STUDY ON MACROBENTHIC MOLLUSCAN AND CRUSTACEAN DIVERSITY AT BAY OF BENGAL COAST OF PURBA MEDINIPUR DISTRICT, WEST BENGAL

A dissertation submitted to the
West Bengal University of Animal and Fishery Sciences,
in partial fulfilment of the requirements for the degree of

MASTER OF FISHERY SCIENCE
in
Aquatic Environment Management

By

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CERTIFICATE

This is to certify that the work embodied in the thesis entitled **"STUDY ON MACROBENTHIC MOLLUSCAN AND CRUSTACEAN DIVERSITY AT BAY OF BENGAL COAST OF PURBA MEDINIPUR DISTRICT, WEST BENGAL"** submitted by **Mr. Nandan Pramanik** in partial fulfilment of requirements for the **degree of Master of Fishery Science (Aquatic Environment Management)** in the Faculty of Fishery Sciences, West Bengal University of Animal and Fishery Sciences, is the faithful and bonafied research work carried out under my supervision and guidance. The results of the investigation reported in this thesis have not so far been submitted for any other Degree or Diploma. The assistance and help received during the course of investigation have been duly acknowledged.

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We, the undersigned, have been satisfied with the performance of **Mr. Nandan Pramanik** in the viva–voce examination, conducted today, the 30th December., 2015, recommend that the thesis be accepted for the award of the degree of Master of Fishery Science in Aquatic Environment Management.

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LIST OF ABBREVIATIONS

AT	Air Temperature
WT	Water Temperature
WpH	Water pH
SpH	Sediment pH
DO	Dissolved oxygen
NO_3-N	Nitrate Nitrogen
PO_4-P	Phosphate Phosphorus
SOC	Sediment Organic Carbon
H'	Shannon Weaver Biodiversity Index
D	Density of Macrobenthos
r	Margalef's Richness Index
J	Pielou's Evenness Index

1. INTRODUCTION

Among all the 9 maritime states of India which have an impressive coastline, the state of West Bengal commands a significant geographical location harbouring the mighty Hoogly-Mathla estuary, shared with the neighbouring country Bangladesh. The coastal area of West Bengal extends over 0.82 million hectare and extends along 220 km of coastal line. Historically and geographically the coastal Medininipur is a contiguous part of deltaic Sudarbans of global importance, limiting the Hoogli-Mathla estuary on the western front (Chakraborty, 2010). Of the two coastal districts of West Bengal (Purba Medinipur, South 24 Parganas) , the undivided Medinipur district is characterised by sand dunes, long shore currents , high salinity, low turbidity and low vegetative coverage in comparison to its counterpart, (The south 24 Parganas District) supported by Sundarban mangrove ecosystem (Annon, 2005; Paul, 2002). The Medinipur coast covers 27% of the West Bengal coastal tract extending along the west bank of Hoogli- Mathla estuary from New Digha at the extreme south point of the Medinipur district and then curving around Gopalpur, Bankiput, Junput, Dadanpatrabarh, Mandarmani, Tajpur, Khejuri and Haldia on the east to further northeast up to Tamluk or even Kolaghat on the bank of Rupnarayan. The Medinipur coastal tract has the longitudinal extension. Biodiversity of this coastal environment, i.e. floral and faunal diversities are in tune with habitat diversity in this short stretch coastal zone and represents striking features with regard to ecosystem functioning, commercial bio-resource production, coastal zone management and promotion of ecotourism. Biodiversity is dynamic at all three levels, the genes, species and habitats and changes over time in response to natural and human induced selection pressures. Diversity of habitats in terms of changing physical, chemical and geomorphological parameters imparts impact on genetic composition which leads to the changes of biotic assemblages spatially and temporally. Mandarmani sea beach and resort is famous among important tourist spots which is 30 km (approximately) away from Contai by road and situated besides Dadanpatrabarh. Gopalpur, a small coastal beach of this district is situated between Junput and Bankiput sea beach on Hoogli estuary. People belonging to below poverty line are engaged in fishing, especially for fish drying. These two beaches are located at the middle stretch of Medinipur coastal tract. Medinipur coastal belt in its extension of 60 km encompasses a diversity habitats and niche which accommodate a galaxy of faunal

components in the form of pelagic and benthic forms. A total number of 48 molluscan species belonging to 3 classes, 15 orders and 36 families have been reported from the intertidal habitats (Khalua *et al.,* 2003). Of the 68 arthropod species recorded from this coast 13 brachyuran crabs, 13 species of prawns and shrimps, 21 insects belonging to 33 families represents the major groups of fauna (Chatterjee *et al.*, 2008). Both the species of horse-shoe crabs, viz. *Carcinocorpius rotundicauta* and *Taphypleus gigas* are also recorded from Digha-Talsari intertidal flats (Annon, 2005).

Macro benthos are greater than 0.5 mm size, resides in sea bottom sediment, performing varieties of ecological function (Anbuchezhian *et al.,* 2009). In the geological time scale, molluscs evolved about 600 million years ago during the Cambrian period. Structurally molluscs are a heterogenous group of animals with different structural form such as slugs, mussles, octopus and snails. Majority of the mollusks are known by their shell, but in some forms the shell is absent. The number of species identified under phylum mollusca vary between 80,000 to 1,00,000. They are more abundant in the littoral zones of tropical seas. Gastropods and bivalves constitute 98% of the total population of mollusca. (Anandaraj *et al.*, 2012).

In India, till today, 5,070 species of molluscs have been recorded of which, 3,370 are from marine habitats (Subba Rao, 1991). In India about 3370 species of marine and coastal molluscans and about 705 species of brachyuran (comes under crustacean) species are found (Venkataraman, 2005). Amongst different crustacean invertebrates, crabs are highly diverse group comprising 5000 species and 700 genera. The species distributed on diverse habitat play important role in the maintenance of the ecosystem. (Arya *et al.*, 2014). Out of about 640 species of marine crabs so far recorded from Indian waters only 15 species are edible, which inhabit the coastal waters and adjoining brackish water environments, support commercial fisheries (Varadharajan *et al*, 2009; Varadharajan, 2012).

Roll of macrobenthos

The importance of molluscan resources is manifold. It serves as food both for animals and human being. Pearls production enables to establish pearl industry. The content of $CaCO_3$ made it possible to use in poultry feed. In India, especially in eastern India, molluscs play a significant role in different industry (De *et al.*, 1987)

Macrobenthos in marine sediment plays an important role in ecosystem processes such as nutrient cycling, pollutant metabolism, dispersion and in secondary production (Snelgrove, 1998). They act as a connecting link between the biotopes of substratum and water column in the aquatic systems. They take part in breakdown of particulate organic material and export energy to higher trophic level and can potentially support off-shore and pelagic communities (Lee, 1997; Schrijvers *et al.*, 1996).

Crabs (crustaceans) are the vital component of the marine food chain. Most of the crabs feed on either detritus or the organic matter thus controlling the ecological functioning. In inter tidal area, these organisms work as a super creatures adapting to the harshness of the environment (Arya *et al.*, 2014).

Brachyuran crabs are noteworthy amongst intertidal groups and are considered as the most relevant group in terms of their community dominance and biomass (Virnstein, 1987; Sheridan, 1992). Some species including crabs have been recognized as regulators of the structure of estuarine communities (Dittel *et al.,* 1995; Heck and Coen, 1995).

In India about 15 crab species are edible (Varadharajan *et al*, 2009; Varadharajan, 2012). Crabs are the good source of protein and have a great export value all over the world.

Molluscs in general had a tremendous impact on Indian tradition and economy and were popular among common people as ornaments, currency and curio materials. Moreover, Molluscs (shell) have been found to be important raw materials for poultry feeds, cement producer, fertilizers. India exports sea-shells mainly bivalves and large gastropods to various countries. Molluscs are second largest after arthropods as numerical abundance (Paul *et al.,* 2014). Any fluctuation in their quality and quantity will directly affect the abundance of demersal fishes that are important fishery resources in the sea. Therefore, a benthic study may be used as baseline information to evaluate the existing demersal stocks and may serve as a baseline study of future investigations on environmental changes in an area (Giere, 1993). Brachyuran crabs play a significant positive role in maintaining the steady state condition of the ecosystem and enhance its biological potentiality. Brachyuran crabs constituting an important faunal component in the food web of the coastal belt, play a significant role in accelerating the decomposition cycle as a macro decomposers influencing the ecosystem function to a large extent and are morphologically, physiologically and behaviourally well adapted to their environment (Chatterjee and Chakraborty, 2014). Benthic organisms living in the sub-tidal habitats are sensitive to environmental changes and thus serve as indicators of changes occurring in their habitats.

Community structure of benthic organism is largely determined by energy equilibrium and nutrient input (Sanagoudra and Bhat, 2013).

Justification of the study

As there is no study on macrobenthos in this two selected study area are undertaken, hence the present study has been undertaken to understand the community structure, density and diversity of macrobenthic molluscan and crustacean fauna in relation to environmental parameters.

Research objectives

The research objectives of the present study are:

1. To study the physico- chemical parameters of coastal sediment and water.
2. To analyse the species diversity and seasonal abundance of macrobenthic molluscans and crustaceans.
3. To correlate the relationship between physico-chemical parameters and species diversity.

2. REVIEW OF LITERATURE

An attempt has been made to review the available literature to the present work and has been presented as per the following heads.

2.1. THE PHYSIO-CHEMICAL PARAMETERS OF WATER AND SEDIMENT

The Physico-chemical characteristics affect distribution and growth of the benthic organisms. One of the main goal of benthic ecology has been to understand the mechanisms regulating relationships between physio-chemical parameter and organisms (Aller *et al.*, 2001).

There is a strong physical, chemical and biological relationship between benthic communities and the prevailing environment (Odunaike *et al.*, 2013).

2.1.1. SALINITY

Manoharan *et al.* (2011) studied on biodiversity and abundance of benthos along south east coast of India at Tamil Nadu along with some physio-chemical parameters and noticed salinity of the sea water ranged from 26 to 35.5 ppt. They also reported that maximum salinity was in the month of May and minimum in the month of November.

Chandra and Chakraborty (2008) made a study on ecological parameters with community ecology of macrobenthic intertidal polychaetes in the coastal tract of Midnapore, West Bengal, India and noticed the salinity of water varied from 8.6 ‰ to 26.0 ‰ annually. And the lowest salinity was observed during the southwest monsoon (July-October) in all the three study sites (Junput, Gopalpur and Talsari) and the highest was recorded during premonsoon (March-June) followed by postmonsoon (November-February).

Datta *et al.* (2008) made a study on the physic-chemical parameters of low tide water of the shore along with temporal and spatial differences in species diversity in the intertidal region of south Mumbai and recorded the salinity in between 26.0- 34.0 ppt annually. They noticed the salinity had established the highest relationship with biological parameters.

Anbuchezhian *et al.* (2009) studied the macrobenthic composition and diversity in the coastal belt of Thondi, south east coast of India with some ecological parameters and observed the salinity ranged from 25.5 ppt (November) to 29 ppt (September) at Station I and from 26 ppt (November) to 29.5 ppt (September) at Station II. The low salinity observed in November was due to heavy downpour.

Thilagavathi *et al.* (2013) made an analysis of distribution and diversity of macrobenthos in different mangrove ecosystems of Tamil Nadu coast, India along with some physio-chemical parameters and found the salinity of water ranged from 18 to 35 ppt in all stations in the studied year. They did not found characteristic relationship between salinity and macro-faunal distribution in this study.

Varadharajan *et al.* (2010) made a study on seasonal abundance of macro benthic composition and diversity along the south east coast of India of Tamilnadu in relation to environmental factor. They noticed the maximum and minimum salinity all stations were 35 ppt (July- August) to 24 (December) ppt respectively.

Kumar and Khan (2013) focused attention on the distribution and diversity of benthic macro-invertebrate fauna in Pondicherry mangroves, India at four stations (Veerampattinam, Thengaithittu, Ariyankuppam, .Murungapakkam) to identify the relationships between water quality and benthic macro-invertebrate fauna characteristics and noticed salinity ranged from 12.5 ppt (monsoon) to 35.2 (summer) ppt. They observed lower salinity in monsoon due to fresh water runoff.

Satheeshkumar (2012) made a study on mangrove vegetation and community structure of brachyuran crabs as ecological indicators of Pondicherry coast, south east coast of India at four stations along with some ecological parameters and found Salinity variations ranged between 6.36-36.77 ppt. They observed salinity at all the stations was high during summer and low during the monsoon season.

2.1.2. DISSOLVE OXYGEN

Thilagavathi *et al.* (2013) made an analysis of some physio-chemical parameters and diversity of macro-benthos in mangrove ecosystems of Tamil Nadu Coast, India and recorded the dissolved oxygen of water ranged from 3.22 mg/l to 5.65 mg/l in all

stations in the studied year. They also found that the dissolved oxygen was high during the monsoon season due to heavy rainfall and heavy wind action. The lower values found during summer due to increased surface water temperature which reduces the dissolution of oxygen in the coastal waters. It is well known that temperature and salinity affect the dissolution of oxygen Viijayakumar *et al.* (2000).

Magdoom *et al.* (2010) focused attention on the seasonal distribution of macro-benthos from the Gulf of Mannar along with some physio-chemical parameters and observed dissolved oxygen between 4.7 and 4.9 mg/l. The maximum levels of dissolved oxygen observed during the monsoon season was due to the heavy rainfall.

Datta *et al.* (2008) made a study on the physico-chemical parameters with Temporal and spatial differences in species diversity in the intertidal region of south Mumbai and recorded the dissolved oxygen in varied between 5.4 to 6.8 mg/l throughout the year.

Varadharajan *et al.* (2010) studied on macro benthic composition and diversity along the south east coast of India of Tamilnadu in relation to environmental factor and noticed the maximum and minimum dissolved oxygen concentrations in all stations were 3.0 mg/l (October) to 4.6 mg/l (August) respectively. They found the dissolve oxygen didn't play any considerable role in benthic faunal distribution.

Kumar and Khan (2013) focused attention on the distribution and diversity of benthic macro-invertebrate fauna in Pondicherry mangroves, India at four stations to identify the relationships between water quality and benthic macro-invertebrate fauna characteristics and noticed dissolved oxygen concentration was ranged from 3.71 to 5.16 mg/l. Low dissolved oxygen concentrations found during summer season was due to high surface water temperature and also attributed to high saline waters.

Chandra and Chakraborty (2008) made an analysis of community ecology of macro-benthic intertidal polychaetes in the coastal tract of Medinipur, West Bengal and observed the dissolved oxygen was ranged from 3.24 mg/l to 5.47 mg/l. The highest value of dissolved oxygen was during monsoon and the lowest was during premonsoon.

Satheeshkumar (2012) studied on mangrove vegetation and community structure of brachyuran crabs as ecological indicators of Pondicherry coast, south east coast of India at four stations along with some ecological parameters and found the dissolved oxygen was high (5.16 mg/l) during monsoon and low (3.45 mg/l) during summer and season-wise observation of dissolved oxygen indicated an inverse trend with temperature and salinity.

2.1.3. NITRATE NITROGEN AND PHOSPHATE PHOSPHORUS OF WATER

Datta *et al.* (2008) studied about temporal and spatial differences in species diversity in the intertidal region of South Mumbai and physio-chemical parameters of low tide water and the nitrate nitrogen level of water ranged from 0.19 to 1.3 mg/l. They also recorded the phosphate phosphorus of water ranged between 0.37 to 1.2 mg/l. Low values of NO_3 and PO_4 during the monsoon period also would have restricted the abundance of organisms.

Thilagavathi *et al.* (2013) made an analysis of physio-chemical parameters and diversity of macro-benthos in mangrove ecosystems of Tamil Nadu coast, India and recorded nutrient in water such as nitrate and inorganic phosphate ranged from 1.263 to 5.563 µmol/l and 0.128 to 0.622 µmol/l respectively.

Giri and Chakraborty (2012) made studies on fishery resources in relation to some physio-chemical parameters of water at Sundarban mangrove ecosystem at 5 different stations (Jharkhali, Canning, Saptamukhi, Bokkhali, Freserganj) and found phosphate phosphorus and nitrate nitrogen were minimum 0.15 to maximum 1.3 mg/l and 0.36 to 3.8 mg/l respectively during low tide from all the stations.

2.1.4. ORGANIC CARBON OF SEDIMENT

Total organic carbon of the sediment influences fertility of the soil, thereby enhancing biological activity (Kumar, 1996). Organic nutrients enhance the growth of different types of algae that provide food resources for benthos (Hearld and Odum, 1970).

Macro-benthic composition and diversity in the coastal belt of Thondi, south east coast of India in relation to environmental parameters were studied by Anbuchezhian *et al.*, (2009). The observed organic carbon content in the sediment

ranged from 0.71% (November 2005) to 3.28% (January) at station I and 0.42% (October) to 2.89% (January) at station II.

Thilagavathi *et al.* (2013) made a study on distribution and diversity of macro-benthos in different mangrove ecosystems of Tamil Nadu coast, India and found the total organic carbon ranged between 2.517 to 12.132 mg/g. They observed organic matter gets deposited during the post-monsoon season in the mangrove areas and would be converted into available organic carbon by various fungal and bacterial sources, which in turn increase the macrobenthic forms. They also observed the organic carbon content of sediment is higher in monsoon season and lower in summer season.

Seasonal distribution of macrobenthos from the Gulf of Mannar (south east coast) of India were studied by Magdoom *et al.* (2010). They found total organic carbon ranged between 0.807 to 2.707 mg/g, 3.899 to 4.564 mg/g, 1.517 to 2.595 mg/g and 2.158 to 3.742 mg/g in Shingle Island, Pamban backwaters, Kurusadai Island and Rama feet back waters respectively. They observed at Shingle Island the organic carbon was higher during premonsoon and lower during summer. At Pamban backwaters the organic carbon was higher during post monsoon and lower during summer. At Kurusadai Island organic carbon content was higher in summer and lower in months of pre monsoon and at Rama feet back waters it was high in pre monsoon and low in post monsoon.

Biodiversity and abundance of benthos along the south east coast of India were studied by Manoharan *et al.* (2011) at four stations of Tamil Nadu. They found the total organic carbon of the sediment ranged from 0.71 to 3.75 mg/g. Maximum total organic carbon was recorded 3.75 mg/g in the month of November and minimum 0.71 mg/g in the month of April.

2.1.5. WATER AND AIR TEMPERATURE

Biodiversity and abundance of benthos along the south east of India in relation to changing abiotic factors were done by Manoharan *et al.* (2011) at four stations of Tamilnadu. They found the water temperature was ranged between 28^0C to 34.5^0C in all stations from Januery to December. The maximum temp was found in the August and the minimum was found in the November. They found temperature is one of the important factors among the external factors which influence the benthic production.

Thilagvathi *et al.* (2013) studied on distribution and diversity of macrobenthos in different mangrove ecosystems of Tamilnadu coast among with some physio-chemical parameters and found the water temperature was ranged from 18.2^{0}C to 30.1^{0}C. They did not find any characteristic relation between the temperature and macrobenthic fauna.

Chandra and Chakraborty (2008) studied on distribution, density and community ecology of macrobenthic intertidal polychaetes in the coastal tract of Midnapore, West Bengal and recorded the water temperature ranged from 20.8^{0}C to 32.8^{0}C.

Datta *et al.* (2008) made a study on temporal and spatial differences in the species diversity in the intertidal region of South Mumbai and recorded the air and water temperature at low tide ranged from 28.5^{0}C to 32^{0}C and 27^{0}C to 31^{0}C respectively.

Varadharajan *et al.* (2010) made an analysis on abundance of macrobenthic composition and diversity in relation to environmental factors along southeast coast of India at four stations of Tamil Nadu and noticed the water temperature ranged from 23^{0}C to 35^{0}C. They also found temperature was an important ecological factor which influence the distribution of benthic organisms. High temperature (35^{0}C) recorded in premonsoon season influence the distribution of macrobenthic organisms. Low temperature recorded in December and that influence the higher faunal density.

The distribution and diversity of benthic macro invertebrate fauna in Pondicherry mangroves in relation to water quality was studied by Kumar and Khan (2013). They found air temperature was ranged from 17.9^{0}C to 41.7^{0}C with minimum and maximum values in November and June respectively. The surface water temperature was ranged from 19.6^{0}C to 35.9^{0}C with the highest temperature from April to June. Low temperature was recorded during monsoon season.

2.1.6. pH OF SEDIMENT AND WATER

Thilagavathi *et al.* (2013) made an analysis on some physio-chemical parameters and diversity of macro-benthos in mangrove ecosystems of Tamil Nadu

Coast, India and recorded the pH of the water ranged from 7.3 to 8.4. They described hydrogen ion concentration (pH) in surface waters remained alkaline at all sites throughout the study period with the maximum value during summer seasons and minimum during the monsoon.

Chandra and Chakraborty (2008) studied on distribution, density and community ecology of macrobenthic intertidal polychaetes in the coastal tract of Midnapore, West Bengal and recorded the pH of coastal sediment ranged in between 7.68 to 8.72. The pH of water ranged from 7.15 to 8.17.

Datta *et al.* (2008) made a study on the physic-chemical parameters with Temporal and spatial differences in species diversity in the intertidal region of south Mumbai and recorded the pH of water ranged from 7.45 to 8.35 throughout the study period.

Biodiversity and abundance of benthos along the south east coast of India were studied by Manoharan *et al.* (2011) at four stations Tamil Nadu. They recorded the pH of the sediment ranged from 7.3 to 8.2 in all stations. pH maximum was recorded as 8.2 in the month of April and minimum was recorded as 7.3 in the month of October.

Varadharajan *et al.* (2010) studied on macro benthic composition and diversity along the south east coast of India at Tamilnadu in relation to environmental factor and observed the pH of water in between 7.2 (October) to 8.4 (July and August). They also found pH didn't play any considerable role in benthic faunal assemblage.

Kumar and Khan (2013) focused attention on the distribution and diversity of benthic macro-invertebrate fauna in Pondicherry mangroves, India to identify the relationships between water quality and benthic macro-invertebrate fauna characteristics and They also observed the lowest pH was 7.11 during monsoon and highest was 8.36 during summer.

Satheeshkumar (2012) made an analysis on mangrove vegetation and community structure of brachyuran crabs as ecological indicators of Pondicherry coast, South east coast of India along with some ecological parameters and found hydrogen ion concentration (pH) varied from 7.11-8.36, pH in surface waters remained slightly alkaline throughout the study period with maximum during summer and minimum during monsoon.

2.2. RELATIONSHIP BETWEEN PHYSIOCO-CHEMICAL PARAMETERS AND BENTHIC MACRO INVERTIBRATE

Kumar and Khan (2013) during the study of diversity of benthic macro invertebrate in Pondicherry mangroves found relationship between different physiochemical parameters and benthic faunal assemblage. They found a significant negative correlation between dissolved oxygen and salinity ($r = -0.48$; $p < 0.01$). A significant negative correlation between water temperature and dissolved oxygen was found ($r = -0.51$; $p < 0.05$). A significant positive correlation was found between water pH and water temperature ($r = 0.72$; $p < 0.05$). The found a negative relationship between Shannon Weaver index and dissolved oxygen but the relationship was not significant. No relationship was found between water temperature and Shannon Weaver index also. A significant positive correlation between water temperature and salinity was found by them ($r = 0.90$; $p < 0.01$).

Datta et al. (2008) during the study of diversity in the intertidal region of south Mumbai found that the low salinity in the monsoon period had strong negative effect on the abundance of intertidal organisms. They also found that low values of NO_2, NO_3, PO_4 during the monsoon period also had restricted the abundance of organisms.

Anbuchezhian *et al.* (2009) during the study of macrobenthic diversity in the coastal belt of Thoni observed that temperature was an important ecological factor which influence distribution of benthic organisms. High temperature recorded in premonsoon season influence the distribution of macrobenthic organisms. Low temperature recorded in December and January months influence higher faunal density. They found positive relationship between the abundance of benthic fauna and the concentration of organic carbon in the sediments but the relationship was not significant. Salinity was also considered to be a dominant limiting factor. The salinity level was drastically changed during November due to surface run off which caused low density in the benthic fauna in November. They also found that pH and DO didn't play any considerable role in benthic faunal assemblage.

2.3. MACRO BENTHOS

Macrobenthos are an important and integral component of all aquatic ecosystems which lives on, in or near the bottom of water bodies (Hossain, 2011). Benthic organisms serve as direct food for other higher trophic organisms (fin and shell fishes) and act as ecological engineer recycling the organic matter and other debris (Gray and Elloitt, 2009). They have been used for long time as indicator of water and sediment quality by major bio-monitoring programs (Gray and Elloitt, 2009). Some benthic organisms (shrimp, crab, oyster, clametc.) are important source of protein for human and some are used as ingredients for fish and poultry feed production (Hossain *et al.*, 2009). Lime and pearl are two important products of macro-benthos (Aitken *et al.*, 1988). A detailed and complete knowledge of the bottom fauna is not only important for the determination of productivity but is also helpful in understanding the diversity of the habitat (Raveenthiranath, 1990). One of the main goals of benthic ecology has been to understand the mechanisms regulating relationships between physico-chemical parameter and organisms (Aller *et al.*, 2001).

Mitra *et al.* (2001) made a study on preliminary observations on macro-benthic mollscan diversity in relation to physio-chemical variables in Bay of Bengal coast at ten stations and found 9 numbers of molluscan species and highest biodiversity was found to be 1.604 at station 8 (Lothian Island). The molluscan species included *Nerita articulata, Nerita smithi, Nerita violacea, Telescopium telescopium, Cerithedia cingulata, Cerithedia obtusa, Enigmonea aenigmatica, Saccostrea cucullata, Cymia lacera.* They also found a strong positive relation of Shannon Weaver species diversity index with surface water salinity and pH (table no. 1) reveals the preference of molluscan species towards high saline habitat in the coastal and estuarine zone. According to them benthic molluscan communities thrive in dynamic ecosystem which exhibit pronounced seasonal variation. They also found study on community structure of the molluscan assemblage is very important to understand the tolerance of each species or species assemblage with respect to changing physio-chemical variables of the ambient medium.

Magdoom *et al.* (2010) studied on seasonal distribution of macrobenthos from the Gulf of Mannar (south east coast) of India and found the total macrobenthos consisting of 21 species in 5 major groups, viz. crustaceans (6), gastropods (5),

bivalves (4), polychaetes (11) The population densities of benthic macrofauna ranged from 307 to 497 ind./m^2, the diversity ranged from 1.0630 to 1.2480 the richness varied between 3.263 and 4.324, and the evenness varied between 0.8885 and 0.9557. Bivalves including *Meretrix meretrix, M. casta, Anadara granosa,* and *Cardium setosum.* Gastropods including *Umbonium vestiarium, Natica* sp., *Littorina scabra, Cerithedia cingulata* and *Turritella attenuata.*

The intertidal ecosystem is rich in biodiversity and plenty of data is available on biodiversity of intertidal ecosystem in India (Goswami, 1992). Datta *et al.* (2008) worked on species diversity in the intertidal region of south Mumbai. During the study, a total of 49 species of intertidal organisms (41 gastropods, 4 pelecypods, and of one each crustacean, anthozoan, cephalopod and ophiuroid) belonging to 22 families and 29 genera. They found that Maximum value of Pielou's evenness index was in February and April (0.81) and minimum in August (0.57). As the Shannon's diversity index is dependent on evenness of distribution, it was also highest in April (2.91) and minimum in August (1.98). The highest value of Margalef richness index was found in December (5.18) and lowest in November (3.46). They also found that Pollution and other environmental disturbances in the coastal waters play a major role for changes in benthic community and Seasonal variations in the environmental factors and biological properties of organisms (breeding, gonadal maturity etc.) influence the occurrence of organisms in the intertidal region. The most crucial factor responsible for the death of intertidal organisms is salinity which decreased considerably during monsoon.

Day and Mitra, (2005) studied on molluscan community around Digha coast and found 90 species belonging to 46 families. It includes 54 species of gastropods, 2 species of scaphopods, 29 species of bivalves and 5 species of cephalopods. Out of these 82 species reported from intertidal zone. The intertidal coastal sandy areas showed the presence of 73 species of which 43 species were gastropods forming major constituent and four species of molluscs on hard substratum, e.g., *Saccostrea cucullata, Enigmonia aenigmatica, Gurineum natator* and *Thais blanfordi* were evaluated ascertaining their diversity index (Shannon Weaver, 1949). Out of these four species *Saccostrea cucullata* was found during the entire study period. They found that the pre monsoon season to be the best in terms of biodiversity. They

observed the drastic fall in population density and diversity index during monsoon due to sudden fall of *Saccostrea cucullata*. Complete absence of *Enigmonia aenigmatica*, *Gurineum natator* and *Thais blanfordi* during the month from July to December in 2002 and August to December in 2003 may be attributed to low aquatic salinity due to high precipitation and run-off.

Dey *et al.* (2005) studied on distribution of intertidal malacofauna at Sagar islands at four stations (Kachuberia, Costala, Chemaguri, Gangasagar) and recorded a total of 37 species of molluscs of which 24 species were gastropods and 13 bivalves. 31 species had been recorded from Sagar south (Gangasagar), followed by 14 species from Chemaguri, 11 from Kachuberia and 9 species from Costala. They found Gangasagar is in the immediate vicinity of the sea thus having the maximum influence of marine species. They also recorded maximum species from the mud banks and mud flats. The species common on these areas were *Assiminea brevicula, Assiminia beddomeana, Telescopium telescopium, Cerithidea cingulata, Stenothyra deltae, Nassarius stolatus, Haminea crocata, Onchidium tenerum, Macomo birmanica, Theora opalina* and *Strigilla splendida*. In the sandy beach the malacofauna observed from mid tidal zone to low tide mark and the common species were *Nassarius stolatus, Natica tigrina, Natica gualteriana, Acrilla acuminate, Amalda ampla, Donax incarnatus and Meritrix meritrix.* Others *are Barnea canida* and *Solen kempi.* In the pillar of jetty, dykes *Littorina scabra* was observed as the dominant malacofauna followed by *Saccostrea cucullata*, *Thais lacera* and *Onchidium sp.*

The estuarine and coastal water benthic communities on West and East coast of India were studied by many workers. Prabhu *et al.* (1993) worked on Macrobenthic fauna in nearshore sediments of Gangolli, west coast of India. Ansari *et al.* (1994) worked on Macrobenthic assemblage in the soft sediment of Marmugao harbour, Goa (Central west coast of India). Prabha Devi *et al.* (1996) worked on Water quality and benthic fauna of the Kayamkulam backwaters and Arattupuzha coast along southwest coast of India.

Anbuchezhian *et al.* (2009) studied on macrobenthic composition and diversity in the coastal belt of Thoni and found 54 species of which 24 species belonged to

gastropods, 15 species to bivalves, 5 species to amphipods, 6 species to decapods and 4 species to echinoderms. In general, the species diversity varied from 0.531 to 1.175. High species diversity indices was observed during post-monsoon followed by pre-monsoon. The species richness varied from 0.36 to 0.48, 0.47 to 0.62. Species richness was more during monsoon followed by pre-monsoon and post-monsoon seasons. Species evenness varied from 0.38 to 0.73; 0.34 to 0.71. Evenness was more during premonsoon period followed by monsoon and postmonsoon period. The species composition of the macrofauna showed the dominance of gastropods followed by polychaetes, bivalves, amphipods, decapods and echinoderms. They also found that the single species of gastropods *Cerethidea cingulata* was dominant. It shows the substratum favours the high proliferation of *Cerethidea cingulata.* Among the bivale species *Gafrarium sp, Mactra cuneata, Lunulicardia retusa, Vepricardium asiaticum, Meritrix casta* And *Anadora granosa* were found to be common. Amphipods, decapods and echinoderms contributed minimum percentage.

Abundance and seasonal variation of marine molluscs have been reported throughout India by different authors. Jayaseeli and Murugan (2003) have recorded 77 species of bivalves on Tuticorin coast. Khade and Mane (2012) dealed with the diversity of molluscs at four localities from West coast of India. The availability of marine molluscs in north east coast of India were also done by several worker. The malacofauna of Hoogly estuary was also studied by Subba Rao *et al.* (1995). The availability of marine molluscs in north-east coast of India were also done by some worker. The distribution of intertidal malacofauna at Sagar Islands was reported by Dey *et al.* (2005) and detailed study of mangrove associate molluscs of sundarbans by Dey (2006). Subba Rao (1991) recorded 324 species from entire coastal part of Odisha, among them 170 species belonging to gastropods, 147 species of bivalves, one species of Schapods and 6 species of cephalopods. In Rushikulya estuary a total of 41 species of which gastropods consists of 14 species and bivalves 27 species were recorded (Subba Rao *et al.*, 1992).

Paul *et al.* (2014) documented a total of 63 species of molluscs, among them 32 species of gastropods belonging to 22 genera out of 19 families and 31 species of bivalves belonging to 23 genera out of 19 families from the selected localities of Digha, Shankarpur, Bakkhali (West Bengal) Talsari and Chandipur (Odisha) coasts.

They reported that in family wise landings among gastropods the maximum recorded family were Naticidae, Nassariidae and Trochidae and minimum representation were from the family Ellobidae, Neritidae, Epitomidae and in case of bivalves the most abundant families are Veneridae, Mactridae and Tellinidae and the family Arcidae, Solenidae and Cultellidae contributed the least numbers. They found among the gastropods group of fauna *Umbonium vestiarium*, *Natica tigrina, Cerithidea cingulata*, *Turritella attenuata*, *Turricula javana* was dominant during the study period and the other species followed by *Architectonica perspectiva*, *Pugilina cochlidium*, *Olivancillaria gibbosa* was not dominant and very less in number. They also found that the lowest density was in the month of July because of monsoon season when the salinity and temperature dropped down. The population density increased steadily from September to reach the maximum number in December during post-monsoon season. Seasonal contribution of gastropods and bivalves both was maximum in the post monsoon followed by premonsoon and monsoon season which might be due to stable environment factors such as dissolved oxygen and salinity.

Yennawar *et al.* (2014) studied on macro-benthic fauna around Digha coast (Talsari, Udaipur, Digha, Mohana, Shankarpur) and found 141 species under 88 genera and 52 families. They found that phylum Mollusca was most abundant among all the study location. They were recorded 106 species of mollusca from 32 families. Arthropoda contributed 21 species from 11 families. Digha was represented with 32 species of bivalves from 10 families, 9 species of gastropods from 8 families, 8 species of arthropods from 6 families. The percentage composition at Digha location was 65% bivalve, 18% gastropods, 14% arthropods and 2% cnidarian. The major dominant species were *Mactra cuneata*, *Mactra dissimilis*, *Mactra luzonica, Mactra mera, Bernea candida*. They also found the maximum species diversity was during the postmonsoon and winter months (October-January) which highlights the recruitment and settlement of many species during the period and the minimum during the early summer months (March-April). The population studies of benthic invertebrates showed that the high species diversity at Udaipur and Talsari provides suitable substratum for macrobenthic invertebrate population. Old Digha with low species diversity showed many species in sparse distribution which may be due to increasing anthropogenic activity in the area. This location showed only two species

with moderate distribution which was due to construction of wall and cement boulder around coast provided suitable substratum of the settlement of rock oyster. They found *Balanus amphitrite, Metuta planipes, Portunus sanguinolentus, Charybdis feriata, Ocypoda macrocera, Scylla serrata, Portunus sanguinolentus, Portunus pelagicus, Uca triangularis* etc with other crustacean species. *Tachypleus gigas and Carcinoscorpius rotundicauda* were the two species of chelicerates found. The bivalves found were *Anadara antiquata, Saccostrea cucullata, Mactra luzonica, Mactra mera, Macoma birmanica, Donax scortum, Meretrix meretrix, Paphia malabricus, Tachycardium asiaticum, Bernea candida* etc. The gastropods found were *Umbonium vestarium, Telescopium telescopium, Natica tigrina, Polinices didyma, Turritella attenuata, Thais lacera, Nassarius stoletus, Olivancillaria gibbosa, Turricula javana, Pugilina cochlidium, Architectonica perspectiva* etc with other gastropods.

Pandya and Vachhrajani (2013) studied on brachyuran crab diversity of lower estuarine mud flats of Mahi River of Gujrat, India and recorded 10 crab species belonging to eight genera and eight families from the downstream of the estuary and surrounding areas. The species found by them are *Uca lactea annulipes, Uca dussumieri, Macrophthalmus depressus, Macrophthalmus brevis, Dotilla intermedia, Scylla serrata, Cardisoma carnifex, Ashtoret lunaris, Parasesarma pictum, Metopograpsus frontalis.* Among them family Ocypodidae and Macrophthalmidae reported two species in each while rest of the families showed occurrence of single species. They found that sediment type and intertidal zonation were seen to be the governing factors in the brachyuran distribution. *Macrophthalmus (Macrophthalmus)brevis , Ashtoret lunaris, Dotilla intermedia* preferred sandy sediment where the other species preferred silty or silty clayey sediment.

Satheeshkumar (2012) made a study on mangrove vegetation and community structure of brachyuran crabs as ecological indicators of Pondicherry coast, south east coast of India at four stations and found totally 22 species of brachyuran crabs belonging to 12 genera and 5 families. Crabs belonging to the family Portunidae and Ocipodidae are most dominant group. They found maximum diversity values during post monsoon. They observed seasonal fluctuation in the population density of crabs and *Uca lactea annulipes, U. inversa* and *U. triangularis* are largely caught during monsoon. *Scylla*

serrata and *T. crenata* are mostly caught during post monsoon. *Portunus sanguinolentus* and *C. lophos were* observed mostly near the mouth region.

Varadharajan *et al.* (2010) studied on seasonal abundance of macro benthic composition and diversity along the south east coast of India (Tamil Nadu) at five different stations (Arukkattuthurai, Point calimer, Mallipattinam, Manalmelkudi, Aiyammpattinam) and found a total of 112 no. of species. Among them Polycheates are dominant (61 no.) and Decapods and bivalves are the second dominant group, gastropods and others remaining groups were contributed minimum percentage. Among the bivalve species *Anadara granosa, A. veligers, Cardium setosum, C. veligers, Crassostrea madrasensis, Donax cuneatus, D.veligers, Katalysia opmia, Meretrix casta, M. merretrix, M. veligers, Paphia textile, Pecten sp and Placenta placenta* were commonly found. Among the decapods 12 species were recorded in all five stations. *Scylla tranqubarica, S. serrata, Portunus pelagicus, P. sanguinolentus, Charybdis feriata, C. sp, Penaeus semisulcatus, P. monodon, P. indicus, Idunella sp, Metapenaeus dopsoni,* Peneaid shrimp larvae were dominant among the decapods (crustaceans). Among the gastropods the recorded species are *Bullia vitata, Cerethedia cingulate, Cerithium sp, Littorina scaraba, Natica sp, Oliva nebulosa, Turritella attenuata, Umbonium vestiarium, Xancus sp.* They found that high temperature in premonsoon season influence the distribution of macro-benthic organisms. Low temperature recorded in December which influence higher faunal density. They also found that low density in November was due to heavy downpour which caused drastic fluctuations in the sampling stations. They found salinity also a dominant limiting factor, in the distribution of benthic fauna. They did not found any considerable role of DO and pH in benthic faunal assemblage.

Kumar and Khan (2013) studied on the distribution and diversity of benthic macro-invertebrate fauna in Pondicherry mangroves, India at four stations (Veerampattinam, Thengaithittu, Ariyankuppam, Murungapakkam) and found a total of 76 invertebrate taxa including 35 molluscs (16 bivalves and 21 gastropods) and 22 crustaceans. They found gastropod densities ranged from 36–333 organism/m^2. Among gastropods *Cerithedia cingulata* was the most dominant, followed by *Cassidula nucleus*, *Melampus ceylonicus*, *Sphaerassiminea minuta* and *Telescopium telescopium*. Among bivalves *Crassostrea madrasensis* was the most dominant,

followed by *Meretrix meretrix*, *M. casta*, *Perna viridis* and *Anadara granosa*. Densities of brachyuran crabs ranged from 29–71 number/m^2. Among brachyuran crabs belonging to 12 genera and 5 families were recorded; crabs belonging to the families Portunidae and Ocipodidae were the most dominant, representing a total of 16 species. They found highest diversity in post monsoon season and lowest in monsoon season. They also found Shannon diversity (*H'*) which varied between the stations ranging from 1.80- 2.83 and Pielous's evenness (*J'*) index value was minimum during monsoon (*J'*=0.45) and the maximum value during pre-monsoon (*J'*=0.72). They found the faunal density ranged between 140 to 1113 number/m^2.

Abundance and distribution of sub tidal macrobenthic diversity in shore water off Gulf of Kutch, Gujrat was studied by Shivanagouda and Bhat (2013). During this study they found a total of 34 number of species out of which gastropods consists of 9 in number, bivalves consists of 7 in number in all stations. Among gastropods *Cerithidea cingulate, Nassarius pullus, N. dorsatus, Umbonium* sp, *cirratulidae* sp and *Dentalium* sp were observed more abundant. Bivalves are mainly represented by *Solen lamarcki*, *Epitonium scalare*, *Cucullea cucullata* and *Donax cuneatus*. In sub tidal habitat, gastropods recorded highest percentage of density whereas polychaete showed more diversity. Crustacean showed second highest density. The Shannon diversity index values (H) were ranged between 2.80 to 2.65 at all the stations. The evenness values were ranged from 0.8697 to 0.8967.

Thilagavathi *et al.* (2013) worked on distribution and diversity of macro-benthos in different mangrove ecosystems of Tamil Nadu coast, India and found a total of 292 macro-benthic faunal species represented by six diverse groups of which polychaetes, gastropods, bivalves, amphipods, isopods and cumacea were the most important groups. Polychaetes were dominated in the macro-benthic fauna (188 species) and contributed numerically up to 64.38% of the population. Bivalves consist of 12 species and contribute to 4.11% of the total fauna production. Gastropods consist of 17 species and contribute to 5.82% of the total fauna population. The bivalves species found were *Anadara granosa, Anadara rhombea, Cardium setosum, Donax scortum, Donax cuneatus, Donax spinosus, Meretrix meretrix, Modiolus metcalfei, Perna viridis, Pincdata fucata, Placenta placenta, Paphia malabarica.* The

gastropods species found were *Bullia vitata, Cerithedia cingulate, Cerithedia obtusa, Epitonium scalare, Littorina scabra, Nassarius variegatus, Natica tigerina, Oliva nebulosa, Turritella attenuata, Turritella albenuata, Turritella acqutangula, Umbonium vestiarium, Telescopium telescopium, Murex tribulex, Nassa jacksoniana, Nassarius scabra* and *Oliva nebulosa.* They also found the low benthic richness and diversity during monsoon might be due to the high fresh water inflow with low saline condition which in turn affect the distribution of benthos.

Surya Rao and Mitra (1998) recorded 149 species of molluscan fauna from Mahanadi estuary, Odisha in which gastropods comprise of 70 species, bivalves 75 species, schapods 1 species and cephalopods 3 species. Rama Rao *et al.* (1992) species of mollusca from Rushikulya estuary, Odisha of which gastropods consists of 14 species and bivalves 27 species.

Mitra (2013) studied on malacofauna of subarnarekha estuary (Balasore Odisha): their economical importance and conservation at four stations (Talsari Kirtania, Udaypur, Pantei) and found a total 81 species of molluscs belonging to 61 genera and 41 families. He found a maximum 73 species of molluscs at Talsari, 15 species from Udaypur. He found very low faunal diversity at Pantei, the uppermost reaches of the estuary, probably due to very lower salinity. He also found among the molluscs the bivalves dominated in the river bed and the canal bed are *Meritrix meritrix, Anadara granosa, Macoma birnanica, Sanguinolaria accuminata, Glaconoma sculpta,* and *Bernea canida.* The dominated gastropods are *Pugilina cochilidium* and *Cerithidea cingulata.* The mudflat associated bivalves are *Placuna placuna, Meritrix meritrix, meritrix casta, Paphia textiles* and *Mactra luzonica* and the dominated gastropods are *Bursa spinosa, Tonna sulcosa, Murex tribulus* and *Umbonium vestriam.*

Khade and Mane (2012) worked on diversity of bivalves and gastropods of some selected study localities of Raigad district, Maharashtra, west coast of India and found a total of 49 gastropod species and 14 bivalve species. A total of 8 bivalves and 12 gastropods were found at Dada. Total 6 bivalves and 30 gastropods found at Jivanabander. Total 5 bivalves and 22 gastropods recorded at Harihareshwar. And 3 bivalves and 3 gastropods were recorded at Shrivardhan. They observed that bivalves

are more diverse in muddy as well as mangrove habitats and gastropods are much more diverse on rocky habitat. They also found the lowest density was in the month of July because of monsoon season. In monsoon, due to self-dilution of the body fluid, the sensitive molluscs were unable to adjust the fluctuating osmotic balance quickly hence their mortality was high. After the month July because of adjustment, the mortality rate of molluscs decreased gradually. As a result, density of molluscs increased. It was noticed that in the month of July, the salinity and temperature dropped down which made the condition adverse for the molluscs (Patole, 2010). The population density was at its peak in the month of November, during post monsoon period.

Chatterjee and Chakraborty (2014) worked on feeding behaviour and functional role of some selected species of brachyuran crabs in nutrient cycle at coastal belt of midnapore (East), West Bengal, India with 10 species of brachyuran crabs for his work which were *Sesarma bidens, Sesarma taeniolatum, Metopograpsus maculatus, Metaplax intermedia, Uca acuta acuta, Uca lactea annulipes, Uca triangularis bengali, Ocypoda macrocera, Dotilla blanfordi* and *Dotillopsis brevitarsis.*

Macrobenthos of Kakinada Bay in the Godavari delta (Andhra Pradesh), east coast of India: comparing decadal changes was studied by Raut *et al.* (2005). During the study they found 95 species of macrobenthos among them 32 species were contributed upto 95%. The most predominant species were *Cerithidea cingulata, Paphia textrix, Modiolus undulatus, Typhlocarcinus sp., Tellina iridescens, Abra maxima, Acaudina molpadioides* and *Nassarius foveolatus.* They found paucity of gastropods and bivalves during July and November. They also found there was a general decrease in epifaunal abundance with salinity (Pearson correlation $r = 0.2925$; $n= 56$; $P < 0.05$). The Shannon Weaver biodiversity index were ranged from 0.038 to 1.502.

Spatial distribution of molluscan fauna in Minicoy Island, Lakshadweep, India were studied by Susan *et al.* (2012). A total of 70 species of molluscs which included 52 gastropods and 12 bivalves were found during the study. The total density of macro fauna were varied from 137-604 number/0.25m^2. The highest biomass was

observed during postmonsson season at southern sea grass bed and the least was observed during premonsoon season.

Bandekar *et al.* (2011) studied on biodiversity of crabs in Karwar mangrove environment, West coast of India and found 13 species of crab which were *Sesarma quadratum, Metapograpssus latifrons, Metapograpssus messor, Grapsus albolineatus, Metapograpsus latifrons, Ocypodidae cordimonas, Ocypoda ceratophthalmus, Uca annulipes, Uca vocans, Dotilla myctiroides, Scylla serrate, Thalamita crenata, Matuta lunaris.* They found the high crab population during monsoon and post monsoon months during the study. They also noticed low salinity and possible substrate changes in the substrate composition might be attributed to greater abundance.

2.4. MACROBENTHOS STUDIES OUT SITE OF INDIA

Asadujjaman *et al.* (2012) studied the distribution of intertidal macrobenthos of Hatiya and Nijhum Dweep of Bangladesh during premonsoon. They found macrobenthos which included polychaetes (45.03 %), oligochaetes (16.65 %), shrimp larvae (13.93 %), crab (9.63 %), gastropods (3.56 %), isopods (1.15 %), bivalves (1.15 %), copepods (0.73 %), annelids (0.42 %), amphipods (0.63 %) and others (7.12 %). Gastropods constituted the density of 53.97 number/m2 and had its highest density 288.89 number/m2 and lowest 22.22 number/m2. Maximum value 111.11 number/m2, minimum 11.11 number/m^2 and constituted 17.46 number/m2 over all. Crab constituted Maximum value 111.11 number/m^2) and minimum (11.11 number/m^2). And the maximum density of all the species were found 4511 number/m^2 and the minimum were 433 number/m^2.

Hossain and Hossain (2009) studied on intertidal macrobenthos of Chittagong coast of Bangladesh at four sites and found polychaeta, amphipoda, bivalves and crabs at all four sites, gastropoda at three sites and sipuncula, oligochaeta at two sites. The maximum density of macro invertebrates were found 6402.78 number/m^2. They also found that south Kattoly was most abundant with macrobenthos which may be due to the high organic content in the sediment.

Nassaj *et al.* (2010) worked on species diversity of macrobenthic communities in Salakh region, Qeshm Island, Iran and found Polychaeta (54.14%) were the most dominant group followed by the crustacean (27.24%), amphipods (9%), gastropoda (8%), bivalvia (7%), copepoda (2%) and other group (4%). They observed the numerical abundance of macrobenthos was between 2937 to 1008 number/m^2. The highest Shannon Weaver index was found 1.878 at summer. The gastropods found were *Haminoea uitera, Eulima Polita, Turitella torulosa,* Crasipira sp, *Acilla scaphella, Dentalium octangulatum* and *Pupa affinis.* The bivalves found were *Dosinia alta, Telinia sp*, and *Bulla sp.*

Analysis of macrobenthic assemblages of coastal lagoon Illawarra, New South Wales, Australia were studied by Li and Morrison (2011). In total, 45 species of macrobenthos were identified by them. Mollusca represented as the most abundant taxon with 17 species (38%), followed by polychaeta with 16 species (36%), crustacea with 9 species (20%), Pisces with 1 species (2%) and other groups with 2 species (4%). The Shannon Weaver index among 15 stations were varied from 0 to 2.71.

3. MATERIALS AND METHODS

3.1. STUDY AREA AND ITS ENVIRONMENT

The two coastal stations are selected for the study of macro benthic molluscan and crustacean biodiversity in Purba Medinipur District of West Bengal. The first one is intertidal zone of Mandarmani Sea Beach and the second one is Gopalpur Sea Beach (near Junput). Among two stations Mandarmani is a seaside resort village and famous as a tourist spot and because of this beach is disturbed with human pressure. The entire beach area of Mandarmani is sandy in nature. The second station Gopalpur is relatively undisturbed and anthropogenic activity is less than the first one and the beach is muddy in nature but the upper part of supra-littoral zone is quite sandy in nature which is very minimum compare to total beach profile. Vegetation is found in high tide zone of Gopalpur beach which show that the sea moves backwards. Fishing is one of the main occupation in both the stations. The Mandarmani beach is approximate 13km long and argued to be the longest derivable beach of India situated between Dadanpatrabar and Tajpur (www.westbengaltourism.gov.in/web/guest/sea-mandarmani, 2015 and www.mandarmani.com/mandarmani.html, 2015). But the Gopalpur beach is relatively short and situated between Junput and Bankiput sea beach. The two stations are rich in terms of Macro-benthic faunal composition. The varied and diverse nature enticed to study the biological and physio-chemical nature of the selected two stations.

3.2. WORK PLAN OF THE STUDY

The study was carried out for a period of twelve months from July, 2014 to June, 2015. About 1km long coastal stretch were selected in the intertidal zone of the two selected stations. Samples were collected in low tide condition monthly. The physical, chemical and biological parameters of each sample studied in the investigation are presented diagrammatically in figure-3.

Figure-1. Map showing the location of study area of the Mandarmani station.

Figure-2. Map showing the location of study area of the Gopalpur station.

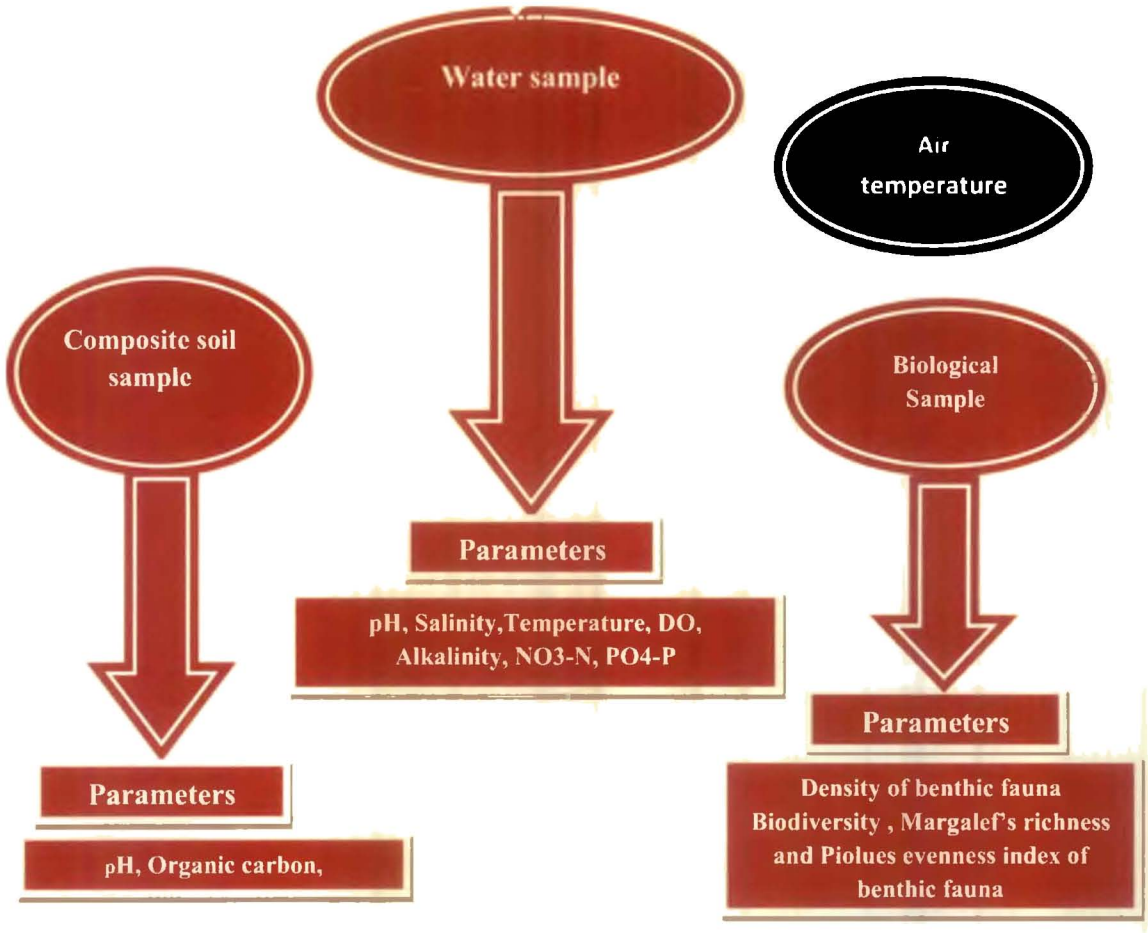

Figure-3. Diagrammatic representation of work plan of the study.

PLATE-1

Fig.I: A view of Gopalpur beach at high tide condition.

Fig.II: A view of Gopalpur beach at low tide condition.

Fig.III: A view of Gopalpur beach showing fisheries activity.

PLATE-2

Fig.IV: A view of Mandarmani beach at high tide condition.

Fig.V: A view of Mandarmani beach at low tide condition.

Fig.VI: A view of Mandarmani beach with anthropogenic activities.

3.3. COLLECTION AND PRESERVATION OF SAMPLES

3.3.1. WATER SAMPLES

Water samples were separately collected from every sampling stations from three different points in labelled and pre-treated polyethylene bottles by random sampling technique taking all the necessary precautions not to entrap any air bubbles and without disturbing the bottom sediment. The temperature of water and air was recorded on the spot by using centigrade thermometer (0 to 50°c).The parameters like dissolve oxygen, alkalinity, pH and salinity were estimated in the field and the Nitrate and Phosphate were estimated in the laboratory. The water samples were fixed and preserved carefully in deep freeze (APHA, 2002).

3.3.2. BIOLOGICAL SAMPLES

Macro-benthos from each station from different places were collected using $1m^2$ quadrate constructed from nylon ribbon and wood sticks and sieved through a 40 no. sieve (256 mesh cm^{-2}). After collection the benthos samples were preserved in 5% formalin for further analysis.

3.3.3. SOIL SAMPLES

Soil samples from each sampling site were collected by dredging separately and prepared a composite soil sample for the estimation of different soil parameters. Then the samples were air dried and pulverized to fine size and sieved through a standard test sieve. Well dried and sieved soil samples were stored in plastic container for estimation of soil pH and soil organic carbon.

3.4. METHODOLOGIES OF ESTIMATION

3.4.1. PHYSICO -CHEMICAL PARAMETERS OF WATER

3.4.1.1. ESTIMATION OF TEMPERATURE

The surface water temperature was recorded by using a mercury centigrade thermometer (0 to 50°c). It was immersed at surface level for five minutes. Then the temperature for water was recorded from the thermometer (Adoni *et al.*, 1985).

3.4.1.2. WATER pH

The pH of water samples were measured on the spot following the electrometric method by using HANNA pHep® pocked-sized pH meter.

3.4.1.3. WATER SALINITY

The salinity of water samples were measured on the spot by using Erma portable hand refractometer (RHS-10ATC).

3.4.1.4. DISSOLVED OXYGEN (APHA 2002)

Dissolved oxygen (DO) of the each site of the water body was estimated by Winkler's Iodometric titration method. After collecting the water samples from the each site in a 300 ml DO bottles were fixed by adding Winkler's A ($MnSO_4$) and Winkler's B (alkaline solution) on the field. The obtained precipitation was dissolved by conc. H_2SO_4. The sample was then titrated against 0.025 (N) $Na_2S_2O_3$ solutions using starch as an indicator till blue colour turned into colourless and expressed as mg/l after calculation.

Dissolved oxygen (mg/l) = $(N\times S)/V \times 1000$

Where,

N= Strength of $Na_2S_2O_3$

S= Volume of $Na_2S_2O_3$ consumed (ml)

V= Volume of water sample (ml)

3.4.1.5. TOTAL ALKALINITY (APHA, 2002)

Total alkalinity was calculated from the sum of bicarbonate and alkalinity following the acid base titration method. 50 ml of water sample was taken in a 100 ml of conical flask. Then 2-3 drops of phenolphthalein indicator was added to it. If pink colour developed, sample was titrated against 0.02N H_2SO_4 till the colour disappears. The burette reading was noted down and the sample was saved for next step. Two drops of methyl orange indicator was added to it and the solution turn to orange in colour. Titration was continuing with 0.02N H_2SO_4 until the orange colour turn into pink. The total burette reading was noted down. If pink colour did not appear with phenolphthalein indicator, the sample was titrated against 0.02N H_2SO_4 after adding methyl orange as

indicator. The total alkalinity calculated by the following formula and expressed as mg/l as $CaCO_3$.

Total alkalinity (mg/l as $CaCO_3$) = (S×1000)/V

Where,

S= Volume of 0.02N H_2SO_4 consumed (ml)

V= Volume of water sample (ml)

3.4.1.6. PHOSPHATE PHOSPHORUS (APHA, 2002)

Phosphate phosphorus of the each site of the water sample was estimated by Stannous Chloride method. The 10 ml of water sample was taken in a test tube and added 1 drop of phenolphthalein indicator. If sample turned into pink then strong acid (H_2SO_4 and HNO_3 solution) was added to discharge the colour. Then 0.4 ml of ammonium molybdate and 1 drop of stannous chloride were added to it. Then the blue colour was developed in sample. After 10 minutes, but before 12 minutes, the absorbance was taken in spectrophotometer at 690 nm wave length.

3.4.1.7. NITRATE NITROGEN (Bain *et al.*, 2009)

Nitrate nitrogen of each sample was estimated by Brucine Method. First 10 ml of water sample was taken in a conical flask. Then 10 ml sulphuric acid solution (4:1) was added to the sample and mix well by shaking while cooling in flowing water. After cooling the sample, 0.5 ml brucine in sulfanilic acid solution was mixed by shaking. Then the sample was heated 25 minutes at 100° C in the water bath. After that the sample was placed in a cool water bath maintained 10-20°C. Yellow colour was developed in the sample. Then the absorbance was taken in spectrophotometer at 410 nm wave length.

3.4.2. SOIL PARAMETERS

3.4.2.1. pH (TAN, 1996)

For the estimation of soil pH electrometrically, 10 g of soil sample was added to 50 ml of distilled water (1: 5) in a beaker and vigorously shacked for 5 minutes. Then the mixture was kept for 30 minutes. The electrodes of pH meter (Systronics: Model No. MK - VI) were immersed into the solution and the pH value was recorded after proper calibration.

3.4.2.2. ORGANIC CARBON (Walkley and Black, 1943)

For the estimation of organic carbon, 1 gm air dried powered sediment soil sample was digested with 10 ml (N) $K_2Cr_2O_7$ and 20 ml concentrated H_2SO_4. After digestion, the digested sample was kept for 30 minutes at dark. The sample was then diluted with 200 ml distilled water and 10 ml ortho-phosphoric acid. 1ml diphenyl amine indicator was added to it. It was then titrated against 0.5N ferrous ammonium sulphate (Mohr's salt) until brilliant green colour appeared. It was expressed as the percentage of organic carbon and was calculated by following formula:

Organic carbon (%) = $10\times (B-S) \times 0.03\times 100/ (B\times W)$

Where,

B= Volume of $Fe_2 (NH_4)_2 SO_4$ consumed by the blank (ml)

S= Volume of $Fe_2 (NH_4)_2 SO_4$ consumed by the sample (ml)

W= Weight of the sample (g)

3.4.3 QUAITATIVE AND QUANTITATIVE ANALYSIS OF BENTHIC MOLLUSCS AND CRUSTACEANS

3.4.3.1. IDENTIFICATION OF STUDIED MACROFAUNA

Soon after retrieval, the organisms were preserved in 5% (V/V) formalin and brought to the laboratory (Department of Aquatic Environment Management, Faculty of Fishery Sciences, Kolkata) for further identification. The sorted organisms were first segregated into different groups and then identified to specific, generic or other higher levels to the greatest extent possible with the help of standard taxonomic references (Dey, 2006; Chakraborty *et al.,* 1986). The unidentified samples were sent to Zoological Survey of India, Kolkata for further identification.

3.4.3.2. QUALITATIVE AND QUANTITATIVE ESTIMATION

Population estimation of macro-benthic molluscs and crustaceans were done at the selected sampling stations using a $1m^2$ quadrats constructed from nylon ribbon and wood sticks were temporarily established along the stations from 9 spots of each station. The total no. was computed per m^2. The quadrat, thus formed was pushed into the sediment and the enclosed deposit was searched first and the deep burrowing organisms were counted by observing their burrows (Khade and Mane, 2012) and then collected by

digging the soil until the organism was not collected. Faunal densities are given as the number of individuals/m^2 using the formula given below. In the present study, the qualitative and quantitative assessments of benthic macrofauna were noted only to molluscs (Bivalves, Gastropods), Crustaceans and Chelicerata (horseshoe crab).

$$\textbf{Density of the species/ } m^2 = \frac{\text{Total number of individuals of the species}}{\text{Total number of quadrats studied}} \times 100$$

Reference- Muller-Dombois and Ellenburg (1974)

Number of species and the total number of individuals per species per m^2 were used to compute the species diversity index (H) as per Shannon Weaner (1964).

3.4.3.2. DIVERSITY AND EVENNESS INDEX:

3.4.3.2.1 The diversity index of benthic population was assessed by the **Shannon Weaner (1964)** calculated as:

$$H' = -\sum_{i=1}^{S} Pi\ (\ln Pi)$$

Where pi is the proportion of individuals belonging to species i and S is the total no. of species in the community.

3.4.3.2.2. The evenness index of benthic fauna was calculated by **Pielou's (1966) evenness index (J)** as:

$$J = H' / \ln S$$

Where H is the observed species diversity and S is the total no of species.

3.4.3.2.3. Margalef's richness index (r): $(S-1 / \ln(n)$

Where n is total number of individuals and S is the Number of species (Source: Wilson, 1988).

3.4.4 STATISTICAL ANALYSIS

The interaction between the different parameters of water and sediments with studied benthic macro invertebrates were tested through Pearson correlation analysis. The correlation analysis was done by statistical software IBM SPSS (version-20). All other statistical procedures were done with the help of statistical software Microsoft Excell-2013.

4. RESULTS

The results of physico-chemical and biological parameters of the coastal areas of East Medinipur studied from July 2014 to April 2015 are illustrated and geographically presented from the original data obtained in this chapter. The results of the parameters are presented here on the basis of monthly average value of each sampling station. The original data obtained from the investigations are tabulated as "Appendix" for easy reference.

4.1. PHYSICO-CHEMICAL PAREMETERS OF AIR AND WATER

4.1.1. Temperature of air:

Air temperature readings from each station of water body at the time of sampling were given in the Fig. 4(a). During the study period at Mandarmani the highest temperature was recorded as 35.5^{0}C in the month of June and the lowest value recorded was 26^{0}C in the month of December. At Gopalpur the highest temperature was recorded as 34.5^{0}C in the month of June and the lowest value was 27^{0}C in the month of December.

4.1.2. Temperature of water:

Water temperature readings from each station of water body at the time of sampling were given in the Fig. 4(b). The water temperature of Mandarmani coast throughout the year was ranging from 26^{0}C (November) to 34^{0}C (June, July) and the water temperature of Gopalpur coast was ranging from 26.5^{0}C (November) to 34.5^{0}C (June). The water temperature showed a positive significant correlation with air temperature in both station.

4.1.3. pH of water

The water pH of both stations were alkaline in nature throughout the year. pH recorded in Mandarmani coast was ranging from 7.5 (December) to 8.5 (June). At Gopalpur station the pH was ranging from 7.5 (November, December) to 8.4 (June). pH values showed a significant positive correlation with water temperature, air temperature and alkalinity in both the stations. The pH values of the waters of two stations throughout the year were presented in Fig. 4(c).

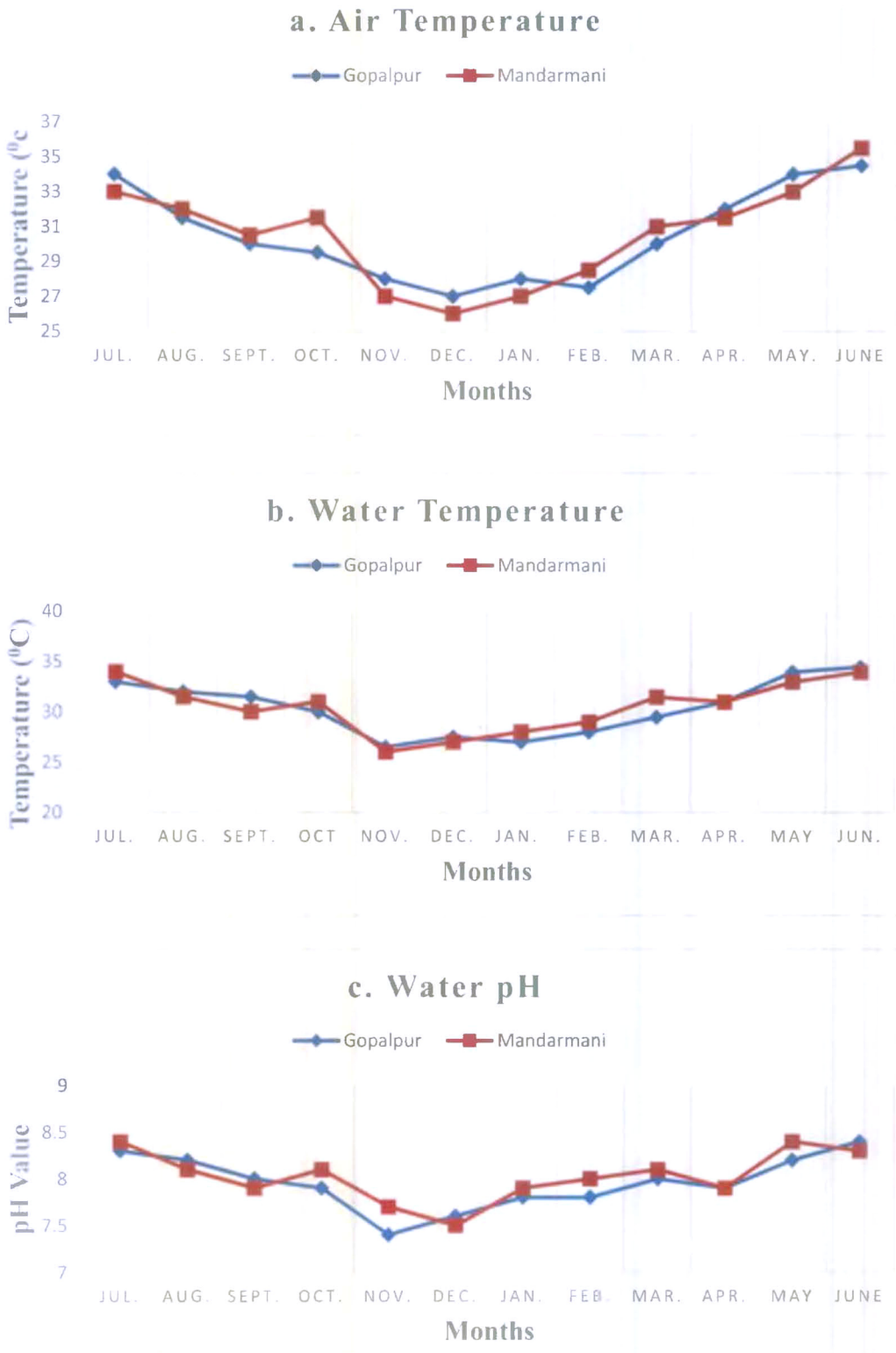

Fig. 4: Monthly fluctuation in (a) Air temperature, (b) Water temperature and (c) pH of water.

4.1.4. Salinity of water

The salinity of Gopalpur and Mandarmani showed a decreased pattern during monsoon and an increased pattern from post monsoon to Pre monsoon. At Gopalpur the highest value of salinity was recorded as 31 ppt in the months of June and the lowest value was recorded as 14 ppt in the months of September. Salinity recorded in Mandarmani was ranging from 18 ppt (September) to 34 ppt (June). Salinity values at two stations shows a significant positive correlation with sediment organic carbon and phosphate and nitrate of water. The salinity values of the waters of two stations throughout the year were presented in Fig. 5(a).

4.1.5. Dissolved oxygen of water

The fluctuations in the dissolved oxygen of the coastal water of two selected stations were reflected in Fig. 5(b). It was observed that the dissolved oxygen content of Mandarmani ranged from 3.2 ± 0.08 mg/l (June) to 5.89 ± 0.12 mg/l (September). At Gopalpur the dissolved oxygen concentration was ranged from 3.41 ± 0.09 mg/l (June) to 6.05 ± 0.09 mg/l (September). In both the stations the dissolved oxygen showed an increasing pattern in monsoon seasons and in the pre monsoon seasons very low dissolved oxygen concentration was found. DO showed a significant negative correlation with air and surface water temperature, salinity in both the stations.

4.1.6. Total alkalinity of water

Distribution of total alkalinity during July 2014 to June 2015 at each sampling station was given in Fig. 5(c). The total alkalinity value of Mandarmani varied between 91.33 ± 2.309 mg/l (December) to 127.33 ± 3.215 mg/l (July). At Gopalpur the total alkalinity value was ranged between 83 ± 2.646 mg/l to 122.67 ± 2.082 mg/l. The maximum value was found in the month of June and the minimum value was found in the month of November. Alkalinity showed a significant positive correlation with air temperature, surface water temperature and water pH.

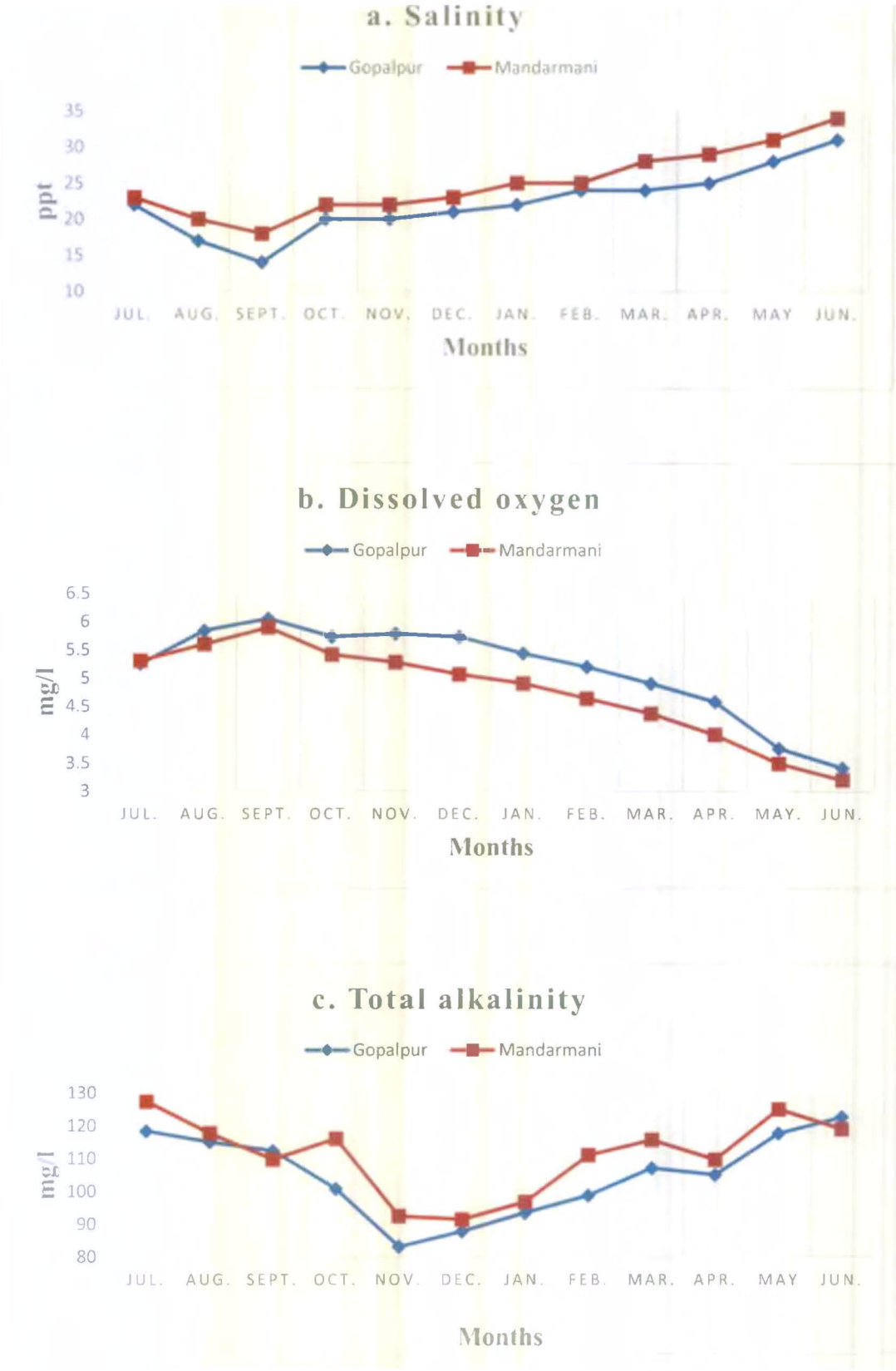

Fig. 5: Monthly fluctuation in (a) salinity, (b) dissolved oxygen and (c) total alkalinity of water.

4.1.7. Nitrate-Nitrogen of Water

The average values of nitrate nitrogen from each sampling stations were presented in Fig. 6(a). At Gopalpur the nitrate nitrogen concentrations were varied between 0.209 ± 0.025 mg/l to 0.919 ± 0.052 mg/l. The maximum value was found in the month of March and the minimum was found in the month of August. At Mandarmani the maximum nitrate nitrogen concentration was 0.838 ± 0.02 mg/l (April) and the minimum was 0.128 ± 0.014 mg/l (September). In both station the lower values of nitrate nitrogen concentration was found in the monsoon months. Nitrate nitrogen of water showed a positive significant correlation with salinity, phosphate phosphorus of water, sediment organic carbon and significant negative correlation with dissolved oxygen of water in both station. In Mandarmani station there was positive significant correlation between nitrate nitrogen and Shannon Weaver Biodiversity index.

4.1.8. Phosphate-Phosphorus of Water

The monthly variations of phosphate phosphorus of water in each sampling station was presented in Fig. 6(b). Over all a similar trend in monthly fluctuations of phosphate phosphorus was observed in both stations with a lower value during July to November months and higher value during March to June months. The values of phosphate phosphorus of Mandarmani coast was ranged between 0.117 ± 0.004 mg/l (October) to 0.784 ± 0.016 mg/l (June). The maximum values of phosphate phosphorus of Gopalpur coast was 0.767 ± 0.02 mg/l (May) and the minimum was 0.101 ± 0.012 mg/l (August). In both station phosphate phosphorus value showed a positive significant correlation with salinity and soil organic carbon and showed a negative significant correlation with dissolved oxygen of water.

4.2. SEDIMENT PARAMETERS

4.2.1. pH of the sediment

The values of the sediment pH from both sampling stations were presented in Fig. 7(a). The sediment pH of the both stations reflects slightly alkaline to alkaline in nature. The maximum and minimum values of sediment pH of Mandarmani and Gopalpur sampling stations were varied from 7.41 (December) to 8.25 (July), 7.28 (December) to 8.17 (June) respectively. In both stations the sediment pH and water pH positively significantly correlated.

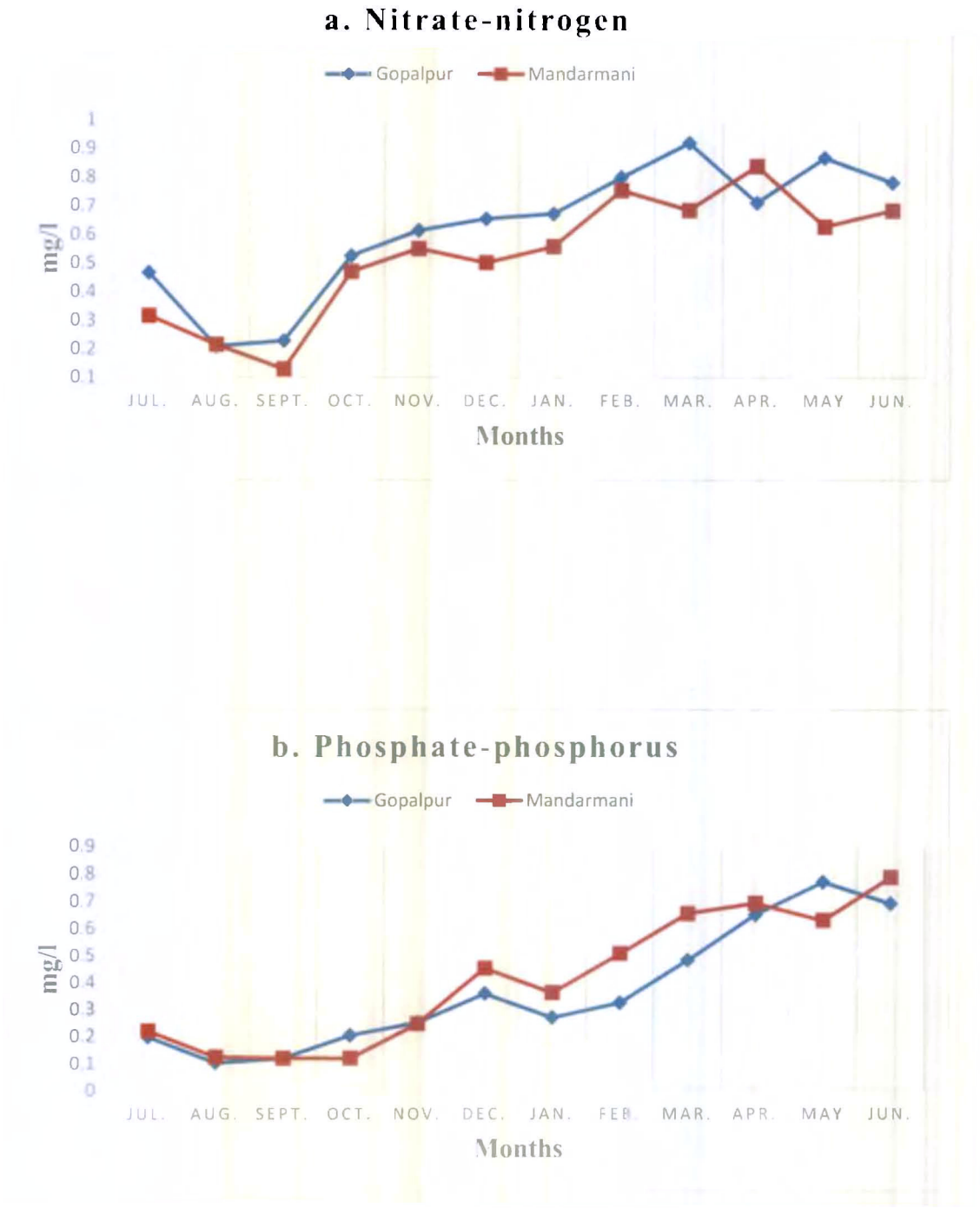

Fig. 6: Monthly fluctuation in (a) nitrate nitrogen and (b) phosphate phosphorus of water.

In both the stations the sediment pH values showed a positive significant correlation with temperature and total alkalinity of water.

4.2.2. Organic carbon of sediment

The monthly fluctuation of the organic carbon content of the sediment recorded from each station was given in Fig. 7(b). At Mandarmani the sediment organic carbon values ranged from 1.004 ± 0.0028% to 2.155 ± 0.073%. The maximum organic carbon value was found in the months of February and minimum in the months of August. In case of Gopalpur the maximum value was 2.298 ± 0.078% (March) and the minimum value was 1.154 ± 0.016% (August).

4.3. MACROBENTHIC MOLLUSCA, CRUSTACEA AND CHELICERATA

4.3.1. Composition of studied macrobenthos

A total of 47 species belonging to 31 families and 42 genera had been identified in two stations. Among them 13 species of crustaceans (arthropods) belonging to 7 families and 12 genera, 14 species of bivalves (molluscs) belonging to 9 families and 12 genera, 19 species gastropods (molluscs) belonging to 14 families and 17 genera and 1 species of chelicerates (arthropods) were found. The systematic position of the studied macroinvertebretes found in above two stations were represented in the Table. 1.

At Mandarmani sampling station a total of 40 species belonging to 28 families and 36 genera had been found. The species composition of the Mandarmani sampling station are given in Table. 2.

a. **Crustacea:** Crustaceans were the third dominant group observed in the Mandarmani station. They represented by the 8 numbers of species among them 7 numbers of species are crabs. The species represented were *Clibanarius padavensis, Dotilla blanfordi, Ocypoda macrocera, Varuna litterata* (October-November), *Scylla tranqueberica* (August-November), *Charybdis rostata* (July-October), *Balanus sp* (April), *Metuta planipes* (July-November). Species *Ocypoda macrocera, Clibanarius padavensis, Dotilla blanfordi* were found throughout the study of observation and these 3 species are one of dominant species. The crustaceans were dominated during monsoon to early post monsoon season.

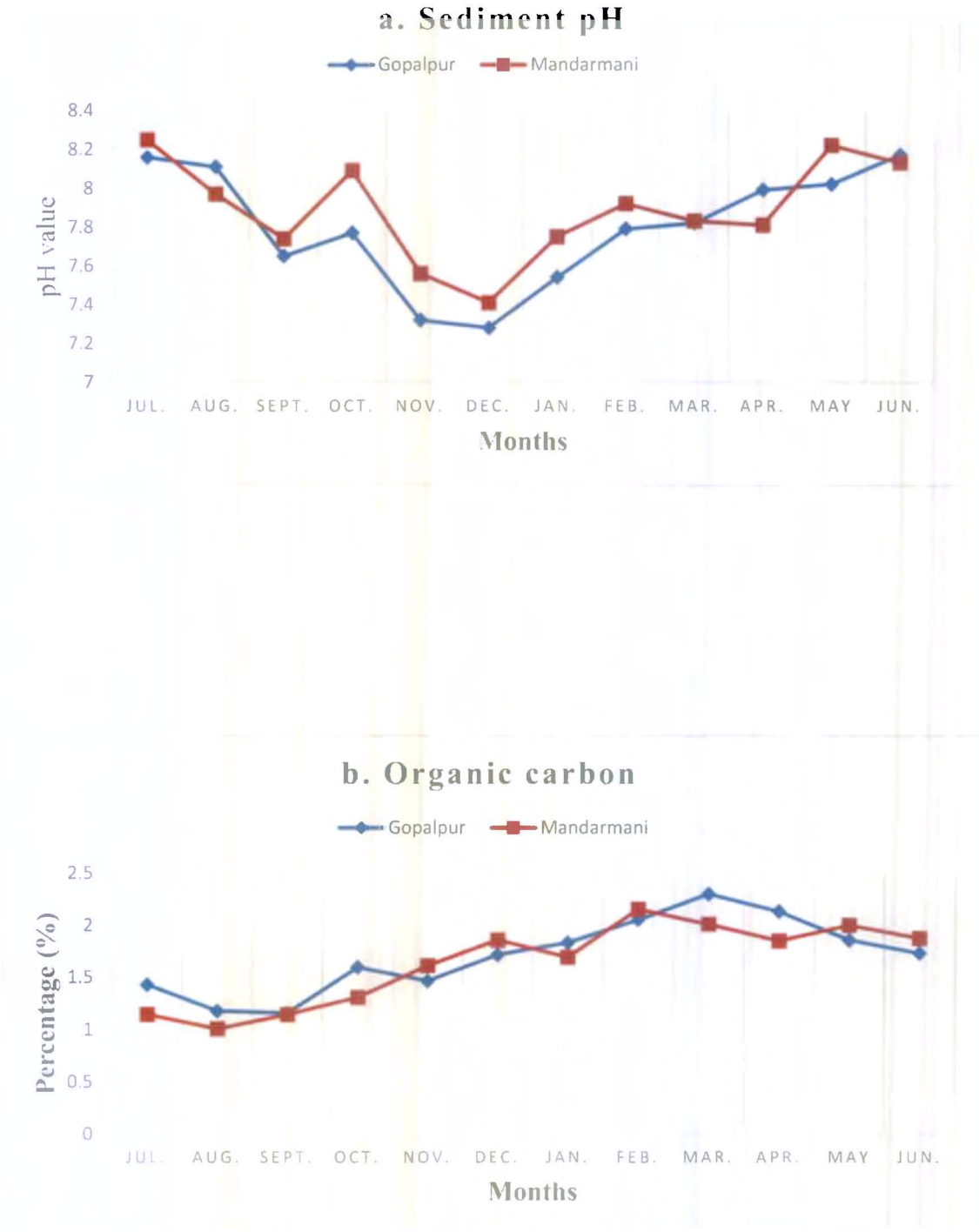

Fig. 7: Monthly fluctuation in (a) pH and (b) organic carbon of sediment.

Table. 1: Systematic position of the macrobenthos of two stations.

Phylum	Subphylum	Class	Order	Family	Species
Arthropoda	Crustacea	Malacostraca	Decapoda	Diogenidae	*Clibanarius padavensis*
				Ocypodidae	*Uca rosea*
					Uca lactea
					Dotilla blanfordi
					Ocypoda macrocera
				Varunidae	*Varuna litterata*
					Metaplax intermedia
				Portunidae	*Scylla tranqueberica*
					Portunus sanguinolentus
					Charybdis rostata
				Matutidae	*Metuta planipes*
				Macrophthalmidae	*Macropthalmus convexus*
		Maxillopoda	Sessilia	Balanidae	*Balanus sp.*
	Chelicerata	Merostomata	Xiphosura	Limulidae	*Tachypleus gigas*
Mollsca		Bivalvia	Arcoida	Arcidae	*Anadara antiquata*
			Ostreoida	Ostreidae	*Saccostrea sp*
					Saccostrea cucullata
			Veneroida	Donacidae	*Donax scortum*
				Veneridae	*Meritrix meritrix*
					Paphia malabaricus
					Dosinia prostata
					Timoclea imbricata
				Psammobiidae	*Sanquinolaria acuminata*
				Mactridae	*Mactra mera*
					Mactra luzonica
				Tellinidae	*Macoma birmanica*
				Cardiidae	*Tachycardium asiaticum*
			Myoida	Pholadidae	*Barnea canida*
		Gastropoda	Littorinimorpha	Cypraeidae	*Monetaria moneta*
				Naticidae	*Polinices didyma*
					Notocochlis tigrina
				Bursidae	*Bufonaria crumena crumena*
			Caenogastropoda	Potamididae	*Telescopium telescopium*
					Cerithidea cingulata
					Cerithidea obtusa
				Turritellidae	*Turritella attenuata*
			Neogastropoda	Melongenidae	*Pugilina cochlidium*
					Palustrina melanostoma
				Nassariidae	*Nassarius faveolatus*
					Nassarius stoletus
				Clavatulidae	*Turricula javana*
				Cancellariidae	*Trigonostoma scalariformis*
				Olividae	*Olivancillaria gibbosa*
				Muricidae	*Thais lacera*
				Trochidae	*Umbonium vestarium*
				Architectonicidae	*Architectonica perspectiva*
			Cycloneritimorpha	Neritidae	*Nerita articulata*

Table. 2: Seasonal availability of macrobenthic species at Mandarmani.

Mandarmani													
		Months											
		Monsoon			Postmonsoon			Winter			Premonsoon		
Family	Crustaceans	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apl	May	Jun
Diogenidae	*Clibanarius padavensis*	+	+	+	+	+	+	+	+	+	+	+	+
Ocypodidae	*Dotilla blanfordi*	+	+	+	+	+	+	+	+	+	+	+	+
	Ocypoda macrocera	+	+	+	+	+	+	+	+	+	+	+	+
Varunidae	*Varuna litterata*	_	_	_	+	+	_	_	_	_	_	_	_
Portunidae	*Scylla tranqueberica*	_	+	+	+	+	_	_	_	_	_	_	_
	Charybdis rostata	+	+	+	+	_	_	_	_	_	_	_	_
Matutidae	*Metuta planipes*	+	+	+	+	+	_	_	_	_	_	_	_
Balanidae	*Balanus sp.*	_	_	_	_	_	_	_	_	_	+	_	_
	Chelicerata												
Limulidae	*Tachypleus gigas*	_	_	_	_	+	+	+	+	+	+	_	_
	Bivalves												
Arcidae	*Anadara antiquata*	_	_	_	_	+	-	_	_	_	_	_	_
Ostreidae	*Saccostrea sp*	_	_	_	_	_	_	_	_	_	_	+	+
	Saccostrea cucullata	_	_	_	_	_	_	_	_	_	_	+	+
Donacidae	*Donax scortum*	_	_	_	_	_	_	+	+	_	_	_	_
Veneridae	*Meritrix meritrix*	_	_	_	_	_	+	+	+	+	+	+	+
	Paphia malabaricus	_	_	_	_	_	_	_	_	_	_	+	+
	Dosinia prostate	_	_	_	_	_	+	+	+	+	_	_	_
	Timoclea imbricata	_	_	_	_	_	+	+	+	_	+	_	_
Pholadidae	*Barnea canida*	+	+	+	+	+	+	+	+	+	+	+	+
Psammobiidae	*Sanquinolaria acuminata*	_	_	_	_	_	+	+	+	+	_	_	_
Mactridae	*Mactra mera*	_	_	_	_	+	+	_	+	+	+	+	_
	Mactra luzonica	_	_	_	_	_	_	_	_	+	+	+	+
Tellinidae	*Macoma birmanica*	_	_	_	_	_	+	+	+	+	_	_	_
Cardiidae	*Tachycardium asiaticum*	_	_	_	_	_	_	_	_	+	+	_	_
	Gastropods												
Cypraeidae	*Monetaria moneta*	_	_	_	_	_	+	_	_	_	_	_	_
Naticidae	*Polinices didyma*	_	_	_	_	_	+	+	_	_	_	_	_
	Notocochlis tigrina	_	_	_	_	_	+	+	+	+	+	+	_
Potamididae	*Telescopium telescopium*	+	+	+	+	+	+	+	+	+	+	+	+
	Cerithidea cingulata	_	_	_	_	_	+	+	+	+	+	_	_
	Cerithidea obtusa	_	_	_	_	_	_	+	_	_	_	_	_
Melongenidae	*Pugilina cochlidium*	_	_	_	+	+	+	_	_	_	_	_	_
Nassariidae	*Nassarius faveolatus*	_	_	_	_	+	_	_	_	_	_	_	_
	Nassarius stoletus	_	_	_	+	+	+	+	+	+	+	+	_
Bursidae	*Bufonaria crumena crumena*	_	_	_	+	+	_	_	_	_	_	_	_
Clavatulidae	*Turricula javana*	_	_	_	+	+	+	+	_	+	+	+	_
Trochidae	*Umbonium vestarium*	_	_	_	_	_	_	_	_	+	+	+	_
Architectonicidae	*Architectonica perspectiva*	_	_	_	+	+	_	_	_	_	_	_	_
Cancellariidae	*Trigonostoma scalariformis*	_	_	_	_	_	_	_	+	_	_	_	_
Turritellidae	*Turritella attenuata*	_	_	_	+	+	+	_	_	_	_	_	_
Olividae	*Olivancillaria gibbosa*	_	_	_	+	+	+	+	+	+	+	_	_
Muricidae	*Thais lacera*	_	_	_	_	+	+	+	+	+	+	+	+

+ denotes presence, - denotes absence.

b. **Chelicerata:** This group was comprised with only one species, namely, *Tachypleus gigas* (November-April) which was found in post monsoon to early premonsoon season.

c. **Bivalvia:** This group was comprised of 14 species belonging to 9 families and 12 genera. *Anadara antiquate* (November), *Saccostrea sp* (May-June), *Saccostrea cucullata* (May-June), *Donax scortum* (Januery-Februery), *Meritrix meritrix* (December-June), *Paphia malabaricus* (May-June), *Dosinia prostate* (December-March), *Timoclea imbricate* (December to Februery & March), *Barnea canida, Sanquinolaria acuminate* (December-March), *Mactra mera* (November-December & February-May), *Mactra luzonica* (March-June), *Macoma birmanica* (December-March), *Tachycardium asiaticum* (March-April) were representatives of Bivalvia. All the species showed a seasonal pattern except *Barnea canida* which was found throughout the study period (Table. 2). Bivalves were dominated during late post monsoon followed by winter and pre monsoon season. It was the second dominant group of Mandarmani sampling station.

d. **Gastropoda:** This group was comprised of 17 species belonging to 12 families and 15 genera. It was represented by *Monetaria moneta* (December), *Polinices didyma* (December-Januery), *Notocochlis tigrina* (December-May), *Telescopium telescopium, Cerithidea cingulate* (December-April), *Cerithidea obtuse* (Januery), *Pugilina cochlidium* (October-December), *Nassarius faveolatus* (November), *Nassarius stoletus* (October-May), *Bufonaria crumena crumena* (October-November), *Turricula javana* (October-Januery & March-May), *Umbonium vestarium* (March-May), *Architectonica perspectiva* (October-November), *Trigonostoma scalariformis* (Februery), *Turritella attenuata* (October-December), *Olivancillaria gibbosa* (October-April) and *Thais lacera* (November-June). All the species showed a seasonal pattern except *Telescopium telescopium* which was found throughout the study period. Gastropods were dominated during post monsoon and winter season and found very less in monsoon months. It was the most dominant group in this station. The seasonality of the species found in Mandarmani sampling station was presented in Table. 2.

At Gopalpur sampling station a total of 32 species belonging to 20 families and 29 genera had been found. The species composition of the Gopalpur sampling station are represented in Table. 3.

a. **Crustacea:** Crustaceans were the second dominant group observed in the Gopalpur sampling station. A total of 13 species belonging to 7 families and 12 genera were represented this group. *Clibanarius padavensis, Uca rosea* (July-Januery), *Uca lactea* (July-Januery), *Dotilla blanfordi, Ocypoda macrocera, Varuna litterata* (October-Januery), *Metaplax intermedia* (August-November), *Scylla tranqueberica* (September-December), *Portunus sanguinolentus* (April-June), *Charybdis rostata* (December-March), *Metuta planipes* (July-Januery), *Macropthalmus convexus* (May-June) and *Balanus sp* (October-June) were the crustacean species found in Gopalpur sampling station. Among the above species *Clibanarius padavensis, Dotilla blanfordi, Ocypoda macrocera* were found throughout the year. The crustaceans are dominated during monsoon, post monsoon season and early winter seasons.

b. **Chelicerata:** No species of this group was found in Gopalpur station.

c. **Bivalvia:** Bivalvia was the least dominant group in the Gopalpur stations. This group comprised of 4 species belonging to 3 families and 4 genera. This group was the represented by the species namely *Dosinia prostate* (October-June), *Timoclea imbricate* (May), *Barnea* canida and *Mactra mera* (October-May). Species *Barnea Canida* was found throughout the year in Gopalpur sampling station. Bivalves were dominated during middle part of post monsoon and winter seasons.

d. **Gastropoda:** It was the most dominant group in the Gopalpur sampling station. A total of 15 species belonging to 10 families and 13 genera were represented this group. The species represented the group were *Monetaria moneta* (December), *Polinices didyma* (November-February), *Notocochlis tigrina* (November-June), *Telescopium telescopium, Cerithidea cingulata* (November-July), *Cerithidea obtusa* (October-November), *Pugilina cochlidium* (April-May), *Palustrina melanostoma* (October-Januery), *Nassarius faveolatus* (November-December), *Nassarius stoletus* (October-April), *Trigonostoma scalariformis* (November-Decmber), *Nerita articulata* (October-Februery), *Turritella attenuata* (October-December), *Olivancillaria gibbosa* (November-June) and *Thais lacera* (November-June). Species *Telescopium telescopium* was found throughout the year. The gastropods were dominated from middle part of the post monsoon to early pre monsoon seasons. The seasonality of the species found at Gopalpur station presented in Table. 3.

Table. 3: Seasonal availability of macrobenthic species at Gopalpur.

Gopalpur													
		Months											
		Monsoon			Postmonsoon			Winter			Premonsoon		
Family	Crustaceans	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apl	May	Jun
Diogenidae	*Clibanarius padavensis*	+	+	+	+	+	+	+	+	+	+	+	+
Ocypodidae	*Uca rosea*	+	+	+	+	+	+	+	_	_	_	_	_
	Uca lactea	+	+	+	+	+	+	+	_	_	_	_	_
	Dotilla blanfordi	+	+	+	+	+	+	+	+	+	+	+	+
	Ocypoda macrocera	+	+	+	+	+	+	+	+	+	+	+	+
Varunidae	*Varuna litterata*	_	_	_	+	+	+	+	_	_	_	_	_
	Metaplax intermedia	_	+	+	+	+		_	_	_	_	_	_
Portunidae	*Scylla tranqueberica*	_	_	+	+	+	+	_	_	_			
	Portunus sanguinolentus										+	+	+
	Charybdis rostata	_	_	_	_	_	+	+	+	+	_	_	_
Matutidae	*Metuta planipes*	+	+	+	+	+	+	+					
Macrophthalmidae	*Macropthalmus convexus*	_	_	_	_	_	_	_	_	_	_	+	+
Balanidae	*Balanus sp.*	_	_	_	+	+	+	+	+	+	+	+	+
	Bivalves												
Veneridae	*Dosinia prostata*	_	_	_	+	+	+	+	+	+	+	+	+
	Timoclea imbricata	_	_	_	_	_	_	_	_	_	_	+	_
Pholadidae	*Barnea canida*	+	+	+	+	+	+	+	+	+	+	+	+
Mactridae	*Mactra mera*	_	_	_	+	+	+	+	+	+	+	+	_
	Gastropods												
Cypraeidae	*Monetaria moneta*	_	_	_	_	_	+	_	_	_	_	_	_
Naticidae	*Polinices didyma*	_	_	_	_	+	+	+	+	_	_	_	_
	Notocochlis tigrina	_	_	_	_	+	+	+	+	+	+	+	+
Potamidae	*Telescopium telescopium*	+	+	+	+	+	+	+	+	+	+	+	+
	Cerithidea cingulata	+	_	_	_	+	+	+	+	+	+	+	+
	Cerithidea obtusa	_	_	_	+	+	_	_	_	_	_	_	_
Melongenidae	*Pugilina cochlidium*	_	_	_	_	_	_	_	_	_	+	+	_
	Palustrina melanostoma	_	_	_	+	+	+	+	_	_	_	_	_
Nassariidae	*Nassarius faveolatus*	_	_	_	_	+	+	_	_	_	_	_	_
	Nassarius stoletus	_	_	_	+	+	+	+	+	+	+	_	_
Cancellariidae	*Trigonostoma scalariformis*	_	_	_	_	+	+	_	_	_	_	_	_
Neritidae	*Nerita articulata*	_	_	_	+	+	+	+	+	_	_	_	_
Turritellidae	*Turritella attenuata*	_	_	_	+	+	+	_	_	_	_		_
Olividae	*Olivancillaria gibbosa*	_	_	_	_	+	+	+	+	+	+	+	+
Muricidae	*Thais lacera*	_	_	_	_	+	+	+	+	+	+	+	+

+ denotes presence, - denotes absence.

PLATE-3

Species found only at Mandarmani sampling station

Fig. VII: *Anadara antiquata*

Fig. VIII: *Saccostrea sp*

Fig. IX: *Saccostrea cucullata*

Fig. X: *Donax scortum*

Fig. XI: *Meritrix Meritrix*

Fig. XII: *Sanquinolaria acuminata*

PLATE-4

Species found only at Mandarmani sampling station.

Fig. XIII: *Paphia malabaricus*

Fig. XIV: *Mactra luzonica*

Fig. XV: *Macoma birmanica*

Fig. XVI: *Tachycardium asiaticum*

Fig. XVII: *Bufonaria crumena crumena*

Fig. XVIII: *Turricula javana*

PLATE-5

Species found only at Mandarmani sampling station.

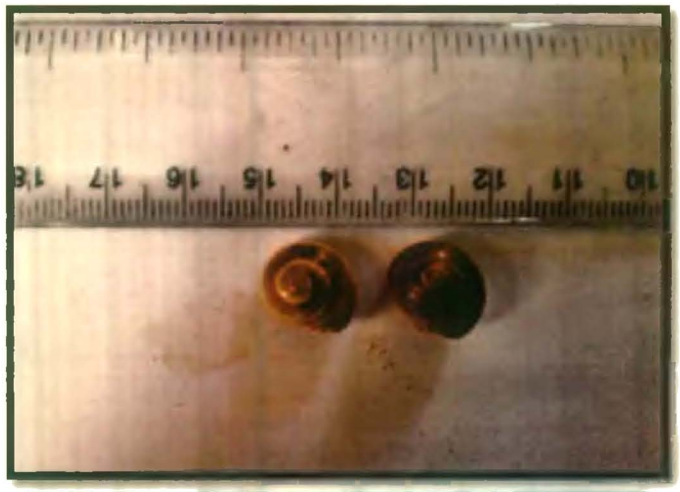

Fig. XIX: *Umbonium vestarium*

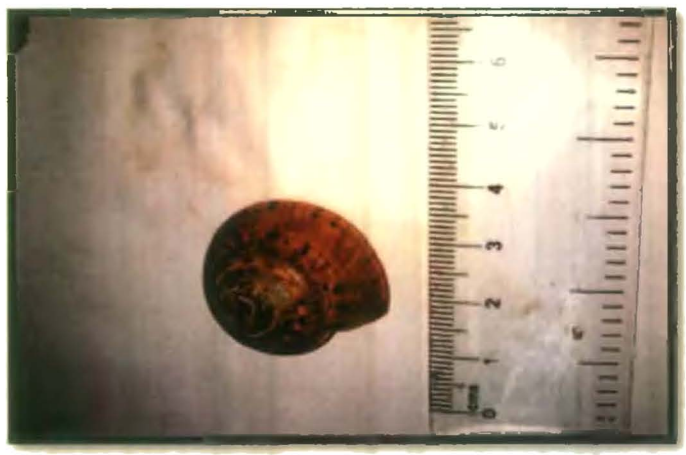

Fig. XX: *Architectonica perspectiva*

Fig. XXI: *Tachypleus gigas*

PLATE-6

The species found only at Gopalpur sampling station.

Fig. XXII: *Uca rosea*

Fig. XXIII: *Uca lactea*

Fig. XXIV: *Metaplax intermedia*

Fig. XXV: *Portunus sanguinolentus*

PLATE-7

The species found only at Gopalpur sampling station.

Fig. XXVI: *Macropthalmus convexus*

Fig. XXVII: *Palustrina melanostoma*

Fig. XXVIII: *Nerita articulata*

PLATE-8

The species found at both the sampling stations.

Fig. XXIX: *Clibanarius padavensis*

Fig. XXX: *Balanus sp.*

Fig. XXXI: *Ocypoda macrocera*

Fig. XXXII: *Metuta planipes*

Fig. XXXIII: *Charybdis rostata*

Fig. XXXIV: *Scylla tranqueberica*

PLATE-9

The species found at both the sampling stations.

Fig. **XXXV:** *Varuna litterata*

Fig. XXXVI: *Dotilla blanfordi*

Fig. XXXVII: *Dosinia prostata*

Fig. XXXVIII: *Timoclea imbricata*

Fig XXXIX: *Barnea canida*

Fig. XL: *Mactra mera*

Plate-10

The species found at both the sampling stations

Fig. XLI: *Monetaria moneta*

Fig. XLII: *Polinices didyma*

Fig. XLIII: *Notocochlis tigrina*

Fig. XLIV: *Telescopium telescopium*

Fig. XLV: *Cerithidea cingulata*

Fig. XLVI: *Cerithidea obtusa*

Plate-11

The species found at both the sampling stations

Fig. XLVII: *Pugilina cochlidium*

Fig. XLVIII: *Nassarius faveolatus*

Fig. XLIX: *Nassarius stoletus*

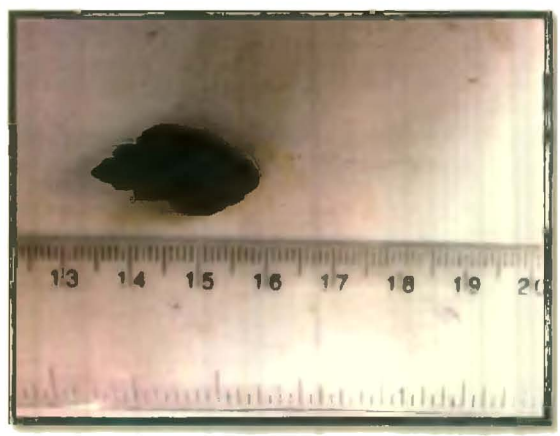

Fig. L: *Trigonostoma scalariformis*

PLATE-12

The species found at both the sampling stations

Fig. LI: *Turritella attenuata*

Fig. LII: *Olivancillaria gibbosa*

Fig. LIII: *Thais lacera*

4.3.2. Seasonal abundance of macrobenthos of the two sampling stations

The macrobenthic invertebrates at two sampling stations showed a seasonal pattern of distribution. In both stations the macrobenthic abundance and density is high during middle to late monsoon months (November to December). And the minimum density was found in the months of monsoon (July to September). The winter and pre-monsoon months showed a medium density in both the stations. The overall bivalve density were high at Mandarmani stations as compared to the Gopalpur station and the overall crustacean density were high at Gopalpur station as compared to Mandarmani station. Species *Clibanarius padavensis, Dotilla blanfordi, Ocypoda macrocera* were found in all months at both stations among crustaceans. Among bivalves species *Barnea canida* and among gastropods *Telescopium telescopium* was found in all months at both station. Species *Barnea canida, Clibanarius padavensis, Dotilla blanfordi, Ocypoda macrocera, Cerithidea cingulata, Nassarius stoletus, Mactra mera, Notocohlis tigrina* were the dominant taxa in both stations. At Mandarmani sampling station the species *Mactra luzonica, Meritrix meritrix* was also one of the dominant taxa during post-monsoon and premonsoon months. A high density of crustaceans (crabs) were observed in monsoon and postmonsoon months at Gopalpur station. Species *Uca rosea* and *Uca lactea* were also one of the dominant taxa during monsoon to early winter season at Gopalpur sampling station. At Mandarmani station no such clear differences were found but in monsoon to middle part of the post monsoon months relatively the crustacean density were high. The gastropod density was high during post monsoon to early pre monsoon months in both the stations and was peak during middle to late post monsoon. The minimum and maximum density of macrobenthos at Mandarmani sampling station was 478 number/m^2 (July) in monsoon and 2145 number/m^2 (December) in late post monsoon respectively. The minimum and maximum density of macrobenthos at Gopalpur sampling station was 667 number/m^2 (August) in monsoon and 2510 number/m^2 (December) in post monsoon respectively (Table. 4)

Table. 4: Total and group wise density (number/m^2) of macrobenthos at two stations.

Seasons	Months	Gopalpur				Mandarmani			
		Total	Crustaceans	Bivalves	Gastropods	Total	Crustaceans	Bivalves	Gastropods
Monsoon	July	712	567	78	67	478	378	56	44
	August	667	589	22	56	545	422	56	67
	September	677	622	11	44	511	389	44	78
Post-monsoon	October	1133	711	122	300	923	500	67	356
	November	1977	722	311	944	1822	544	311	967
	December	2510	833	333	1344	2145	322	767	1056
Winter	January	1489	622	200	667	1678	411	567	700
	February	1322	456	233	633	1734	367	678	689
	March	1312	500	256	556	1433	356	533	544
Pre-monsoon	April	1389	478	189	722	1344	400	422	522
	May	1055	400	244	411	1233	311	489	433
	June	967	467	156	344	755	333	289	133

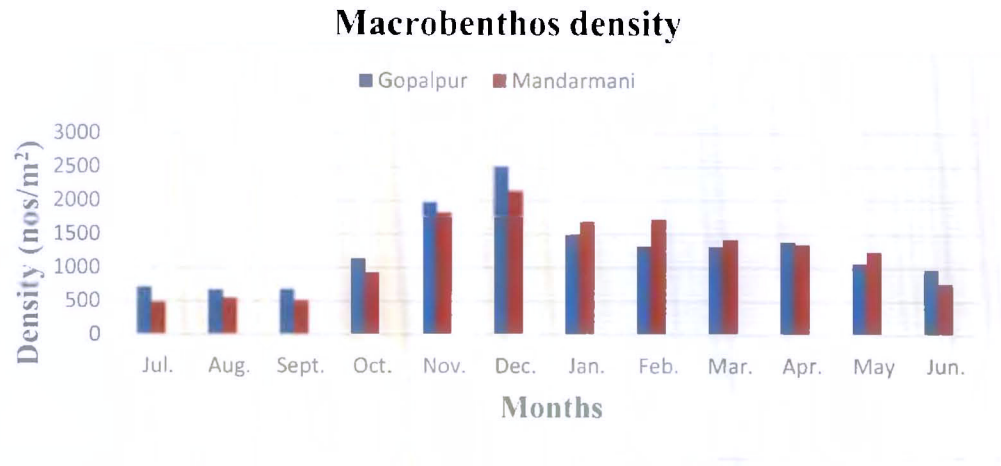

Fig. 8(a): Monthly variation in density of macrobenthos at two selected sampling stations.

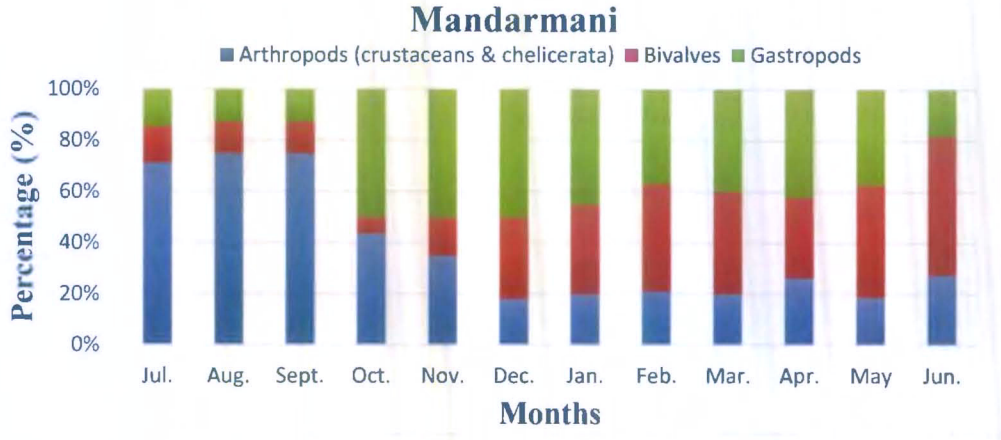

Fig. 8(b): Monthly variation in qualitative composition of groups of macrobenthos at Mandarmani sampling station.

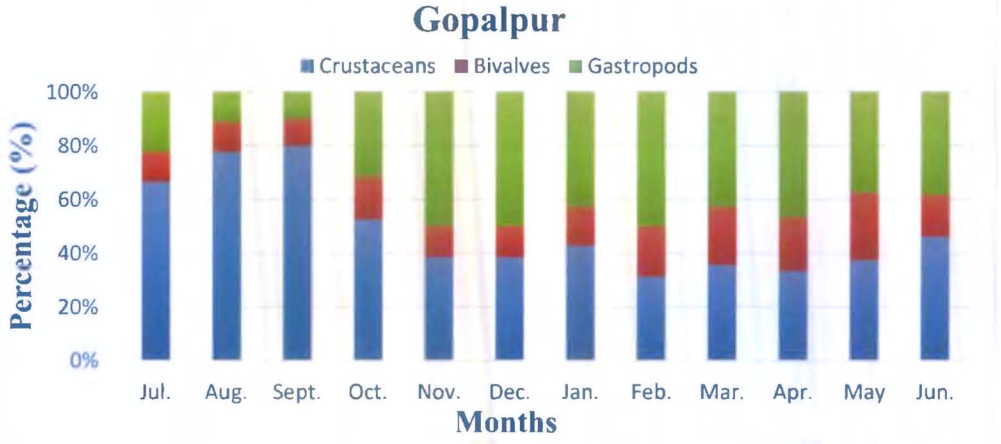

Fig. 8(c): Monthly variation in qualitative composition of groups of macrobenthos at Gopalpur sampling station.

4.3.3. The Shannon Weaver biodiversity index

The monthly variation of the Shannon Weaver biodiversity index was shown in Fig. 9(a). At Gopalpur sampling station the maximum and minimum biodiversity was 3.143 (December) and 2.08 (July) respectively. The maximum biodiversity was found in the months of post monsoon followed by winter and pre monsoon months in both the stations. At Mandarmani the Shannon Weaver biodiversity was ranged from 1.807 (July) to 3.023 (December). The biodiversity values at Mandarmani showed a positive significant correlation with nitrate-nitrogen, sediment organic carbon, total density of macro benthos and Margalef's richness. And showed a negative significant correlation with surface water temperature, water pH and total alkalinity. In case of Gopalpur sampling station the biodiversity values showed a positive significant correlation with macrobenthos density and Margalef's richness. A positive relation with sediment organic carbon, nitrate-nitrogen and phosphate-phosphorus and biodiversity was found but relationship was not significant. The biodiversity values showed a negative significant correlation with air and surface water temperature, sediment and water pH and total alkalinity. In both the stations the Shannon Weaver biodiversity index showed a positive relationship with water salinity however the relationship was not significant.

4.3.4. Margalef's richness index

The monthly variation of the Margalef,s richness index at two selected station was represented in fig. 9(b). The Margalef's richness index at Mandarmani sampling station was ranged from 1.595 (July) to 3.99 (December). At Gopalpur sampling station it was ranged from 1.924 (July) to 4.825 (November). At both station the Margalef's richness values showed a positive significant correlation with density, biodiversity and showed a negative significant correlation surface water temperature and total alkalinity. At Gopalpur sampling station the richness values showed a negative significant correlation with sediment and water pH also.

4.3.5. Pielou's evenness index:

The Pielou's evenness index was ranged from 0.921 (October) to 0.978 (August, December) at Mandarmani sampling station. At Gopalpur sampling station it was ranged from 0.93 (May) to 0.979 (October). The Pielou's evenness index didn't show any characteristic seasonal pattern at both the stations. The evenness value showed a negative significant correlation with surface water temperature at both station. At Mandarmani it also showed negative significant correlation with sediment and water pH. There were no positive significant correlation was found with evenness index and any other parameters. Monthly variation of Pielou's evenness index at two selected sampling stations was given in fig no. 9(c). The yearly data of the Shannon Weaver Index, Margalef's richness index and Pielou's evenness index were represented in Table-5.

4.4. STATISTICAL ANALYSIS

The correlation co-efficient between different physic-chemical parameters of water and sediment was calculated and presented in the appendix II and apeendix III at 1% and 5% level of significance. The species diversity index has been computed for studied macrobenthos and illustrated in Table-5 using Shannon Weaver index (H), Pielou's evenness index (J) and Margalef's richness index (r). The correlation co-efficient (r) between different physico-chemical parameters of water, sediment and calculated diversity indexes was calculated and presented in appendix II and appendix III.

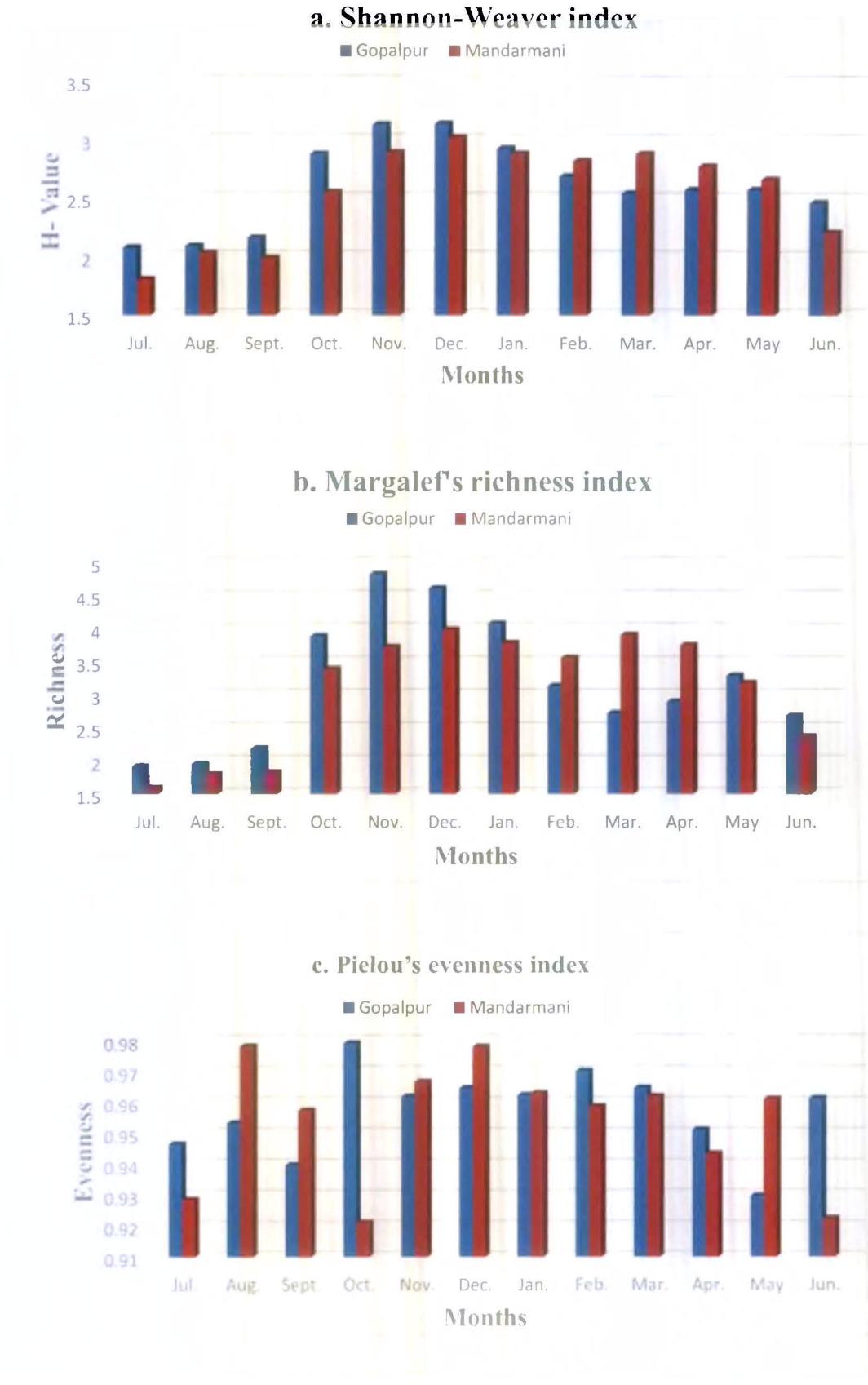

Fig. 9: Monthly variations in (a) Shannon-Weaver index (b) Margalef's richness index and (c) Pielou's evenness index of two stations.

Table. 5: Shannon Weaver index (H), Pielou's Evenness index and Margalef's richness index of studied macrobenthos at two sampling stations.

Months	Gopalpur			Mandarmani		
	H	J	R	H	J	R
July	2.08	0.947	1.924	1.807	0.929	1.595
August	2.095	0.953	1.954	2.034	0.978	1.799
September	2.164	0.94	2.189	1.991	0.957	1.828
October	2.883	0.979	3.892	2.554	0.921	3.395
November	3.134	0.962	4.825	2.896	0.967	3.726
December	3.143	0.965	4.612	3.023	0.978	3.99
January	2.93	0.962	4.083	2.885	0.963	3.787
February	2.69	0.97	3.139	2.823	0.959	3.564
March	2.546	0.965	2.725	2.882	0.962	3.91
April	2.576	0.951	2.9	2.778	0.943	3.753
May	2.578	0.93	3.294	2.665	0.961	3.185
June	2.466	0.961	2.687	2.212	0.922	2.37

5. DISCUSSION

In the present study a seasonal pattern of macrobenthic mollusca, crustacea and chelicerata were observed in two selected stations of coastal Purba Medinipur district during one year study period from July 2014 to June 2015. The probable causes of differences in physic-chemical and biological characteristics of the two coastal stations were discussed and substantiated in the present chapter.

5.1. PHYSIC-CHEMICAL PARAMETERS OF WATER

There is a strong physical, chemical and biological relationship between benthic communities and the prevailing environment (Odunaike *et al.*, 2013).

Temperature, the measure of intensity of heat stored in a volume of water is the resultant effect of morphometric features and atmospheric temperature. In the present study the air temperature of Mandarmani and Gopalpur sampling stations were ranged from 26^0C (December) to 35.5^0C (June) and 27^0C (November) to 34.5^0C (June) respectively. The values of air temperature observed by Datta *et al.* (2008) and Kumar and Khan (2013) 28.5^0C to 32^0C and 17.9^0C (November) to 41.7^0C (June) respectively at different coasts of India support the present findings.

The surface water temperature of Mandarmani and Gopalpur sampling stations were ranged from 26^0C (November) to 34^0C (June, July) and 26.5^0C (November) to 34.5^0C (June) respectively. Varadharajan *et al.* (2010) reported that the surface water temperature of the Tamil Nadu coast was ranging from 23^0C (December) to 35^0C (pre-monsoon). Datta *et al.* (2008) reported that the water temperature at intertidal region of South Mumbai was ranging from 27^0C to 31^0C. Manoharan *et al.* (2011) also reported that the water temperature at Tamil Nadu coast was ranging from 28^0C (November) to 34.5^0C (August). Chandra and Chakraborty (2008) also reported the water temperature of coastal tract of Medinipur which was ranging from 20.8^0C to 32.8^0C.

Water pH is one of the most important indicator of water quality, which express the intensity of acidity or alkalinity. The surface water pH of two selected stations remain alkaline throughout the study period. The pH values of Mandarmani and Gopalpur sampling stations were ranged from 7.5 (December) to 8.5 (June) and 7.5 (November, December) to 8.4 (June) respectively. The values of water pH observed by Thilagavathi *et*

al. (2013) (7.3 to 8.4), Chandra and Chakraborty (2008) (7.68 to 8.72), Datta *et al.* (2008) (7.45 to 8.35), Varadharajan *et al.* (2010) (7.2 to 8.4) and Kumar and Khan (2013) (7.11 to 8.36) at different coasts of India supports the present findings. The High pH value of water during pre-monsoon season and low during post monsoon season might be due high temperature during pre-monsoon and low temperature in post monsoon respectively, which showed a positive relationship between water pH and water temperature. In the present study in both the stations the pH values of water showed positive significant correlation with water temperature. Kumar and Khan (2013) also found a significant positive correlation between water pH and water temperature.

Salinity was considered to be a dominant limiting factor in benthic macro-faunal distribution. In this present study the water salinity of Mandarmani and Gopalpur sampling stations ranged from 18 ppt (September) to 34 ppt (June) and 14 ppt (September) to 31 ppt (June) respectively. The lower values of water salinity were found in monsoon months and higher values were found in pre-monsoon months. The lower values of water salinity was in monsoon months might be due to heavy downpour which dilute the water of the sea. The higher values of water salinity were found in pre-monsoon months might be due to high evaporation rate of sea water. Kumar and Khan (2013) also reported that the water salinity ranging from 12.5 ppt (monsoon) to 35.2 ppt (summer or pre-monsoon) at Pondicherry mangroves. Chandra and Chakraborty (2008) also reported the salinity of water ranging from 8.6% to 26% at coastal tract of Medinipur and also observed the lowest salinity during the South-West monsoon (July-October) and the highest during pre-monsoon (March-June) which supports the present findings.

Dissolved oxygen is regulator of metabolic processes of both plant and animal communities which acts as an indicator of water quality. In the present study the dissolved oxygen was high during monsoon which might be due to cumulative effect of higher wind velocity coupled with heavy rainfall and the resultant fresh water mixing. Relatively lower values were observed during summer or pre-monsoon months which might be due to the increased surface water temperature reducing the dissolvation of oxygen in the coastal water. It is well known that temperature and salinity affect the dissolution of oxygen Viijayakumar *et al.* (2000). Thilagavathi *et al.* (2013) reported the dissolved oxygen of water ranging from 3.22 mg/l (summer or pre-monsoon) to 5.65 mg/l (monsoon) at Tamil Nadu coast. Chandra and Chakraborty (2008) also reported the dissolved oxygen of water

ranging from 3.24 mg/l (pre-monsoon) to 5.47 mg/l (monsoon) at coastal tract of Medinipur which is comparable with present findings.

Total alkalinity of water is generally the result of carbonate and bicarbonate ions. In this present study the total alkalinity of water ranged from 91.33 ± 2.309 mg/l (December) to 127.33 ± 3.215 (July) mg/l and 83 ± 2.646 mg/l (November) to 122.67 ± 2.082 mg/l (June) at Mandarmani and Gopalpur stations respectively. In this present study the total alkalinity showed positive significant correlation with water temperature and water pH. The higher values of alkalinity during pre-monsoon may be due to high pH and high temperature of water during pre-monsoon and the lower values of alkalinity during post monsoon may be due to low pH and low temperature of water during post monsoon.

Nitrate nitrogen and phosphate phosphorus are the important nutrient of water for the growth of the any aquatic organism. The Nitrate nitrogen (NO_3) of the water at Mandarmani and Gopalpur sampling stations ranged from 0.128 ± 0.014 mg/l (September) to 0.838 ± 0.02 mg/l (April) and 0.209 ± 0.025 mg/l (August) to 0.919 ± 0.052 mg/l (March) respectively. The phosphate phosphorus (PO_4) of water at Mandarmani and Gopalpur ranged from 0.117 ± 0.004 mg/l (October) to 0.784 ± 0.016 mg/l (June) and 0.101 ± 0.012 mg/l (August) to 0.767 ± 0.02 mg/l (May) respectively. The lower values of nitrate nitrogen and phosphate phosphorus were found during monsoon which might be due to heavy rainfall and from late post monsoon months increased pattern was found. Datta *et al.* (2008) reported the nitrate nitrogen and phosphate phosphorus of water was ranging from 0.19 mg/l to 1.3 mg/l and 0.37 mg/l to 1.2 mg/l respectively at intertidal region of South Mumbai and also reported that the lower values of NO_3 and PO_4 of water were found during monsoon. Giri and Chakraborty (2012) also recorded the NO_3 and PO_4 of water ranging from 0.36 mg/l to 3.8 mg/l and 0.15mg/l to 1.3 mg/l respectively at Sundarban mangrove. The above findings supports this result.

5.2. SEDIMENT

The pH of the sediment of Mandarmani and Gopalpur sampling stations were ranged from 7.41 (December) to 8.25 (July) and 7.28 (December) to 8.17 (June) respectively which is similar with the findings of Manoharan *et al.* (2011) (7.3 to 8.2) and Chandra and Chakraborty (2008) (7.68 to 8.72) at Tamil Nadu and coastal tract of Medinipur respectively. The higher values of sediment pH were found during pre-monsoon, early monsoon months and lower values were found during post-monsoon months may be due

to the higher values of water pH during pre-monsoon and early monsoon months and lower values of water pH during post-monsoon months which influenced the sediment pH.

The sediment organic carbon content of the Mandarmani and Gopalpur sampling stations were ranged from 1.004 ± 0.0028% to 2.155 ± 0.073% and 1.154 ± 0.016% to 2.298 ± 0.078% respectively. Magdoom *et al.* (2010) reported the organic carbon of the sediment was ranging from 0.807% to 3.742% from Gulf of Mannar. Manoharan *et al.* (2011) also reported the organic carbon of the sediment was in between 0.71% to 3.75% from the selected stations of Tamil Nadu coast. The above findings supports the present study. In both the stations the organic carbon content of sediment showed a declined nature in monsoon months. During the monsoon season which was associated with heavy rain and high water current, the organic carbon was washed away to the open ocean and apparently reduced their concentrations in coastal environments, might be responsible for the lower values of sediment organic carbon during monsoon months. Kamaruzzaman *et al.* (2010) also observed the similar findings.

5.3. MACROBENTHIC MOLLUSCA, CRUSTACEA AND CHELICERATA

5.3.1. Composition of macrobenthic population

A total of 47 species belonging to 31 families and 42 genera had been identified in two stations. Among them 13 species of crustaceans (arthropods) belonging to 7 families and 12 genera, 14 species of bivalves (molluscs) belonging to 9 families and 12 genera, 19 species gastropods (molluscs) belonging to 14 families and 17 genera and 1 species of chelicerates (arthropods) were found.

Among crustaceans *Clibanarius padavensis, Uca rosea, Uca lactea, Dotilla blanfordi, Ocypoda macrocera, Varuna litterata, Metaplax intermedia, Scylla tranqueberica, Portunus sanguinolentus, Charybdis rostata, Metuta planipes, Macropthalmus convexus* and *Balanus sp* were observed at two stations (Gopalpur and Mandarmani).

Yennawar *et al.* (2014) reported *Balanus amphitrite, Metuta planipes, Portunus sanguinolentus, Charybdis feriata, Ocypoda macrocera, Scylla serrate, Portunus sanguinolentus, Uca triangularis* with other crustacean species from around Digha coast which is almost similar with the present findings. Chatterjee and Chakraborty (2014)

reported *Uca lactea annulipes, Metaplax intermedia, Dotilla blanfordi, Ocypoda macrocera* with other crab species from coastal belt of Medinipur which also is comparable with the present findings. Pandya and Vachhrajani (2013) reported *Uca lactea annulipes, Uca dussumieri, Macrophthalmus depressus, Macrophthalmus brevis, Dotilla intermedia, Scylla serrate* from Mahi river estuary of Gujrat. Satheeshkumar (2012) also observed *Uca lactea annulipes, U. inversa* and *U. triangularis, Scylla serrata, Portunus sanguinolentus* from Pondicherry coast. Varadharajan *et al.* (2010) reported *Scylla tranqubarica, S. serrata, Portunus pelagicus, P. sanguinolentus, Charybdis feriata, C. sp* from Tamil Nadu coast. The above findings also supports the present study.

The crustacean species were found more at Gopalpur sampling station compared to Mandarmani sampling station which might be due to muddy nature of Gopalpur beach which provide good substratum for their living.

The chelicerates were found only at Mandarmani sampling station which was *Tachypleus gigas*. The finding is similar with the observations of Yennawar *et al.* (2014) and Annon (2005).

The bivalves found at two stations were *Anadara antiquate, Saccostrea sp, Saccostrea cucullata, Donax scortum, Meritrix meritrix, Paphia malabaricus, Dosinia prostata, Timoclea imbricate, Pholus Orientalis, Sanquinolaria acuminate, Mactra mera, Mactra luzonica, Macoma birmanica, Tachycardium asiaticum.*

Paul *et al.* (2014) reported *Saccostrea cucullata, Mactra luzonica, Mactra mera, Macoma birmanica, Donax scortum, Timoclea imbricata, Meretrix meretrix, Paphia textile, Dosinia prostata, Barnea candida* with other bivalves from North East coast of India (Digha, Sankarpur, Talsari, Chandipur, Bakkhali) and their findings are in agreement with the present investigation. Magdoom *et al.* (2010) reported *Meretrix meretrix, M. casta, Anadara granosa* from the Gulf of Mannar. Varadharajan *et al.* (2010) observed *Anadara granosa, Crassostrea madrasensis, Donax cuneatus, D.veligers, Meretrix casta, M. merretrix, Paphia textile* from Tamil Nadu coast. Yennawar *et al.* (2014) also reported *Anadara antiquata, Saccostrea cucullata, Mactra luzonica, Mactra mera, Macoma birmanica, Donax scortum, Meretrix meretrix, Paphia malabricus, Tachycardium asiaticum, Bernea candida* from the nearby location of Digha coast which are comparable with the present study.

A Total of 14 bivalve species were found at Mandarmani sampling station and only 4 bivalve species were found at Gopalpur sampling station. Comparatively more bivalves were found at Mandarmani sampling station which might be due to sandy nature of the intertidal zone.

The gastropods found at the two selected stations were *Monetaria moneta, Polinices didyma, Notocochlis tigrina, Telescopium telescopium, Cerithidea cingulata, Cerithidea obtusa, Pugilina cochlidium, Palustrina melanostoma, Nassarius faveolatus, Nassarius stoletus, Bufonaria crumena crumena, Turricula javana, Umbonium vestarium, Architectonica perspectiva, Trigonostoma scalariformis, Nerita articulate, Turritella attenuata, Olivancillaria gibbosa, Thais lacera.*

Paul *et al.* (2014) recorded *Cerithidea cingulata, Cerithidea obtusa, Turritella attenuata, Telescopium telescopium, Natica tigrina, Polinices didyma, Thais lacera, Nassarius faveolatus, Nassarius stoletus, Pugilina cochlidium, Olivancillaria gibbosa, Turricula javana, Architectonica perspectiva* with other gastropods from North East coast of India (Digha, Sankarpur, Talsari, Chandipur, Bakkhali).

Mitra *et al.* (2001) reported *Nerita articulata, Telescopium telescopium, Cerithedia cingulata, Cerithedia obtusa* from the Bay of Bengal coast. Magdoom *et al.* (2010) found *Umbonium vestiarium, Natica* sp., *Cerithedia cingulata* and *Turritella attenuata* from Gulf of Mannar. Anbuchezhian *et al.* (2009) also reported *Cerethidea cingulata* from coastal belt of Thoni.

Yennawar *et al.* (2014) observed *Umbonium vestarium, Telescopium telescopium, Natica tigrina, Polinices didyma, Turritella attenuata, Thais lacera, Nassarius stoletus, Olivancillaria gibbosa, Turricula javana, Pugilina cochlidium, Architectonica perspectiva* from around Digha coast which supports this result.

5.3.2. Seasonal abundance and density of the macrobenthos

A clear seasonal pattern of abundance and diversity of the macrobenthos was found in both the sampling stations. The fluctuations of different physico-chemical parameters in different seasons may be responsible for this. The benthic molluscan communities thrives in the dynamic ecosystems of Bay of Bengal coast exhibiting pronounced seasonal variation (Mitra *et al.*, 2001). The crustacean species found more in the months of monsoon to early winter months (August to Januery) at Gopalpur. Species *Uca rosea, Uca lactea, Metuta planipes* were dominant during monsoon to early winter months and *Scylla*

tranqueberica was found during late monsoon to entire post monsoon months which was quite similar with Satheeshkumar (2012). Factor such as low salinity and possible environmental changes in the substrate composition may be attributed to the greater abundance. The number of crustacean species found was relatively low in Mandarmani sampling station but in early post monsoon months the crustacean density was high. Bandekar *et al.* (2011) reported high crab population during monsoon and post monsoon months which supports the above findings. Satheeshkumar (2012) also reported the maximum diversity values during post monsoon months. Among the crustaceans family Ocypodidae was dominant in both the stations which was comparable with the observations of Kumar and Khan (2013).

Among molluscs bivalves and gastropods both showed a clear seasonal pattern in both the samplings stations. In both the stations the abundance of molluscs was highest during post-monsoon followed by winter and pre-monsoon. During monsoon months lowest abundance was found which was comparable with the study of Paul *et al.* (2014). Thilagavathi *et al.* (2013) reported the lowest abundance of benthos during monsoon months. Khade and Mane (2012) also reported the highest density of molluscs during post-monsoon and lowest density during monsoon. In monsoon months due to downpour the salinity was drastically decreased which may be responsible for the lower abundance of Molluscs during monsoon. The lowest density of molluscs was found in the month of July because of monsoon season when the salinity and temperature dropped down. The population density increased steadily from September to reach the maximum number in December during post-monsoon season which might be due to stable environment factors such as dissolved oxygen and salinity (Paul *et al.*, 2014). Among bivalves *Barnea canida, Mactra mera* were the dominant species in both the stations. At Mandarmani sampling station the species *Mactra luzonica, Meritrix meritrix* was also one of the dominant taxa. Yennawar *et al.* (2014) reported *Mactra luzonica, Mactra mera, Bernea candida* as one of the dominant species which is similar with the present findings. Among gastropods species *Cerithidea cingulata, Nassarius stoletus, Notocohlis tigrina* were the dominant species at both the stations. Paul *et al.* (2014) observed *Natica tigrina, Cerithidea cingulata* as one of the dominant species from the selected localities of West Bengal and Odisha coast. Anbuchezhian *et al.* (2009) also reported *Cerethidea cingulata* as dominat gastropods from coastal belt of Thoni.

The species density of macro-benthos was ranged from 478 number/m^2 to 2145 number/m^2 and 667 number/m^2 to 2510 number/m^2 at Mandarmani and Gopalpur sampling

stations respectively. Asadujjaman *et al.* (2012) observed maximum density of benthos as 4511 number/m^2 and the minimum as 433 number/m^2. Susan *et al.* (2012) reported the density of molluscs between 548 number/m^2 to 2416 number/m^2. Kumar and Khan (2013) reported the density of macro-invertebrate fauna ranged from 140 number/m^2 to 1113 number/m^2. Hossain and Hossain (2009) also reported maximum density of macro invertebrates to be 6402.78 number/m^2. The above findings are quite in agreement with the present study.

5.3.3 Shannon Weaver, Margalef's richness and Pielou's evenness index

'Biological diversity' means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems (Convention on Biological Diversity, 1992).

During the present study the Shannon Weaver biodiversity index was ranged between 1.807 (July) to 3.023 (December) and (July) 2.08 (July) to 3.143 (December) at Mandarmani and Gopalpur sampling stations respectively. Datta *et al.* (2008) reported the biodiversity values of macrobenthos of South Mumbai in between 1.98 to 2.91. Kumar and Khan (2013) observed the biodiversity values ranged from 1.80- 2.83 Pondicherry mangroves. Shivanagouda and Bhat (2013) also reported the biodiversity values in between 2.80 to 2.65 at Gulf of Kutch. The above findings are quite similar with this result. Both the stations showed minimum biodiversity values during monsoon months and maximum during post-monsoon months followed by winter and pre-monsoon months which is quite comparable with the findings of Yennawar *et al.* (2014) and Thilagavathi *et al.* (2013). The reason behind the low diversity values during monsoon might be due to low salinity because of heavy downpour. The most crucial factor responsible for the death of intertidal organisms is salinity which decreased considerably during monsoon (Datta *et al.* (2008). Organic carbon of the sediment also played an important role for studying macrobenthos. During the present study a positive correlation was found between biodiversity and organic carbon of the sediment at Gopalpur sampling station however the relationship was not significant which is quite comparable with the findings of Anbuchezhian *et al.* (2009). At Mandarmani sampling station a significant positive relationship between benthic diversity and sediment organic carbon was found. Positive relationship between the abundance of benthic fauna and concentration of organic carbon in sediments had been documented by Parulekar *et al.* (1975) and Damodaran (1973).

Salinity is a limiting factor which influenced the diversity of the macrobenthos at both the stations. Sudden fall in salinity in monsoon months due to downpour restricted the assemblage of benthic population as a result of it the biodiversity values also decreased. Salinity was a dominant limiting factor in the distribution of benthic fauna (Anbuchezhian *et al.* (2009). In the present study a positive relationship in between benthic diversity and salinity was found at both the stations but the relationship was not significant. In this present study a significant positive relationship between Shannon Weaver biodiversity index and studied macrobenthic density was found which is similar with the findings of Thilagavathi *et al.* (2013).

In this present study a significant negative relationship in between water temperature and benthic diversity was found which indicate a reverse relation between temperature and benthic biodiversity at both the stations. (Anbuchezhian *et al.* (2009) also observed high temperature recorded in premonsoon season influence the distribution of macrobenthic organisms, low temperature recorded in December and January months influence higher faunal density. A positive relationship in between phosphate phosphorus of water and benthic diversity was found at both the stations during the study. A significant positive relationship in between nitrate nitrogen of water and biodiversity at Mandarmani sampling station and in case of Gopalpur sampling station only positive relationship in between nitrate nitrogen of water and diversity was found. The above relationships indicated if the nitrate nitrogen and phosphate phosphorus values were increased the benthic diversity was also changed with an increasing pattern and vice-versa. Low values of NO_3, PO_4 during monsoon period had restricted the abundance and diversity of benthic organisms in the present study at both the stations which is comparable with the findings of Datta *et al.* (2008).

The Margalef's richness index of Mandarmani and Gopalpur sampling station was ranged from 1.595 (July) to 3.99 (December) and 1.924 (July) to 4.825 (November) respectively during the study. The Margalef's richness index showed a significant positive relationship with Shannon Weaver biodiversity index which was similar with Thilagavathi *et al.* (2013).

Magdoom *et al.* (2010) reported the Margalef's richness index in between 3.263 and 4.324. Datta *et al.* (2008) also reported the Margalef's richness index which ranged from 5.18 (December) to 3.46 (November). The above findings are somehow comparable with the present study.

The Pielou's evenness index was ranged from 0.921 (October) to 0.978 (August, December) at Mandarmani sampling station and at Gopalpur sampling station it was ranged from 0.93 (May) to 0.979 (October) which are quite comparable with the study of Magdoom *et al.* (2010). Shivanagouda and Bhat (2013) reported the evenness index was in between 0.8697 and 0.8967. Thilagavathi *et al.* (2013) also reported Pielou's evenness index was in between 0.998 to 0.999.

6. SUMMARY AND CONCLUSION

The present study was carried out to assess the macrobenthic diversity and abundance along with the physico-chemical parameters of water and sediment at Mandarmani and Gopalpur sampling stations. The study was conducted for a period of twelve months from July, 2014 to June, 2015.

An overview of available literature related to the present study have been considered under the chapter "review of literature".

The location and description of the two selected stations, the materials used and the methods adopted for carrying out the present investigation were mentioned in the chapter "materials and methods".

The results obtained on different physico-chemical parameters of water, sediment and abundance, diversity indices of macrobenthos were given in the chapter "results".

The water temperature of Mandarmani and Gopalpur sampling stations varied from 26^0C to 34^0C and 26.5^0C to 34.5^0C respectively.

The water pH of Mandarmani and Gopalpur sampling stations were ranged between 7.5 to 8.5 and 7.5 to 8.4 respectively.

The water salinity at Mandarmani and Gopalpur sampling stations varied from 18 ppt to 34 ppt and 14 ppt to 31 ppt respectively.

The dissolved oxygen of water was ranged from 3.2 ± 0.08 mg/l to 5.89 ± 0.12 mg/l and 3.41 ± 0.09 mg/l to 6.05 ± 0.09 mg/l at Mandarmani and Gopalpur respectively.

At Mandarmani and Gopalpur sampling station the total alkalinity of water was found in between 91.33 ± 2.309 mg/l to 127.33 ± 3.215 mg/l and 83 ± 2.646 mg/l to 122.67 ± 2.082 mg/l respectively.

The nitrate nitrogen and phosphate phosphorus concentration of water at Mandarmani station was ranged from 0.128 ± 0.014 mg/l to 0.838 ± 0.02 mg/l and 0.117 ± 0.004 mg/l to 0.784 ± 0.016 mg/l respectively.

At Gopalpur sampling station the nitrate nitrogen and phosphate phosphorus concentration of water was in between 0.209 ± 0.025 mg/l to 0.919 ± 0.052 mg/l and 0.101 ± 0.012 mg/l to 0.767 ± 0.02 mg/l respectively.

The pH and organic carbon of the sediment at Mandarmani from 7.41 to 8.25 and 1.004 ± 0.0028% to 2.155 ± 0.073% respectively.

In case of Gopalpur the pH and organic carbon of the sediment were ranged from 7.28 to 8.17 and 1.154 ± 0.016% to 2.298 ± 0.078% respectively.

The Shannon Weaver biodiversity, Margalef's richness, Pielou's evenness index and density of studied macrobenthos was done monthly at two sampling stations in the present study. At the both sampling stations Mollsca was the dominant followed by crustaceans.

The Shannon Weaver biodiversity index was ranged from 2.08 to 3.143 and 1.807 to 3.023 at Goapalpur and Mandarmani respectively.

The Margalef's richness index was ranged from 1.595 to 3.99 and 1.924 to 4.825 at Mandarmani and Gopalpur respectively.

The Pielou's evenness index was in between 0.921 to 0.978 and 0.93 to 0.979 at Mandarmani and Gopalpur respectively.

The macrobenthos density showed a minimum value during monsoon months and maximum during late monsoon. At Mandarmani sampling station the maximum and minimum density was 478 number/m^2 and 2145 number/m^2 respectively. At Gopalpur sampling station the maximum and minimum density was 667 number/m^2 and 2510 number/m^2 respectively.

The physico-chemical parameters of water and sediment, abundance and biodiversity index of macrobenthos showed a seasonal pattern at both the sampling stations.

During the present study Shannon Weaver biodiversity index at Mandarmani showed a positive significant correlation with nitrate-nitrogen, sediment organic carbon, total density of macro benthos and Margalef's richness. And showed a negative significant correlation with surface water temperature, water pH and total alkalinity. In case of Gopalpur sampling station the biodiversity values showed a positive significant correlation with macrobenthos density and Margalef's richness. A positive relation with sediment organic carbon, nitrate-nitrogen and phosphate-phosphorus and biodiversity was found but relationship was not significant. The biodiversity values showed a negative significant correlation with air and surface water temperature, sediment and water pH and total alkalinity.

Based on the result obtained it can be concluded that the abundance and diversity of macro-faunal community of the intertidal zone of the two selected stations were influenced by the physico-chemical factors of the existing environment. The species diversity was recorded maximum during the months of October to January (Gopalpur) and November to March (Mandarmani), which suggested that the recruitment and settlement of the fauna are maximum during the post-monsoon to winter. The overall diversity of Mandarmani was lower as compared to Gopalpur which indicates Mandarmani was under pressure due to increasing tourism and other anthropogenic activities. The macrobenthos had a great importance on the coastal environment. However, indiscriminate catch of macrobenthic molluscs and crustaceans from the area without paying attention might threatened the macrobenthos associated industries so we have to pay attention for the conservation of coastal macrobenthos.

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APPENDIX- I

(A) PHYSICO-CHEMICAL PARAMETERS OF AIR AND WATER

Table. 6: Monthly fluctuations in (a) Air Temperature and (b) Water Temperature during July 2014 to June 2015 at Gopalpur and Mandarmani sampling stations.

a. Air Temperature (^{0}C)

	Temperature (^{0}C)											
Months / **Stations**	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
Gopalpur	34	31.5	30	29.5	28	27	28	27.5	30	32	34	34.5
Mandarmani	33	32	30.5	31.5	27	26	27	28.5	31	31.5	33	35.5

b. Water Temperature (^{0}C)

	Temperature (^{0}C)											
Months / **Stations**	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
Gopalpur	33	32	31.5	30	26.5	27.5	27	28	29.5	31	34	34.5
Mandarmani	34	31.5	30	31	26	27	28	29	31.5	31	33	34

Table. 7: Monthly fluctuations in (a) pH and (b) Salinity of water during July 2014 to June 2015 at Gopalpur and Mandarmani sampling stations.

a. Water pH

Water pH												
Months / Stations	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
Gopalpur	8.3	8.2	8.1	7.9	7.5	7.5	7.8	7.9	8.1	8.1	8.3	8.4
Mandarmani	8.4	8.3	7.9	8.1	7.6	7.5	7.9	8	8.1	8.2	8.3	8.5

b. Water Salinity (ppt)

Salinity (ppt)												
Months / Stations	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
Gopalpur	22	17	14	20	20	21	22	24	25	27	29	31
Mandarmani	23	20	18	22	22	23	25	27	28	29	31	34

Table. 8: Monthly fluctuations in (a) Dissolved Oxygen and (b) Total Alkalinity of water during July 2014 to June 2015 at Gopalpur and Mandarmani sampling stations.

a. Dissolved Oxygen of Water (mg/l)

Dissolved Oxygen (Mean ± S.D. in mg/l)												
Months / Stations	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
Gopalpur	5.25 ± 0.05	5.84 ± 0.08	6.05 ± 0.09	5.73 ± 0.12	5.79 ± 0.17	5.73 ± 0.05	5.44 ± 0.08	5.2 ± 0.14	4.91 ± 0.12	4.59 ± 0.17	3.76 ± 0.16	3.41 ± 0.09
Mandarmani	5.31 ± 0.12	5.6 ± 0.08	5.89 ± 0.12	5.41 ± 0.17	5.28 ± 0.14	5.07 ± 0.05	4.91 ± 0.09	4.64 ± 0.14	4.37 ± 0.05	4.00 ± 0.00	3.49 ± 0.09	3.20 ± 0.08

b. Total Alkalinity of Water (mg/l)

Total Alkalinity (Mean ± S.D. in mg/l)												
Months / Stations	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
Gopalpur	118.3 ± 1.53	115 ± 2.00	112.3 ± 0.58	100.7 ± 1.15	83.0 ± 2.65	87.67 ± 2.08	93.33 ± 1.15	98.67 ± 1.53	107 ± 1.73	105 ± 1.00	117.7 ± 0.58	122.7 ± 2.08
Mandarmani	127.3 ± 3.21	117.7 ± 2.08	109.7 ± 2.52	116 ± 1.00	92.33 ± 3.06	91.33 ± 2.31	96.67 ± 1.15	111 ± 3.61	115.7 ± 1.53	109.7 ± 2.52	125 ± 2.65	119 ± 2.00

Table. 9: Monthly fluctuations in (a) Nitrate Nitrogen and (b) Phosphate Phosphorus of water during July 2014 to June 2015 at Gopalpur and Mandarmani sampling stations.

Nitrate Nitrogen (Mean ± S.D. in mg/l)

Months / Stations	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
Gopalpur	0.466 ± 0.013	0.209 ± 0.025	0.227 ± 0.015	0.525 ± 0.032	0.613 ± 0.023	0.653 ± 0.036	0.671 ± 0.041	0.798 ± 0.016	0.919 ± 0.052	0.71 ± 0.02	0.867 ± 0.017	0.781 ± 0.011
Mandarmani	0.316 ± 0.024	0.214 ± 0.033	0.128 ± 0.014	0.469 ± 0.015	0.549 ± 0.019	0.5 ± 0.012	0.557 ± 0.01	0.753 ± 0.032	0.684 ± 0.045	0.838 ± 0.02	0.627 ± 0.014	0.684 ± 0.045

a. Nitrate Nitrogen of Water (mg/l)

b. Phosphate Phosphorus of Water (mg/l)

Phosphate Phosphorus (Mean ± S.D. in mg/l)

Months / Stations	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
Gopalpur	0.196 ± 0.02	0.101 ± 0.012	0.117 ± 0.007	0.202 ± 0.009	0.149 ± 0.004	0.356 ± 0.006	0.268 ± 0.007	0.322 ± 0.002	0.48 ± 0.008	0.648 ± 0.003	0.767 ± 0.02	0.689 ± 0.006
Mandarmani	0.219 ± 0.005	0.122 ± 0.002	0.118 ± 0.004	0.117 ± 0.004	0.245 ± 0.004	0.45 ± 0.009	0.359 ± 0.011	0.505 ± 0.014	0.652 ± 0.004	0.689 ± 0.005	0.627 ± 0.045	0.784 ± 0.016

(B) PHYSICO-CHEMICAL PARAMETERS OF SEDIMENT

Table. 10: Monthly fluctuations in (a) pH and (b) Organic Carbon of sediment during July 2014 to June 2015 at Gopalpur and Mandarmani sampling stations.

a. Sediment pH

Sediment pH												
Months / Stations	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
Gopalpur	8.16	8.11	7.65	7.77	7.32	7.28	7.54	7.79	7.82	7.99	8.02	8.17
Mandarmani	8.25	7.97	7.74	8.09	7.56	7.41	7.75	7.92	7.83	7.81	8.22	8.13

b. Organic Carbon of Sediment (%)

Organic Carbon (Mean ± S.D. in %)												
Months / Stations	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
Gopalpur	1.429 ± 0.019	0.887 ± 0.006	1.154 ± 0.016	1.595 ± 0.033	1.464 ± 0.011	1.715 ± 0.023	1.831 ± 0.013	2.052 ± 0.073	2.298 ± 0.078	2.133 ± 0.042	1.858 ± 0.025	1.731 ± 0.024
Mandarmani	1.143 ± 0.016	0.591 ± 0.004	0.721 ± 0.01	1.305 ± 0.027	1.61 ± 0.011	1.858 ± 0.025	1.69 ± 0.011	2.155 ± 0.073	2.01 ± 0.013	1.849 ± 0.037	2.001 ± 0.026	1.875 ± 0.025

APPENDIX- II

Table. 11: Correlation co-efficient between different physico-chemical parameters of water and sediment and biodiversity indices of Gopalpur sampling stations.

GOPALPUR													
	AT	WT	WpH	SpH	DO	SALINITY	ALKALINITY	NO_3-N	PO_4-P	SOC	H'	D	r
WT	.947**												
WpH	.897**	.924**											
SpH	.872**	.861**	.942**										
DO	-.686*	-.607*	-.605*	-.578*									
SALINITY	.488	.358	.386	.428	-.941**								
ALKALINITY	.892**	.957**	.982**	.904**	-.544	.295							
NO_3-N	.011	-.114	-.029	-.017	-.669*	.837**	-.131						
PO_4-P	.475	.390	.354	.324	-.918**	.923**	.286	.780**					
SOC	-.152	-.239	-.097	-.047	-.487	.696*	-.221	.881**	.630*				
H'	-.671*	-.746**	-.835**	-.775**	.121	.117	-.860**	.465	.125	.431			
D	-.666*	-.742**	-.855**	-.796**	.177	.068	-.850**	.406	.118	.377	.889**		
r	-.649*	-.724**	-.853**	-.808**	.181	.026	-.860**	.355	.053	.292	.982**	.867**	
J	-.586*	-.589*	-.509	-.349	.279	-.051	-.541	.185	-.252	.267	.546	.416	.449

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX- III

Table. 12: Correlation co-efficient between different physico-chemical parameters of water and sediment and biodiversity indices of Mandarmani sampling stations.

MANDARMANI													
	AT	WT	WpH	SpH	DO	SALINITY	ALKALINITY	NO_3-N	PO_4-P	SOC	H'	D	r
WT	.958**												
WpH	.934**	.949**											
SpH	.843**	.885**	.905**										
DO	-.453	-.433	-.460	-.344									
SALINITY	.438	.436	.476	.371	-.987**								
ALKALINITY	.892**	.946**	.908**	.932**	-.293	.304							
NO_3-N	-.021	-.030	.061	-.013	-.773**	.812**	-.092						
PO_4-P	.259	.266	.271	.091	-.936**	.936**	.115	.835**					
SOC	-.167	-.124	-.112	-.097	-.737**	.774**	-.173	.919**	.821**				
H'	-.653*	-.642*	-.605*	-.572	-.268	.278	-.638*	.688*	.413	.755**			
D	-.785**	-.751**	-.725**	-.677*	-.158	.173	-.748**	.580*	.333	.711**	.945**		
r	-.601*	-.587*	-.557	-.525	-.271	.292	-.593*	.717**	.414	.755**	.987**	.903**	
J	-.634*	-.601*	-.581*	-.634*	.262	-.318	-.521	-.147	-.110	-.015	.391	.491	.267

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).