 139% increase in foreign currency earned. Tamil Nadu is one of the major players in aquaculture with other states such as Kerala, Gujarat, Maharashtra, Andhra Pradesh and Odisha (Nagarajan and Thiyagesan, 2006).

Shrimp culture accounts for a large chunk of area under aquaculture, about 68,000 ha (Ayyakannu, 1994). Shrimp culture in India can be of three types: traditional, scientific-extensive and semi-intensive. In the coastal belt of Tamil Nadu, Andhra Pradesh and Pondicherry intensive and semi-intensive aquaculture gained momentum as a part of blue revolution (Mukul, 1994). Compared to the traditional practice, intensive and semi-intensive aquaculture gives at least 10 times more yields. While the yield (shrimp/ha) from traditional aquaculture is 100-140 kg, that from intensive aquaculture is around 1000 kg; but the inputs are also accordingly higher.

Aquaculture from the Perspective of Environment

The environmental impacts of aquaculture farms are widely documented. The study carried out by NEERI revealed that most of the coastal aquaculture farms are not scientifically designed and not appropriately located. Many a time the cost of environmental damages far outweigh economic benefits. (Nagarajan and Thiyagesan, 2006). Aquaculture farms pose threat to coastal ecosystems including estuarine mangroves (Asadi et al., 2014). Almost 10% decline in mangroves is reported in Gujarat due to expansion of shrimp farming (Nagarajan and Thiyagesan, 2006). Change in physio-chemical characteristics of water and loss of biodiversity is observed due to the loss of mangroves (Shyam and Ojha, 2002). Apart from the mangroves and wetlands of avian importance are also disturbed by aquaculture farms, resulting in notable decline in avian fauna. Environmental degradations of similar nature are also reported in other parts of India. In the Sundarbans, the expansion of aquafarms has led to fall in fish stocks which has negatively impacted the migratory birds (Nagarajan and Thiyagesan, 2006). This loss in fish stocks due to the expansion of aquafarms also severely impact the dependent livelihoods.

Aquaculture is a resource intensive venture. The intensive use of energy and water is mandatory for shrimp culture. A hectare of aqua-farm can stock 0.1 to 0.3 million shrimps, and that would require monitoring of critical parameters like pH, temperature, salinity, and dissolved oxygen and their maintenance at optimum levels. Site resources like land and water and heavy doses of antibiotics, pro-biotics and fuel are utilized in shrimp culture (Mukul, 1994). The traditional extensive aquaculture, predominant until the 1990s, posed low environmental threats while the intensive shrimp cultivation practiced currently (Shyam and Ojha, 2002) poses greater threats. The exotic species introduced in aquaculture along with various chemical and food supplements used to increase production have far reaching implications. Aquaculture farms are known to cause ground water pollution, increased salinity ingress into ground water table (Puthethi et. al., 2008; James *et. al*., 1986). Land based aquaculture has potential to increase the rate of saline water intrusion and thus increase the salinity of ground water (Harikrishna *et al*., 2012). Aquaculture farms also alter soil quality, such as reducing infiltration capacity affecting crops such as rice, a major crop in the coastal wetlands (Shyam and Ojha, 2008).

Private companies, multinational corporations and some rich private individuals are involved in aquaculture resulting in change in land ownership as well (Mukul, 1994). That results in radical change in land ownership. This change in ownership catalyzed hike in land value in the coastal region of Nagapattinum district of Tamilnadu. Livelihood pattern also got reoriented along with the land use change. There was also change in livelihood patterns. In place of 180 labour days provided per annum by traditional occupation of paddy cultivation, aquafarms gave 600 labour days per crop (Paul Raj et al., 1997). The uncontrolled spread of aquafarms were not viewed favourably by certain sections such as fisherfolk, farmers, landless labourers and their organizations. The large-scale shrimp culture / farms leading to denial of access to coast and fish landing locations (Mukul, 1994) is a serious issue that tend to disturb the normal life and livelihood of fishers. Further, the access denial to benefits (harvests) from common resources put the fishery sector in danger. Collection of brooder prawns and prawn seeds is known to impede the yield of conventional crafts, in southern region of India, threatening local subsistence economy to suffer (Shyam and Ojha, 2008). Such observations gave a different perspective of aquaculture farms *in lieu* of being a complimentary sector to open access fisheries.

Negative impacts of aquaculture are observed in many Asian countries such as People's Republic of Cambodia, Bangladesh, India, Thailand, Indonesia and Vietnam. Implication on biodiversity and existence of indigenous species also found. The negative impacts of aquaculture accentuate on the need to have ecologically responsible and sustainable aquaculture. The socio-ecological systems are dynamic and they overlap with each other. It is found that loss of mangroves may lead to ecological, environmental and social consequences. Devastation of mangroves will result in the loss of breeding and nursery grounds of economically important aquatic species. Decline in availability of larvae and post larvae are observed this probably resulted in the drop in catch from traditional fish catch. The integration of aquaculture into social and environmental system is expected to balance between aquaculture farms and other potential users of the common resource. The importance of carrying out Environmental Impact Assessment for establishing aquaculture farms are needed while considering the implication caused by aquaculture farms and the need of managing the coastal area and the resources sustainably (Pillai and Narsimham, 1996).

It is significant to study the interaction of aqua farms with other stakeholders. It is important to study how an emerging private property-based fisheries enterprise is interacting to a socio-ecological system where a common resource-based livelihood existed for a long time.

The Fishers' Hamlets in the Area

Fisher's hamlets are situated near to the beach, in the background of calm sea. Organic and artificial flotsam renders a clammy appearance to the beaches in Palk Bay. A layer of decaying organic matter stranded on the shore appears to be the boundary between shore and water. The organic flotsam was chiefly dead seagrass and sponges. The common vegetation in the village is Prosopis (*Prosopis juliflora*) in addition Palmyra and Coconut. The villager's dependency on the local vegetation was visible in the village. Fronds of Palmyra and coconut are commonly used for fencing.

In Devipattinam region of Ramanathapuram district, hamlets of traditional fishers are more or less divided based on their religion (although there are exceptions). Houses are aligned in a clustered manner. There are several places of worship like church, mosques and temples managed well in these coastal hamlets. The work routines of the fishers are aligned in tune with the local festivals and auspicious days followed in their respective religion.

The common resting places of the villages are well maintained and utilized by fisherfolk. Common resting places stood in the village as the flagship of unity and coherence of

fishing community. Fishers prefer to take nap in common resting spaces with their fellow-persons, rather than going and resting in their houses. Fishers mending their crafts and gears in community spaces is a common sighting. In addition, veranda of houses and sheltered places in the beach were also occupied by the fishers.

Thriving on Commons: Diversity and Sharing of Resources

A number of craft and gear combinations exist in the Palk Bay. The use of crafts and gears vary from hamlet to hamlet and according to the economic status of the fishers. Fishing in the northern part of Palk Bay region in Ramanathapuram district of Tamil Nadu is generally of subsistence nature. The people engaged in fishing activity are generally traditional fishers. They call themselves as 'Parambariya Meenavarkal' (which can be translated to English as Traditional Fisher folk).

Economic status of the fisher is an important determining factor about the craft and gear they employed. Mechanized fibre boat is generally used for fishing. Fishers use the name of their main catch to name the type of the fishing net. Gill net is used exclusively for crab fishing. Drift net and gill net are the two commonly employed fishing nets in the Palk Bay. '*Silanka valai*' a modified drift net, which is a combination of three layers of nets with different mesh size, is used by relatively well-off among the traditional fishers. Few of the fishers looked at it as an improved and useful method to earn more money from fishing while the elderly from *Morppannai* hamlet conveyed reservation against this particular fishing gear. According to them, this gear is a destructive method like bottom trawling since both the gears are harvesting juveniles and brings in large share of by catch.

Shore seine method is also practiced in this region. This method, similar to trawling, is labour intensive and requires at least 10 labourers to pull in the net. The catch is constituted of diverse species, both commercially important as well unimportant, including different species of puffer fish. The catch also includes numerous juvenile fishes that constitute the by-catch. The economically important catch was constituted by parrotfish, octopus, squid and several large fish varieties. For squid fishes, they adopt a different technique. Fishers leave the shore in single boats carrying buoys made out of thermocol. In the pre-decided fishing area, they detach themselves from the mother boat and independently do the fishing sitting in their buoys. Later they return to the mother boat with their harvest.

Resource sharing is important for the societies thriving on common property resources. There exists a system of regulating the Catch. Different dimensions of resource-sharing are observed in the study area; there is a differentiation / isolation as some specialize on some type of fishes. For example, in *Karankadu* hamlet the fishers are exclusively into crab fishing, whereas, fishers from the neighboring hamlets survive by harvesting fishes.

Social Structure of the Fishing Communities

Various aspects of fishing are ruled by a range of social factors. Generally, the working days are in tune with their local religious practices and rituals. Church festival appears to serve as a refreshing break for the people from their daily chores. Christian fisherfolk avoid fishing during the church festival. Hindu fishers avoid fishing during amavasiya. They also avoid fishing on the demise of a community member. avoid fishing on the demise of anyone from their fishing hamlet.

Fishers emphasized the bond they have with the sea, which is providing them a living. During the interaction, they pointed at the trawlers entering into the zone reserved for the country crafts with anguish. They even raised the question regarding the gap of knowledge betweens the traditional fisherfolk and the new players like trawlers. They put themselves in a superior position by considering that they are living in this coastal belt for generations and doing this job for a living, thus they know the sea and the lives better than any big players from outside.

They tend to portray themselves as ecosystem people.

Both male and female members of the community are involved in fishing and allied activities, even though only men are involved directly in fishing. Women of the community are generally involved in the selling of the fish, gleaning of fish from the net, cleaning the net etc. collecting the fish from the net, cleaning the net etc. In shore-seine, female labourers are also included in pulling in of the net.

According to the type of fishing, the ancillary activities also vary; salted dry-fish preparation and sales is high in the southern region and regions where mechanized bottom trawling is in practice. In Nambuthalai, a number of women belonging to the fishing community are engaged in preparing dry-fish by sun drying by-catch. These women buy by-catch from the trawlers, segregate and dry the fishes and sell them to the intermediaries who send it elsewhere for sale.

Gender Landscape of Fisheries in the Area

Female workers were not found engaged in fishing activity directly. In *Morpannai*, a number of women helped the men collect the fish from the net and clean the net by removing all the trash that came along with the fish. Females of the fishing community take up fish sales as an occasional job. Fishers are bound to an agent from whom they receive money as loan or advance. With the money thus received, they become indebted to that agent and they sell the harvested fish to that particular agent. Women from the fishing community collect the catch refused by the agent and sell them in the local market. In *Uppur*, a number of women were present in the local market. In large fish markets like *Thondi*, also women from fisher community were engaged in fish sales. A few women also are found getting fish from the regular auction held in the *Thondi* fish market, where there are a few rare women getting fish from their own boats and selling them directly in the market.

In all the fish markets surveyed, dry-fish sales were found to be exclusively a women's occupation, except in *Pamban* where a number of men were also engaged in dry-fish processing and sales. In *Uppur, Thiruppalaikkudi, Thondi* and *Nambuthalai* markets dry-fish sales is found to be a gendered occupation. The people engaged in dry-fish processing get the by-catch from the trawlers. They sell the processed fish in the local markets and also to the intermediaries. Lack of capital is cited as a reason for limiting the sales into dry-fish. In the Southern parts, the increased involvement of women of different age groups in dry-fish processing indicated the uncertainty associated with trawler fishery.

According to a woman engaged in dry-fish processing and sales, it is impossible to leave this occupation. This served as the alternative source of income available to families exclusively dependent on the fishery for livelihood in this conflict zone. This prevailing air of conflict lead to an inconsistency in the family income and the women are forced to take up this occupation. In the North, dry-fish sellers were mostly aged women who cannot afford to do any other work (except the few women fish sellers, who process dry-fish out of the remaining fish).

As already mentioned, northern parts of *Ramanathapuram* district the open access fishery is dominated by small-scale traditional fishers, whereas in south trawlers are the major crafts under operation. The nature of fishery is also a determining factor that decides the involvement and role of women is various activities. The gender status and involvement in fishery in this region can be looked through a lens of capital investment and technology dissemination along with the issue of international border between India and Sri Lanka. Women from fishing community cannot venture into sales of fresh fish, since it is a capital-intensive business. Dry-fish processing is the solution in front of them to deal with their condition of economic instability. Since they are using the cheaply available by-catch for preparing salted dry-fish,

the expenditure is bearable for them, giving them an alternative source of income.

Aquaculture Scenario in the Region

Land based saline aquaculture is widely adopted in *Ramanathapuram* district of Tamil Nadu. Ponds are dug out in land near to the beach and are filled with saline water from sea or bore well. According to the many owners, they operate the farms in their own land. Labor from an aquaculture farm in *Pasipattinam* also made similar claim. In all the farms utilizing seawater for culture, the water was filtered multiple times before reaching the culture ponds. Monthly water treatment is found to be an essential practice to get better yield from the aquaculture pond. The duration of culture is 120 days. Culturing shrimps begin by August and September (Tamil months *Adi* and *Avani* respectively). Juvenile prawns are purchased and brought from the hatcheries located in Pondicherry.

Two varieties of prawns are widely cultured in the farms of this region. *Penaes vanamei* (White leg shrimp) is the predominant variety for its hardy nature. *Penaes monodon* (Tiger prawn) is also cultured but not in a comparable scale to the previous one. The normal duration of one culture is 120 days. P. *vanamei* is replacing P. *monodon* due to the advantages associated with its culture. For P. *monodon*, it is necessary to change water regularly and timely removal of feces and feed refuse is important. For P. *vanamei* there is no need to change water on daily basis. In one aquaculture farm near to *Karankadu Penaeus monodon* and *Penaeus vanamei* were under culture.

Most of the farms were not functional at the time of the survey, due to a sudden outbreak of white-spot disease. In many farms, premature harvest was done on the 45th day of culture to reduce economic washout. During our survey, after evacuating the remains of previous culture cycle, preparatory operations for the next cycle was going on. The machineries used to aerate the pond were lying idle, on the embankments. Decaying shrimp carapaces were spread across few ponds. The drainage pipes from the ponds were directly connected to the sea. In some of the ponds, pond preparation is undertaken with the help of heavy machinery like earthmovers and tractors. Labourers are also involved in scraping the pond bottom. Bottom scraping is done to control *Cerithidea*, a major pest in aquaculture farms.

Migrant workers from distant localities constitute majority of the workforce in the farms. Although aquaculture farm workers are expected to be there in the farm throughout the culture season, for the disease outbreak most farms gave a deserted looks since the migrant labors went back in the off-season. Aquaculturists are working towards to avoid the disease outbreak in the next culture. In one of the aquaculture farm near to *Devipattinam* bore wells are made as an alternate source of saline water. Usage of bore well water is found to be safer for farms over seawater.

Among the aquaculture ponds visited around *Devipattinam*, very few farms were operational and these were hostile to our entry and data collection. In one of the farms, the labourers forced us to leave the place since the owner will not entertain outsiders in the farm. We visited a farm in Devipattinam that was one among the very few not affected by the disease outbreak. Although the farm workers refused to interact with us, the owner of the farm turned up in a few minutes. This aquafarms bordered the mangrove forest and beach. The geographical location has a great role in keeping this farm free of white spot disease. This particular farm was located away from other aquaculture units clustered near to the East- Coast road. The soil type was also notably different in the farm we visited than in other farms where the soil type was predominantly red soil; in the farm that was not affected, the ponds were made in sandy soil.

One farm visited was located near a mangrove patch in *Karankadu*, where prawn harvest was going on. The Aquaculture farm owner, a marine

science graduate turned lawyer, was present in the farm. The owner has four farms other than the one in *Karankadu*. Harvest was done by emptying the pond. The water was drained to the stream flowing nearby and the prawns are collected in collection-bag net attached to the outlet. Men were managing the bag and collecting the prawns, and women were engaged in sorting and transporting the prawns. The harvested prawns were being immediately handed over to the export company from the farm gate, to be transported in ice to the Tuticorin port for export. The destination market of the prawn from the aquaculture products were said to be USA and Europe.

Soil types also help decide the location of aquaculture farms. One fisher from the *Ilanthaithottam* fishing hamlet indicated the absence of aquaculture farms in that locality due to highly porous nature of the soil. In *Pasipattinam*, the Aquaculture farm was located in sandy soils and the culture ponds dried up due to heavy seepage loss, forcing the operator to deepen the pond to reduce seepage loss. While some farms culture throughout the year some allow the farms to lay fallow in an alternating fashion. The latter practice was found to be superior. This also helps in better management and preparation of ponds.

The marine aquaculture products are primarily meant for export market. The fish markets of *Ramanathapuram* district were surveyed and no linkage of the farm produce with domestic market was seen. Cultured shrimp was not present in any of the surveyed market. The merchants told that the prawn from the aquaculture farms reach the domestic market only in the case of early harvest carried out following a disease outbreak. The market survey also helped to find out the demand and preference of the local consumers. It is found that the locals prefer fishes other than prawns. Hence, the farm activity and profits depend on international scene and not on local market preferences.

Fishers' Perception on Aquaculture Farms

Fishers expressed mixed reaction when asked about the impact of aquaculture farms. Out of 24 respondents, 17 reportedly had some difficulties associated with the functioning of aquaculture farms in their locality. The near shore area is the fishing ground for traditional fishers. Even with motorized boats, they operate within 20 kilometers. The nearness of their fishing grounds to the shore accelerates the interaction with aquaculture farms and fishers. The discharge of effluents from aquaculture farms is found to reduce the fish catch and increase fish mortality. Very few fishers shared their concern regarding the market competition they are facing from aquaculture farms, since aquaculture farms are largely export oriented.

Comparing the graphs, it is clear that majority of the respondents are facing difficulties associated with aquaculture farms (Figure 50). The difficulties they cited were associated with their livelihood; drop in fish catch due to release of water from the farms to the sea. Some respondents from *Velivayal* hamlets reported skin irritation on being exposed to the seawater after the release of effluents from the farms. There are also reported cases of increase in salinity (Figure 51) associated with the operation of the farms. Surprisingly the respondents, who rely on water tankers (Figure 52) never have observed any drastic salinity increase in ground water.

Areal Expansion of Aquaculture in the Area

The areal expansion of aquaculture farms were examined for the last 13 years. Due to the non-availability of data for the years 2003 and 2004, the available data from the year 2005 was analyzed. The area under aquaculture farms were calculated for a particular time of each sample years. The area under aquaculture farms on 12.30 pm of 15th May is mapped. An increase in the area under aquaculture farms is noted from 2005 (Table 17).

Figure 50
Perceived Impact of Aquaculture Farms on Fishers' Life

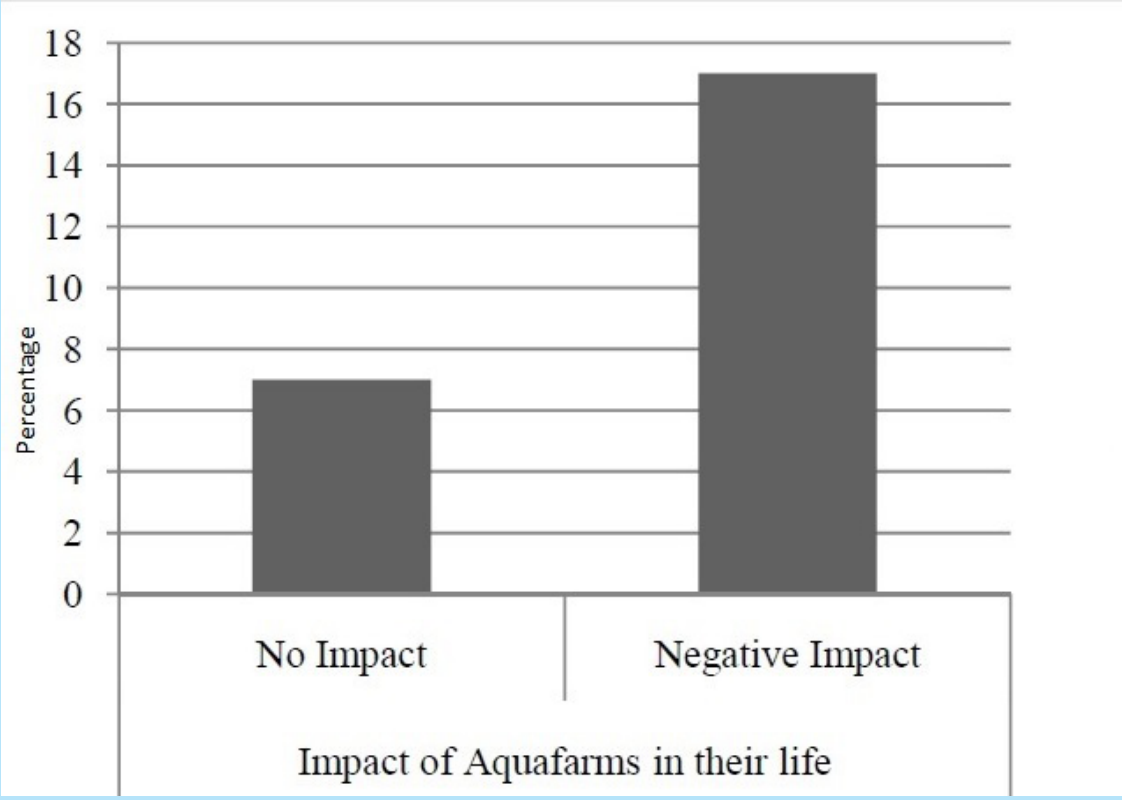


Table 17
Growth in Area Under Aqua-Farms in the Study Area

Year	Square metre
2005	3325874
2007	3361228
2011	3055165
2015	5138208

Figure 51
Perceived Changes in Salinity in the Study Area As Per the Respondents

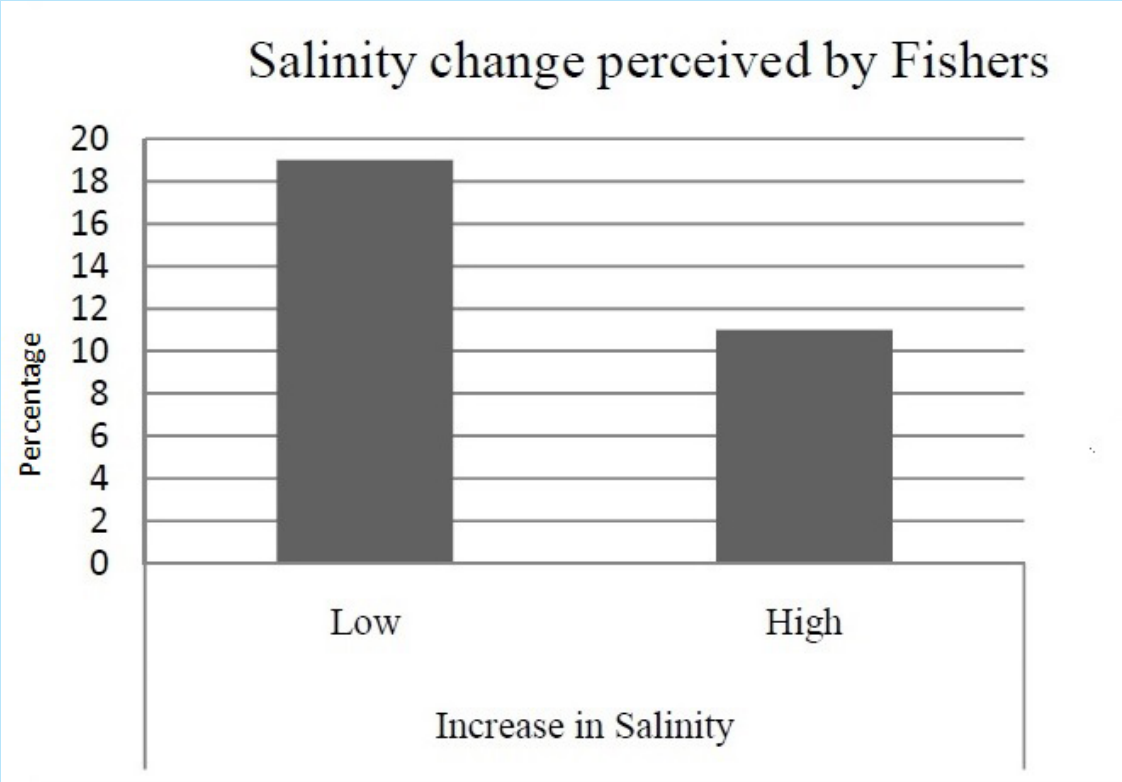
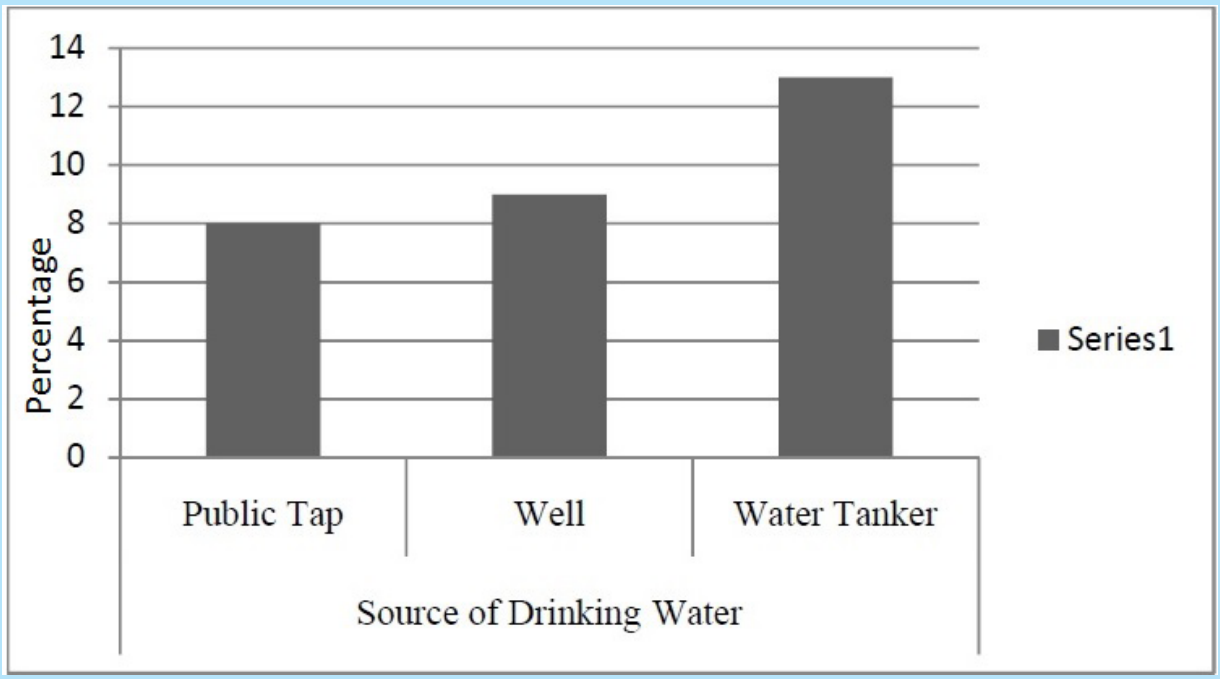
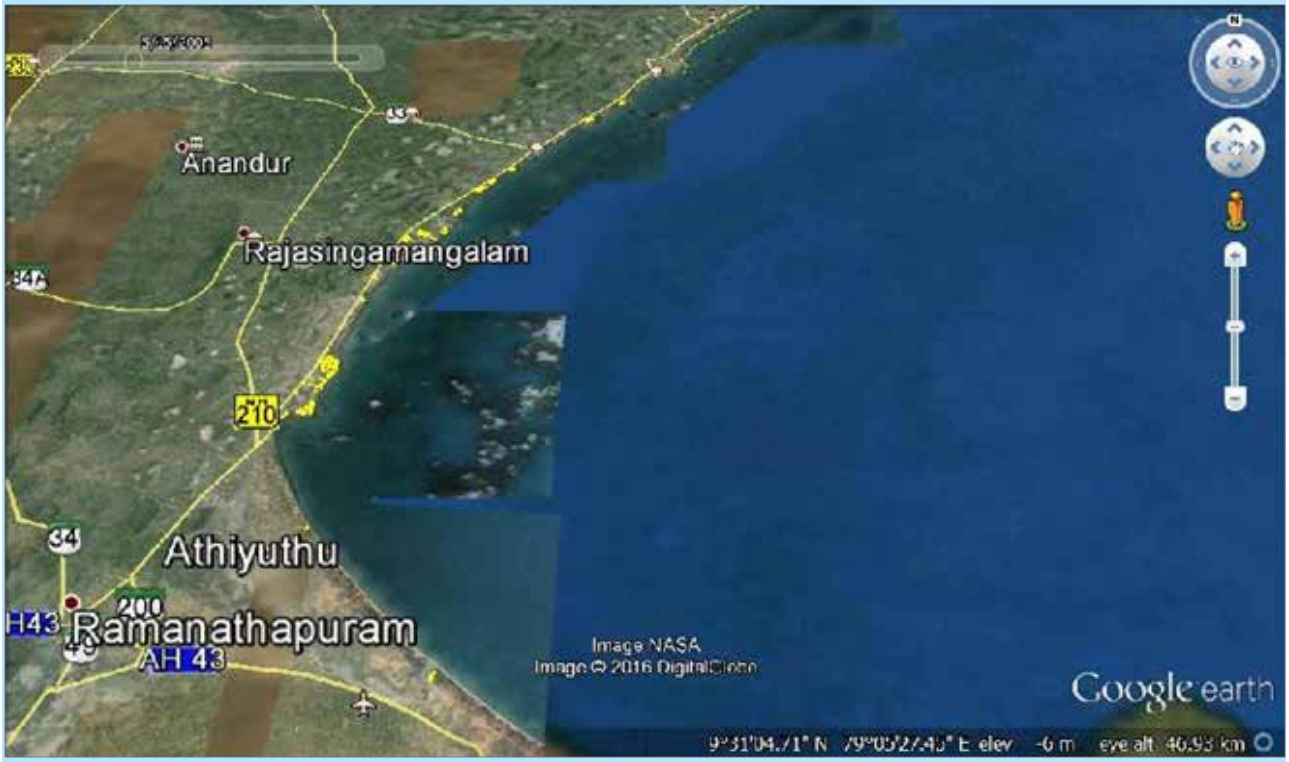


Figure 52
Source of Drinking Water for Fishers in the Study Area as Per the Respondents



Map 1
12.30 pm, 5th May 2005



Map 2
12.30 pm, 5th May 2007

Map 3
12.30 pm, 5th May 2011

Map 4
12.30 pm, 5th May 2015

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About the Study

The study *The Ecological Baseline Assessment of the Palk Bay* was done on the request of the CMPA Project of GIZ-India. The objective was to conduct a rapid ecological baseline survey for Palk Bay (off the Ramanathapuram coast) of the southern coastal state of Tamil Nadu. The work was based on the "Conceptual Framework for a Baseline Study on the Ecological Status of the Pilot Sites for the CMPA Project" by the Leibniz Center for Tropical Marine Ecology, Bremen, Germany, but contextualized for Palk Bay. The study explored water quality and sediment quality across the Palk Bays along specific transects; various habitats in the coastal ecosystem (focusing on mangroves, seagrass and corals); etc. It also delved into the issues and concerns of the booming aquaculture industry and the impact of the same on the ecology and dependent livelihoods.

The CMPA Project

The Project "Conservation and Sustainable Management of Coastal and Marine Protected Areas" (CMPA) is a project of the Indo-German technical cooperation. It is funded by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and implemented by the Ministry of Environment, Forests and Climate Change (MoEFCC), Government of India, and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of BMUB.

Established to support the achievement of the Aichi targets of the Convention on Biological Diversity, the Project's overall goal is to contribute to conservation and sustainable use of biodiversity in selected areas along the coast of India. Taking into consideration the economic importance of the coastal zone for large segments of the population, the Project's approach is people-centered, thus ensuring the support for conservation by those depending on coastal ecosystems.

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06

The Ecological Baseline Assessment of the Palk Bay

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Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
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Conservation and Sustainable Management of Coastal and Marine Protected Areas