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Assessment of impact of release of effluents on ecology of inshore and coastal areas of Maharashtra and their management

Part A: (Main Report)

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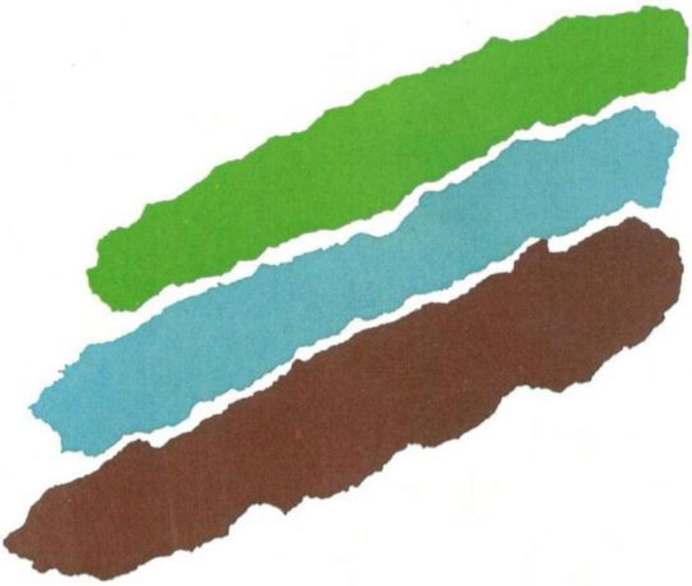

December 2018

सीएसआईआर - राष्ट्रीय समुद्र विज्ञान संस्थान
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Assessment of impact of release of effluents on ecology of inshore and coastal areas of Maharashtra and their management

Part A: (Main Report)

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Associate Project Leaders
Dr. Rakesh P. S.
Dr. Abhay B. Fulke
Dr. Sabyasachi Sautya

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EXECUTIVE SUMMARY

The 720 km long and 30-35 km wide coastal region of the Maharashtra state is a place of hectic human activity, intense urbanization in pockets and enhanced industrialization, resulting in degradation, directly or indirectly, of marine environment through indiscriminate release of domestic and industrial effluents, reclamation, offshore constructions movement of ships/fishing vessels and loading and unloading of a variety of cargo at ports etc. Thus the coastal regions are now disturbed to a varying degree and threatened, encountering various problems including pollution. A pragmatic approach is therefore required to manage the vital marine zones while acknowledging the necessity to have coastal developments for the economic progress of the Konkan region.

CSIR-National Institute of Oceanography (CSIR-NIO) carried out the preliminary monitoring during 2006-2007 and submitted the report entitled "Monitoring of Coastal Marine and Estuarine Ecology of Maharashtra" to the Maharashtra Pollution Control Board (MPCB) during December 2009. MPCB approached the CSIR-NIO, Mumbai to revisit the sites and find changes along the Maharashtra coast that might have occurred since 2007. The CSIR-NIO conducted these studies during November 2015-January 2016 (Postmonsoon) and March-May 2016 (Premonsoon) and the findings of these studies are presented in the report. The long term objectives of the study are as follows:

- To conduct ecological monitoring of inshore and coastal areas to identify changes, if any, in water quality, sediment quality and biological characteristics due to effluent releases and utilize the findings to suggest corrective measures.
- To monitor indicator pollutants in areas identified to be contaminated with specific pollutants and assess recovery of the ecosystems or otherwise.

The findings based on the field investigations during postmonsoon and premonsoon of 2015-16 at 22 transects and associated inshore waters of Maharashtra are presented in this report. The report is presented in two parts: Part A: Main Report and Part B: Data

Study area and waste water influxes

During the present study the sampling stations along the open coast were selected, as far as possible, to represent inshore (0 to 0.5 km), mid-level (2 to 3 km) and offshore (4 to 5 km) regions. Estuaries/creeks/bays were sampled to represent lower, middle and upper zones and the transects extended to the open sea. At least one station on each transect was operated over a tidal cycle and the remaining stations were sampled during low and high tides. Particular attention was given to sample marine and estuarine areas in the vicinity of significant urban, industrial or maritime establishments.

The details of each transect and its pollutant sources are given below.

1. Dahanu - Industrial and domestic wastes
2. Tarapur - Industrial and domestic wastes
3. Bassein - Industrial and domestic wastes
4. Manori - Industrial and domestic wastes
5. Versova - Industrial and domestic wastes
6. Mahim - Industrial and domestic wastes
7. Bandra - Domestic waste through marine outfall
8. Worli - Domestic waste through marine outfall
9. Thane Creek - Industrial, domestic and port based wastes
10. Patalganga - Industrial waste
11. Amba Estuary - Industrial and Port based wastes
12. Thal - Industrial waste (RCF, DP)
13. Kundalika Estuary- Industrial and domestic (minor) wastes
14. Murud - Domestic (minor) waste
15. Savitri Estuary - Industrial and domestic (minor) wastes
16. Vashishti Estuary- Industrial and domestic (minor) wastes
17. Jaigad Creek - Domestic (minor) and Port based wastes
18. Ratnagiri - Industrial (minor) Port based and domestic wastes
19. Vijaydurg - Domestic (minor) and port based wastes
20. Deogad - Domestic (minor) and fishery harbour wastes
21. Achara - Domestic (minor) and fishery harbour wastes
22. Malvan - Domestic (minor) and fishery harbour wastes

The station locations were plotted on satellite imageries and presented in respective sections in the report.

Data on 26 environmental parameters were collected at about 127 sampling locations with more than 1048 sampling events. All the analyses were done following standard oceanographic procedures.

Prevailing Environment/Ecological status

Results of the present monitoring are discussed transect-wise in the section 4 entitled “Prevailing environment” under the sub-heads of water quality, sediment quality and flora and fauna to facilitate discussion. They have been grouped under appropriate segments like coastal water, lower segment, middle and upper segment in the case of creek/estuaries. Stations 1 to 3 were part of the open coastal area. The stations operated in the bay/creek/river/estuary were grouped appropriately depending on the length of the respective water body. Comparison of the two season data i.e. postmonsoon and premonsoon for a given transect is included in the report.

The results of temporal variations which would reveal tidal variability of selected parameters were plotted graphically and included in section 4.

The parameter-wise ecological assessment for the study area was done for coastal and creek/estuarine waters separately for two major regions: North Maharashtra (Dahanu to Murud) and South Maharashtra (Savitri to Malvan) coasts.

Segment-wise ecological assessment of all transects in combination with the historical data (wherever available) was also made and presented as bar charts. Therefore, the section under “Ecological assessment” the overall status of prevailing marine environment along the coastal Maharashtra - north and south, as well as transect-wise ecological status in reference to pollution stress are reported and discussed extensively.

a) Parameter-wise status

During monsoon the high freshwater flow results in efficient flushing out of contaminants entering the creek/riverine/estuarine zones while flushing efficiency decreases considerably with the dry season. Majority of rivers have dams and barrages constructed on them to impound freshwater and regulate the flow thereby starving the creek/estuaries of freshwater inflow to enhance seaward transport of pollutants. The data on water quality as evaluated from various physico-chemical and biological parameters indicated that the coastal waters (upto 5 km) between Dahanu and Malvan are healthy except for a few areas near highly industrialized centres like Tarapur and Mumbai along the north Maharashtra.

i) Water quality: Overall, most of environmental parameters showed normal values along the south Maharashtra coast compared to the north Maharashtra with noticeable deviations.

As expected for shallow areas, the water temperature varied in accordance with the air temperature. In general, the various coastal segments of north Maharashtra revealed marginally higher average temperature (1.4ºC) than that of south Maharashtra. This could be due to difference in time of sampling since the water temperature in shallow regions is intimately linked with the solar radiation and wind effect.

Salinity was generally lower in creek/estuaries and increased towards open coastal waters. Salinity of the open coast, creek/estuary of north and south Maharashtra was closely comparable suggesting absence of significant freshwater influx to the coastal area during dry season.

The pH of the coastal and creek segments of Maharashtra was comparable. Southern coast indicated higher pH than that of coastal waters of northern Maharashtra. However, the pH of some estuaries and creeks varied over wider ranges depending on the input of organic load.

Suspended solids were in the range of 7-505 mg/l in the coastal waters of Maharashtra. The north coast revealed higher SS as compared to south coast. Turbidity generally varied in accordance with SS in most of the areas. However, abnormally high turbidity in Bassein, Thane creek and Kundalika estuary indicated influence of organic and colour imparted to water possibly due to releases of effluents.

Except for Tarapur and Bassein, coastal waters of Maharashtra indicated DO of >3.5 mg/l suggesting good oxidizing potential inspite of organic waste reaching the coastal system from urban and industrial areas. This also supported good assimilative capacity for the open coastal system off Maharashtra. Lower values of DO in the coastal waters off Tarapur (1.6-7.0 mg/l) and Bassein (2.5-6.2 mg/l) indicated the impact of industrial as well as domestic sewage laden organic waste in these coastal waters. However, many creek/estuary segments revealed deterioration with DO <0.3 mg/l along the coastal Maharashtra. The coastal waters of northern region sustained elevated levels of BOD (0.3-69.2 mg/l) than that of the south (0.6-19.4 mg/l) which could be due to relatively low volume of effluents released to the southern coast and better oxidative conditions than that of northern segment. The synoptic levels of DO and BOD along the coast was suggestive of effective assimilation of organic load entering the open coast through various creeks/estuaries.

The nutrients like PO_4^{3-}-P, NO_3^--N, NO_2^--N and NH_4^+-N indicated higher values in the creeks and some estuarine segments with considerable reduction towards the sea. The higher levels of NO_2^--N and NH_4^+-N in the inshore waters along the north Maharashtra as compared to the south segment suggested high organic input to the northern coast through anthropogenic sources leading to severe environmental deterioration in many instances. The concentration of PO_4^{3-}-P, NO_2^--N, NO_3^--N, and NH_4^+-N varied respectively in the ranges ND-49.4 µmol/l, ND-31.4 µmol/l, ND-71.6 µmol/l and ND-97.1 µmol/l respectively during the study period in the coastal system of Maharashtra. In general, these nutrients were relatively low and at normal levels in the open coastal waters unlike in some creeks/estuaries. However, increased concentration of NH_4^+-N in the coastal waters off Tarapur (26.9 µmol/l), Bassein (12.8 µmol/l), Bandra (41.6 µmol/l), Worli (12.9 µmol/l) and Thal (35.5 µmol/l) indicated the impact of domestic and industrial wastewaters entering the coastal area.

PHc (0.8 to 112.8 µg/l) and phenols (2.6 to 922.3 µg/l) indicated relatively higher petroleum contamination in the creeks/estuaries of the northern segments than that of the southern Maharashtra. The open coastal waters indicated low to moderate and variable contamination of PHc during the study period. The average concentration of phenols in water widely varied with no discernible trends.

Severe water quality deterioration was evident at transect like Tarapur, Bassein, Manori, Versova, Mahim, Thane, Patalganga, Kundalika, Vashishti and Ratnagiri Bay.

ii) Sediment quality: Bed sediments were by and large free from anthropogenic trace metals except for Hg in some instances around Mumbai. However, the higher levels of Cr, Hg and Pb in Tarapur creek; Cr, Ni, Zn and Hg in Ulhas estuary; Cr, Co, Ni, Zn, Hg and Pb in Patalganga; and Cr, Cd and Pb in Kundalika Estuary revealed anthropogenic source. It is also evident from above results that the creek/estuaries of north Maharashtra had higher levels on metals as compared to the southern coast. Elevated concentration of some metals in estuaries of south Maharashtra along with high concentrations of Al, Fe and Mn indicated their lithogenic origin. Overall, the results indicated enrichment of selected metals in some coastal segments of Maharashtra.

The low to moderate level of PHc contamination in the sediment of selected coastal segments along Maharashtra was noticed. However, C_{org} and P indicated mixed trend with high values associated with both anthropogenic activities and high biological production respectively along north and south coastal Maharashtra.

iii) Flora and fauna: The coastal and creeks/estuaries along coastal Maharashtra revealed high variations in bacterial counts viz; TVC, TC and FC in surface waters. In general, bacterial counts were abnormally high along the northern shore than that of the southern coast. The counts of TVC, TC and FC both in water and sediment were abnormally high at Tarapur, Bassein, Manori, Versova, Bandra, Mahim, Thane, Patalganga and Kundalika transects of the northern shore due to high volume of domestic wastewater released to these coastal areas. Along the southern shore Vashishti, Ratnagiri, Vijaydurg and Malvan sustained high counts of TVC, TC and FC. Compared to the 2007-08 results, counts of TVC, TC and FC had increase in most of the coastal/estuarine/creek regions.

The biological productivity interms of phytopigments and cell counts indicated higher primary production potential for the northern coastal segment as compared to the southern areas of Maharashtra. Such trend in high primary production along northern shore was probably associated with the nutrients input through anthropogenic fluxes such as sewage. Abnormally high values of chlorophyll *a* at Dahanu, Tarapur, Bassein, Manori, Versova, Bandra, Mahim, Worli, Thane, Patalganga, Kundalika, Savitri, Vashishti, Ratnagiri Bay and Deogad could be related to regional differences, environmental conditions like organic input to the coastal system and lack of grazing pressure by secondary producers.

The trend of phytopopulation was in accordance with phytopigments along coastal Maharashtra. The generic composition of phytoplankton at different coastal segments varied widely. Overall, the generic diversity of phytoplankton was comparable at coastal Maharashtra where the dominance of opportunistic species under enhanced stress conditions was evident. In general, the dominant genera of phytoplankton between northern and southern coastal Maharashtra were broadly comparable.

The zooplankton standing stock in terms of biomass and population ranged widely due to patchiness in their distribution associated with spatial, temporal and seasonal variability. Generally, in the north high primary production did not yield expected high zooplankton standing stock and diversity especially in polluted areas where more tolerant opportunistic species like carnivore became dominant resulting in low grazing pressure and high mortality of phytoplankton as evident from high phaeophytin values. Whereas in the south naturally induced high zooplankton standing stock associated with healthy and balanced community structure was noticed.

The open coastal waters sustained wider range of benthic biomass in the north than south Maharashtra. The faunal group diversity of macrobenthos widely varied in the study area with better diversity along the coastal segment of south than north Maharashtra. The macrobenthic population generally depended on the sediment quality and texture. Selected tolerant species like polychaetes and amphipods were more dominant in organic polluted areas along the coast. The meiobenthic biomass also varied widely in the coastal system of Maharashtra. The open coastal waters indicated higher variations in the south whereas in the north the biomass was comparable and low.

b) Segment-wise status

The environmental/ecological status of the 22 monitoring transects of the Maharashtra coast is discussed here.

i) Dahanu: The Dahanu Creek experiences strong tidal influences and receives water discharges from a thermal power plant. The water and sediment qualities were within expected ranges and the existing effluent releases had not grossly deteriorated the creek ecology except for relatively high temperature in the immediate vicinity of the cooling water release location. The comparison of earlier data indicated that the parameters like temperature, pH and DO were comparable over the years along this transect but an increase in NH_4^+-N concentration was recorded over the years especially in the creek system suggesting increase in the input of organic wastes to the creek system.

Overall, organic pollution induced primary production without adequate support of secondary producers was noticed. Macrobenthic organisms which, because of their sedentary nature were more prone to anthropogenic perturbations and did not reveal measurable adverse impact of release of warm effluent. In contrast the creek region sustained better standing stock and group diversity than the coastal segment.

ii) Tarapur: Tarapur Creek, a minor creek, with poor tidal flushing carrying industrial effluents, is highly degraded and resembled a sewer during low tide. To improve the creek environment MIDC has convey the treated effluent to coastal area through a pipeline. However, due to inadequate effluent release location, a major fraction of the effluent spreads in the nearshore zone and along beaches and enters the creek with the tidal ingress. The effluents entering the creek caused severe deterioration of the creek ecology with low DO; low pH; high SS, turbidity and nutrients in water as well as elevated levels of Zn and Cr in sediment. High bacterial counts and high phytopigments and cell counts in water supported good benthic standing stock instead of zooplankton. The results indicated organic pollution induced biological production.

iii) Bassein Creek (Ulhas Estuary): The coastal water of Bassein the mouth zone of the Ulhas Estuary, did not reveal gross impact of fluxes of pollutants transported through the estuary. Inner and middle estuarine segments exhibited low pH and low DO along with high BOD and nutrients. The sediment from the inner estuary had high burden of selective metals (Cr, Co, Ni, Zn, Hg, Pb). The microbial populations were elevated both in water and sediment. Phytopigments revealed an increasing trend from the coast to the upper creek with unusual cell counts. The high zooplankton standing stock at the upper estuary as compared to the rest was due to their tolerance to high environmental stress. Hence, organic pollution induced high primary production was supported by secondary producers like zooplankton especially at the upper estuary. Low benthic productivity off Bassein increased in the middle and upper segments with pollutant tolerant benthic community.

In general, the estuary indicated deterioration in water and sediment quality as well as induced biological productivity at different tropic levels associated with high organic input through anthropogenic fluxes.

iv) Manori: The creek is minor with limited tidal flushing. The creek which received domestic and industrial wastewaters was under considerable environmental stress with low and variable DO and high nutrients and probability of active denitrification. The sediment contamination was limited to Pb and Hg. The creek sustained high bacterial counts both in water and sediment. Phytoplankton indicated an enhanced primary production probably due to increase in nutrients associated with organic pollution. The creek sustained variable zooplankton standing stock. Marked variation with high values was also noticed in macrobenthos. The selected macrofaunal communities like polychaetes and amphipods which are tolerant to organic pollution proliferated in such a creek ecosystem. Upper creek region sustained better meiobenthic potential than the lower creek in postmonsoon, whereas the reverse trend occurred in premonsoon season.

v) Versova: Versova Creek which received voluminous domestic wastewater was also under acute environmental stress with variable DO falling to zero at low tide in some instances with high BOD and nutrients. Sediments did not indicate any serious metal contamination except for marginal increase in Cr, Cu, Zn, Hg and Pb content. Bacterial populations were very high both in water and sediment. Biological productivity in terms of phytoplankton was high. The zooplankton population was low in the area while the costal segment exhibited relatively high standing stock. Versova Creek sustained low macrobenthos and meiofauna. Overall, the creek revealed deteriorated water quality, low metal contamination in sediment, high bacterial count and nutrients induced primary production.

vi) Mahim Creek: The creek continued to exhibit highly deteriorated environment due to poor flushing and high input of anthropogenic wastes. Significant reduction in DO with high levels of phosphates and ammonia were observed at the creek stations. The impact of pollution was low along the open coast. The distribution of trace metals in sediment was patchy with enhanced levels of Cr, Zn, Hg, Cd and Pb. The PHc and C_{org} contents did not indicate any enrichment. P revealed minor increase. Mahim Creek sustained high count of bacterial population and induced primary production associated with organic wastes. Zooplankton standing stock was low with variable faunal diversity. Macrobenthic standing stock was normal with low meifaunal standing stock.

In general, the creek revealed deteriorated water quality, high bacterial contamination, enrichment of metals in sediment and organic pollution induced primary productivity.

vii) Bandra: Bandra area receives sewage through a massive submarine outfall and diffuser system at a depth of 7m CD. Mostly the water quality was in normal range with occasional drop in DO and high ammonia. Selected metals like Cr, Cd, Hg and Pb indicated minor elevated level. Bacterial counts were relatively low both in water and sediment compared to adjacent creek systems. Phytoplankton and zooplankton were normal with occasional high values and variable generic/faunal diversity. However, benthic standing stock was low with poor faunal diversity.

The coastal system, in general indicated minor environmental stress due to waste disposal.

viii) Worli: The coastal area of Worli also receives domestic waste through a large marine outfall. The water quality in the vicinity of the outfall was good with high DO and low BOD. Minor elevation in the concentration of NH_4^+-N and NO_2^--N indicated their build up. The metals contents in sediment did not indicate any serious contamination except for Hg by representing lithogenic concentrations. Bacterial counts were low. Phytoplankton productivity was high and comparable with adjacent coastal areas. The zooplankton and benthic standing stocks were normal.

This segment indicated a normal coastal system with low environmental stress.

ix) Thane Creek: Thane Creek/ Mumbai Harbour is a dynamic water body with good tidal flushing rendered this creek in a relatively better health than other creeks. However, the waste water entering the creek had severely deteriorated the water quality in some segments. In the inner segment, the DO levels were tide dependent with values sometimes falling to <3 mg/l during low tide with higher nutrient content. The creek also sustained high SS and turbidity. The openshore coastal water had good water quality. DO and BOD distribution pattern indicated that the organic load entering every day was being effectively dispersed and consumed. The PHc and phenols concentrations were normal. During the present study substantial reduction in the concentration of heavy metals was recorded compared to the earlier results, C_{org}, and phosphorus contents were mostly low, however PHc showed enhancement suggesting minor PHc contamination in sediment. Bacterial counts were high both in water and sediment. Phytoplankton revealed wide spatial and temporal variations. Zooplankton standing stock was high and varied widely with predominance of carnivores. Macrobenthic and meiobenthic standing stock was normal and exhibited wide spatial and temporal variation.

Overall, the creek revealed deterioration in water quality, sediment quality and organic pollution induced biological productions which do not represent a healthy and diverse ecosystem.

x) Patalganga: The water quality was tide dependent in different segments of the estuary. DO was highly variable (0.3-7.0 mg/l) with low values at the middle estuary due to excess loading of organic matter that lead to high BOD (6.5-35.6 mg/l) in the middle estuary. High concentration of phosphate, nitrite and ammonia indicated impact of organic load on the water environment of the estuary. PHc and phenols were higher than expected for uncontaminated waters. The heavy metals distribution in sediment varied widely with elevated levels of Cr, Co, Ni, Cu, Zn, Cd and Hg and indicated possible metal enrichment. C_{org}, P and PHc also varied with relatively higher content in the middle segment. The Patalganga estuary is highly contaminated by faecal as well as pathogenic microbes. Phytoplankton, zooplankton and benthic standing stock varied widely, temporally and spatially with low to normal generic/faunal diversity.

Overall, the estuary indicated deterioration in water and sediment quality and organic pollution induced biological productivity.

xi) Amba Estuary: Due to high tidal ranges the shallow estuary is well flushed. The estuary was characterized by normal water quality expected for unpolluted environments. However, higher concentration of phenols (2.6-592.1 µg/l) with maximum concentration during postmonsoon season suggesting land based contamination. The content of trace metals, C_{org}, P and PHc in sediment revealed considerable scatter but there was no evidence for their accumulation in the estuarine sediments. Bacterial counts were low. Phytoplankton, zooplankton, and benthic standing stock indicated considerable spatial, seasonal and temporal variability with normal generic/faunal diversity.

In general, the estuary did not reveal noticeable environmental stress except high nutrients which could be associated with tidal waters entering from Patalganga Estuary and Mumbai Harbour to Amba Estuary (during flood).

xii) Thal (RCF, DP): The treated effluent from the fertilizer plant is released off the coast and hence in the area of high tidal dispersion. The most of the water quality parameters were in normal ranges as compared with open coastal waters along Mumbai coast. However, elevated levels of NO_3^--N and NH_4^+-N were possibly associated with the impact of waste disposals as well as the waters draining during low tide from the Mumbai Harbour to the Thal coast. The trace metals in sediment were in the expected ranges and enrichment of C_{org} and PHc was absent. Bacterial counts were low. Phytoplankton and zooplankton standing stocks varied but did not indicate any abnormality. Benthic standing stock was low with poor diversity.

In general, the Thal coastal system revealed low level environmental stress.

xiii) Kundalika Estuary: The study area represents dynamic coastal water and three estuarine segments with marine and freshwater dominance respectively. The inner and middle estuarine segments experience moderate tidal ingress with poor flushing. Water quality of the estuarine segments varied widely with polluted lower and middle segments due to poor flushing. However, coastal waters revealed good and water quality comparable with adjacent coastal system. Estuarine segments sustained increase in temperature, low and variable pH and salinity, frequently low DO and often high BOD and nutrients. The levels of PHc and phenols were associated with release of industrial effluents and domestic wastes. The deviations in water quality in respect of high nitrate, nitrite, ammonia, PHc and phenols were clearly evident at the disposal site. The trace metal contents in sediment were variable with high values of Cr, Cd, Hg and Pb at the inner segment. Higher bacterial counts were recorded both in water and sediment in the estuarine segments as compared to the openshore areas. The standing stock of phytoplankton strongly suggested induced primary production by organic pollution. The zooplankton and benthic standing stock indicated wide variation with normal distribution.

Overall, the estuary indicated high environmental stress due to industrial and domestic wastes.

xiv) Murud: Murud/Rajpuri Bay is a dynamic ecosystem with good flushing characteristics. The coastal and bay waters were relatively free from anthropogenic pollutants and the prevailing water quality represented natural variability. The variation in salinity, pH, SS, DO and BOD were not marked as the tide progress from coastal to the creek. The nutrients were variable and indicated presence of some organic load in the region. PHc and phenols levels remained low throughout the tidal cycle. The selective metals except Mn and Fe revealed comparatively less scatter of values in sediment. The levels of other metals possibly represented the lithogenic concentration.

Relative high P suggested enrichment through mangrove ecosystem. Bacterial populations in water and sediment were low with narrow spatial and temporal variations. Phytoplankton and zooplankton standing stock varied widely with spatial, seasonal and temporal fluctuations. Macro and meiobenthic biomass and population varied both seasonally and spatially variability. They were low in the coastal and relatively high in the creek system.

Overall, the coastal system was free from anthropogenic stress and indicated high bio-potential of natural origin.

xv) Savitri Estuary: The tidal influence was observed upto upper segment and presently disposal point is located in the weak tidal zone (Station S8). The impact of the wastewater on the estuarine ecology at different segments was clearly evident. Thus the status of water quality in the inner estuary was distinctly different from that of the lower estuary. Water quality parameters like salinity, temperature, SS, DO and BOD exhibited seasonal, spatial and temporal variability. The coastal waters though revealed low nutrient concentrations, the estuary indicated higher contents of nutrients and noticeably high at the upper estuary due to waste disposals. P, C_{org} and PHc were marginaly high in estuarine segments as compared to the coastal sediment. Metals in sediment varied widely without any discernible trends. In the presence of high Al, Mn and Fe values, elevated concentration of some of the metals seems to be lithogenic in nature. The bacterial population were much higher in the estuarine segments as compared to the open coastal waters. The standing stocks of phytoplankton, zooplankton and benthos varied widely with spatial, temporal and seasonal variability. Phytoplankton production induced zooplankton standing stock prevailed in the estuary. Macrobenthic distribution also indicated wide fluctuations. The estuarine segment sustained high benthic standing stock with low diversity indicating adverse effect of effluent on estuarine ecology.

Overall, the estuary revealed deterioration in water quality and sustained organic pollution induced biological productivity. Increased metal concentrations in sediment appeared to be associated with the lithogenic source.

xvi) Vashishti Estuary: Vashishti is a relatively large estuary of the Konkan region with excellent flushing due to the large quantity of freshwater released at upstream and considerable tidal influences. The water quality which was normal in the coastal water had not changed appreciably over the years and comparable with clean coastal water off Maharashtra. However, the estuary revealed low pH, variable salinity and occasional decrease in DO coupled with high BOD and nutrients mainly associated with effluent disposal in the upper estuary. The water quality of the entire estuary had deteriorated though to a varying extent due to tidal oscillations which distributed the effluent in different segments of the estuary. The open coastal waters had very good assimilative capacity with little influence of the contaminated estuarine water. C_{org} in sediment was low with seasonal variability. However, enhanced concentration of PHc (0.2-8.2 µg/g) in sediment indicated moderate petroleum contamination. Metal contents in sediment were relatively high in the mouth of the estuary. It appeared that sediment at mouth acted as the sink for metals due to change of matrix and more so because of sand bar at the mouth. The content of heavy metals like Cr, Mn, Co, Ni, Cu and Zn were also higher at the upper segments. However, analysis of effluent from MIDC Lote did not reveal gross input of these metals. The bacterial counts were relatively high in the coastal area than that of estuarine segments. Whereas a reverse trend was noticed in sediment with higher values confined to the estuarine segments. Biological productivity indicated spatial, temporal and seasonal variability. Phytopigments were normal and variable with occasional high values. The zooplankton standing stock varied widely and indicated an overall normal secondary potential. The inner segment sustained higher macrobenthic standing stock during both the seasons. Meiofaunal distribution showed wide variations in Vashishti, and no clear trend was observed.

Overall, the estuary revealed moderate environmental stress as indicated by the water and sediment quality.

xvii) Jaigad/Shastri Estuary: Jaigad Creek/Shastri Estuary experienced limited tidal impact and tidal ingress is expected to be weak in the middle and upper segments. The Jaigad coastal and estuarine water were free from any anthropogenic input and sustained clean water quality. The pH was constant and in the expected range. The average DO content was above 4.8 mg/l and consequently BOD was low. Phosphate, nitrate and nitrite were uniformly low and in the normal range and seasonal as well as spatial variations were absent. However, elevated concentration of NH_4^+-N (0.3-5.8 µmol/l) in the creek water may be due to mainly mangrove and fishing based organic load. Concentration of PHc and phenols were also in the normal ranges. The heavy metals in sediment showed considerable spread without any spatial variation with higher level of Al, Cr, Fe, Mn, Co, Cu, and Hg. These levels can be of lithogenic origin associated with the basalts of the catchments. Estuary sustained high content of C_{org} and low PHc in sediments. Bacterial counts were high both in water and sediment. Phytoplanktons were patchy and varied widely spatially as well as temporally. Zooplankton distribution revealed seasonal and spatial variation. The benthos revealed faunal diversity, generally recorded in the coastal waters with a less seasonal trend.

In general, the estuary indicated low level of environmental stress associated with fish landing activities.

xviii) Ratnagiri: The inner Mirya Bay has very poor flushing resulting in highly deoxygenated conditions. The coastal water off Ratnagiri however remained relatively free from anthropogenic fluxes of pollutants and the water quality represented the natural background. However, inner part of Mirya Bay was severely affected by organic pollution due to very poor flushing and was characterized by low DO; and high phosphate, ammonia and phenols. P, C_{org} and PHc were generally low in sediment. The metals (Mn, Cr, Fe, Cu and Hg) in sediment were highly variable which could be attributed to changes in sediment texture as well as Al and Fe content apart from anthropogenic fluxes. The open coastal waters of Ratnagiri sustained the lowest counts of TVC and FC for the coastal Maharashtra suggesting clean coastal system unlike the Ratnagiri Bay which sustained much higher counts of bacterias. Biological standing stock in terms of phytoplankton, zooplankton and macrobenthos was in the normal ranges and exhibited spatial, temporal and seasonal changes in coastal waters. However, biological productivity in the bay suggested organic pollution induced primary production. Zooplankton and benthic productivity represented low faunal diversity in the bay.

In general, the Ratnagiri Bay continued to experience severe organic pollution due to sewage disposals and organic discards from fishing activities, whereas the coastal waters were clean and healthy.

xix) Vijaydurg Creek: The tidal influence in the inner segment of the creek is expected to be low with poor flushing. In the absence of known anthropogenic fluxes, the water quality of Vijaydurg Creek is considered to represent unpolluted marine environment. However, relatively low DO and elevated concentration of PO_4^{3-}-P, NH_4^+-N, PHc and phenols in the upper estuarine segments indicated some inputs of the organic load to the system probably associated with port activities. The organic carbon and PHc in sediment were low while elevated concentration of Cr, Fe, Mn, Co, Ni, Cu and Zn appeared to be natural and lithogenic.

Bacterial (TVC, TC, FC) counts were low with absence of many pathogens. The distribution of phytoplankton, zooplankton and benthos was normal with variable generic/faunal diversity.

Overall, the coastal waters were clean and healthy but the creek system revealed low level organic pollution due to fishing activities at the port.

xx) Deogad Creek: The study area represents coastal, bay and creek segments, where the upper creek segment is expected to be with poor flushing. There are no known sources of effluent release in this coastal system but hectic fishing activities can influence the marine environment.

The openshore and creek waters were characterized mostly by normal ranges of water quality parameters which included salinity, temperature, pH, SS and DO suggesting clean waters. The selective nutrients (phosphate, nitrate, nitrite and ammonia) were uniformly low without any spatial and seasonal variations. PHc and phenols were low. Phosphorous and C_{org} build-up in sediment appeared to be of natural origin and the elevated levels of PHc could be due to operational discharges of fishery harbour. Similarly elevated concentrations of heavy metals were of lithogenic origin. The bacterial counts were variable but high in the bay and creek mouth. The phytoplankton production was relatively high in the inner creek. The zooplankton biomass was better in the coastal segment while population was comparable between the different segments. High benthic standing stock was indicative of good benthic productivity with spatial and seasonal variations.

The coastal system of Deogad in general represented clean coastal area with minor organic pollution stress in the creek.

xxi) Achara: The Achara Creek is surrounded by lush healthy mangroves. Sand deposition at the mouth of the creek makes navigation difficult especially during ebb. There is no known anthropogenic discharge in the creek. However, due to attractive natural beach, some disturbance due to tourism may be expected, apart from activities of Achara village and a small fishing port.

Coastal water of Achara revealed the natural background for SS, turbidity, pH, salinity, DO, BOD, phosphate, nitrate, nitrite and PHc. The creek water however sustained relatively high concentration of ammonia and phenols indicating some anthropogenic influence or due to detritus from mangroves or both. Concentration of C_{org} and PHc was low in coastal and creek sediments. Concentration of all trace metals was low. However, the elevated concentration of Fe and Cr may be associated with the lithogenic matrix as in the other part of south Maharashtra. Achara Creek sustained relatively high bacterial counts during premonsoon which suggested sewage contamination. The standing stock of phytoplankton and diversity were comparable between different segments suggesting strong marine influence in the creek system. Zooplankton standing stock both in terms of biomass and population were normal with occasionally high secondary production. Higher meiofaunal standing stock was recorded in postmonsoon with the upper creek sustaining the highest meiofaunal density and biomass.

The Achara Creek represented clean marine environment with low anthropogenic influence.

xxii) Malvan: Port and fishing activities in the Malvan Bay are the major sources of disturbance in the bay which experiences weak tidal flushing. In the absence of any known and major anthropogenic source of effluent, Malvan coast represented an unpolluted marine environment. The water quality was good with minor spatial and temporal variations. The pH, salinity, water temperature and SS were in the normal ranges and indicated a typical marine area with low freshwater inflow. The water was well-oxygenated and the BOD was low. The nutrient contents were uniformly low and within normal range. PHc and phenols showed moderate petroleum contamination, which may be attributed to fishing and port based contamination. Metal contents in the bay were low compared to the coastal areas and there was no evidence of enrichment of any particular trace metal in sediment. C_{org}, P and PHc in sediment were low but occasionally elevated. Bacterial populations in the bay indicated human influence through port and fishery activities. Phytoplankton, zooplankton and macrobenthic standing stock were high with good generic/faunal diversity as well as spatial and seasonal variability. The bay region sustained highest meiobenthic standing stock.

Overall, the coastal system of Malvan represented clean area and healthy marine ecosystem with good assimilative capacity for organic pollutants.

Water quality index (WQI): The result of WQI indicated that most of the coastal (beyond 5 km from the coast) waters could be characterised in medium to good category. However, the WQI of the creeks/estuaries and bays varied spatially, temporally and seasonally. Thus the Bassein/Ulhas estuary was in the bad category followed by Tarapur Creek in premonsoon, and Patalganga in both seasons was in bad to medium range. Upper Thane Creek was in medium range. Similarly Mahim Creek was close to bad range during premonsoon. Kundalika Estuary was in bad range in the vicinity of effluent disposal. The WQI was in the medium range in the open coast of Kundalika estuary. WQI was in the low category for south Maharashtra Estuaries in the vicinity of effluent release. The WQI of Shastri estuary was low in the upper estuary during premonsoon season though there is no known anthropogenic discharge in the region. Similar WQI was also recorded in Achara Creek and Malvan Bay.

Effluent Analysis: During monitoring period effluents were collected in the presence of MPCB officials from different CETPs, discharging effluent to nearshore water bodies of Maharashtra coast. From the results, it is evident that only CETP of Mahad MIDC (20.2 mg/l of BOD) and CETP at Ambernath (Chemical) (44.8 mg/l of BOD) met BOD criteria specified by MPCB, during postmonsoon season. This is because the inlet BOD of effluent at CETP of Ambernath (96.0 mg/l) and CETP Mahad (60.2 mg/l) itself was lower. However, BOD of other CETPs was above 120 mg/l and some of them exceeded 800 mg/l in the final effluent. Similarly, COD values of final effluents were several folds higher than the specified criteria of MPCB for CETPs and some are discharging effluent containing COD value above 31000 mg/l. The concentration of metals and PHc were within the prescribed limits of MPCB/CPCB for CETPs. However, total load calculated based on the effluent quantity, the estuaries and coast receive substantial amount of metals. Apart from point sources, the creeks/estuaries and coastal water received effluents from several non-point sources of industrial and domestic sources, which released organic load several times higher than the known industrial wastes.

Metals and PHc in biota: The bioaccumulation of selected metals like Cr, Co, Ni, Cu, Zn, Hg and Pb and PHc was investigated in fish obtained during experimental trawling as well as through local fishermen in areas between Dahanu and Vijaydurg. Overall, the results indicated that the fishes/prawns collected from different part of Maharashtra coast were relatively free from contamination of toxic metals and PHc compared to the permissible limits for human consumption.

Recommendation

The recommendations made in this report are based on the two sets of monitoring with respect to water quality, sediment quality and biological characteristics conducted at 22 transects along the Maharashtra coast during 2015-16 and 2007-2008, information made available by MPCB, data-base at CSIR-NIO and available published literature. Thus the recommendations in this report would emerge from ecological status of the inshore and coastal environments of Maharashtra vis-à-vis the anthropogenic contaminants entering the systems through domestic, industrial and other sources.

The present results indicate that the coastal sea off Maharashtra is by and large unpolluted except for the pockets off Tarapur and Mumbai wherein some degradation limited to a few kilometers off the shoreline is evident.

The inshore water bodies comprising of estuaries, creeks and bays are shallow with wide mouth and tidal ingress is good in the outer segments but decreases considerably inland from the mouth. The catchment derived freshwater discharge is high during monsoon but decreases considerably over the dry season and becomes insignificant after about December leading to conditions of near stagnation in the inner zones. Presence of prominent sand bars in the mouth zone of several estuaries hinders the outflow of water particularly during low tides. These characteristics of the water bodies have considerable bearing on their flushing behaviour. It is paradoxical that many of these estuaries and creeks receive effluents predominantly in their inner zones.

Based on the above preamble which briefly describes the features of the Maharashtra coast, and the results of the monitoring the following recommendations are made.

a) General

i. The creek/estuarine system which were identified to be under high environmental stress during 2007-2008 monitoring revealed similar conditions during present study; in fact some of them had become more sever.

ii. Domestic wastewater being the major contributor to degradation it is vital to free these inshore areas from such unplanned releases and sewage should be released in the Arabian Sea through properly sited and designed marine outfalls after meeting the CPCB/MPCB norms. This should be carried out on priority basis for selected critical areas identified around Mumbai. Reliable model studies to understand the coastal hydrodynamics, flushing characteristics and pollutants transport at the critical areas should be initiated in order to formulate suitable remedial measures.

iii. Release of effluents meeting CPCB/MPCB norms in the estuarine segment where tidal flushing is high and salinity is > 5.0 ppt during driest season (as per CRZ notification 2011), should be permitted only after proper studies. Wherever feasible, new industries should be persuaded to convey the treated effluent to the open sea at a properly identified site.

iv. Domestic/industrial effluents release to the inner bay/creek/estuarine zones must be stopped. Existing discharges should be shifted downstream/coastal water to a site selected after proper hydrographic, ecological and numerical modelling studies. This should be carried out on priority for the critical areas like Tarapur, Ulhas, Thane Creek, Patalganga, Kundalika, Savitri, Vashisti and Ratnagiri Bay.

v. Apart from point sources, non-point sources contribute substantial amount of effluent having potential to degrade the aquatic system. All the non-point discharges should be assessed and channelized to the effluent collection systems.

vi. Suitable measures to reduce the bacterial and pathogenic contaminations are needed.
vii. The baseline for water quality, sediment quality and biological characteristics in order to make reliable future comparison of the coastal Maharashtra, should be established.
viii. Considering the toxicity of Hg and other toxic metals, bioaccumulation of these metals in edible marine resources of the affected area should be monitored periodically.
ix. Environmental awareness programme for the fishermen in order to discourage them for throwing trash fishes and boat generated oily wastes into the inshore waters should be evolved. Also they should be provided suitable collection system onshore to dispose above such wastes.
x. Study should be initiated to find out the exact impact of anthropogenic activities on the selected coastal system by establishing the carbon and nutrient fluxes and isotopic analysis.
xi. A clean and healthy creek/estuarine ecology should be maintained in order to conserve and protect the fragile and high bio-diverse coastal wetland and nearshore ecosystem of Maharashtra.

b) Site specific

After compilation and discussion of the data, following corrective measures are recommended:

Dahanu: Periodic monitoring of the creek segment especially water quality with reference to temperature should be considered.

Tarapur: It appears that the waste assimilation capacity of the creek has been exceed. It may be therefore necessary to undertake numerical modeling of the coastal area and convey the treated effluent through a submarine pipeline and released at a suitable site in the open shore waters.

Bassein: There is urgent need to reverse the trend through urgent measures taken by municipalities and MIDC by strict compliance to MPCB norms for wastewater and release it through subsurface pipelines at locations identified after detailed studies of the assimilation capacity of the estuary.

Manori: Urgent measures to ensure the effluents comply with the MPCB norms before release are required. It will be also necessary to assess the waste assimilative capacity of the creek and findings used to release the treated wastewater at scientifically identified outfall either within the creek or the open-shore area.

Versova: Considering the volume of seawater available in the creek even during high tide and the quantity of sewage released, it is unlikely that the creek water quality would improve even if the effluents released in the creek meet MPCB norms. It may therefore be inevitable to release these effluents through a submarine pipeline to the coastal water at scientifically identified outfall.

Mahim: To improve the environmental quality, all sources of effluents may be identified and adequate treatment provided before its disposal. It may even be necessary to convey the treated effluents through a pipeline and release it at a scientifically identified site off the mouth of Mahim creek / bay after detailed investigations aimed at assessing the waste assimilation capacity of the system.

Bandra and Worli: The coastal system represents low environmental stress sustaining better marine ecosystem as compared to the creeks around Mumbai. However, the water quality (bacteria, DO, BOD and nutrients) and sediment quality (bacteria, Cr, Cd, Hg and Pb) needs to be monitored.

Thane Creek/Mumbai Harbour: Though several measures have been taken in past to curtail the load of pollutants entering in the Thane Creek, the water quality of the creek has not improved sufficiently. The major contributor is sewage. Hence, proper action is required to collect, treat and dispose the sewage to the aquatic system after proper study of assimilation capacity of the receiving water body.

Patalganga Estuary: To improve the water quality, apart from treatment to the effluent to meet desired norms, it is necessary to assess the assimilative capacity of the estuary and limit the organic load within the assimilative capacity. The effluent release location needs also to be identified after proper studies and adequate treatment to effluents needs to be ascertained.

Amba Estuary: The ecological quality of the estuary did not reveal deterioration over the years within the natural variability inherent to coastal waters. However, in view of several developments planned along the banks including port facilities, regular monitoring of the estuary needs to be undertaken, to enable corrective measures if necessary.

Thal: Periodic monitoring off Thal needs to be undertaken to identify changes in ecological quality if any to enable corrective action**.**

Kundalika Estuary: It is necessary to ascertain proper treatment to the industrial effluent prior to release and other sewage releases in the inner estuary are quantified and treated adequately.

Savitri Estuary: Effluent collected and analyzed from Mahad CETP meets the MPCB/CPCB criteria. However, the quality of the Savitri Estuary has not improved adequately. It is possible that there are non-point discharges of sewage and industrial effluents. These need to be identified and treated before release. Other possibility is that the load entering the estuary from the CEPT is in excess of the assimilative capacity of the upper estuary. This can be resolved through proper numerical modeling of the estuary with respect to load being released.

Vashishti Estuary: The industrial effluent from MIDC Lote-Parshuram discharged at the confluence of the Jagbudi and Vaishisti Rivers continue to cause stress on ecology of the upper estuary. The effluent from the CETP did not meet MPCB/CPCB norms. This needs immediate corrective measures. It is also suggested that the assimilative capacity of the estuary is studied through proper numerical modeling and suitability of the present effluent release location or otherwise is ascertained.

Jaigad/Shastri Estuary: The estuary sustains good ecological environment though some minor influence of the fishing activities and fringing mangroves was evident. However, estuary may be periodically monitored due to increasing human activities along the estuary.

Ratnagiri: The treated sewage may be released through a sub-surface pipeline at a scientifically identified location that permits sufficient dilution of effluents. Discarding of unwanted fishes in the harbor/bay needs to be stopped by providing waste collection bins at the landing centre and the collected waste is appropriately disposed.

Deogad and Achara: These areas may be periodically monitored for their ecological status to ascertain their healthy environment.

Malvan: To prevent further deterioration of the bay, the sewage releases may be identified and treated in septic tank – soak pit. Discarding of unwanted fish in the bay needs to be stopped by providing waste collection bins at the landing centre and the collected waste is appropriately disposed.

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EXPLANATORY NOTE

Av	-	Average
B	-	Bottom
BOD	-	Biological Oxygen Demand (mg/l)
COD	-	Chemical Oxygen Demand (mg/l)
C_{org}	-	Organic carbon (%)
CS	-	Coastal Segment
DO	-	Dissolved Oxygen (mg/l)
LS	-	Lower Segment
Max	-	Maximum
Min	-	Minimum
MS	-	Middle Segment
ND	-	Not Detected
NH_4^+-N	-	Ammonium nitrogen (μmol/l)
NO_2^--N	-	Nitrite nitrogen (μmol/l)
NO_3^--N	-	Nitrate nitrogen (μmol/l)
PHc	-	Petroleum hydrocarbons (μg/l)
PO_4^{3-}-P	-	Reactive phosphate phosphorus (μmol/l)
S	-	Surface
SS	-	Suspended Solids (mg/l)
Temp	-	Temperature (^oC)
TN	-	Total nitrogen (μmol/l)
TP	-	Total phosphorus (μmol/l)
US	-	Upper Segment
TVC	-	Total viable count
TC	-	Total coliform
FC	-	Faecal coliform
ECLO	-	*Escherichia coli* like organism
SHLO	-	*Shigella* like organism
SLO	-	*Salmonella* like organism
PKLO	-	*Proteus, Klebsiella* like organism
VLO	-	*Vibrio* like organism
VPLO	-	*Vibrio parahaemolyticus* like organism
VCLO	-	*Vibrio cholerae* like organism
PALO	-	*Pseudomonas aeruginosa* like organism
SFLO	-	*Streptococcus faecalis* like organism

1 INTRODUCTION

1.1 Background

Nearly three quarters of the world population lives on the coast. The coastal region is thus a place of hectic human activity due to intense urbanization and industrialization resulting in uncontrolled human interference with the fragile coastal ecosystems. Evidently, the majority of the coastal ecosystems is now highly disturbed and seriously threatened encountering problems like pollution, habitat destruction, reclamation, siltation, erosion, flooding, saltwater intrusion and many other human-induced activities. Maharashtra is no exception to this and appropriate management strategies are urgently needed to ensure sustainable development and management of coastal areas and their resources.

The Maharashtra coast that stretches between Bordi/Dahanu in the north and Redi/Terekhol in the south is about 720 km long and 30-50 km that stretches all along wide; the width of the coastal strip being restrained by the Western Ghats to the west. The shoreline is indented by numerous west-flowing river mouths, creeks, bays, headlands, promontories and cliffs. Being one of the important maritime and industrialized state in India, many industrial clusters are established in the coastal belt of Maharashtra. However, much of the industrial development in the State has taken place several kilometres inland from the coastline. This is because of the primary considerations for such developments in the past had been the availability of fresh water, electricity and transport, while environment received the lowest priority. Hence, many industries are located near highways and railway stations and release their effluents in nearby estuaries, creeks and bays (hereinafter referred as inshore waters). Of the coastal districts, Thane and Mumbai are heavily industrialized while Sindhudurg district is the least developed, industrially. The majority of industries located in the Thane and Mumbai districts are housed in large industrial clusters namely, Trans Thane-Belapur belt, Kalyan-Ulhasnagar-Ambernath belt, western bank of Thane Creek, around Patalganga and Amba rivers and Tarapur-Boisar. Evidently, nearby water bodies are the recipients of a variety of wastes. Industries in other coastal districts are mainly located in the MIDC areas and discharge their effluents through a common collection centre to inshore waters. Thus, Thane Creek and Ulhas, Patalganga, Amba, Kundalika, Savitri, Vashishti estuaries etc have been receiving such effluents. Only a few industries such as the nuclear power station at Tarapur and the fertilizer complex at Thal release their effluents directly to the coastal (depth of water <10 m) Arabian Sea (hereinafter referred as coastal sea).

The inshore and coastal waters of Maharashtra particularly around cities and towns also receive domestic wastewater often untreated that has severely deteriorated the ecological quality of these water bodies. In fact, in some instances such as Versova, Mahim and Thane Creeks; Ratnagiri Bay; and the coastal sea off Mumbai, domestic wastewater is the major source of degradation of the marine zone.

The inshore waters and the coastal sea forms a small fraction of the shelf waters of Maharashtra and their contribution to the marine fish landings of the state is relatively low as compared to the rest of the shelf area. However, these areas are critically important to the health of the fishery due to the fact that majority of commercially exploited fishes, crustaceans and molluscs spend part of their life cycle in inshore and coastal seas and if these zones of vital importance to fishery are degraded it will have irreversible adverse impact on the fishery resources.

A pragmatic approach is therefore required to manage the vital marine zones while acknowledging the necessity to have coastal developments for the economic progress of the Konkan region. CSIR-National Institute of Oceanography (CSIR-NIO) carried out the preliminary monitoring during 2006-2007 and submitted the report entitled "Monitoring of Coastal Marine and Estuarine Ecology of Maharashtra" to the Maharashtra Pollution Control Board (MPCB) during December 2009.

Maharashtra Pollution Control Board (MPCB) approached the CSIR-National Institute of Oceanography (CSIR-NIO), Mumbai to revisit the sites and find changes along the Maharashtra coast that might have occurred since 2007. The CSIR-NIO conducted these studies during November 2015-January 2016 (postmonsoon) and March-May 2016 (Premonsoon) and the findings of these studies are included in this report. The findings are presented in two parts:

Part A : Main Report

Part B: Data

1.2 Objectives

Marine environmental management through proper assessment of water quality vis-à-vis the existing wastewater discharges and impacts on the ecosystem due to ongoing activities are prerequisite for optimum utilization of marine areas without unduly disturbing the ecosystem. A comprehensive programme for coastal area development management and protection therefore requires detailed information as regards levels of macro- and micro-pollutants; wastewater quality and quantity entering the system; productivity at different levels; species inhabiting the area; and sediment nature, composition and associate fauna. Evidently, environmental data requirements are extremely broad and it is necessary to adopt a multidisciplinary approach. With this view the objectives of this present study encompass the following:

i) Ecological monitoring of inshore and coastal areas to identify changes, if any, in water quality, sediment quality and biological characteristics and utilize the findings to suggest corrective measures.

ii) Monitor for indicator pollutants in areas identified to be contaminated with specific pollutants and assess recovery of the ecosystems or otherwise.

Accordingly, the CSIR-NIO had submitted the project proposal with the above objectives to the MPCB which was accepted during May 2015. As per the approved proposal, the estuarine and coastal waters to be studied are: Dahanu Creek, Tarapur Creek, Bassein/Ulhas Estuary, Manori Creek, Versova Creek, Bandra and Worli outfalls, Thane Creek, Patalganga Estuary, Amba Estuary, Thal, Kundalika Estuary, Rajapuri Creek, Savitri Estuary, Vaishisti Estuary, Shastri Estuary, Ratnagiri Bay, Vijaydurg, Deogad, Achara and Malvan. Accordingly, the field studies were conducted during November 2015 to January 2016 (Postmonsoon) and March 2016 to May 2016 (Premonsoon).

1.3 Scope of studies

The investigations to be conducted as per the agreed scope are as follows:

1.3.1 Ecological monitoring

Sampling areas

Inshore as well as the coastal sea at pre-decided sites were monitored as per the details given below:

Inshore areas

The inshore areas were include Dahanu, Tarapur, Bassein/Ulhas, Manori, Versova, Mahim, Thane, and Ulhas, Patalaganga, Amba, Kundalika, Savitri, Vashishti, Shastri and Achara estuaries.

Coastal sea

Coastal sea was monitored off Tarapur, Bassein, Bandra (sewage outfall), Worli (sewage outfall), Thal (Industrial outfall), Murud, Ratnagiri, Malvan and off the mouths of Kundalika, Savitri, Shastri and Vashishti estuaries.

1.3.2 Sampling locations

Inshore areas

All stations covered during 2007-08 monitoring were sampled with additional stations in some estuaries for better understanding of environmental status.

Coastal sea

Three samples will be collected in duplicate (nearshore, 2-3 km from coast and 5-7 km from coast) along a transect perpendicular to the shore.

1.3.3 Sampling pattern

Surface and bottom samples were collected when the depth of water exceeds 3 m. Otherwise, only surface samples will be obtained. One station in each estuary and a few creeks will be sampled temporally for selected parameters to understand the tidal variability in water quality.

1.3.4 Sampling frequency

Monitoring at all inshore areas and coastal transects were conducted once during postmonsoon and premonsoon.

1.3.5 Parameters

Water quality

The water samples were studied for temperature, pH, salinity, Suspended Solids (SS), turbidity, DO, BOD, nitrate, nitrite, ammonia, dissolved phosphate, Petroleum Hydrocarbons (PHc), phenols and microbial counts [Total Viable Counts, Total Coliforms (TC), Faecal Coliforms (FC) etc].

Sediment quality

Determination of trace pollutants such as heavy metals in water often reveals fluctuations as the concentrations depend on the location and the time of sampling, nature of pollutant and chemical characteristics of water. Samples for such analysis must be collected with great care to avoid contamination and determinations should be conducted in “Clean” specially constructed laboratories. Most trace metals get rapidly fixed to SS and thus removed from the water column. It has been observed in several instances that even close to location of release, the content of pollutant in water often decreases to normal value making the assessment of contamination through analysis of water a difficult task.

The pollutants adsorbed by SS are ultimately deposited on the bed sediment on settling. Evidently, concentrations of pollutants in sediment increase over a period of time in regions receiving their fluxes. Hence, sediments are useful indicators of pollution by certain contaminants.

Under the proposed monitoring, the sediment from subtidal regions were analysed for texture, C_{org}, phosphorous, aluminium, chromium, manganese, iron, cobalt, nickel, copper, zinc, cadmium, lead, mercury and PHc. Aluminium and iron are the major metals in most marine sediments and often control the concentrations of trace metals. Hence, these metals also will be estimated.

Flora and fauna

Whenever probable implications of a proposed coastal development on marine environment are assessed, it must be remembered that despite many changes, the activity may cause in the physico-chemical properties of the water body and the bed sediment, the ultimate concern is inevitably the biological resource. Hence, characteristics of flora and fauna of an area are essential prerequisite to evaluate the eco-sensitivity of a potential coastal development.

Marine organisms undergo natural stress which varies in magnitude and frequency depending on changes in physico-chemical characteristics of the water mass. Though organisms have evolved to withstand the natural changes, they may not be well adapted to sudden and high artificial stress which may even affect their adaptive capability to natural variations. Hence the study should be sufficiently extensive to cover the area potentially at risk, and critical biological variables including production at different trophic levels should be identified and monitored.

In the proposed study, phytoplankton and zooplankton were considered to assess the respective primary and secondary production levels of the water mass. The benthic (macro and meio) fauna which support mainly secondary and also partly tertiary production will be also considered because these organisms reflect integrated effect of stress more effectively, due to their sedentary nature.

Thus, the biological characteristics were assessed based on phytopigments, phytoplankton populations and their generic diversity; biomass, population and group diversity of zooplankton; and biomass, population and group diversity of benthos. Fish collected by experimental trawling and obtained from the local fishermen during field trips will be analysed for trace metals such as chromium, copper, zinc, lead, cadmium and mercury and PHc.

1.4 Approach

The approach envisages collection of secondary data from available literature and augmenting the data base by conducting two seasons study all along the Maharashtra coast by selecting representative stations in the coastal region as well as estuarine stretches.

Stations were selected as far as possible to represent the area in a transect form so as to represent inshore, mid level and off shore region. Locations in identified estuaries were selected to represent their inner, middle and outer segments and the transect extended off the mouth to coastal sea. At least one station in each transect was operated over a tidal cycle and the remaining were spot sampled. Care was also taken to include stations where industrial and sewage releases as well as maritime activities were dominant. The total transects monitored along the Maharashtra coast are illustrated in Figure 1.4.1. The following table gives the geographic locations of the stations.

Table 1.4.1: Sampling Transect & location of monitoring along maharshtra coast

Transect Name	Station Code	Latitude	Longitude
Dahanu	DH1	19º 58’51.19”N	72º 38’11.72”E
	DH2	19º 58’53.10”N	72º 39’56.60”E
	DH3	19º 58’15.50”N	72º 42’50.20”E
	DH4	19º 57’35.00”N	72º 43’51.70”E
	DH5	19º 57’48.30”N	72º 44’23.50”E
	DH6	19º 56’31.60”N	72º 44’27.00”E
Tarapur	TP1	19º 48’ 00.30”N	72º 36’00.80”E
	TP2	19º 48’10.90”N	72º 37’51.20”E
	TP3	19º 47‘00.50”N	72º 41’06.75”E
	TP4	19º 47’15.64”N	72º 41’08.37”E
	TP5	19º 47’48.78”N	72º 41’18.37”E
	TP6	19º 48’09.13”N	72º 41’17.42”E
Bassein	BS1	19º 18’25.6.0”N	72º 44’32.90”E
	BS2	19º 19’01.00”N	72º 49’02.00”E
	BS3	19º 19’27.00”N	72º 49’06.00”E
	BS4	19º 19’11.00”N	72º 50’57.00”E
	BS5	19º 17’18.00”N	72º 54’18.00”E
	BS6	19º 16’21.50”N	72º59’33.21”E
	BS7	19º 14’18.00”N	73º 00’12.00”E
	BS8	19º 12’02.30”N	73º 01’33.99”E
	BS9	19º 14’16.00”N	73º 04’21.00”E
	BS10	19º 14’04.10”N	73º 05’56.90”E

	BS11	19º 15’27.71”N	73º 06’28.40”E
	BS12	19º 16’04.90”N	73º 08’30.00”E
	BS13	19º 15’33.80”N	73º 09’28.42”E
Manori	BYMa4	19º 12’15.00”N	72º 47’44.00”E
	BYMa5	19º 13’42.00”N	72º 48’54.00”E
	BYMa6	19º 14’36.00”N	72º 49’19.00”E
Versova	BYV4	19º 07’12.00”N	72º 47’44.00 E
	BYV5	19º 08’41.00”N	72º 48’12.00”E
Mahim	BYM4	19º 02’20.00”N	72º 48’56.00”E
	BYM5	19º 02’27.00”N	72º 49’32.50”E
	BYM6	19º 02’38.50”N	72º 49’58.70”E
Bandra	BYB1	19º 03’33.10”N	72º 45’19.80”E
	BYB2	19º 02’47.40”N	72º 47’34.70”E
Worli	BYW1	19º 00’13.00”N	72º 45’52.00”E
	BYW2	19º 00’11.80”N	72º 47’02.00”E
Thane Creek	BY1	18º 52’04.00”N	72º 46’16.50 E
	BY2	18º 52’00.17”N	72º 47’03.80”E
	BY3	18º 52’00.80 ”N	72º 48’59.00”E
	BY4	18º 52’04.00”N	72º 50’38.00”E
	BY5	19º 00’23.40”N	72º 57’23.60”E
	BY6	19º 02’37.00”N	72º 58’38.00”E
Patalganga Estuary	PT4	18º 48’14.50”N	72º 59’35.10”E
	PT4A	18º 48’53.80”N	73º 01’08.98”E
	PT5	18º 48’42.90”N	73º 03’17.19”E
	PT6	18º 48’35.80”N	73º 04’17.20”E
	PT7	18º 50’19.20”N	73º 05’31.40”E
	PT8	18º 50’32.80”N	73º 06’50.60”E
	PT9	18º 50’32.80”N	73º 07’10.40”E
	PT10	18º 50’32.80 N	73º 09’24.90”E
	PT11	18º 53’17.90”N	73º 11’23.90”E
Amba Estuary	AB4	18º 47’46.45”N	72º 58’16.57”E
	AB5	18º 46’09.42”N	72º 59’35.34”E
	AB6	18º 45’11.10”N	72º 59’04.20”E
	AB7	18º 38’01.23”N	73º 01’42.12”E
	AB8	18º 38’27.40”N	73º 03’44.40”E
	AB9	18º 36’10.20”N	73º 05’08.82”E
Thal	Thal DP	18º 43’ 03.48”N	72º 50’04.50”E
Kundalika Estuary	K1	18º 32’58.80”N	72º 51’36.20”E
	K2	18º 32’53.50”N	72º 52’49.30”E
	K3	18º 32’40.40”N	72º 54’22.00”E
	K4	18º 32’34.30”N	72º 56’0.11”E
	K5	18º 32’24.66”N	72º 57’49.67”E
	K6	18º 29’58.55”N	72º 59’7.87”E
	K7	18º 27’25.12”N	73º 00’36.91‘‘E
	K8	18º 28’46.00”N	73º02.17.60”E
	K9	18º 27’52.60”N	73º 05’14.90”E

	K10	18º 26’32.47”N	73º 07’05.81”E
Murud	MR1	18º 18’03.00”N	72º 53’49.30”E
	MR2	18º 17’51.10”N	72º 55’23.50”E
	MR3	18º 17’35.50”N	72º 56’53.90”E
	MR4	18º 15’52.90”N	72º 59’35.70”E
	MR5	18º 15’01.30”N	73º 02’18.70”E
	MR6	18º 14’17.10”N	73º 03’51.80”E
	MR7	18º 15’49.30”N	73º 03’28.70”E
Savitri Estuary	S1	17º 58’23.20”N	72º 58’23.50”E
	S2	17º 58’32.30”N	72º 59’27.60”E
	S3	17º 58’32.10”N	73º 00’51.60”E
	S4	17º 59’04.10”N	73º 03’39.00”E
	S5	17º 59’29.81”N	73º 07’18.53”E
	S6	18º 03’24.00”N	73º 10’20.10”E
	S7	18º 04’00.10”N	73º 16’37.50”E
	S8	18º 04’21.60”N	73º 19’46.90”E
	S9	18º 04’57.10”N	73º 23’33.60”E
Vashishti Estuary	VS1	17º 34’52.64”N	73º 05’15.77”E
	VS2	17º 34’50.81”N	73º 06’21.10”E
	VS3	17º 34’52.85”N	73º 07’55.64”E
	VS4	17º 34’02.28”N	73º 10’38.28”E
	VS5	17º 34’08.10”N	73º 14’01.10”E
	VS6	17º 34’44.10”N	73º 18’20.40”E
	VS7	17º 34’05.90”N	73º 21’32.30”E
	VS8	17º 35’02.70”N	73º 24’19.80”E
	VS9	17º 34’55.80”N	73º 25’56.70”E
	VS10	17º 34’36.80”N	73º 27’33.40”E
Jaigad Creek	J1	17º 18’56.70”N	73º 08’13.80”E
	J2	17º 18’59.90”N	73º 09’43.30”E
	J3	17º 18’58.60”N	73º 11’16.20”E
	J4	17º 17’27.20”N	73º 13’29.80”E
	J5	17º 17’20.04”N	73º 14’05.76”E
	J6	17º 17’17.63’’N	73º 16’20.40”E
Ratnagiri	R1	17º 00’42.80”N	73º 13’09.20”E
	R2	17º 00’16.00”N	73º 14’35.00”E
	R3	17º 00’28.00”N	73º 15’43.00”E
	R4	17º 00’25.00”N	73º 16’35.00”E
	R5	17º 00’12.60”N	73º 16’43.30”E
Vijaydurg	VJ1	16º 34’46.02”N	73º 17’40.92”E
	VJ2	16º 34’27.78”N	73º 19’03.90”E
	VJ3	16º 34’00.92”N	73º 19’54.30”E
	VJ4	16º 33’23.22”N	73º 20’24.30”E
	VJ5	16º 32’20.40”N	73º 20’51.50”E
	VJ6	16º 31’33.60”N	73º 21’22.14”E
Deogad	D1	16º 23’32.94”N	73º 19’29.10”E
	D2	16º 23’24.66”N	73º 20’44.10”E

	D3	16º 23'29.22"N	73º 22'22.02"E
	D4	16º 22'58.44"N	73º 22'35.22"E
	D5	16º 24'15.80"N	73º 24'13.40"E
	D6	16º 24'28.70"N	73º 24'26.40"E
Achara	ACH1	16º 11'10.13"N	73º23'42.61"E
	ACH2	16º 11'30.95"N	73º 25'09.74"E
	ACH3	16º 11'59.23"N	73º 25'59.54"E
	ACH4	16º 12'19.23"N	73º 26'19.93"E
	ACH5	16º 13'03.76"N	73º 26'45.19"E
Malvan	M1	16º 02'50.35"N	73º 25'11.30"E
	M2	16º 03'21.60"N	73º 26'26.30"E
	M3	16º 02'52.20"N	73º 27'17.80"E
	M4	16º 02' 36.24"N	73º 28'01.24"E

The station locations are plotted on satellite imageries and presented in respective sections.

1.5 Field investigations

1.5.1 Water quality

a) Sampling procedure

Surface water for general analyses was collected using a polythene bucket while an adequately weighted Niskin sampler (Figure 1.5.1) with a closing mechanism at a desired depth was used for obtaining subsurface water samples. Sampling at the surface and bottom (1m above the bed) was done when the station depth exceeded 3 m. For shallow regions only surface samples were collected.

b) Methods of analysis

Majority of water quality parameters was analysed in the field laboratory temporarily established in the nearest town. Colorimetric measurements were made on a 1240 UV (Shimadzu) Spectrophotometer (Grasshoff 1983). RF-5301 Shimadzu Spectrofluorometer was used for estimating PHc. The analytical methods of estimations were as follows:

i) Temperature

Temperature was recorded using a mercury thermometer with an accuracy of 0.1ºC.

ii) pH

The pH was measured on a microprocessor controlled pH analyzer. The instrument was calibrated with standard buffers just before use.

iii) SS

A known volume of water was filtered through a pre-weighted 0.45 um Millipore membrane filter paper, dried and weighed again.

iv) Turbidity

Turbidity was determined by nephalometric method using a calibrated turbidity meter (ORION AQ4500, ThermoScientific USA)

v) Salinity

Salinity was measured using AUTOSAL salinometer (GUILDLINE Instruments Ltd., Canada). The instrument was standardised with IAPSO standard sea water (OSIL, UK).

vi) DO and BOD

DO was determined by Winkler method. For the determination of BOD, direct un-seeded method was employed. The sample was filled in a BOD bottle in the field and was incubated in the laboratory for 3 days after which DO was again determined. Direct unseeded method was used (Grasshoff 1983) for uncontamiated or less contaminated samples (Based on earlier monitoring results. BOD of samples inherently having low DO such as those from Tarapur, Ulhas Estuary, Versova, Mahim, Ratnagiri Creeks etc were determined using seeded method (APHA 2005).

vii) Phosphate

Acidified molybdate reagent was added to the sample to yield a phosphomolybdate complex, which was then reduced with ascorbic acid to a high coloured blue compound, which was measured at 882 nm.

viii) Nitrite

Nitrite in the sample was allowed to react with sulphanilamide in acid solution. The resulting diazo compound was reached with N-(1-napthyl)-ethylenediaminedihydrochloride to form a highly coloured azo dye. The light absorbance was measured at 543 nm.

ix) Nitrate

Nitrate was determined as nitrite as above after its reduction by passing the sample through a column packed with amalgamated cadmium.

x) Ammonia

Ammonium compounds (NH_3 + NH_4^+) in water were reacted with phenol in presence of hypocholorite to obtain blue colour of indophenol. The absorbance was measured at 630 nm.

xi) Total phosphorus

Phosphorus compounds in the sample were oxidised to phosphate with alkaline potassium persulphate at high temperature and pressure. The resulting phosphate was analyzed as described under (vii).

xii) Total nitrogen

Nitrogen compounds in the sample were oxidised to nitrate with alkaline potassium persulphate at high temperature and pressure. The resulting nitrate was estimated as given under (viii).

xiii) PHc

Water sample was extracted with hexane and the organic layer was separated, dried over anhydrous sodium sulphate and reduced under low pressure. Fluorescence of the extract was measured at 360 nm (excitation at 310 nm) with Saudi Arabian Crude residue (boiling point >100^{o} C) as a standard.

xiv) Phenols

Phenol in water was converted to an orange coloured antipyrine complex by adding 4-aminoantipyrine. The complex was extracted in chloroform (25 ml) and the absorbance was measured at 460 nm using phenol as a standard.

1.5.2 Sediment quality

a) Sampling procedure

Surficial bed sediment from all locations was either handpicked from intertidal areas or obtained with a van Veen grab in sub-tidal areas (Figure 1.5.2). The sediment after retrieval was transferred to a polythene bag and preserved for further analysis at Mumbai.

b) Methods of analyses

i) Metals

The dried and powdered sediment was brought into solution by treatment with conc HF-$HClO_4$-HNO_3-HCl acids and the metals aluminium, chromium, manganese, iron, cobalt, nickel, copper and zinc were estimated by dual view inductively coupled plasma emission optical emission spectrophotometer (ICP-OES, plasma 7300 DV, Perkin Elmer, Singapore), while lead and cadmium were analysed by graphite AAS on a Perkin Elmer Analyst 600 atomic absorption spectrophotometer.

For the estimation of Hg, the sample was treated with concentrated aquaregia and Hg after reduction was estimated by cold vapour AAS.

Fish samples for metal analyses were dried at < 60°C in an electric oven, powdered and digested in microwave accelerated reaction system (MARS 5, CEM, USA). Digested samples were analysed by using ICP-OES and AAS as above.The results are given on dry weight basis. For the analysis of Hg, fresh fish tissues were used and results presented on wet weight basis.

ii) Organic carbon

The C_{org} in sediment was determined by oxidizing the organic matter in the sample by chromic acid and estimating excess chromic acid by titrating against ferrous ammonium sulphate.

iii) Phosphorus

The sediment was brought into solution by treatment with conc HF-$HClO_4$-HNO_3 acids and phosphorus was estimated as described under Section 1.5.1 (bvii).

iv) PHc

The sediment after refluxing with KOH-methanol mixture was extracted with hexane. After removal of excess hexane, the residue was subjected to a clean-up procedure on alumina column. The PHc content was then estimated by measuring the fluorescence as described in Section 1.5.1 (bxiii) with Saudi Arabian Crude residue as standard.

Local fishes were analysed for their PHc content in wet samples and the results are presented in wet weight basis.

v) Effluent analysis

Treated effluents were collected from different CETPs, were analysed for pH, COD, BOD, PHc and heavy metals. pH and PHc were analysed by using methods described in Section 1.5.1. BOD was analysed by seeded method and COD by dichromate method (APHA, 2005). Heavy metals were analysed after digesting the effluent with HNO_3. Mercury was analysed after digestion in microwave digestion unit. Analyses were done by using the instruments as in 1.5.2 (b) i.

1.5.3 Flora and Fauna

a) Sampling procedure

Water and sediments samples for microbiological analysis were collected in a sterilized BOD bottles and in sampling bag/polycarbonate bottle respectively. Hands and polyethylene bucket were cleaned by detergent and clean water, then surface sterilized by 70% isopropanol. Sample was collected in bucket and then collected in sterile BOD bottles with appropriate label.

Sediment samples were collected by using van-Veen Grab with proper precautions and the subsample was transferred to sterile sampling bag or sterile polycarbonate bottle with lids. All microbiology samples were immediately stored in ice box and transported to microbiology laboratory within two hours.

Polyethylene bucket and Niskin sampler were used for sampling surface and bottom waters respectively for the estimation of phytoplankton pigments and population. Sample for phytoplankton cell count was fixed in Lugol's iodine and a few drops of 3% buffered formaldehyde.

Zooplanktons were collected by oblique haul using a Heron Tranter net with an attached calibrated flow meter. All collections were of 5 min duration. Samples were preserved in 5% buffered formaldehyde.

Sediment samples for subtidal macrobenthos were collected using a van-Veen grab of 0.04 m^2 area. The sediment was sieved through a 0.5 mm mesh sieve and animals retained were preserved in 5% buffered formaldehyde Rose Bengal.

Meiobenthic samples were collected from undistrurbed van-Veen grab by pushish modified syringe core (dia. 3 cm) upto 6 cm depth. The preservation was followed by relaxation, staining and fixation with an interval of 10 minutes by addition of $MgCl_2$, 0.5% Rose bengal and 5% formaldehyde respectively.

Fish trawling was done at suitable locations (Figure 1.5.3) to obtain samples for the analyses of bioaccumulation of metals and PHc.

b) Methods of analyses

i) Microbes

Samples were analyzed by serial dilution followed by spread plate techniques for Total Viable Counts (TVC), Total Coliform (TC), *Escherichia coli* like organisms (ECLO), Faecal coliform like organisms (FC), *Shigella* like organisms (SHLO), *Salmonella* like organisms (SLO), *Proteus / Klebsiella* like organisms (PKLO), *Vibrio* like organism (VLO), *Vibrio parahaemolyticus* like organisms (VPLO), *Vibrio cholerae* like organism (VCLO), *Pseudomonas aeruginosa* like organism (PALO) and *Streptococcus faecalis* like organisms (SFLO). Colonies of TC, ECLO, VLO and VPLO were counted separately. The media employed for growth of bacteria were as follows:

Nutrient agar (NA) for TVC, MacConkey agar(MC) for TC, M7HrFC agar for ECLO, MFC agar for faecal coliform, Xylose-lysine Deoxycholate agar (XLD) for SHLO, SLO and PKLO, Thiosulphate citrate bile salts sucrose medium (TCBS) for VLO, VPLO and VCLO, Centrimide agar (CS) for PALO and M-Enterococcus agar for SFLO.

ii) Phytoplankton pigments

Known volume of water was filtered through a 0.45 um Millipore membrane filter paper and pigments retained on the filter paper were extracted in 90% acetone. For the estimation of chlorophyll a and phaeophytin, the extinction of the acetone extract was measured at 665 and 750 nm before and after treatment with dilute acid.

iii) Phytoplankton population

The cells in the sample preserved with Lugol's solution were allowed to settle and 1 ml volume was transferred into a Sedgwick rafter slide. Enumeration and identification of phytoplankton were done under a microscope.

iv) Mangroves

Mangroves were not covered in the present study. However, these will be discussed on the basis of data and literature, available with NIO.

v) Zooplankton

Volume (biomass) was obtained by displacement method. A portion of the sample (25-50%) was analysed under a microscope for faunal composition and population count.

vi) Benthos

(a) Macrobenthos: Total population was estimated as number of animals in 1 m^2 area and biomass on wet weight basis and expressed as g/m^2.

(b) Meiobenthos: Total population was estimated as number of animals in $10cm^2$ area. Body volume was estimated using the formula given by Feller and Warwick (1988) and translated them to biomass using factors given by Wieser (1960).

vii) Photographs

Photographs taken during field studies are reproduced in relevant section.

Sr.No	Location	Spot/Tidal	12Hrs	Total
	Sindhudurg Dist.			
1	malvan	3	1	4
2	Achera	4	1	5
3	Deogad	5	1	6
4	Vijaydurg	5	1	6
	Ratnagiri Dist.			
5	Ratnagiri	4	1	5
6	Jaigad (shastri river)	5	1	6
7	Dabhol Creek (Vashsthi River,Lote Pershuram MIDC)	8	2	10
	Raigad Dist.			
8	Savitri River (Mahad MIDC)	7	2	9
9	Rajapuri Creek (Murud)	6	1	7
10	Kundalika River (Roha MIDC)	8	2	10
11	Thal	0	1	1
12	Amba River (Dharamtar Creek)	5	1	6
13	Patalganga River (Rasayani MIDC)	7	2	9
	Thane Dist.			0
14	Dahanu	5	1	6
15	Tarapur	5	1	6
16	Mumbai Bassien	11	2	13
17	Thane Creek	4	2	6
	Mumbai Coast			
18	Versova	1	1	2
19	Manori	2	1	3
20	Mumbai Mahim Bay	2	1	3
21	Mumbai Harbour (Bndra,worli)	2	2	4
	Total	99	28	127

Figure 1.4.1: Transect monitored along Maharashtra Coast

Figure 1.5.1: MPCB officials being trained during water sample collections

Figure 1.5.2: Photo showing collection of sediment

Figure 1.5.3: Fish Trawling carried out during MPCB sampling.

2 AREA DESCRIPTION

Maharashtra with an approximate area of 3.07 x 10^5 km^2 and a population density of 256 no/km^2, is the third largest state in the country both interms of size and population. It is bordered by the Arabian Sea in the west, Gujarat in the north-west, Andhra Pradesh in the south-east and Karnataka and Goa in the south. The main rivers flowing through the state are Godavari, Bhima and Krishna but they meet the Bay of Bengal. Several smaller rivers like Ulhas, Amba, Kundalika, Savitri, Shastri and Vashishti flow into the Arabian Sea. Most of these rivers have substantial length that forms the estuarine segments.

2.1 Maharashtra coast

The coast traditionally known as Konkan coast lies between Lat $15^0$43' to 20^0N and Long $72^0$49' to $77^0$41' E. The coastline is about 720 km long and is indented by numerous rivers mouths, creeks, small bays, headlands and promontories. The coast also has several beaches some of which are flanked by rocky cliffs of Deccan basalt and luxuriant mangroves in patches largely confined to estuaries, creeks and bays. The Konkan coast is a narrow stretch with an average width of about 30-50 km between the sea and the hilly terrain of the Western Ghats or Sahyadris which runs parallel to the sea coast. The rocks present along the coast are mostly granite and laterite boulders.

The main drainage in the coastal area tends in a general east-west direction and flows to the Arabian Sea in the west. The Dudh, Vaitarna, Ulhas, Amba, Kundalika, Savitri, Vashishti, Kajvi, Machkandi, Gad, Shastri and Terekhol Rivers and their tributaries form the main drainage. The major rivers that join the Arabian Sea form the estuaries whose nature depends on the variation of fresh water influx and tidal ranges at the mouth of the estuary. There are about 18 major estuaries along the Maharashtra coast harbouring a vast wetland ecosystem with many mangroves, floral and faunal species in varying density. The Konkan coast is an important sector on the west shore of India because of its physical distinctiveness, biota and marine resources. The adjoining continental shelf area of 1.12 x 10^5 km^2 is extensively used for exploiting living- and non-living resources like fishes and oil and gas. In fishery resources Maharashtra ranked 2 or 3^{rd} in the marine production. The total marine fish landing of the Maharashtra state which was 4.64x 10^5 t during 2014-15 was predominated bySardines (14.48%) non-penaeid prawns (11.97%), Bombay duck (10.99%), penaeid prawns (10.33%), cephalopods (5.67%), Anchovies (4.44%), *Otolithes* sp. (4.19%), Catfishes(3.42%),mackerals(3.26%), and Upeneus (2.82%).

Some of the major problems faced by the littoral zone and the shore front areas of Maharashtra coast are related to coastal erosion; siltation; pollution; population pressure; industrialization; uncleaned beaches;

destruction of mangroves swamps, salt marshes and mudflats; sea level rise; landslides and slope failure; road transport etc.

2.1.1 Climate

The general climate of the region is typical of that of the south west coast of India, with plentiful of rain during southwest monsoon, oppressive weather in the hot months and high humidity throughout the year. The summer season from March to May is followed by the southwest monsoon season from June to September. October and November months form the post monsoon season followed by cold season in December to February.

The region receives a yearly rainfall of 260-300 cm, 90% of which occurs during July-September. Being a coastal area, the diurnal and seasonal variations in temperature are not large. May is the hottest month with a mean daily maximum temperature at 31.7^{0}C and mean daily minimum temperature at 26.4^{0}C. The onset of southwest monsoon in June brings down the temperature slightly. The atmospheric average temperature ranges from 21 to 35^{0}C with minimum and maximum values in December-January and May-June. The relative humidity varies from 70% (April) to 90% (July). The winds are variable with higher wind speed upto 30 km/h in June-August as against 13-17 km/h during the remaining months of the year.

2.1.2 Physical processes

The physical processes of coastal regions including estuaries are governed by tides and coastal currents. Tides along Maharashtra coast are predominantly semidiurnal with a diurnal inequality. The tidal ranges progressively increase from Malvan to Dahanu. The tidal ranges decrease progressively from mouth area of an estuary to the head of the river. The following Table illustrates the tidal characteristics of different area along the Maharashtra coast.

Location	MLWS (m)	MLWN (m)	MSL (m)	MHWN (m)	MHWS (m)	MeanNeap Range (m)	MeanSpring Range (m)
Dahanu	1.2	2.0	2.8	3.7	4.7	1.7	3.5
Tarapur (Satpati)	0.9	2.0	2.8	3.7	4.8	1.7	3.9
Bassein (Vasai)	0.9	1.8	2.5	3.3	4.1	1.5	3.2
Versova	0.95	1.82	2.6	3.31	4.2	1.49	3.25
Bandra	0.93	1.81	2.6	3.33	4.15	1.52	3.22
Mumbai (Apollo Bunder)	0.76	1.9	2.5	3.3	4.4	1.44	3.64

Location	MLWS (m)	MLWN (m)	MSL (m)	MHWN (m)	MHWS (m)	MeanNeap Range (m)	MeanSpring Range (m)
Rewas (Amba and Patalganga)	0.2	2.3	2.35	3.4	4.5	1.1	4.3
Alibaug	0.3	1.97	2.15	2.8	4.0	1.03	3.7
Revdanda (Kundalika)	0.6	1.7	2.04	3.3	3.6	1.6	3.0
Murud	0.8	1.6	2.2	3.0	3.3	1.4	2.5
Bankot (Savitri)	1.1	1.3	2.0	2.7	2.9	1.4	1.8
Dabhol (Vashishti)	0.6	1.2	1.7	2.4	2.6	1.2	2.0
Jaigad	0.7	1.3	1.8	2.5	2.6	1.2	1.9
Ratnagiri	0.5	1.2	1.5	2.1	2.3	0.9	1.8
Vijaydurg	0.4	1.1	1.4	2.0	2.1	0.9	1.7
Deogad	0.5	1.1	1.4	1.9	2.1	0.7	1.6
Malvan	0.3	1.0	1.2	1.7	1.8	0.7	1.5

The coastal currents are clockwise or shoreward during February-September, anticlockwise during November-January and transitional in October.

2.2 Study area

The coastal region of Maharashtra comprises of (i) Thane (ii) Greater Mumbai (Mumbai main and suburb district) (iii) Raigad (iv) Ratnagiri and (v) Sindhudurg districts.

(i) Thane District

Thane District lies in the north-west of Maharashtra state and is situated between 18°42’ to 20°20’ N and 72°45’ to 73°48’ E. The headquarters of the district is the ThaneCity. Other major cities in the district are Navi Mumbai,Kalyan-Dombivli, Mira-Bhayander, Bhiwandi,Ulhasnagar, Ambernath, Kulgaon-Badlapur, Dahanu, Shahapur, Wada and Vasai-Virar. This is the third-most industrialized district in Maharashtra. As per 2011 census, the total population of Thane district was 8,070,032 with a population density of 1,157 no/km^2.

Vaitarna and Ulhas are the two main rivers and Uttan, Arnala, Mahim, Satpati, Vasai, Chinchani and Dahanu are the important fish landing centres in the district. Vasai-High mineral oilfield is located off the coast of the district. There are many salt-pans particularly at Vasai, Bhayander and Dahanu. Many small creeks occur all along the western coast which submerge low-lying areas during flood tide. The main creeks are Bhiwandi, Chinchani and Dahanu.

During the present study sampling was carried out along the transects off Dahanu, Tarapur and Bassein (Ulhas Estuary).

(ii) Greater Mumbai

Mumbai is located at 18˚58' N and 72˚48' E and consists of two distinct regions: Mumbai City and Mumbai Suburban District. Mumbai as an urban entity spans a total area of 606 km^2 while Greater Mumbai, the area under the administration of Brihan Mumbai Municipal Corporation spans a total area of 437.71 km^2 with the island city spread over 67.79 km^2 and the suburban district has an area of 370 km^2.

There are six major lakes that supply water to Mumbai city. Three small rivers, Dahisar, Boisar and Oshiwara originate in the Sanjay Gandh National Park, while the polluted MithiRiver originates from the TulsiLake and gathers water overflowing from Vihar and Powai lakes. The coastline of the city is indented with numerous creeks and bays, stretching from Thane Creek on the eastern to Madh-Marve on the western front. According to the 2011 census, the population of Mumbai was 12,478,447. The region has highly industrialized zones. As a result, voluminous domestic industrial and effluents are released to inshore and coastal waters.

During the present investigations sampling was conducted along Manori, Versova, Mahim, Bandra, Worli and Thane Creek transects along the coast of Greater Mumbai.

(iii) Raigad District

The Raigad District formerly known as Kolaba has a 240 km long coastline with Alibaug as its district headquarter and a total population of over 2,500,000. It is situated between 17˚51' and 19˚80'N and 72˚51' to 73˚40' E and occupies total area of 7162 km^2.

Ruggedness and uneven topography of the district is typical of the Konkan belt. The region is generally undulating and rugged with narrow river valleys and coastal belt. The district has several areas of reserved forest and agriculture is limited to narrow alluvial plains of the rivers and the coastal belt. Patalganga, Amba, Kundalika and Savitri are the main rivers of the district. Fishery is the second most active profession in the district with 21,000 km^2 coastal area (marine) and 103 fishing villages. There are total 39 centres handling fish catch spread in five fishing zones namely Mora-Karanja, Alibaug, Revdanda, Murud and Shrivardhan. The 240 km long coastline of Raigad District has 7 ports.

The transects off Patalganga, Amba, Thal, Alibaug, Kundalika, Murud and Savitri were sampled during the present study.

(iv) Ratnagiri District

Ratnagiri District lies between 16˚30' to 18˚04'N and 73˚02' to 73˚52' E and has north south length of about 180 km with average east-west extension of about 64 km, except in its extremities. The total area of the district is 8208 km^2 and has population of 1,615,069 persons with a density of 197 no/km^2. All rivers in the district originate in the Sahyadris ranges and flow from east to west and merge with the Arabian Sea. The important rivers of the district are Savitri, Vashishti, Bor, Shastri, Jagabudi, Ratnagiri, Muchkundi, Kajali and Naringe. Marine fishing is one of the main occupations of this district with Harnai, Dabhol, Jaigad and Ratnagiri as major fish landing centres.

The sampling during the present study was carried out along Jaigad (Shastri Estuary), Dabhol (Vashishti estuary) and Ratnagiri Bay transects.

(v) Sindhudurg District

Sindhudurg District was carved out from the old Ratnagiri District in May 1981 and is one of the smallest district of the state situated between 15˚37' to 16˚40'N latitude and 73˚19' to 74˚13' E longitude occupying 5088 km^2 area. With the coastline of 121 km in length, the coastal region constitutes 29 percent of the total area of the district. Oras Budruk (Kudal) is the headquarter of Sindhudurg District.

The outstanding features in the relief of the district are its highly uneven nature and very narrow riverine plains that fringe the coastline. The estuarine portions have good soils on either banks and form agriculturally the best lands of the district. All the rivers in the district originate from the Sahyadri ranges and flow from east to west and merge in the Arabian Sea. The important rivers of the district are Vagothan, Devgad, Karli, Kalavali, Terekhol, Ghodhkalawal, Achara and Mochemad. These rivers are of little value from the navigational and fisheries point of view. Sindhudurg is one of the most industrially backward districts of the state. Government of Maharashtra has declared Sindhudurg District as a tourist district and tourism as an industry. Fishery remains the main profession with Vijaydurg, Devgad, Malvan and Vengurla as main landing centres.

Vijaydurg, Devgad, Achara and Malvan transects, along which sampling was done during the present study, form part of the Sindhudurg District.

During the present study stations were selected as far as possible to represent the area in a transect form as mentioned in Section 1.3. The details of transects and their surrounding environments are given below.

2.2.1 Dahanu (DH, Figure 2.2.1)

Dahanu town located at a distance of 111 km from Mumbai is surrounded by Dahanu (Khonda), Danda and Savta creeks. The main Dahanu Creek branches into a smaller Savta Creek and a larger Danda Creek. The depth at the centre of the main creek is around 4 to 5 m during low tide. The Danda Creek terminates near Kompada village. The two arms of the Danda Creek extend 2-3 km inland. Other branch, namely, Savta Creek is itself a small seasonal river which originates near Santoshi hill about 10-12 km east of Dahanu. In the dry season, during high tide sea water in the Savta Creek extends to about 1.5-2 km inside. The tidal range during spring tide is about 5 m.

On 20 June 1991, the Ministry of Environment and Forests (MoEF) declared Dahanu as an ecologically fragile area, and imposed restrictions on the establishment of industries under Section 3(2)(v) of the Environment (Protection) Act of 1986 (EPA).

Dahanu transect was represented by 6 stations out of which, 3 stations DH1 to DH3 were in coastal water, station DH4 was in mouth area and station DH5 and DH6 in the upper creek zone.

2.2.2 Tarapur (TP, Figure 2.2.2)

Tarapur is an industrial town and houses a Nuclear Power Plant and an industrial cluster of Boisar/Tarapur MIDC. Dandi Creek which is about 10 km long originates from Dandi village and flows between Dandi and Navapur villages. Its mouth is narrow and shallow and not navigable during low tide. It carries the total effluents load from industrial and domestic sectors.

Tarapur transect was represented by 6 stations with station TP1 to TP3 located in the coastal region and station TP4 in the mouth area of the Dandi Creek. Stations TP5 and TP6 represent the creek region.

2.2.3 Bassein (BS, Figure 2.2.3)

Bassein, also called Vasai lies about 48 km north of Mumbai just across the Ulhas River/Bassein Creek. Ulhas River originates near Karjat in the Western Ghats (North of Tungarli near Lonavala) and flows westward through Raigad and Thane districts between Kulgaon-Badlapur, north to Ulhasnagar (to which it gives its name) and to Kalyan, where it turns west to Thane. Near the raw water pump house of MIDC at Jambhul, the river meets the Barvi Dam discharge water also called as Barvi River. At Thane the river splits into two branches which flow west and south, respectively. Both branches are estuarine. The main branch turns northward to Ghodbunder, where it opens into the estuary or Bassein Creek and the southern tributary flows into the Thane Creek. Ulhas Estuary is 135 km long and has many tributaries; three important of them are Barvi, Kalu and Bhatsa.

A total of 13 stations represented the Bassein transect. Out of these stations BS1 to BS3 were in coastal water, BS4 and BS5 lower, BS6 to BS8 middle segment and BS9 to BS13 represented upper segment of the Ulhas estuary.

2.2.4 Manori (BYMa, Figure 2.2.4),Mumbai

Manori is a coastal fishing village of Mumbai and forms a part of Manori-Gorai Creek system. Manori Creek-Gorai Creek is tidal and forms the drainage of the minor Boisar and Dahisar rivers. Poisar River originates back of the Sanjay Gandhi National Park and is nothing more than a stream when it begins and is contaminated with the industrial effluents and sewage. The Dahisar River which originates in the Tulsi Lake is also highly polluted due to dumping of industrial effluents from workshops and sewage from slums.

A total 3 stations were monitored at this transect. Station BYMa4 and BYMa5 represented the lower and other station BYMa6 was located in the upper region of the creek.

2.2.5 Versova (BYV, Figure 2.2.4), Mumbai

Versova a coastal fishing village in metropolitan Mumbai is located on the mouth of the Malad Creek (Versova Creek). Oshiwara River drains into it. The creek sustained vast mangrove areas (1000 ha) in the past which have been gradually reduced due to urban pressures and at present estimated to be around 400 acres. The total length of Malad Creek is about 5 km. Oshiwara River begins in the Aarey Milk Colony and is highly polluted and encroachments have shrunk it to a narrow stream.

A total of 2 stations represented this transect with BYV4 at the mouth and BYV5 inside the creek.

2.2.6 Mahim Creek (BYM, Figure 2.2.5), Mumbai

Mahim Creek which forms the boundary between the city and suburbs has extensive mangrove swamps. The polluted Mithi River drains into the Mahim Creek which in turn drains into the Bay.

The semi enclosed Mahim Bay that provides shelter to fishing crafts is open to the Arabian Sea on the west. The northern shores of the bay are predominantly rocky with mud patches in-between, while the central and the southern zones are largely sandy with occasional rock outcrops. Mahim Creek which is wide and shallow in the inland, harbours extensive mangrove habitats. The mouth of the Mahim Bay between Bandra and Worli is about 1600 m wide. Apart from domestic and industrial wastes draining via the creek, the Bay also receives effluents through several point sources.

Totally 3 stations represented this transect. Station BYM4 and BYM5 were located in the lower whereas other 1 station (BYM6) was located in upstream zone.

2.2.7 Bandra (BYB, Figure 2.2.5), Worli (BYW, Figure 2.2.5) Mumbai

Bandra and Worli marine outfalls are located about 3.4 and 3.7 km off the mouth of Mahim Bay and off Worli respectively in the Arabian Sea. Mumbai city with more than 12 million populations is the hub of commercial and industrial activities and has witnessed a rapid growth during the past few decades. The city generates 2671 mld sewage out of which only 53.36% is treated and the rest is released untreated to the sea through several point sources to inshore as well as coastal sea causing wide spread impairment of coastal water quality.

The shelf associated openshore area with the 50 km long coastline of Mumbai is gradually slopping and the 10 m depth contour is roughly 10 km off the coast. The high tidal influence results in swift water movements with the average current speed often exceeding 50 cm/s. Circulation along the coast is elliptical with the major axis parallel to the shoreline. Hence, the inshore contaminated waters from creeks and bays draining into the coast tend to circulate before being transported offshore. The coastal water mass is well mixed vertically even during monsoon.

As a part of the integrated wastewater management scheme Mumbai Municipal Corporation of Greater Mumbai (MCGM) divides the municipal region into seven drainage zones. For Colaba, Worli and Bandra the plan provides the disposal options through outfalls in the coastal sea. Accordingly Worli and Bandra outfalls are built to dispose sewage into the sea after preliminary treatment through large diffusers at the depth of 7 m CD. The release is through massive tunnels of 4.5 m diameter fully lined with precast concrete. The tunnels are several meters below the seafloor and sewage jets out into the seawater through a series of riser pipes. The marine outfall off Worli has become operational in June 1999 and Bandra outfall has been commissioned during May 2003.

During present monitoring sampling was done at 2 stations at Bandra and 2 stations at Worli outfalls.

2.2.8 Thane Creek (BY, Figure 2.2.6),Mumbai

The Mumbai city is separated from the main land of Konkan by the Thane Creek system which comprises Thane Creek and Mumbai Harbour. The length of the Thane Creek from the mouth to the head, is about 27 Km with a width of 15 km at the mouth (off Colaba) narrowing to a few hundred meters at the head.

Both Mumbai and Jawaharlal Nehru (JN) Ports are located in the mouth of the Mumbai Bay or Harbour. The bay is V shaped semi-enclosed basin that opens to the Arabian Sea at its southwest approach and connected at its northern extremity to the Ulhas Estuary through a narrow channel. The creek though broad is shallow, forcing frequent dredging to maintain the navigational depths in the channel and at the berths. The water depth decreases in the upstream due to the positive bed gradient and the creek is barely navigable beyond the Vashi bridge even for medium size fishing crafts. The tidal inlet of Dharamtar, Nava-Sheva and Panvel are the major tributaries to the creek discharging into its eastern shore. The tides in the region are semi-diurnal type with an appreciable diurnal inequality. In the bay the mean spring tidal range of 5.0 m in the mouth decreases to 4.2 m at Vashi but increases further north (4.9 m) due to funnelling effect. The tides at upstream region lag by 30-45 min with respect to the tide at mouth. The neap tidal range is 1.6, 1.2 and 1.5 m at the respective locations.

The impressive tidal influence generates swift water movements with excursion length of 4-11 km and average current speed of 25-55 cm/s. Modelling of the residual circulation indicates that the western side of the bay had ebb dominated flow an against slight flood dominated currents along the eastern segment.

Both Mumbai and JN Ports are the major gateways for Indian's import and export and handle over 4.5 x 10^7 t of cargo annually which includes crude oil and its product, fertilizers, rock phosphate, sulphur, food grains, metals, chemicals, containerized cargo etc. Apart from spillages due to port operations, the Bay also receives large quantities of domestic and industrial waste waters from Mumbai, Thane, New Mumbai and surrounding region.

Total 6 stations (BY1 to BY6) were sampled along the Thane Creek transect. Out of these stations BY1 to BY3 were in the coastal water and stations BY4 to BY6 represented Mumbai Harbour/Thane Creek region.

2.2.9 Patalganga (PT, Figure 2.2.7)

The Patalganga River originates from the hilly range of Sahyadri near Khopoli and flows westward through the Khopoli city and ultimately joins to Dharmatar Creek near Kharpada village. The tail-waters of the Khopoli power project are let into the river near Khopoli. Bhogeswari, Bhogwati and Balganga Rivers also join in the southern segment of Patalganga. Patalganga and Bhagwati are navigable to a short distance by small vessels.

Many industries have been established in the vicinity of the Patalganga River which includes Patalganga Industrial Area and Karjat MIDC. The river is a main source of water supply to these industries and also to near by villages. However, due to the ongoing industrial and domestic discharges the estuary has become polluted.

A total of 9 stations (PT4 to PT11) were sampled along the Patalganga transect with stations PT4, PT4A, PT5 and PT6 in the lower estuarine segment, stations PT7 to PT9 in the middle and PT10 and PT11 in upper estuarine segment and the rest in the freshwater zone.

2.2.10 Amba Estuary (AB, Figure 2.2.8)

Amba Estuary which originates in the Western Ghats follows a narrow and meandering course along her length of over 140 km before opening into the MumbaiBay. A Konkan type Bandhara constructed across the river at Nagothane (about 50 Km upstream) impounds the river flow which forms the source of supply of freshwater through the MIDC water supply scheme.

The lower reaches of the river often referred to as the Dharamtar Creek is navigable upto the Dharamtar jetty by medium size crafts, under all tidal conditions. During dry season when the inflow of freshwater in the Amba Estuary is meagre, the estuary is dominated by ingress of water from the Bay during flood tide. Hence, the quality of the Mumbai Bay water would greatly influence the ecology of the Amba Estuary apart from the impact of direct release of effluents in the estuary and outflow from the Patalganga Estuary.

A total of 6 stations (AB4 to AB9) were sampled in the estuary with station AB4 and AB5 in the lower, stations AB6 and AB7 in middle and station AB8 and AB9 are located in upper segment of the estuary.

2.2.11 Thal (Thal DP, Figure 2.2.8)

Thal is a small town located about 10 Km north of Alibaug at a coastline. Rashtriya Chemicals and Fertilizers (RCF) are operating one of the largest fertilizer plant in the world at Thal which was commissioned in 1985. The area of study situated in the coastal approaches to Mumbai Harbour from the south, at a distance of 10-15 Km from harbour entrance.

The coast is fringed with sandbanks and reefs, extending upto about 2 Km offshore. Khanderi Island lies at a distance of about 4 km from the shore. The tide at Thal is mixed semi-diurnal. The time of occurrence of high and low water is approximately 30 min ahead of the corresponding time at Apollo Bunder. The fertilizer complex releases treated effluents (13000 m^3/d) through a submarine outfall located about 3.5 Km away from the coast at a depth of 5 m (CD). This site of effluent release is marked by a “Light marker buoy” with 6 ton sinker block at the diffuser site as a navigational guide.

This transect is represented by a single station Thal D.P. which was monitored for temporal variations.

2.2.12 Kundalika (K, Figure 2.2.9)

The Kundalika River which is the main line of drainage for central Raigad District, rises in a Sahyadris near the Garbolot Pass. After a westerly course of about 65 km it meets the Arabian Sea at Revdanda. The upper part of its course has scenes of a great beauty. Between Kolad and Roha the bed is rocky and the banks are muddy with some fine mangroves. After the construction of Dabhol weir, the waters of Kundalika are used on fairly large scale for growing paddy and vegetables. A small bund about 1.5 m high built upstream of Roha, meets the freshwater requirements of the town and the Industrial estate. Several small islets covered with thick mangroves exist in the mid-estuarine zone. The estuary is shallow and except for the mouth region is not convenient for surface transport. The Revdanda Port is an important fish landing centre of the district and provides shelter for many fishing boats.

The wastewater from Dhatav and Roha (MIDC) industrial areas is collected and released after treatment in the mid estuarine zone. The shallow estuary experiences considerable tides with the spring range of 3.8 m in the mouth decreasing to 1.3 m at 35 Km inland. This decrease is from 0.7 to 0.5 m during neap.

Ten stations (K1 to K10) were sampled along this transect out of which station K1 to K3 were in the coastal water. Station K4 to K8 represented lower estuarine zone and the rests upper K9 and K10 zones of the estuary.

2.2.13 Murud (MR, Figure 2.2.10)

Murud is a small historical town at the mouth of the Rajpuri Bay or Creek. The 25 Km long creek or bay is bordered by hills with about 3.2 km wide opening to the sea. Dighi Port, an all weather port is situated at the foot of the Dighi Hills on the southern shore of the creek. At the north, the 38 m high and conspicuous Janjira Fort stands on a rocky islet abreast the village of Rajpuri. The Rajpuri Creek also extends south-eastward joining the Mhasla creek - a 15 Km long shallow and narrow water body strewn with mud flats. Rajpuri Creek which is 7 to 8 m deep and rocky at the mouth becomes substantially shallower in the upstream. Rajpuri is the important centre for fish landing, passenger traffic and for visitors to the fort. Aquaculture is also prominent along the bay shores in the upstream.

Out of the 7 stations sampled along the Rajpuri transect, stations MR1 to MR3 were located in the offshore region off Rajpuri Bay, station MR4 and lower creek and rest (MR6 and MR7) in the upstream of the bay.

2.2.14 Savitri Estuary (S, Figure 2.2.11)

The river Savitri originates from the mountains at Tiger’s spring near Mahabaleshwar and flows towards Poladpur, and further downstream forms a natural boundary between Ratnagiri and Raigad districts before merging with the Arabian Sea near Bankot. Bankot, formerly an important town but now little more than a fishing village, extends about 2 km along the south bank of the Savitri River. Savitri River narrows above Bankot and fishing stakes impede navigation but small medium craft can navigate upto Mahad 50 km upstream.

The water is supplied from this river to Navenagar of Mahad, the industrial estate and some near by villages. The upper and middle segments of the estuary receive treated and untreated domestic and industrial waste waters.

Out of the 9 stations sampled at this transect, stations S1 to S3 were in the coastal water while stations S4 to S7 were in the lower estuarine zone and S8 and S9 in upper estuarine zone.

2.2.15 Vashishti Estuary (VS, Figure 2.2.12)

The Vashishti River which is an important line of drainage for the Ratnagiri District, has a course of about 50 km. Her source water rises in the Tiwa section of Sahyadris. In her mountainous course, she has a narrow and steep profile while on reaching the plains she broadens and develops a meandering course. The importance town of Chiplun is located on her southern bank. The river becomes tidal near Chiplun. Below the island of Govalkot, the river widens in sweeping meanders and after a course of 40 km through low mud banks and mangroves, she meets the Arabian Sea at

Dabhol. The estuary mouth is shallow due to a sand bar which reduces the navigational advantage of the river. The estuary is marked by promontories and the fort of Anjanwel stands on the southern headland. Dabhol Port is located on a narrow strip of low ground between the creek and the northern headland.

Apart from major Jagbudi tributary, several smaller tributaries are received by the Vashishti on either bank. The passage in the smaller streams is obstructed by mud banks and mangroves. The Vashishti is navigable irrespective of the tide for medium size crafts as far as the village Diva about 12 km below Govalkot. Large crafts can navigate upto Govalkot, 45 km from the mouth of the river, during high tides.

The coastline around river mouth is irregular marked by bluffs and carving bays but the region is shallow and hence has a limited use for navigation. The region around the river is highly rocky and the upper and middle reaches of the river do not favour much development.

Deeply entrenched gullies of the Sahyadrian face feed the river during monsoon resulting in voluminous flow of freshwater in the estuary. However, during dry season the flow is regulated by the tail race water from the hydel power station at Popheli. There is another bigger hydel power station at Koyna upstream of Popheli. The water level variations in the estuary vary considerably depending on the tidal state and the distance from the mouth. There is a MIDC industrial estate at Lote-Parshuram at the freshwater zone of the river.

In all 10 stations were sampled along this transect. The coastal water of the estuary was represented by station VS1 to VS3 and station VS4 was in the estuary mouth opposite the Dabhol Port. Stations VS5 to VS10 were located in middle and upstream region while station VS9 was in the vicinity of the location where the treated effluent from MIDC, Lote-Parshuram near Chiplun was discharged.

2.2.16 Jaigad (J, Figure 2.2.13)

Jaigad is a small fishing village and a natural harbour at the mouth of the Shastri River in the Ratnagiri District. Shastri River rises in the Sahyadris and flows westward before meeting the sea near Jaigad. The tidal impact through the estuary is upto Sangameshwar and during this course several small rivers unite with the Shastri. Shastri Estuary has two bays viz. Dhamankhol Bay (depths of 7 to 8 m) and Jaigad Harbour (depths of 12 to 13 m) inside the harbour but has a sand bar at the entrance. A confluence of the Shastri River and the Arabian Sea is called Jaigad Creek. The inner estuarine region has good mangroves. Presently the estuary does not receive any known point discharges of waste water.

During the present monitoring 6 stations (J1 to J6) were studied along this transect. Stations J1 to J3 represented the coastal water, station J4 mouth region of the estuary and stations J5 and J6 in the middle and the upper estuarine regions. Many development activities have been proposed and approved around Jaigad Creek.

2.2.17 Ratnagiri (R, Figure 2.2.14)

Ratnagiri region receives heavy rainfall which has resulted into highly eroded land scape in the coastal region. Over 85% of land is hilly. Ratnagiri is a small port and all port activities are confined in the Mirya Bay. The bay is protected by a 900 m long breakwater with a 300 m long jetty to handle passenger and cargo traffic. The existing jetty is mainly used to transport clinkers for the cement plants. Mirya Port which is also known as Mirkarwada is a prominent fish landing centre used by more than 400 trawlers.

Though industrial effluents are not received at the transect, untreated sewage from the Ratnagiri town enters the bay in addition to fish discard and fish related wastes from fish landing centres which contaminate the bay. Several break water bunds constructed to protect the bay from waves, obstruct flushing of the area thereby enhancing environmental degradation.

In all 5 stations sampled along this transect.The open coastal waters were represented by stations R1 to R3 and station R4 in the outer bay off the Bhagwati Port (cement jetty) during the present study. The inner Mirya Port was represented by station R5.

2.2.18 Vijaydurg Creek (VJ, Figure 2.2.15)

The configuration of Vaghotane River and Arabian Sea is known as Vijaydurg Creek. Vijaydurg lies at the southern bank of the Burmana Bay near the mouth of Vaghotane River. Vaghotane River rises in the Kajirda pass of Sahyadri Hills and flow south west for about 25 km receiving the waters of several tributaries. The river becomes tidal near Kharepatan and further west the channel rapidly widens and passing the quay of its left bank, reaches the Arabian Sea. The mouth of the river is completely sheltered from the south-west and splits in to several backwaters. The region offers a very panoramic view of the creek and the fort and has a number of virgin beaches close by.

At present the port has one jetty with maximum permissible draft of 3.0 m. In coming days 70% of the traffic potential of Kolhapur and 20% of Solapur are expected to be handled at the Vijaydurg Port. Apart from this, M/S Midex

Global Pvt Ltd (MGPL) has developed the Vijaydurg sea Port for its molasses operations.

The Vijaydurg Creek does not receive any drainage of industrial and domestic effluents. However, operations of handling of molasses and fish landings have the potential to influence its environmental quality.

Among 6 stations sampled along this transect, stations VJ1 to VJ3 were sampled in the coastal waters off Vijaydurg, while the Vijaydurg Port was represented by station VJ4. Stations VJ5 and VJ6 were the creek stations in the river Vaghotane.

2.2.19 Deogad Creek (D, Figure 2.2.16)

Deogad is a major fish landing centre located at southern shore of the Deogad Bay. Deogad River which joins the Deogad Bay or Creek rises in the Sivgad pass, and after a comparatively straight course of about 50 m from east to west reaches the sea at the fort of Deogad. Several small islands have been formed in the bed of the tidal section, and it is only navigable for a few kilometres. The total length of creek is about 16.5 km with estuarine area of 1900 ha. The inner part of estuary has extensive mangroves. All the fishing activities are conducted from the Anandwadi Port.

During the present study the samplings were carried out at stations D1 and D2, which were in the open coastal waters; station D4 in the mouth region and stations D5 and D6 in the estuarine region of the creek.

2.2.20 Achara (ACH, Figure 2.2.17)

Achara Creek is a remote end of the Devgad Tahsil. It is a well-known and rich habitat for the typical creek biodiversity in Sindhudurg district. Achara beach is considered as a paradise beach especially for anglers, swimmers and for sunbathing. This beach is situated at a distance of 36 km from Kankavali and 22 km away from Malvan. This Achara beach is regarded as one of the most charming beaches other than Sindhudurg beach. Moreover, the sea off Achara beach has rich population of dolphins. The Achara Creek is surrounded by lush healthy mangroves. Sand deposition at mouth of creek makes navigation difficult especially during low tide.

In all total 5 stations were sampled in Achara Creek. Out of these stations 1-3 represent coastal area and station 4 is near to the Achara fishing port and station 5 represents upper creek region.

2.2.21 Malvan (M, Figure 2.2.18)

Malvan Bay, with its entrance encumbered by rocky shoals, is accessible to shallow draught vessels but only during the fair weather season. Malvan town with a population of 1 lakh or so stands on the northern bank of the Malvan Bay almost hidden by coconut palms. Sindhudurg Fort is located at a fortified island on the south side of the entrance of the Malvan Bay. There is a landing jetty at the custom. There is no perennial river or a creek joins the bay, however, some influence of Kalavali River in the north and Karli River in the south as well as that of tidal creek at Chiwallyachi Bandar is possible. Surrounding region of Malvan is an open coast ecosystem, and is dominated by rocky outcrops with intermittent sandy beaches.

No known industrial and domestic point release exists to the marine area off Malvan though domestic waste water from the town enters the Bay through a few non-point sources. The port operates as the fish landing centre and has a passenger jetty for the tourists. The Malvan has Marine Wildlife Sanctuary, which includes Padamged Island and other submerged rocky structures.

The coastal waters of Malvan was monitored at stations M1 to M3 and station M4 representing the Malvan Bay during the present study.

Figure 2.2.1: Station Locations at Dahanu Creek (DH)

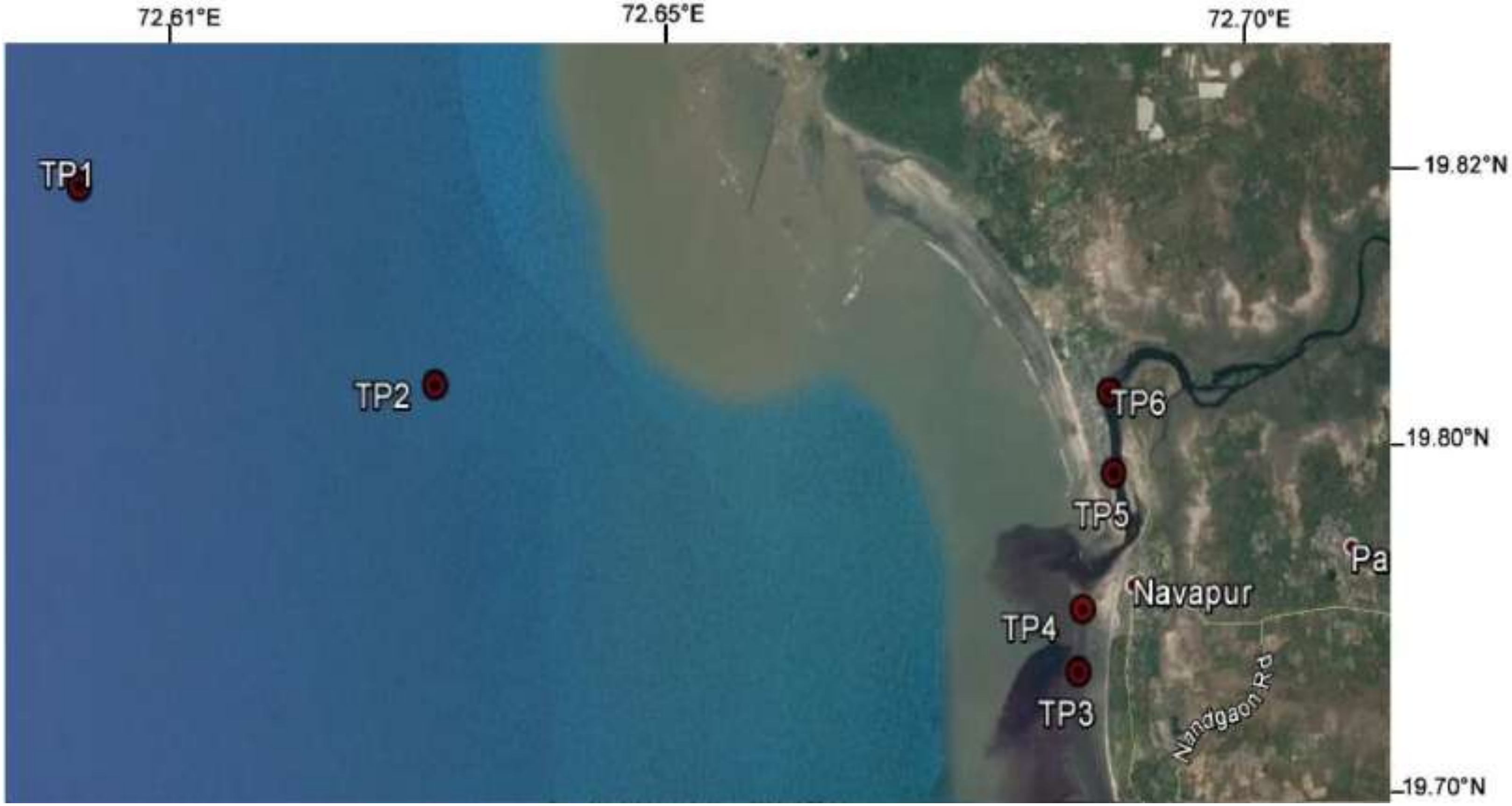
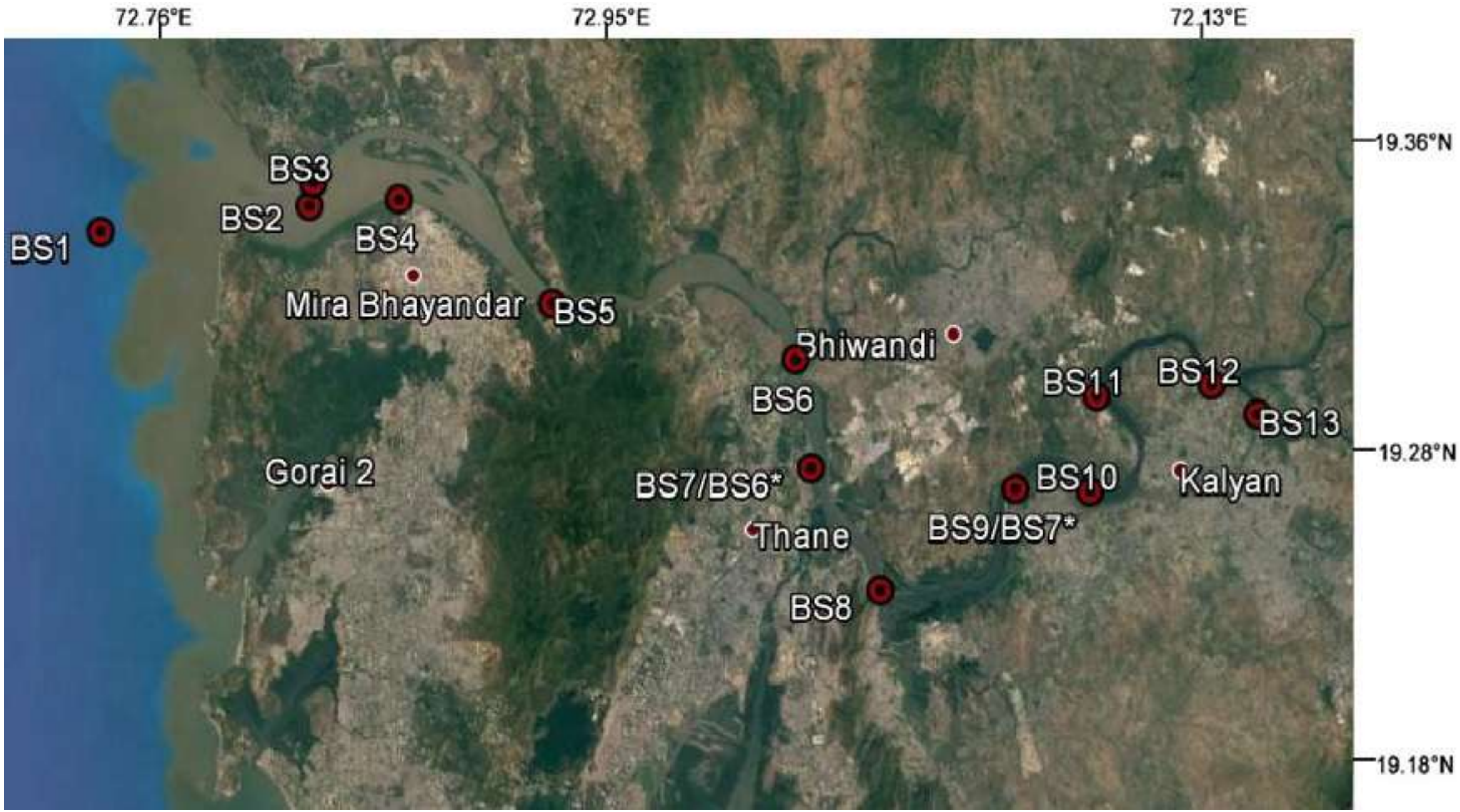


Figure 2.2.2: Station Locations at Tarapur Creek (TP)



* Station number of 2007-2008 study

Figure 2.2.3: Station Locations at Bassein/Ulhas Estuary (BS)

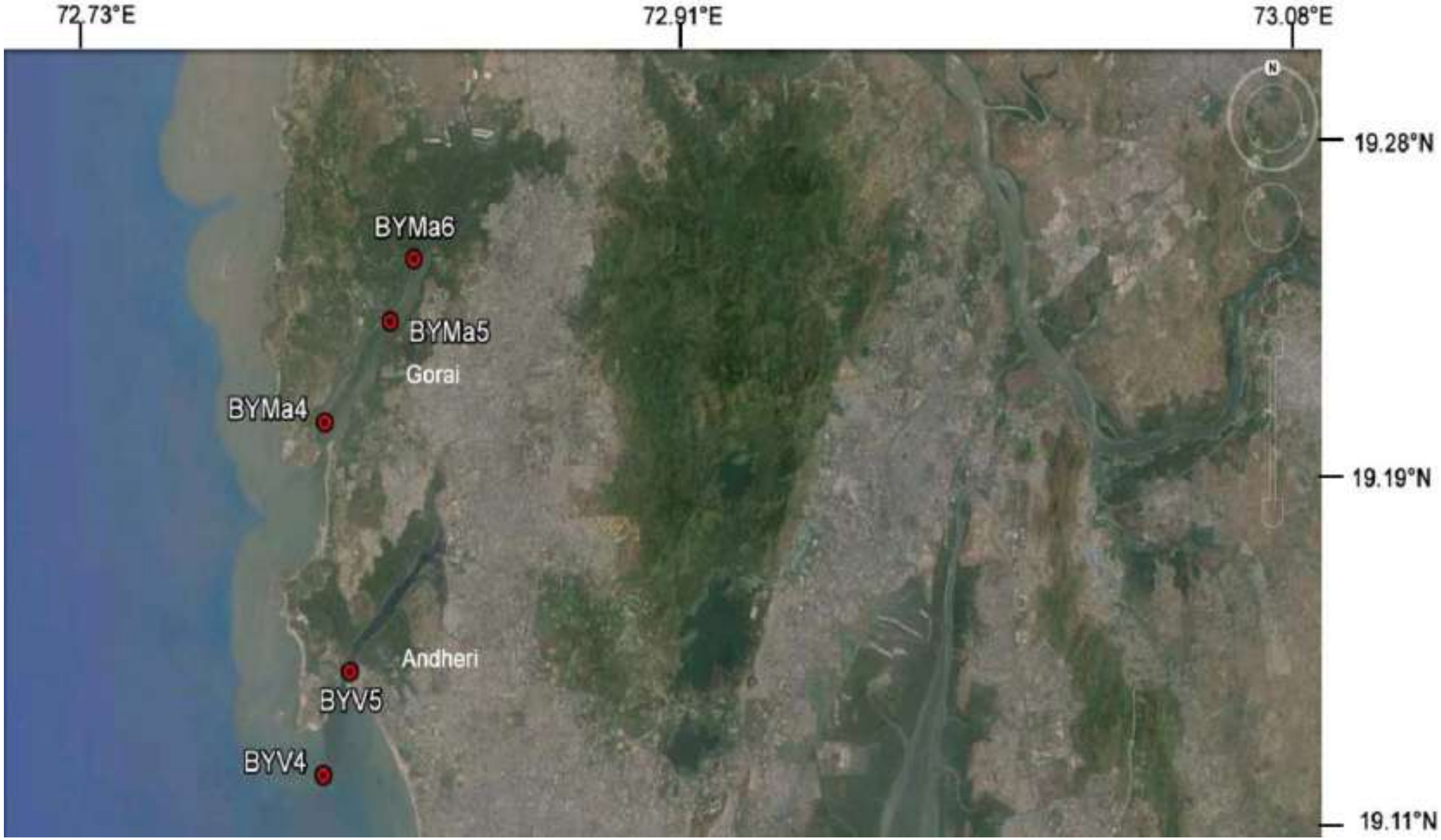


Figure 2.2.4: Station Locations at Manori (BYMa) and Versova (BYV)

Figure 2.2.5: Station Locations at Mahim (BYM), Bandra (BYB) and Worli (BYW)

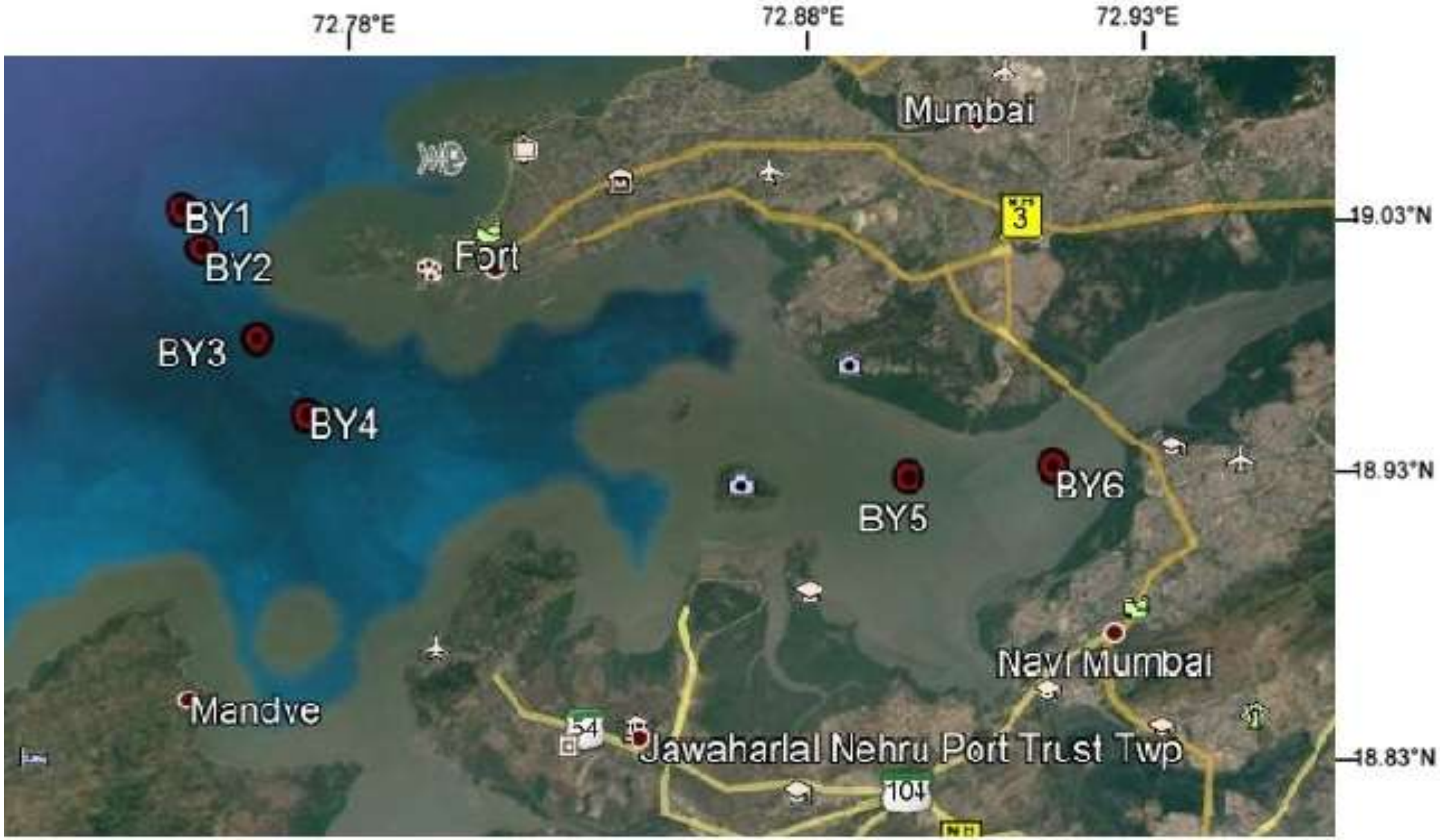
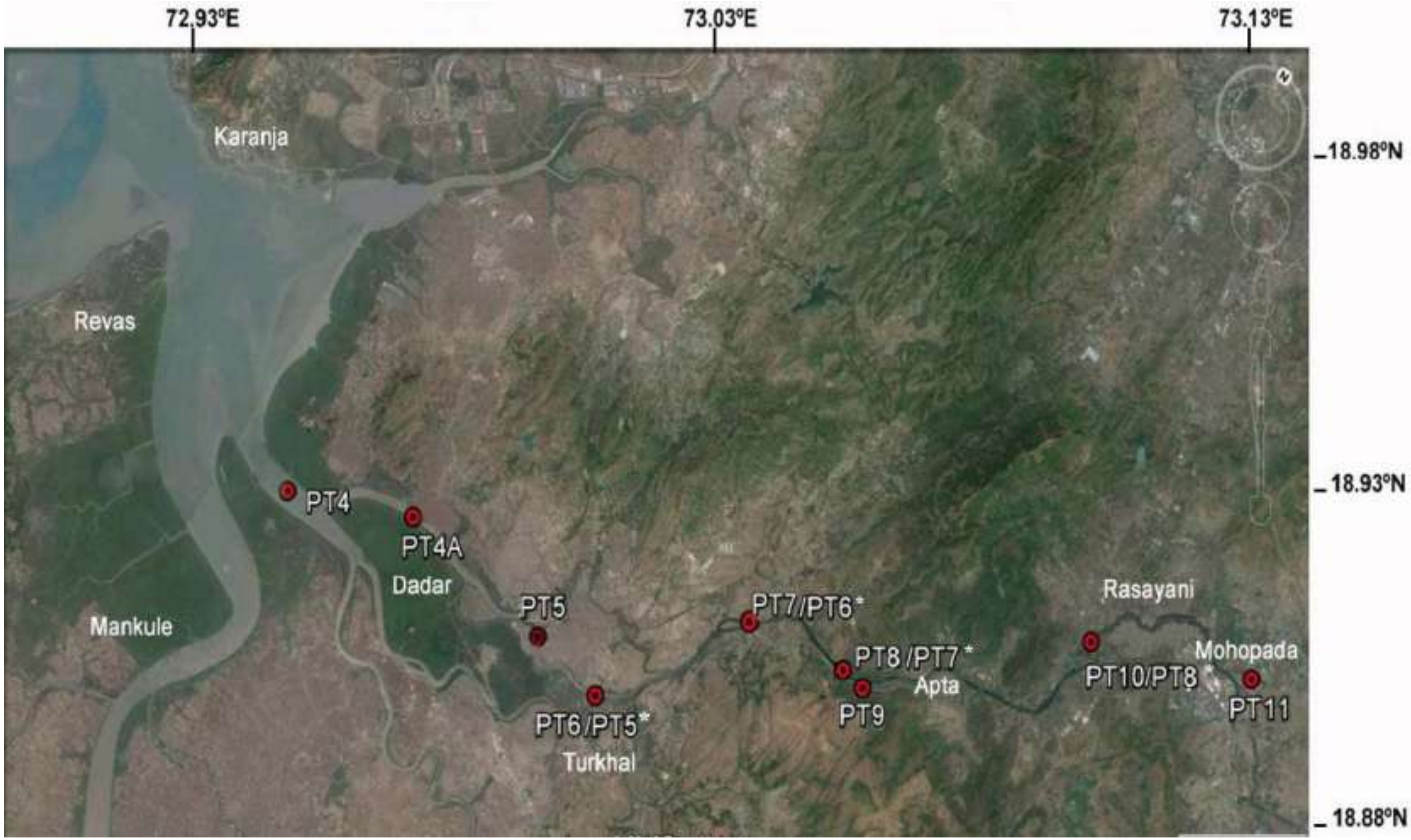
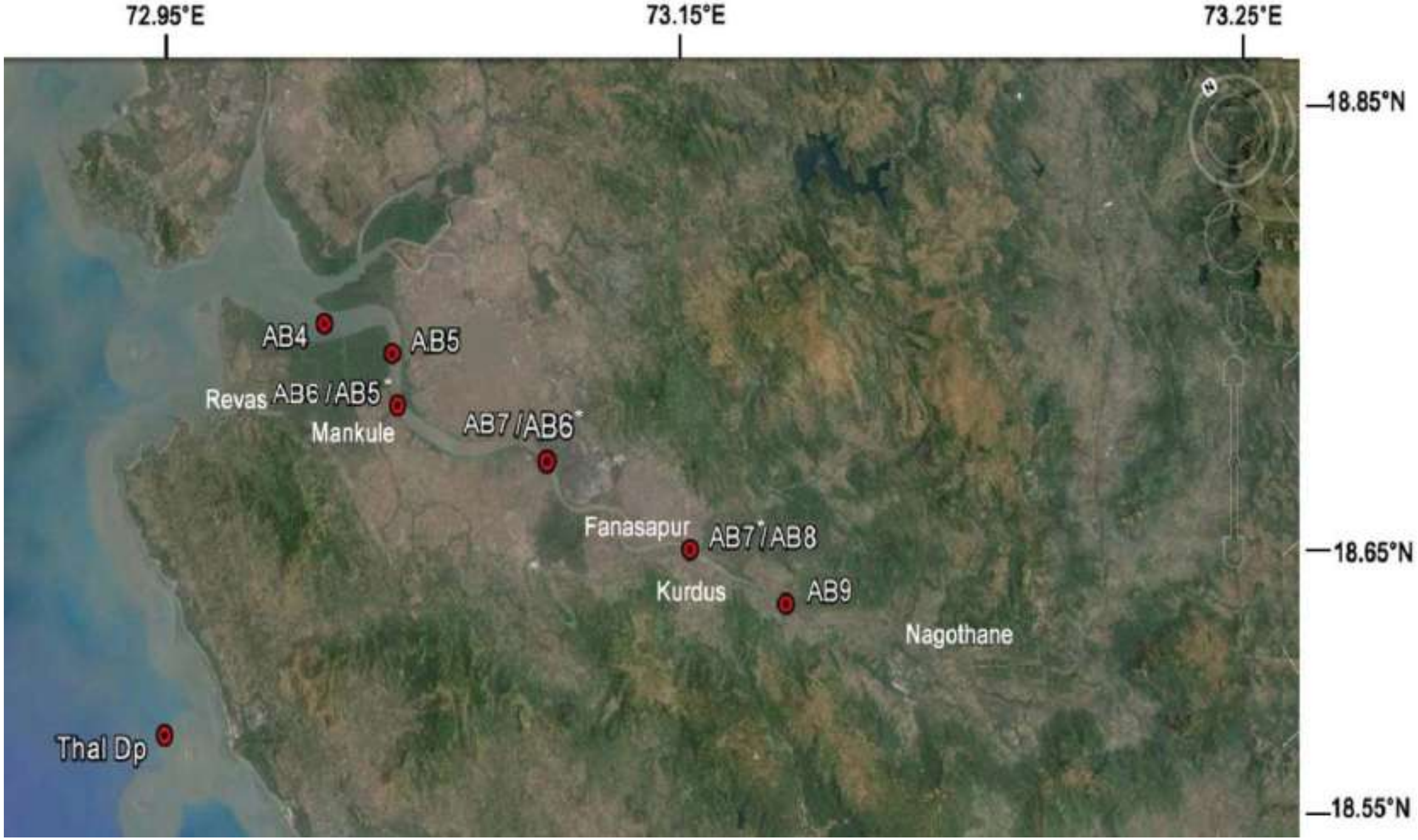


Figure 2.2.6: Station Locations at Thane Creek (BY)



* Station number of 2007-2008 study

Figure 2.2.7: Station Locations at Patalganga Estuary (PT)



* Station number of 2007-2008 study

Figure 2.2.8: Station Locations at Amba Estuary (AB)

*Station number of 2007-2008 study

Figure 2.2.9: Station Locations at Kundalika Estuary (K)

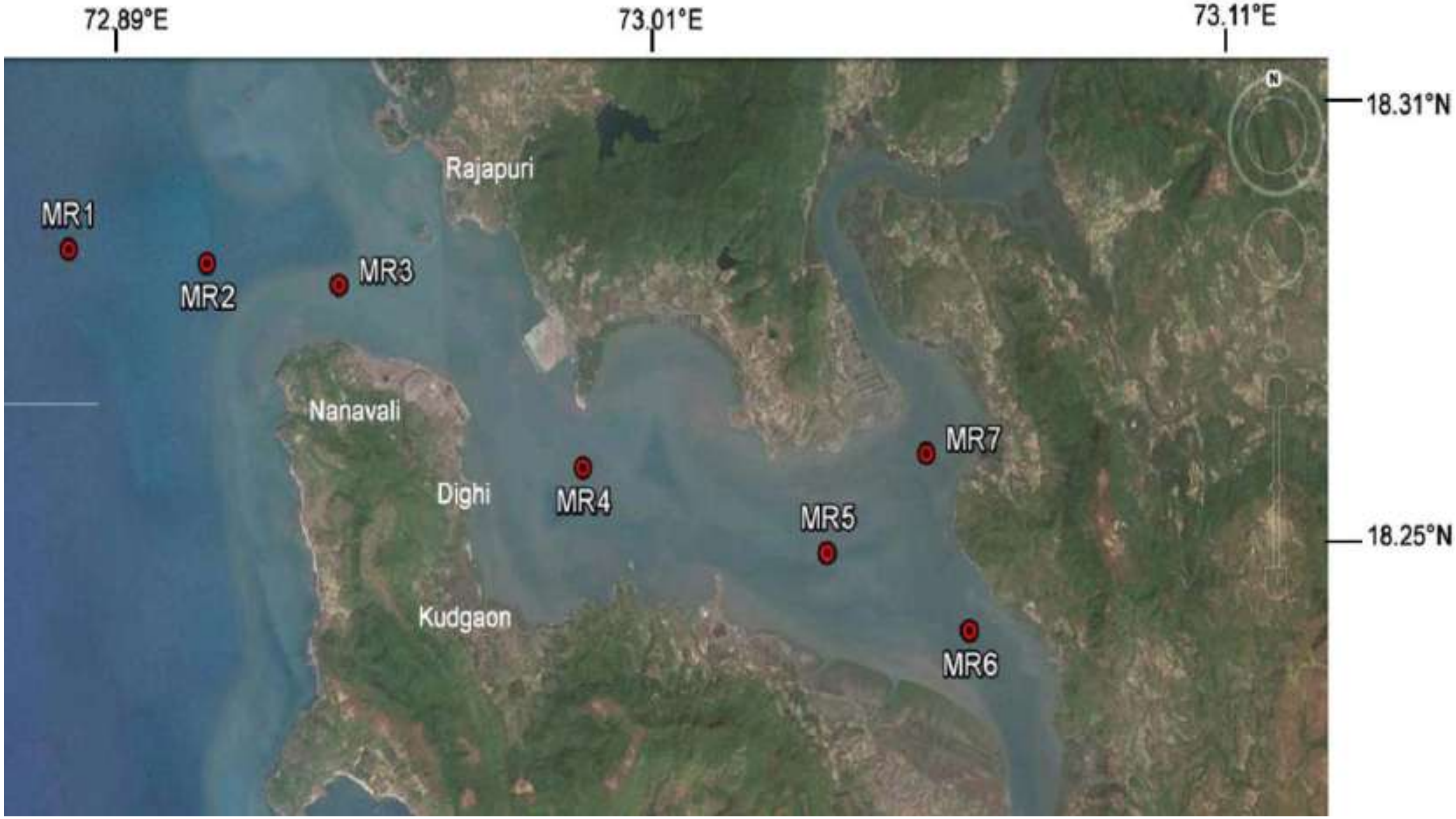
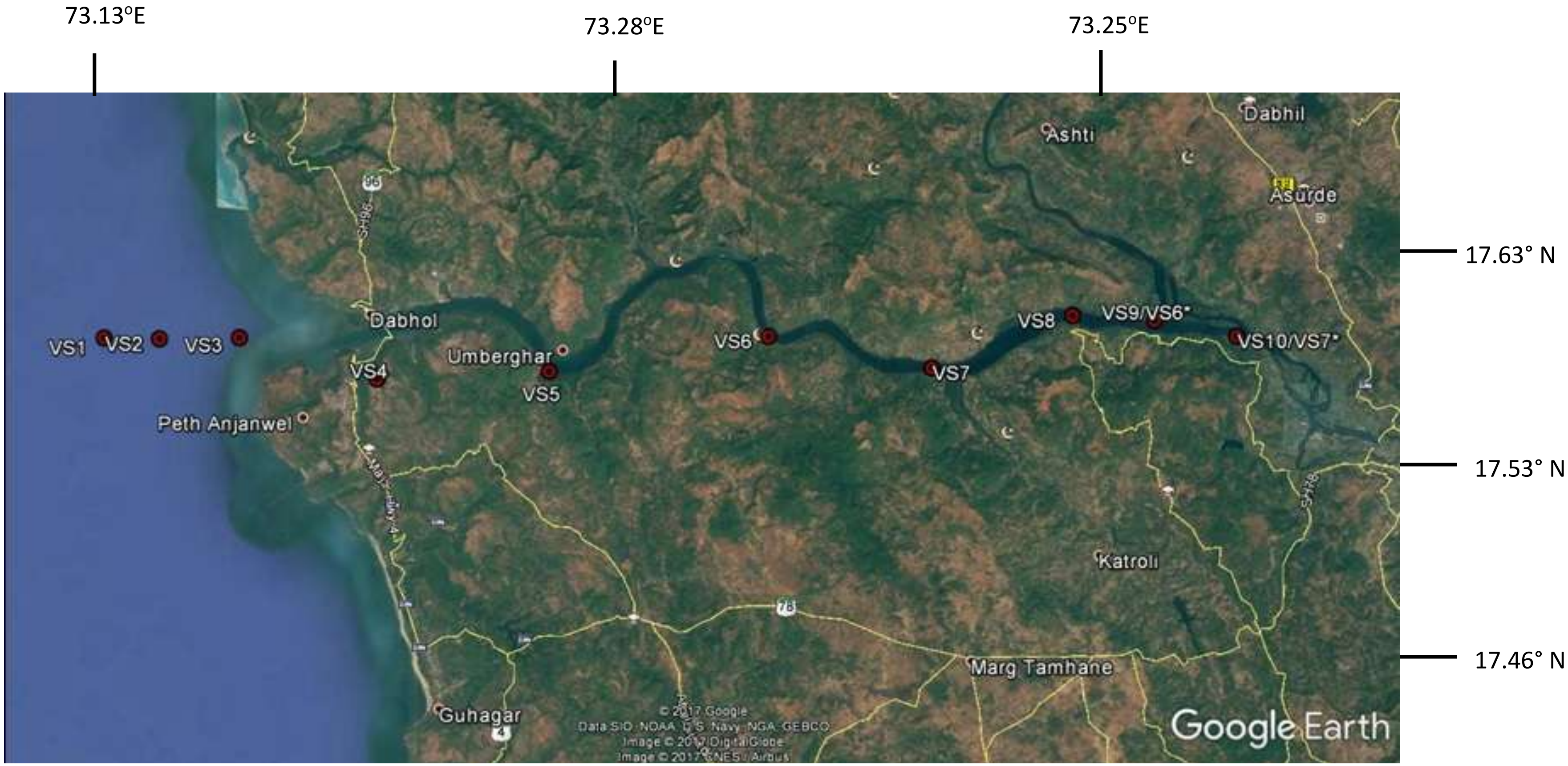


Figure 2.2.10: Station Locations at Murud (MR)

* Station number of 2007-2008 study

Figure 2.2.11: Station Locations at Savitri Estuary (S)



* Station number of 2007-2008 study

Figure 2.2.12: Station Locations at Vashishti Estuary (VS)

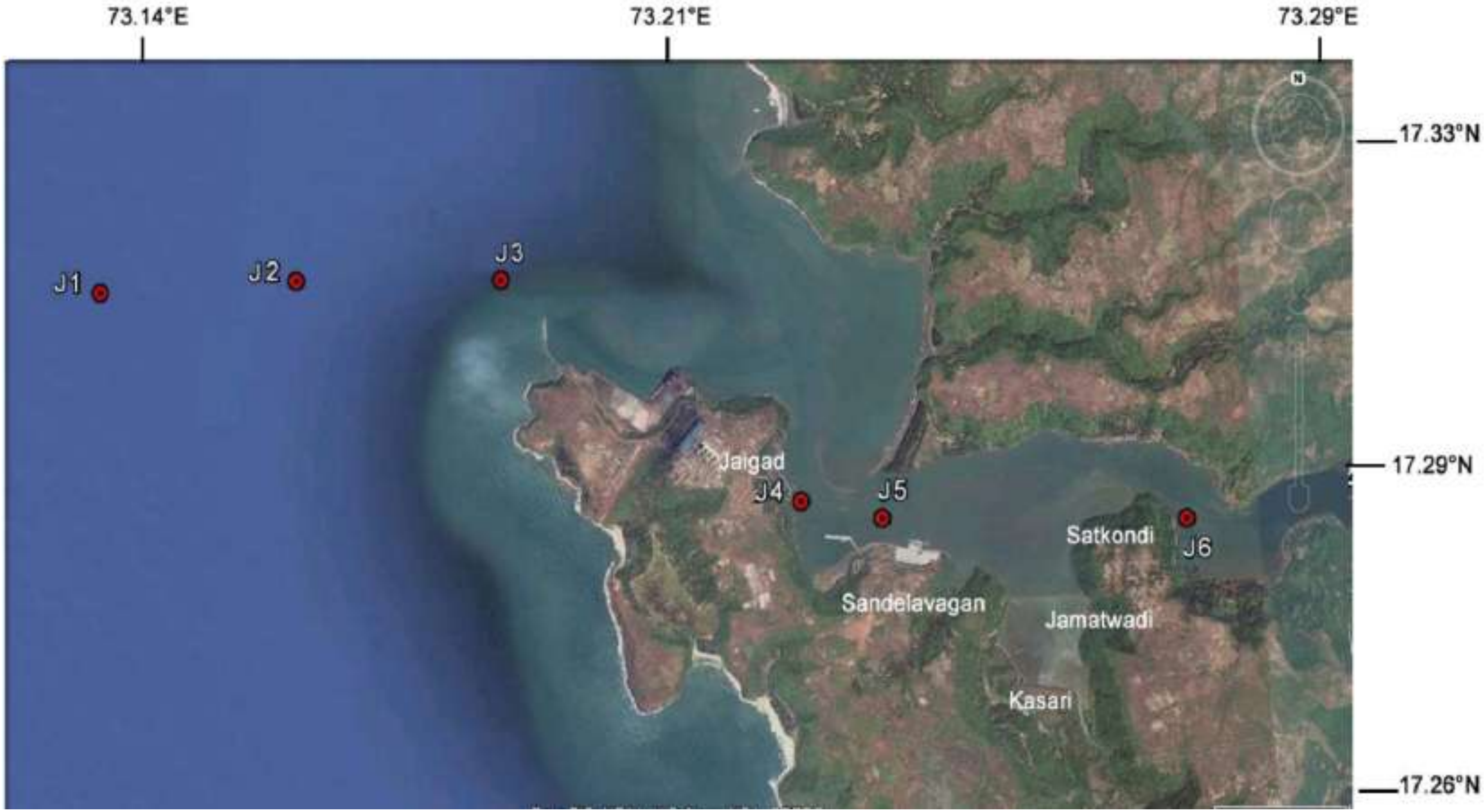


Figure 2.2.13: Station Locations at Jaigad/Shastri Estuary (J)

Figure 2.2.14: Station Locations at Ratnagiri (R)

Figure 2.2.15: Station Locations at Vijaydurg (VJ)

Figure 2.2.16: Station Locations at Deogad (D)

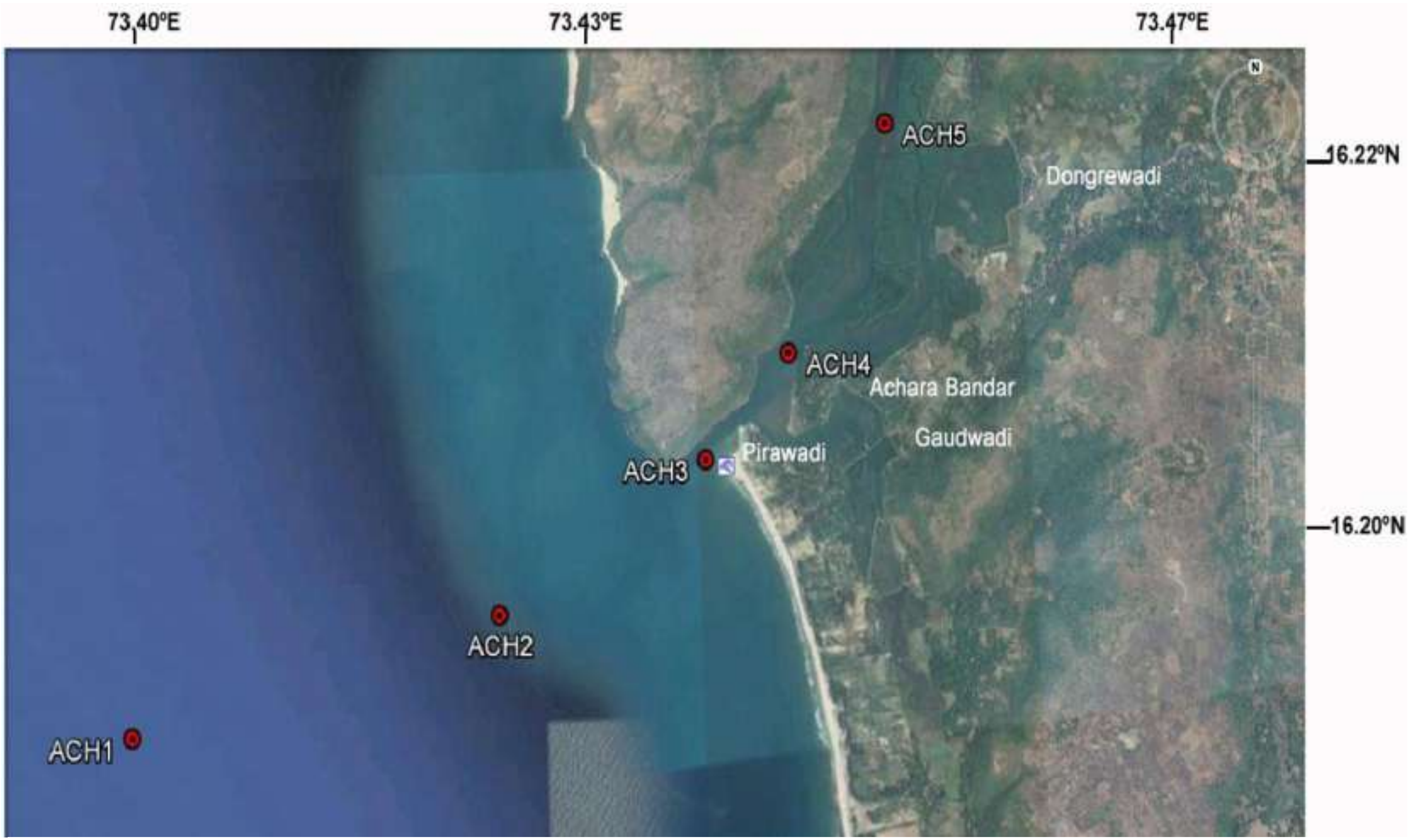


Figure 2.2.17: Station Locations at Achara (ACH)

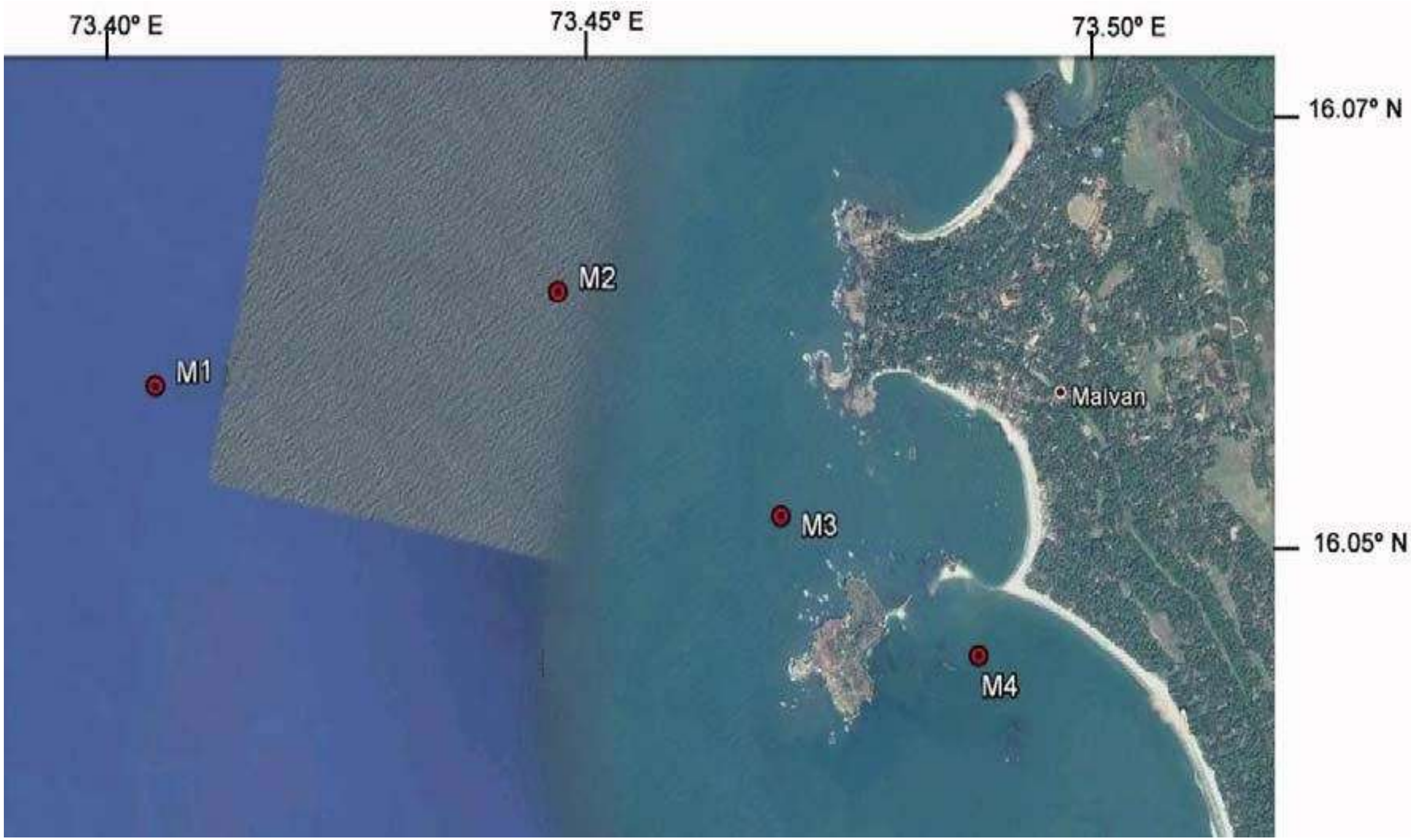


Figure 2.2.18: Station Locations at Malvan (M)

3 WASTEWATER INFLUX

The inshore and coastal areas of Maharashta receive a variety of contaminants through point sources emanating from domestic and industrial establishments located in the narrow coastal belt. The number of towns and villages in the districts within 20 km of the coastline is given in Table 3.1. The domestic wastewater is generally released to nearby inshore waters wherever sewage collection network has been laid. A significant fraction of sewage generated by the coastal population does not reach the sea in the absence of suitable collection facilities.

In Maharashtra State there are 26 Municipal Corporations, 222 Municipal Councils, 7 Cantonment Boards and 3 Nagarparishads. The total domestic wastewater generated from 20 corporations is estimated at 7041MLD but some kind of treatment facility is available with only 17 corporations. Out of 254 local bodies, including Cantonment Boards, Nagar Panchayats and Municipal Councils, only 45 have partial treatment arrangement for domestic effluent, while, 190 local bodies lack in any facility to treat domestic wastewater. The total effluent generated by these local bodies is 820 MLD. The details of Municipal Corporations in Maharashtra, domestic wastewater quantities they generate and the nature of disposal are given in Table 3.2. It is evident from the table that the Municipal Corporations generate 7041 MLD of domestic wastewater out of which Mumbai and nearby regions account for nearly 70% of the total. Thus about 4927 MLD of domestic wastewater generated in and around Mumbai enters the Arabian Sea, directly or via creeks, bays and estuaries. Almost half of the city's 12 million residents are either slum dwellers or homeless without any access to sewage and sanitation facilities and use coastal area in and around city as a natural toilet.

Nearly 15 percent of the total number of manufacturing units in India is located in Maharashtra and include textiles, chemicals, metallurgical industries, transport equipment, automobiles and machinery, machine tools, each of which account for more than one-fourth of the country's production in those industries. Other significant industries in Maharashtra include food products, beverages, tobacco and tobacco products, paper and paper products, printing, rubber, plastic, petroleum and coal products, electronic hardware and software, metal products, pharmaceuticals, engineering goods, steel and iron casting. These industries are grouped into large scale, medium scale and small scale as shown in Table 3.3. Investment friendly industrial policy, good infrastructure, rail and road connectivity, port facilities and a strong human resource base have made Maharashtra a favourable destination for the manufacturing, export distribution and financial services sectors. The state has attracted 9,412 new projects with a total investment of Rs. 2,17,225 crores since 1991. Of these, 3,817 projects which involved an investment of over Rs. 57,132 crores are operational and have employed approximately 3.81 lakh people.

Industrial development in the State is largely through the Maharashtra Industrial Development Corporation (MIDC). It has been mainly responsible for Maharashtra’s economic growth since it was constituted in 1962 and has developed more than 215 industrial estates, including nine ‘five star’ estates and 63 growth centres. Most of the industrial estates of MIDC are located a few kilometres inland from the coast and release their effluents in nearby creeks and estuaries.

The principal industrial zone in Maharashtra is the Mumbai - Thane - Pune belt, accounting for almost 60% of the State's output. Efforts are being made to promote other industrial areas like Nagpur, Aurangabad, Solapur, Jalgaon, Raigad, Amravati and Ratnagiri by building the necessary infrastructure and creating an environment conducive to industrial development.

The Industries that are prone to water pollution are listed in Table 3.4 and the status of treatment is given in Table 3.5. Larger industries can maintain their own effluent treatment plants. For medium and small scale industries Common Effluent Treatment Plants (CETPs) are the only way out and such facilities are available at many industrial sites. The CETPs operational as on July 2016 are listed in Table 3.6.

Based on the information made available by MPCB and gathered from other sources, the domestic and industrial effluents entering in inshore and coastal waters at sites sampled during the present monitoring are discussed in the following sections. It may be however mentioned here that the information available on such releases is often fragmentary and is by no means complete.

3.1 Dahanu

Dahanu, a major commercial and industrial town in the Thane District, is a coastal city and a municipal council with population of 44,393. A 500 MW thermal power plant consisting of two 250 MW units, commissioned in 1999, is operated by the Reliance Energy Limited. Though there is no domestic waste discharged by thermal power plant, 528 MLD of warm return seawater is discharged to the nearby creek. The input to the sea interms of pollution are heat, additional salinity and sulphates from the FGD system. Around 0.8 MLD of industrial effluent is released to the Dahanu Creek by paper and distillery units. Dahanu Municipal Council discharges around 4 MLD of domestic waste to the creek without significant treatment. The mouth of the Dahanu Creek is shown in Figure 3.1.1.

3.2 Tarapur

Tarapur area houses around 2110 medium and small scale industries largely located in MIDC-Tarapur and Additional Tarapur Industrial Estate. The major industries include bulk drug manufacturing units, specialty chemical manufacturing units, steel recycling plants and a few textile plants. Around 2.0 MLD treated effluent generated in Tarapur town with a population of 37,500 is discharged to the coastal waters. At present the effluents amounting to 25 MLD are being treated in a Common Effluent Treatment Plant (CETP) and released in to the coastal water off Tarapur through a submarine outfall. This facility was planned several years ago but the effluent quantity of the Industrial estate has increased multifold and the present effluent quantity is about 80 MLD for which the present discharge location and release mode are not tenable. MIDC is now proposing to expand effluent treatment and disposal facility to 120 MLD to cater for future needs. The atomic power plant also uses the sea water for cooling and lets out the thermal effluent to the coastal waters. A view of downstream segment of Tarapur creek is shown in Figure 3.2.1.

3.3 Bassein/Ulhas estuary

The six rivers namely Bhatsa, Kalu, Vaitarna, Tansa, Surya and Ulhas flow through the Thane district and are important sources of water supply to industries as well as drinking water for nearby localities. Due to increase in population and density of polluting industries, this area becomes environmentally sensitive. Thus the faster industrialization of the region has resulted in rapid growth of residential area in Kalyan, Ulhasnagar and Bhiwandi. Each of these urban settlements was once Municipal Council and now got the status of Municipal Corporations. As per the available records, there are 4217 industries in the Kalyan region alone. Out of these 1704 industries are in “Red” category”. There are 5 major industrial estates namely MIDC. Dombivli Phase I &II, MIDC, Ambarnath, MIDC Badlapur, MIDC Saravali and MIDC Bhiwandi. Some large-scale industries are also located in scattered areas. Besides these some re-rolling type industries also exist in Wada taluka.

Apart from industrial waste, the Bassein/Ulhas estuary also receives 511 MLD of domestic sewage. Discharge of all these effluents has resulted severe deterioration of Ulhas Estuary especially in middle and upper segments. A view showing upper estuarine region of Ulhas Estuary is given in Figure 3.3.1.

3.4 Manori

Manori Creek (also known as Gorai/Marve Creek) is a creek (tidal channel) in northern Mumbai. The industries in and around Manori feeding their waste into Manori creek include Metlab industries, Fair Pent plastic, Dip Chemical, SA industry, Amol Industry, JK Forge, Madam Agro Food Industry, Gei Haman Industry, Rabi Industry, Arvind Pipes and Fittings Industries Pvt. Ltd. Domestic wastewater generated in the catchment of the creek is also pumped to the creek. However, the effluent quantity of these industries is not known. An amusement park known as Essel World is spread over 64 acres on the bank of Manori Creek, and attracts 10000 visitors everyday. The waste generated by the park is also expected to reach the Manori/Gorai Creek. Presently, the Manori Creek receives wastewater and sewage from open drains and partially treated sewage from Malad (240 MLD) treatment plant. Figure 3.4.1 shows a view of the Manori Creek.

3.5 Versova

Versova Creek, also known as Malad Creek is a minor creek in north-west Mumbai. The Oshiwara River drains into it. In the past the creek was surrounded by a 1000 acre area of mangroves which has now shrunk to 400 acres as the real estate prices in Malad went up. Oshiwara River begins in the Aarey Milk Colony, cuts through the Goregaon hills, across the Aarey Milk Colony before emptying into the Versova Creek. On the way it is joined by another creek near Swami Vivekanand Road, before picking up industrial effluents and sewage while crossing the Oshiwara industrial estates and slums of Andheri. The river resembles a sewer and highly polluted and encroachments have shrunk it to a narrow stream. Presently, the Versova Creek receives wastewater and sewage from open drains and partially treated sewage from Versova (200 MLD) treatment plants.

3.6 Mahim

The Mahim Creek receives overflow of the Vihar and the Powai Lakes during monsoon via the 14 km long Mithi River. During its course, the Mithi River carries waste water discharged from several small scale industries (non-point sources) and urban settlements. The total effluent load retained in the Mahim creek system has been estimated at 93,000 m^3 that formed 16 % of the spring tide and 40 % of the neap tide volume of the creek.

3.7 Bandra

Around 1553 MLD of sewage, which is discharged off the Bandra coast through an underground tunnel is likely to increase to 1747 MLD by 2025. However, except for removal of grit, no treatment is given to the sewage before its disposal off Bandra.

3.8 Worli

Love-Grove sewage pumping station situated at Worli discharges around 757 MLD of sewage is discharged to the Arabian Sea through a marine outfall.A preliminary treatment and aerated degritting is imparted to the sewage before it is let into the tunnel.

3.9 Thane Creek

The water quality of Thane Creek is a result of the balance between the anthropogenic fluxes of pollutants emanating from domestic wastewater and variety of industries located along its eastern and western shores and removal of contaminants by natural processes. Domestic wastewater, often untreated or partially treated, is released as point discharges along the western shores. The major releases are through a subsurface outfall off Colaba and through pipelines and/or natural tributaries off Tank Bandar, Wadala, Ghatkopar, Bhandup and Thane on the western part of the creek, whereas the eastern part of the creek receives sewage from Koparkhairane, Nerul, Belapur, Vashi and Airoli. Altogether the creek receives around 1260 MLD of sewage.

3.10 Patalganga Estuary

The river Patalganga originates from the hilly range of Sahyadri near Khopoli and flows to the west side through Khopoli city and joins the Dharamtar creek. The river is not only the main source of water supply to these industries but also to nearby villages.

The domestic wastewater of the Khopoli city is a substantial source of pollution. Presently industries release their effluents in Patalganga in the fresh water zone below the weir (Figure 3.10.1). The accidental discharges of effluents directly or indirectly from the industries and the use of explosives and poisonous chemicals for fishing, unethical disposal of solid waste in the vicinity of the river banks that may find way into the river in rainy season and the washing of chemical tankers in the river are the causes of pollution of the river water. A CETP having capacity of 15 MLD is constructed and commissioned during 2005. The treated effluent is presently disposed through 700 mm dia at a location about 9 km from CETP.

3.11 Amba Estuary

Amba River which originates in the Western Ghats follows a narrow and meandering course along her length of over 140 km before opening into the Mumbai Bay. The estuary receives industrial effluents (Figure 3.11.1) directly as well as via the Patalganga River in the mouth segment. The estuary is fed by the tidal water of the Bay to which it opens, thereby transferring a portion of the contaminants from the Bay to the estuary. Around

6000-7000 m^3/d treated effluent is discharged to the estuary by Maharashtra gas Cracker Complex established at Nagothane on the western bank of Amba estuary. Other major industries in the vicinity include Ispat Industries, Vikram Ispat, Gas Authority of India Limited (GAIL) and HP- LPG. Figure 3.11.2 gives a view of the coal handling at the PMP port.

3.12 Thal

Rashtriya Chemicals and Fertilizers (RCF) have set up a large fertilizer complex at Thal, which is operational since 1982. The complex generate around 13,000m^3/d waste water, which is treated as per the norms laid by MPCB and released in the nearby coastal water at a distance of 3.5 km from the shore line, through a submarine out fall (Figure 3.12.1).

3.13 Kundalika Estuary

Kundalika River, a perennial river, flows through the forests below the Mulshi and Bhira Dams. Over 90% of Kundalika's water is consumed by industries, including RCF's Thal Project and many MIDCs. MIDC has developed an industrial area at Roha on the southern bank of KundalikaRiver. The industrial estate is fully operational and about 40 chemical units have gone into production. The effluents from these industries amounting to 14.0 MLD after minimal treatment is collected in storage sumps and subsequently pumped into the Kundalika River through a point discharge about 7 km downstream of the industrial estate. Prior to 2014, the effluent from MIDC was flowing through land due the broken pipe line (Figure 3.13.1).The polluted status of the estuary is depicted in Figures 3.13.2 and 3.13.3. However, in recent year, MIDC has laid pipeline and discharges effluent of MIDC Roha near to Gophan Village using diffuser system (Figure 3.13.4).This point of release is about 30 km upstream from the mouth of the estuary. Apart from industrial waste, the estuary receives around 1.4 MLD of domestic wastes.

3.14 Murud

Murud is just 45 km south of Alibaug and a tourist destination. Rajpuri Creek opens in the coastal area of Murud. Though the area does not receive any known effluent, it could be receiving domestic wastewater from point sources.

3.15 Savitri Estuary

The Savitri River originates near Mahabaleshwar in the western slopes of the Sahyadrian range and after a meandering course of about 80 km meets the Arabian Seanear Harihareshwar. MIDC has developed an industrial complex 6 km west of Mahad town adjoining Goa-Mumbai road. Majority of establishments in the complex are chemical industries manufacturing a wide range of products. The wastewater generated by the MIDC area was estimated to be under 6.0MLD. The wastewater treated by individual industry is collected into the collection system provided by MIDC. The combined effluent is released in the Savitri River upstream of Ambet (Figure 3.15.1). Apart from the industrial effluent, the river receives 7.5 MLD of domestic sewage.

3.16 Vashishti Estuary

Vashishti River, originates at the western slopes of the Western Ghats and meets the Arabian Sea at Dabhol. The estuary receives about 4.5 MLD of industrial wastewater from Lote Parsuram industrial area. At present, the wastewater generated in various units is collected and released through a point subsurface outfall in Vashishti Estuary near the confluence with the Jagbudi River (Figure 3.16.1). The estuary also receives domestic wastewater estimated at 7.7 MLD.

3.17 Jaigad/Shastri Estuary

The coastal water of Jaigad and the estuary does not receive any effluent from point sources and harbours luxuriant mangroves. The port is an active fish landing centre at this transect and has bauxite export from the port at Lavgaon and some industries are being set up around Jaigad Port in recent years. JSW Thermal Power complex discharge about 13 MLD of their coolant water to the open sea.

3.18 Ratnagiri

Ratnagiri Port and fishery harbour (Figure 3.18.1) is located inside the Mirya Bay. Bhagawati Bunder is used by Narmada Cements for receiving clinker. Minja Bay which is a fishing harbour used by about 400 trawlers, is contaminated with trash fish, fishing related wastes and bilge from trawlers (Figure 3.18.2).Though, any industrial effluents are not received at this coastal system, untreated sewage from the Ratnagiri town enters the bay. The quantam of waste released to this system is not known.

3.19 Vijaydurg

Vijaydurg Port is used by Midex for export of molasses. Except this, the coastal area and creek does not receive any drainage of industrial or domestic effluents. However, operations pertaining to handling of molasses and fish landing at the port have the potential to influence environmental quality of the region (Figure 3.19.1).

3.20 Deogad

Deogad Harbour/Creek does not receive any known industrial or domestic effluents except unknown volume of untreated sewage from DeogadTown and wastes from Anandwadi Fishery harbour (Figure 3.20.1).

3.21 Achara

Achara Creek is a remote end of the Devgad Tahsil. It is a well-known and rich habitat for typical creek biodiversity including dense mangroves (Figure 3.21.1) in Sindhudurg district of South Konkan.There is no known effluent discharge in the Achara Creek. .

3.22 Malvan

No known industrial or domestic point release exists in the coastal waters of Malvan though few non-point discharges of domestic waste waters (about 1 MLD) enter the bay. The port operates as the fish landing centre and a passenger jetty for the tourists. The port operations generate unknown quantum of waste which can degrade the environmental quality locally since the tidal flushing in the semi enclosed bay may not be efficient.

Table 3.1: Districts and Talukas within 20 km from the coast of Maharashtra

District	Taluka	Towns (no)	Villages(no)	River basin
Thane	Palghar	05	12	Ulhas river
	Vasai	04	27	
Raigad	Urap	04	11	Savitri river
	Alibag	06	19	
	Roha	03	14	
	Murud	03	15	
	Mhasla	00	08	
	Shrivardhan	03	12	
Mumbai	Andheri	08	25	Mithi river
	Borivali	09	31	
Ratnagiri	Dapoli	03	35	Vashishti river
	Guhagar	05	38	
Sindhudurg	Devgad	02	20	
	Malvan	01	22	
	Vengurla	02	21	

Table 3.2: Status of Municipal Corporations as on March 2014

Sr. No.	Region	Quantity of Domestic Effluent MLD	Mode of Effluent Disposal
1	Mumbai	2671	Arabian Sea
2	Vashi	230	Vashi Creek
3	Thane	350	Thane Creek
4	Bhandup	280	
5	Ghatkopar	285	
6	Kopar Khairane	150	
7	Nerul	150	
8	Belapur	150	
9	Airoli	150	
4	Kalyan-Dombivali, Ulhasnagar	350	Ulhas Creek
5	Pune	734	River Mula Mutha
6	Nagpur	380	Nag & Pili River
7	Nashik	215	Untreated effluent from Ganeshwadi pumping station is used on land for irrigation & treated effluent from STP is disposed in Nasardi and the Godavari river to D/S of Nashik city
8	Amravati	50	Via Amba nalla to Pedhi river
9	Aurangabad	107	Sukhana & Kham river
10	Kolhapur	90	Partly used for irrigation & remaining into Panchganga river
11	Solapur	9	Partly on land & remaining into nallah
12	Malegaon	15	Partly used for irrigation & remaining into Mosam & Gima river
13	Jalgaon	48	Nallah
14	Dhule	28	Partly into Panzara river & partly for irrigation
15	Ahemdnagar	35	In open nallah
16	Sangli Miraj Kupwad	40	Nallah/irrigation
17	Nanded-Waghala	36	Godavari river
18	Bhiwandi-Nijampur	84	Kamavari river
19	Akola	27	Morna river
20	Mira Bhayander	77	Creek
	Total	**7041**	

Table 3.3: Industry statistics as on March 2015

Sr.No.	Regions	Sub Regions	No. of Industries									
			RED			Orange			Green			
			Large	Medium	Small	Large	Medium	Small	Large	Medium	Small	TOTAL
1	**Mumbai**	SRO Mumbai-I	39	13	36	120	21	118	2	12	253	**614**
		SRO Mumbai II	35	12	118	143	49	260	0	0	1253	**1870**
		SRO Mumbai III	29	2	63	68	3	88	0	1	162	**416**
		SRO Mumbai IV	10	3	57	131	7	25	4	4	274	**515**
2	**Thane**	SRO Thane-I	15	1	154	3	1	92	1	0	654	**921**
		SRO Thane- II	16	6	330	1	2	209	0	1	1351	**1916**
		SRO Tarapur-I	50	28	394	3	5	53	26	24	500	**1083**
		SRO Tarapur-II	22	10	290	2	6	157	6	3	640	**1136**
3	**Navi Mumbai**	SRO Navi Mumbai-I	57	28	357	31	38	366	7	4	286	**1174**
		SRO Navi Mumbai-II	34	16	339	92	57	462	28	35	775	**1838**
		SRO Taloja	67	40	242	8	14	109	2	1	248	**731**
4	**Amravati**	SRO Amravati-I	7	2	482	3	2	633	0	0	923	**2052**
		SRO Amravati-II	3	1	90	2	1	73	0	0	210	**380**
		SRO Akola	17	3	284	3	3	793	1	1	821	**1926**
5	**Kolhapur**	SRO Kolhapur	102	18	1042	19	9	537	6	11	6593	**8337**
		SRO Sangli	55	19	373	5	7	440	0	0	2587	**3486**
		SRO Ratnagiri	13	4	27	6	17	369	0	0	634	**1070**
		SRO Chiplun	41	18	240	0	10	249	0	0	133	**691**
6	**Pune**	SRO Pune-I	114	89	538	80	150	442	16	53	975	**2457**
		SRO Pune-II	291	51	531	315	66	388	159	109	1092	**3002**
		SRO Pimpri-Chinchwad	54	5	124	18	8	172	10	8	990	**1389**
		SRO Satara	149	6	478	18	28	684	10	6	1002	**2381**
		SRO Solapur	85	198	654	3	65	151	5	25	952	**2138**

7	**Kalyan**	SRO Kalyan-I	9	7	296	1	2	73	0	3	250	**641**
		SRO Kalyan-II	36	15	849	12	3	90	7	2	733	**1747**
		SRO Kalyan-III	52	27	213	24	17	312	5	1	716	**1367**
		SRO Bhiwandi	5	9	186	1	4	56	1	2	198	**462**
8	**Chandrapur**	SRO Chandrapur	75	9	230	0	0	382	1	0	160	**857**
		Dist. Gadchiroli	3	2	35	0	0	235	0	0	29	**304**
		Dist. Yavatmal	23	4	135	0	1	38	0	0	81	**282**
9	**Aurangabad**	SRO Aurangabade-I	119	177	749	20	41	535	6	40	3012	**4699**
		SRO Aurangabade-II	20	17	275	3	0	192	1	0	1119	**1627**
		SRO Nanded	22	9	388	4	0	323	0	0	912	**1658**
		SRO Latur	58	4	343	1	4	739	1	3	758	**1911**
		SRO Parbhani	18	2	107	0	0	11	0	0	1123	**1261**
10	**Nagpur**	SRO Nagpur-I	55	27	705	9	7	842	4	3	1146	**2798**
		SRO Nagpur-II	112	147	640	16	19	1314	1	9	1460	**3718**
		SRO Bhandara	18	5	549	0	1	673	0	0	190	**1436**
11	**Nashik**	SRO Nashik	133	150	1113	37	65	781	9	18	5414	**7720**
		SRO Nagar	81	53	897	0	6	284	2	22	2399	**3744**
		SRO Jalgaon	41	8	400	2	6	568	11	3	1377	**2416**
		SRO Dhule	20	19	137	5	2	373	0	0	1191	**1747**
12	**Raigad**	SRO Raigad-I	97	53	119	2	36	173	8	13	302	**803**
		SRO Raigad-II	74	7	72	11	3	21	4	4	62	**258**
		SRO Mahad	42	23	112	2	2	30	2	1	207	**421**
		Total	**2418**	**1347**	**15793**	**1224**	**788**	**14915**	**346**	**422**	**46147**	**83400**

Table 3.4: Water Pollution Prone Industries as on March 2008

Sr.No	Region	Pollution prone Industries	Effluent Quantity(MLD)	
			Generated	Treated
1	Mumbai	326	4712.44	4712.44
2	Navi Mumbai	888	59.8	59.8
3	Thane	704	15.73	15.73
4	Kalyan	950	87.29	87.29
5	Raigad	209	80.73	80.73
6	Pune	1683	129.56	129.56
7	Nashik	1569	144.11	144.11
8	Amravati	496	39.42	39.18
9	Aurangabad	697	43.85	43.43
10	Nagpur	1036	377.25	376.9
11	Kolhapur	1050	66.94	66.94
	Total	**9608**	**5757.12**	**5756.11**

Table 3.5: Status of Treatment and Disposal Facilities Provided by Industries as on March 2010

Sr.No.	Region	Industries having adequate Treatment/Disposal facilities	Industries having Partial Treatment/Disposal facilities	Industries having no Treatment/Disposal facilities
1	Mumbai	201	89	36
2	Navi Mumbai	1144	0	0
3	Thane	526	178	0
4	Kalyan	1078	1	194
5	Raigad	193	14	02
6	Pune	1070	581	32
7	Nashik	2402	89	06
8	Amravati	402	72	22
9	Aurangabad	751	48	07
10	Nagpur	687	93	35
11	Kolhapur	2675	674	04
	Total	**11129**	**1839**	**338**

Table 3.6: Status of CETP’s in Maharashtra as on 21.07.2016

Sr.No.	Name of CETP	Designed Capacity (MLD)	Outfall /Disposal
1.	Additional Ambernath CETP	7.5	Valdhuni Nalla leads to creek
2.	Chikhloli-Morivali Effluent Treatment	0.8	Valdhuni Nalla leads to creek
3.	ACMA - CETP-Co-operative Society Ltd	0.25	Valdhuni Nalla leads to creek
4.	Dombivli Better Environment System Association	16	Nalla leads to Ulhas creek
5.	Dombivli CETP (Chemical) (Phase-II)	1.5	Nalla leads to Ulhas creek
6.	Tarapur Environment Protection Society CETP	2	Marine coastal area
7.	Tarapur Industrial Manufacturing Association	25	Marine coastal area
8.	Thane-Belapur Association	27	Marine coastal area
9.	Taloja CETP Co Operative Society	22.5	Marine coastal area
10.	PRIA CETP (I) Ltd.	15	Saline water zone of Patalganga river at Near Apta
11.	MMA-CETP Co Operative Society Ltd., Mahad	7.5	Saline zone of Savtri River
12.	RIA CETP Co-op. Society Ltd.	10	Marine coastal area at Are Khurd
13.	Lote Parshuram Environment Protection Co-op Society	6	Karambavane Creek
14.	Badlapur CETP Association	8	Valdhuni Nalla leads to creek

Figure 3.1.1: Dahanu Creek and Fishing Jetty

Figure 3.2.1: A view of downstream of Tarapur Creek showing coloured water

Figure 3.3.1: The upper estuarine region of Ulhas Estuary

Figure 3.4.1: A view of Manori Creek

Figure 3.10.1: Effluents disposal in Patalganga in the area almost fresh water zone

Figure 3.11.1: Existing disposal point of RIL (IPCL), Nagothane in Amba Estuary

Figure 3.11.2: The PMP Port located at Dharamtar in Amba Estuary

Figure 3.12.1: Existing disposal point of RCF, Thal

Figure 3.13.1: Earlier effluent disposal in Kundalika Estuary

Figure 3.13.2: MIDC effulent flow in Kundalika Estuary
(2007-08)

Figure 3.13.3: The polluted segment of Kundalika Estuary (2007-08)

Figure 3.13.4: The present effluent disposal through diffuser of MIDC Roha near to Gophan Village

Figure 3.15.1: Existing disposal point in the Savitri Estuary

Figure 3.16.1: Wastewater outfall in Vashishti Estuary near the Jagbudi River

Figure 3.18.1: Fishery Harbour at Mirya Bay, Ratnagiri

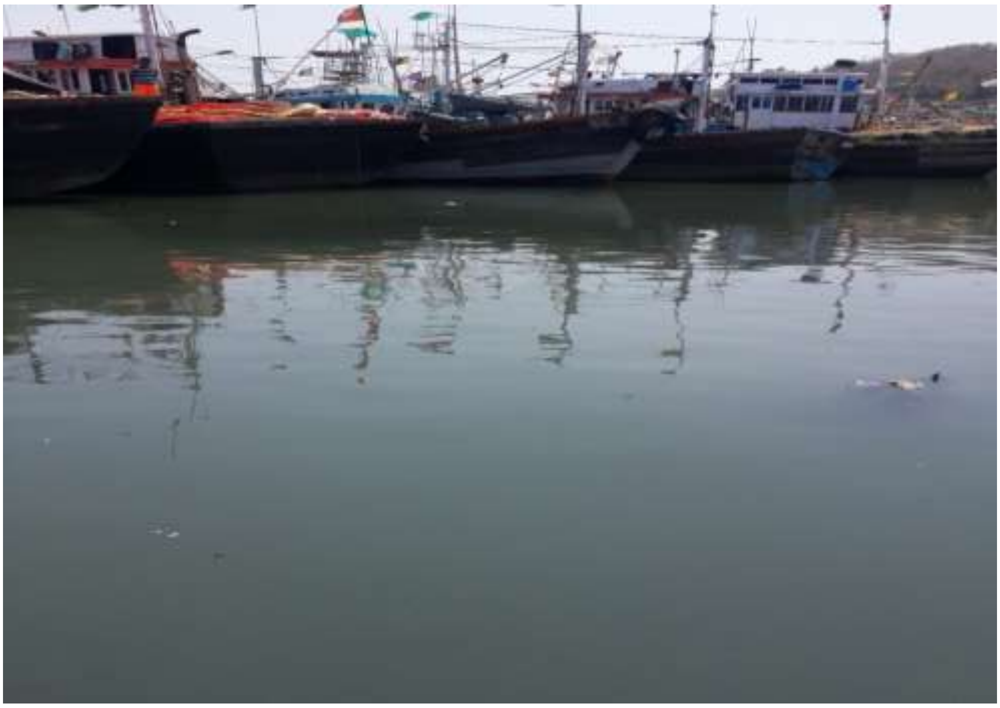


Figure 3.18.2: Fishery related contamination at Mirya Bay, Ratnagiri

Figure 3.19.1: The mouth region of Vijaydurg Creek

Figure 3.20.1: The Anandwadi Harbour at Deogad

Figure 3.21.1: Achara Creek surrounded by mangroves

4 PREVAILING ENVIRONMENT

Results of present monitoring are discussed transect wise in this chapter under the sub-heads water quality, sediment quality and flora and fauna. To facilitate discussion the data have been grouped under different zones like coastal water, lower segment, middle segment and upper segment. Stations 1 to 3 were the part of the open coastal area. The stations operated in the bay / creek / river / estuary were grouped accordingly depending on the length of the respective water body sampled. Comparison of the two season data i.e. premonsoon and postmonsoon for a given transect is also included in this chapter.

4.1 Dahanu (DH)

The coastal stations were DH1, DH2 and DH3 of which DH3 represents the nearshore. The creek segment of Dahanu was represented by 3 stations viz; DH4 (lower), DH5 (middle) and DH6 (upper). The station locations are illustrated in Figure 2.2.1.

4.1.1 Water quality

The results of water quality off Dahanu are presented in Tables 4.1.1 and 4.1.2 as well as in Figures 4.1.1 and 4.1.4 which represent temporal variations at station DH4 and DH6. The average water quality results are summarized in the table below.

Parameter	November 2015 (Postmonsoon)				May 2016 (Premonsoon)			
	Coastal (Sts DH1, DH2 & DH3)	Lower creek (St DH4)	Middle creek (St DH5)	Upper creek (St DH6)	Coastal (Sts DH1, DH2 & DH3)	Lower creek (St DH4)	Middle creek (St DH5)	Upper creek (St DH6)
WT(°C)	28.4	29.2	28.3	31.1	33.2	35.5	35.5	35.1
pH	8.0	7.7	7.9	7.7	8.1	8.0	7.8	7.8
SS (mg/l)	81	53	42	56	71	112	93	130
Turbidity(NTU)	10.9	36.5	39.6	29.8	11.6	41.1	35.6	30.4
Salinity (ppt)	35.7	35.7	35.4	36.0	36.7	36.7	34.9	34.1
DO(mg/l)	6.1	6.4	6.5	5.4	5.1	6.4	6.6	5.8
BOD(mg/l)	2.6	2.7	3.1	2.3	2.0	3.1	2.9	2.9
PO_4^{3-}-P (µmol/l)	1.4	2.0	1.8	2.4	1.2	2.3	1.9	1.4
TP (µmol/l)	2.4	3.1	4.0	3.0	2.5	3.2	3.4	3.1
NO_3^--N (µmol/l)	13.5	13.3	12.6	6.2	2.8	2.7	12.8	2.4
NO_2^--N (µmol/l)	0.5	0.8	0.7	0.7	0.6	0.4	0.8	0.4
NH_4^+-N (µmol/l)	1.2	1.9	1.7	3.9	1.5	1.3	2.3	1.5
TN (µmol/l)	34.7	27.3	34.1	33.1	42.5	43.2	46.4	35.3
PHc (µg/l)	5.0	4.9	10.4	5.4	3.0	3.8	11.0	4.3
Phenols (µg/l)	80.9	138.7	66.2	91.9	87.8	127.3	68.6	93.8

The above data revealed that the average water temperature varied from 28.3 to 35.5°C suggesting spatial and seasonal trends. The creek segments sustained higher temperature of the order of 2 to 3°C than that of coastal water. These temperatures marginally exceeded the upper threshold of 35°C for aquatic larvae of tropical biota during summer season. The pH varied in a narrow range (7.7 to 8.1) generally lower pH in estuarine segment as expected with the mixing of fresh water. The SS (42 to 130 mg/l) was in the range, generally recorded in shallow nearshore and estuarine waters and varied without definite trend. The turbidity (10.9 to 41.1 NTU) varied mostly according to the concentration of SS. Salinity varied in a narrow range (34.1 to 36.7 ppt) with the coastal water and the lower creek sustaining highest salinity of 36.7 ppt during premonsoon, while highest salinity of 36.0 ppt was recorded in upper creek during postmonsoon season. The DO levels (5.1 to 6.6 mg/l) were generally good though marginally low DO values were noticed in the creek segment suggesting some external organic inputs. The BOD (2.0 to 3.1 mg/l) was low. Levels of PO_4^{3-}-P, NO_3^--N, NO_2^--N, NH_4^+-N and PHc were of the order expected for natural coastal areas. Phenol was high (127.3 to 138.70 µg/l) in lower creek region, indicating some anthropogenic influence.

As evident from Figures 4.1.1 to 4.1.4, the water quality does not vary appreciably with the tidal state except for PO_4^{3-}-P, NO_3^--N and DO which increased gradually with the ebb during May 2016 at station DH4 probably due to some local factors.

4.1.2 Sediment quality

The results of sediment quality are presented in Tables 4.1.3 and 4.1.4. The summary of sediment quality of Dahanu is given in the table below.

Parameter		Range	
		November 2015 (Postmonsoon)	May 2016 (Premonsoon)
Metals	Al (%)	6.5-7.3	3.1-7.2
	Cr (µg/g)	127-159	118-165
	Mn (µg/g)	1076-1094	899-2153
	Fe (%)	6.6-7.3	5.1-7.1
	Co (µg/g)	29-48	29-55
	Ni (µg/g)	57-64	58-76
	Cu (µg/g)	76-95	58-110
	Zn (µg/g)	91-104	42-101
	Cd (µg/g)	0.16-0.28	0.10-0.15
	Hg (µg/g)	0.07-0.18	0.01-0.20
	Pb (µg/g)	15.7-19.4	8.6-19.0
P (µg/g)		177-803	176-1020

C_{org} (%)	0.9-1.5	0.2-1.2
PHc (µg/g)	1.2-3.2	0.6-2.4

Dry wt basis except PHc which is wet wt basis

The concentrations of trace metals namely Cr, Co, Ni, Cu and Zn varied considerably not only from station to station but also from collection to collection. These levels are however in the range reported for the basalts and soils of the central west coast of India and suggest their lithogenic origin. The concentrations of Hg – the trace metal of more concern from human health point of view, represented the baseline. The concentrations of P, C_{org} and PHc were low indicating uncontaminated status of the coastal sediments off Dahanu with respect to sewage and petroleum residues.

4.1.3 Flora and Fauna

The results of biological characteristics off Dahanu are given in Tables 4.1.5 to 4.1.22 as well as in Figures 4.1.5 to 4.1.10 which represents temporal variations at station DH4 and DH6.

a) Microbes

In Postmonsoon 2015, Dahanu Creek sustained higher count (CFU/ml)) of TVC, TC, FC and VLO during ebb period than that of flood at stations DH3 and DH4 as evident in Table 4.1.5 which suggests contamination of the region by sewage. However, higher counts of PALO, PKLO and VLO were observed at station DH3, DH4 and DH6 during Premonsoon 2016. The overall microbial counts of the lower creek (Station DH4) were higher than coastal (stations DH1, DH2 & DH3) and middle creek (station DH5) during premonsoon season as given below.

Type of bacteria	November 2015 (Postmonsoon)				May2016 (Premonsoon)			
	Coastal (Sts DH1, DH2& DH3)	Lower creek (St DH4)	Middle creek (St DH5)	Upper creek (St DH6)	Coastal (Sts DH1, DH2 & DH3)	Lower creek (St DH4)	Middle creek (St DH5)	Upper creek (St DH6)
TVC X10^3	10.5	35	1.5	1.5	33	10	34.5	14.5
TC	47	15	50	20	122	320	ND	ND
FC	42	5	45	10	60	320	ND	10
ECLO	17	ND	15	ND	37	265	ND	ND
SHLO	2	ND	5	ND	23	ND	ND	ND
SLO	ND	35	ND	ND	ND	ND	ND	ND
PKLO	2	90	20	ND	273	15	ND	ND
VLO	644	185	415	55	50	5060	165	270
VPLO	117	ND	ND	5	8	ND	ND	265
VCLO	560	185	410	50	42	5060	165	5
PALO	30	60	ND	ND	253	400	ND	ND
SFLO	18	80	15	ND	198	400	ND	25

Microbial count (CFU/g) recorded in the sediment off Dahanu are presented segment wise in the Table below.

Type of bacteria	November 2015 (Postmonsoon)				May2016 (Premonsoon)			
	Coastal (Sts DH1, DH2& DH3)	Lower creek (St DH4)	Middle creek (St DH5)	Upper creek (St DH6)	Coastal (Sts DH1, DH2 & DH3)	Lower creek (St DH4)	Middle creek (St DH5)	Upper creek (St DH6)
TVC X10^3	14	ROCKY BOTTOM	7	2	1000	300	300	400
TC	90		70	10	1000	3000	ND	ND
FC	77		60	10	866	2500	ND	ND
ECLO	37		20	10	333	2100	ND	ND
SHLO	ND		ND	ND	ND	ND	ND	ND
SLO	ND		ND	ND	ND	ND	ND	ND
PKLO	ND		30	ND	3000	600	1000	ND
VLO	67		740	50	ND	2000	2000	ND
VPLO	17		ND	ND	ND	ND	ND	ND
VCLO	50		740	50	ND	2000	2000	ND
PALO	2		ND	ND	2000	ND	ND	ND
SFLO	ND		ND	ND	1000	ND	ND	ND

The microbial counts (CFU/g) of sediments as evident in Table 4.1.6 indicate significantly high numbers of TC and FC in the sediment of the lower creek (Station DH4) and coastal water (Station DH2) during Premonsoon 2016 as compared to Station DH3 of coastal water during Postmonsoon 2015.TC, FC and ECLO, are common at all stations but counts were high during premonsoon at lower (Station DH4) and middle creek (Station DH5) regions. The creek sustained relatively higher counts of TVC, TC and FC in sediment than that of coastal area.

b) Phytoplankton

The results of phytoplankton of Dahanu creek and associated coastal areas are presented in Table 4.1.7 to 4.1.12 and average concentrations of phytopigments are given in the table below.

Zone	Chlorophyll *a* (mg/m^3)			Phaeophytin (mg/m^3)		
	Min	Max	Avg	Min	Max	Avg
November 2015 (Postmonsoon)						
Coastal water (Sts DH1 to DH3)	0.5	25.4	3.3	0.3	9.8	1.4
Lower creek (St DH4)	1.5	3.7	2.2	0.3	0.9	0.5
Middle creek (St DH5)	1.3	3.1	1.9	0.2	0.7	0.4

Upper creek (St DH6)	1.3	4.1	2.7	0.4	1.3	0.9
May 2016 (Premonsoon)						
Coastal water (Sts DH1 to DH3)	1.9	21.5	4.9	0.11	1.9	0.6
Lower creek (St DH4)	2.8	22.6	13.5	0.23	2.5	1.2
Middle creek (St DH5)	9.3	30.6	16.5	1.23	14.8	5.3
Upper creek (St DH6)	2.5	21.0	11.4	0.04	0.9	0.5

As evident from above data, the values of chlorophyll *a* (0.5-30.6 mg/m^3) and phaeophytin (0.04-14.8 mg/m^3) varied widely during the study period. Chlorophyll *a* values were high during May 2016 in all the segments when compared to November 2015 (Tables 4.1.7 and 4.1.8). Where as The higher values of chlorophyll *a* during May 2016 at the creek segment indicated an induced primary production associated with organic waste inputs. Highest values of chlorophyll *a* were recorded during ebb at station DH4 in post as well premonsoon seasons. However, such clear trend was not observed at station DH6 (Figures 4.1.5-4.1.8).

Phytoplankton cell count also varied widely as evident from the following table.

Zone	Cell density (no $x10^3$ Cells/l)			Total genera (Nos.)		
	Min	Max	Avg	Min	Max	Avg
November 2015 (Postmonsoon)						
Coastal water (Sts DH1 to DH3)	4.4	82.2	48.55	4.0	14.0	9
Lower creek (St DH4)	3.2	11.6	18.4	7.0	10.0	9.25
Middle creek (St DH5)	21.4	76.4	47.35	11.0	12.0	11.75
Upper creek (St DH6)	9.4	72.2	25.25	5.0	12.0	9.25
May 2016 (Premonsoon)						
Coastal water (Sts DH1 to DH3)	22	22340	3531.5	4	13	8.5
Lower creek (St DH4)	143	9545	3241	9	12	10
Middle creek (St DH5)	1702	9452	4788.5	7	11	9
Upper creek (St DH6)	86	7828	3229	3	8	7

The average phytoplankton cell counts were highest in coastal waters 48.55 x10^3 Cells/l in postmonsoon and in Middle creek 4788.5 x10^3 Cells/l in premonsoon whereas the generic diversity was maximum in Middle creek 11.7 no. during postmonsoon and it was maximum 10 no. in lower creek during premonsoon (Tables 4.1.9 and 4.1.10). The dominant genera during November 2015 were *Nitzschia, Pleurosigma*, *Peridinium*, *Prorocentrum* and *Skeletonema* whereas the dominance of *Chaetoceros*, *Peridinium*, *Thalassiosira*, *Nitzschia* and *Cylindrotheca* were noticed during May 2016 (Tables 4.1.11 and 4.1.12), Thus change in generic dominanace was noticed between the two phases.

c) Zooplankton

The results of zooplankton in the coastal system off Dahanu are presented in the Tables 4.1.13 to 4.1.16. The zooplankton biomass, population and total group (range and average) off Dahanu are summarized in the table given below.

Zone	Biomass (ml/100m^3)			Population (nox10^3/100m^3)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
November 2015 (Postmonsoon)									
Coastal water (Sts DH1 to DH3)	0.1	1.5	0.7	0.3	6	2.3	11	17	14
Lower creek (St DH4)	2.7	6.9	5.7	8.2	68.3	30.6	4	18	11
Middle creek (St DH5)	-	-	9.9	-	-	72.2	-	-	18
Upper creek (St DH6)	1	2.5	1.8	4.3	22.9	13.6	13	14	14
May 2016 (Premonsoon)									
Coastal water (Sts DH1 to DH3)	0.3	18.2	5.1	3.1	73.1	22.5	9	16	13
Lower creek (St DH4)	0.2	9.1	2.9	1.7	223.6	45.5	6	11	9
Middle creek (St DH5)	0.3	1.5	0.9	2.5	15.3	8.9	7	11	9
Upper creek (St DH6)	0.8	1.4	1.1	8.5	12.9	10.7	12	13	13

As evident from above data the standing stock of zooplankton in-terms of biomass (0.1-6.9 ml/100m^3; avg 4.5 ml/100m^3) and population (0.3-68.3 nox10^3/100m^3), varied widely (Tables 4.1.13 and 4.1.14) without any significant trend. The corresponding values for biomass and population during premonsoon were 0.2 to 18.2 ml/100m^3 (av 2.5 ml/100m^3) for biomass and 1.7 x 10^3 to 223.6 x10^3 no/100m^3 (avg 21.9 x10^3 no/100m^3) respectively.

No distinct trend in the group diversity of zooplankton was evident. However, the group diversity was better during November 2015 than May 2016 (Tables 4.1.15 and 4.1.16). A temporal variation of zooplankton indicates better standing stock during flood than ebb tide (Figures 4.1.9 and 4.1.10). In premonsoon, the dominant faunal groups were copepods, decapod larvae, chaetognaths, lamellibranchs, gastropods and fish larvae. Whereas during postmonsoon the most common groups were copepods, decapod larvae, gastropods, appendicularians and fish eggs and larvae thereby suggesting changes in the dominance of selected faunal groups.

d) Macrobenthos

The results of macrobenthos in the coastal system off Dahanu are presented in Tables 4.1.17 and 4.1.19. The macrobenthic biomass, population and total group (range and average) off Dahanu are summarized in the table given below.

Stations	Biomass (g/m^2; wet weight)			Population (Ind./m^2)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
November 2015 (Postmonsoon)									
Coastal water (Sts DH1 to DH3)	0.03	0.41	0.16	25	1325	353	1	2	1
Lower creek (St DH4)	Rocky bottom								
Middle creek (St DH5)	1.21	3.07	1.75	975	1525	1281	2	4	3
Upper creek (St DH6)	0.03	0.34	0.18	25	725	281	1	5	3
Overall	0.03	3.07	0.56	25	1525	567	1	5	2
May 2016 (Premonsoon)									
Coastal water (Sts DH1 to DH3)	0.01	0.37	0.18	25	350	119	1	2	1
Lower creek (St DH4)	Rocky bottom								
Middle creek (St DH5)	0.26	0.49	0.35	500	1550	863	3	5	4
Upper creek (St DH6)	0.20	2.65	0.95	125	350	200	2	4	3
Overall	0.01	2.65	0.41	25	1550	325	1	5	2

As shown above the macrobenthic standing stock in terms of biomass (0.01-3.07 g/m^2; wet wt.), population (25-1550 Ind./m^2) and total groups (1-5 no.) varied widely in the study area (Table 4.1.17). Postmonsoon sustained relatively better standing stock in terms of biomass (0.03-3.07 g/m^2; wet wt) and population (25-1525 Ind/m^2) as compared to the biomass (0.01-2.65 g/m^2; wet wt) and population (25-1550 Ind/m^2) of premonsoon. The spatial trend in population was distinct in both the seasons. In general, the upper and coastal areas sustained low standing stock of macrobenthos. The faunal group diversity showed similar range in both the seasons i.e. 1-5 and also resembled similar trend in comparison to population i.e. increased groups in the middle of the creek (Table 4.1.17). Polychaetes were the most dominant group in the study area (Tables 4.1.18 and 4.1.19).

e) Meiobenthos

Meiobenthic standing stock in Dahanu and associated coastal area is given in table 4.1.20 and the segment-wise results are given in the table below.

Stations	Biomass (µg/10cm^2)			Population (Ind./10cm^2)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
November 2015 (Postmonsoon)									
Coastal water (Sts DH1 to DH3)	3.41	96.63	48.27	7	57	24	1	4	2
Lower creek (St DH4)	Rocky bottom								
Middle creek (St DH5)	30.15	37.95	34.05	38	62	50	2	4	3
Upper creek (St DH6)	84.62	218.22	151.42	10	265	137	3	6	4
May 2016 (Premonsoon)									
Coastal water (Sts DH1 to DH3)	16.68	131.51	67.18	13	112	47	2	5	4
Lower creek (St DH4)	Rocky bottom								
Middle creek (St DH5)	9.66	20.24	15.45	25	79	52	2	4	3
Upper creek (St DH6)	238.38	921.08	579.73	187	1901	1044	7	8	7

The overall average meiofaunal abundance was higher in premonsoon (615 Ind /10cm^2) than postmonsoon (73 Ind /10cm^2). The lower region of Dahanu creek had rocky substratum, hence sediment samples could not be collected. In both the seasons, the meiofaunal abundance increased gradually from the coastal to the upper region of the creek. During postmonsoon, the meiofaunal biomass varied from 3.41 µg/10cm^2 in the coastal zone to 218.22 µg/10cm^2 in the upper creek, whereas in premonsoon, the minimum biomass was observed in the middle creek (9.66 µg/10cm^2) and the maximum biomass of 921.08 µg/10cm^2 was recorded from the upper creek. Nematodes were the most dominant faunal group in both the seasons (Tables 4.1.21 and 4.1.22)

4.2 Tarapur (TP)

The coastal waters off Tarapur are represented by stations TP1 to TP2, station TP3 being close to the shore while station TP1 is towards open sea and stations TP4 to TP6 are in the creek as shown in Figure 2.2.2. Stations TP4, TP5 and TP6 represent lower, middle and upper creek respectively.

4.2.1 Water quality

The results of water quality off Tarapur are presented in Tables 4.2.1 and 4.2.2 as well as Figures 4.2.1 and 4.2.2 which represent temporal variations at station TP5. The summary of the results for different coastal segments off Tarapur are given in the table below:

Parameter	November 2015 (Postmonsoon)				May 2016 (Premonsoon)			
	Coastal (Sts TP1 to TP3)	Lower (St TP4)	Middle (St TP5)	Upper (St TP6)	Coastal (Sts TP1 to TP3)	Lower (St TP4)	Middle (St TP5)	Upper (St TP6)
WT(°C)	29.7	29.5	29.0	29.0	32.7	29.5	31.7	29.4
pH	7.9	7.9	7.9	7.9	8.0	8.0	7.6	7.6
SS (mg/l)	28	30	24	23	40	24	31	62
Turbidity (NTU)	5.7	4.9	5.9	10.1	6.1	6.1	8.1	10.5
Salinity (ppt)	34.9	35.1	34.4	34.3	36.6	34.6	35.8	36.4
DO(mg/l)	6.0	5.3	6.5	6.4	4.5	2.3	2.4	2.1
BOD(mg/l)	2.7	2.7	4.6	3.0	9.4	18.2	9.5	12.3
PO_4^{3-}-P (µmol/l)	1.4	1.1	1.4	1.5	1.3	1.6	2.3	2.3
TP (µmol/l)	1.9	2.0	2.2	2.4	2.5	2.5	3.6	3.2
NO_3^--N (µmol/l)	12.6	11.2	12.9	9.8	16.7	15.9	12.8	14.2
NO_2^--N (µmol/l)	0.1	0.6	1.5	1.6	0.7	2.2	5.8	5.4
NH_4^+-N (µmol/l)	4.8	12.7	18.3	16.7	7.3	26.4	37.3	39.0
TN (µmol/l)	25.4	31.2	55.2	28.5	29.3	48.3	68.6	73.4
PHc (µg/l)	10.1	6.3	14.4	7.7	4.9	9.8	14.7	8.1
Phenols (µg/l)	89.4	90.1	138.4	97.8	101.3	114.0	174.5	133.8

The above data indicated that water temperature in the coastal segments off Tarapur varied on a narrow range with no spatial trends. The pH (7.6 to 8.0) was normal and stable. SS (23 to 62 mg/l) was relatively low and varied without any trend. Turbidity (3.9 to 10.9 NTU) varied in accordance with SS. The salinity varied between 34.3 and 36.6 ppt in the coastal water and Tarapur Creek indicating the marginal influence of freshwater input during the dry season. The DO (4.5 to 7.0 mg/l) recorded during November 2015 was in the range generally recorded in the nearshore coastal waters. However, during May 2016 DO concentration was depressed (2.1 to 4.5 mg/l) indicating anthropogenic discharge of organic load in the region. Cocurrently BOD, which was (2.7 to 4.6 mg/l) during November 2015, increased (9.4 to 18.2

mg/l) during May 2016. The nutrients like PO_4^{3-}-P (1.1to 2.3 µmol/l) and NO_3^--N (9.8 to 16.7 µmol/l) varied without any trends. However NO_2^--N (0.1 to 5.8 µmol/l) and NH_4^+-N (4.8 to 39.0 µmol/l) showed increasing trends towards the creek, indicating source of organic waste in excess of the assimilation capacity of the creek. PHc (4.9 to 14.7 µg/l) was in the range of nearshore coastal water, while phenols (89.4 to 174.5 µg/l) indicated elevated levels.

As shown in Figures 4.2.1 and 4.2.2 at station TP5, the salinity varied only marginally with distinct tidal variation over the temporal measurements as expected for areas with minor fresh water inflow. Unusually high concentrations of NO_2^--N and NH_4^+-N in May 2016 and NH_4^+-N in November 2015 and May 2016 and high levels of PO_4^{3-}-P in May 2016 were probably associated with the sewage entering the creek. The impact of sewage on DO in the creek was high during May 2016. However, during November concentration of DO was fairly high. It was likely that the DO was replenished through photosynthesis supported by high chlorophyll a in the creek during postmonsoon season. The DO depletion to critical levels could however occur during night with the suspension of photosynthesis.

4.2.2 Sediment quality

The summary of the sediment quality (Tables 4.2.3 and 4.2.4) is presented in the table below:

Parameter		Range	
		November 2015 (Postmonsoon)	May 2016 (Premonsoon)
Metals	Al (%)	1.4-7.1	3.4-6.9
	Cr (µg/g)	125-520	139-522
	Mn (µg/g)	821-1473	840-1464
	Fe (%)	2.4-10	6.6-10.8
	Co (µg/g)	17-70	49-102
	Ni (µg/g)	26-83	68-94
	Cu (µg/g)	19-88	69-217
	Zn (µg/g)	97-189	82-253
	Cd (µg/g)	0.18-0.75	0.11-0.36
	Hg (µg/g)	0.03-0.25	0.01-0.09
	Pb (µg/g)	4.2-15.6	13.0-28.4
P (µg/g)		156-909	879-2209
C_{org} (%)		0.1-0.8	0.2-1.3
PHc (µg/g)		0.8-4.5	0.3-4.3

Dry wt basis except PHc which is wet wt basis

It is evident from above data that the concentrations of many metals in the surficial sediment of the coastal and creek segments varied in wide ranges making assessment of trace metal accumulation a difficult task in the absence of dependable baseline. The concentrations of Cr and Zn were often high a part of which could be of anthropogenic origin. Similarly concentration of Pb and PHc was high in some instances.The concentrations of other metals, C_{org} and PHc were however in the expected ranges.

4.2.3 Flora and Fauna

The results of biological characteristics off Tarapur are presented in Tables 4.2.5 and 4.2.22 as well as Figures 4.2.3 and 4.2.6 which represent temporal variations at station TP5.

a) Microbes

In Postmonsoon 2015, Tarapur Creek sustained higher count (CFU/ml) of TVC, TC, FC,VLO and PKLO during ebb period than that of flood at stations TP3,TP4,TP5 and TP6 whereas in Premonsoon 2016,PKLO, VCLO and VLO were higher at stations TP2-TP6 as evident in Table 4.2.5 as well as summarized in the Table below**.**The occurrence of TC, FC, ECLO, SHLO, SLO, PKLO, VCLO organisms were high in coastal water (Station TP1 to TP3) during Postmonsoon. The count of TC, FC, ECLO, SHLO, VLO, PKLO in the middle creek (Station TP5) were in high number as compared to lower creek (Station TP4), upper creek (St TP6) and coastal water (Station TP1 to TP3) during Premonsoon 2016.

Type of bacteria	November2015 (Postmonsoon)				May 2016 (Premonsoon)			
	Coastal (Sts TP1 to TP3)	Lower (St TP4)	Middle (St TP5)	Upper (St TP6)	Coastal (Sts TP1 to TP3)	Lower (St TP4)	Middle (St TP5)	Upper (St TP6)
TVC $X10^3$	59	34	444	28	10	8	21	13.5
TC	438	375	155	200	75	25	175	130
FC	355	315	95	100	72	15	165	80
ECLO	300	20	200	90	37	10	185	55
SHLO	47	50	65	60	ND	ND	100	ND
SLO	ND	ND	65	25	ND	ND	ND	ND
PKLO	403	95	30	25	182	335	550	550
VLO	195	265	280	205	192	465	1100	380
VPLO	7	45	55	10	5	5	ND	ND
VCLO	195	220	225	195	187	460	1100	380
PALO	8	10	10	10	3	25	80	ND
SFLO	5	5	5	10	ND	ND	ND	ND

The microbial counts of sediments (CFU/g) as evident in Table 4.2.6 and summarised below was higher in premonsoon 2016 as compared to Postmonsoon 2015.The presence of organisms like FC, ECLO, SHLO, SLO, PKLO, VCLO was higher at upper creek (Station TP6) as compared to other region like coastal (Stations TP1 to TP3), middle creek (Station TP4) and lower creek (Station TP4). Thus, it seemed that Tarapur Creek sediment sustained higher count of TVC, TC, FC, VLO and PKLO than coastal stations.

The creek did not indicate any enrichment of bacterial counts inspite of receiving wastes from domestic, industrial and power plant.

Type of bacteria	November2015 (Postmonsoon)				May 2016 (Premonsoon)			
	Coastal (Sts TP1 to TP3)	Lower (St TP4)	Middle (St TP5)	Upper (St TP6)	Coastal (Sts TP1 to TP3)	Lower (St TP4)	Middle (St TP5)	Upper (St TP6)
TVC X10^3	43	30	66	35	135	300	5000	4000
TC	77	50	40	90	ND	ND	200	4000
FC	43	20	20	40	ND	ND	200	4000
ECLO	ND	30	30	60	ND	ND	150	2000
SHLO	ND	ND	ND	20	ND	ND	ND	ND
SLO	ND	ND	60	30	ND	ND	ND	ND
PKLO	47	80	40	120	ND	ND	300	2000
VLO	173	240	ND	480	ND	ND	900	8000
VPLO	3	ND	ND	240	ND	ND	ND	ND
VCLO	173	240	ND	480	ND	ND	900	8000
PALO	ND	ND	ND	ND	ND	ND	200	5000
SFLO	3	ND	10	90	ND	ND	ND	ND

b) Phytoplankton

Results of phytoplankton viz; pigments, cell counts and community structure off Tarapur are given in the Tables 4.2.7 to 4.2.12 and the segment-wise values (range and average) of phytopigments are given in the table below.

Zone	Chlorophyll *a* (mg/m^3)			Phaeophytin (mg/m^3)		
	Min	Max	Avg	Min	Max	Avg
November 2015 (Postmonsoon)						
Coastal water (Sts TP1 to TP3)	0.8	31.5	6	0.2	5.2	0.9
Lower creek (St TP4)	15	37.6	21.3	0.7	1.1	1.25
Middle creek (St TP5)	10.4	43.6	24.1	1.5	31.9	2.3
Upper creek (St TP6)	17.1	39.5	24.05	1	4.4	2.15
May 2016 (Premonsoon)						
Coastal water (Sts TP1 to TP3)	1.04	3.87	2.21	0.35	1.25	0.63
Lower creek (St TP4)	1.55	9.30	5.09	0.28	0.78	0.55
Middle creek (St TP5)	2.36	26.27	10.07	0.33	1.84	1.27

Upper creek (St TP6)	4.57	17.27	7.84	0.90	2.55	1.4

As evident from above data, the average values of phytopigments widely varied at different segments off Tarapur during the study period. The creek system especially the middle and upper segments sustained higher values of chlorophyll *a*. The concentration of phaeophytin was more in the middle creek and coastal waters (Tables 4.2.7 and 4.2.8). The levels of phytopigments during November 2015 indicated high values especially in the middle creek segments (43.6 mg/m^3) probably due to the loading of anthropogenic nutrients through sewage. High Chl a: phaeohytin ratio (2.2-545.0) supports the above statement. There was no clear tidal trend of chl. a concentration during the present study (Figures 4.2.3 and 4.2.4).

Phytoplankton cell count also varied widely as evident from the following table.

Zone	**Cell density (no x10³ Cells/l)**			**Total genera (Nos.)**		
	Min	**Max**	**Avg**	**Min**	**Max**	**Avg**
November 2015 (Postmonsoon)						
Coastal water (Sts TP1 to TP3)	28.6	955.0	240.2	11	23	16.25
Lower creek (St TP4)	381.4	751.8	498	15	25	18
Middle creek (St TP5)	551.2	1088.2	826.45	18	23	20.25
Upper creek (St TP6)	833.6	1374.6	991.95	18	21	19.75
May 2016 (Premonsoon)						
Coastal water (Sts TP1 to TP3)	19	103	57.5	7	13	11
Lower creek (St TP4)	49	421	235.5	12	20	15
Middle creek (St TP5)	88	2561	710.5	15	17	14.5
Upper creek (St TP6)	252	1707	619.5	7	8	7.5

The average cell counts were maximum in the upper creek (991.95 x10³ Cells/l) during November 2015 while it was maximum in the middle creek (710.5 x10³ Cells/l) during May 2016.The generic diversity was found to be maximum in the middle creek during November 2015 and in the lower creek during May 2016 (Tables 4.2.9 and 4.2.10).

The overall 36 and 40 genera were observed during postmonsoon and premonsoon respectively. The dominant genera during November 2015 were *Thalassiosira*, *Alexandrium, Coscinodiscus*, *Nitzschia*, *Prorocentrum* whereas the dominance of *Thalassiosira, Gymnodium*, *Coscinodiscus, Peridinium* and *Cyclotellain* in that order was noticed during April 2016 (Tables 4.2.11 and 4.2.12).

c) Zooplankton

The standing stock of zooplankton (Tables 4.2.13 and 4.2.14) was broadly comparable between the two study periods. Segment-wise standing stock and total faunal group is given in the table below.

The average zooplankton standing stock and group diversity in different segments were low with the creek sustaining relatively higher biomass and population in general.

Zone	Biomass ($ml/100m^3$)			Population ($nox10^3/100m^3$)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
November 2015 (Postmonsoon)									
Coastal water (Sts TP1 to TP3)	0.1	2.5	0.8	0.5	17.4	9	9	16	13
Lower creek (St TP4)	-	-	0.1	-	-	1.8	-	-	12
Middle creek (St TP5)	0.4	0.9	0.6	1.5	4.3	2.7	10	14	13
Upper creek (St TP6)	-	-	0.4	-	-	5	-	-	12
May 2016(Premonsoon)									
Coastal water (Sts TP1 to TP3)	0.3	3.7	1.5	2.7	74.9	23.3	8	14	12
Lower creek (St TP4)	0.5	1.4	1.0	6.9	8.3	7.6	10	13	12
Middle creek (St TP5)	0.4	4.2	1.8	4.9	29.5	17.3	7	11	9
Upper creek (St TP6)	-	-	1.2	-	-	16.0	-	-	8

As evident from above data the standing stock of zooplankton in-terms of biomass (0.3-4.2 $ml/100m^3$; avg 1.3 $ml/100m^3$) and population (2.7-74.9 $nox10^3/100m^3$), during premonsoon varied widely (Tables 4.2.13 and 4.2.14) without any significant trend. The corresponding values for postmonsoon were 0.1 to 2.5 $ml/100m^3$ (av 0.45 $ml/100m^3$) for biomass and 0.5 x 10^3 to 17.4 $x10^3$ $no/100m^3$ (av 4.6 $x10^3$ $no/100m^3$) respectively. At station TP5, abundance was higher during premonsoon with higher diversity as compared to postmonsoon (Figures 4.2.5 and 4.2.6).

The dominant faunal groups were copepods, decapod larvae, foraminiferans, lamellibranchs and chaetognaths during May 2016. The dominant faunal groups in November 2015 were copepods, decapod larvae, gastropods, mysids and foraminiferans (Tables 4.2.15 and 4.2.16).

d) Macrobenthos

The distribution of macrobenthic standing stock of the study area are presented in (Table 4.2.17). The segment-wise results of macrobenthos are given in the following table:

Stations	Biomass (g/m^2; wet weight)			Population (Ind./ m^2)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
November 2015 (Postmonsoon)									
Coastal water (Sts TP1 to TP3)	0.00	2.42	0.37	0	700	154	0	5	2
Lower creek (St TP4)	0.02	0.62	0.40	50	200	94	1	2	2
Middle creek (St TP5)	0.01	0.90	0.43	100	300	188	1	2	2
Upper creek (St TP6)	3.29	37.83	13.02	1075	3350	1975	3	6	4
Overall	0.00	37.83	2.25	0	3350	396	0	6	2
May 2016 (Premonsoon)									
Coastal water (Sts TP1 to TP3)	0.00	3.27	0.50	0	325	83	0	3	1
Lower creek (St TP4)	0.04	0.23	0.10	75	125	106	1	3	2
Middle creek (St TP5)	2.45	12.15	7.33	625	800	675	1	2	1
Upper creek (St TP6)	0.49	24.57	8.48	100	750	313	1	2	2
Overall	0.00	24.57	3.59	0	800	202	0	3	2

The standing stock of macrobenthos in Postmonsoon was found to be better than Premonsoon in terms of biomass and population. The biomass of macrobenthos ranged from 0-37.83 g/m^2; wet wt. in Premonsoon to 0-24.57 g/m^2; wet wt. in Postmonsoon. The standing stock of macrobenthos was relatively high at the inner creek as compared to the rest. Similarly, the faunal group diversity was more at the inner creek. Overall, the faunal group diversity was low at the study area (Table 4.2.17). The faunal groups also showed marked decrease in the Premonsoon season in comparison to Postmonsoon, similar trend was also followed by biomass and population. The macrobenthic fauna was mostly represented by polychaetes with occasional occurrence of isopoda and brachyura especially at the inner creek segments (Tables 4.2.18 and Table 4.2.19).

e) Meiobenthos

Meiobenthic standing stock in Tarapur Creek and associated coastal area is given in Table 4.2.20 and the segment-wise results are given in the table below.

Stations	Biomass ($\mu g/cm^2$)			Population (Ind./ $10cm^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
November 2015 (Postmonsoon)									
Coastal water (Sts TP1 to TP3)	17.32	695.17	153.11	20	90	47	1	2	2
Lower creek (St TP4)	997.12	4663.64	2830.38	127	801	464	4	4	4
Middle creek (St TP5)	69.72	81.06	75.39	55	92	74	3	3	3
Upper creek (St TP6)	8094.32	11933.96	10014.14	4512	5248	4880	6	7	6
May 2016(Premonsoon)									
Coastal water (Sts TP1 to TP3)	9.48	554.94	176.16	11	451	147	1	5	2
Lower creek (St TP4)	298.29	779.15	538.72	188	706	447	3	4	3
Middle creek (St TP5)	1052.36	1336.2	1194.28	109	283	196	7	8	7
Upper creek (St TP6)	718.91	3904.55	2311.73	274	2404	1340	5	6	5

Tarapur creek showed increased average meiofaunal abundance in postmonsoon (1489 ind./$10cm^2$) than premonsoon (532 ind./$10cm^2$). In both seasons, the coastal region showed lowest meiofaunal density whereas the upper creek region showed highest, although there was no clear trend in the observed density distribution. Biomass also varied greatly from 17.32 to 10014.14 $\mu g/10cm^2$ in postmonsoon and from 9.48 to 3904.55 $\mu g/10cm^2$ in premonsoon (Table 4.2.20). Nematodes were the most dominated group, contributed 87.13% in postmonsoon and 93.02% in premonsoon (Table 4.2.21 and Table 4.2.22).

4.3 Bassein Creek (BS)/Ulhas Estuary

The Bassein Creek forms lower segment of the Ulhas Estuary which in turn joins the Arabian Sea. In the present study ten estuarine stations (BS4 to BS13) and three coastal locations (BS1 to BS3) are considered. Locations like coastal (Stations BS1 to BS3), lower (Stations BS4 and BS5), middle (Stations BS6 to BS8) and upper (Stations BS9 to BS13) are segment-wise identified and discussed. These stations are shown in the map in Figure 2.2.3.

4.3.1 Water quality

The results of water quality off Bassein/Ulhas estuary are presented in Tables 4.3.1 and 4.3.2 as well as Figures 4.3.1 to 4.3.4 which represent temporal variations at station BS4 and BS9.The segment-wise averaged water quality is given in the table below:

Parameter	November 2015 (Postmonsoon)				May 2016 (Premonsoon)			
	coastal (Sts BS1 to BS3)	lower (Sts BS4 & BS5)	middle (Sts BS6,BS7, BS8)	upper (Sts BS9,BS10,BS11,BS12&BS13)	coastal (Sts BS1 to BS3)	lower (Sts BS4 & BS5)	Middle (Sts BS6,BS7, BS8)	upper (Sts BS9,BS10, BS11,BS12 &BS13)
WT(ºC)	28.0	27.3	28.6	28.7	31.9	29.1	32.5	32.6
pH	7.9	7.6	7.3	7.3	8.1	7.9	7.6	7.4
SS (mg/l)	370	341	270	224	358	202	251	192
Turbidity (NTU)	184.5	110.7	163.2	47.2	176.7	102.2	163.3	65.3
Salinity (ppt)	30.6	27.6	14.2	3.5	36.0	31.5	23.5	13.3
DO(mg/l)	4.1	2.1	0.7	0.7	5.2	3.6	0.9	0.6
BOD(mg/l)	2.0	6.5	33.0	46.2	1.2	2.2	40.7	73.2
PO_4^{3-}-P(µmol/l)	7.1	4.9	8.7	4.5	2.7	6.0	7.4	13.1
TP (µmol/l)	12.1	11.1	12.3	7.2	3.9	8.9	12.1	14.7
NO_3^-N(µmol/l)	32.8	57.2	35.1	25.5	6.3	30.9	23.3	19.2
NO_2^--N(µmol/l)	2.5	2.5	11.0	2.0	0.4	2.0	10.5	4.8
NH_4^+-N (µmol/l)	5.2	5.6	23.7	73.1	2.0	1.6	5.5	28.7
TN (µmol/l)	57.3	89.0	101.9	145.9	55.4	55.0	85.1	175.5
PHc (µg/l)	4.6	12.2	18.8	38.7	3.8	3.2	3.2	11.6
Phenols (µg/l)	84.4	89.2	72.8	113.1	87.5	106.7	101.9	131.9

The water temperature (27.3-32.6ºC) varied on a wide range but spatial variations were marginal. The pH (7.3 to 8.1) varied considerably with invariably low values in the creek/estuarine segment especially the upper estuary. A decrease in pH from coastal to the upper estuary was evident. The relative low pH of the estuary could be due to high microbial activity supported by organic wastes entering the system. The SS (192 to 370 mg/l) varied widely with highervalues invariably through out the estuary and coastal waters due to greater tidal influence and silty substratum. Turbidity was also high (47.2-184.5 NTU). Salinity varied widely (3.5 to 36.0 ppt) as expected for a typical estuarine system with fresh water inflow. Salinity indicated spatial trends with low salinity at the upper estuary. The average DO varied from 0.6

to 5.2mg/l with a decrease in the inland direction (often <0.2 mg/l) due to its consumption for oxidation of anthropogenic organic matter. Substantially high BOD (33.0-73.2 mg/l) in the middle and upper estuarine region indicates the severity of the organic pollution load in the estuary. PO_4^{3-}-P varied from 2.7-13.1µmol/l indicating elevated levels in the estuary especially during May 2016. However, with ingress of freshwater during monsoon, the load is pushed towards the down stream, giving rise to elevated concentration in downstream region. NO_3^--N was higher in the lower estuary and coastal waters as compared to the rest of the estuary. Build up of NO_2^--N in the middle estury was recorded during both the seasons. NH_4^+-N was high through out the estuary with substial build up in the middle and upper estuarine regions. These results suggested stress associated with release of sewage and industrial waste in the inner creek. The PHc levels suggested some petroleum contamination.

The Ulhas estuary receives a variety of wastes, which has impacted its water quality significantly (Figures 4.3.1 to 4.3.4). From the results of temporal measurements presented in Figures 4.3.1 and 4.3.4 it appeared that the water quality at the mouth (Station BS4) had improved as compared to the inner creek though the water quality parameters varied temporally due to the changing volume of the estuary with the incursion of seawater.

4.3.2 Sediment quality

The results for sediment quality of Bassein Creek/Ulhas Estuary are presented in Tables 4.3.3 and 4.3.4.

The concentrations of metals and P at station BS4 are compared with the average concentration of the respective metal in the catchment soil in the following table:

Constituent	Catchment soil			Station BS4
	Minimum	Maximum	Average	
Al (%)	8.2	14.2	10.8	6.8
Cr (µg/g)	82	567	263	291
Mn (µg/g)	896	4729	2047	905
Fe (%)	11.5	29.5	18.6	8.1
Co (µg/g)	20	72	50	68
Ni (µg/g)	57	1181	212	90
Cu (µg/g)	76	365	208	133
Zn (µg/g)	44	168	115	177
Cd (µg/g)	0.03	0.53	0.2	0.23
Hg (µg/g)	<0.005	0.14	0.03	0.04
Pb (µg/g)	2.1	97.5	21.7	10.1
P (µg/g)	120	1830	726	1316

As evident from above, the concentrations of all the constituents were within the range of the catchment soil but often deviated from the average. Thus the sediment at station BS4 appeared to be depleted in Al, Mn, Fe, Ni and Cu while the remaining metals indicated higher levels as compared to the average concentration in the catchment soil. The texture and average concentrations of metals and P in sediment of Ulhas Estuary are compared in the following table:

Parameter		Range	
		Novembe 2015 (Postmonsoon)	May 2016 (Premonsoon)
Texture (%)	Sand	0.6-98.4	3.7-59.6
	Silt	1.1-81.6	25.8-93.9
	Clay	0.4-53.1	2.4-48.8
Metals	Al (%)	5.4-8.2	6.3-7.7
	Cr (µg/g)	148-586	197-691
	Mn(µg/g)	904-2211	822-1727
	Fe (%)	7.3-10.0	6.5-8.7
	Co (µg/g)	34-96	50-83
	Ni (µg/g)	60-116	76-128
	Cu (µg/g)	44-210	97-231
	Zn (µg/g)	105-706	95-777
	Cd (µg/g)	0.15-0.90	0.17-0.52
	Hg (µg/g)	0.04-0.91	0.08-0.72
	Pb (µg/g)	8.1-76.5	9.0-68.6
P (µg/g)		488-1793	684-2224
C_{org} (%)		0.0-3.0	0.4-3.7
PHc (µg/g)		0.4-8.8	0.3-7.5

Dry wt basis except PHc which is wet wt basis

The sediment texture was dominantly sandy-silt in the study area. Because of high lithogenic Cr in the region it was difficult to conclude whether high concentrations occasionally observed in the estuary (and coastal segments) were natural or had anthropogenic component. Mn indicated its lithogenic concentration and varied in the range 822 to 2211 µg/g in the sediment transported to the estuary. The concentration of Co in sediment (34-96 µg/g) was markedly higher than the average concentrations in the catchment soil (50 µg/g). Ni and Cu concentrations in sediment were within the range of catchment soil values. However concentration of Zn was high in the sediment of upstream region. Concentration of Hg was also high especially in the upstream region, which may be the left-over signature of mercury released though the effluent of the chlor-alkali idustry in the past and trapped in the sediment. The concentration of P in sediment though variable the average trend suggested a baseline concentration. C_{org} was low (0.0- to 3.3%) suggesting minor enrichment in the upstream region. However, low level contamination of PHc (0.3 to 8.8 µg/g) in the sediment was noticed.

In general sediment quality did not indicate any noticeable contamination by anthropogenic fluxes excepting some elevations in Cr, Zn, Hg and PHc.High concentrations of Hg (3.38-38.45 µg/g) have been reported in the innermost zone of the Ulhas estuary based on periodic sampling conducted during May 1996 and June 1999 (Ram et al., 2003). Chlor alkali industries were considered to be the source of this anthropogenic Hg. Present results however indicated significantly low concentrations of Hg in sediments of the estuary. This could be because of the scrap down/changeover of chlor-alkali industries from Hg-cell process to diaphragm process that eliminated the use of Hg. Hence, concentrations of Hg are expected to decrease with the passage of time.

4.3.3 Flora and fauna

The results of biological characteristics of Ulhas estuary and associated coastal area are presented in Tables 4.3.5 to 4.3.24 as well as Figures 4.3.5 to 4.3.12 which represents temporal variations at station BS4 and BS9.

a) Microbes

In Postmonsoon 2015, Ulhas estuary sustained higher counts (CFU/ml) of TVC, TC, and FC during the period of the study as evident in Table 4.3.5 and 4.3.7. Which suggests contamination of the region by sewage. However, higher counts of SLO, PKLO, PALO and SFLO were observed at the upper estuary. In Premonsoon 2016, higher counts of TVC were found throughout the study area while presence of fecal pollution indicator bacteria FC and other pathogenic organisms like VLO and SFLO were recorded especially at the upper estuary. The overall microbial counts of the creek at upper estuary (Station BS9 and BS10) were higher than coastal (stations BS1-BS3), lower (BS4 and BS5) and middle creek (station BS6, BS7 & BS8) during postmonsoon season whereas in premonsoon 2016, microbial counts of coastal and lower estuary. (Station BS1-BS5) were higher than middle and upper estuary (stations BS6-BS10) as given below.

Type of bacteria	November 2015 (Postmonsoon)				May 2016 (Premonsoon)			
	coastal (Sts BS1 to BS3)	lower (Sts BS4 & BS5)	middle (Sts BS6, BS7, BS8)	upper (sts BS9, BS10)	coastal (Sts BS1 to BS3)	lower (Sts BS4 & BS5)	middle (Sts BS6, BS7, BS8)	upper (sts BS9, BS10)
TVC X10^3	10.33	20	137	138	17	10	164	189
TC	125	78	1180	1025	6048	3234	96	782
FC	90	58	1163	750	3999	1350	53	537
ECLO	40	50	1033	700	3200	1845	27	464
SHLO	3	53	34	50	618	341	50	574
SLO	7	ND	34	350	ND	ND	1	NG
PKLO	47	45	1733	285	6	60	145	4
VLO	28	35	800	730	831	816	215	422
VPLO	8	35	117	NG	148	65	122	57
VCLO	20	5	683	730	800	751	93	365
PALO	ND	ND	400	270	393	359	NG	NG
SFLO	30	33	117	325	ND	ND	9	84

The microbial counts in sediments (CFU/g) followed a similar trend as that of samples (Table 4.3.6. The presence of TVC, TC, FC, ECLO, PKLO, VCLO, PALO were high at coastal (Station BS1 to BS3) and lower estuary (Station BS4 & BS5) as compared to the rest of the estuary. The pathogenic bacteria like SHLO and VPLO in sediments were high at the upper estuary (Station BS10) during post monsoon where as at the middle estuary (Station BS6, BS7, BS8) during Premonsoon (Tables 4.3.7 and 4.3.8) as detailed below:

Type of bacteria	November 2015 (Postmonsoon)				May 2016 (Premonsoon)			
	coastal (Sts BS1 to BS3)	lower (Sts BS4 & BS5)	middle (Sts BS6, BS7, BS8)	upper (sts BS9, BS10)	coastal (Sts BS1 to BS3)	lower (Sts BS4 & BS5)	middle (Sts BS6, BS7, BS8)	upper (sts BS9, BS10)
TVC X10^3	77	85	161	75	2013	70	110	208
TC	67	120	2666	3750	ND	1500	109	78
FC	33	80	2066	3150	ND	1500	59	60
ECLO	33	20	1933	1050	ND	1500	37	116
SHLO	33	20	NG	NG	ND	ND	34	61
SLO	33	30	667	50	ND	ND	7	NG
PKLO	ND	95	667	800	ND	ND	153	62
VLO	ND	145	NG	NG	ND	10000	206	80
VPLO	33	115	NG	NG	2667	500	10	46
VCLO	67	25	NG	50	4333	6780	196	35
PALO	ND	ND	600	200	7000	7250	NG	NG
SFLO	ND	ND	2333	1500	ND	ND	17	12

b) Phytoplankton

The data on phytopigments, cell counts and total genera of the Ulhas estuary are presented in the Tables 4.3.9 to 4.3.14 and summarized in the following table:

Zone	Chlorophyll *a* (mg/m^3)			Phaeophytin (mg/m^3)		
	Min	Max	Avg	Min	Max	Avg
November 2015 (Postmonsoon)						
Coastal (Sts. BS1 to BS3)	1.2	4.9	2.55	1	11	3.3
Lower (Sts. BS4 & BS5)	0.8	10.1	3.4	1.1	9.9	4.35
Middle (Sts.BS6 to BS8	16.6	33.7	26.15	2.8	16.2	7.2
Upper (Sts. BS9 to BS13)	4.6	42.4	31.7	3.4	23.3	9.8
May 2016 (Premonsoon)						
Coastal (Sts. BS1 to BS3)	1.01	5.8	3.14	0.08	1.73	0.85
Lower (Sts. BS4 & BS5)	1.73	5.5	3.78	0.10	5.93	2.55
Middle (Sts.BS6 to BS8)	5.95	36.7	22.88	0.56	4.28	2.21
Upper (Sts. BS9 to BS13)	2.94	36.3	26.9	1.19	13.28	4.67

The results clearly revealed an increasing trend of chlorophyll *a* from the coast to the upper estuary with very high values in the estuary due to high primary productivity fuelled by nutrient-rich waters during November 2015. Middle and upper estuary represented high chlorophyll values during both the periods (November 2015 and May 2016). However, Chl. *a* to phae ratio was < 1 in lower estuarine zones during postmonsoon season, indicating deterioriation of the estuarine water quality (Table 4.3.9 Figure 4.3.5 and 4.3.6). The results indicate that the organic load accumulated in the upper estuary gets pushed toward the coatal region during postmonsoon, hence affecting the coastal environment. The results of DO and ammonia also showed similar observations (section 4.3.1). However, during premonsoon season the ratio was mosltly 1, indicating that the organic load released in the upper and midle estuarine region circulated largely in the upper region due to poor flushing during dry season (Table 4.3.10 and Figures 4.3.7 and 4.3.8). Phytoplankton cell count also varied widely as evident from the following table.

Zone	Cell density (no. X10³ Cells/l)			Total genera (Nos.)		
	Min	Max	Avg	Min	Max	Avg
November 2015 (Postmonsoon)						
Coastal (Sts. BS1 to BS3)	32.4	228.4	104.7	7	14	11
Lower (Sts. BS4 & BS5)	14.2	940.2	171.5	6	15	11
Middle (Sts.BS6 to BS8)	80	4218.0	1825.5	3	14	10
Upper (Sts. BS9, to BS13)	1086.8	49529.2	9868.6	10	24	18
May 2016 (Premonsoon)						
Coastal (Sts. BS1 to BS3)	19	377	127.5	6	18	13
Lower (Sts. BS4 & BS5)	49	162	79	7	15	10
Middle (Sts.BS6 to BS8)	145	3851	1906	8	17	12
Upper (Sts. BS9 to BS13)	1650	45996	7813	10	17	13

Phytoplankton Avg. cell count (Tables 4.3.11and 4.3.12) varied widely between 104.7 x 10^3 and 9868.6 x 10^3 Cells/l with higher counts confined to post monsoon . Phytoplankton population recorded at the upper estuary revealed prevalence of eutrophic conditions. *Thalassiosira* was the most dominant genera followed by *Merimopedia, Skeletonema*, *Scenedesmus*and Chlorella in November 2015 whereas *Thalassiosira* was the most dominant genera followed by *Merimopedia, Cylindrotheca*, *Skeletonema* and *Chaetoceros* in May 2016 (Tables 4.3.13 and 4.3.14), thus suggesting changes in the seasonal dominance of phytoplankton genera.

c) Zooplankton

The results of zooplankton standing stock and community structure of the coastal and the estuarine system are presented in the Tables 4.3.15 and 4.3.16 and summarized in the table given below.

Zone	Biomass ($ml/100m^3$)			Population ($nox10^3/100m^3$)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
November 2015 (Postmonsoon)									
Coastal (Sts BS1 to BS3)	0.3	3.8	1.5	1.8	22.1	8.6	1	15	11
Lower creek (Sts BS4 & BS5)	0.5	9.3	3.1	3.0	85.0	22.6	8	13	11
Middle (Sts BS6 to BS8)	0.7	1.8	1.2	3.5	21.2	10.7	3	6	5
Upper (BS9 to BS13)	0.3	6.7	1.8	5.8	258.9	36.1	2	10	4
May 2016 (Premonsoon)									
Coastal (Sts BS1 to BS3)	0.5	7.6	3.1	6.6	68.7	42.8	9	12	10
Lower (Sts BS4 & BS5)	1.3	4.2	2.5	15.5	131.5	45.1	7	13	9
Middle (St BS6 to BS8)	0.2	9	3.8	4.4	45.6	30.1	1	10	6
Upper (BS9 to BS13)	0.5	12.3	3.7	1.4	235.5	50.1	1	5	3

Average biomass and population was comparably higher during premonsoon than postmonsoon period. The lower segment of the estuary revealed higher biomass as compared to the other segments during postmonsoon, whereas middle segment sustained highest biomass during premonsoon season. The population was highest at the upper segment during post as well as Premonsoon seasons. The faunal groups showed a decreasing trend from the coastal to the upper estuary which sustained the lowest faunal group diversity (Tables 4.3.17 and 4.3.18, Figures 4.3.9, 4.3.10, 4.3.11 and 4.3.12).

Due to higher environmental stress associated with disposal of wastes the zooplankton standing stock and faunal group diversity were low in the inner estuary though primary production was very high. The community structure of zooplankton was dominated by copepods, decapod larvae, gastropods, chaetognaths, cladocerans and lamellibranchs during November 2015 and May 2016.

d) Macrobenthos

The biomass, population and total group of macrobenthos (range and average) off Bassein/Ulhas estuarine system (Table 4.3.19) are summarized in the table given below.

Stations	Biomass (g/m^2; wet weight)			Population (Ind./ m^2)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
November 2015 (Postmonsoon)									
Coastal (Sts BS1 to BS3)	0.00	0.30	0.10	0	375	72	0	4	2
Lower (Sts BS4 & BS5)	0.03	1.56	0.59	0	1150	335	0	2	1
Middle (Sts BS6 to BS8)	0.05	4.40	1.49	100	3800	1838	1	3	2
Upper (Sts BS9 to BS13)	0.00	64.10	4.64	0	14200	1218	0	2	1
Overall	0.00	64.10	2.42	0	14200	1035	0	4	1
May 2016 (Premonsoon)									
Coastal (Sts BS1 to BS3)	0.00	7.50	1.91	0	625	271	0	7	3
Lower (Sts BS4 & BS5)	0.00	0.40	0.19	0	775	241	0	3	2
Middle (Sts BS6 to BS8)	0.24	401.00	1.20	1075	7425	3857	1	5	3
Upper (Sts BS9 to BS13)	0.00	24.10	3.02	0	6900	1210	0	2	1
Overall	0.00	401.00	2.07	0	7425	1576	0	7	2

The biomass of macrobenthos ranged from 0-401.00 g/m^2; wet wt. in Premonsoon and 0-64.10 g/m^2; wet wt. in Postmonsoon. Whereas population ranged from 0-7425 ind./m2 in Premonsoon and 0-14200 ind./m2 in Postmonsoon . The average standing stock of macrobenthos varied widely with significant reduction from the upper estuary to the open coast. This could be due to unstable sandy/silty bottom conditions of the lower estuary and the open coastal zone, which normally support poor assemblage of macrobenthic fauna. The faunal group diversity was low without any specific trend. Although the upper estuary revealed an environmental stress due to waste disposals, the standing stock of macrobenthos was high at this tolerant/opportunistic segment strongly suggesting favourable conditions for selected benthic community to adapt and proliferate under such modified conditions.

The community structure of benthos was mostly consisted of Polychaeta, Oligochaeta and Pelecypoda. Polychaetes and gastropods were dominant especially at the inner estuary (Table 4.3.20 and 4.3.21).

e) Meiobenthos

Meiobenthic standing stock in the Bassein/Ulhas estuary and the associated coastal area is given in Table 4.3.22 to 4.3.24 and the segment-wise results are given in the table below.

Stations	Biomass ($\mu g/10cm^2$)			Population (Ind./ 10 cm^2)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
November 2015 (Postmonsoon)									
Coastal (Sts BS1 to BS3)	70	213	123	40	170	104	3	4	4
Lower (Sts BS4 to BS5)	0	411	235	0	277	153	0	7	4
Middle (Sts BS6 to BS8)	0	762	381	0	57	23	0	4	2
Upper (Sts BS9 to BS13)	64	321	140	93	491	205	5	8	6
May 2016 (Premonsoon)									
Coastal (Sts BS1 to BS3)	97	305	213	18	306	86	1	4	2
Lower (Sts BS4 to BS5)	8	8667	2464	3	7313	1987	1	7	4
Middle (Sts BS6 to BS8)	3	10	7	4	27	15	1	1	1
Upper (Sts BS9 to BS13)	8	556	178	8	212	81	2	9	4

The average meiobenthic faunal density was higher in premonsoon (574 ind./10cm^2) than postmonsoon (163 ind./10cm^2). The overall faunal density in Bassein/Ulhas estuary was low throughout. However, in premonsoon the lower estuary recorded significantly high density compared to the other segments, due to the contribution of station BS5, which is responsible for the overall higher average density in this season. Biomass variations were wide. Lower estuary (st. BS5) recorded the highest average biomass of 4780 $\mu g/10cm^2$ in premonsoon (Table 4.3.22). In postmonsoon foraminiferans were the most abundant, whereas nematodes dominated the meiofauna community in premonsoon (Table 4.3.23 and 4.3.24).

4.4 Manori (BYMa)

The creek locations off Manori are represented by BYMa4 to BYMa6. The stations BYMa4 and BYMa5 represented lower creek while station BYMa6 denoted upper creek. These stations are shown in a consolidated station location map of Mumbai and around (Figure 2.2.4).

4.4.1 Water quality

The results of water quality off Manori are presented in Tables 4.4.1 and 4.4.2 as well as Figures 4.4.1 and 4.4.2 which represent temporal variations at station BYMa4 summarized below.

Parameters	Zone			
	December2015 (Postmonsoon)		May 2016 (Premonsoon)	
	Lower Creek (Sts BYMa4 & BYMa5)	Upper Creek (St BYMa6)	Lower Creek (Sts BYMa4 & BYMa5)	Upper Creek (St BYMa6)
WT(^oC)	27.7	27.8	28.4	27.4
pH	7.9	7.8	7.7	7.8
SS (mg/l)	76	72	101	84
Turbidity (NTU)	21.1	21.7	21.4	20.0
Salinity (ppt)	33.0	32.2	32.8	32.2
DO(mg/l)	4.0	2.2	5.2	4.3
BOD(mg/l)	2.3	1.3	3.2	1.6
PO_4^{3-}-P (µmol/l)	5.3	12.2	19.3	23.4
TP (µmol/l)	6.5	13.4	29.2	36.7
NO_3^--N (µmol/l)	15.2	10.5	20.4	34.0
NO_2^--N (µmol/l)	3.6	5.2	1.7	4.4
NH_4^+-N (µmol/l)	14.7	39.7	38.6	41.7
TN (µmol/l)	43.3	65.4	44.8	61.6
PHc (µg/l)	2.9	5.5	2.2	1.6
Phenols (µg/l)	75.0	75.8	79.4	43.2

The variations in water temperature were within the normal ranges and the waters were thermally well-mixed. The pH varied from 7.7 to 7.9 with the majority of values falling in the range for seawater. The SS (72 to 101 mg/l) which were largely of natural origin rendered the waters turbid (turbidity 20.0 to 21.7 NTU) and muddy. Though DO was under saturated and low values were recorded in many instances, the mean DO was indicative of fairly good oxidizing conditions excepting the upper creek region during December 2015.

Marked enrichment in the levels of PO_4^{3-}-P, NO_2^--N and NH_4^+-N was evident in the Manori Creek. Abnormal high concentrations of PO_4^{3-}-P, NO_2^--N and NH_4^+-N often recorded in the creek are typical of marine areas under environmental stress due to release of sewage. PHc and phenols were in the range often recorded in coastal waters suggesting absence of noticeable petroleum and phenol contamination.

Temporal variations (Figures 4.4.1 and 4.4.2) at station BYMa4 indicated wide fluctuations in salinity pH, DO, PO_4^{3-}-P, NO_3^--N, NO_2^--N and NH_4^+-N. High DO particularly at the surface during flood was probably associated with the incursion of oxygen-rich coastal seawater. Increase in PO_4^{3-}-P and high concentrations of NH_4^+-N particularly during ebb was in the line expected for tidal creeks receiving sewage in excess of their capacity to effectively assimilate organic matter. The influence of seawater intrusion in the creek during flood tide is clearly seen in the profiles of temporal measurements. Thus, salinity, DO and NO_2^--N increased while PO_4^{3-}-P and NH_4^+-N markedly decreased with the flood tide.

4.4.2 Sediment quality

The sediment quality of the Manori Creek presented in Tables 4.4.3 and 4.4.4 is summarized in the following table.

Parameter		Range	
		December2015 (Postmonsoon)	April 2016 (Premonsoon)
Texture (%)	Sand	5.5-39.5	13.8-21
	Silt	40.2-79.5	34.6-68.4
	Clay	15-20.3	17.9-46.9
Metals	Al (%)	8.0-8.1	6.3-7.0
	Cr (μg/g)	182-205	142-168
	Mn (μg/g)	760-1115	592-981
	Fe (%)	7.5-8.5	5.9-7.4
	Co (μg/g)	33-42	26-37
	Ni (μg/g)	54-60	45-50
	Cu (μg/g)	103-127	85-99
	Zn (μg/g)	130-158	114-129
	Cd (μg/g)	1.1-2.8	1.1-2.1
	Hg (μg/g)	0.24-0.34	0.20-0.30
	Pb (μg/g)	18.5-28.8	18.2-25.4
P (μg/g)		234-314	239-320
C_{org} (%)		1.9-2.1	1.5-1.7
PHc (μg/g)		3.9-12.2	3.4-9.5

Dry wt basis except PHc which is wet wt basis

The sediment texture varied from silty sand to clayey silt. Though the region receives high volume of domestic wastewater, there was no accumulation of C_{org} and phosphorus in sediments of the creek. The levels of PHc (3.4-12.2μg/g) in sediment were higher than reported for uncontaminated sediments indicating some anthropogenic source of PHc in the region. The concentration of metals was comparable between the two periods of study indicating absence of significant enrichment excepting minor elevations in Hg compared to the expected baseline (0.2 μg/g, dry wt).

4.4.3 Flora and Fauna

The results of biological characteristics (December 2015 and May 2016) off Manori are presented in Tables 4.4.5 to 4.4.22 as well as Figures 4.4.3 to 4.4.6 which represent temporal variations at station BYMa4.

a) Microbes

In Postmonsoon 2015, Manori Creek sustained higher count (CFU/ml) of TVC, TC, FC and VLO at station BYMa 6 as compared to other stations. In Premonsoon 2016, higher counts of TVC and VLO occurred at station BYMa4 and higher counts of TC, FC and VLO were confined to stations BYMa5 and BYMa6 as evident from Table 4.4.5.The overall microbial counts at upper creek (station BYMa6) were higher as compared to lower creek (station BYMa4 and BYMa5) during Postmonsoon 2015 whereas in Premonsoon 2016, lower creek (station BYMa4 and BYMa5) had higher counts as compared to upper creek as given in Table below.

Type of bacteria	Zone			
	December 2015 (Postmonsoon)		May 2016 (Premonsoon)	
	Lower Creek (Sts BYMa4 & BYMa5)	Upper Creek (St BYMa6)	Lower Creek (Sts BYMa4 & BYMa5)	Upper Creek (St BYMa6)
TVC X10^3	13.75	30	15.5	2.5
TC	138	300	25	20
FC	15	350	20	20
ECLO	10	240	20	20
SHLO	ND	ND	15	ND
SLO	ND	ND	ND	ND
PKLO	15	ND	35	10
VLO	25	50	4810	90
VPLO	10	ND	30	60
VCLO	15	50	315	30
PALO	ND	40	25	5
SFLO	ND	ND	15	ND

The microbial counts (CFU/g) of sediments as evident in Table 4.4.6 was higher in Premonsoon 2016 as compared to Postmonsoon 2015. However counts of TC, FC, PKLO, and VLO were much higher in premonsoon 2016 in lower creek (Station BYMa4 & BYMa5) as compared to other stations as given below.

Type of bacteria	Zone			
	December2015 (Postmonsoon)		May 2016 (Premonsoon)	
	Lower Creek (Sts BYMa4 & BYMa5)	Upper Creek (St BYMa6)	Lower Creek (Sts BYMa4 & BYMa5)	Upper Creek (St BYMa6)
TVC X10^3	780	200 x 103	10	2 x 103
TC	ND	80	3550	ND
FC	ND	50	3050	ND
ECLO	ND	40	3250	ND
SHLO	ND	ND	ND	ND
SLO	ND	ND	ND	ND
PKLO	350	ND	1480	1000

VLO	2000	2400	7650	4000
VPLO	500	1000	2150	NG
VCLO	2150	1400	5500	4000
PALO	ND	ND	ND	ND
SFLO	ND	ND	ND	ND

b) Phytoplankton

The results of phytoplankton in terms of phytopigments are presented in the Tables 4.4.7 to 4.4.12 and the results of chlorophyll *a* and phaeophytin (range and average) are summarized in the table given below.

Zone	Chlorophyll *a* (mg/m^3)			Phaeophytin (mg/m^3)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)						
Lower creek (Sts BYMa4 & BYMa5)	2.0	11.6	5.15	0.3	3.9	1.9
Upper creek (St BYMa6)	12.4	32.2	22.3	2.3	4.4	3.5
April 2016 (Premonsoon)						
Lower creek (Sts BYMa4 & BYMa5)	13.88	17.08	16.58	2.91	7.35	9.06
Upper creek (St BYMa6)	11.49	41.62	19.12	2.26	8.69	5.17

The average concentrations of phytopigments viz; chlorophyll *a* (5.15-22.3 mg/m^3) and phaeophytin (1.9-9.06 mg/m^3) varied widely in the creek system. The upper creek sustained the highest chlorophyll *a* (22.3 mg/m^3) and phaeophytin (3.5 mg/m^3) during December 2015 due to induced primary production associated with organic waste disposals in the creek (Tables 4.4.7 and 4.4.8). Concentration of Chl. *a* showed increasing trend during ebb of postmonsoon season, but there was no trend during premonsoon season (Figures 4.4.3 and 4.4.4).

Phytoplankton cell count also varied as evident from the following table.

Zone	Cell counts (no x 10^3/l)			Total genera (no)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)						
Lower creek (Sts BYMa4 & BYMa5)	44.4	67.0	55.3	7	14	11.15
Upper creek (St BYMa6)	56.6	102.0	79.3	9	11	10.0
April 2016 (Premonsoon)						
Lower creek (Sts BYMa4 & BYMa5)	553	2815	1601.5	13	20	16.5
Upper creek (St BYMa6)	315	900	598	11	15	13.5

The average cell counts were maximum in Upper creek (79.3 x10^3 Cells/l) during December 2015 while it was maximum in lower creek (1601.5 x10^3 Cells/l) during April 2016 (Tables 4.4.9 and 4.4.10).The generic diversity was maximum in the lower creek during both the seasons.

The dominant genera during December 2015 were in following order; *Thalassiosira*, *Cylindrotheca, Navicula, Chaetoceros* and *Coscinodiscus* whereas in April 2016, *Chaetoceros*, *Thalassiosira*, *Cryptomonas*, *Skeletonema* and *Pseudo-nitzschia* were predominant (Tables 4.4.11 and 4.4.12). Stress related change in generic dominanace is evident.

c) Zooplankton

The results of zooplankton off Manori Creek are given in the (Tables 4.4.13 and 4.4.14) and summarized in the following table.

Zone	Biomass (ml/100m^3)			Population (nox10^3/100m^3)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Lower creek (Sts BYMa4 & ByMa5)	1.0	9.4	3.3	1.0	102	48.2	11	15	12
Upper creek (Sts BYMa6)	0.4	0.8	0.6	3.4	8.3	5.8	15	16	16
April 2016 (Premonsoon)									
Lower creek (Sts BYMa4 & ByMa5)	0.4	94.1	20.6	1.5	508	102.5	6	12	8
Upper creek (Sts BYMa6)	2.6	3.1	2.9	38.3	60	49.3	10	12	11

At BYMa4, the population was higher during premonsoon as compared to post monsoon with high biomass after flood tide (Figures 4.4.5 and 4.4.6). The average standing stock of zooplankton viz. biomass (0.6 - 20.6 ml/100m^3) and population (5.8-102.5 nox10^3/100m^3) varied widely in the creek during two consecutive seasons respectively .The group diversity increased from the lower to the upper creek during the study period with copepods, decapod larvae and Lamellibranchs dominanting the population during December 2015. The major zooplankton groups were copepods, gastropods, lamellibranchs; medusa and foraminiferans during April 2016 (Tables 4.4.15 and 4.4.16).

d) Macrobenthos

The results of macrobenthos are given in the Table 4.4.17 are summarized in the table given below.

Stations	Biomass (g/m^2; wet weight)			Population (Ind./m^2)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Lower Creek (Sts BYMa4 & BYMa5)	0.01	74.19	23.84	25	23950	10370	0	7	4
Upper Creek (St BYMa6)	0.79	7.28	3.54	1200	4975	2438	2	5	3
Overall	0.01	74.19	17.07	25	23950	7726	0	7	4
April 2016 (Premonsoon)									
Lower Creek (Sts BYMa4 & BYMa5)	0.14	19.60	4.14	300	4000	2138	1	8	4
Upper Creek (St BYMa6)	197.0	513.0	322.66	925	2250	1606	3	6	5
Overall	0.14	513.0	110.32	300	4000	1960	1	8	4

The standing stock of macrobenthos in Postmonsoon was found to be better than Premonsoon in terms of population, while biomass showed contrasting results. The biomass of macrobenthos ranged from 0.14-513.06 g/m^2; wet wt. in Premonsoon and 0.01-74.19 g/m^2; wet wt. in Postmonsoon. The standing stock of macrobenthos was relatively high at the lower creek as compared to the rest in Postmonsoon, contrastingly highest biomass was found at upper creek in the Premonsoon due to high density of bigger sized phoronids and pelecypods. Overall, the faunal group diversity was low in the study area (Table 4.4.18 and 4.4.19). It appeared that selected macrofaunal communities like Polychaeta, Phoronida, Oligochaeta and Amphipoda which are tolerant to organic pollution proliferated in such a creek ecosystem.

e) Meiobenthos

Meiobenthic standing stock in Manori creek and associated coastal area is given in table 4.4.20 and the segment -wise results are given in the table below.

Stations	Biomass (g/cm^2; wet weight)			Population ($Ind./cm^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Lower Creek (Sts BYMa4 & BYMa5)	7.28	2193.5	1075.46	10	232	106	4	8	6
Upper Creek (St BYMa6)	23.56	2917.24	1470.4	13	403	208	4	7	5
April 2016 (Premonsoon)									
Lower Creek (Sts BYMa4 & BYMa5)	415.56	47374.56	12438.24	133	1114	477	4	8	6
Upper Creek (St BYMa6)	471.69	686.31	579.0	14	24	19	2	3	2

The Manori creek region showed overall low meiofaunal density. In postmonsoon upper creek sustained higher density than lower creek, whereas the reverse trend was observed in premonsoon. The highest and lowest observed meiofaunal densities were 477 $ind./10cm^2$ and 19 $ind./10cm^2$ in lower and upper creek respectively, in premonsoon. The extremely high biomass at station BYMa5 in premonsoon was due to the presence of large number of comparitively bigger body sized polychaetes in meiofaunal composition (Table 4.4.21 and 4.4.22).

4.5 Versova (BYV)

Versova a coastal fishing suburb in Metropolitan Mumbai, with the Madh Island in its neighbourhood is an area affected by sewage disposal. A few pharmaceutical and other small industries use the creek for waste disposal.

Two creek stations BYV4 (lower) and BYV5 (upper) selected for the present study are shown in a consolidated station location map of Mumbai and around (Figure 2.2.4).

4.5.1 Water quality

The results of water quality are presented in Tables 4.5.1 and 4.5.2 and variations over a tide cycle (Station BYV5) are presented in Figures 4.5.1

and 4.5.2. The summary of the water quality (average) of the creek segments off Versova is given in the table below.

Parameters	Zone			
	December 2015 (Postmonsoon)		April 2016 (Premonsoon)	
	Lower Creek (St BYV4)	Upper Creek (St BYV5)	Lower Creek (St BYV4)	Upper Creek (St BYV5)
WT(ºC)	26.9	27.5	29.5	29.3
pH	8.1	7.7	8.1	7.7
SS (mg/l)	71	64	121	99
Turbidity (NTU)	24.7	20.7	25.6	22.6
Salinity (ppt)	35.1	27.1	35.2	29.9
DO(mg/l)	2.6	0.8	3.0	3.2
BOD(mg/l)	8.0	9.5	9.8	15.6
PO_4^{3-}-P (µmol/l)	0.4	2.6	3.9	17.1
TP (µmol/l)	1.2	3.6	6.1	5.0
NO_3^--N (µmol/l)	16.7	8.0	13.4	13.5
NO_2^--N (µmol/l)	3.5	1.8	1.1	1.6
NH_4^+-N (µmol/l)	5.7	23.0	8.5	29.3
TN (µmol/l)	33.6	26.5	10.9	35.6
PHc (µg/l)	3.4	3.2	3.8	2.3
Phenols (µg/l)	75.4	182.5	36.0	40.8

As evident from abovet water temperatures varied noticeably between the two study periods and the difference between two stations was marginal. The pH was in the range of 7.7 to 8.1 with invariably low pH in the upper creek due to sewage release. SS (64 to 121 mg/l) varied with higher values confined to the lower creek. Turbidity was between 20.7 and 25.6 NTU. The relative low salinity especialy in upper creek even in dry season was due to the influence of effluents released in the creek. The average DO levels were invariably low wirh high BOD due to the impact of organic loading. Overall, the nutrients (PO_4^{3-}-P and NH_4^+-N) were relatively high at the upper creek than the lower creek as expected.

Temporal measurements indicated that the Versova Creek was characterized by abnormally high and tide dependant levels of PO_4^{3-}-P, NO_2^--N and NH_4^+-N and variable DO falling to zero at low tides in some instances (Figures 4.5.1. and 4.5.2) is typical of inshore tidal waters receiving oxidizable organic waste in excess of their assimilative capacity. Thus though the swage was treated in aerated lagoons before released in the Versova Creek, from the monitoring results it was clear that either the volume released is much higher than the creek could assimilate or aerated lagoons would be mal-functioning. Marginal elevations in phenols was evident in upper creek during postmonsoon while during premonsoon it wasin the range range expected for coastal waters. There was no evidence of build up of PHc in the water of Versova Creek.

4.5.2 Sediment quality

The results of sediment quality of Versova Creek are presented in Tables 4.5.3 and 4.5.4 and summarized in the following table.

Parameter		Range	
		November 2015	April 2016
Texture (%)	Sand	3.7-4.4	1.7-2.3
	Silt	81-87.7	80.1-85.7
	Clay	8.6-14.6	12.6-17.6
Metals	Al (%)	6.3-9.7	4.8-6.4
	Cr (µg/g)	154-226	123-157
	Mn (µg/g)	878-983	700-947
	Fe (%)	7.2-8.3	6.2-6.3
	Co (µg/g)	24-96	45-50
	Ni (µg/g)	61-63	78-80
	Cu (µg/g)	104-139	149-160
	Zn (µg/g)	116-168	132-180
	Cd (µg/g)	1.1-2.4	2.5-2.7
	Hg (µg/g)	0.12-0.28	0.11-0.3
	Pb (µg/g)	22.7-28.4	20.1-23.8
P (µg/g)		622-968	1116-1449
C_{org} (%)		2.2-2.4	2.2-2.3
PHc (µg/g)		1.2-2.7	1.4-2.2

Dry wt basis except PHc which is wet wt basis

The creek bed was mainly composed of clayey slit. The concentration of metals varied in the expected ranges except for minor elevation in the concentrations of Cr, Ni, Cu, Zn and Hg. The concentration of P, C_{org} and PHc were also in the expected ranges.

4.5.3 Flora and Fauna

The results of biological characteristics are presented in Tables 4.4.5 to 4.5.22 and as well as variations over a tide cycle (Station BYV5) are presented in Figures 4.5.3 to 4.5.6. .

a) Microbes

Versova Creek sustained higher count (CFU/ml) of TVC, TC, FC, PKLO, PALO, SFLO and VLO at station BYV5 during both Postmonsoon 2015 and Premonsoon 2016 as evident in Table 4.5.5. The overall microbial counts at the upper creek were higher as compared to lower creek during both the seasons.

Type of bacteria	Zone			
	December 2015 (Postmonsoon)		April 2016 (Premonsoon)	
	Lower Creek (St BYV4)	Upper Creek (St BYV5)	Lower Creek (St BYV4)	Upper Creek (St BYV5)
TVC X10^3	10.5	36	6	31.5
TC	25	300	15	260
FC	10	255	15	120
ECLO	10	130	10	80
SHLO	ND	60	85	25
SLO	ND	25	ND	5
PKLO	ND	80	20	150
VLO	10	70	210	255
VPLO	ND	40	25	60
VCLO	10	30	185	205
PALO	5	100	ND	10
SFLO	ND	205	35	120

The microbial counts (CFU/g) of sediments as evident in Table 4.5.6 showed higher levels of TVC in Postmonsoon 2015 whereas higher levels of SFLO in Premonsoon 2016. Also microbial counts were quite high at upper creek (Station BYV5) in both the seasons. Pathogenic contamination of the creek was evident.

Type of bacteria	Zone			
	December 2015 (Postmonsoon)		April 2016 (Premonsoon)	
	Lower Creek (St BYV4)	Upper Creek (St BYV5)	Lower Creek (St BYV4)	Upper Creek (St BYV5)
TVC X10^3	220 x 10^3	490 x 10^3	1 x 10^3	8 x 10^3
TC	ND	80	10	30
FC	ND	70	ND	20
ECLO	ND	30	ND	10
SHLO	ND	ND	ND	50
SLO	ND	ND	ND	ND
PKLO	10	ND	ND	30
VLO	20	10	60	80
VPLO	ND	ND	40	10
VCLO	20	10	20	70
PALO	ND	ND	ND	ND
SFLO	ND	40	ND	370

b) Phytoplankton

The results of phytoplankton are given in Tables 4.5.7 to 4.5.12 and summarized below.

Zone	Chlorophyll *a* (mg/m^3)			Phaeophytin (mg/m^3)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)						
Lower creek (St BYV4)	3.4	7.1	5.1	1.1	1.7	1.55
Upper creek (St BYV5)	1.3	15.9	7.5	0.8	4.3	1.95
April 2016 (Premonsoon)						
Lower creek (St BYV4)	11.47	17.08	14.63	2.91	7.35	9.06
Upper creek (St BYV5)	11.49	41.62	19.12	2.26	8.69	5.17

The phytopigments viz; chlorophyll *a* (5.1-19.12 mg/m^3) and phaeophytin (1.55-9.06 mg/m^3) varied widely with higher values confined to April 2016 (Tables 4.5.7 and 4.5.8 and Figures 4.5.3 and 4.5.4).

Phytoplankton cell count also varied as evident from the following table.

Zone	Cell counts (no x 10^3/l)			Total genera (no)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)						
Lower creek (St BYV4)	65	220.8	128.8	12	19	16.0
Upper creek (St BYV5)	38	187.4	108.2	8	18	13.75
April 2016 (Premonsoon)						
Lower creek (St BYV4)	876	1373	1083.5	14	20	18
Upper creek (St BYV5)	1250	2059	1548.5	14	18	16

The average cell counts were maximum in the lower creek (128.8 x10^3 Cells/l) during November 2015 while it was maximum in the upper creek (1548.5 x10^3 Cells/l) during April 2016.The generic diversity was found to be maximum in lower creek during both the seasons.*Chaetoceros*, *Thalassiosira*, *Navicula*, *Leptocylindrus* and *Nitzschia* were the common genera during post monsoon period while, *Chaetoceros*, *Skeletonema*, *Rhodomonas*, *Thalassiosira* and *Rhizosolenia* were the common genera during Premonsoon period (Tables 4.5.9 and 4.5.12). Seasonal changes in the generic dominance were evident.

c) Zooplankton

The zooplankton standing stock (Tables 4.5.13 and 4.5.14) is summarized in the table below.

Zone	Biomass ($ml/100m^3$)			Population ($nox10^3/100m^3$)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Lower (Sts BYV4)	4.9	5.2	5.1	81.9	144.6	113.2	11	16	14
Upper (Sts BYV5)	0.6	2.4	1.5	1.6	60.1	18.7	8	10	9
April 2016 (Premonsoon)									
Lower (Sts BYV4)	0.3	0.7	0.5	4.5	6.9	5.7	10	10	10
Upper (Sts BYV5)	0.2	1.4	0.7	0.02	18.2	9.4	3	11	8

No apparent trend was observed temporally at station ByV5 during both the seasons, but the population density was higher during postmonsoon with higher diversity (Figures 4.5.5 and 4.5.6).The average zooplankton standing stock at the two creek segments viz; biomass (0.5-5.1 $ml/100m^3$) and population (5.7-113.2$nox10^3/100m^3$) varied considerably with the lower creek sustaining the highest population (144.6 $nox10^3/100m^3$) during December 2015. The faunal group diversity varied without any distinct trend. The faunal groups like copepod, gastropods and lamellibranchs were dominant during December 2015. During April 2016, the dominant genera were copepods, gastropod and lamellibranchs larvae (Tables 4.5.15 and 4.5.16).

d) Macrobenthos

The macrobenthic standing stock in terms of biomass (0-22.03 g/m^2, wet wt), population (0-3275 $Ind./m^2$) and faunal groups (0-7 no.) indicated low benthic potential of the creek system during the study period. The segment-wise benthic standing stock (range and average) is given in the table below (4.5.17).

Stations	Biomass (g/m^2; wet weight)			Population ($Ind./m^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Lower Creek (St BYV4)	0.30	0.89	0.55	200	425	325	1	3	2
Upper Creek (St BYV5)	6.03	22.03	13.96	1725	3275	2525	5	7	6
Overall	0.30	22.03	7.26	200	3275	1425	1	7	4
April 2016 (Premonsoon)									
Lower Creek (St BYV4)	0.00	0.04	0.02	0	25	13	0	1	1
Upper Creek (St BYV5)	0.07	0.46	0.19	75	250	138	1	2	2
Overall	0.00	0.46	0.10	0	250	75	0	2	1

The average standing stock interms of biomass (0-0.89 g/m^2; wet wt), population (0-425 Ind./m2) and total genera (0-3 no) of macrobenthos in the lower creek segments off Versova was very poor compared to upper zone (Table 4.5.18 and 4.5.19). The upper creek marginally had better standing stock than that of lower creek. The benthic fauna was mostly dominated by polychaeta.

e) Meiobenthos

Meiobenthic standing stock in Versova creek and associated coastal area is given in table 4.5.20 and the segment -wise results are given in the table below.

Stations	Biomass ($\mu g/10cm^2$)			Population ($Ind./ 10cm^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Lower Creek (St BYV4)	14.41	19.63	17.02	65	140	103	4	4	4
Upper Creek (St BYV5)	16.65	25.81	21.23	34	90	62	4	5	4
April 2016 (Premonsoon)									
Lower Creek (St BYV4)	4.06	6.4	5.23	14	28	21	2	2	2
Upper Creek (St BYV5)	1016	2564.7 4	1790.5	414	974	694	4	5	4

The Versova region is generally poor in faunal count and biomass. However, the upper creek region sustained maximum density (avg. 694 ind./$10cm^2$) in premonsoon, and also showed very high biomass. The population is almost entirely dominated by nematodes in premonsoon (Table 4.5.22), but in postmonsoon, foraminiferans are the most abundant (Table 4.5.21).

4.6 Mahim (BYM)

The Mahim transect is at the seaward end of Mithi river. The untreated sewage and effluents from the small scale industries of Dharavi slums are received in this creek. The creek represented by three stations viz; BYM4, BYM5 and BYM6. These stations are shown in a consolidated station location map of Mumbai and around (Figure 2.2.5).

4.6.1 Water quality

The results of water quality off Mahim are presented in Tables 4.6.1 and 4.6.2 as well as Figures 4.6.1 and 4.6.2 which represent temporal variations at station BYM6.

The water quality results (average) are summarized in the table given below.

Parameters	Zone			
	December 2015 (Postmonsoon)		April 2016 (Premonsoon)	
	Lower Creek (Sts BYM4 & BYM5)	Upper Creek (St BYM6)	Lower Creek (Sts BYM4 & BYM5)	Upper Creek (St BYM6)
WT(ºC)	27.7	27.5	28.8	28.3
pH	8.1	8.0	8.1	7.9
SS (mg/l)	60	73	97	88
Turbidity (NTU)	33.0	18.2	41.4	20.4
Salinity (ppt)	33.8	34.8	26.7	30.2
DO(mg/l)	2.7	3.0	2.8	3.4
BOD(mg/l)	2.2	0.9	2.3	1.2
PO_4^{3-}-P (µmol/l)	3.2	3.2	2.9	9.1
TP (µmol/l)	4.4	3.9	19.2	36.7
NO_3^--N (µmol/l)	22.0	18.0	4.8	8.0
NO_2^--N (µmol/l)	5.7	5.5	2.3	1.5
NH_4^+-N (µmol/l)	5.8	6.9	7.0	5.6
TN (µmol/l)	42.3	44.5	32.8	61.6
PHc (µg/l)	2.0	3.7	2.7	2.6
Phenols (µg/l)	88.6	81.1	36.1	27.8

The water temperature varied along the creek segments, but noticeable variations were evident between the two study periods. The pH was in the normal range with a decrease in the upper creek as compared to the lower creek. Reduction in DO in Mahim creek was associated with the organic load entering the creek system. High PO_4^{3-}-P and NH_4^+-N observed at the upper creek were associated with the domestic and industrial wastewater inputs. Concentration of PHc and phenols were in the range generally observed in the nearshore coastal waters.

4.6.2 Sediment quality

The sediment quality of the study area is presented in Tables 4.6.3 and 4.6.4 and summarized in the following table.

Parameter		Range	
		December 2015 (Postmonsoon)	April 2016 (Premonsoon)
Texture (%)	Sand	0.4-1.1	0.9-16.0
	Silt	49-81.1	43.4-70.6
	Clay	17.8-50.6	13.4-55.7
Metals	Al (%)	8.6-9.8	5.0-6.9
	Cr (µg/g)	143-159	134-162
	Mn (µg/g)	975-1157	887-995
	Fe (%)	7.8-8.5	6.3-7.1
	Co (µg/g)	34-36	37-52
	Ni (µg/g)	53-61	62-79
	Cu (µg/g)	91-105	107-114
	Zn (µg/g)	104-124	98-131
	Cd (µg/g)	0.96-1.43	0.32-0.36
	Hg (µg/g)	0.24-0.25	0.19-0.30
	Pb (µg/g)	16.1-27.0	17.4-26.2
C_{org} (%)		1.3-1.7	1.3-2.2
P (µg/g)		1320-1621	866-1346
PHc (µg/g)		1.2-1.7	0.9-1.1

Dry wt basis except PHc which is wet wt basis

The texture of sediment was mostly clayey-silt. The distribution of trace metals in sediments was patchy but the results indicated elevated levels of Hg in some instances. The P, C_{org} and PHc contents did not indicate any enrichment in the sediments.

4.6.3 Flora and fauna

The results of biological characteristics of Mahim Creek are presented in the Tables 4.6.5 to 4.6.22 as well as variations over a tide cycle (Station BYM6) is presented in Figures 4.6.3 to 4.6.6.

a) Microbes

Mahim Creek sustained higher count (CFU/ml) of TVC, TC, and FC at all the stations (BYM4, BYM5 and BYM6) and PKLO and SFLO were higher at station BYM4 and BYM6 during Postmonsoon 2015. In Premonsoon 2016, higher microbial counts were found at BYM5 and BYM6 as evident in Table 4.6.5. The overall microbial counts (other than TVC) at upper creek were higher as compared to lower creek during both the seasons as given in Table below.

Type of bacteria	Zone			
	December 2015 (Postmonsoon)		April 2016 (Premonsoon)	
	Lower Creek (Sts BYM4 & BYM5)	Upper Creek (St BYM6)	Lower Creek (Sts BYM4 & BYM5)	Upper Creek (St BYM6)
TVC X10^3	20.25	29.5	7	2.5
TC	203	295	515	610
FC	58	190	238	305
ECLO	45	140	145	155
SHLO	5	ND	10	10
SLO	ND	ND	ND	ND
PKLO	53	230	160	425
VLO	30	20	113	645
VPLO	20	ND	53	100
VCLO	10	60	60	545
PALO	ND	ND	8	ND
SFLO	105	100	558	305

The microbial counts (CFU/g) in sediments as evident in Table 4.6.6 were high at the upper region of the estuary (St BYM6) than lower (Sts BYM4 & BYM5) part of the creek.

Type of bacteria	Zone			
	December 2015 (Postmonsoon)		April 2016 (Premonsoon)	
	Lower Creek (Sts BYM4 & BYM5)	Upper Creek (St BYM6)	Lower Creek (Sts BYM4 & BYM5)	Upper Creek (St BYM6)
TVC X10^3	135	170	2	3
TC	25	60	ND	ND
FC	15	40	ND	ND
ECLO	10	30	ND	ND
SHLO	ND	ND	ND	ND
SLO	ND	ND	ND	ND
PKLO	50	90	ND	ND
VLO	35	50	ND	ND
VPLO	10	ND	ND	ND
VCLO	25	50	ND	ND
PALO	ND	ND	ND	ND
SFLO	ND	ND	ND	ND

b) Phytoplankton

The results of phytoplankton are given in Tables 4.6.7 to 4.6.12 and summarized below:

Zone	Chlorophyll *a* (mg/m^3)			Phaeophytin (mg/m^3)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)						
Lower Creek (Sts.BYM4 & BYM5)	2	21.6	8.9	0.7	1.7	1.2
Upper Creek (St. BYM6)	1.3	12.8	5.1	0.5	1.8	1.15
April 2016 (Premonsoon)						
Lower Creek (Sts.BYM4 & BYM5)	16.5	32.0	25.44	0.21	7.6	2.9
Upper Creek (St. BYM6)	14.0	29.0	24.6	0.7	9.3	4.0

The average concentrations of phytopigments viz; chlorophyll *a* (8.9-25.44 mg/m^3) and phaeophytin (1.15-4.0 mg/m^3) varied widely in the creek system (Tables 4.6.7 and 4.6.8). The high chlorophyll *a* values throughout the creek during April 2016 indicated primary production induced by nutrients loading mainly through domestic wastewater. In general higher concentrations of Chl. *a* was recorded during flooding (Figures 4.6.3 and 4.6.4)

Phytoplankton cell count also varied widely as evident from the following table.

Zone	Cell counts (no x 10^3/l)			Total genera (no)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)						
Lower Creek (Sts.BYM4 & BYM5)	71.2	417.2	214.05	10	12	11
Upper Creek (St. BYM6)	38.8	145.2	138.25	9	16	12
April 2016 (Premonsoon)						
Lower Creek (Sts.BYM4 & BYM5)	855	7793	4440.5	10	21	15
Upper Creek (St. BYM6)	3302	8719	5131	9	19	13

The average cell counts were maximum in lower creek (214.05 x10^3 Cells/l) during November 2015 while it was maximum in upper creek (5113.0 x10^3 Cells/l) during April 2016.The generic diversity was found to be maximum in upper creek during November 2015 and in lower creek during Premonsoon (Tables 4.6.9 and 4.6.10).

The dominant genera during December 2015 are in following order; *Thalassiosira*,*Skeletonema,Chaetoceros*, Navicula and *Cylindrotheca*whereas in April 2016, *Chaetoceros*, *Thalassiosira*, *Skeletonema*, *Cryptomonas*, *Pseudo-nitzschia*, and *Rhizosolenia* were predominant (Tables 4.6.11 and 4.6.12).

c) Zooplankton

The standing stock and community structure of zooplankton of Mahim Creek for the study period presented in the Tables 4.6.13 to 4.6.16 are summarized in the table below.

Zone	Biomass (ml/100m^3)			Population (nox10^3/100m^3)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Lower Creek (Sts.BYM4 & BYM5)	1.0	9.4	5.7	1.0	101.5	147.7	11	15	11
Upper Creek (St. BYM6)	0.4	0.8	0.6	3.4	8.3	5.8	15	16	16
April 2016 (Premonsoon)									
Lower Creek (Sts.BYM4 & BYM5)	1.2	3.4	2.7	18.9	31.1	24.4	9	13	10
Upper Creek (St. BYM6)	0.8	4.3	2.3	24.7	99.0	49.3	8	13	11

At ByM6, zooplankton biomass and population were high during postmonsoon as compared to premonsoon with no apparent temporal trend (Figures 4.6.5 and 4.6.6).The averaged zooplankton biomass (0.6-5.7ml/100m^3) indicated wide variation of secondary production in the area whereas, the population ranged from (5.8-147.7nox10^3/100m^3) with a striking difference at different segments of the creek viz; upper and lower estuary respectively during December 2015. The average faunal group diversity was comparable between two study periods.

The faunal groups like copepods, lamellibranchs and gastropods were dominant in December, 2015 (Tables 4.6.13 and 4.6.14). Whereas copepods, gastropods and lamellibranchs were dominant in the creek during April 2016 (Tables 4.6.15 and 4.6.16).

d) Macrobenthos

Macrobenthic standing stock in the Mahim Creek in terms of biomass (0.01-56.46 g/m^2; wet wt) and population (25-4350 Ind./m^2) varied widely (Table 4.6.17). The averaged biomass, population and total groups of macrobenthos are given in the table below.

Stations	Biomass (g/m²; wet weight)			Population (Ind./m²)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Lower Creek (Sts BYM4 and BYM5)	0.16	55.65	14.84	25	4350	713	1	3	2
Upper Creek (St BYM6)	3.18	47.70	16.04	850	2625	1669	2	5	3
Overall	0.16	55.65	15.24	25	4350	1031	1	5	2
April 2016 (Premonsoon)									
Lower Creek (Sts BYM4 and BYM5)	0.12	56.46	7.88	75	1925	422	1	7	4
Upper Creek (St BYM6)	0.01	0.11	0.05	25	150	81	1	4	3
Overall	0.01	56.46	5.27	25	1925	308	1	7	3

The faunal group diversity was low in the creek system (Table 4.6.18 and 4.6.19). Postmonsoon showed better standing crop in terms of population in the creek. The most dominant faunal group was Polychaeta in the postmonsoon season but in premonsoon Polychaeta and Pelecypoda.

e) Meiobenthos

Meiobenthic standing stock in Mahim creek and associated coastal area is given in table 4.6.20 and the segment -wise results are given in the table below.

Stations	Biomass (µg/10cm²)			Population (Ind./ 10cm²)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Lower Creek (Sts BYM4 and BYM5)	19.26	61.35	37.93	33	144	111	2	6	4
Upper Creek (St BYM6)	15.78	45.5	30.64	20	197	108	3	4	3
April 2016 (Premonsoon)									
Lower Creek (Sts BYM4 and BYM5)	22.64	236.42	125.3	71	362	214	2	5	4
Upper Creek (St BYM6)	13.96	23.14	18.55	42	115	79	2	4	3

Meiobenthic standing stock in the Mahim Creek in terms of biomass (13.96 to 236.42 µg/10cm^2) and population (20 to 362 ind/10cm^2) varied widely. Average group diversity varied between 3 and 4. In both the season meiofauna community was dominated by nematodes followed by foraminiferans (Tables 4.6.21 and 4.6.22).

4.7 Bandra (BYB)

Arabian Sea off Bandra receives sewage through a massive submarine outfall and diffuser system at a depth of 7m CD. Two locations off Bandra sampled are represented by BYB1 and BYB2. These stations are shown in consolidated station location map of Mumbai and around (Figure 2.2.5).

4.7.1 Water quality

The results of water quality off Bandra are presented in Tables 4.7.1 and 4.7.2 as well as Figures 4.7.1 and 4.7.2 which represent temporal variations at station BYB2. The average water quality is given in the following table.

Parameter	Zone	
	December 2015 (Postmonsoon)	April 2016 (Premonsoon)
	Coastal (BYB1 & BYB2)	Coastal (BYB1 & BYB2)
WT(°C)	28.9	28.6
pH	8.0	8.2
SS (mg/l)	71	119
Turbidity (NTU)	8.3	8.2
Salinity (ppt)	34.9	33.1
DO(mg/l)	4.9	6.1
BOD(mg/l)	1.6	1.2
PO_4^{3-}-P (µmol/l)	2.2	4.8
TP (µmol/l)	3.7	7.1
NO_3^--N (µmol/l)	16.7	14.2
NO_2^--N (µmol/l)	3.3	1.8
NH_4^+-N (µmol/l)	3.2	7.4
TN (µmol/l)	38.1	32.3
PHc (µg/l)	0.9	1.4
Phenols (µg/l)	77.2	48.2

The water temperature varied widely between two study periods. The pH, SS and salinity varied as expected for the coastal area of Mumbai. DO was fairly good and except for NH_4^+-N (Tables 4.7.1 and 4.7.2). Which was high especially in surface water, the other nutrients were in the range excepted for waters off Mumbai. Hence, it appeared that the sewage-associated ammonia entering seawater through diffusers is not immediately oxidized. Temporal measurements revealed the influence of sewage on water quality during both the seasons. The salinity difference in the vertical with bottom water often having relatively high salinity during the monitoring cycle resulted from the spread of the effluent plume of low salinity in the surface layer with delayed mixing due to density differences between sewage and the ambient seawater. This is supported by frequent high concentrations of PO_4^{3-}-P and NH_4^+-N in the surface samples.

4.7.2 Sediment quality

The sediment quality off Bandra is presented in Tables 4.7.3 and 4.7.4 and summarized in the following table.

Parameter		Range November 2015 (Postmonsoon)	Range April 2016 (Premonsoon)
Texture (%)	Sand	0.5-1.0	10.2
	Silt	79.6-95.3	66.8
	Clay	4.2-19.4	23.1
Metals	Al (%)	8.7-9.1	7.9
	Cr (µg/g)	149-152	136
	Mn (µg/g)	940-989	900
	Fe (%)	8.1-8.2	7.5
	Co (µg/g)	34-38	34
	Ni (µg/g)	54-58	49
	Cu (µg/g)	94-107	85
	Zn (µg/g)	102-126	93
	Cd (µg/g)	1.1-1.6	1.1
	Hg (µg/g)	0.23-.27	0.2
	Pb (µg/g)	17.1-24.8	20
P (µg/g)		301-463	274
C_{org} (%)		1.1-1.2	1.0
PHc (µg/g)		0.7-1.0	0.9

Dry wt basis except PHc which is wet wt basis

The texture of the sediment was mainly silty in nature at the study area. The concentration of various metals was in the range expected for sediments off Mumbai and comparable between the two study periods. P, C_{org} and PHc contents did not indicate their accumulation in sediments.

4.7.3 Flora and Fauna

The results of biological characteristics in the coastal waters off Bandra are presented in the Tables 4.7.5 to 4.7.22 as well as Figures 4.7.3 to 4.7.6 which represent temporal variations at station BYB2.

a) Microbes

Coastal water off Bandra sustained higher count (CFU/ml) of TVC, TC, FC, PKLO, VLO and SFLO at BYB2 during Postmonsoon 2015. In Premonsoon 2016, higher microbial counts were found at BYB2 as evident in Table 4.7.5. The overall microbial counts at during post monsoon were higher as compared to premonsoon as given in Table below.

Type of bacteria	December 2015 (Postmonsoon)	April 2016 (Premonsoon)
	Coastal (BYB1 & BYB2)	Coastal (BYB1 & BYB2)
TVC x 10^3	10	7
TC	175	53
FC	150	40
ECLO	145	28
SHLO	ND	15
SLO	ND	ND
PKLO	253	28
VLO	138	48
VPLO	ND	30
VCLO	ND	18
PALO	ND	ND
SFLO	100	158

As given in Table 4.7.6, levels of TVC, TC, FC and VLO count (CFU/g) in sediment of coastal stations of Bandra were also higher in Postmonsoon 2015 as compared to Premonsoon 2016.

Type of bacteria	December 2015 (Postmonsoon)	April 2016 (Premonsoon)
	Coastal (BYB1 & BYB2)	Coastal (BYB1 & BYB2)
TVC X10^3	420	2
TC	1000	ND
FC	750	ND
ECLO	750	ND
SHLO	ND	ND
SLO	ND	ND
PKLO	150	ND
VLO	1900	20
VPLO	350	ND
VCLO	1550	20
PALO	ND	ND
SFLO	ND	ND

b) Phytoplankton

Phytopigments, cell counts and community structure of phytoplankton Bandra are presented in the Tables 4.7.7 to 4.7.12 and the distribution of chlorophyll *a* and phaeophytin are given in the table below.

Zone	Chlorophyll *a* (mg/m^3)			Phaeophytin (mg/m^3)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)						
Coastal (Sts. BYB1 & BYB2)	2.7	14.8	6.0	0.3	2.8	1.3
April 2016 (Premonsoon)						
Coastal (Sts. BYB1 & BYB2)	5.56	32.36	21.43	0.05	3.04	1.2

The average concentrations of phytopigments viz; chlorophyll *a* (6-21.43 mg/m^3) and phaeophytin (1.2-1.3 mg/m^3) were variable off Bandra (Tables 4.7.7 and 4.7.8) with average values revealing good primary production potential of the coastal waters especially during the premonsoon (Figures 4.7.3 and 4.7.4).

The averaged cell counts and total genera off Bandra are given in the following table.

Zone	Cell counts (no x 10^3/l)			Total genera (no)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)						
Coastal (Sts. BYB1 & BYB2)	56.6	185.2	123.3	11	17	15
April 2016 (Premonsoon)						
Coastal (Sts. BYB1 & BYB2)	532	5642	3134	15	20	18

The average cell counts in coastal water off Bandra were found to be 123.3no x10^3/l during December 2015 which increased to 3134 x 10^3/l during April 2016 (Tables 4.7.9 and 4.7.10). The generic diversity also increased from 15 to 18 no. as the season changed. In Post monsoon, *Thalassiosira, Prorocentrum*, *Skeletonema*, *Chaetoceros* and *Navicula* were the most dominant genera, whereas, *Chaetoceros ,Rhizosolenia, Thalassiosira,* *Pseudo-nitzschia* and *Skeletonema* were the most abundant in Pre monsoon Tables 4.7.11 and 4.7.12).

c) Zooplankton

The standing stock of zooplankton in the coastal system off Bandra (Tables 4.7.13 and 4.7.14) is summarized in the following tables.

Zone	Biomass (ml/100m^3)			Population (nox10^3/100m^3)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Coastal (Sts. BYB1& BYB2)	0.6	8.4	3.0	2.0	120.2	54.6	8	14	10
April 2016 (Premonsoon)									
Coastal (Sts. BYB1& BYB2)	0.3	3.6	2.2	3.4	64.6	31.1	6	11	8

At BYB2, the population density was higher at flood tide as compared to ebb tide, with higher diversity during post monsoon (Figures 4.7.5 and 4.7.6). The average zooplankton biomass and population at the stations varied in 2.2-3.0 ml/100m^3 and 31.1 – 54.6 nox10^3/100m^3 ranges respectively. The dominant zooplankton faunal groups were copepods, lamellibranchs and decapod larvae during December 2015, and copepods, *Lucifer sp.* and decapode larvae during April 2016 (Tables 4.7.13 and 4.7.14).

d) Macrobenthos

The standing stock of macrobenthos off Bandra (Table 4.7.17) is summarized in the table below.

Stations	Biomass (g/m^2; wet weight)			Population (Ind./m^2)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Coastal (Sts. BYB1 & BYB2)	0.04	17.35	3.86	25	875	206	1	3	1
Overall	0.04	17.35	3.86	25	875	206	1	3	1
April 2016 (Premonsoon)									
Coastal (Sts. BYB1 & BYB2)	0.19	1.86	1.20	175	475	331	3	5	4
Overall	0.19	1.86	1.20	175	475	331	3	5	4

The average macrobenthic standing stock was very poor suggesting unfavourable substrate conditions for benthos. The faunal group diversity was also very poor indicating 1-5 nos. during the study period (Table 4.7.18 and 4.7.19) with Polychaetes dominating the populations.

e) Meiobenthos

The standing stock of meiobenthos off Bandra (Table 4.7.20) is summarized in the table below.

Stations	Biomass ($\mu g/10cm^2$)			Population (Ind./ $10cm^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Coastal (Sts BYB1 & BYB2)	9.29	209.16	87.07	65	413	215	4	6	5
April 2016 (Premonsoon)									
Coastal (Sts BYB1 & BYB2)	306.96	557.88	432.42	74	170	122	3	4	3

The average meiobenthic standing stock was low. Though density was higher in postmonsoon, biomass was higher in premonsoon due to the increased percentage of polychaetes, as shown in table 4.7.21. The faunal group diversity varied from 3 to 6 faunal groups; Nematode being the most dominant faunal group (Tables 4.7.21 and 4.7.22).

4.8 Worli (BYW)

The coastal area off Worli which recives sewage through marine outfall is represented by two stations viz. BYW1 and BYW2 (Figure 2.2.5).

4.8.1 Water quality

The results of water quality off Worli are presented in Tables 4.8.1 and 4.8.2 as well as Figures 4.8.1 and 4.8.2 which represent temporal variations at station BYW2.

The water quality results (average) off Worli are summarized in the table below:

Parameter	December 2015 (Postmonsoon)	April 2016 (Premonsoon)
	Coastal (Sts BYW1 & BYW2)	Coastal (Sts BYW1 & BYW2)
WT(ºC)	28.6	27.0
pH	8.2	8.1
SS (mg/l)	79	91
Turbidity (NTU)	16.4	16.7
Salinity (ppt)	34.9	36.4
DO(mg/l)	6.2	6.9
BOD(mg/l)	2.6	2.2
PO_4^{3-}-P (µmol/l)	2.0	0.5
TP (µmol/l)	2.6	1.9
NO_3^--N (µmol/l)	14.9	7.3
NO_2^--N (µmol/l)	3.1	0.3
NH_4^+-N (µmol/l)	3.8	1.8
TN (µmol/l)	38.1	14.4
PHc (µg/l)	0.8	1.9
Phenols (µg/l)	52.4	64.2

Except for somewhat elevated levels of NH_4^+-N, the water quality off Worli was that expected for the coastal area of Mumbai and the release of sewage had not impacted the water quality.

Temporal measurements which revealed relative high concentrations of PO_4^{3-}-P and NH_4^+-N indicated some signature of sewage entering the sea as discussed under Section 4.7.1 for Bandra.

4.8.2 Sediment quality

The sediment quality of the Worli coastal system is presented in Tables 4.8.3 and 4.8.4 and summarized in the following table.

Parameter		Range	
		December 2015 (Postmonsoon)	April 2016 (Premonsoon)
Texture (%)	Sand	0.8-1.6	0.5-5
	Silt	55.1-82.2	58.7-88.3
	Clay	16.223.2	6.7-40.8
Metals	Al (%)	8.9-9.3	6.2-6.9
	Cr (µg/g)	152-154	111-138
	Mn (µg/g)	897-932	689-925
	Fe (%)	8.2-8.2	6.1-6.8
	Co (µg/g)	36-39	44-50
	Ni (µg/g)	57-59	70.87
	Cu (µg/g)	94-99	100-112
	Zn (µg/g)	106-116	92-104
	Cd (µg/g)	0.41-0.94	0.17-0.33
	Hg (µg/g)	0.22-0.24	0.18-0.20

	Pb (µg/g)	17.5-21.2	14.6-17.7
P (µg/g)		519-558	960-1220
C_{org} (%)		1.6-1.6	1.4-1.9
PHc (µg/g)		0.2-0.3	0.5-.1.5

Dry wt basis except PHc which is wet wt basis

The sediment is generally silty with trace metals in the expected ranges except for occasional high levels of Cd and Hg represented expected lithogenic concentrations. The levels of C_{org} and PHc were in expected ranges. The results indicated general absence of sediment contamination by anthropogenic metals off Worli.

4.8.3 Flora and fauna

Biological characteristics off Worli are presented in Tables 4.8.5 to 4.8.22 as well as Figures 4.8.3 to 4.8.6 which represent temporal variations at station BYW2.

a) Microbes

Population of microbes in the coastal water off Worli was low in comparison with the result of Mahim and Versova creeks as evident in Table 4.8.5.Presence of faecal indicator bacteria like TC, FC and ECLO were more at coastal region during post monsoon and pathogenic bacteria like SHLO, SLO, VLO, VPLO and VCLO were recorded in low numbers or were absent during Premonsoon.

Type of bacteria	December 2015 (Postmonsoon)	April 2016 (Premonsoon)
	Coastal (Sts BYW1 & BYW2)	Coastal (Sts BYW1 & BYW2)
TVC x 10^3	13 x 10^3	6 x 10^3
TC	36	43
FC	16	28
ECLO	8	15
SHLO	18	8
SLO	14	ND
PKLO	6	ND
VLO	18	5
VPLO	12	ND
VCLO	6	5
PALO	ND	ND
SFLO	25	ND

The microbial counts of sediments (CFU/g) as evident in Table 4.8.6 shows almost similar trend of both seasons except VLO and VPLO which were higher in Postmonsoon 2015.

Type of bacteria	December 2015 (Postmonsoon)	April 2016 (Premonsoon)
	Coastal (StsBYW1 BYW2)	Coastal (StsBYW1& BYW2)
TVC x 10^3	60 x 10^3	8 x 10^3
TC	33	37
FC	23	23
ECLO	17	23
SHLO	ND	3
SLO	ND	ND
PKLO	ND	ND
VLO	33	7
VPLO	33	7
VCLO	ND	ND
PALO	7	ND
SFLO	7	ND

b) Phytoplankton

The results of phytoplankton off Worli are presented in Tables 4.8.7 to 4.8.12 and concentrations of phytopigments are given in the table below.

Zone	Chlorophyll *a* (mg/m^3)			Phaeophytin (mg/m^3)		
	Min	Max	Avg	Min	Max	Avg
April 2007 (Premonsoon)						
Coastal (Sts. BYW1 & BYW2)	1.8	12.5	5.2	0.5	2.5	1.1
April 2016 (Premonsoon)						
Coastal water (Sts. BYW1 & BYW2)	1.52	7.6	14.0	0.02	2.12	1.0

High values of chlorophyll *a* indicated organic pollution induced primary production in the coastal system off Worli. The values of phaeophytin were comparable between two study seasons (Figures 4.8.3 and 4.8.4). The averaged cell counts and total genera of phytoplankton off Worli are given in the table below.

Zone	Cell density (no. X10^3 Cells/l)			Total genera (Nos.)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)						
Coastal (Sts. BYW1 & BYW2)	188.6	1301.6	605.55	12	20	16
April 2016 (Premonsoon)						
Coastal water (Sts. BYW1 & BYW2**)**	106.4	1650.6	593.4	17	23	20

The averaged phytoplankton cell counts (593.4-605.55 x10^3 Cells/l) and generic diversity (16 and 20 no.) during the study period varied in a close range.

The dominant genera during December 2015 were *Thalassiosira, Skeletonema* and *Chaetoceros*. Whereas the dominance of *Skeletonema, Chaetoceros* and *Cylindrotheca* in that order was noticed during April 2016 (Tables. 4.8.11 and 4.8.12).

c) Zooplankton

The zooplankton standing stock off Worli (Tables 4.8.13 and 4.8.14) is summarized in the table below.

Zone	Biomass (ml/100m^3)			Population (nox10^3/100m^3)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Postmonsoon December 2015									
Coastal (Sts BYW1 & BYW2)	0.3	4.0	1.8	9.3	63.4	25.8	8	14	10
Premonsoon April 2016									
Coastal (Sts BYW1 & BYW2)	0.2	7.7	4.2	1.1	53.1	24.7	9	11	10

The average standing stock in terms of biomass and population ranged between 1.8 - 4.0 ml/100m^3 and 24.7 - 25.8 nox10^3/100m^3 respectively. Zooplankton group diversity was found low and comparable with Bandra. At BYW2, population and diversity was higher during postmonsoon as compared to premonsoon (Figures 4.8.5 and 4.8.6).

The population dominated by groups like *copepods, appendicularians and lamellibranchs* during both seasons (Tables 4.8.13 and 4.8.14). The distribution of various groups of the study area is presented in Table 4,8,15 and 4.8.16.

d) Macrobenthos

The standing stock of macrobenthos off Worli (Table 4.8.17) is summarized in the following table.

Stations	Biomass (g/m^2; wet weight)			Population (Ind./m^2)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Coastal (Sts BYW1 & BYW2)	0.20	26.5	4.25	175	2450	531	1	2	1
Overall	0.20	26.5	4.25	175	2450	531	1	2	1
April 2016 (Premonsoon)									
Coastal (Sts BYW1 & BYW2)	0.20	11.9	5.00	350	1275	732	1	10	3
Overall	0.20	11.9	5.00	350	1275	732	1	10	3

The average standing stock and community structure of macrobenthos in the worli region was relatively low in the postmonsoon period (Tables 4.8.18 and 4.8.19). Population showed marginal increase in the Premonsoon season, while faunal groups were less in the Postmonsoon.

e) Meiobenthos

Meiobenthic standing stock in Worli area is given in table 4.8.20 and the segment -wise results are given in the table below.

Stations	Biomass (µg/10cm^2)			Population (Ind./ 10cm^2)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Coastal (Sts BYW1 & BYW2)	86.0	112.1	99.41	171	321	233	2	5	4
April 2016 (Premonsoon)									
Coastal (Sts BYW1 & BYW2)	60.7	155.6	111.98	92	386	197	2	4	3

The Worli outfall region had low meiofaunal density ranging from 92 to 386 ind./10 cm^2(Table 4.8.20). Biomass and group diversity were also low. A total of 7 groups were encountered in postmonsoon compared to only 4 in premonsoon (Tables 4.8.21 and 4.8.22) with dominance of nemaodes.

4.9 Thane Creek and Mumbai Harbour (BY)

Six stations were selected namely BY1, BY2, BY3 in deeper coastal waters and BY4, BY5 and BY6 in shallow waters along the creek axis to study the creek quality (Figure 2.2.6).

4.9.1 Water quality

The results of water quality (average) of the Thane Creek and associated coastal waters is presented in Tables 4.9.1 and 4.9.2 and variations over a tide cycle are shown in Figures 4.9.1 and 4.9.4 at station BY4 and BY6. The results of water quality are summarized in the table below.

Parameter	December 2015 (Postmonsoon)				April 2016 (Premonsoon)			
	Coastal (Sts BY1 to BY3)	Lower creek (St BY4)	Middle creek (St BY5)	Upper creek (BY6)	Coastal (Sts BY1 to BY3)	Lower creek (St BY4)	Middle creek (St BY5)	Upper creek (BY6)
WT(°C)	28.5	28.5	27.6	28.6	28.6	28.4	28.0	28.0
pH	8.1	8.0	7.9	7.8	8.1	8.1	8.0	8.0
SS (mg/l)	73	76	78	93	130	149	262	239
Turbidity (NTU)	35.0	21.5	30.4	33.7	44.1	23.5	100.7	36.2
Salinity (ppt)	34.6	34.8	33.1	31.7	36.4	36.6	36.2	35.4
DO(mg/l)	5.8	4.9	4.5	5.8	6.4	6.1	5.9	6.0
BOD(mg/l)	1.8	1.5	2.2	5.5	2.5	3.4	3.5	4.3
PO_4^{3-}-P (µmol/l)	1.7	2.5	4.9	6.2	0.6	1.8	4.7	7.1
TP (µmol/l)	2.6	5.1	6.7	10.4	1.6	3.8	6.5	24.7
NO_3^--N (µmol/l)	29.0	31.9	31.0	20.3	12.9	20.8	21.1	32.0
NO_2^--N (µmol/l)	0.2	0.4	13.0	24.8	0.4	0.5	7.5	9.7
NH_4^+-N(µmol/l)	2.0	0.7	2.0	9.2	2.7	1.0	2.0	20.3
TN (µmol/l)	40.6	35.1	97.3	90.7	13.4	26.2	36.1	109.6
PHc (µg/l)	2.9	2.9	3.0	3.7	1.6	2.7	3.2	4.9
Phenols (µg/l)	93.0	49.2	65.2	203.5	43.8	52.0	36.6	102.2

The water temperature and SS were in the ranges expected for the Thane Creek region. The pH was in the range expected for seawater. The reduction in salinity in the creek – particularly in the inner segments was the reflection of release of effluent; sewage in particular. Some depletion of DO was noticed during postmonsoon season (December 2015). During premonsoon season (April 2016) also DO decreased during ebb, but values were noticeably higher than the postmonsoon season. DO was as low as 2.6 mg/l at sewage receiving sites particularly inner creek. Relative high DO in the inner creek zone during December 2015 was likely to be due to abnormally high chlorophyll *a* which compensated for depletion of DO during the day time. That means low DO would occur during night when photosynthesis would be suspended. This segment probably received sewage inflow that was in excess of its assimilative capacity due to relative limited volume and weakening of the tidal influence in this segment. Relative high concentrations of PO_4^{3-}-P, NO_2^--N and NH_4^+-N also indicate deterioration in water quality of the inner creek. Abnormaly high concentration of NO_2^--N, sometimes exceeding the concentration of NO_3^--N indicates build-up of NO_2^--N before its oxidation to NO_3^--N. PHc (1.6-4.9 µg/l) were low but phenols (36.6-203.5µg/l) revealed higher values than expected for unpolluted coastal areas.

The temporal variations during December 2015 (Figure 4.9.1) at station BY4 indicated vertically well-mixed waters but increase in salinity from ebb to flood was due to the influence of postmonsoonal freshwater probably through Ulhas Estuary. However, such tidal variation was not observed during April 2016 (Figure 4.9.2). Decrease in concentrations of PO_4^{3-}-P, NO_3^--N, NO_2^--N and NH_4^+-N during ebb and increase in DO and chlorophyll *a* at station BY4 indicates uptake of nutrients by phytoplankton and replenishing of DO with increased photosynthesis. The temporal trend indicated that in these oxygenated waters ammonia was effectively oxidized to nitrate via nitrite accounting for high concentrations of the products of oxidation. The temporal trend in variation in water quality was different at station BY6 (Figures 4.9.3 and 4.9.4). From the relative concentrations of nutrients it appeared that the ammonia released to the sea via sewage was not effectively oxidized though DO was above 2.5 mg/l throughout resulting in high concentrations of NH_4^+-N. Substantial decrease in NH_4^+-N concentration and increase in NO_3^--N concentration during flood indicated oxidation of NH_4^+-N to NO_3^--N via NO_2^--N though substantial build-up of NO_2^--N took place prior to its oxidation to NO_3^--N during December 2015. Abnormaly high concentration of chlorophyll *a* had produced DO in high concentration especially in the surface water. During April 2016 similar trend of DO and $NH4^+$-N was recorded. However, trend of other nutrients was not clear.

4.9.2 Sediment quality

The sediment quality of Thane Creek and Mumbai Harbour is presented in Tables 4.9.3 and 4.9.4 and the results are summarized in the following table.

Parameter		Range	
		December 2015 (Postmonsoon)	February 2008 (Premonsoon)
Texture (%)	Sand	1.4-3.2	3.6-5.3
	Silt	78.8-86.2	69.1-88.3
	Clay	11-19	6.7-25.6
Metals	Al (%)	5.5-9.3	6.1-6.8
	Cr (µg/g)	94-208	117-130
	Mn (µg/g)	549-1153	762-818
	Fe (%)	5.0-9.9	6.6-6.8
	Co (µg/g)	24-51	47-49
	Ni (µg/g)	36-78	73-79
	Cu (µg/g)	56-108	102-139
	Zn (µg/g)	62-131	85-129
	Cd (µg/g)	0.28-0.35	0.16-0.18
	Hg (µg/g)	0.10-0.17	0.11-0.21
	Pb (µg/g)	18.4-25.7	15.2-23.6
P (µg/g)		892-1744	796-1436

C_{org} (%)	1.0-2.2	0.9-2.2
PHc (μg/g)	0.2-1.3	0.2-1.2

Dry wt basis except PHc which is wet wt basis.

The sediment texture in the region was largely a combination of silt and clay with their proportions varying widely temporally and spatially. The concentrations of trace metals except Hg and Cd were in the range expected for the region based on their levels in the catchment soil and in sediments deposited prior to industrialization. High concentrations of Hg relative to the expected background (0.1μg/g) have been reported in the inner creek attributed to the release of effluents from a chlor-alkali industry. From the analysis of a sediment core from the vicinity of the effluent release site of the chlor-alkali industry it has been demonstrated that the sediment deposited in 1967-just after the chlor-alkali unit went into production, had Hg content of as high as 49.19 μg/g with a steady decrease along the length upto the surface. The present results indicated that the marginally high Hg persisted in the sediment of some sites of the creek. The Cd levels were also high at some sites. Its source however could not be identified. Relative high concentrations of Cd have been reported in marine sites receiving effluents from fertilizer industry and sewage.

The sediment even from the inner creek was free from high accumulation of C_{org} and P even though large volume of sewage was entering the creek. The concentrations of PHc are marginally higher than expected for coastal sediments free from contamination by oil.

4.9.3 Flora and fauna

The results of biological investigations are presented in the Tables 4.9.5 to 4.9.22 and variations over a tide cycle are shown in Figures 4.9.3 to 4.9.6 at station BY4.

a) Microbes

In Postmonsoon 2015, Thane Creek sustained higher count (CFU/ml) of TC, FC, VLOand PKLO at stations BY4,BY5 and BY6and SFLO at station BY5 whereas in Premonsoon 2016, higher counts of TC,FC,SHLO,PKLO and VLO were found at station BY4 and BY6 as evident in Table 4.9.5.The overall microbial counts during Postmonsoon 2015 at lower creek (Station BY4) were higher than the rest and during Premonsoon 2016, upper creekBY6 and lower creek BY4 had higher microbial counts as compared to coastal and middle creek. Thus these high bacteria counts in the openshore waters of Thane could also be influenced by the cumulative impact of discharges from Patalganga and Amba estuaries. The high counts of selected pathogens like PKLO, VPLO, and PALO etc showed pathogenic contamination of the coastal system of Thane creek.

Water / Type of Bacteria	December 2015 (Postmonsoon) Coastal (Sts BY1, BY2 & BY3)	Lower (St BY4)	Middle (St BY5)	Upper (BY6)	April 2016 (Premonsoon) Coastal (Sts BY1, BY2 & BY3)	Lower (St BY4)	Middle (St BY5)	Upper (BY6)
TVC	43 x 10^3	18 x 10^3	50 x 10^3	2 x 10^3	11 x 10^3	32 x 10^3	35 x 10^3	49 x 10^3
TC	ND	90	15	15	3	40	ND	45
FC	ND	75	10	15	3	30	ND	30
ECLO	ND	75	5	10	3	10	ND	ND
SHLO	ND	ND	10	ND	8	105	ND	365
SLO	ND	ND	10	ND	ND	10	ND	ND
PKLO	ND	55	10	15	ND	80	ND	50
VLO	ND	60	10	10	25	860	ND	575
VPLO	ND	ND	ND	5	3	ND	ND	ND
VCLO	ND	60	5	5	30	860	10	30
PALO	ND	ND	ND	ND	ND	5	ND	30
SFLO	ND	ND	25	20	ND	5	ND	ND

The microbial counts (CFU/g) of sediments as evident in Table 4.9.6 were higher in Postmonsoon 2015 and counts of VLO being higher at lower creek (StationBY4).This could be due to transport of surfacial contaminated sediment from upper to loer creekduring the monsoon fluxes.

Sediment / Type of Bacteria	December 2015 (Postmonsoon) Coastal (Sts BY1, BY2 & BY3)	Lower (St BY4)	Middle (St BY5)	Upper (BY6)	April 2016 (Premonsoon) Coastal (Sts BY1, BY2 & BY3)	Lower (St BY4)	Middle (St BY5)	Upper (BY6)
TVC	33 x 10^3	600 x 10^3	800 x 10^3	200 x 10^3	Hard substratum	5 x 10^3	16 x 10^3	46 x 10^3
TC	67	ND	ND	ND		10	ND	ND
FC	33	ND	ND	ND		ND	ND	ND
ECLO	33	ND	ND	ND		ND	ND	ND
SHLO	ND	ND	ND	ND		ND	ND	ND
SLO	ND	ND	10	ND		ND	ND	ND
PKLO	ND	ND	ND	ND		ND	ND	ND
VLO	ND	100	30	30		ND	10	10
VPLO	ND	ND	30	ND		ND	ND	ND
VCLO	ND	100	ND	30		ND	10	10
PALO	ND	ND	20	ND		ND	ND	ND
SFLO	ND	500	ND	ND		ND	ND	ND

b) Phytoplankton

Results of phytoplankton pigments and population in the waters of Thane creek and associated coastal region are given in the Tables. 4.9.7 to 4.9.12 and the range and average of chlorophyll *a* and phaeophytin are summarized in the table below.

Zone	Chlorophyll *a* (mg/m^3)			Phaeophytin (mg/m^3)		
	Min	Max	Avg	Min	Max	Avg
December2015 (Postmonsoon)						
Coastal (Sts BY1 to BY3)	1.5	3.6	2.25	0.2	0.9	0.6
Lower creek (St BY4)	0.7	3.2	1.15	0.4	1.9	1.3
Middle creek (St BY5)	5.1	17.1	9.15	0.2	0.7	0.5
Upper creek (St BY6)	11	47	31.02	0.9	3.6	2.1
April 2016 (Premonsoon)						
Coastal (Sts BY1 to BY3)	1.77	6.81	3.93	0.01	1.70	0.8
Lower creek (St BY4)	0.81	4.06	2.27	0.39	4.09	1.4
Middle creek (St BY5)	1.65	2.11	1.86	1.30	1.84	1.6
Upper creek (St BY6)	1.22	9.75	4.53	0.92	6.98	2.6

The upper creek sustained the highest value of chlorophyll *a* and phaeophytin during the study period compared to other zones. The average chlorophyll *a* value for the study region varied from 1.15 to 31.02 mg/m^3. The average chlorophyll *a* value was very high in upper creek (31.02 mg/m^3) during December 2015 compared to April 2016 (Figures 4.8.3 and 4.8.4). The enhanced concentration of phytopigments in the creek could be associated with disposal of large volume of sewage in the creek.

The Segment-wise results (range and average) of phytoplankton population are summarized in the table given below.

Zone	Cell density (no. x10^3 Cells/l)			Total genera (Nos.)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)						
Coastal (Sts. BY1 to BY3)	31.2	91.4	56.45	11	16	14
Lower Creek (Sts. BY4)	35	57	44.95	8	14	11
Middle Creek (St. BY5)	606	3332.4	1779.8	13	19	18
Upper Creek (St. BY6)	6132.8	13343.4	9182.55	13	20	16
April 2016 (Premonsoon)						
Coastal (Sts. BY1 to BY3)	76	932	296	14	22	17
Lower Creek (Sts. BY4)	97	459	268	15	23	20
Middle Creek (St. BY5)	137	214	180.5	14	20	18
Upper Creek (St. BY6)	231	315	270	19	22	21

No clear trend is evident in the distribution of phytoplankton population in the study area. The middle and upper creek sustained very high cell counts during December 2015. The higher cell counts in the upper creek can be attributed to sewage disposal in this segment as well as the trend corressponds with high primery production noticed during postmonsoon.

The dominant genera during December 2015 were *Skeletonema, Thalassiosira, Prorocentrum* and *Navicula*. Whereas the dominance of *Pseudo-nitzschia, Chaetoceros,Thalassiosira, Skeletonema* and c*ylindrotheca* in that order was noticed during April 2016 (Tables.4.9.11 and 4.9.12).

c) Zooplankton

Zooplankton standing stock in terms of biomass (0.2-38.9 ml/100m^3) and population (0.6-72.8 no x10^3/100m^3) varied considerably during postmonsoon. Wheras, during premonsoon it varied on a wide range (0.4-570.8 ml/100m^3 and 7.1-147.6 no x10^3/100m^3) (Tables 4.9.13 and 4.9.14).Segment-wise zooplankton standing stock and total genera are given in the following table.

Zone	Biomass (ml/100m^3)			Population (nox10^3/100m^3)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Coastal (Sts BY1 to BY3)	0.5	3.8	1.6	2.3	25.7	15.6	10	20	15
Lower creek (St BY4)	0.6	3.8	1.9	1.8	21.1	11.6	11	19	15
Middle creek (St BY5)	0.2	0.7	0.5	0.6	10.1	5.4	12	15	14
Upper creek (St BY6)	0.3	38.9	11.4	1.0	72.8	21.0	9	10	11
April 2016 (Premonsoon)									
Coastal (Sts BY1 to BY3)	2.3	6.2	4.0	10.5	44.9	23.6	9	17	13
Lower creek (St BY4)	0.4	94.4	25.1	11.9	46.8	26.6	13	16	14
Middle creek (St BY5)	16.2	22.4	19.3	24.2	31.3	27.8	11	12	12
Upper creek (St BY6)	22.0	570.8	156.3	7.1	147.6	43.0	6	14	10

The upper creek sustained abnormally high values of standing stock especially during April 2016. Same trend was seen on a lower degree during Postmonsoon. The dominant faunal groups were copepods, decapod larvae, medusae, ctenophores, chaetognaths and gastropods. The high biomass whenever occurred was generally due to higher occurrence of medusae and ctenophores. The population structure was mainly constituted by copepods, decapod larvae, *Acetes* sp., chaetognaths, ctenophores, fish larvae and gastropods (Tables 4.9.13 and 4.9.14). The distributions of various faunal groups in the study area are given in the Table 4.9.15 and 4.9.16. No apparent temporal tend was observed at BY4 or BY6 (Figures 4.9.9, 4.9.10, 4.9.11 and 4.9.12).

d) Macrobenthos

Macrobenthic standing stock in Thane Creek and associated coastal area is given in Table 4.9.17 the Segment-wise results are given in the table below.

Stations	Biomass (g/m^2; wet weight)			Population ($Ind./m^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Coastal (Sts BY1 to BY3)	0.62	3.54	1.93	275	1675	813	2	3	2
Lower creek (St BY4)	0.30	0.70	0.40	75	125	94	1	2	1
Middle creek (St BY5)	0.66	58.32	23.24	1050	2500	1544	2	9	5
Upper creek (St BY6)	0.50	217.80	56.20	475	4550	1619	1	7	4
Overall	0.30	217.80	20.44	75	4550	1017	1	9	3
April 2016 (Premonsoon)									
Coastal (Sts BY1 to BY3)	No collection (Rocky bottom)								
Lower creek (St BY4)	0.10	3.10	1.70	50	350	181	1	3	2
Middle creek (St BY5)	13.96	43.08	29.01	2000	2500	2225	5	6	5
Upper creek (St BY6)	10.40	25.40	16.70	700	2525	1276	4	7	6
Overall	0.10	217.80	16.96	50	4550	1175	1	9	4

The upper and middle creek sustained the highest standing stock of macrobenthic fauna as compared to rest of the creek during the study period. The faunal group diversity did not indicate any trend in the group distribution (Tables 4.9.18 and 4.9.19). The macrobenthic fauna was mostly dominated by Polychaeta, Amphipoda and Pelecypoda.

e) Meiobenthos

Meiobenthic standing stock in Thane Creek and associated coastal area is given in Table 4.9.20 and the segment -wise results are given in the table below.

Stations	Biomass ($\mu g/10cm^2$)			Population (Ind./ $10cm^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Coastal (Sts BY1 to BY3)	41.32	73.98	57.65	116	182	149	2	3	2
Lower creek (St BY4)	23.36	47.48	35.42	45	127	86	3	4	3
Middle creek (St BY5)	8.51	28.29	18.4	7	109	58	1	4	2
Upper creek (St BY6)	11.69	30.03	20.86	14	326	170	2	5	3
April 2016 (Premonsoon)									
Coastal (Sts BY1 to BY3)	Rocky Bottom								
Lower creek (St BY4)	126.38	169.34	147.86	23	93	58	2	4	3
Middle creek (St BY5)	1.24	29.22	15.23	1	42	22	1	1	1
Upper creek (St BY6)	23.56	95.68	59.62	7	85	46	1	3	2

In general, biomass was higher in coastal and lower creek region with the absence of discernible trend in the faunal group diversity. The dominant faunal groups included foraminiferans (in postmonsoon) and nematodes (in premonsoon) (Tables 4.9.21 and 4.9.22).

4.10 Patalganga Estuary (PT)

Patalganga is a minor river joining the Amba River which in turn joins the Mumbai harbour near Rewas. A CETP having capacity of 15.0 MLD is constructed and commissioned during 2005 and the effluent after treatment is disposed off in Patalganga Estuary through 700 mm dia underground disposal main which is about 9 km from CETP, near station PT9. Also a non-MIDC pipe line discharge is located near station PT8, quantity and quality of which is not known.

The segment represented by stations PT4 to PT6 is the lower-estuary indicated marine influence which decreased considerably in the middle estuary (stations PT7 to PT9) particularly during premonsoon. The upstream segment (stations PT10 to PT11) did not show any seawater incursion and is essentially the fresh water zone (Figure 2.2.7).

4.10.1 Water quality

The results of water quality of Patalganga is presented in Tables 4.10.1 and 4.10.2 and temporal variations at stations PT4 and PT7 shown in Figures 4.10.1 to 4.10.4.The results (average) are summarized in the following table.

Parameters	Zone					
	December 2015 (Postmonsoon)			April 2016 (Premonsoon)		
	Lower estuary (PT4 to PT6)	Middle estuary (PT7 to PT9)	Upper estuary (PT10 & PT11)	Lower estuary (PT4 to PT6)	Middle estuary (PT7 to PT9)	Upper estuary (PT10 & PT11)
WT(ºC)	28.6	27.3	26.5	31.1	28.6	30.1
pH	7.6	7.5	7.0	7.6	7.5	7.2
SS (mg/l)	20	17	10	104	71	60
Turbidity (NTU)	18.6	20.9	15.7	19.9	22.6	18.2
Salinity (ppt)	17.4	1.3	0.4	23.2	3.2	0.3
DO(mg/l)	4.8	1.8	6.4	4.5	1.8	5.9
BOD(mg/l)	2.2	19.4	4.0	2.8	26.9	3.4
PO_4^{3-}-P (µmol/l)	1.8	11.8	2.2	2.4	2.9	0.7
TP (µmol/l)	2.7	7.6	12.9	3.6	3.7	1.6
NO_3^--N (µmol/l)	35.8	4.4	21.5	21.1	11.4	8.4
NO_2^--N (µmol/l)	9.1	2.0	3.4	15.7	8.7	1.5
NH_4^+-N (µmol/l)	25.3	56.9	13.8	17.9	27.5	1.1
TN (µmol/l)	80.2	34.5	50.5	81.9	70.4	31.4
PHc (µg/l)	7.1	43.4	1.0	16.4	34.9	2.3
Phenols (µg/l)	232.9	215.4	63.0	137.2	138.8	64.9

As expected, generally the water temperature varied in accordance with prevailing air temperatures. The lowest pH in the estuary was 7.0 in the upper estuary, which was below the pH expected for natural estuarine system suggesting high microbial activity in water. SS mostly varied randomly (10 to 51 mg/l) throughout the estuary.

Salinity was relatively low (17.0 to 23.2 ppt) even in the lower estuary and decreased substantially (0.3 ppt) towards the upstream due to freshwater inflow. DO was highly variable (1.8 to 6.4 mg/l) in the estuary indicating excess loading of organic matter.

The nutrients like phosphate (0.7 to 11.8 µmol/l), nitrate (4.4 to 35.8 µmol/l), nitrite (1.5 to 15.7 µmol/l) and ammonia (1.1 to 56.9 µmol/l) varied on a wide range and averages revealed significant enhancement in the entire water body. The high levels of ammonia and nitrite in the estuary clearly indicated deterioration in its water quality.

Occurrence of high concentrations of NH_4^+-N and sometimes NO_2^--N in the estuary throughout the temporal measurements (Figures 4.10.1 to 4.10.4) as well as under saturated DO supported the deteriorated water quality of the estuary probably due to release of effluents.

4.10.2 Sediment quality

The consolidated result for sediment quality of the Patalganga Estuary is presented in Tables 4.10.3 and 4.10.4 and summarized in the following table.

Parameter		Range	
		December 2015 (Postmonsoon)	April 2016 (Postmonsoon)
Texture (%)	Sand	3.5-66.2	2.6-67.4
	Silt	25.6-85.1	5.5-87.1
	Clay	6.4-54.7	2.2-87.1
Metals	Al (%)	5.5-7.5	6.0-8.3
	Cr (µg/g)	174-525	148-507
	Mn (µg/g)	750-1397	689-1512
	Fe (%)	6.9-11.8	6.7-11.2
	Co (µg/g)	31-604	51-940
	Ni (µg/g)	55-158	67-218
	Cu (µg/g)	77-377	83-3880
	Zn (µg/g)	85-388	72-592
	Cd (µg/g)	0.32-2.10	0.22-1.80
	Hg (µg/g)	0.04-2.60	0.04-3.64
	Pb (µg/g)	10.8-31.9	9.2-33.6
P (µg/g)		1002-3673	869-3908
C_{org} (%)		0.6-4.0	0.3-4.1
PHc (µg/g)		0.9-13.9	1.6-13.5

Dry wt basis except PHc which is wet wt basis

The texture of sediment in the estuary varied from silty-sand to clayey-silt varying seasonaly. The concentration of metals varied widely with definite build up in the middle estuary, indicating input from anthropogenic sources. Similar results were also observed for C_{org} and phosphorus and PHc concentrations.Sediments of the lower estuary represented the concentrations generally observed in the catchment soil. Hg showed an increase in the both season.

4.10.3 Flora and fauna

The results of biological characteristics of the Patalganga Estuary are presented in Tables 4.10.5 to 4.10.24 and temporal variations at stations PT4 and PT7 shown in Figures 4.10.5 to 4.10.11.

a) Microbes

Based on faecal indicator bacteria like TVC, TC, FC, ECLO and pathogenic microbes like, SHLO, PKLO, VPLO and VCLO Patalganga is a highly contaminated estuary. The estuary harbourered high number of microbial counts (in CFU/ml) at lower and middle regions during postmonsoon and upper and middle during premonsoon seasons as given in the table below.

Water	Zone					
	December 2015 (Postmonsoon)			April 2016 (Premonsoon)		
Type of Bacteria	Lower estuary (StnPT4, PT4A, PT5,PT6)	Middle Estuary (Stn PT7, PT8&PT9)	Upper estuary (Stn PT10 & PT11)	Lower estuary (Stn PT4, PT4A, PT5,PT6)	Middle estuary (Stn PT7, PT8 & PT9)	Upper estuary (Stn PT10 & PT11)
TVC	274×10^3	722×10^3	24×10^3	25×10^3	318×10^3	256×10^3
TC	584	1620	90	150	210	2085
FC	168	600	80	130	1250	245
ECLO	71	297	70	22	44	100
SHLO	49	393	40	60	10	35
SLO	25	100	10	240	0	425
PKLO	116	1313	70	10	55	5
VLO	266	760	80	332	163	1465
VPLO	104	460	40	650	50	35
VCLO	201	266	40	247	130	215
PALO	198	528	45	792	155	250
SFLO	50	55	15	540	75	5

In sediment samples the microbial counts (CFU/g) were high during post monsoon as compared to premonsoon. The TVC counts were abnormally high at all stations during pre and postmonsoon (Tables 4.10.5 to 4.10.8). The sediments of the estuary revealed very high contamination of pathogenic bacteria during the study period.

Sediment	Zone					
	December 2015 (Postmonsoon)			April 2016 (Premonsoon)		
Type of Bacteria	Lower estuary (Stn PT4, PT4A, PT5,PT6)	Middle estuary (Stn PT7, PT8 & PT9)	Upper estuary (Stn PT10 & PT11)	Lower estuary (Stn PT4, PT4A, PT5,PT6)	Middle estuary (Stn PT7, PT8 & PT9)	Upper estuary (Stn PT10 & PT11)
TVC	3750×10^3	1400×10^3	2850×10^3	168×10^3	239×10^3	307×10^3
TC	375	1100	160	10	40	45
FC	170	157	135	20	1235	15
ECLO	105	137	120	80	60	25
SHLO	30	183	0	57	25	5
SLO	90	103	0	143	0	405
PKLO	27	593	0	0	15	5

VLO	265	230	25	7	145	185
VPLO	113	110	0	10	475	15
VCLO	127	187	25	20	270	140
PALO	247	103	50	30	795	155
SFLO	117	0	75	0	190	5

b) Phytoplankton

The results on phytoplankton in the Patalganga estuary are given in Tables. 4.10.9 to 4.10.14. The Segment-wise distribution of chlorophyll *a* and phaeophytin (range and average) are summarized below.

Zone	**Chlorophyll *a* (mg/m^3)**			**Phaeophytin (mg/m^3)**		
	Min	**Max**	**Avg**	**Min**	**Max**	**Avg**
December 2015 (Postmonsoon)						
Lower estuary (Sts PT4, PT4A, PT5 & PT6)	2.3	26	8.45	0.4	5	1.4
Middle estuary (Sts PT7, PT8 & PT9)	14.5	30.7	22.2	1.4	7.8	5.2
Upper estuary (Sts PT10 & PT11)	23.1	29.2	25.7	2.2	6.7	5.3
April 2016 (Premonsoon)						
Lower estuary (Sts PT4, PT4A, PT5 & PT6)	1.14	25.22	8.38	0.3	10.58	3.19
Middle estuary (Sts PT7, PT8 & PT9)	5.29	15.22	9.75	3.05	10.36	7.22
Upper estuary (Sts PT10 & PT11)	0.98	2.57	1.67	1.22	3.65	2.13

The concentration of chlorophyll *a* was often high in the middle and upper zones of the estuary due to high primary productivity fuelled by high concentrations of nutrients during the study period. The concentration of phaeophytin was much lower than that of chlorophyll *a* indicating an environment conducive to the growth of phytoplankton. The average concentration of chlorophyll *a* and phaeophytin ranged from 1.67 to 25.7 mg/m^3 and 1.4 to 7.22 mg/m^3 respectively during the study period (Tables 4.10.9 and 4.10.10 and Figures 4.10.5 to 4.10.8). The distribution of phytoplankton cell count and population is given in the table below.

Zone	Cell density (x10³ Cells/l)			Total genera (Nos.)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)						
Lower estuary (Sts PT4, PT4A, PT5 & PT6)	151.8	12479.2	2314.2	15	32	22
Middle estuary (Sts PT7, PT8 & PT9)	2974.4	96607	37108.4	28	40	34
Upper estuary (Sts PT10 & PT11)	7517.6	19614.2	13565.9	35	52	44
April 2016 (Premonsoon)						
Lower estuary (Sts PT4, PT4A, PT5 & PT6)	257.2	2395.6	1099.2	21	29	26
Middle estuary (Sts PT7, PT8 & PT9)	257.2	2395.6	1099.2	21	29	26
Upper estuary (Sts PT10 & PT11)	103.8	312.4	208.1	16	22	19

Phytoplankton cell count (Tables 4.10.11 and 4.10.12) varied widely between 103.8 x 10^3 and 19614.2 x 10^3 Cells/l during the study period. Postmonsoon sustained very high phytoplankton population as compared to premonsoon. Phytoplankton population recorded at the upper estuary revealed prevalence of eutrophic conditions especially during postmonsoon. *Merismopedia* was the most dominant genera followed by *Cyclotella, Aulacoseira* and *Dictyosphaerium* in December 2016. Whereas, *Synechocystis* was the most dominant genera followed by *Scenedesmus, Thalassiosira* and *Coelastrum* in April 2016(Tables 4.10.13 and 4.10.14). Thus, a noticeable change in the generic dominance of phytoplankton was evident.

d) Zooplankton

Zooplankton standing stock interms of biomass (0.3-6.1 ml/100m^3) and population (0.3-13.5 nox10^3/100m^3) varied considerably during postmonsoon, wheras during premonsoon it varied on a wide range (0.5-27 ml/100m^3 and 16.6-283 nox10^3/100m^3) (Tables 4.10.15 and 4.10.16).

During premonsoon season the Copepods and Decapod larvae were the most dominant group. Other major groups were Mysids, gastropods, and chaetognaths. A significant decrease in diversity of zooplankton at the upper estuary as compared to the lower estuary suggested the impact of anthropogenic pollutants on zooplankton community. The population and diversity was higher in premonsoon at station PT4 (Figures 4.10.9 and 4.10.10). The segment-wise averaged zooplankton standing stock is given in the table below.

Zone	Biomass (ml/100m^3)			Population (no x 10^3/100m^3)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Lower estuary (Sts PT4 to PT6)	0.3	6.1	1.5	0.3	13.5	2.3	4	11	8
Middle estuary (St PT7 to PT9)	Samples not collected								
Upper estuary (St PT10& PT11)	Samples not collected								
April 2016 (Premonsoon)									
Lower estuary (Sts PT4 to PT6)	0.5	27.0	7.0	16.6	283.3	63.0	14	18	15
Middle estuary (St PT7 to PT9)	Samples not collected								
Upper estuary (St PT10& PT11)	Samples not collected								

The community consisted of high population of decapod larvae, copepods, *Acetes* sp, and polychaetes. The other common groups were medusae, mysids, gastropods, *Lucifer* sp., lamellibranchs, appendicularians and isopods Overall, 4-18 groups of zooplankton were encountered (Tables 4.10.17 and 4.10.18).

d) Macrobenthos

The results on macrobenthic standing stock interms of biomass, population and total faunal group are given in Table 4.10.19 and segment wise distribution of macrobenthos (range and average) is given below.

Stations	Biomass (g/m^2; wet weight)			Population (Ind./m^2)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Lower estuary (PT4, PT4A, PT5 & PT6)	0.13	5.53	1.79	100	950	480	1	4	2
Middle estuary (Sts PT7, PT8 & PT9)	0.10	5.10	1.73	50	5700	1667	1	4	2
Upper estuary (St PT10 & PT11)	0.42	14.10	4.62	25	2000	674.88	1	1	1
Overall	0.10	14.10	2.40	25	5700	919	1	4	2
March 2016 (Premonsoon)									
Lower estuary (PT4, PT4A, PT5 & PT6)	0.03	25.51	4.79	50	3000	1170	1	8	3
Middle estuary (Sts PT7, PT8 & PT9)	0.01	19.56	5.24	100	15725	4882	1	5	2

Upper estuary (St PT10& PT11)	No collection								
Overall	0.70	105.0	16.0	200	13175	4011	3	7	5

The macrobenthic biomass was relatively poor in the estuary during December 2015 which would be probably affected during monsoon and increased during March 2016 indicating considerable temporal variations. The populations also varied widely and ranged from 25 to 5700 ind./m^2 in Postmonsoon and 200-13175 ind./m^2 in Premonsoon. The fauna was constituted mainly by Polychaeta and Oligochaeta. A total of 10 faunal groups were identified during the Postmonsoon and 15 in Premonsoon (Tables 4.10.20 and 4.10.21).

e) Meiobenthos

Meiobenthic standing stock in Patalganga estuary and associated coastal area is given in Tables 4.10.22 and the segment-wise results are given in the table below.

Stations	Biomass (µg/10cm^2)			Population (Ind./ 10cm^2)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Lower estuary (PT4, PT4A, PT5 & PT6)	53.29	5341.05	1625.57	75	1035	583	4	7	6
Middle estuary (Sts PT7, PT8 & PT9)	93.93	2782.81	830.18	37	2606	687	5	8	7
Upper estuary (St PT10& PT11)	2.85	117.48	31.96	28	41	34	2	4	3
March 2016 (Premonsoon)									
Lower estuary (PT4, PT4A, PT5 & PT6)	8.32	311.24	74.56	10	341	74	2	6	4
Middle estuary (Sts PT7, PT8 & PT9)	64.28	22651.8	7465.77	25	4069	1340	3	8	6
Upper estuary (St PT10& PT11)	6945	8679.04	7812	7161	7691	7426	7	9	8

In premonsoon, the lower estuary showed the lowest meiofaunal density (avg. 74 Ind./10cm^2) whereas, the upper estuary showed the highest meiofaunal density (avg. 7691 Ind./10cm^2). The exact reverse trend was observed in postmonsoon which may be indicative of monsoonal wash-off from upper to lower estuary and consequential displacement of fauna. The high biomass in postmonsoon (PT6) and premonsoon (PT7) (Table 4.10.22) is mainly contributed by Polychaetes (Table 4.10.23 and 4.10.24).

4.11 Amba Estuary (AB)

Amba estuary joins Mumbai harbour at Rewas, The river receives effluents from several industries mainly petrochemical. Four stations AB4 & AB5 (lower), AB6 & AB7 (middle) and AB8 & AB9 (upper) representing different estuarine segments were considered for study as shown in Figure 2.2.8.

4.11.1 Water quality

The results of water quality of the Amba Estuary are compiled in Tables 4.11.1 and 4.11.2 and the temporal variations are illustrated in Figures 4.11.1 to 4.11.2 at station AB4. The average water quality of different segments of the estuary is given in the following table.

Parameter	Zone					
	December 2015 (Postmonsoon)			April 2016 (Premonsoon)		
	Lower Estuary (Sts AB4 & AB5)	Middle Estuary (Sts AB6 & AB7)	Upper Estuary (Sts AB8, AB9)	Lower Estuary (Sts AB4 & AB5)	Middle Estuary (Sts AB6 & AB7)	Upper Estuary (Sts AB8)
WT(^oC)	29.4	28.1	28.1	30.3	32.1	31.8
pH	7.6	7.6	7.6	7.8	7.8	7.7
SS (mg/l)	35	47	46	78	48	36
Turbidity(NTU)	7.0	4.4	11.2	7.0	5.9	13.6
Salinity (ppt)	31.8	27.8	10.5	35.8	34.9	29.3
DO(mg/l)	5.7	6.3	6.3	4.4	5.2	4.6
BOD(mg/l)	1.9	3.4	3.5	2.1	2.6	2.7
PO_4^{3-}-P (µmol/l)	1.9	2.6	2.2	9.0	4.8	9.0
TP (µmol/l)	8.0	3.3	7.8	14.1	9.0	12.5
NO_3^--N(µmol/l)	29.2	8.8	21.2	15.8	37.0	45.1
NO_2^--N(µmol/l)	6.8	2.4	2.4	1.3	2.5	4.3
NH_4^+-N(µmol/l)	10.8	3.5	2.5	4.3	5.6	1.4
TN (µmol/l)	37.0	19.6	59.0	47.4	76.0	64.6
PHc (µg/l)	5.3	6.0	5.4	5.9	6.6	6.1
Phenols (µg/l)	185.2	415.7	305.7	22.8	35.1	58.9

The variations in water temperature were in narrow range for each season as expected for shallow coastal waters. The SS was of natural origin and resulted from dispersion of bed sediment in water by currents. The lower and middle estuarine segments were seawater dominated during dry season and had average salinity of more than 27.8 ppt. Considerable influence of fresh water in the inner estuary was indicated during postmonsoon. The pH

(7.6-7.8) of the estuary was almost in the range observed for typical estuarine waters (7.8-8.3).

The DO though varied widely generally averaged above 4.0 mg/l. High concentrations of NH_4^+-N and to some extent NO_2^--N and PO_4^{3-}-P, and its increase in the mouth reason suggested influence of Patalganga Estuary in the downstream. Similarly high concentration of phenols during postmonsoon season indicated build up of phenols during postmonsoon season. Though the estuary receives effluent from a petrochemical complex, the build up of PHc was not noted in the region during study period.

Temporal variations in the estuary (Figures 4.11.1 to 4.11.2) revealed high DO over the period of measurements. High concentrations of NH_4^+-N and NO_2^--N during some temporal measurements indicated that the estuary was under some environmental stress.

4.11.2 Sediment quality

The sediment quality of the Amba Estuary is presented in Tables 4.11.3 and 4.11.4 and summarized in the following table.

Parameter		Range	
		December 2015 (Postmonsoon)	April 2016 (Premonsoon)
Texture (%)	Sand	1.0-44.6	0.9-4.2
	Silt	27.6-86.2	51.4-89.9
	Clay	9.6-56.4	9.2-47.2
Metals	Al (%)	2.3-7.5	5.1-8.1
	Cr (µg/g)	95-307	111-210
	Mn (µg/g)	183-1187	773-1421
	Fe (%)	3.7-8.4	5.1-8.6
	Co (µg/g)	25-67	36-62
	Ni (µg/g)	26-104	56-88
	Cu (µg/g)	34-132	64-139
	Zn (µg/g)	10-109	53-104
	Cd (µg/g)	0.15-0.23	0.20-0.29
	Hg (µg/g)	0.04-0.15	0.08-0.15
	Pb (µg/g)	10.2-28.7	8.4-20.2
P (µg/g)		1068-1548	1000-1364
C_{org} (%)		1.4-2.6	0.8-2.6
PHc (µg/g)		1.1-3.0	0.3-2.1

Dry wt basis except PHc which is wet wt basis

The sediment was mainly silty clay though texture varied widely. Though the concentrations of trace metals varied considerably, ranges did not indicate gross contamination of sediment by anthropogenic sources. Likewise, the concentrations of C_{org} and P, and PHc in sediment of the estuary were also low and did not indicate their built-up.

4.11.3 Flora and fauna

The results of the biological characteristics of the Amba estuary are summarized in Tables 4.11.5 to 4.11.22 and temporal variation for station AB4 and AB5 shown in Figures 4.11.3 to 4.11.5.

a) Microbes

In Postmonsoon 2015, Amba estuary sustained higher count of (CFU/ml) TVC, TC, FC and VLO during ebb period at stations AB4 and AB7 as evident in Table 4.11.5. This suggests contamination of the region by sewage.However; organisms such as SFLO, PALO, SHLO, PKLO and SLO were either absent or recorded in very low numbers.

Water	Zone					
	December 2015 (Postmonsoon)			April 2016 (Premonsoon)		
Type of Bacteria	Lower Estuary (Sts AB4 & AB5)	Middle Estuary (Sts AB6 & AB7)	Upper Estuary (Sts AB8, AB9)	Lower Estuary (Sts AB4 & AB5)	Middle Estuary (Sts AB6 & AB7)	Upper Estuary (Sts AB8)
TVC	43 x 10^3	38 x 10^3	55 x 10^3	15 x 10^3	13 x 10^3	11 x10^3
TC	38	40	40	88	100	30
FC	25	27.5	25	56	75	20
ECLO	8	7.5	5	43	60	10
SHLO	3	20	30	5	0	ND
SLO	15	0	0	ND	0	ND
PKLO	10	5	0	60	37.5	10
VLO	45	10	35	118	122.5	40
VPLO	8	7.5	10	90	77.5	40
VCLO	30	2.5	25	27.5	45	ND
PALO	3	5	5	ND	0	ND
SFLO	3	0	0	ND	0	ND

Bacterial counts (CFU/g) in sediments are given in the table below. Organisms like TC, FC, ECLO, SHLO, PKLO, VPLO and VCLO were relatively high at stations AB7 and AB8 during Post monsoon 2015 as compared to stations AB4 and AB6. During Pre monsoon 2016, TC, FC and ECLO were recorded at middle and lower estuary (AB4, AB5 and AB7) while counts for VL and VPLO were very low numbers at middle and lower estuary.

Sediment	Zone					
	December 2015 (Postmonsoon)			April 2016 (Premonsoon)		
Type of Bacteria	Lower Estuary (Sts AB4 & AB5)	Middle Estuary (Sts AB6 & AB7)	Upper Estuary (Sts AB8, AB9)	Lower Estuary (Sts AB4 & AB5)	Middle Estuary (Sts AB6 & AB7)	Upper Estuary (Sts AB8)
TVC	51500x 10^3	100000 x 10^3	700000 x 10^3	160 x 0^3	130 x 10^3	100 x 10^3
TC	ND	50	60	40	40	ND
FC	ND	45	60	20	25	ND
ECLO	ND	10	50	10	15	ND
SHLO	ND	40	320	ND	0	ND
SLO	ND	0	ND	ND	0	ND
PKLO	ND	10	40	15	0	ND
VLO	40	140	390	10	15	ND
VPLO	ND	95	190	10	10	ND
VCLO	20	45	200	ND	5	ND
PALO	ND	0	10	ND	0	ND
SFLO	ND	0	10	ND	0	ND

Thus, pathogenic contamination of the estuary was evident from above results.

b) Phytoplankton

The distribution of chlorophyll *a* and phaeophytin are given in Tables 4.11.7 to 4.11.12 and summarized in the following table.

Zone	Chlorophyll *a* (mg/m^3)			Phaeophytin (mg/m^3)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (postmonsoon)						
Lower estuary (Sts AB4 & AB5)	2.4	7.4	4.2	0.8	2.6	1.5
Middle estuary (Sts AB6& AB7)	2.1	4.8	3.1	0.6	1.8	1.3
Upper estuary (Sts AB8 to AB10)	2.0	4	2.9	1.1	1.6	1.45
May 2016 (Premonsoon)						
Lower estuary (Sts. AB4 & AB5)	7.1	20.2	7.2	0.1	6.3	3.5
Middle estuary (Sts AB6 & AB7)	5.7	24.5	12.9	0.8	6.4	3.1
Upper estuary (Sts AB8 to AB10)	3.1	6.6	4.7	2.0	3.9	2.7

The concentration of chlorophyll *a* in the estuary varied considerably with a definite increase in premonsoon though discernible trend of distribution in the estuary (Tables 4.11.7 to 4.11.12 and Figures 4.11.3 and 4.11.4) was absent. High levels of phaeophytin occurred during premonsoon but were in the expected range during postmonsoon.

Phytoplankton cell count also varied widely as evident from the following table.

Zone	Cell density (No. X10³ Cells/l)			Total genera (Nos.)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)						
Lower estuary (Sts AB4 & AB5)	54.2	236	134.2	17	25	21
Middle estuary (Sts AB6 & AB7)	21	101.2	58.55	10	16	12
Upper estuary (Sts AB8 to AB10)	22.6	35.6	26.95	8	12	11
May 2016 (Premonsoon)						
Lower estuary (Sts AB4 & AB5)	133.4	394.4	290.15	19	27	22.5
Middle estuary (Sts AB6 & AB7)	188.8	2866.4	804	20	32	25
Upper estuary (Sts AB8 to AB10)	180.6	602.6	372.7	17	22	20

No major spatial variation in phytopigments was discernable but cell counts were relatively high in middle estuary whereas generic diversity was always better in the lower estuary. The community structure in terms of generic distribution varied from 8 to 32 (Tables 4.11.9 and 4.11.10). In all 22 genera were common during the two seasons. The dominant genera from December 2015 are in following order; *Skeletonema, Thalassiosira, Navicula, Thalassionema, Coscinodiscus* and *Alexandrium;* whereas in May 2016 *Skeletonema* was the dominant as same in postmonsoon followed by *Cylindrotheca, Nitzschia, Thalassiosira* and*Ditylum* (Tables 4.11.11 and 4.11.12). Thus the change in seasonal generic dominance was noticed.

c) Zooplankton

Zooplankton standing stock interms of biomass (av 8.1ml/100m^3) and population (av 19.7 x 10^3 no/100m^3) was indicative of an overall low secondary productivity in the estuary during the premonsoon of 2016, with 2-3 fold decrease was seen for zooplankton, during postmonsoon (December 2015), in biomass (av 3.3 ml/100m^3) and population (37.4 x 10^4 no/100m^3) (Tables 4.11.13 and 4.11.14, Figure 4.11. 5).The distribution of zooplankton biomass and population was highly variable. Results of zooplankton biomass, population and total genera are summarized seasonally and zone wise below.

Zone	Biomass (ml/100m^3)			Population (no x 10^3/100m^3)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Postmonsoon December 2015									
Lower Estuary (Sts AB4 , AB5)	**No samples collected**								
Middle Estuary (Sts AB6 and AB7)	0.9	6.2	3.4	2.9	24.7	13.3	13	15	14
Upper Estuary (Sts AB8 and AB9)	-	-	3.2	-	-	61.5	-	-	11
Premonsoon May 2016									
Lower Estuary (Sts AB4 , AB5)	3.4	16.8	9.1	12.8	99.0	34.4	11	14	12
Middle Estuary (Sts AB6 and AB7)	8.1	15.8	10.6	9.8	14.4	12.6	9	13	11
Upper Estuary (Sts AB8 and AB9)	2.3	7.3	4.8	2.2	22.2	12.2	9	11	10

These results reveal that zooplankton production interms of biomass, population and group diversity was high in the lower estuary. Similarly the standing stock and community structure were low in the upper estuary. Thus a gradual reduction in the standing stock and diversity of zooplankton from lower to upper estuary was noticed.

The community structure mainly consisted of copepods, decapod larvae, chaetognaths and *Lucifer* sp. The other common groups were foraminiferans, medusae, ctenophores, polychaetes, amphipods, mysids, lamellibranchs, appendicularians and gastropods. Overall, 9- 15 groups were recorded respectively during the study period (Tables 4.11.15 and 4.11.16). Good numbers of fish eggs and fish larvae were noticed suggesting fairly good fishery potential for Amba Estuary.

d) Macrobenthos

The standing stock of macrobenthos interms of population (0 to 1875 Ind/m^2) and biomass (0 to 24.30 g/m^2; wet wt) varied widely (Table 4.11.17) and no appreciable seasonal and spatial variability in benthic standing stock was evident.

The range and average standing stock with total faunal groups are summarized below.

Stations	Biomass (g/m^2; wet weight)			Population ($Ind./m^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Lower estuary (Sts AB4 & AB5)	0.30	1.40	0.80	275	725	519	1	5	3
Middle estuary (Sts AB6 & AB7)	0.59	3.00	1.60	125	950	453	1	7	3
Upper estuary (Sts AB8 & AB9)	0.03	24.30	3.90	125	1875	809	1	4	3
Overall	0.03	24.30	2.10	125	1875	594	1	7	3
May 2016 (Premonsoon)									
Lower estuary (Sts AB4 & AB5)	1.20	9.10	4.80	100	500	279	2	4	3
Middle estuary (Sts AB6 & AB7)	0.10	1.90	0.73	200	1250	641	2	7	4
Upper estuary (Sts AB8 & AB9)	0.00	0.90	0.29	0	675	272	0	8	4
Overall	0.00	9.10	1.94	0	1250	397	0	8	4

It is evident from the above table that though no specific trend was noticed in biomass distribution, population counts remained higher in the upper estuarine segment during Postmonsoon. The number of faunal groups encountered varied from 0 to 8 during study period; average values being 3 and 4 during Postmonsoon and Premonsoon respectively with Polychaeta as the major group (Tables 4.11.18 1nd 4.11.19).

e) Meiobenthos

Meiobenthic standing stock in Amba estuary and associated coastal area is given in table 4.11.20 and the segment-wise results are given in the table below.

Stations	Biomass ($\mu g/10cm^2$)			Population ($Ind./ 10cm^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Lower estuary (Sts AB4 & AB5)	88.6	170.24	129.43	55	68	62	6	7	6
Middle estuary (Sts AB6& AB7)	11.34	219.32	105.72	28	611	288	2	8	4
Upper estuary (Sts AB8 & AB9)	374.35	342.99	358.67	221	257	239	2	2	2
May 2016 (Premonsoon)									
Lower estuary (Sts AB4 & AB5)	414.88	948.6	681.74	72	978	525	2	12	7

Middle estuary (Sts AB6 & AB7)	255.17	902.51	578.84	249	497	402	6	9	8
Upper estuary (Sts AB8 & AB9)	20.36	24.88	22.62	65	72	69	4	6	5

The standing stock of meiobenthos in terms of population (28 to 978 ind./ 10cm^2 and biomass (11.34 to 948.6 µg/10cm^2) varied widely (Tables 4.11.20) and no appreciable seasonal and spatial variability in meio benthic standing stock was evident. In both seasons, nematodes dominated the meiofaunal community (Tables 4.11.21 1nd 4.11.22).

4.12 Thal (Thal D.P.)

A single station was considered for study in the nearshore waters off Thal (Figure 2.2.8). Treated effluent from Rashtriya Chemicals and Fertilizers Corporation (RCF) is being discharged through a marine outfall in the vicinity of the sampling location.

4.12.1 Water quality

The result of water quality off Thal is compiled in Tables 4.12.1 and 4.12.2 and the temporal variations are illustrated in Figures 4.12.1 and 4.12.2 at station Thal D.P. The average water quality is summarized in the following table.

Parameter	Zone	
	December 2015 (Postmonsoon)	April 2016 (Premonsoon)
WT(ºC)	28.4	29.5
pH	7.9	7.9
SS (mg/l)	230	120
Turbidity (NTU)	53.6	55.9
Salinity (ppt)	34.9	36.3
DO(mg/l)	4.2	5.5
BOD(mg/l)	2.2	3.1
PO_4^{3-}-P (µmol/l)	2.3	2.9
TP (µmol/l)	4.2	5.5
NO_3^--N (µmol/l)	30.9	9.2
NO_2^--N (µmol/l)	0.9	0.9
NH_4^+-N (µmol/l)	4.9	1.2
TN (µmol/l)	127.8	48.1
PHc (µg/l)	11.1	10.0
Phenols (µg/l)	228.0	182.0

The temperature, SS, salinity, pH, DO, BOD nutrients and PHc off Thal indicated natural coastal waters with no evidence for deterioration in water quality due to release of effluents from the fertilizer complex. The phenol however was markedly high, especially during postmonsoon season suggesting terrestrial input in the coastal water off Thal.

Temporal variations at station Thal DP revealed markedly high concentrations of NO_3^--N and NH_4^+-N, especially during postmonsoon season. Repeat monitoring is necessary to identify if such high concentrations persist in the region or it was a chance occurrence since the possibility of outflow from the Thane Creek during monsoon influencing the Thal area exists.

4.12.2 Sediment quality

The consolidated results for sediment quality of the Thal coastal system are presented in Tables 4.12.3 and 4.12.4 and summarized in the following table.

Parameter		Range	
		Postmonsoon	Premonsoon
Texture (%)	Sand	2.6	1.5
	Silt	81.8	85.3
	Clay	15.6	13.2
Metals	Al (%)	7.1	6.9
	Cr (µg/g)	182	193
	Mn (µg/g)	882	473
	Fe (%)	8.2	8.5
	Co (µg/g)	68	63
	Ni (µg/g)	69	73
	Cu (µg/g)	124	123
	Zn (µg/g)	93	92
	Cd (µg/g)	0.17	0.15
	Hg (µg/g)	0.02	0.06
	Pb (µg/g)	15.8	13.3
P (µg/g)		1715	1625
C_{org} (%)		1.3	1.2
PHc (µg/g)		1.0	1.6

Dry wt basis except PHc which is wet wt basis

The sediment of coastal waters of Thal was mostly clayey-silt. The results indicated that the sediment is grossly free from anthropogenic trace metals, C_{org} and P.

4.12.3 Flora and fauna

The results of the biological characteristics of the Thal are summarized in Tables 4.12.5 to 4.12.22 and temporal variation for station Thal D.P. shown in Figures 4.12.3 to 4.12.6.

a) Microbes

TC, FC, ECLO, SHLO and SLO counts (CFU/ml) were comparable during post and pre monsoon periods. TVC counts were high during pre monsoon compareto post monsoon while other pathogens were high with absence of SLO. (Table 4.12.5).

Water	Zone	
Type of Bacteria	December 2015 (Postmonsoon)	April 2016 (Premonsoon)
TVC	$32x10^3$	$231\ x10^3$
TC	285	390
FC	235	245
ECLO	165	160
SHLO	220	165
SLO	ND	ND
PKLO	40	240
VLO	145	4750
VPLO	125	ND
VCLO	20	4750
PALO	ND	70
SFLO	170	20

In sediment sample during pre monsoon the TVC counts (CFU/g) were high compared to post monsoon season. Generally, high counts occurred during pre monsoon (Table 4.12.6). Also the sediment was contaminated with many other pathogens as given in table below.

Sediment		
Type of Bacteria	December 2015 (Postmonsoon)	April 2016 (Premonsoon)
TVC	$320x\ 10^3$	$1000x\ 10^3$
TC	50	360
FC	10	190
ECLO	10	ND
SHLO	ND	510
SLO	ND	ND
PKLO	70	30
VLO	70	390
VPLO	50	20
VCLO	20	370
PALO	ND	ND
SFLO	ND	ND

b) Phytoplankton

The phytopigments in Thal showed high temporal variation. In premonsoon, phaeophytin concentration was greater than chlorophyll a which is indicative of environment non-conducive to phytoplankton growth. But the reverse condition was observed in postmonsoon (Tables 4.12.7 and 4.12.8) (Figures 4.12.3 and 4.12.4) as indicated in the table below.

Zone	Chlorophyll (mg/m^3)			Phaeophytin (mg/m^3)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (postmonsoon)						
Thal DP	1.4	18.8	4.55	0.5	7.2	2.4
April 2016 (Premonsoon)						
Thal DP	1.29	1.78	1.49	1.00	3.60	2.01

Zone	Cell counts (no x 10^3/l)			Total genera (no)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)						
Thal DP	57.6	150.4	99.85	16	22	20
April 2016 (Premonsoon)						
Thal DP	24.8	45	37.95	9	12	10

The average phytoplankton cell count and generic diversity was much lower in premonsoon than postmonsoon and so also phytopigments (Tables 4.12.9 and 4.12.10). In premonsoon, *Thalassiosira, Gymnodium, Nitzschia* were the most dominant genera, whereas, *Prorocentrum, Pseudonitzschia, Thalassiosira and Asterionella* were the most abundant in postmonsoon (Tables 4.12.11 and 4.12.12) suggesting seasonal changes in generic dominance.

c) Zooplankton

Zooplankton biomass didn't show much variation seasonally. Although population was higher in premonsoon (73.2 x 10^3/100m^3) with respect to post monsoon (25 x 10^3/100m^3). Overall, 17 and 13 faunal groups were recorded during premonsoon and postmonsoon periods respectively (Tables 4.12.13 and 4.12.14). Copepods, foraminiferans, lamellibranchs, decapod larvae, chaetognaths, and gastropods were the common faunal groups during premonsoon, whereas copepods, lamellibranchs, decapod larvae, *Lucifer* sp., chaetognaths, gastropods, foraminiferans, polychaetes, fish larvae and isopods were common faunal groups during postmonsoon (Tables 4.12.15 and 4.12.16, Figures 4.12.5 and 4.12.6).

Zone	Biomass (ml/100m³)			Population (no x 10³/100m³)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Postmonsoon December 2015									
Thal DP	1.8	6.0	3.1	20.9	43.7	25	15	17	16
Premonsoon April 2016									
Thal DP	1.1	8.3	3.4	28.4	150.3	73.2	7	14	10

d) Macrobenthos

The macrobenthic biomass was comparable (avg. 0.04-0.05 g/m^2) between the two study periods as given in the table below. The macrofaunal population ranged from 0.10 to1.10 Ind./m^2 suggested overall low benthic productivity for the study area. Polychaetes were the only most dominant group in both the seasons (Table 4.12.18 and 4.12.19).

Stations	Biomass (g/m^2; wet weight)			Population (Ind./m^2)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Thal DP	0.10	1.10	0.40	25	150	82	1	2	2
April 2016 (Premonsoon)									
Thal DP	0.10	0.70	0.50	175	625	350	1	2	2

e) Meiobenthos

Meiobenthic standing stock off Thal is given in Table 4.12.20 and the seasonal results are given in the Table below.

Stations	Biomass (µg/10cm²)			Population (Ind./ 10cm²)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Thal DP	104.68	131.02	117.85	183	327	255	6	7	6
April 2016 (Premonsoon)									
Thal DP	101.25	597.27	349.26	35	290	163	2	5	3

The meiofaunal density was higher in postmonsoon (avg.255 ind./10cm²) than premonsoon (avg.163 ind./10cm²) as evident from above table. Biomass showed the reverse trend with higher average in premonsoon (349.26 µg/10cm²) than postmonsoon (117.85 µg/10cm²). This difference is atributed to the sizes of nematodes, the most abundant group (Table 4.12.21 and 4.12.22).

4.13 Kundalika Estuary (K)

Kundalika Estuary receives industrial wastes from MIDC estate near Dhatav situated on the southern bank of the river. Apart from industrial waste the estuary also receives around 14.0 MLD of domestic waste. The station locations are illustrated in Figure 2.2.9

Earlier (2007-08) treated effluent from CETP of MIDC, Dhatav (Roha) was being discharged at station K9. The green coloured liquid entered the estuary along the southern bank and transported downstream. MIDC has shifted the discharge point near Gophan (Station K8) and the effluent is released through a diffuser for better dispersion. Unloading operations of solid cargo, mainly iron ore is being done at Revadanda Port (Station K4) from where it is transported further inland by a conveyer belt to the refining unit. A coal handling jetty has also been established and is operational on the opposite bank of Gophan.

4.13.1 Water quality

The results of water quality of Kundalika Estuary is presented in Tables 4.13.1 and 4.13.2, temporal variations at stations K4 and K8 are illustrated in Figures 4.13.1 to 4.13.4 and summarized in the following table.

Parameter	Zone					
	December 2015 (Postmonsoon)			April 2016 (Premonsoon)		
	Coastal (Sts K1 to K3)	Lower (Sts K4, K5 K6, K7& K8)	Upper (Sts K9 & K10)	Coastal (Sts K1 to K3)	Lower (St K4, K5 K6, K7& K8)	Upper (Sts K9 & K10)
WT(°C)	27.7	27.7	27.8	29.1	29.4	29.8
pH	7.8	7.6	7.5	7.9	7.6	7.4
SS (mg/l)	139	145	114	114	147	154
Turbidity (NTU)	61.7	67.4	62.0	72.4	77.7	57.9
Salinity (ppt)	34.8	24.2	0.2	36.2	27.4	1.1
DO(mg/l)	5.8	4.9	4.6	5.8	4.8	4.1
BOD(mg/l)	2.8	3.2	8.6	3.2	3.6	8.0
PO_4^{3-}-P (µmol/l)	2.7	3.0	9.6	2.6	5.2	4.5
TP (µmol/l)	4.5	4.9	12.0	4.1	7.6	10.1
NO_3^--N (µmol/l)	10.9	19.3	29.2	12.9	25.6	15.8
NO_2^--N (µmol/l)	1.3	3.9	2.8	0.7	4.6	6.2
NH_4^+-N (µmol/l)	5.1	13.3	19.3	2.8	9.4	18.5
TN (µmol/l)	25.3	49.0	65.7	61.4	55.5	67.7
PHc (µg/l)	6.1	11.0	11.3	3.8	11.8	10.6
Phenols (µg/l)	267.9	403.7	342.8	48.6	167.4	94.6

The temperature varied with the air temperature as expected. The SS (114-154 mg/l) and turbidity were high (57.9-77.7 NTU) in both seasons and appear to be of natural origin. The pH was generally low in the estuary and its decrease in the landward direction suggested the influence of the effluent in the estuary. The estuarine waters were well-oxygenated with the DO content of 4.1 to 5.8 mg/l. However, area within the vicinity of present effluent release (station 7 to 9) was DO depleted with high BOD indicating the impact of effluent prior to its dispersion.

The inner estuary exhibited high levels of phosphate, nitrite and ammonia due to the influence of the effluent release. PHc and phenols varied widely but the concentration of phenols was high in the estuary during postmonsoon season, indicating land based source of phenols.

Temporal variations at station K8 (estuarine mouth) indicated high concentration of PO_4^{3-}-P and NH_4^+-N in both the seasons. PO_4^{3-}-P, NO_2^--N and $NH4^+$-N were high at station K4 also. DO concentration was low during both seasons at station K8 with an increase durin flood in postmonsoon season. However, such trend was not noticed during premonsoon season. The deterioration of water quality in the middle of estuary may be due to sewage and industarial waste.

4.13.2 Sediment quality

The consolidated results for sediment quality of the Kundalika transect are presented in Tables 4.13.3 and 4.13.4 and summarized in the following table:

Parameter		Range	
		December 2015 (Postmonsoon)	April 2016 (Premonsoon)
Texture (%)	Sand	0.3-98.0	0.6-94.6
	Silt	1.2-89-5	2.4-90.0
	Clay	0.8-33.8	1.2-33.8
Metals	Al (%)	4.0-7.4	4.4-8.4
	Cr (µg/g)	107-254	161-275
	Mn (µg/g)	610-1527	712-1817
	Fe (%)	5.9-9.5	7.3-11.2
	Co (µg/g)	29-47	51-83
	Ni (µg/g)	51-85	68-99
	Cu (µg/g)	53-154	62-152
	Zn (µg/g)	73-114	60-116
	Cd (µg/g)	0.20-1.8	0.11-0.57
	Hg (µg/g)	0.11-0.5	0.02-0.12
	Pb (µg/g)	4.7-27.6	8.4-32.0
P (µg/g)		1182-1908	786-2123
C_{org} (%)		0.1-2.4	0.1-2.7
PHc (µg/g)		0.6-6.1	0.7-5.0

Dry wt basis except PHc which is wet wt basis

The sediment texture varied considerably with the coastal area, mouth and the estuary representing mainly silt, silty-sand and clayey-silt bed respectively. Among trace metals Hg was relatively high at station K9 during postmonsoon indicating its local accumulation in sediments of the effluent-receiving zone of the estuary.

4.13.3 Flora and fauna

The results of biological characteristics of the Kundalika Estuary are presented in Tables 4.13.5 to 4.13.22 and temporal variations at station K4 is illustrated in Figures 4.13.5 to 4.13.12.

a) Microbes

In premonsoon 2016, Kundalika Estuary sustained higher count (CFU/ml) of TVC, TC, FC and VLO during ebb period at stations K1 and K4 as evident in Table 4.13.5 suggesting contamination by sewage. Presence of TVC, TC, FC ECLO, PKLO, VCLO, and PALO was observed at Coastal (Stns. K1 to K3), Lower (Stns K4, K5 K6, K7 & K8) and Upper (Stn K9 & K10) region of the estuary. In general, the estuary was contaminated with pathogens during the study period due to effluent disposal.

Water	Zone					
	December 2015 (Postmonsoon)			April 2016 (Premonsoon)		
Type of Bacteria	Coastal (Sts K1 to K3)	Lower (Sts K4 to K8)	Upper (Sts K9 & K10)	Coastal (Sts K1 to K3)	Lower (Sts K4 to K8)	Upper (Sts K9 &K10)
TVC	$14.6x10^3$	$20.4x10^3$	$30x10^3$	$32.6x10^3$	$90.6x10^3$	$57.25x10^3$
TC	128	230	220	577	244	150
FC	86	175	163	400	190	105
ECLO	67	142	138	227	126	70
SHLO	44	110	95	24	237	305
SLO	12	37	68	0	0	3
PKLO	20	33	30	306	295	133
VLO	82	163	110	377	1401	85
VPLO	25	108	65	0	52	65
VCLO	57	54	45	377	1374	85
PALO	ND	46	58	7	19	83
SFLO	52	61	63	0	42	3

Sediment also sustained high microbial counts (CFU/g) during the study period especially at the coastal and the upper segments of the estuary as summarised in the table (4.13.6) below.

Sediment	Zone					
	December 2015 (Postmonsoon)			April 2016 (Premonsoon)		
Type of Bacteria	Coastal (Sts K1 to K3)	Lower (Sts K4 to K8)	Upper (Sts K9& K10)	Coastal (Sts K1 to K3)	Lower (Sts K4 to K8)	Upper (Sts K9 & K10)
TVC	$180x10^3$	$292x10^3$	$810x10^3$	$1223.3x10^3$	$265.8x10^3$	$1550x10^3$
TC	24	48	115	24	18	185
FC	14	30	75	0	16	105
ECLO	10	22	70	0	16	60
SHLO	14	4	175	0	64	205
SLO	7	4	120	0	0	40
PKLO	20	2	135	67	74	170
VLO	14	144	190	227	362	320
VPLO	4	24	50	184	28	15
VCLO	10	120	165	43	334	305
PALO	0	0	40	0	4	60
SFLO	4	0	80	0	22	30

b) Phytoplankton

The chlorophyll *a* values ranged from 1 to 25.4 mg/m^3 with wide variations, spatially, seasonally as well as temporally (Tables 4.13.7 and 4.13.8 and Figures 4.13.5 to 4.13.8). During April 2016 phaeophytin values were higher than chlorophyll *a* indicating the environmental stress in the estuary. Segment wise averages are summarized below.

Zone	Chlorophyll *a* (mg/m^3)			Phaeophytin (mg/m^3)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (postmonsoon)						
Coastal (Sts K1 to K3)	1.6	3.5	2.45	0.6	2.8	1.65
Lower (Sts K4 to K8)	1.0	20.8	4.9	0.5	3.9	1.8
Upper (Sts K9 and K10)	2.3	25.4	19	1.2	2.9	2.2
April 2016 (Premonsoon)						
Coastal (Sts K1 to K3)	2.17	4.37	3.32	1.61	4.38	2.47
Lower (Sts K4 to K8)	1.30	5.59	3.49	1.10	6.31	2.86
Upper (Sts K9 and K10)	9.45	21.12	17.09	0.25	3.28	0.91

As is evident from the table, chlorophyll *a* values increased from coastal to upper estuary, in both seasons. Phaeophytin values showed no clear trend. In general, the upper estuary sustained good phytoplankton production induced by the waste disposal which corresponds with trends of other polluted estuaries.

Phytoplankton cell count (Tables 4.13.9 and 4.13.10) varied generally in line with the concentration of chlorophyll *a*. In premonsoon, *Thalassiosira, Pseudo-nitzschia and Chlamydomonas* were the most dominant genera, whereas, *Cyclotella, Thalassiosira, Aulacoseira, Cylindrotheca* and *Guinardia* were the most abundant in postmonsoon.

Segment wise averages of cell counts and total genera of phytoplankton are given below.

Zone	Cell counts (no x 10^3/l)			Total genera (no)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)						
Coastal (Sts K1 to K3)	87	268	144.25	11	19	14
Lower (Sts K4 to K8)	92.8	972	360.15	10	21	14
Upper (Sts K9 and K10)	362.2	2941.8	1999.7	17	22	20
April 2016 (Premonsoon)						
Coastal (Sts K1 to K3)	58	108	79.5	12	15	13
Lower (Sts K4 to K8)	39	217	116.5	9	13	10
Upper (Sts K9 and K10)	493	1570	895	9	14	10

The total phytoplankton cell count showed increasing trend from coastal to upper estuary similar to the trend of phytopigments. Seasonally, postmonsoon sustained better standing stock of phytoplankton than premonsoon. Total number of genera showed little spatial variation, but seasonally postmonsoon sustained higher generic diversity (Tables 4.13.11 and 4.13.12).

c) Zooplankton

Standing stock of zooplankton (Tables 4.13.13 and 4.13.14) varied widely. Overall, 20 and 23 faunal groups were encountered during Premonsoon and Postmonsoon period respectively. The biomass and population in the estuary (2.1ml/100m^3 and 10.5 x10^3/100m^3) was higher as compared to coastal waters (2.6ml/100m^3 and 5.0 x10^3/100m^3) in postmonsoon. This reversed during premonsoon season, where coastal waters show higher biomass and population (11.2 ml/100m^3 and 322.3 x10^3/100m^3) as compared to the estuary (4.0 ml/100m^3 and 140.6 x10^3/100m^3). Segment wise zooplankton biomass, population and faunal groups are summarized below (Tables 4.13.15 and 4.13.16).

Zone	Biomass (ml/100m^3)			Population (no x 10^3/100m^3)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Coastal (Sts K1 to K3)	0.3	6.6	2.6	1.3	8.5	5.0	11	17	14
Lower Estuary (Sts K4 to K8)	0.1	10.6	3.9	0.3	71.4	20.5	9	18	15
Upper Estuary (Sts K9 and K10)	-	-	0.2	-	-	0.1	-	-	7
April 2016 (Premonsoon)									
Coastal (Sts K1 to K3)	2.4	26.1	11.2	39.2	692.9	322.3	11	14	12
Lower Estuary (Sts K4 to K8)	2.6	18.1	5.7	1.6	346.1	68.7	7	11	9
Upper Estuary (Sts K9 and K10)	-	-	2.3	-	-	213.2	-	-	9

Copepods dominated the zooplankton community and their percentage contribution varied from 37.0% to 98.8%. The other major groups were foraminiferans, *Lucifer* sp, decapod larvae, chaetognaths, gastropods, mysids, fish larvae, lamellibranchs, isopods, medusae, ctenophores, polychaetes, siphonophores, ostracods and cladocerans. The diurnal variation of zooplankton standing stock is presented in Figures 4.13.9 to 4.13.12 which revealed absence of definite trends.

d) Macrobenthos

Benthic standing stock in terms of biomass ranged from 0 to 27 g/m^2; wet wt. Though benthic biomass was comparable during both the seasons population counts was slightly higher during postmonsoon (avg 740 Ind./m^2) than premonsoon (avg 550 Ind./m^2) (Table 4.13.17). Segment wise distribution of macrobenthos is given below.

Stations	Biomass (g/m²); wet weight)			Population (Ind./m²)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Coastal (Sts K1 to K3)	0.00	9.30	2.70	0	2400	711	0	6	3
Lower (Sts K4 to K8)	0.20	9.50	1.32	75	3075	790	1	7	3
Upper (Sts K9 & K10)	0.00	8.00	3.30	0	1600	660	0	1	1
Overall	0.00	9.50	2.13	0	3075	740	0	7	3
April 2016 (Premonsoon)									
Coastal (Sts K1 to K3)	0.00	3.50	0.97	0	1000	296	0	6	3
Lower (Sts K4 to K8)	0.00	17.10	4.82	0	2350	518	0	5	2
Upper (Sts K9 & K10)	0.70	27.00	12.75	225	1875	1013	1	3	3
Overall	0.00	27.00	5.25	0	2350	550	0	6	3

The macrobenthic biomass and population on an average was low in the coastal water during premonsoon season with increasing trends towards the upper estuary.

Overall, 13 faunal groups of macrobenthos were encountered during postmonsoon and premosoon seasons (Tables 4.13.18 and 4.13.19). During postmonsoon polychaetes (82.5%) were the major group followed by Tanaidacea (4.1%), Oligochaeta (3.6%) and Amphipods (3.2%), whereas during Premonsoon, polychaetes were the common group (60.90%), followed by Oligochaeta (24.30 %), amphipods (4.80%) and Pelecypoda (4.30%).

e) Meiobenthos

Meiobenthic standing stock in Kundalika estuary and associated coastal area is given in table 4.13.20 and the segment-wise results are given in the table below.

Stations	Biomass (µg/10cm²)			Population (Ind./ 10cm²)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Coastal (Sts K1 to K3)	3.14	635.4	234.9	16	531	243	1	5	4
Lower (Sts K4 to K8)	0.64	66.02	30.71	1	142	70	1	5	4
Upper (Sts K9 & K10)	3.11	136.16	54.71	10	856	295	2	8	5

April 2016 (Premonsoon)									
Coastal (Sts K1 to K3)	102.39	1314.8	393.47	31	885	257	4	7	5
Lower (Sts K4 to K8)	58.64	282.19	143.53	74	161	122	5	7	6
Upper (Sts K9 & K10)	13.31	3777.12	1283.62	28	660	232	3	7	5

As seen in the table above, the Kundalika estuary showed low average meiofaunal density and biomass in all the segments in postmonsoon. However, in premonsoon the upper estuary sustained considerable increase in biomass, despite a slight decrease in average density. This increased biomass was due to the abundance of polychaetes and oligochaetes in station K9 (Tables 4.13.21 and 4.13.22).

4.14 Murud (MR)

Murud is a historically important place at the mouth of the Rajpuri Creek. A private port at Dighi is under development in the creek. The region does not receive any wastewaters through point sources. Hence, the marine environment is expected to represent the baseline for the region except for port operatios. Seven stations were considered for study in the coastal waters off Murud and estuarine segments (Figure 2.2.10).

4.14.1 Water quality

The results of water quality of Murud are presented in Tables 4.14.1 and 4.14.2 and temporal variations at station MR4 are illustrated in Figures 4.14.1 and 4.14.2. The results are summarized in the table below:

Parameter	Zone					
	December 2015 (Postmonsoon)			April 2016 (Premonsoon)		
	Coastal (MR1 to MR3)	Lower (MR4 & MR5)	Upper (MR6 & MR7)	Coastal (MR1 to MR3)	Lower (MR4 & MR5)	Upper (MR6 & MR7)
WT(ºC)	27.3	27.0	26.9	29.2	28.6	27.8
pH	8.0	8.0	8.0	8.0	8.0	8.1
SS (mg/l)	78	124	91	129	81	74
Turbidity (NTU)	16.6	8.8	12.4	18.8	11.3	14.8
Salinity (ppt)	35.3	34.9	34.7	36.4	36.9	37.2
DO(mg/l)	6.3	6.0	6.3	6.0	5.7	5.8
BOD(mg/l)	1.8	2.4	2.4	3.1	3.0	3.3
PO_4^{3-}-P (µmol/l)	1.5	1.5	0.8	1.5	0.9	1.0
TP (µmol/l)	2.8	3.0	2.7	2.4	1.9	1.8
NO_3^--N (µmol/l)	6.2	6.9	4.9	14.3	2.2	1.9
NO_2^--N (µmol/l)	0.3	0.5	0.3	1.3	0.4	0.4
NH_4^+-N (µmol/l)	2.8	3.5	2.5	1.8	1.6	1.4

TN (µmol/l)	15.1	20.4	17.0	54.9	34.7	26.4
PHc (µg/l)	2.4	2.3	2.2	4.3	4.1	5.7
Phenols (µg/l)	106.5	109.6	112.6	52.0	66.8	41.3

The temperature, pH and SS were in the expected ranges. However, salinity of upper region was high in April 2016 as compare to seawater, indicating high rate of evaporation and absence of substantial freshwater in flow which could lower the salinity. As expected for uncontaminated waters, the DO was high and the BOD was low. The concentrations of ammonia were low as expected. PHc and phenols were also low. Somewhat higher concentrations of ammonia in postmonsoon in the entire area were probably a natural occurrence.

Temporal variations at station MR4 revealed, variation of water temperature on a narrow range and stable pH throughout the tidal cycle indicating insignificant effect of intruding tidal water. Generally, nitrite, nitrate, phosphate, ammonia remained low throughout the tidal cycle.

4.14.2 Sediment quality

The consolidated results for sediment quality of the Murud area are presented in Tables 4.14.3 and 4.14.4 and summarized in the following table.

Parameter		Range	
		December 2015 (Postmonsoon)	April 2016 (Premonsoon)
Texture (%)	Sand	1.9-94.2	0.4-55.6
	Silt	1.2-78.3	13.4-94.4
	Clay	4.6-40.7	5.2-32.9
Metals	Al (%)	1.4-6.4	4.7-8.0
	Cr (µg/g)	39-169	148-183
	Mn (µg/g)	548-1082	635-1059
	Fe (%)	4.8-8.4	6.0-9.1
	Co (µg/g)	16-41	43-60
	Ni (µg/g)	13-61	56-76
	Cu (µg/g)	17-85	85-109
	Zn (µg/g)	28-83	55-80
	Cd (µg/g)	0.16-0.25	0.14-0.18
	Hg (µg/g)	0.1-0.16	0.005-.18
	Pb (µg/g)	5.5-11.1	7.2-13.9
P (µg/g)		1221-2769	1205-2108
C_{org} (%)		0.2-1.8	1.1-2.2
PHc (µg/g)		0.2-1.6	0.2-1.9

Dry wt basis except PHc which is wet wt basis.

The coastal sediment off Murud was mainly silty-sand, whereas the creek was silty with higher percentage of clay. The concentrations of trace metals varied considerably but in the absence of significant anthropogenic sources of trace metals, the observed concentrations could be considered as lithogenic. Concentrations of C_{org} were low but that of phosphate was occasionally high compare to typical characteristics of the central Konkan coast which has been attributed to high primary productivity in the associated coastal waters. The levels of PHc were low and represented the baseline for the region.

4.14.3 Flora and fauna

The results of biological characteristics off Murud and Rajpuri Creek are presented in Tables 4.14.5 to 4.14.22 and temporal variations at station MR4 are illustrated in Figures 4.14.3 to 4.14.6.

a) Microbes

In Postmonsoon 2015, Murud and Rajpuri Creek sustained higher count (CFU/ml) of TVC, TC, FC and VLO in sediment than water as given in table below which suggested contamination of the region during monsoon. However, higher counts of PKLO and VLO was observed at station MR1, MR3 and station MR4 during Premonsoon 2016.The overall microbial counts of the creek at upper (Station MR6 and MR7) were higher than coastal (stations MR1 & MR3) and lower (Station MR4 and MR5) during premonsoon season which could be attributed to intense fishing activity (Table 4.14.5).

Water	**Zone**					
	December 2015 (Postmonsoon)			**April 2016 (Premonsoon)**		
Type of Bacteria	**Coastal (MR1 to MR3)**	**Lower (MR4 & MR5)**	**Upper (MR6 & MR7)**	**Coastal (MR1 to MR3)**	**Lower (MR4 & MR5)**	**Upper (MR6 & MR7)**
TVC	2.5×10^3	12×10^3	24×10^3	6	8	20
TC	157	25	ND	5	5	8
FC	122	15	ND	5	ND	ND
ECLO	62	13	ND	2	ND	ND
SHLO	ND	ND	ND	ND	3	ND
SLO	ND	ND	ND	ND	13	ND
PKLO	188	13	ND	8	13	ND
VLO	107	25	5	85	65	88
VPLO	ND	ND	ND	45	15	33
VCLO	107	25	5	40	48	55
PALO	ND	ND	ND	ND	ND	ND
SFLO	ND	ND	ND	ND	ND	ND

Similar to water, microbial counts in sediment (CFU/g) also followed more or less a comparable trend as evident in table below and Table 4.14.6.

Sediment	Zone					
	December 2015 (Postmonsoon)			April 2016 (Premonsoon)		
Type of Bacteria	**Coastal (MR1 to MR3)**	**Lower (MR4 & MR5)**	**Upper (MR6 & MR7)**	**Coastal (MR1 to MR3)**	**Lower (MR4 & MR5)**	**Upper (MR6 & MR7)**
TVC	260 x10^3	150	150	400	1250	200
TC	767	100	ND	ND	ND	ND
FC	733	100	ND	ND	ND	ND
ECLO	500	50	ND	ND	ND	ND
SHLO	ND	ND	ND	ND	45	45
SLO	ND	ND	ND	ND	ND	ND
PKLO	67	100	ND	ND	5	90
VLO	1067	200	200	3	190	140
VPLO	ND	ND	ND	216	135	10
VCLO	1067	200	200	147	105	130
PALO	ND	ND	ND	70	50	ND
SFLO	33	ND	ND	ND	ND	ND

b) Phytoplankton

The distribution of chlorophyll *a* and phaeophytin presented in Tables 4.14.7 to 4.14.12 are summarized in the following table.

Zone	Chlorophyll a (mg/m^3)			Phaeophytin (mg/m^3)		
	Min	**Max**	**Avg**	**Min**	**Max**	**Avg**
December 2015 (Postmonsoon)						
Coastal water (Sts. MR1 to MR3)	1.3	3.7	2	0.3	2.8	1.3
Lower (Sts. MR4 & MR5)	2.4	13	7	0.5	2.9	1.15
Upper (Sts. MR6 & MR7)	6.8	9.9	7.75	0.8	1.6	1.25
April 2016 (Premonsoon)						
Coastal water (Sts. MR1 to MR3)	1.03	12.56	6.275	0.63	4.03	1.6
Lower (Sts. MR4 & MR5)	11.59	18.8	15.59	0.08	2.76	1.67
Upper (Sts. MR6 & MR7)	10.47	16.99	13.80	0.72	2.08	1.48

The concentration of chlorophyll *a* in the creek varied considerably with a definite increase in premonsoon and also with the trend of increasing concentration towards the upper creek (Tables 4.14.7 and 4.14.8 and Figures 4.14.3 and 4.14.4). Unusually high levels of phaeophytin occurred during premonsoon compared to postmonsoon which could be associated with intense fishing activities. Phytoplankton cell count also varied widely as evident from the following table.

Zone	Cell counts (no x 10^3/l)			Total genera (no)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (postmonsoon)						
Coastal water (Sts. MR1 to MR3)	17.4	185.6	65.65	14	22	17
Lower Creek (Sts. MR4 & MR5)	74.2	713.6	403.95	20	33	24
Upper Creek (Sts. MR6 & MR7)	309.2	621.4	483.1	20	33	27

Zone	Cell counts (no x 10^3/l)			Total genera (no)		
	Min	Max	Avg	Min	Max	Avg
April 2016 (Premonsoon)						
Coastal water (Sts. MR1 to MR3)	44	2082	646.5	10	27	19
Lower Creek (Sts. MR4 & MR5)	835	1797	1546.5	21	30	25
Upper Creek (Sts. MR6 & MR7)	510	870	683	18	25	22

No major spatial variation in phytopigments was discernable but cell counts were relatively high in the lower creek in during premonsoon season. The results suggested a wide variation in the distribution of population (17.4 x 10^3 to 2082 x 10^3 no/l) and genera (10 to 33 no) as evident in Tables 4.14.9 and 4.14.10. The dominant genera in December 2015 were in the following order; *Skeletonema, Thalassiosira, Navicula, Thalassionema, Coscinodiscus* and *Alexandrium;* whereas in April 2016, *Thalassiosira* was the most dominant followed by *Skeletonema* and *Cylindrotheca* (Tables 4.14.11 to 4.14.12) and also these results indicated seasonal changes in the generic dominance of phytoplankton.

c) Zooplankton

Zooplankton standing stock interms of biomass (0.2-24.2 ml/100m^3) and population (1.4-83.0 x 10^3 no/100m^3) showed variation in their distribution associated with seasonal trends. Average biomass (0.9 ml/100m^3) and average population (6.3 x 10^3 no/100m^3) were indicative of an overall low secondary production potential of the coastal/creek area during the study period.

Zooplankton biomass, population and faunal diversity in different segments off Murud (Tables 4.14.13 to 4.14.16; Figures 4.14.5 and 4.14.6) are summarized in the table below:

Zone	Biomass (ml/100m^3)			Population (no x 10^3/100m^3)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Postmonsoon December 2015									
Coastal (Sts MR1 to MR3)	0.6	1.1	0.8	1.4	13	5.0	10	13	11
Lower (Sts MR4 & MR5)	0.7	24.2	5.7	1.5	19.2	8.38	10	15	13
Upper (Sts MR6 & MR7)	7.2	13.9	10.0	7	12.2	9.36	10	13	12
April 2016 (Premonsoon)									
Coastal (Sts MR1 to MR3)	0.2	2.1	0.9	1.4	25.3	7.5	9	11	10
Lower (Sts MR4 & MR5)	1.0	7.5	3.6	16.9	83.0	31.6	9	14	11
Upper (Sts MR6 & MR7)	1.4	3.9	2.7	12.0	19.4	15.7	10	10	10

The Rajpuri Creek sustained higher biomass, population and total faunal groups as compared to the coastal waters during premonsoon and also the results showed an increasing trend in zooplankton biomass and faunal group diversity from coastal towards the upper creek region. The community structure mainly consisted of high population of copepods, foraminiferans, lamellibranchs, gastropods decapod larvae, *Lucifer* sp, and fish eggs. Chaetognaths, medusae, fish larvae and appendicularians formed next common groups. The composition was fairly diverse and the number of faunal groups varied between 9 and 15 (avg 12 no). Overall, 16 and 21 no of faunal groups of zooplankton (Tables 4.14.15 and 4.14.16) were seen during premonsoon and postmonsoon period respectively.

d) Macrobenthos

Segment wise distribution of macrobenthic biomass, population and total groups of Murud (Table 4.14.17) is summarized below.

Stations	Biomass (g/m^2; wet weight)			Population ($Ind./m^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Coastal (Sts MR1 to MR3)	0.02	64.00	8.17	50	1900	548	1	5	3
Lower (Sts MR4 & MR5)	3.08	279.60	39.78	1075	3125	2247	5	12	10
Upper (Sts MR6 & MR7)	0.20	17.18	3.69	375	3925	1484	4	13	8
Overall	0.02	279.60	15.92	50	3925	1301	1	13	6
April 2016 (Premonsoon)									
Coastal (Sts MR1 to MR3)	0.52	133.05	47.48	400	1750	1019	3	11	6
Lower (Sts MR4 & MR5)	7.06	26.04	15.18	850	3075	1519	6	14	10
Upper (Sts MR6 & MR7)	0.00	138.24	27.64	0	4700	2194	0	15	9
Overall	0.00	138.24	32.58	0	4700	1497	0	15	8

Thus the macrobenthic standing stock in terms of biomass (0-279.60 g/m^2; wet wt.), population (0-4700 ($Ind./m^2$) and total groups (0-15 no.) varied widely in the study area (Table 4.14.17 to Table 4.14.19). Premonsoon sustained better standing stock in terms of biomass (avg. 32.58 g/m^2; wet wt.) as compared to the postmonsoon (avg. 15.92 g/m^2; wet wt.). Similarly the population was high in Premonsoon. The spatial trend in population was not distinct during the study period. The faunal group diversity was comparable between postmonsoon (1-13) and premonsoon (0-15) with the lower creek sustained high diversity compared to rest (Table 4.14.18 and Table 4.14.19).

Overall, postmonsoon sustained lesser faunal diversity (total 6 no) with polychaetes (62.96%) and amphipods (13.69%) as the components whereas, the premonsoon with enhanced diversity revealed dominance of polychaetes (61.04%), amphipods (8.17%) and ophiuroids (7.76%) as the major groups.

e) Meiobenthos

The table below summarizes the meiofaunal standing stock in different coastal/creek segments of Murud.

Stations	Biomass ($\mu g/10cm^2$)			Population (Ind./ $10cm^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Coastal (Sts MR1 to MR3)	59.32	341.36	143	61	330	218	4	9	6
Lower (Sts MR4 & MR5)	141.28	437.52	256.9	120	195	165	6	8	7
Upper (Sts MR6 & MR7)	113.06	1627.3	606.53	266	1019	665	6	12	8
April 2016 (Premonsoon)									
Coastal (Sts MR1 to MR3)	25.89	147.43	84.05	61	205	126	4	7	6
Lower (Sts MR4 & MR5)	187.4	805.66	482	55	386	154	5	9	8
Upper (Sts MR6 & MR7)	126.59	1390.46	789.29	44	791	421	4	13	9

The overall meiofaunal density was higher in postmonsoon (349 ind./ $10cm^2$) than premonsoon (234 ind./ $10cm^2$), whereas the average biomass was higher in premonsoon (451.78 $\mu g/10cm^2$) than postmonsoon (335.48 $\mu g/10cm^2$). The group diversity ranged from 4 to 13 groups per station. A total of 22 groups were recorded during the study period, making it a high diversity region. Station MR6 had the highest meiofaunal density, biomass and diversity during study period (Table 4.14.20). Though nematodes were the most dominant, rare groups like echiurans, sipunculids and brachiopods were also encountered (Tables 4.14.21 and 4.14.22).

4.15 Savitri Estuary (S)

Savitri River receives effluents from Mahad industrial estate of MIDC that mainly houses chemical and pharmaceuticals industries. Treated effluent from CETP, which is black in colour is discharged on the south bank of the estuary at station S8. Untreated sewage from Mahad town also enters the estuary in the upstream of station S9 (Figure 2.2.11).

4.15.1 Water quality

The results of water quality of Savitri Estuary are presented in Tables 4.15.1 and 4.15.2 and temporal variations recorded at stations S4 and S8 are illustrated in Figures 4.15.1 to 4.15.4. The results are summarized in the table below:

Parameter	Zone					
	December 2015 (Postmonsoon)			March-April 2016 (Premonsoon)		
	Coastal (S1 to S3)	Lower (S4 & S5, S6 & S7)	Upper (S8 & S9)	Coastal (S1 to S3)	Lower (S4 & S5, S6 & S7)	Upper (S8 & S9)
WT(°C)	25.8	25.8	27.1	26.9	29.1	29.8
pH	7.9	7.6	7.7	8.0	7.8	7.6
SS (mg/l)	25	114	45	70	143	35
Turbidity (NTU)	15.5	42.9	1.9	15.3	36.6	1.9
Salinity (ppt)	35.2	25.5	11.9	36.1	30.8	14.3
DO(mg/l)	6.4	6.2	6.6	6.0	5.3	5.1
BOD(mg/l)	1.7	1.8	1.9	3.3	2.9	2.5
PO_4^{3-}-P (µmol/l)	1.1	0.5	0.5	0.8	0.8	0.6
TP (µmol/l)	2.2	1.2	1.0	1.8	2.4	5.8
NO_3^--N (µmol/l)	11.9	9.6	18.0	3.4	7.1	19.5
NO_2^--N (µmol/l)	0.6	3.7	4.3	0.8	1.3	8.2
NH_4^+-N (µmol/l)	1.7	3.2	3.2	0.7	1.1	2.6
TN (µmol/l)	24.2	21.4	29.9	12.75	22.9	38.9
PHc (µg/l)	3.3	7.4	9.1	2.9	7.1	9.4
Phenols (µg/l)	76.9	73.8	67.1	64.6	88.3	104.9

The temperature varied in accordance with the air temperature. The pH decreased in the inner estuary probably influenced by the effluent. SS was low in the region which would help primary production. The DO though decreased in the inner estuary was fairly high even in the segment of effluent release, especially during premonsoon season indicating effective consumption of oxidizable organic matter entering through the effluent. The phosphate and nitrate were in expected ranges but nitrite was markedly high in the inner estuary and so also ammonium indicating some deterioration in water quality of the inner estuary.

Temporal variations at station S4 indicated no marked seasonal variations in the temporal behaviour of water quality in both the seasons. Howoever, ingress of freshwater was observed upto station 4 during postmonsoon season.

Temporal variations at station S8 close to release site for MIDC effluent indicated that the temperature varied on a narrow range while pH varied randomly over the tidal cycle. Though the surfaces to the bottom variations were negligible throughout the tidal cycle, the enhancement of salinity was evident during flooding, especially during postmonsoon. The values of ammonia and nitrite increased in upper estuary irrespective of seasons indicating their source at the upstream.

4.15.2 Sediment quality

The consolidated results for sediment quality of the coastal and estuarine segments of Savitri Estuary are presented in Tables 4.15.3 and 4.15.4 and summarized in the following table.

Parameter		Range	
		December 2015 (Postmonsoon)	March-April 2016 (Premonsoon)
Texture (%)	Sand	2.0-96.4	0.4-97.4
	Silt	2.0-84.9	1-91.8
	Clay	0.6-13.1	1.0-17.0
Metals	Al (%)	6.0-9.2	5.6-8.9
	Cr (µg/g)	144-365	153-291
	Mn (µg/g)	706-2663	631-1749
	Fe (%)	6.7-15.2	7.3-13.4
	Co (µg/g)	33-95	48-99
	Ni (µg/g)	52-105	69-100
	Cu (µg/g)	61-273	103-236
	Zn (µg/g)	80-199	73-135
	Cd (µg/g)	0.11-0.24	0.16-0.25
	Hg (µg/g)	0.04-0.26	ND-0.18
	Pb (µg/g)	3.7-13.7	2.7-16.3
P (µg/g)		686-1578	918-2143
C_{org} (%)		0.4-3.8	0.2-3.8
PHc (µg/g)		0.3-3.9	0.2-3.7

Dry wt basis except PHc which is wet wt basis

The texture of sediment in the study area varied from sandy-silt to silty-sand. The concentrations of Co, Ni, Cu and Zn were markedly high in the estuary as compared to the coastal area. The high concentrations were probably natural and associated with high content of Al and Fe in these sediments rather than contribution through effluents released in the Savitri estuary. Phosphorus, C_{org} and PHc in the sediment were generally low in the study area.

4.15.3 Flora and fauna

The results of biological characteristics in Savitri Estuary and associated coastal waters are presented in Tables 4.15.5 to 4.15.22 and temporal variations recorded at stations S4 and S8 are illustrated in Figures 4.15.5 to 4.15.12.

a) Microbes

From the results it appeared that Savitri was less polluted than other estuaries like Patalganga, Amba, and Manori. The presence of faecal indicator bacteria like TVC, TC, FC, ECLO and pathogenic microbes like, SHLO, PKLO, VPLO and VCLO were in the same range and in low counts during the study period. Also SHLO, SLO, PALO and SFLO were mostly absent during the study period as summarised in the Table (4.15.5) below.

Type of Bacteria	Zone					
	December 2015 (Postmonsoon)			March-April 2016 (Premonsoon)		
	Coastal (S1 to S3)	Lower (S4 to S7)	Upper (S8 & S9)	Coastal (S1 to S3)	Lower (S4 to S7)	Upper (S8 & S9)
TVC	$3.83x10^3$	$3.11\ x10^3$	$2.25\ x10^3$	$4\ x10^3$	$3.27\ x10^3$	$4\ x10^3$
TC	15	65	150	90	107	82
FC	10	27.5	155	45	30	55
ECLO	10	15	125	20	22	42
SHLO	ND	ND	ND	5	16	25
SLO	ND	ND	ND	ND	5	ND
PKLO	ND	100	ND	5	5	ND
VLO	45	107	175	103	100	135
VPLO	5	65	ND	80	25	62
VCLO	40	37	175	103	55	77
PALO	5	ND	ND	ND	ND	ND
SFLO	ND	ND	ND	ND	ND	25

In sediment TVC counts (CFU/g) were high at all the three regions of the estuary. Except TVC, TC and FC other microbial community were generally absent in the study area as given in the table below (Table 4.14.6).

Type of Bacteria	Zone					
	December 2015 (Postmonsoon)			March-April 2016 (Premonsoon)		
	Coastal (S1 to S3)	Lower (S4to S7)	Upper (S8 & S9)	Coastal (S1 to S3)	Lower (S4 to S7)	Upper (S8 & S9)
TVC	$466.6x10^3$	$507.5x10^3$	$240x10^3$	$346x10^3$	$345x10^3$	$320x10^3$
TC	ND	232	550	15	45	30
FC	ND	227	400	10	61	15
ECLO	ND	205	200	5	70	10
SHLO	ND	ND	ND	ND	ND	25
SLO	ND	ND	ND	ND	ND	ND
PKLO	ND	100	ND	ND	ND	ND
VLO	ND	382	ND	56	70	145
VPLO	ND	80	ND	26	ND	70
VCLO	ND	302	ND	30	80	75
PALO	ND	ND	ND	ND	ND	ND
SFLO	ND	ND	ND	ND	ND	ND

b) Phytoplankton

The distribution of chlorophyll *a* was patchy and varied widely (Tables 4.15.7 and 4.15.8) during postmonsson (0.2-9.5 mg/m^3; av 3.0 mg/m^3) and (0.9-6.1 mg/m^3; av 3.0 mg/m^3) premonsoon. Segment wise distribution of chlorophyll *a* and phaeophytin is given in the table below.

Zone	Chlorophyll *a* (mg/m³)			Phaeophytin (mg/m³)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)						
Coastal (Sts. S1 to S3)	1.2	2.1	1.7	0.3	3.4	1.75
Lower (Sts. S4 to S7)	0.2	5.2	2.9	0.7	6.3	1.75
Upper (Sts. S8 & S9)	2.1	9.5	4.5	1	6.9	1.9
March-April 2016 (Premonsoon)						
Coastal (Sts. S1 to S3)	1.1	4.3	2.5	0.46	1.84	1.0
Lower (Sts. S4 to S7)	1.8	6.1	4.0	0.13	1.73	0.7
Upper (Sts. S8 & S9)	0.9	4.4	2.5	0.81	1.21	1.0

The overall level of chlorophyll *a* did not reveal spatial and seasonal variation but higher values were observed with an increasing trend from coastal waters to upper estuary during postmonsoon. Higher values of chlorophyll a were recorded during ebb in premonsoon (station S4) and postmonsoon (station S8). During premonsoon higher values were during flood at station S8 (Figures 4.15.5 to 4.15.8). Such seasonal and temporal variations are noticed due to waste disposals in the upper estuary part. Higher phaeophytin values over chlorophyll a were recorded in some instances. Phytoplankton cell counts (Tables4.15.9 and 4.15.10) varied widely and are summarized in the following table.

Zone	Cell count (no x 10³/l)			Total genera (no)		
	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)						
Coastal (Sts. S1 to S3)	11.4	106.6	34.9	10	26	14
Lower (Sts. S4 to S7)	10.2	69.4	38.75	6	18	11.5
Upper (Sts. S8 & S9)	19.8	1614.4	610.85	13	21	16
March-April 2016 (Premonsoon)						
Coastal (Sts. S1 to S3)	27	106	65.7	8	23	14
Lower (Sts. S4 to S7)	47.2	149.4	82.8	15	21	17.5
Upper (Sts. S8 & S9)	26.6	145.6	69.25	11	19	14.5

Variations in phytoplankton cell counts corresponded with distribution of chlorophyll *a*. Counts varied widely from 26.6 x 10^3 to 149.4 x 10^3nos./l (av 72.6 x 10^3 no/l) during premonsoon whereas, high values (10.2 x 10^3 to 1614.4 x 10^3no/l; av 228.2 x 10^3 no/l) were noticed during postmonsoon season.

Overall, 48 and 57 genera of phytoplankton were recorded during premonsoon and postmonsoon respectively (Tables 5.15.11 and 4.15.12). *Coscinodiscus* and *Navicula* were most common genera during the study period. *Cylindrotheca, Prorocentrum, Trichodesmum, Skeletonema, Thalassiosira, Coscinodiscus and Thalassionema* were common during premonsoon. Whereas, *Thalassiosira, Nitzschia, Coscinodiscus, Navicula, Amphora, Cocconeis, Cyclotella,* and *Guinardia* were most common in postmonsoon.

c) Zooplankton

The segment-wise distribution of the zooplankton standing stock (Tables 4.15.13 and 4.15.14) is summarized below.

Zone	Biomass ($ml/100^3$)			Population (no x 10^3 /$100m^3$)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Coastal (Sts S1 to S3)	0.1	0.9	0.6	0.04	9.5	5.0	3	13	9
Lower (Sts S4 to S7)	0.2	2.5	0.4	1.3	8.9	6.5	6	14	9
Upper (Sts S8 and S9)	0.3	2.7	1.0	0.6	31.7	10.5	4	9	6
March-April 2016 (Premonsoon)									
Coastal (Sts S1 to S3)	1.9	50.0	11.2	7.2	137.6	37.1	8	11	10
Lower (Sts S4 to S7)	0.3	16.8	6.5	1.7	36.3	18.0	6	11	9
Upper (Sts S8 and S9)	0.4	5.7	3.3	11.4	24.2	19.1	4	8	6

The population was lower during ebb tide as compared to flood tide during the study period with higher diversity and population noticed during premonsoon at station S4 (Figures 4.15.9 and 4.15.10).

The coastal waters and lower segments of Savitri Estuary sustained higher zooplankton standing stock during premonsoon. The present study indicated the absence of discernible impact of effluent disposal on zooplankton in the upper estuary. The composition of zooplankton population was fairly diverse and dominated by copepods, decapod larvae, chaetognaths, lamellibranchs, *Lucifer* sp, polychaetes, gastropods, isopods and amphipods (Tables 4.15.15 and 4.15.16). Overall, 18 and 20 faunal groups were identified during premonsoon and postmonsoon periods respectively. The average group diversity varied from 3 to 14 no (av 8 no) and 4 to 11 no (avg 8 no) during premonsoon and postmonsoon respectively.

d) Macrobenthos

Segment wise and seasonal distribution of macrobenthic biomass, population and total groups (Table 4.15.17) are given below.

Stations	Biomass (g/m^2; wet weight)			Population ($Ind./m^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Coastal (Sts S1 to S3)	0.02	4.50	2.10	50	5125	1114	1	4	2
Lower (Sts S4 to S7)	0.01	6.30	0.86	25	1050	250	1	4	2
Upper (Sts S8 & S9)	3.90	19.90	10.50	775	9700	4613	2	5	5
Overall	0.01	19.90	3.42	25	9700	1508	1	5	2
March-April 2016 (Premonsoon)									
Coastal (Sts S1 to S3)	0.10	43.30	10.50	75	1675	563	1	3	2
Lower (Sts S4 to S7)	0.00	8.40	2.60	0	1825	492	0	6	3
Upper (Sts S8 & S9)	0.00	5.10	0.91	0	200	47	0	2	1
Overall	0.00	43.30	4.86	0	1825	417	0	6	2

The results indicated wide fluctuations in macrobenthic standing stock with low diversity. Premonsoon period sustained higher benthic biomass, while population was found to be lower than postmonsoon and total faunal groups were comparable between two seasons.

Polychaeta was the dominant group during the study period (Tables 4.15.18 and 4.15.19). Overall, 12 and 9 faunal groups were recorded during postmonsoon and premonsoon period respectively. The other common groups were *Tanaidacea, Amphipoda and Pelecypoda*.

e) Meiobenthos

Meiobenthic standing stock in Savitri estuary and associated coastal area is given in table 4.15.20 and the segment-wise results are given in the table below.

Stations	Biomass (µg/10cm²)			Population (Ind./ 10cm²)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
December 2015 (Postmonsoon)									
Coastal (Sts S1 to S3)	216.38	482.77	389.86	318	836	456	2	6	4
Lower (Sts S4 to S7)	31.65	182.24	92.77	48	501	218	1	7	4
Upper (Sts S8 and S9)	31.65	130.98	64.07	47	313	186	3	7	5
March-April 2016 (Premonsoon)									
Coastal (Sts S1 to S3)	68.74	225.96	122.19	35	255	123	2	5	3
Lower (Sts S4 to S7)	22.16	280.47	142.66	28	515	246	2	7	5
Upper (Sts S8 and S9)	4.26	246.84	67.0	7	134	67	1	4	2

The meiofaunal faunal density and diversity varied considerably in the region. Postmonsoon period sustained higher meiobenthic standing stock as compared to premonsoon (Table 4.15.20). Biomass ranged from 4.26 µg/10cm^2 in premonsoon to 482.77 µg/10cm^2 in postmonsoon. Meiofaunal density was minimum in the upper estuary during the study period. Overall, group diversity ranged from 1 to 7. Nematodes and foraminiferans dominated the meiofaunal community in both seasons (Tables 4.15.21 and 4.15.22).

4.16 Vashishti Estuary (VS)

Vashishti estuary receives effluents from the MIDC industrial estate at Lote-Parasuram in the inner segment (Station VS9). Dabhol a minor port is situated near the mouth of the estuary. Enron a gas-based plant utilizes the sea water as coolant and discharges its effluents in to open sea. Ten stations were considered for the present study in the coastal waters off Vashishti and estuarine segments (Figure 2.2.12).

4.16.1 Water quality

The results of water quality of Vashishti Estuary is presented in Tables 4.16.1 and 4.16.2 while the temporal variations at stations VS4 and VS9 are illustrated in Figures 4.16.1 and 4.16.4. The segment-wise water quality of the estuary is given in the table below:

Parameter	Zone					
	January 2016 (Postmonsoon)			March 2016 (Premonsoon)		
	Coastal (Sts VS1 to VS3)	Lower (Sts VS4,VS5 & VS6)	Upper (Sts VS7, VS8 &VS9,VS10)	Coastal (Sts VS1 to VS3)	Lower (Sts VS4,VS 5& VS6)	Upper (St VS7, VS8 &VS9, VS10)
WT(°C)	24.8	26.4	25.7	28.4	28.3	28.8
pH	8.1	7.7	7.1	8.0	7.7	7.1
SS (mg/l)	90	23	25	105	97	61
Turbidity (NTU)	7.9	15.6	6.4	10.9	16.9	6.0
Salinity (ppt)	35.1	26.5	8.3	35.9	28.8	11.5
DO(mg/l)	6.8	5.3	4.6	5.9	5.5	4.1
BOD(mg/l)	2.7	2.1	4.5	3.7	3.9	3.8
PO_4^{3-}-P (µmol/l)	1.0	1.3	1.5	1.2	0.8	0.3
TP (µmol/l)	2.7	2.6	2.6	2.3	1.7	0.9
NO_3^--N (µmol/l)	8.0	20.9	29.1	4.6	13.4	22.3
NO_2^--N (µmol/l)	0.7	7.6	7.6	2.2	5.7	7.8
NH_4^+-N (µmol/l)	1.9	2.6	15.9	2.6	1.3	14.8
TN (µmol/l)	26.1	43.0	55.5	40.0	55.7	57.6
PHc (µg/l)	4.6	5.7	6.4	4.3	5.8	6.1
Phenols (µg/l)	73.7	75.8	91.9	49.5	85.2	109.3

The marked decrease in pH in the inner estuary appeared to be due to the influence of the effluents released in the inner zone. The salinity distribution indicated influence of fresh water inflow in the estuary even during premonsoon that would facilitate seaward movement of contaminants entering the system. The stratification was seen at the upper estuary (Stations VS9 and VS10) possibly because of weak currents. Low DO levels in the effluent release region suggested consumption of DO in oxidization of organic matter entering the estuary through the effluents. Concentrations of phosphate and nitrate were in the expected ranges, however, the levels of nitrite, ammonium and phenols were often high in the estuary indicating stress conditions. Concentration of PHc was low and did not indicate gross contamination by this contaminant.

Temporal variations at station VS4 indicated increase of nitrite during ebb. Though the behaviour was similar in both the seasons, the column variation was more pronounced during premonsoon. In comparison at station VS9 (upper estuary) temperature and pH did not show marked variations during premonsoon. Though the variations in DO and nitrite were random, these parameters behaved differently at the surface and the bottom. Phosphate and ammonia did not show any distinguished tidal variations. During postmonsoon salinity decreased and pH increased when ebbing whereas nutrients did not show any clear trend. The vertical variations were pronounced during premonsoon.

Hence, the Vashishti Estuary indicated some deviations in respect of nitrate, nitrite and ammonia, which could have their source in the effluent released at the upper estuary (Station VS9).

4.16.2 Sediment quality

The consolidated result for sediment quality of the Vashishti Estuary and associated coastal area is presented in Tables 4.16.3 and 4.16.4 and summarized in the following table.

Parameter		Range	
		January 2016 (Postmonsoon)	March 2016 (Premonsoon)
Texture (%)	Sand	1.5-80.2	0.1-98.6
	Silt	11-89.9	0.8-98.7
	Clay	6.6-29.9	0.6-17.4
	Al (%)	5.3-9.0	6.1-7.3
	Cr (µg/g)	156-283	113-196
	Mn (µg/g)	732-2428	599.4-2092
	Fe (%)	7.7-17.2	6.2-13.1
	Co (µg/g)	38-114	43-95
Metals	Ni (µg/g)	62-92	70-100
	Cu (µg/g)	89-465	105-297
	Zn (µg/g)	89-239	76-166
	Cd (µg/g)	0.08-0.27	0.14-0.24
	Hg (µg/g)	0.06-0.41	0.02-0.20
	Pb (µg/g)	8.0-19.8	2.9-16.6
P (µg/g)		1014-1740	712-1892
C_{org} (%)		0.7-4.1	0.2-2.6
PHc (µg/g)		0.1-8.2	0.2-7.2

Dry wt basis except PHc which is wet wt basis

The sediment texture was predominantly silty-sand type with low percentage of clay. The concentration of Cr, Cu, Zn and Hg were markedly high in the estuary. High concentrations of Fe and Mn were also recorded in estuarine sediments. C_{org} and P were in expected ranges revealing that the sediment was free from their gross accumulation. Build up of PHc in the vicinity of effluent release indicated its source in the industrial waste.

4.16.3 Flora and fauna

The results of biological characteristics of Vashishti Estuary and coastal waters of Dabhol are presented in Tables 4.16.5 to 4.16.22 and the temporal variations at stations VS4 and VS9 are illustrated in Figures 4.16.5 to 4.16.12.

a) Microbes

The counts of faecal indicator bacteria (CFU/ml) TVC were in low as compare to sediment sample, where counts were comparatively very high. TVC, TC, FC, ECLO were present at all the three regions Coastal (Stn VS1 to VS3), Lower (Stn VS4 and VS5 & VS6) and Upper (VS7, VS8 & VS9, VS10). SHLO, SLO, PALO and PKLO were mostly absent. Higher pathogenic bacterial counts especially at the upper estuary could be related to the waste disposal at station VS9.

Type of Bacteria	Zone					
	January 2016 (Postmonsoon)			March 2016 (Premonsoon)		
	Coastal (Stn VS1 to VS3)	Lower (Stn VS4 and VS5& VS6)	Upper (stn. VS7, VS8, VS9 & VS10)	Coastal (Stn VS1 to VS3)	Lower (Stn VS4 and VS5& VS6)	Upper (stn. VS7, VS8, VS9 & VS10)
TVC	$0.9 x10^3$	$3.83x10^3$	63	$2.4x10^3$	$3.16x10^3$	6
TC	40	51	40	10	60	100
FC	33	40	30	7	56	60
ECLO	33	33	25	7	28	40
SHLO	ND	ND	NG	43	5	25
SLO	ND	ND	NG	43	10	25
PKLO	ND	53	NG	ND	21	NG
VLO	90	116	40	70	144	55
VPLO	ND	ND	NG	36	100	10
VCLO	90	116	40	33	12	45
PALO	ND	ND	NG	ND	ND	NG
SFLO	ND	5	NG	ND	ND	NG

In sediment samples, the TVC counts (CFU/g) were high at all the three regions of the estuary. Except TVC, TC and FC other microbial community was absent during pre- as well as post monsoon as illustrated in table below. The bacterial contaminants released through the effluents at the upper estuary could be possibly carried to the lower estuary and coastal segments to get settle at the bottom thereby indicating higher microbial counts in the sediments of respective regions.

Type of Bacteria	Zone					
	January 2016 (Postmonsoon)			March 2016 (Premonsoon)		
	Coastal (Stn VS1 to VS3)	Lower (Stn VS4 and VS5& VS6)	Upper (stn. VS7, VS8, VS9 & VS10)	Coastal (Stn VS1 to VS3)	Lower (Stn VS4 and VS5& VS6)	Upper (stn. VS7, VS8, VS9 & VS10)
TVC	$667x10^3$	$186.6x10^3$	40	$183.3x10^3$	$240x10^3$	62
TC	ND	67	NG	ND	70	30
FC	ND	33	NG	ND	40	20
ECLO	ND	33	NG	ND	36	20
SHLO	ND	ND	NG	ND	ND	NG
SLO	ND	ND	NG	ND	ND	NG
PKLO	67	ND	NG	ND	ND	NG
VLO	1333	33	NG	17	63	NG
VPLO	ND	ND	NG	17	10	30
VCLO	ND	ND	NG	ND	23	10
PALO	ND	ND	NG	ND	ND	40
SFLO	ND	ND	NG	ND	ND	NG

b) Phytoplankton

The levels of phytopigments are given in Tables 4.16.7 to 4.16.12 and in Figures 4.16.5 to 4.16.8. Segment wise seasonal trend in the concentration of phytopigments is given below. The chlorophyll *a* varied during premonsoon (0.74-12.46 mg/m^3;avg 1.9 mg/m^3) and postmonsoon (0.4-7.4mg/m^3;avg 1.4 mg/m^3) as given in the table below.

Zone	Chlorophyll *a* (mg/m³)			Phaeophytin (mg/m³)		
	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)						
Coastal (Sts. VS1 to VS3)	0.7	1.5	1	0.4	1.4	0.9
Lower (Sts.VS4 to VS6)	0.8	2.1	1.4	0.4	1.6	1
Upper (Sts. VS7 to VS10)	0.4	7.4	1.9	0.3	2.9	1.6
March 2016 (Premonsoon)						
Coastal (Sts. VS1 to VS3)	0.74	2.21	1.485	0.3	2.73	0.97
Lower (Sts.VS4 to VS6)	1.05	2.4	1.7	0.53	4.31	2.16
Upper (Sts. VS7 to VS10)	1.16	12.46	2.55	0.17	3.11	1.36

Spatial variation of phytopigments indicated higher concentration in the lower and upper estuarine segments compared to coastal waters (Tables 4.16.7 and 4.16.8). Segment wise distribution of cell counts and total genera of phytoplankton is summarized in the table below. There was no clear temporal variation of Chlorophyll a and phaeophytin, but higher concentration of phaeophytin compare to chlorophyll a in some instances (Figures 4.16.5 to 4.16.8) showed impact of anthropogenic discharge in the estuary.

Zone	Cell count (no x 10^3/l)			Total genera (no)		
	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)						
Coastal (Sts. VS1 to VS3)	12.8	28.8	17.4	9	12	11
Lower (Sts.VS4 to VS6)	14.8	24.6	19.65	8	14	11
Upper (Sts. VS7 to VS10)	16.8	152.4	60.9	10	18	14
March 2016 (Premonsoon)						
Coastal (Sts. VS1 to VS3)	15.4	34.6	22	9	12	10
Lower (Sts.VS4 to VS6)	13	63.8	32.7	9	17	12
Upper (Sts. VS7 to VS10)	51.6	128.6	73.7	11	21	14

Variations in phytoplankton cell counts (Tables 4.16.9 and 4.16.10) corresponded with the chlorophyll *a* distribution. The counts varied widely from 13 x 10^3 to 128.6 x 10^3no/l (av 42.8 x 10^3no/l) during premonsoon to 12.8 x 10^3 to 152.4 x 10^3no/l (av 32.7 x 10^3no/l) during postmonsoon.

It is evident from the above table that the seasonal variability in the cell counts was marginal. The dominance of *Guinardia, Peridinium, Pleurosigma, Prorocentrum* and *Rhizosolenia* during premonsoon and *Thalassiosira, Mallomonas,Prorocentrum,Ceratium,Surirella, Trichodesmium, Dinophysis*and *Dactyliosolen* during postmonsoon (Tables 4.16.11 and 4.16.12) was evident. In all 44 genera genera of phytoplankton were recorded during the study period with *Coscinodiscus, Cyclotella, Cylindrotheca, Thalassionema, Navicula* and *Nitzschia* common at most stations.

c) Zooplankton

The zooplankton standing stock (Tables 4.16.13 and 4.16.14) varied widely and indicated an overall low secondary potential of the estuary (Figures 4.16.9 to 4.16.12). The seasonal and spatial variability of zooplankton in different segments are summarized below.

Zone	Biomass (ml/100m³)			Population (no x 10³/100m³)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal (Sts. VS1 to VS3)	0.5	0.9	0.8	9.1	30	17.8	8	13	10
Lower (Sts.VS4 to VS6)	0.5	2.5	1.3	0.6	19.8	6.9	4	15	10
Upper (Sts. VS7 to VS10)	0.1	1.3	0.7	0.0 3	0.4	0.15	3	9	6
March 2016 (Premonsoon)									
Coastal (Sts. VS1 to VS3)	2.3	3.8	3.2	12.5	28.5	20.2	7	12	10
Lower (Sts.VS4 to VS6)	1.8	14.3	5.2	6.9	22.3	17.3	6	11	9
Upper (Sts. VS7 to VS10)	0.3	9.1	1.7	0.05	18.0	3.6	2	8	6

Thus the lower estuary sustained higher biomass as compared to the rest of the segments. However, the population density and faunal diversity of zooplankton indicated a decreasing trend from coastal to the estuarine region. The region sustained diverse faunal groups (Tables 4.16.15 and 4.16.16). Overall, 17 and 20 groups were seen during Premonsoon and Postmonsoon period respectively. The predominant groups were copepod and decapod larvae followed by foraminiferans, gastropods, lamellibranchs, *Lucifer* sp, fish eggs, fish larvae, chaetognaths, polychaetes and appendicularians.

d) Macrobenthos

The macrobenthic standing stock (Table 4.16.17) is summarized in the following table:

Stations	Biomass (g/m²; wet weight)			Population (Ind./m²)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal (Sts. VS1 to VS3)	0.03	6.20	1.70	50	875	231	1	2	2
Lower (Sts.VS4 to VS6)	0.03	1.10	0.40	25	700	223	1	1	1
Upper (Sts. VS7 to VS10)	0.03	40.20	16.30	75	9425	3047	2	5	3
Overall	0.03	40.20	6.13	25	9425	1167	1	5	2
March 2016 (Premonsoon)									
Coastal (Sts. VS1 to VS3)	0.10	12.80	4.30	125	3150	815	1	4	2

Lower (Sts.VS4 to VS6)	0.20	90.70	21.47	175	5925	1271	1	6	4
Upper (Sts. VS7 to VS10)	3.40	116.3	23.10	275	10825	3721	2	6	4
Overall	0.03	116.3	10.49	25	10825	1496	1	6	3

Overall, premonsoon period sustained better macrobenthic standing stock in terms of biomass, population and diversity than postmonsoon. In all, 6 and 11 groups were present in the premonsoon and postmonsoon samples respectively (Tables 4.16.18 and 4.16.19) with dominance of polychaetes in postmonsoon and Amphipoda in premonsoon.

e) Meiobenthos

Meiobenthic standing stock in Vashishti estuary and associated coastal area is presented in table 4.16.20 and the segment-wise results are given in the table below.

Stations	Biomass ($\mu g/10cm^2$)			Population (Ind./ $10cm^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Av	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal (Sts. VS1 to VS3)	103.54	626.83	409.85	253	1059	695	3	10	6
Lower (Sts.VS4 to VS6)	12.36	158.74	88.19	17	191	130	3	5	4
Upper (Sts. VS7 to VS10)	119.54	968.36	528.78	85	893	471	4	9	6
March 2016 (Premonsoon)									
Coastal (Sts. VS1 to VS3)	12.36	426.86	122.34	8	692	187	2	5	3
Lower (Sts.VS4 to VS6)	17.65	185.28	93.43	23	512	217	2	7	4
Upper (Sts. VS7 to VS10)	39.63	244.41	97.46	37	156	93	3	7	4

Vashishthi estuary showed higher meiofaunal standing stock in postmonsoon than premonsoon. Coastal region showed highest faunal density in postmonsoon whereas middle estuary showed highest faunal density in premonsoon. In general, Meiofaunal distribution was erratic at study area (Table 4.16.20). Overall, 15 and 12 meiofaunal groups were identified in postmonsoon and premonsoon respectively (Tables 4.16.21 and 4.16.22).

4.17 Jaigad/Shastri Estuary (J)

Six stations were selected for study of the Shastri Estuary and associated coastal waters off Jaigad as depicted in Figure 2.2.13.

The coastal water body off Jaigad/shastri estuary do not receive any known point discharges of wastewater.

4.17.1 Water quality

The results of water quality off Jaigad and Shastri estuary is presented in Tables 4.17.1 and 4.17.2 whereas temporal variations recorded at station J5 are illustrated in Figures 4.17.1 and 4.17.2. The results are summarized in the following table.

Parameter	January 2016 (Postmonsoon)			March 2016 (Premonsoon)		
	Coastal (Sts J1 to J3)	Lower (Sts J4 & J5)	Upper (St J6)	Coastal (Sts J1 to J3)	Lower (Sts J4 & J5)	Upper (St J6)
WT(ºC)	28.1	26.7	26.9	28.8	28.5	28.8
pH	8.0	7.8	7.9	8.1	8.0	8.0
SS (mg/l)	16	28	19	17	25	21
Turbidity (NTU)	1.4	1.5	1.6	1.3	0.6	0.5
Salinity (ppt)	35.5	33.4	29.8	35.8	35.6	34.6
DO(mg/l)	6.6	6.3	6.1	6.0	5.8	5.3
BOD(mg/l)	1.9	2.4	2.3	2.4	2.7	2.9
PO_4^{3-}-P (µmol/l)	0.6	0.7	0.4	0.4	0.5	0.1
TP (µmol/l)	1.2	1.2	0.9	1.1	1.3	0.6
NO_3^--N (µmol/l)	4.1	6.6	6.3	1.6	1.0	0.9
NO_2^--N (µmol/l)	0.9	1.4	1.9	0.1	0.1	0.1
NH_4^+-N (µmol/l)	2.8	1.9	2.0	0.7	0.4	0.4
TN (µmol/l)	14.0	21.5	17.4	15.1	14.1	14.8
PHc (µg/l)	2.5	7.8	1.6	4.3	4.2	8.0
Phenols (µg/l)	50.6	73.7	93.4	53.0	85.1	75.1

As expected, the above results indicated clean coastal waters of the Konkan coast. The temporal variation at station J5 (Jaigad Port) revealed that temperature varied on a narrow range with a stable pH over a tidal range. Salinity increased during flooding as expected. Nitrate, nitrite, phosphate and ammonia were low throughout the tidal cycle. DO though remain high on a narrow range during premonsoon, varied randomly during postmonsoon.

4.17.2 Sediment quality

The consolidated data for sediment quality of the Shastri Estuary/Jaigad is presented in Tables 4.17.3 and 4.17.4 and summarized below.

Parameter		Range	
		January 2016 (Postmonsoon)	March 2016 (Premonsoon)
Texture (%)	Sand	4.2-96.6	1.6-91.6
	Silt	1.2-90.7	2.8-86.0
	Clay	2.2-20.8	5.6-12.4
Metals	Al (%)	5.4-11.0	4.7-8.8
	Cr (µg/g)	186-298	178-341
	Mn (µg/g)	1138-1864	1206-2371
	Fe (%)	10.1-16.2	10.2-20.9
	Co (µg/g)	52-100	55-147
	Ni (µg/g)	74-99	70-129
	Cu (µg/g)	158-286	169-415
	Zn (µg/g)	105-178	104-290
	Cd (µg/g)	0.06-0.22	0.13-0.19
	Hg (µg/g)	0.1-0.18	0.07-0.30
	Pb (µg/g)	7.1-12.6	7.1-12.8
P (µg/g)		198-559	758-1516
C_{org} (%)		0.4-4.5	0.1-2.3
PHc (µg/g)		0.2-2.8	0.1-1.6

Dry wt basis except PHc which is wet wt basis

The sediment texture of the coastal/estuarine system of Jaigad varied from silty-sand to sandy-silt. The concentrations of Cr, Co, Ni, Cu, Zn and Hg were occasionally high in the estuarine sediments which was most likely to be due to high content of Fe in these sediments and hence of lithogenic origin. The contents of C_{org} and PHc were generally low except for one value for C_{org} (4.5%) which could be a chance occurrence.

4.17.3 Flora and fauna

The results of biological characteristics of the Shastri Estuary and coastal waters off Jaigad are presented in Tables 4.17.5 to 4.17.22 whereas temporal variations recorded at station J5 are illustrated in Figures 4.17.3 to 4.17.6.

a) Microbes

The estuary was less polluted than estuaries like Patalganga, Amba, and Manori. TVC counts (CFU/ml) in the water appear to be normal for the coastal segment of Jaigad. However elevated levels especially noticed at the upper estuary during premonsoon could be related to the intense fishing activities at the study area.

Type of Bacteria	January 2016 (Postmonsoon)			March 2016 (Premonsoon)		
	Coastal (Sts J1 to J3)	Lower (Sts J4 & J5)	Upper (St J6)	Coastal (Sts J1 to J3)	Lower (Sts J4 & J5)	Upper (St J6)
TVC	$14.6x10^3$	$14.5x10^3$	$14.5x10^3$	$10x10^3$	$12.2x10^3$	$23x10^3$
TC	ND	5	ND	37	225	ND
FC	ND	5	ND	33	213	50
ECLO	ND	5	ND	33	223	40
SHLO	ND	ND	ND	ND	5	ND
SLO	ND	ND	ND	ND	ND	ND
PKLO	ND	ND	ND	67	305	ND
VLO	30	20	20	193	577	165
VPLO	7	8	5	17	13	5
VCLO	7	8	5	170	565	160
PALO	ND	ND	ND	ND	ND	ND
SFLO	ND	ND	ND	ND	ND	ND

In sediment samples, the TVC counts (CFU/g) were high at all the three regions of the estuary. Except TVC, TC and FC other microbial community were generally lower at many stations (Tables 4.17.5 and 4.17.6) with some exceptions like premonsoo where pathogenic contamination was more at the study area which coul be attributed to intense fishing activities.

Type of Bacteria	January 2016 (Postmonsoon)			March 2016 (Premonsoon)		
	Coastal (Sts J1 to J3)	Lower (Sts J4 & J5)	Upper (St J6)	Coastal (Sts J1 to J3)	Lower (Sts J4 & J5)	Upper (St J6)
TVC	$207x10^3$	$200x10^3$	$230x10^3$	$333x10^3$	$260x10^3$	$280x10^3$
TC	ND	ND	ND	ND	ND	ND
FC	ND	ND	ND	ND	ND	1000
ECLO	ND	ND	ND	2333	ND	8000
SHLO	17	ND	ND	ND	ND	ND
SLO	17	ND	ND	ND	ND	ND
PKLO	ND	ND	ND	ND	3150	11000
VLO	23	40	50	6000	1800	12000
VPLO	5	10	10	666	ND	ND
VCLO	20	30	40	5333	1800	12000
PALO	ND	ND	ND	ND	ND	ND
SFLO	ND	ND	ND	ND	ND	ND

b) Phytoplankton

Results of chlorophyll *a* and phaeophytin in different segment of Shastri Estuary and associated coastal waters are given in Tables 4.17.7 to 4.17.12 and Figures 4.17.3 and 4.17.4 .Concentrations of chlorophyll *a* ranged from 0.45-3.10 mg/m^3 (av 1.96 mg/m^3) during premonsoon and from 0.1-2.2 mg/m^3 during postmonsoon (avg 1.3 mg/m^3) respectively.

Zone	Chlorophyll *a* (mg/m³)			Phaeophytin (mg/m³)		
	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)						
Coastal (Sts. J1 to J3)	0.1	1.1	0.75	0	0.7	0.35
Lower (Sts. J4 & J5)	0.2	2	1.3	0.1	2.5	1.3
Upper (St. J6)	1.1	2.2	1.7	0.4	0.7	0.55
March 2016 (Premonsoon)						
Coastal (Sts. J1 to J3)	0.45	1.73	1.2	0.3	0.69	0.42
Lower (Sts. J4 & J5)	1.52	3.1	2.4	0.14	0.69	0.48
Upper (St. J6)	1.9	3.05	2.3	0.32	0.58	0.47

The concentrations of phytopigments were normal in the estuary as well as in the coastal area (Tables 4.17.7 and 4.17.8 and Figures 4.17.3 and 4.17.4). Segment wise comparison of total cell counts and genera during thestudy period is given in the following table.

Zone	Cell count (no x 10³/l)			Total genera (no)		
	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)						
Coastal (Sts. J1 to J3)	6.6	26.2	13.3	5	8	6
Lower (Sts. J4 & J5)	10.8	34.6	20.75	5	9	8
Upper (St. J6)	12.8	39	25.45	7	9	9
March 2016 (Premonsoon)						
Coastal (Sts. J1 to J3)	8.4	17.2	14.15	6	10	8
Lower (Sts. J4 & J5)	22.6	52.8	38	8	16	13
Upper (St. J6)	35.2	96.4	64.7	14	16	16

The premonsoon season sustained higher cell counts and total genera with an increasing trend from coastal to the upper estuarine segment. However, such a distinct feature was absent during postmonsoon. Overall, 38 and 37 genera of phytoplankton were reported during premonsoon and postmonsoon period respectively (Tables 4.17.9 to 4.17.10).*Thalassiosira, Navicula, Ceratium, Mallomonas*, *Coscinodiscus,* and *Nitzschia* were dominant in premonsoon and *Mallomonas*, *Thalassiosira, Guinardia, Cyclotella*, *Dityocha*, *Navicula*, *and* were dominant in postmonsoon (Tables 4.17.11 and 4.17.12) during the study period.

c) Zooplankton

Zooplankton standing stock (Tables 4.17.13 and 4.17.14) in the Shastri Estuary and coastal segment off Jaigad (Figures 4.17.5 and 4.17.6) is summarized below.

Zone	Biomass ($ml/100m^3$)			Population ($no \times 10^3/100m^3$)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal (Sts. J1 to J3)	0.7	3.6	1.9	8.8	50.1	23.9	10	13	12
Lower (Sts. J4 & J5)	0.2	1.2	0.4	3.3	20.1	11.7	8	12	10
Upper (St. J6)	0.1	0.2	0.2	4.6	8.7	6.7	8	9	9
March 2016 (Premonsoon)									
Coastal (Sts. J1 to J3)	2.4	5.3	3.2	27.4	49.1	34.3	8	14	11
Lower (Sts. J4 & J5)	0.5	1.4	1.0	3.9	20.9	10.7	8	15	11
Upper (St. J6)	0.9	1.1	1.0	6.7	12.2	9.4	8	10	9

The zooplankton standing stock in terms of biomass (0.1 to 3.6 $ml/100m^3$; av 0.8 $ml/100m^3$) and population (3.3×10^3 to 50.1×10^3 $no/100m^3$; av 14.1×10^3 $no/100m^3$) was relatively lower during postmonsoon (Tables 4.17.13) and increased during premonsoon. The zooplankton biomass and population during premonsoon were in the range of 0.5 to 5.3 $ml/100m^3$ (av 1.7 $ml/100m^3$) and 3.9×10^3 to 49.1×10^3 $no/100m^3$ (av 18.1×10^3 $no/100m^3$) respectively (Table 4.17.14).

The community structure consisted mainly of copepods, chaetognaths, siphonophores, appendicularians, *Lucifer* sp., decapod larvae, fish eggs lamellibranchs and gastropods. Other groups present were foraminiferans, medusae and polychaetes Overall, 20 (premonsoon) and 17 (postmonsoon) groups of zooplankton were identified (Tables 4.17.15 and 4.17.16) during the study period.

d) Macrobenthos

The subtidal macrobenthic standing stock (Table 4.17.17) of Jaigad is summarized in the following table.

Stations	Biomass (g/m^2; wet weight)			Population (Ind./m^2)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal (Sts. J1 to J3)	1.40	10.80	5.10	875	4350	2261	4	5	5
Lower (Sts. J4 & J5)	3.00	15.10	6.40	900	3075	1972	2	4	4
Upper (St. J6)	0.40	2.20	1.00	175	250	200	2	4	3
Overall	0.40	15.10	4.90	175	4350	1821	2	5	4
March 2016 (Premonsoon)									
Coastal (Sts. J1 to J3)	2.80	20.00	9.80	1300	13175	4765	3	7	5
Lower (Sts. J4 & J5)	7.40	105.00	32.45	3200	7275	4676	5	7	6
Upper (St. J6)	0.70	3.20	1.90	200	600	419	4	5	5
Overall	0.70	105.00	16.00	200	13175	4011	3	7	5

Thus the macrobenthic standing stock in terms of biomass (0.40-105.00 g/m^2; wet wt.), population (175-13175 Ind./m^2) and total groups (2-7 no.) varied widely in the study area during the sampling period. Premonsoon sustained better standing stock in terms of biomass (avg. 16.00 g/m^2; wet wt.) as compared to postmonsoon (avg. 4.90 g/m^2; wet wt.). Similarly, the population was high in Premonsoon than postmonsoon. The spatial trend in population was distinct in both the seasons with the density decreasing from the coastal to the upper estuary. The faunal group diversity was comparable during the study period (2-5) in Postmonsoon and 3-7 in Premonsoon (Table 4.17.17).

These results indicated high patchiness in the distribution of subtidal macrobenthos. In general, about 12 and 15 faunal groups of macrobenthos were recorded during postmonsoon and premonsoon respectively (Tables 4.17.18 and 4.17.19).The faunal composition indicated the dominance of polychaetes while other faunal groups widely varied during the study period.

e) Meiobenthos

Meiobenthic standing stock in Shastri estuary and associated coastal area is given in table 4.17.20 and the segment-wise results are given in the table below.

Stations	Biomass ($\mu g/10cm^2$)			Population (Ind./ $10cm^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal (Sts. J1 to J3)	106.33	3612.17	1187.59	272	1496	900	6	9	8
Lower (Sts. J4 & J5)	11.02	461.1	225.72	64	106	92	3	6	4
Upper (St. J6)	226.58	290.88	258.73	416	510	463	3	7	5
March 2016 (Premonsoon)									
Coastal (Sts. J1 to J3)	42.35	2995.98	901.91	99	1132	544	2	12	5
Lower (Sts. J4 & J5)	86.24	1118.76	476.25	361	892	656	2	10	6
Upper (St. J6)	131.62	145.84	138.73	219	293	256	7	7	7

Meiofaunal biomass was the highest in the coastal region during the study period whereas, the density was the highest in coastal and the lower estuary in post and premonsoon respectively. Station J2 had the highest meiofaunal density for the region during the study period (Table 4.17.20). Nematodes dominated the meiofaunal community. Copepod nauplii were observed in both seasons indicating suitable conditions for this sensitive group of organisms. Kinorhynchs were encountered from stations J2 and J3 in both seasons (Tables 4.17.21 and 4.17.22) suggesting the nature of clean coastal system.

4.18 Ratnagiri (R)

Ratnagiri is a small port where barges transport clinker for the cement plants. Though the coastal system is free from industrial effluents, untreated sewage from the Ratnagiri town enters the bay. In addition fish discard at the landing centre is also a significant contaminant in the Mirya Bay. Overall, five stations (R1 to R5) were considered for study in the Ratnagiri segment (Figure 2.2.14).

4.18.1 Water quality

The results of water quality of Ratnagiri are presented in Tables 4.18.1 and 4.18.2 and the temporal variations at station R4 are illustrated in Figures 4.18.1 to 4.18.2. The Water quality results are summarized in the table below:

Parameters	January 2016 (Postmonsoon)			March 2016 (Premonsoon)		
	Coastal (sts R1 to R3)	Outer Bay (st R4)	Inner Bay (sts R5)	Coastal (sts R1 to R3)	Outer Bay (st R4)	Inner Bay (sts R5)
WT(°C)	27.1	27.0	27.2	28.6	28.9	28.7
pH	8.0	7.9	7.8	8.1	8.1	7.8
SS (mg/l)	19	20	20	16	19	18
Turbidity (NTU)	1.4	1.5	1.3	1.6	1.6	1.8
Salinity (ppt)	35.6	35.5	35.1	35.9	35.9	35.9
DO(mg/l)	6.2	6.2	0.7	6.2	6.4	5.3
BOD(mg/l)	2.2	2.8	12.9	1.9	2.9	2.6
PO_4^{3-}-P (µmol/l)	0.5	0.9	26.5	0.3	0.4	10.0
TP (µmol/l)	2.1	2.1	35.3	1.7	1.5	10.7
NO_3^--N (µmol/l)	2.3	2.0	10.1	0.8	1.1	8.8
NO_2^--N (µmol/l)	0.1	0.2	0.4	0.1	0.1	1.6
NH_4^+-N (µmol/l)	1.5	1.4	16.0	0.6	0.3	11.7
TN (µmol/l)	8.1	2.1	35.3	7.4	6.7	25.2
PHc (µg/l)	2.4	2.6	3.1	6.2	6.6	4.8
Phenols (µg/l)	81.7	91.0	70.1	83.4	86.9	113.8

The water temperature varied in accordance with the air temperature. SS was low. Salinity was close to that of seawater indicating absence of freshwater inflow in the dry season.

DO normally remained high (6.2-6.4 mg/l) in the coastal and outer bay (>5 mg/l). In the case of inner bay (Station R5) DO was low (0.6-1.0 mg/l) during postmonsoon (Table 4.18.1) suggesting severe organic pollution associated with the release of sewage. Phosphate, nitrate, nitrite and ammonia were in normal ranges in the coastal and outer bay segments. Due to sewage discharge in the inner Bay high phosphate (10.0-26.5 µmol/l) and ammonium (11.7-16.0 µmol/l) during both the seasons were recorded.

PHc and phenols levels did not indicate gross contamination by these pollutants.

Temporal variations (Figures 4.18.1 and 4.18.2) at outer bay (Station R4) revealed that temperature and pH varied in narrow ranges while salinity and DO varied randomly over the tidal cycle. Phosphate, nitrite and ammonia also varied randomly but in narrow ranges. Overall the study area revealed a noticeable contamination at the inner bay due to untreated sewage release from Ratnagiri Town.

4.18.2 Sediment quality

The consolidated results for sediment quality off Ratnagiri are presented in Tables 4.18.3 and 4.18.4 and summarized in the following table.

Parameter		Range	
		January 2016 (Postmonsoon)	**March 2016 (Premonsoon)**
Texture (%)	Sand	2.1-92.2	0.2-91.8
	Silt	5.4-67.8	1.8-87.6
	Clay	2.4-37.6	6.4-17.0
Metals	Al (%)	1.4-5.6	1.7-8.2
	Cr (µg/g)	47-155	57-162
	Mn (µg/g)	482-1234	500-1285
	Fe (%)	3.3-9.6	3.7-11.8
	Co (µg/g)	21-72	34-66
	Ni (µg/g)	14-69	33-89
	Cu (µg/g)	29-163	52-170
	Zn (µg/g)	31-112	38-117
	Cd (µg/g)	0.11-0.17	0.14-0.19
	Hg (µg/g)	0.02-0.13	0.01-0.17
	Pb (µg/g)	4.7-10.3	5.0-12.6
P (µg/g)		510-1001	1300-2111
C_{org} (%)		0.3-2.6	0.4-2.7
PHc (µg/g)		0.4-2.8	0.6-3.0

Dry wt basis except PHc which is wet wt basis

The sediment off Ratnagiri varied from sandy-silt (postmonsoon) to silty-sand (premonsoon) with low content of clay. Trace metals and C_{org} were generally in expected ranges and sediment seemed to be free from anthropogenic contaminants. Phosphate (2111 µg/g) and and PHc (3.0 µg/g, wet wt) were high in the inner Bay during premonsoon season due to sewage discharge in the region.

4.18.3 Flora and fauna

The results of biological characteristics of coastal and bay segments off Ratnagiri are presented in Tables 4.18.5 to 4.18.22 and temporal variation at Station R4 are illustrated in Figures 4.18.3 to 4.18.6.

a) Microbes

The TVC, TC, FC and ECLO counts (CFU/ml) were high during post monsoon than pre monsoon. TVC, TC, FC, ECLO were high at outer bay (Stn R4) and inner bay (StR5). SHLO, SLO, PALO and SFLO were absent in study area as illustrated in table below.

Type of Bacteria	January 2016 (Postmonsoon)			March 2016 (Premonsoon)		
	Coastal (sts R1 to R3)	Outer Bay (st R4)	Inner Bay (sts R5)	Coastal (sts R1 to R3)	Outer Bay (st R4)	Inner Bay (sts R5)
TVC	$1.1x10^3$	$1.3x10^3$	$8.6x10^3$	$20.5x10^3$	$32.5x10^3$	$14x10^3$
TC	180	168	2980	175	350	100
FC	82	78	1900	137	345	100
ECLO	33	35	992	85	305	520
SHLO	ND	ND	ND	ND	ND	ND
SLO	ND	ND	ND	ND	ND	ND
PKLO	ND	ND	ND	45	175	500
VLO	ND	443	860	440	60	580
VPLO	ND	158	300	60	10	ND
VCLO	ND	285	560	172	250	580
PALO	ND	ND	ND	ND	ND	ND
SFLO	ND	ND	ND	15	ND	ND

TVC, TC, FC and ECLO counts (CFU/g) in sediment were quite high during pre monsoon compare to post monsoon throughout the study region of the bay. As given in table below, most of the pathogenic bacteria were absent during postmonsoon time at the study area.

Type of Bacteria	January 2016 (Postmonsoon)			March 2016 (Premonsoon)		
	Coastal (sts R1 to R3)	Outer Bay (st R4)	Inner Bay (sts R5)	Coastal (sts R1 to R3)	Outer Bay (st R4)	Inner Bay (sts R5)
TVC	$6.8x10^3$	$x10^3$	$10.9x10^3$	$233x10^3$	$150x10^3$	$800x10^3$
TC	1707	2967	2010	2333	8000	120000
FC	1315	1312	972	1666	7000	90000
ECLO	364	88	638	1600	5000	60000
SHLO	ND	ND	ND	ND	ND	ND
SLO	ND	ND	ND	ND	ND	ND
PKLO	ND	ND	ND	666	17000	15000
VLO	ND	772	252	1733	8000	73000
VPLO	ND	122	162	66	ND	1000
VCLO	ND	650	480	1666	8000	72000
PALO	ND	ND	ND	ND	ND	ND
SFLO	ND	ND	ND	ND	3000	80000

b) Phytoplankton

The concentration of chlorophyll *a* varied widely from 1.4 to 13.4 mg/m^3 (av 5.4 mg/m^3) during premonsoon period and from 1.5 to 17.3 mg/m^3 (av 6.3 mg/m^3) during postmonsoon period. The concentration of phaeophytin was relatively lower (av 0.9 mg/m^3) than chlorophyll *a* (av 6.5 mg/m^3) during premonsoon indicating that the environment was conducive for the growth of phytoplankton.

Segment and season wise range and average of phytopigments are summarized below.

Zone	Chlorophyll *a* (mg/m^3)			Phaeophytin (mg/m^3)		
	Min	**Max**	**Avg**	**Min**	**Max**	**Avg**
January 2016 (Postmonsoon)						
Coastal water (Sts R1 to R3)	1.5	6	2.7	0.2	2.2	1
Outer Bay (St R4)	1.7	17.3	8.5	0.2	4.5	1.2
Inner Bay (St R5)	6.1	8.7	7.6	1.7	1.8	1.8
March 2016 (Premonsoon)						
Coastal water (Sts R1 to R3)	1.4	3.1	2.1	0.3	0.7	0.5
Outer Bay (St R4)	2.9	12.8	4.8	0.1	1.4	0.8
Inner Bay (St R5)	5.1	13.4	9.2	0.8	2.1	1.3

An increasing trend in phytopigments from coastal to the inner bay segment was evident with the bay sustaining high chlorophyll *a* during both seasons (Tables 4.18.7 and 4.18.8 and Figures 4.18.3 and 4.18.4) due to high primary production induced by organic input from sewage. Segment wise distribution of cell counts and total genera of phytoplankton is given below.

Zone	Cell count (no x 10^3/l)			Total genera (no)		
	Min	**Max**	**Avg**	**Min**	**Max**	**Avg**
January 2016 (Postmonsoon)						
Coastal water (Sts R1 to R3)	55	648.6	239.7	13	25	18
Outer Bay (St R4)	434	2352	1146	18	24	22
Inner Bay (St R5)	472	690	601.9	16	19	18
March 2016 (Premonsoon)						
Coastal water (Sts R1 to R3)	23	59	42.5	6	13	9
Outer Bay (St R4)	37	145	99	12	17	14
Inner Bay (St R5)	717	1205	951	14	18	14

The overall distribution of cell counts and genera indicated high values especially confined to the bay (Tables 4.18.9 and 4.18.10). Overall, 34 and 54 genera of phytoplankton were recorded during premonsoon and postmonsoon respectively. *Navicula, Chaetoceros, Cylindrotheca, Guinardia, Nitzschia, Gymnodinium, Ceratium, Skeletonema,* and *Thalassiosira* were the most common genera found at the study area (Tables 4.18.11 and 4.18.12).

c) Zooplankton

Zooplankton standing stock in the coastal and bay region of Ratnagiri (Tables 4.18.13 and 4.18.14) is summarized in the following table.

Zone	Biomass ($ml/100m^3$)			Population (no x $10^3/100m^3$)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal water (Sts R1 to R3)	0.3	0.8	0.6	2.2	3.8	3.3	13	18	15
Outer Bay (St R4)	0.6	1.4	0.9	1.6	11.2	4.3	9	11	13
Inner Bay (St R5)	-	-	0.6	-	-	2.4	-	-	10
March 2016 (Premonsoon)									
Coastal water (Sts R1 to R3)	0.7	24.1	5.1	9.8	331.4	71.71	11	14	13
Outer Bay (St R4)	0.2	2.8	1.3	7.5	57.2	29.3	11	14	12
Inner Bay (St R5)	-	-	0.2	-	-	6.9	-	-	11

The zooplankton standing stock in terms of biomass (0.3 to 1.4 $ml/100m^3$; av 0.8 $ml/100m^3$) and population (1.6 x 10^3 to 11.2 x 10^3 $no/100m^3$; av 3.3 x 10^3 $no/100m^3$) was lower during postmonsoon (Table 4.18.13),while they showed a several fold increase during premonsoon. The zooplankton biomass and population during premonsoon were in the range of 0.2 to 24.1 $ml/100m^3$ (av 2.2 $ml/100m^3$) and 7.5 x 10^3 to 331.4 x 10^3 $no/100m^3$ (av 36.0 x 10^3 $no/100m^3$) respectively (Table 4.18.14).

At R4, the standing stock was higher at flood tide with respect to ebb tide during the study period with higher diversity during premonsoon (Figures 4.18.5 and 4.18.6). The standing stock of zooplankton, in general, decreased from the open shore to the inner bay in premonsoon however no such trend was seen in postmonsoon. The lowest standing stock noticed at the inner bay especially during premonsoon could be due to zooplankton mortality associated with organic pollution and severe depletion in DO.

The community structures mainly consisted of high numbers of copepods, chaetognaths,cladocerans, decapod larvae, siphonophores, appendicularians, Lucifer sp., polychaetes, lamellibranchs, cladocerans, gastropods and fish eggs and fish larvae. The other common groups were foraminiferans, medusae and pteropods. The composition was fairly diverse and total groups varied from 10 to 17 (av 14 no) at different segments (Tables 4.18.15 and 4.18.16).

d) Macrobenthos

The standing stock of macrobenthos and total faunal groups (Table 4.18.17) are summarized below.

Stations	Biomass (g/m^2; wet weight)			Population ($Ind./m^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal water (Sts R1 to R3)	1.00	157.09	25.02	525	3925	1897	3	10	6
Outer bay (St R4)	5.80	12.40	9.00	4550	7200	5680	6	7	6
Inner bay (St R5)	0.04	0.09	0.07	225	725	419	2	3	3
Overall	0.04	157.09	16.83	225	7200	2358	2	10	5
March 2016 (Premonsoon)									
Coastal water (Sts R1 to R3)	2.22	79.59	20.39	1700	12500	5119	4	11	7
Outer bay (St R4)	16.86	65.10	39.05	10175	12475	10956	9	10	9
Inner bay (St R5)	0.47	5.02	2.89	250	1225	819	1	4	3
Overall	0.47	79.59	20.62	250	12500	5426	1	11	7

Thus the standing stock and community structure of macrobenthos remained relatively higher in the outer bay than the coastal waters and was lowest in the inner bay. Overall, there was increase in population density from Postmonsoon to premonsoon and similar trend was also observed for biomass. The faunal diversity was also better in the Premonsoon season. Relatively inner bay sustained less benthic diversity of groups compared to the rest. The major groups were Polychaeta, Pelecypoda, Tanaidacea and Amphipoda (Tables 4.18.18 and 4.18.19).

e) Meiobenthos

Meiobenthic standing stock of Mirya Bay and adjacent coastal area is given in Table 4.18.20 and the segment-wise results are given in the table below.

Stations	Biomass ($\mu g/10cm^2$)			Population ($Ind./10cm^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal water (Sts R1 to R3)	119.36	1013.57	454.32	201	1352	582	3	9	6
Outer bay(St R4)	781.34	1123.82	952.58	251	457	354	3	5	4
Inner bay(St R5)	209.37	252.91	231.14	44	75	59	1	3	2
March 2016 (Premonsoon)									
Coastal water (Sts R1 to R3)	44.19	1423.78	569.1	37	1737	693	2	7	5
Outer bay(St R4)	961.84	2039.36	1500.6	675	1335	1005	8	8	8
Inner bay(St R5)	161.59	346.17	253.88	120	290	205	4	5	4

In meiofaunal standing stock of the study area showed wide fluctuations. Coastal regions showed highest meiofaunal density (av. 582 Ind./10cm^2) in postmonsoon. Outer bay region sustained highest density (av. 1005 Ind./10cm^2) in premonsoon. For the study period, station R3 recorded the highest meiofaunal density, whereas R4 recorded the highest biomass. In all, 14 and 12 meiofaunal groups were observed in postmonsoon and premonsoon respectively. Nematodes and foraminiferans were the most abundant in the study area. Echiurans and hydrozoans were also observed during study period (Tables 4.18.20 and 4.18.21).

4.19 Vijaydurg Creek (VJ)

Stations VJ1 to VJ3 were located in the coastal waters off Vijaydurg, while the Vijaydurg Port at the mouth of the creek was represented by station VJ4. Stations VJ5 and VJ6 are the creek stations in the river Vaghotan termed as Vijaydurg Creek (Figure 2.2.15).

The study area does not receive industrial or domestic effluents. However, operations pertaining to handling of molasses and fish landing at the port have the potential to influence environmental quality of Vijaydurg coastal system.

4.19.1 Water quality

The results of water quality of Vijaydurg coastal system during pre and postmonsoon of 2015 is presented in Table 4.19.1 and 4.19.2 where as the temporal variations at station VJ4 are illustrated in Figures 4.19.1 and 4.19.2. The creek is represented by the lower and upper segments accordingly.

The segment-wise averaged water quality data is given in table below:

Parameter	Zone					
	January 2016 (Postmonsoon)			March 2016 (Premonsoon)		
	Coastal (sts VJ1 to VJ3	Lower (st VJ4)	Upper (sts VJ5 & VJ6)	Coastal (sts VJ1 to VJ3	Lower (st VJ4)	Upper (sts VJ5 & VJ6)
WT(ºC)	27.5	26.6	26.9	29.3	29.1	28.6
pH	8.1	8.2	8.2	8.1	8.1	8.1
SS (mg/l)	31	29	28	153	138	130
Turbidity (NTU)	2.3	1.6	1.9	4.2	1.5	2.0
Salinity (ppt)	35.4	35.3	35.0	35.7	35.8	35.7
DO(mg/l)	6.5	6.0	6.2	6.5	5.7	6.2
BOD(mg/l)	4.2	3.0	3.2	1.8	2.1	3.1
PO_4^{3-}-P (µmol/l)	0.9	0.7	1.6	0.3	0.9	4.2
TP (µmol/l)	2.0	2.1	2.7	1.1	1.8	5.7
NO_3^--N (µmol/l)	2.0	1.4	0.5	1.4	1.3	1.1
NO_2^--N (µmol/l)	0.2	0.1	0.1	0.1	0.2	0.2
NH_4^+-N (µmol/l)	2.1	1.6	16.1	6.0	0.5	3.9
TN (µmol/l)	8.4	10.1	26.7	15.1	9.8	16.6
PHc (µg/l)	5.8	4.1	4.2	13.1	10.9	6.8
Phenols (µg/l)	80.6	91.8	122.8	95.3	96.5	125.5

As evident from above that water temperatures were below 30ºC during the study period and they were lower during postmonsoon; varying in accordance with prevailing air temperatures. The pH was 8.1 to 8.2 during post and premonsoon seasons. SS was below 31 mg/l during the postmonsoon season. However, during premonsoon enhanced concentration (130-153 mg/l) of SS may be due to increased wave action and resuspension of bottom sediment. Salinity was fairly constant and varied in 35.0 - 35.4 ppt range during postmonsoon and marginally increased (35.7—35.8 ppt) during premonsoon.

DO was high - above 5 mg/l during the study period, suggesting good oxidizing environment off Vijaydurg. Low levels of DO were recorded occasionally particularly in the nearshore. As expected BOD was low (1.3-5.1 mg/l) suggesting healthy environment. The nitrate and nitrite concentrations were low. Higher concentration of phosphate in upper estuary and that of ammonia in the entire study area indicated some input of sewage in the system. Surprisingly higher concentration of ammonia even in the openshore region is a matter of concern and further detail study is necessary to identify the source. The PHc (2.2 to 17.2 µg/g; wet wt) and phenols (51.1-144.0 µg/g) though varied widely suggested low level of petroleum contamination in the coastal system especially at the creek segments.

Seasonal variations though evident were not marked in case of temperature, pH, salinity and DO. The trend of progressive increase towards the upper creek was not noticeable in the study area.

Temporal variations (Figures 4.19.1 and 4.19.2) at station VJ4 revealed marginal reduction in salinity, pH, and DO during ebb. A marginal column variation was also evident during ebbing for salinity (premonsoon) and DO (postmonsoon).

4.19.2 Sediment quality

The consolidated data for sediment quality of the Vijaydurg area are presented in Tables 4.19.3 and 4.19.4 and summarized in the following table.

Parameter		Range	
		January 2016 (Postmonsoon)	March 2016 (Premonsoon)
Texture (%)	Sand	2.1-95.4	1.1-89.6
	Silt	3.4-67.9	6.4-79.2
	Clay	1.2-31.6	1.2-51.7
Metals	Al (%)	8.2-9.6	5.9-7.5
	Cr (µg/g)	182-241	213-309
	Mn (µg/g)	1108-2153	863-2148
	Fe (%)	11.1-18.3	8.8-18.7
	Co (µg/g)	63-93	57-162
	Ni (µg/g)	82-133	99-132

	Cu (µg/g)	182-313	122-319
	Zn (µg/g)	114-216	98-251
	Cd (µg/g)	0.10-0.17	0.13-0.21
	Hg (µg/g)	0.04-0.13	0.14-0.21
	Pb (µg/g)	2.4-10.7	8.4-14.0
P (µg/g)		364-2306	368-1961
C_{org} (%)		0.3-2.7	0.7-3.0
PHc (µg/g)		0.3-1.8	0.6-2.7

Dry wt basis except PHc which is wet wt basis

It is evident from above data that calyey-silt in coastal and sandy-silt in creek segment prevailed at the study area irrespective of seasonal variations in sediment texture. No regular trend in the distribution of trace metals either spatial or seasonal in the coastal system of Vijaydurg was noticed. However, selective metals like Cr, Fe, Co, Ni, Cu and Zn were relatively high at the middle to upper creek (station 4 to station 6) as compared to other locations. The reason for such trend is not clear. In the absence of any effluent disposal in the study region, the observed metal content may be considered as the natural background constituted by lithogenic origin. The components like P (368-2306 µg/g) and C_{org} (0.3-3.0 µg/g) in sediments varied on a wide range with an enhancement of C_{org} during premonsoon and P during postmonsoon. Minor increase in the levels of PHc noticed at selected stations viz. VJ4 (1.8-2.7 µg/g; wet wt) could be due to operational release from fishing boats in the close proximity of the Port.

4.19.3 Flora and fauna

The results of biological characteristics off Vijaydurg are presented in Tables 4.19.5 to 4.19.22 where as the temporal variations at station VJ4 are illustrated in Figures 4.19.3 to 4.19.6.

a) Microbes

Counts of faecal indicator bacteria (CFU/ml) TC, FC in water were low compared to counts in sediment samples at the study area. SHLO, SLO, and SFLO were mostly absent (Table 4.19.5) as summerised in Table below.

Type of Bacteria	Zone					
	January 2016 (Postmonsoon)			March 2016 (Premonsoon)		
	Coastal (sts VJ1 to VJ3	Lower (st VJ4)	Upper (sts VJ5 & VJ6)	Coastal (sts VJ1 to VJ3	Lower (st VJ4)	Upper (sts VJ5 & VJ6)
TVC	$18.1x10^3$	$88x10^3$	$56x10^3$	$19x10^3$	$15.5x10^3$	$20.5x10^3$
TC	50	5	10	340	150	500
FC	40	ND	8	303	150	385
ECLO	ND	ND	5	270	105	275
SHLO	190	275	477	ND	ND	ND
SLO	ND	ND	ND	ND	ND	ND

PKLO	13	10	83	353	20	150
VLO	17	35	290	250	135	350
VPLO	13	20	10	ND	ND	40
VCLO	5	15	230	250	135	310
PALO	17	70	53	ND	ND	ND
SFLO	ND	ND	ND	ND	ND	ND

In Sediments samples, the TVC counts (CFU/g) were high at the study area. Except TVC, TC, FC and ECLO other microbial community were absent during post monsoon especially in the coastal (Stn VJ1 to VJ3) and lower creek (Stn VJ4) segments (Tables 4.19.6).

Type of Bacteria	Zone					
	January 2016 (Postmonsoon)			March 2016 (Premonsoon)		
	Coastal (sts VJ1 to VJ3	Lower (st VJ4)	Upper (sts VJ5 & VJ6)	Coastal (sts VJ1 to VJ3	Lower (st VJ4)	Upper (sts VJ5 & VJ6)
TVC	$887x10^3$	$200x10^3$	$250x10^3$	$633x10^3$	$400x10^3$	$250x10^3$
TC	5	ND	ND	4333	1000	ND
FC	5	ND	ND	3000	1000	ND
ECLO	ND	ND	ND	3000	1000	ND
SHLO	5	ND	ND	ND	ND	ND
SLO	ND	ND	ND	ND	ND	ND
PKLO	5	ND	ND	333	ND	ND
VLO	353	ND	160	1000	ND	ND
VPLO	133	10	45	333	ND	ND
VCLO	220	ND	115	667	ND	ND
PALO	ND	ND	ND	ND	ND	ND
SFLO	ND	ND	ND	ND	ND	ND

b) Phytoplankton

The concentration of chlorophyll *a* in the coastal and creek system of Vijaydurg ranged between 1.3 and 4.2 mg/m^3 (avg 2.4 mg/m^3) in premonsoon compared to 0.1-11 mg/m^3 (avg 2.8 mg/m^3) in post monsoon as evident from the table below. The variation from surface to bottom was negligible indicating their uniform distribution throughout the water column (Tables 4.19.7 and 4.19.8). Hence, temporal and tidal variations in the distribution of phytopigments were not discernible (Figures 4.19.3 and 4.19.4)

The concentration of phaeophytin (0.1-9.5 mg/m^3) also varied widely and was lower than chlorophyll *a* during the study period. Overall, the relative concentration of chlorophyll *a* and phaeophytin at Vijaydurg varied as follows.

Zone	Chlorophyll *a* (mg/m³)			Phaeophytin (mg/m³)		
	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)						
Coastal (Sts. VJ1 to VJ3)	0.7	2.2	1.3	0.2	0.9	0.4
Lower (St.VJ4)	0.1	11	3	0.3	9.5	1.5
Upper (Sts. VJ5 & VJ6)	2.6	7.1	4.1	0.4	2.8	1.45
March 2016 (Premonsoon)						
Coastal (Sts. VJ1 to VJ3)	1.4	4.2	1.9	0.1	1.8	0.64
Lower (St.VJ4)	1.3	4.2	2.3	0.1	2.1	0.81
Upper (Sts. VJ5 & VJ6)	2.2	3.9	3	0.5	2.5	1.46

The above results indicated wide spatial and seasonal variation in the phytopigments both in coastal and creek segments. In both seasons coastal region sustained lower chlorophyll *a* than upper creek area. Similarly, phaeophytin values showed no variation and were low during the study period suggesting phytoplankton cells are in exponential growth phase.

In line with the high variability of pigments, the average cell counts also fluctuated in the range of 24.0×10^3 to 300.0×10^3 Cells/l (avg 80.7×10^3 Cells/l) during premonsoon and 12.2×10^3 to 203.2×10^3 Cells/l (avg 52.8×10^3 Cells/l) during postmonsoon (Tables 4.19.9 to 4.19.10).

Segment wise distribution of cell counts and total genera is given below.

Zone	Cell count (no x 10³/l)			Total genera (no)		
	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)						
Coastal (Sts VJ1 to VJ3)	12.2	22.8	16.3	7	10	8
Lower (St VJ4)	15.4	37	23.95	9	14	11
Upper (StS VJ5 & VJ6)	43	203.2	118.15	11	17	14
March 2016 (Premonsoon)						
Coastal (Sts VJ1 to VJ3)	27	67	47	9	15	12
Lower (St VJ4)	24	82	66.5	12	15	14
Upper (StS VJ5 & VJ6)	44	300	128.5	14	18	16

The above results revealed variable phytoplankton cell counts in the study region with marked seasonal and spatial distribution. Overall, the higher average cell counts and generic diversity were noticed during premonsoon period except in the upper creek portion and these results were closely comparable with trend in chlorophyll *a* as noticed earlier.

In all, total 36 and 42 genera of phytoplankton were recorded during premonsoon and postmonsoon period respectively (Tables 4.19.11 and 4.19.12). The most common genera present at all stations irrespective of seasons were *Cylindrotheca, Bascillaria, Navicula, Nitzschia, Thalassionema* and *Thalassiosira* at all the stations during the study period. *Bacteriastrum, Bellorachea, Pleurosiga, Cylindrotheca* and *Guinardia* were most abundant in premonsoon season; while, *Mallomonas, Pseudo-nitzschia, Coscinodiscus, Skeletonema* and *Nitzschia* were in abundance in postmonsoon season.

c) Zooplankton

The zooplankton standing stock (Tables 4.19.13 and 4.19.14) varied widely and indicated an overall low secondary potential of the creek (Figures 4.19.5 and 4.19.6). The seasonal and spatial variability in the different segments are summarized below.

Zone	Biomass ($ml/100m^3$)			Population ($no \times 10^3/100m^3$)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal (Sts VJ1 to VJ3)	2.2	4.0	2.9	9.6	26.9	17.9	13	17	15
Lower (St VJ4)	0.9	7.7	3.0	10.2	29.9	15.8	14	16	15
Upper (StS VJ5 & VJ6)	0.9	5.4	2.7	8.1	18.5	15.0	15	16	15
March 2016 (Premonsoon)									
Coastal (Sts VJ1 to VJ3)	0.3	4.0	1.7	11.1	75.1	36.1	13	17	15
Lower (St VJ4)	1.7	10.9	5.2	22.2	151.8	56.0	15	18	16
Upper (StS VJ5 & VJ6)	0.9	5.6	2.5	14.2	115.5	48.2	14	19	16

The zooplankton standing stock in terms of biomass (0.9 to 7.7 $ml/100m^3$; av 2.9 $ml/100m^3$) and population (9.6×10^3 to 29.9×10^3 $no/100m^3$; av 16.2×10^3 $no/100m^3$) respectively were in postmonsoon (Table 4.19.13). The zooplankton biomass and population during premonsoon were in the range of 0.3 to 10.9 $ml/100m^3$ (av 3.1 $ml/100m^3$) and 11.1×10^3 to 151.8×10^3 $no/100m^3$ (av 46.7×10^3 $no/100m^3$) respectively (Table 4.19.14).

Overall, 22 groups were noticed during the study period with absence of seasonal variability (Tables 4.19.15 and 4.19.16). The predominant groups were Copepods, lamellibranchs, siphonophores gastropods, chaetognaths, decapod larvae, fish eggs, cladocerans, and appendicularians. Other groups present were Amphipods, medusae, doliolids, pteropods, isopods, *Lucifer* sp., and polychaetes.

d) Macrobenthos

The macrofaunal standing stock in terms of population and biomass varied from 0 to 3050 Ind/m^2 (av 1267 Ind/m^2) and from 0 to 28.08 g/m^2 (av 5.77 g/m^2; wet wt.) respectively during Postmonsoon period (Table 4.19.17). During Premonsoon population and biomass varied from 0 to 7000 Ind/m^2 (av 1001 Ind/m^2) and from 0 to 24.08 g/m^2 respectively (av 2.96 g/m^2; wet wt.). The average benthic biomass and population during Premonsoon was lower than Postmonsoon period.

The macrobenthic biomass, population and total faunal groups for different segments are summarized below.

Stations	Biomass (g/m^2; wet weight)			Population (Ind./m^2)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal (Sts VJ1 to VJ3)	0.00	28.08	7.94	0	3050	1513	0	12	6
Lower (St VJ4)	0.45	26.40	7.86	300	2525	1356	5	9	7
Upper (StS VJ5 & VJ6)	0.07	6.13	1.47	250	2725	853	4	10	7
Overall	0.00	28.08	5.77	0	3050	1267	0	12	7
March 2016 (Premonsoon)									
Coastal (Sts VJ1 to VJ3)	0.00	24.08	2.94	0	7000	1075	0	6	3
Lower (St VJ4)	0.27	0.88	0.58	325	575	481	6	10	7
Upper (StS VJ5 & VJ6)	0.02	17.45	4.18	25	3350	1150	1	10	5
Overall	0.00	24.08	2.96	0	7000	1001	0	10	4

The overall distribution of macrobenthos indicated wide spatial and seasonal variation in the coastal segments of Vijaydurg. However, better benthic standing stock was observed in the creek regions during postmonsoon than premonsoon. Faunal group diversity was higher during postmonsoon season probably due to better food availability in the region. Whereas in premonsoon, diversity was found to be high in lower creek region (Tables 4.19.18 and 4.19.19).

e) Meiobenthos

Meiobenthic standing stock in Vijaydurg Creek and associated coastal area is given in table 4.19.20 and the segment-wise results are given in the table below.

Stations	Biomass ($\mu g/10cm^2$)			Population (Ind./ $10cm^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal (Sts VJ1 to VJ3)	695.23	1342.86	895.23	457	1021	738	5	9	7
Lower (St VJ4)	1019.28	1333.84	1176.56	132	268	200	2	3	3
Upper (StS VJ5 & VJ6)	213.65	1537.93	811.18	217	1042	572	4	7	6
March 2016 (Premonsoon)									
Coastal (Sts VJ1 to VJ3)	28.54	2918.56	967.56	40	361	162	2	6	4
Lower (St VJ4)	176.54	204.04	190.29	100	102	101	2	3	3
Upper (StS VJ5 & VJ6)	63.96	816.78	507.685	41	450	243	3	8	7

In Vijaydurg, postmonsoon season showed high standing stock of meio benthos as compared to premonsoon. Biomass ranged from 28.54 to 2918.56 µ g/10cm^2 during study period. Meiofaunal density was high in coastal region, then decreased towards lower creek and increased again in upper creek and increased again in upper creek during the study period. Nematodes and foraminiferans dominated the community in the study area (Tables 4.19.21 and 4.19.22).

4.20 Deogad (D)

The sampling locations D1 to D3 were in the coastal waters while station D4 (mouth) was in the vicinity of the Deogad Port. Stations D5 and D6 were located in the inner creek (Figure 2.2.16).

Though Deogad River joins the creek, as seen in case of rivers in Konkan belt, the creek does not receive any freshwater flow except during monsoon. Mumbri Creek is situated south of the sampling locations. No known industrial or domestic effluent is released in the creek.

4.20.1 Water quality

The results of water quality of the creek and coastal waters of Deogad are given in Tables 4.20.1 and 4.20.2 where as the temporal variations at station D4 (Deogad Port) are illustrated in Figures 4.20.1 and 4.20.2.

Water quality results (average) of Deogad creek and coastal waters are given in the following table:

Parameters	Zone					
	January 2016 (Postmonsoon)			March 2016 (Premonsoon)		
	Coastal (sts D1 & D2)	Lower (sts D3 & D4)	Upper (sts D5 & D6)	Coastal (sts D1 & D2)	Lower (sts D3 & D4)	Upper (sts D5 & D6)
WT(^oC)	27.9	27.0	26.1	28.8	28.3	28.2
pH	8.2	8.1	8.1	8.2	8.2	8.1
SS (mg/l)	19	20	19	19	61	99
Turbidity (NTU)	1.7	1.7	1.7	2.0	1.9	2.9
Salinity (ppt)	35.4	34.9	33.0	35.6	35.4	34.7
DO(mg/l)	6.6	6.0	6.0	6.2	5.9	6.5
BOD(mg/l)	3.8	3.1	4.3	3.6	3.5	4.2
PO_4^{3-}-P (µmol/l)	0.4	0.6	0.7	0.3	0.5	0.4
TP (µmol/l)	1.1	1.3	1.2	1.3	2.8	1.0
NO_3^--N (µmol/l)	1.7	1.8	1.9	1.9	1.6	1.6
NO_2^--N (µmol/l)	0.3	0.2	0.1	0.1	0.1	0.1
NH_4^+-N (µmol/l)	2.0	2.5	3.1	0.5	0.9	0.9
TN (µmol/l)	12.0	11.7	10.4	7.0	1.0	8.0
PHc (µg/l)	2.0	4.8	6.6	2.8	6.6	5.5
Phenols (µg/l)	58.1	27.3	59.4	70.2	50.8	59.3

As evident from above data that, average water temperatures varied from 26.1 to 28.8^{o}C with higher values confined to premonsoon and also they varied in accordance with prevailing air temperatures. Reduction in temperature between coastal and creek stations especially during postmonsoon was evident. The pH was stable at 8.1 to 8.2. SS varied from 19 to 99 mg/l and turbidity was in 1.7-2.9 NTU range and the waters were clear. Salinities during premonsoon were 34.7 to 35.4 ppt and they were lower (33.0-35.4 ppt) during postmonsoon indicating seasonal variations. Though the values decreased towards the upper creek, no clear progressive decrease was noticed.

DO in the creek remained high (5.9-6.6 mg/l) and did not reveal any spatial and seasonal variations. Consequently, BOD was low at 3.1 to 4.3 mg/l, however the observed minor elevated levels could be attributed to the source from fishing activities.

The selective nutrients (phosphate, nitrate and nitrite) were uniformly low without any spatial and seasonal variations. However, elevated concentration of ammonia was recorded during postmonsoon season, indicating some organic source, probably from fishing and land based activities.

PHc and phenols were 2.0 to 6.6 µg/l and 27.3 to 70.2 µg/l respectively indicating clean coastal system with respect to these contaminants.

Clearly the vertical gradient was not evident for temperature, salinity and DO during premonsoon though seen for salinity and DO at station D5 and D6 during postmonsoon. This possibly indicated some stratification in the creek segment during postmonsoon due to drainage of freshwater. Though station D4 (Deogad Port) is located in a semi enclosed bay the water quality was good. However, increased concentration of ammonia was evident during postmonsoon season. This may be due to land based contamination as land run off during monsoon, which gets assimilated with progress of premonsoon season.

No clear trend in temporal variations at station D4 over the tidal cycle was discernible (Figure 4.20.1 and 4.20.2). As the creek did not receive industrial and domestic effluents, the water quality revealed a healthy environment.

4.20.2 Sediment quality

The consolidated results for sediment quality of the study area are presented in Tables 4.20.3 and 4.20.4. The segment wise averaged sediment quality of Deogad is presented in the following table and discussed further.

Parameter		Range	
		January 2016 (Postmonsoon)	March 2016 (Premonsoon)
Texture (%)	Sand	0.4-93.4	2.1-97.8
	Silt	4.4-83.6	0.8-50.2
	Clay	2.2-41.8	1.2-62.9
Metals	Al (%)	4.8-9.5	2.4-7.3
	Cr (µg/g)	167-194	158-234
	Mn (µg/g)	471-1375	517-940
	Fe (%)	7.8-14.4	6.8-11.0
	Co (µg/g)	43-76	38-90
	Ni (µg/g)	53-81	46-100
	Cu (µg/g)	87-208	56-109
	Zn (µg/g)	89-147	51-105
	Cd (µg/g)	0.08-0.16	0.14-0.20
	Hg (µg/g)	0.02-0.15	ND-0.19
	Pb (µg/g)	10.1-17.7	4.8-19.0
P (µg/g)		416-1279	618-2125
C_{org} (%)		0.3-3.4	0.1-3.0
PHc (µg/g)		0.2-1.4	0.3-1.9

Dry wt basis except PHc which is wet wt basis

As noticed above that the sediment texture was highly variable and it was mainly composed of silty-sand with low but variable percentage of clay.

The minor phosphorus and C_{org} build-up in sediment sometimes recorded appeared to be of natural origin in the absence of anthropogenic source in the system except for fishing activities and the elevated levels in PHc could be due to operational discharges from fishing boats especially at the Port. In general, most of the sediment quality parameters did not reveal either spatial or seasonal variability at Deogad.

4.20.3 Flora and fauna

The results of biological characteristics of the coastal/creek areas presented in Tables 4.20.5 to 4.20.22 and where as the temporal variations at station D4 (Deogad Port) are illustrated in Figures 4.20.3 and 4.20.6.

a) Microbes

Microbial counts (CFU/ml) in Deogad Creek waters were high in premonsoon as compared to post monsoon. Counts of TVC, TC, FC ECLO, PKLO, VCLO, and PALO were observed at all the three segments. Except SLO and SFLO other microbial communities were present at all the stations during pre and post monsoon as given in below table.

Type of Bacteria	Zone					
	January 2016 (Postmonsoon)			March 2016 (Premonsoon)		
	Coastal (sts D1 & D2)	Lower (sts D3 & D4)	Upper (sts D5 & D6)	Coastal (sts D1 & D2)	Lower (sts D3 & D4)	Upper (sts D5 & D6)
TVC	$7.5X10^3$	$3.7X10^3$	$14X10^3$	$13X10^3$	$43X10^3$	$9.7X10^3$
TC	70	13	157	110	725	220
FC	25	5	70	100	625	140
ECLO	10	8	13	105	495	82
SHLO	400	107	105	ND	ND	ND
SLO	ND	ND	ND	ND	ND	ND
PKLO	20	5	15	ND	852	60
VLO	35	125	190	165	420	230
VPLO	10	45	13	5	ND	10
VCLO	25	80	177	160	510	220
PALO	25	5	8	ND	62	ND
SFLO	ND	ND	8	ND	ND	ND

Sediment harboured high numbers of TVC counts (CFU/g) during pre and post monsoon at the study area. TC, FC and ECLO were noticed especially at the creek segment during premonsoon as given in (Tables 4.20.5 and 4.20.6).The absence or low number of pathogens in the sediment clearly indicated clean sediment in the study area.

Type of Bacteria	Zone					
	January 2016 (Postmonsoon)			March 2016 (Premonsoon)		
	Coastal (sts D1 & D2)	Lower (sts D3 & D4)	Upper (sts D5 & D6)	Coastal (sts D1 & D2)	Lower (sts D3 & D4)	Upper (sts D5 & D6)
TVC	$450X10^3$	$500X10^3$	$450X10^3$	$65X10^3$	$210X10^3$	$800X10^3$
TC	ND	ND	ND	ND	1200	6000
FC	ND	ND	ND	ND	650	3500
ECLO	ND	ND	ND	ND	500	1500
SHLO	ND	ND	ND	ND	ND	ND
SLO	ND	ND	ND	ND	ND	ND
PKLO	ND	ND	ND	ND	50	ND
VLO	60	80	290	ND	450	ND
VPLO	60	50	135	ND	100	ND
VCLO	ND	30	155	ND	350	ND
PALO	ND	ND	ND	ND	ND	ND
SFLO	ND	ND	ND	ND	ND	ND

b) Phytoplankton

Phytopigment chlorophyll *a* varied from1.2 to13.6 mg/m^3 (av 3.1 mg/m^3) during premonsoon and 1.1-6.9 mg/m^3 range (av 3.0 mg/m^3) during postmonsoon. The concentration of phaeophytin (av 0.6 mg/m^3) was lower than chlorophyll *a* both during premonsoon and postmonsoon (avg 0.8 mg/m^3) (Tables 4.20.7 and 4.20.8; Figures 4.20.3 and 4.20.4).

The values of chlorophyll *a* and phaeophytin in different segments off Deogad are given below:

Zone	Chlorophyll *a* (mg/m³)			Phaeophytin (mg/m³)		
	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)						
Coastal (Sts. D1 to D2)	1.1	1.5	1.3	0.6	1.2	0.7
Lower (Sts.D3 & D4)	1.4	6.9	3.1	0.5	2.6	1.0
Upper (Sts. D5 to D6)	3.7	6.2	4.7	0.5	1.0	0.8
March 2016 (Premonsoon)						
Coastal (Sts. D1 to D2)	1.2	2.03	1.6	0.1	0.5	0.3
Lower (Sts.D3 & D4)	2.2	13.6	4.8	0.2	1.8	0.8
Upper (Sts. D5 to D6)	1.8	3.54	3.1	0.2	1.2	0.7

The above table indicated wide spatial and seasonal variations in phytopigments at the study area. The temporal distribution pattern revealed no specific trend during the study period (Figures 4.20.3 and 4.20.4).

In line with chlorophyll *a* content the phytoplankton cell counts also varied on a wide range from 30.2 x 10^3 to 218.0 x 10^3 Cells/l (av 89.0 x 10^3 Cells/l) and 10.8 x 10^3 to 3747.2x 10^3 Cells/l (av 556.4 x10^3 Cells/l) during premonsoon and postmonsoon respectively (Tables 4.20.9 and 4.20.10).

Segment wise distribution of phytoplankton cell counts and total genera is summarized here.

Zone	Cell count (no x 10³/l)			Total genera (no)		
	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)						
Coastal (Sts. D1 to D2)	10.8	32.4	24.55	6	11	8
Lower (Sts.D3 & D4)	87	3747	899.5	10	17	13
Upper (Sts. D5 to D6)	423	2271	745.1	14	22	18
March 2016 (Premonsoon)						
Coastal (Sts. D1 to D2)	30.2	60.6	41.7	10	14	13
Lower (Sts.D3 & D4)	57.8	218	142.3	13	20	17
Upper (Sts. D5 to D6)	46.4	117.2	82.9	14	21	18

The above data revealed that the postmonsoon season had higher cell counts and higher generic diversity than premonsoon. The spatial variations were distinct without any trend.

Overall, 45 and 37 total genera of phytoplankton were identified in the premonsoon and postmonsoon season respectively (Tables 4.20.11 and 4.20.12).*Cerataulina, Cylindrotheca, Gyrosigma, Mallomonas, Peridinium,* and *Prorocentrum* were more common during premonsoon and *Skeletonema, Pinnularia, Cylindrotheca, Coscinodiscus* and *Nitzschia* were abundant during postmonsoon season. *Navicula, Nitzschia, Pleurosigma* and *Pseudo-nitzschia* were the common genera found during the study period.

c) Zooplankton

The zooplankton standing stock in-terms of biomass (0.4 to 7.1 ml/100 m^3 (av 2.2 ml/100 m^3) and population 3.2 x 10^3 to 44.9 x 10^3no/100 m^3 (av 15.6 x 10^3no/100 m^3) respectively was indicative of low secondary production potential during postmonsoon period (Table 4.20.13) which increased during premonsoon period with a better biomass (1.1 to 8.6 ml/100 m^3; avg 4.3 ml/100m^3) and population (30.5 x 10^3 to189.0 x 10^3no/100 m^3; av 87.5 x 10^3no/100 m^3) (Table 4.20.14 and Figures 4.20.5 and 4.20.6).

Segment wise zooplankton biomass, population and total groups are summarized here.

Zone	Biomass ($ml/100m^3$)			Population (no x $10^3/100m^3$)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal (Sts D1 & D2)	1.0	7.1	4.7	18.6	44.9	34.1	11	16	13
Lower (Sts D3 & D4)	0.4	0.8	0.6	3.2	11.3	6.3	11	14	12
Upper (St D5 & D6)	0.7	1.8	1.4	5.9	6.1	6.5	12	14	13
March 2016 (Premonsoon)									
Coastal (Sts D1 & D2)	3.6	8.6	5.8	30.5	47.5	39.2	12	14	14
Lower (Sts D3 & D4)	1.1	5.2	3.8	31.0	189.0	112.6	12	14	13
Upper (St D5 & D6)	2.3	5.1	3.3	104.8	115.6	110.6	13	16	15

It is evident from above table that the premonsoon season had higher zooplankton standing stock and faunal group diversity than postmonsoon. No clear spatial trend was evident.

The community structure mainly consisted of copepods, cladocerans, cumaceans, decapod larvae, lamellibranchs, chaetognaths and gastropods. The other common groups were siphonophores, appendicularians, polychaetes, *Lucifer* sp., fish eggs, medusae, foraminiferans, isopods, amphipods and fish larvae. The composition was fairly diverse and the number of faunal groups varied between 11-16 no (avg 14 no). Overall, 20 and 18 faunal groups were observed during premonsoon and postmonsoon period respectively (Tables 4.20.15 and 4.20.16).

d) Macrobenthos

Macrobenthic standing stock in terms of biomass and population varied from 0 to 50.09 g/m^2 (avg 5.27 g/m^2; wet wt) and 0 to 6250 Ind./m^2 (avg 955 Ind./m^2) during premonsoon period respectively. The biomass and population of macrobenthos during postmonsoon period were 0.50 to 78.73 g/m^2 (avg 17.82 g/m^2; wet wt) and 225 to 7225 Ind./m^2(avg 1600 no/m^2) indicating good macrobenthic production respectively (Table 4.20.17).

The macrobenthic biomass, population and total faunal groups for different segments are summarized below.

Stations	Biomass (g/m^2; wet weight)			Population ($Ind./m^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal (St D1 & D2)	2.53	49.24	16.17	675	1200	997	5	13	7
Lower (St D3 & D4)	3.01	53.21	20.96	1125	7225	2947	5	10	7
Upper (St D5 & D6)	0.50	78.73	16.32	225	1625	856	4	7	6
Overall	0.50	78.73	17.82	225	7225	1600	4	13	7
March 2016 (Premonsoon)									
Coastal (St D1 & D2)	0.00	12.91	1.81	0	375	97	0	5	1
Lower (St D3 & D4)	0.09	24.29	6.41	200	6250	2200	4	12	8
Upper (St D5 & D6)	0.19	50.09	7.58	175	1375	569	3	6	4
Overall	0.00	50.09	5.27	0	6250	955	0	12	4

The above data revealed very wide spatial and seasonal variation in macrobenthic distribution, however, lower creek showed high population, although premonsoon revealed better standing stock than postmonsoon.

The faunal distribution indicated high faunal diversity with a wide variability of 0 to 13 groups averaging at 4-7 groups. Overall 26 and 25 faunal groups were identified during premonsoon and postmonsoon period respectively (Tables 4.24.19 and 4.24.20). The macrofauna during premonsoon period was represented by Polychaeta (42.75%) followed by Tanaidacea (14.83%) and Amphipoda (11.01%). while, Polychaeta (51.50) followed by Pelecypoda (15.63%) and Tanaidacea (14.71%) were the most dominant during postmonsoon period (Tables 4.20.18 and 4.20.19)

e) Meiobenthos

Meiobenthic standing stock in Deogad Creek and associated coastal area is given in table 4.20.20 and the segment-wise results are given in the table below.

Stations	Biomass ($\mu g/10cm^2$)			Population ($Ind./ 10cm^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal (St D1 & D2)	171.4	755.88	369.88	556	1081	927	5	7	6
Lower (St D3 & D4)	126.35	2121.11	1084.87	149	3114	1462	3	9	6
Upper (St D5 & D6)	166.54	376.97	267.38	216	652	417	3	7	5

March 2016 (Premonsoon)									
Coastal (St D1 & D2)	9.61	286.38	91.97	28	150	83	2	4	2
Lower (St D3 & D4)	10.65	602.28	269.26	7	279	113	1	6	3
Upper (St D5 & D6)	235.29	1546.38	753.38	294	2594	1180	5	7	6

Meiobenthic standing stock in terms of biomass and population varied from 9.61 to 2121.11 µg/10cm^2 and 7 to 3114 ind./10cm^2 respectively (Table 4.20.20). The region sustained higher meiobenthic standing stock in postmonsoon than premonsoon. Nematodes were the most dominant in both seasons, however, harpacticoid copepods showed significant increase in premonsoon season (Tables 4.20.21 and 4.20.22).

4.21 Achara (ACH)

The coastal waters of Achara were represented by stations coastal (ACH1 to ACH2) Lower creek (ACH3 and ACH4) and upper creek (ACH5) (Figure 2.2.17).

4.21.1 Water quality

The results of water quality of Achara Creek is given in Tables 4.21.1 and 4.21.2 where as temporal variations at station ACH4 (Achara Port) are illustrated in Figures 4.21.1 and 4.21.2. These results are summarised in the table below.

Parameter	Zone					
	January 2016 (Postmonsoon)			March 2016 (Premonsoon)		
	Coastal ACH1 & ACH2	Lower ACH3 & ACH4	Upper ACH5	Coastal ACH1 & ACH2	Lower ACH3 & ACH4	Upper ACH5
WT(ºC)	23.8	27.0	26.3	29.0	29.1	29.3
pH	8.2	8.1	7.9	8.2	8.1	8.2
SS (mg/l)	23	18	17	30	21	17
Turbidity(NTU)	1.9	2.6	2.6	1.5	3.3	1.9
Salinity (ppt)	35.0	34.3	32.3	35.7	35.4	34.3
DO(mg/l)	6.7	6.4	6.2	5.9	5.7	5.1
BOD(mg/l)	2.5	2.8	2.2	2.7	2.2	1.7
PO_4^{3-}-P (µmol/l)	0.4	0.5	0.3	0.3	0.3	0.1
TP (µmol/l)	1.2	2.5	2.7	1.3	2.4	2.6
NO_3^--N (µmol/l)	1.5	2.4	2.8	1.0	2.2	2.1
NO_2^--N (µmol/l)	0.5	0.2	0.2	-	0.1	0.2
NH_4^+-N(µmol/l)	1.5	1.9	2.1	0.6	0.7	0.7
TN (µmol/l)	10.3	10.5	10.6	8.5	9.3	9.6
PHc (µg/l)	5.7	7.7	4.4	4.8	6.8	8.8
Phenols (µg/l)	83.0	114.8	115.6	63.2	60.9	73.7

As it is evident from the above table, the average water temperature varied between 23.8 and 27.0°C during postmonsoon, indicating spatial variation, which was not observed during premonsoon season (29.0-29.3°C). The values were below the upper threshold limit of 35°C for aquatic larvae of tropical biota. SS was 17to 23 mg/l and salinities were 32.3 to 35.7 ppt. Salinity revealed seasonal trend. The concentration of DO (5.1-6.7 mgl/l) and BOD (1.7-2.8 mg/l) off Achara revealed healthy marine ecology of the study area. Selective nutrients namely phosphate, nitrate and nitrite were uniformly low i.e. 0.1 to 0.5, 1.0 to 2.8 and ND to 0.5 µmol/l respectively.However, ammonia showed marginal increase during postmonsoon (1.5 to 2.1 µmol/l) compare to premonsoon season (0.6 to 0.7µmol/l). Such trend in low nutrients was commonly observed along the southern coast of Maharashtra

The concentrations of PHc and phenols were in 4.4 to 8.8 µg/l and 60.9 to 115.6 µg/l respectively suggesting low contamination and normal trend in case of port related coastal system.

Temporal variations at station ACH4 indicated tidal variation of salinity with minimum values recorded during ebb. The other parameters remained very low to show any tidal or spatial or seasonal variation.

In absence of any known anthropogenic fluxes, Achara coastal waters represent less polluted environment.

4.21.2 Sediment quality

The consolidated data for sediment quality of the coastal system off Achara is presented in Tables 4.21.3 and 4.21.4. The Sediment quality of Achara is summarized in the following table and discussed further.

Parameter		Range	
		January 2016 (Postmonsoon)	March 2016 (Premonsoon)
Texture (%)	Sand	6.2-92.0	2.9-94.6
	Silt	5.4-80.1	3.8-82.1
	Clay	2.2-13.7	1.6-23.7
Metals	Al (%)	4.8-8.5	1.7-6.6
	Cr (µg/g)	103-367	58-227
	Mn (µg/g)	369-832	203-1098
	Fe (%)	4.2-12.8	1.9-10.3
	Co (µg/g)	30-64	23-90
	Ni (µg/g)	35-76	25-95
	Cu (µg/g)	41-117	28-116
	Zn (µg/g)	34-108	11-113
	Cd (µg/g)	0.16-0.19	0.13-0.18
	Hg (µg/g)	0.05-0.14	0.03-0.10

	Pb (µg/g)	9.5-18.5	7.6-16.1
P (µg/g)		428-2217	200-2073
C_{org} (%)		0.0-2.9	0.1-3.3
PHc (µg/g)		0.6-1.8	0.8-1.1

Dry wt basis except PHc which is wet wt basis

As evident from above the texture of sediment was mostly sandy silt or silty sand with low percentage of clay. Sediment at stations ACH4 and ACH5 however was sandy. Phosphorus (428-2217 µg/g) and C_{org} (0.0-3.3%, dry wt) varied widely suggesting considerable variations associated with sediment texture. PHc varied from 0.6 to 1.8 µg/g; wet wt, suggesting minor contamination of PHc in the coastal system. Metal content indicated lithogenic background.

4.21.3 Flora and fauna

The results of biological characteristics Achara and the fishery port in the creek are presented in Tables 4.21.5 to 4.21.22 where as temporal variations at station ACH4 are illustrated in Figures 4.21.3 to 4.21.6.

a) Microbes

During premonsoon 2016, Achara Creek waters sustained higher count (CFU/ml) of TVC, TC, FC and VLO as evident from below table which suggests contamination of the region by sewage and fishing activities The TVC counts of the lower creek (Stations ACH3 & ACH4) were much higher than the coastal (Stations ACH1-ACH2) and upper creek (Station ACH5) areas during both pre and post monsoon. TC, FC, ECLO, SHLO, PKLO, VPLO and VCLO counts were high at lower (Stations ACH3 & ACH4) and upper creek (ACH5). Most of the microbial communities like TC, FC, ECLO, SLO, PKLO, VLO and SFLO were absent in the coastal waters (Tables 4.21.5 and 4.21.6) as given in the table below.

Type of Bacteria	Zone					
	January 2016 (Postmonsoon)			March 2016 (Premonsoon)		
	Coastal ACH1& ACH2	Lower ACH3 & ACH4	Upper ACH5	Coastal ACH1& ACH2	Lower ACH3 & ACH4	Upper ACH5
TVC	$0.51x10^3$	$20.7x10^3$	$5x10^3$	$12x10^3$	$29.2x10^3$	$11x10^3$
TC	ND	115	130	15	120	210
FC	ND	98	95	15	115	205
ECLO	ND	5	25	15	68	20
SHLO	5	5	100	ND	ND	ND
SLO	ND	ND	ND	ND	ND	ND
PKLO	ND	20	60	ND	13	30
VLO	5	382	1030	375	492	600
VPLO	5	28	10	150	13	ND
VCLO	ND	ND	1020	225	492	600
PALO	ND	ND	230	ND	ND	ND
SFLO	ND	5	35	ND	ND	ND

The microbial counts of sediments (CFU/g) indicated significantly elevated levels of TVC, TC and FC. Counts of microorganisms like TVC, TC and FC were quite high during premonsoon. The microbial communities like TC, FC, ECLO, SLO, PKLO, VLO and SFLO were mostly absent in postmonsoon as illustrated in the table below. The microbial contaminations of the study area is mostly localized due to port and fishing related activities.

Type of Bacteria	Zone					
	January 2016 (Postmonsoon)			March 2016 (Premonsoon)		
	Coastal ACH1& ACH2	Lower ACH3 & ACH4	Upper ACH5	Coastal ACH1& ACH2	Lower ACH3 & ACH4	Upper ACH5
TVC	$120x10^3$	$35x10^3$	$300x10^3$	$900x10^3$	$1000x10^3$	$800x10^3$
TC	ND	20	50	2000	3500	1000
FC	ND	15	10	1000	3500	1000
ECLO	ND	ND	ND	1000	2500	1000
SHLO	5	ND	150	ND	ND	3000
SLO	ND	ND	ND	ND	ND	ND
PKLO	ND	ND	ND	ND	2500	5000
VLO	135	10	300	1525	2000	10000
VPLO	135	ND	20	ND	500	5000
VCLO	30	10	280	1525	1500	ND
PALO	ND	ND	ND	50	50	ND
SFLO	ND	ND	20	10	10	ND

b) Phytoplankton

Phytopigment chlorophyll *a* varied from 0.6 to 4.1mg/m^3 (avg 1.9 mg/m^3) during postmonsoon and 0.6-4.6 mg/m^3 (avg 2.0 mg/m^3) during premonsoon. During postmonsoon phaeophytin content ranged between 0.4 to 1.5 mg/m^3 (avg 0.9). While it variedfrom 0.2 to 1.5 (avg 0.8 mg/m^3) during premonsoon (Figures 4.21.3 and 4.21.4). The values of chlorophyll *a* and phaeophytin in different segments off Achara are given below:

Zone	Chlorophyll *a* (mg/m³)			Phaeophytin (mg/m³)		
	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)						
Coastal (Sts. ACH1 to ACH2)	1.1	2.2	1.6	0.7	1.5	1
Lower (Sts. ACH3 to ACH4)	0.6	2.8	2.3	0.5	1.1	0.8
Upper (St. ACH5)	1.4	2.1	1.7	0.4	0.9	0.6

March 2016 (Premonsoon)						
Coastal (Sts. ACH1 to ACH2)	1.3	2.8	2.1	0.2	1.4	0.6
Lower (Sts. ACH3 to ACH4)	0.6	3.4	1.2	0.2	1	0.5
Upper (St. ACH5)	0.7	4.6	2.6	0.2	1.5	0.9

The above table indicated wide spatial and seasonal variations in phytopigments at different segments. The distribution pattern revealed no specific trend during the study period.

In line with chlorophyll *a* content the phytoplankton cell counts also varied on a wide range from 16.8 x 10^3 to 99.0 x 10^3 Cells/l (av 43.9 x 10^3no/l) and 66.2x 10^3 to 591 x 10^3 Cells/l (av 316.5 x 10^3 Cells/l) during premonsoon and postmonsoon respectively (Tables 4.21.9 and 4.21.10).

Segment wise distribution of phytoplankton cell counts and total genera is summarized below.

Zone	**Cell count (no x 10^3/l)**			**Total genera (no)**		
	Min	**Max**	**Avg**	**Min**	**Max**	**Avg**
January 2016 (Postmonsoon)						
Coastal (Sts. ACH1 to ACH2)	135	188	150	12	20	16
Lower (Sts. ACH3 to ACH4)	66.2	591	376	10	17	16
Upper (St. ACH5)	277	572	425	14	14	14
March 2016 (Premonsoon)						
Coastal (Sts. ACH1 to ACH2)	43	99	68.1	10	17	14
Lower (Sts. ACH3 to ACH4)	16.8	47.8	31	9	15	11
Upper (St. ACH5)	21.4	43.8	32.6	11	14	13

The above data revealed that the postmonsoon season had higher cell counts and higher generic diversity than premonsoon. The spatial variations were distinct without any trend.

Overall, 40 and 42 total genera of phytoplankton were identified in the premonsoon and postmonsoon season respectively (Tables 4.21.11 and 4.21.12). *Pleurosigma, Navicula* and *Surirella* were common in the study area during premonsoon whereas *Pseudo-nitzschia, Plagioselmis, Gyrodinium,* *Alexandrium, Cylindrotheca, Gymnodinium, Navicula,* and *Thalassiosira* were common in the study area during postmonsoon.

c) Zooplankton

Zooplankton standing stock (Tables 4.21.13 and 4.21.14) in the Achara Creek (Figures 4.21.5 and 4.21.6) is summarized below.

Zone	Biomass ($ml/100m^3$)			Population (no x $10^3/100m^3$)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal (Sts. ACH1 to ACH2)	0.3	5.7	2.5	11.2	90.5	59.3	4.0	9.0	8.0
Lower (Sts. ACH3 to ACH4)	0.6	2.6	1.6	11.6	87.9	52.6	10	12	11
Upper (St. ACH5)	**Samples not collected**								
March 2016 (Premonsoon)									
Coastal (Sts. ACH1 to ACH2)	2.6	4.6	3.4	10.1	49.3	29.9	13.0	15.0	14.0
Lower (Sts. ACH3 to ACH4)	1.0	6.0	3.8	19.5	88.2	57.9	12	15	13
Upper (St. ACH5)	**Samples not collected**								

The zooplankton standing stock in terms of biomass (0.3 to 5.7 $ml/100m^3$; avg 2.1 $ml/100m^3$) and population (11.2 x 10^3 to 90.5 x 10^3 $no/100m^3$; avg 56.0 x 10^3 $no/100m^3$) was relatively lower during postmonsoon (Table 4.21.13) and increased during premonsoon. The zooplankton biomass and population during premonsoon were in the range of 1.0 to 6.0 $ml/100m^3$ (avg 3.6 $ml/100m^3$) and 10.1 x 10^3 to 88.2 x 10^3 $no/100m^3$ (avg 43.9 x 10^3 $no/100m^3$) respectively (Table 4.21.14). There were 15 and 19 faunal groups during postmonsoon and premonsoon period respectively (Table 4.21.15 and 4.21.16).

d) Macrobenthos

The standing stock of subtidal macrobenthos in terms of biomass (0.08-30.93 g/m^2; wet wt, av 5.46 g/m^2, wet wt) and population (200-3550 Ind/m^2; av 1188 Ind/m^2) varied widely during premonsoon. The biomass and population of macrobenthos during postmonsoon period were 0.07-95.43 g/m^2 (avg 8.02 g/m^2; wet wt) and 50-2850 Ind/m^2 (avg 1305 Ind/m^2) indicating good macrobenthic production respectively. The faunal groups showed wide variability in postmonsoon as compared to premonsoon through the segmentation of the creek (Table 4.21.17).

Results of macrobenthic biomass, population and faunal groups are given below.

Stations	Biomass (g/m^2; wet weight)			Population ($Ind./m^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal (Sts. ACH1 to ACH2)	0.24	95.43	12.68	700	2150	1097	4	10	6
Lower (Sts. ACH3 to ACH4)	0.07	3.55	1.33	50	2325	863	2	6	4
Upper (St. ACH5)	2.29	33.07	12.06	2400	2850	2606	7	12	10
Overall	0.07	95.43	8.02	50	2850	1305	2	12	6
March 2016 (Premonsoon)									
Coastal (Sts. ACH1 to ACH2)	1.50	7.06	4.10	275	2450	1134	4	11	7
Lower (Sts. ACH3 to ACH4)	0.08	2.41	1.29	200	1425	638	3	11	7
Upper (St. ACH5)	4.43	30.93	16.50	425	3550	2394	2	9	7
Overall	0.08	30.93	5.46	200	3550	1188	2	11	7

The faunal distribution showed diversity with a wide variability of 2 to 12 groups averaging at 6-7 groups. Overall 20 and 23 faunal groups were identified during postmonsoon and premonsoon period respectively (Table 4.21.18 and 4.21.19). The macrofauna during Postmonsoon period was represented by polychaetes (68.64%) and in Premonsoon with a minor decrease in the composition of polychaeta (46.33%). Tanaidacea, Amphipoda, Pelecypoda, Brachyura and Nemertea are the other common groups found in the study area (Table 4.21.18 and 4.21.19).

e) Meiobenthos

Meiobenthic standing stock in Achara Creek and associated coastal area is given in table 4.21.20 and the segment-wise results are given in the table below.

Stations	Biomass ($\mu g/10cm^2$)			Population ($Ind./ 10cm^2$)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal (Sts. ACH1 to ACH2)	103.26	316.62	188.44	137	335	248	2	5	4
Lower (Sts. ACH3 to ACH4)	12.16	152.76	72.24	58	89	76	2	6	4
Upper (St. ACH5)	915.24	945.34	930.29	807	876	841	9	14	10
March 2016 (Premonsoon)									
Coastal (Sts. ACH1 to ACH2)	8.4	143.25	46.4	13	211	65	1	5	2
Lower (Sts. ACH3 to ACH4)	606.35	1143.86	917.43	333	614	459	8	9	8
Upper (St. ACH5)	2766.3	4097.7	3431.99	577	986	782	9	10	9

Achara region showed highest meiofaunal standing stock in the upper creek during the study period (Table 4.21.20). The population was ranged from 58 to 986 Ind./ 10cm^2 during entire study period. Upper creek showed significant increase in the meiofaunal biomass as well as population during the study period. Faunal group diversity varied from 2 to 10 during the study period. This region was also high in diversity recording a total of 17 groups for the two seasons (Table 4.21.21 and 4.21.22).

4.22 Malvan (M)

The coastal waters of Malvan were represented by stations M1 to M3 and station M4 was located in Malvan Bay (Figure 2.2.18) which included Malvan Port and a fort.

4.22.1 Water quality

The results of water quality of Malvan is summarized in Tables 4.22.1 and 4.22.2 where as temporal variations at station M4 (Malvan Port) are illustrated in Figures 4.22.1 and 4.22.2.

The water quality parameters have been averaged and presented below.

Parameter	Zone			
	January 2016 (Postmonsoon)		March 2016 (Premonsoon)	
	Coastal (sts M1 to M3)	Bay (st M4)	Coastal (sts M1 to M3)	Bay (st M4)
WT(^{o}C)	26.3	27.7	29.0	29.8
pH	8.2	8.1	8.2	8.2
SS (mg/l)	13	28	15	28
Turbidity(NTU)	1.8	1.7	1.8	1.6
Salinity (ppt)	35.3	35.4	35.6	35.7
DO(mg/l)	7.1	6.7	6.6	6.6
BOD(mg/l)	3.3	3.1	2.3	3.1
PO_4^{3-}-P(µmol/l)	0.2	0.5	0.2	0.4
TP (µmol/l)	0.7	1.2	0.7	1.0
NO_3^--N (µmol/l)	1.5	1.7	1.8	1.9
NO_2^--N (µmol/l)	0.1	0.04	0.1	0.1
NH_4^+-N(µmol/l)	1.6	1.3	0.7	1.4
TN (µmol/l)	9.6	6.3	8.3	10.3
PHc (µg/l)	5.1	10.4	6.7	5.5
Phenols (µg/l)	74.7	61.4	155.3	42.7

The above result indicates that average water temperature was below 30^{o}C with minima and maxima highly smoothened. The Bay segment revealed relatively high temperature (1 or 2^{o}C) than open coastal waters suggesting spatial variations during the study period and it could be related to shallowness and associated land influence. The values were below the upper limit of 35^{o}C for aquatic larvae of tropical biota. SS was 13 to 28 mg/l and salinities were 35.3 to 35.7 ppt. There were no seasonal variations in DO (6.7-7.1 mg/l) and BOD (2.3-3.3 mg/l). The average DO content of above 6.6 mg/l in the coastal system off Malvan revealed good marine water quality. Spatial variations in salinity, pH and SS were largely absent. Selective nutrients namely phosphate, nitrate and nitrite were uniformly low i.e. 0.2 to 0.5, 1.5 to 1.9, ND to 0.1 µmol/l respectively. Such trend in low nutrients was commonly observed along the southern coast of Maharashtra.

The concentrations of PHc and phenols varied in 5.1-10.4 µg/l and 42.7-155.3 µg/l ranges respectively suggesting normal trend in case of port related coastal system.

Temporal variations at station M4 did not indicate changes in the pH, salinity and DO over the tidal cycle. The selective nutrients remained low throughout without tidal, spatial or seasonal variations.

In absence of any known anthropogenic fluxes, Malvan coastal waters represent clean environment.

4.22.2 Sediment quality

The consolidated data for sediment quality of the coastal system off Malvan is presented in Tables 4.22.3 and 4.22.4. The Sediment quality of Malvan is summarized in the following table and discussed further.

Parameter		Range	
		January 2016 (Postmonsoon)	March 2016 (Premonsoon)
Texture (%)	Sand	0.0-96.2	1.0-2.2
	Silt	1.8-89.4	84.8-89.3
	Clay	2-10.8	9.6-13.4
Metals	Al (%)	5.5-8.7	4.7-6.8
	Cr (µg/g)	88-173	134-233
	Mn (µg/g)	396-560	590-785
	Fe (%)	4.3-7.4	6.0-7.5
	Co (µg/g)	32-42	46-49
	Ni (µg/g)	35-75	53-97
	Cu (µg/g)	41-85	73-86
	Zn (µg/g)	79-84	71-89
	Cd (µg/g)	0.10-0.20	0.08-0.18
	Hg (µg/g)	0.1-0.15	0.06-0.18
	Pb (µg/g)	15.0-16.6	12.9-13.8
P (µg/g)		330-430	242-435
C_{org} (%)		2.1-2.8	1.3-3.3
PHc (µg/g)		0.4-0.6	0.5-0.9

Dry wt basis except PHc which is wet wt basis

As evident from above data that the texture of sediment in the coastal waters (stations M1 to M3) was mostly silty with low percentage of clay. Station M4 however indicated different texture i.e. sandy during postmonsoon season. Phosphorus which varied in 242-435 µg/g range was of lithogenic origin. C_{org} was in the range of 0.3 to 3.4%, dry wt suggesting considerable variations associated with sediment texture. PHc varied from 0.4 to 0.9 µg/g; wet wt, suggesting no contamination of PHc in the coastal system. Metal content revealed the scatter in narrow ranges than generally observed for the coast of Maharashtra. No clear cut seasonal trend in metals was evident. The variability in metals could be related to levels of Al and Fe. Incidentally the Malvan coastal system comes under highly productive zones both flora and fauna-wise.

4.22.3 Flora and fauna

The results of biological characteristics off Malvan and the fishery port in the Bay presented in Tables 4.22.5 to 4.22.22 where as temporal variations at station M4 (Malvan Port) are illustrated in Figures 4.22.3 to 4.22.6.

a) Microbes

During premonsoon 2016, counts of faecal indicator bacteria (CFU/ml) TC, FC were high at the coastal and Bay segments of Malvan compared to post monsoon. TC, FC and ECLO, SHLO, SLO, VCLO, PALO and SFLO were mostly absent during post monsoon in the study area as given in below table.

Type of Bacteria	January 2016 (Postmonsoon)		March 2016 (Premonsoon)	
	Coastal (sts M1 to M3)	Bay (st M4)	Coastal (sts M1 to M3)	Bay (st M4)
TVC	$2.25x10^3$	$46\ x10^3$	$174x10^3$	$200x10^3$
TC	ND	ND	667	800
FC	ND	ND	613	600
ECLO	ND	ND	447	500
SHLO	ND	ND	ND	ND
SLO	ND	ND	ND	ND
PKLO	4	10	220	700
VLO	9	ND	1033	750
VPLO	9	ND	ND	ND
VCLO	ND	ND	1033	750
PALO	ND	ND	ND	ND
SFLO	ND	ND	ND	ND

The microbial counts in sediment (CFU/g) also showed similar trend as that of water with high counts at coastal (Stations M1 to M3) region during Premonsoon and as illustrated in the table below (Tables 4.22.5 and 4.22.6.) The above results indicated pathogenic contamination in the creek and coatral segments of Malvan especially due to port and fishery related activities.

Type of Bacteria	January 2016 (Postmonsoon)		March 2016 (Premonsoon)	
	Coastal (sts M1 to M3)	Bay (st M4)	Coastal (sts M1 to M3)	Bay (st M4)
TVC	$100x10^3$	$7x10^3$	$1466.6x10^3$	$1400x10^3$
TC	ND	NG	3733	ND
FC	ND	NG	2666	ND
ECLO	ND	NG	1667	ND
SHLO	ND	NG	ND	ND
SLO	ND	NG	ND	ND
PKLO	3	NG	167	ND
VLO	283	NG	3200	ND
VPLO	143	NG	ND	ND
VCLO	140	260	ND	ND
PALO	ND	10	ND	ND
SFLO	ND	270	ND	ND

b) Phytoplankton

The distribution of chlorophyll *a* was patchy with values widely fluctuating from 1.5-6.2 mg/m^3 (avg 2.9 mg/m^3) during postmonsoon and 0.5 to 4.0 mg/m^3 (avg 1.9 mg/m^3) during premonsoon (Tables 4.22.7 and 4.22.8 and Figures 4.22.3 and 4.22.4). The concentration of phaeophytin during postmonsoon and premonsoon was 0.3 to 1.3 mg/m^3 (avg 0.7 mg/m^3) and 0 to 3.94 mg/m^3 (avg 1.0 mg/m^3) respectively indicating high concentration of phaeophytin during premonsoon.

Distribution of chlorophyll *a* and phaeophytin in different segment off Malvan is given below.

Zone	Chlorophyll *a* (mg/m³)			Phaeophytin (mg/m³)		
	Min	Max	Avg	Min	Max	Avg
Postmonsoon						
Coastal (Sts M1 to M3)	1.5	6.2	3.8	0.3	1.3	0.7
Bay (St M4)	1.7	2.1	2	0.4	1.2	0.6
Premonsoon						
Coastal (Sts M1 to M3)	0.6	2.7	1.9	0.1	1.6	0.9
Bay (St M4)	0.5	4	1.9	0	3.9	1.09

The overall values of chlorophyll *a* and phaeophytin as shown above revealed spatial as well as seasonal variability with bay water sustaining higher content of both chlorophyll *a* and phaeophytin as compared to coastal waters. High values of chlorophyll *a* and phaeophytins noticed in the bay particularly during premonsoon season clearly suggests poor flushing of the bay waters and organic pollutants associated with fish landing activities.

Variations in phytoplankton cell counts (Tables 4.22.9 and 4.22.10) were well corresponded with chlorophyll *a* distribution. It varied widely from 102.0 x 10^3 to 3746.6 x 10^3 Cells/l; av 1462.3 x 10^3 Cells/l) during postmonsoon and 47 x 10^3 to 1088 x 10^3 Cells/l (av 292.0 x 10^3 Cells/l) during premonsoon period.

Segment wise distribution of phytoplankton cell counts and total genera is given below.

Zone	Cell count (no x 10^3/l)			Total genera (no)		
	Min	**Max**	**Avg**	**Min**	**Max**	**Avg**
Postmonsoon						
Coastal (Sts M1 to M3)	102	3747	2673.4	13	24	20
Bay (St M4)	197	292.8	251.25	15	26	20
Premonsoon						
Coastal (Sts M1 to M3)	47	1088	428.5	9	23	16
Bay (St M4)	64	290	155.5	13	16	15

It is evident from the above data that phytoplankton cell counts were high during postmonsoon than premonsoon suggesting high primary production induced by organic enrichment due to fish landing activities at the port as well as coincide with peak primary production period all along the West coast. Genericdiversity of phytoplankton also shows the same trend

Overall, 42 and 43 total genera of phytoplankton were identified during postmonsoon and premonsoon periods respectively (Tables 4.22.11 and 4.22.12). Genera like *Bacteriastrum, Chaetoceros, Cylindrotheca, Gymnodinium, Gyrodinium, Pleurosigma, Navicula, Guinardia, Plagioselmis, Pseudo-nitzschia* and *Prorocentrum* were present during entire study period.

c) Zooplankton

The zooplankton standing stock in terms of biomass (0.9 to 4.2 ml/100m^3; av 1.9 ml/100m^3) and population (6.1 x 10^3 to 36.6 x 10^3 no/100m^3; avg 12.1 x 10^3 no/100m^3) was low during postmonsoon (Table 4.22.13) and they showed a several fold increase during premonsoon. The zooplankton biomass and population during premonsoon were in the range of 1.0 to 32.7 ml/100m^3 (avg 11.5 ml/100m^3) and 10.5 x 10^3 to 154.9 x 10^3 no/100m^3 (avg 49.8 x 10^3 no/100m^3) respectively (Table 4.22.14).

Zooplankton biomass, population and total groups in different segments of Malvan are summarized below.

Zone	Biomass ($ml/100m^3$)			Population (no x $10^3/100m^3$)			Total groups (no)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal (Sts M1 to M3)	1.5	4.2	2.6	6.1	36.6	16.7	9	16	13
Bay (St M4)	0.9	1.3	1.1	6.2	8.9	7.5	11	18	14
March 2016 (Premonsoon)									
Coastal (Sts M1 to M3)	1.4	32.7	9.2	10.5	154.9	47.3	8	19	13
Bay (St M4)	1.0	2.4	1.7	12.5	78.1	45.8	9	12	11

The overall distribution of zooplankton as shown above revealed wide spatial and seasonal variation off Malvan. Coastal segment, in general sustained relatively higher biomass and population as compared to the Bay. The zooplankton biomass and population showed markedly higher values in premonsoon as compared to postmonsoon (Figures 4.22.5 and 4.22.6). The above results clearly suggest that the grazing on primary producer by the secondary producer was relatively low during postmonsoon than premonsoon in the bay as compared to coastal waters. This could be related to prevailing unfavourable environmental conditions especially in the Bay during postmonsoon for the zooplankton production.

In general, 22 and 25 total faunal groups were recorded during postmonsoon and premonsoon respectively (Tables 4.22.15 and 4.22.16). Copepods, appendicularians, chaetognaths, *Lucifer* sp., decapod larvae, cladocerans, siphonophores, gastropods, lamellibranchs, cumaceans, amphipods, ostracods, foraminiferans, fish eggs, fish larvae, medusae were present during the entire study period. The other common groups occasionally noticed in the study area were heteropods, pteropods, doliolids, salpids, cephalopods, ctenophores, stomatopods and Isopods.

d) Macrobenthos

The standing stock of subtidal macrobenthos interms of biomass (0.02-22.90 g/m^2; wet wt, av 6.20 g/m^2, wet wt) and population (50-5375 Ind/m^2; av 1367 Ind/m^2) varied widely during premonsoon. In postmonsoon macrobenthic biomass showed reduction (0.70-10.43 g/m^2; wet wt, av 4.81 g/m^2; wet wt) whereas population (625-2475 Ind/m^2; avg 1365 Ind/m^2) remained same during study period (Table 4.22.17).

Results of macrobenthic biomass, population and faunal groups are given below.

Stations	Biomass (g/m²; wet weight)			Population (Ind./m²)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Av	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal water (Sts M1 to M3)	1.26	10.43	6.02	675	2475	1381	2	10	5
Bay(St M4)	0.70	4.90	2.40	625	1900	1332	3	5	4
Overall	0.70	10.43	4.81	625	2475	1365	2	10	5
March 2016 (Premonsoon)									
Coastal water (Sts M1 to M3)	0.02	20.27	3.90	50	1100	509	1	9	5
Bay(St M4)	4.40	22.90	10.80	2075	5375	3081	4	6	5
Overall	0.02	22.90	6.20	50	5375	1367	1	9	5

As evident from above, the biomass was higher in premonsoon; however, the macrobenthic abundance was similar in both the seasons. The faunal group diversity was almost same during the study period. The relative benthic production was more in the bay than coastal segments perhaps due to high detrital content associated with high primary production especially in the Bay during premonsoon. Polychaeta (86.17%) was the dominant faunal group found in postmonsoon whereas in premonsoon, Polychaeta (60.67%) and Tanaidacea (18.15%) were dominant (Tables 4.22.18 and 4.22.19).

e) Meiobenthos

Meiobenthic standing stock in Malvan coastal area is given in table 4.22.20 and the segment-wise results are given in the table below.

Stations	Biomass (µg/10cm²)			Population (Ind./ 10cm²)			Total groups (No.)		
	Min	Max	Avg	Min	Max	Av	Min	Max	Avg
January 2016 (Postmonsoon)									
Coastal water (Sts M1 to M3)	94.42	649.5	334.6	597	1022	782	4	5	5
Bay(St M4)	734.25	834.93	784.59	1169	1190	1180	5	5	5
March 2016 (Premonsoon)									
Coastal water (Sts M1 to M3)	9.69	190.02	94.33	1221	191	158	3	4	4
Bay(St M4)	187.56	251.36	219.46	299	351	325	4	6	5

Malvan coastal region showed higher average biomass and density of meiofauna in postmonsoon. Bay area sustained higher meiofaunal standing stock interms of population and biomass in comparison to coastal waters off Malvan. Faunal group diversity showed little or no variation spatially, but temporally 10 groups were encountered during postmonsoon as compared to 6 in premonsoon (Tables 4.22.21 and 4.22.22).

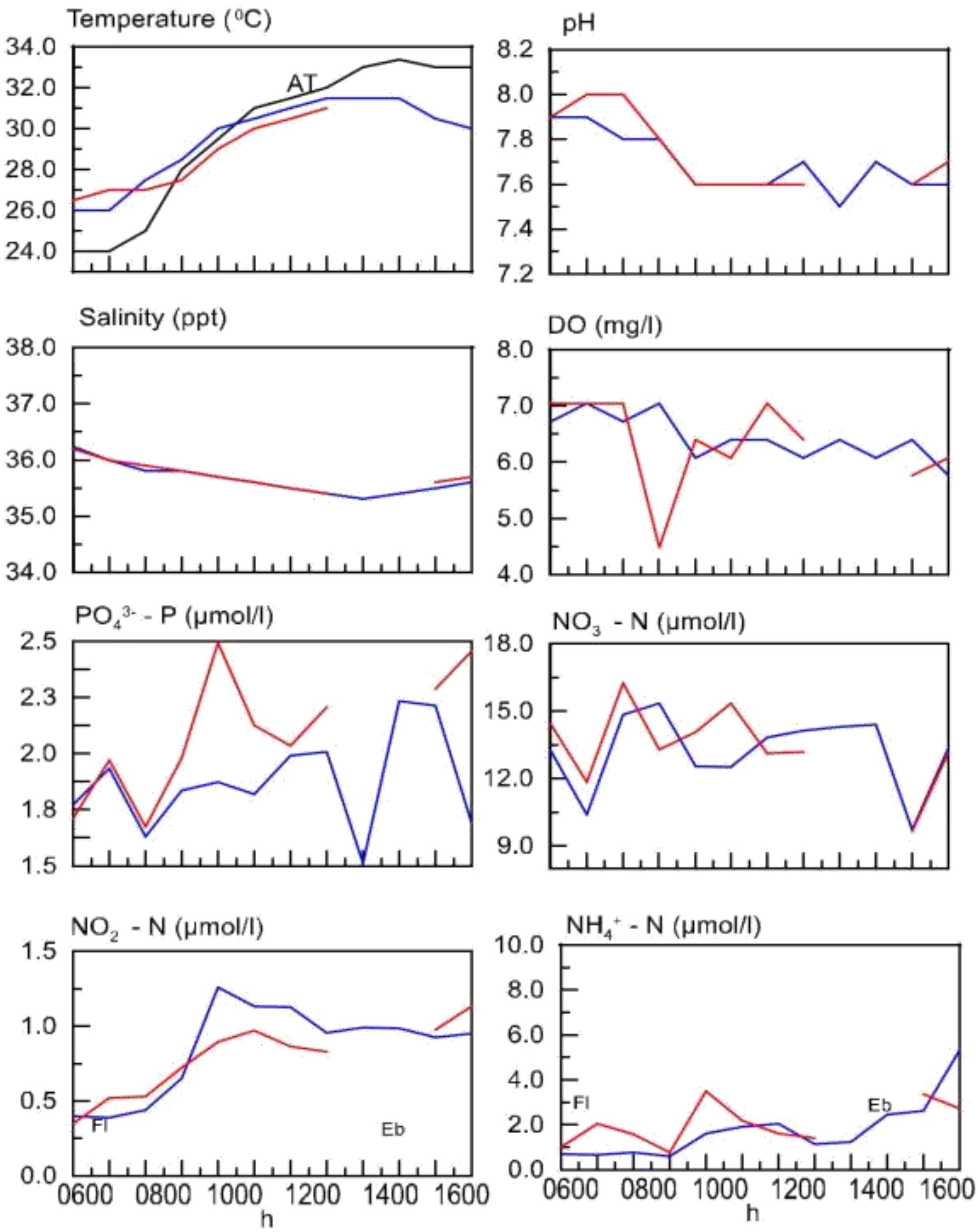


Figure 4.1.1: Temporal Variation of water quality parameters at DH4 (——— S) & (——— B) on 19th Nov 2015

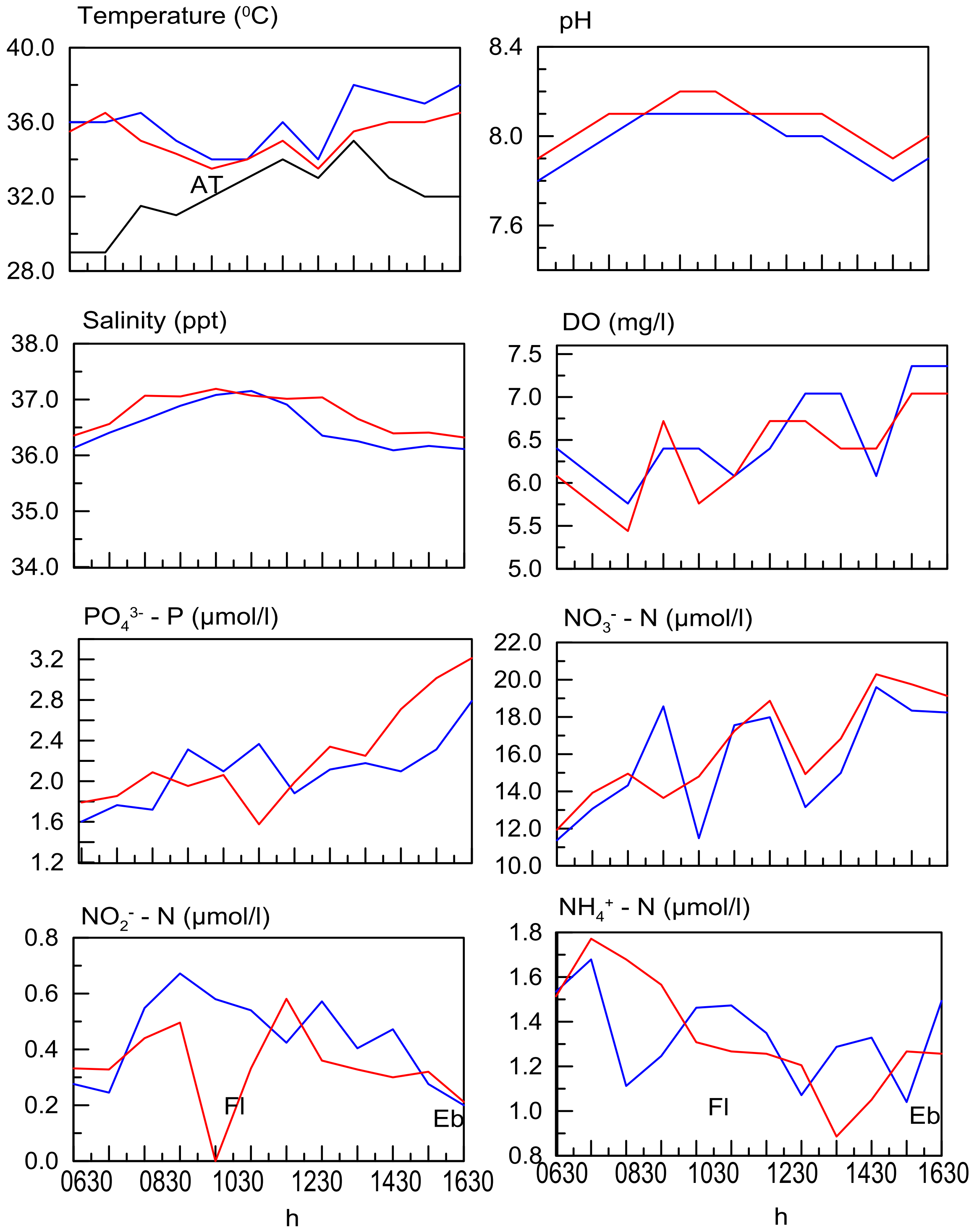


Figure 4.1.2: Temporal Variation of water quality parameters at DH4 (S) & (B) on 16th May 2016

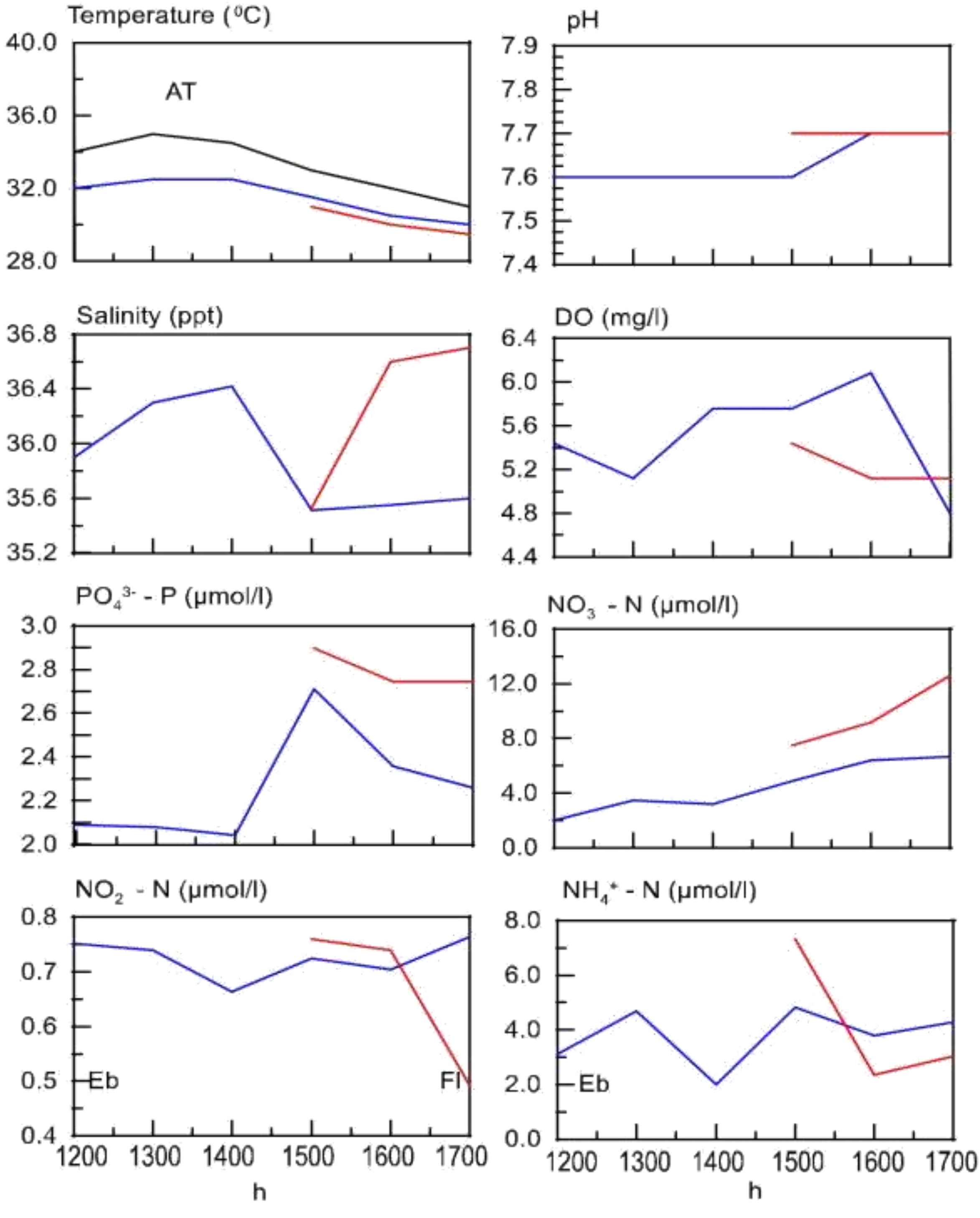


Figure 4.1.3: Temporal Variation of water quality parameters at DH6 (S) & (B) on 18th Nov 2015

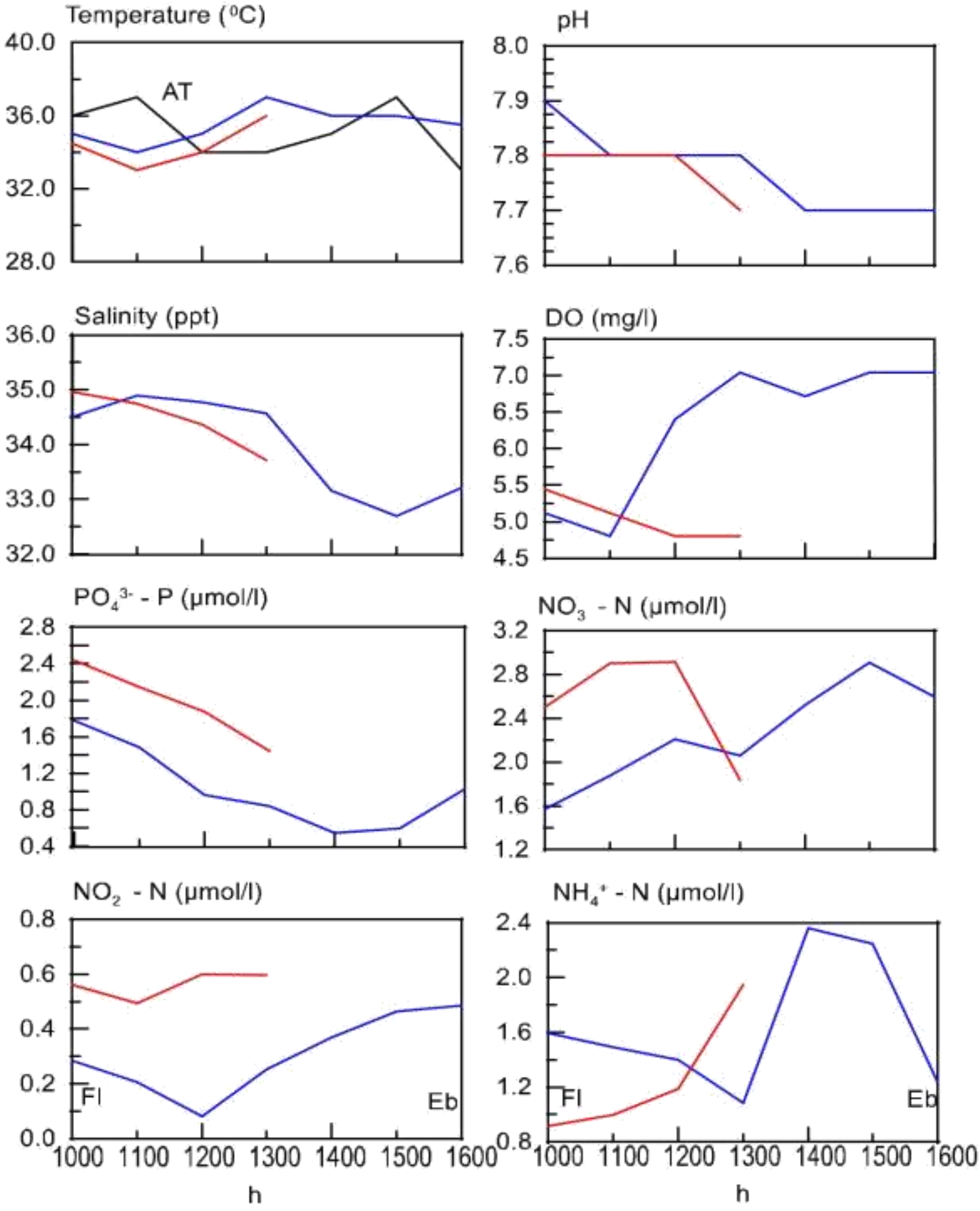


Figure 4.1.4: Temporal Variation of water quality parameters at DH6 (——— S) & (——— B) on 18th May 2016

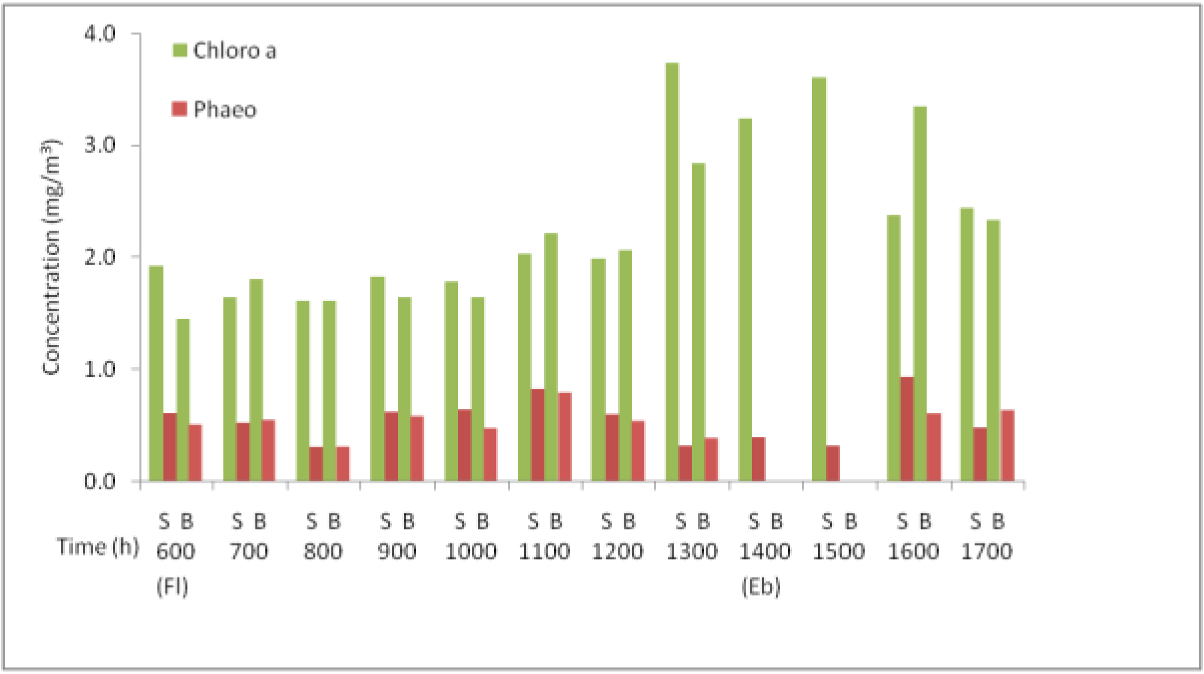


Figure 4.1.5: Temporal Variation of Phytopigments at station DH4 on 19.11.2015.

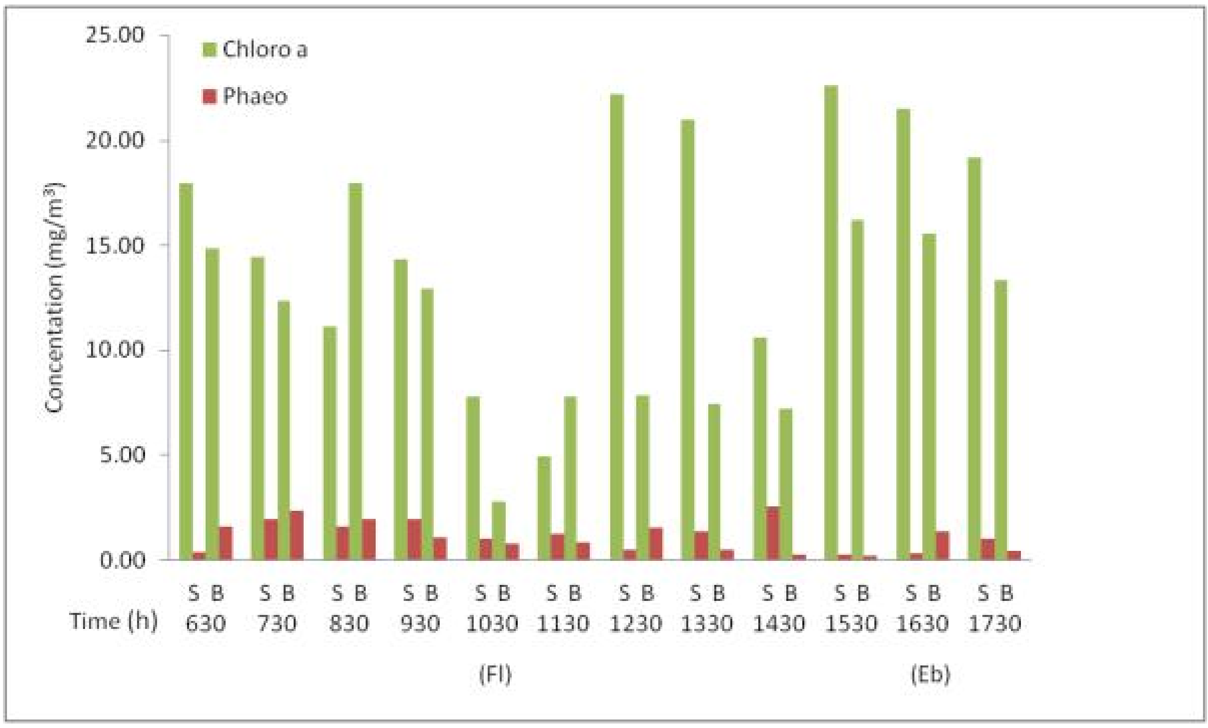


Figure 4.1.6: Temporal Variation of Phytopigments at station DH4 on 16.05.2016

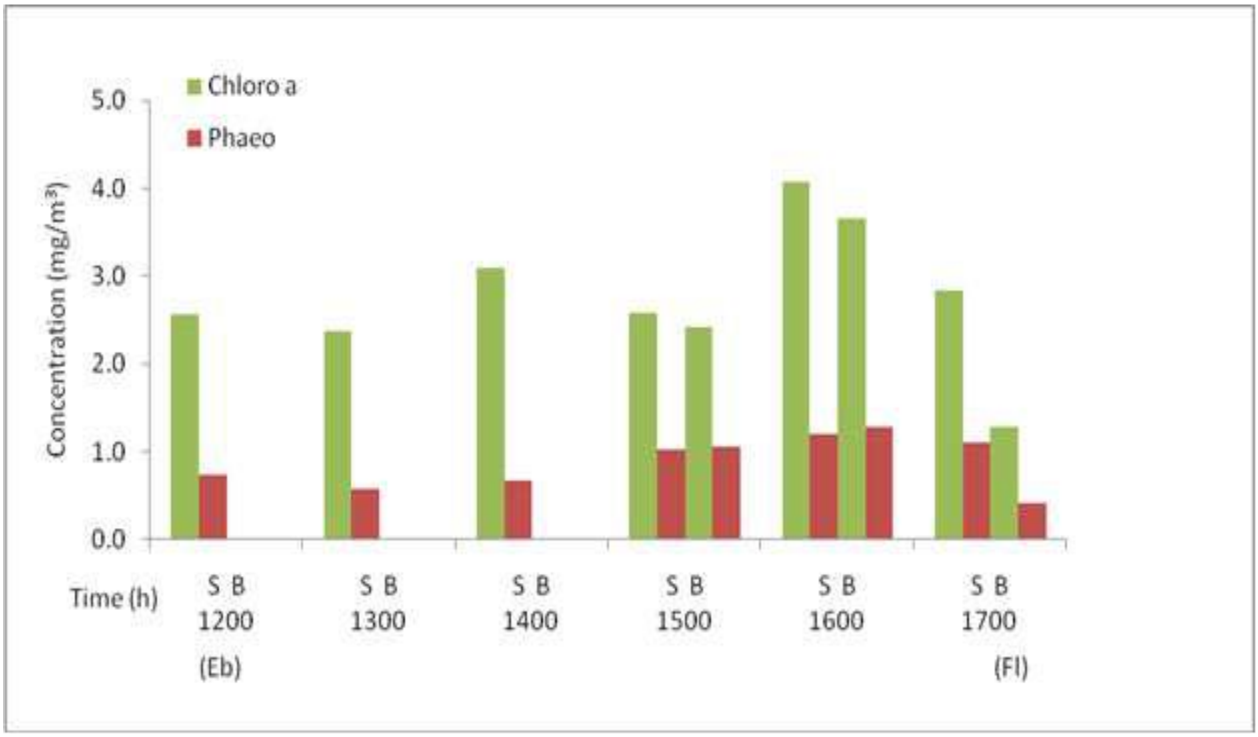


Figure 4.1.7: Temporal Variation of Phytopigments at station DH6 on 18.11.2015.

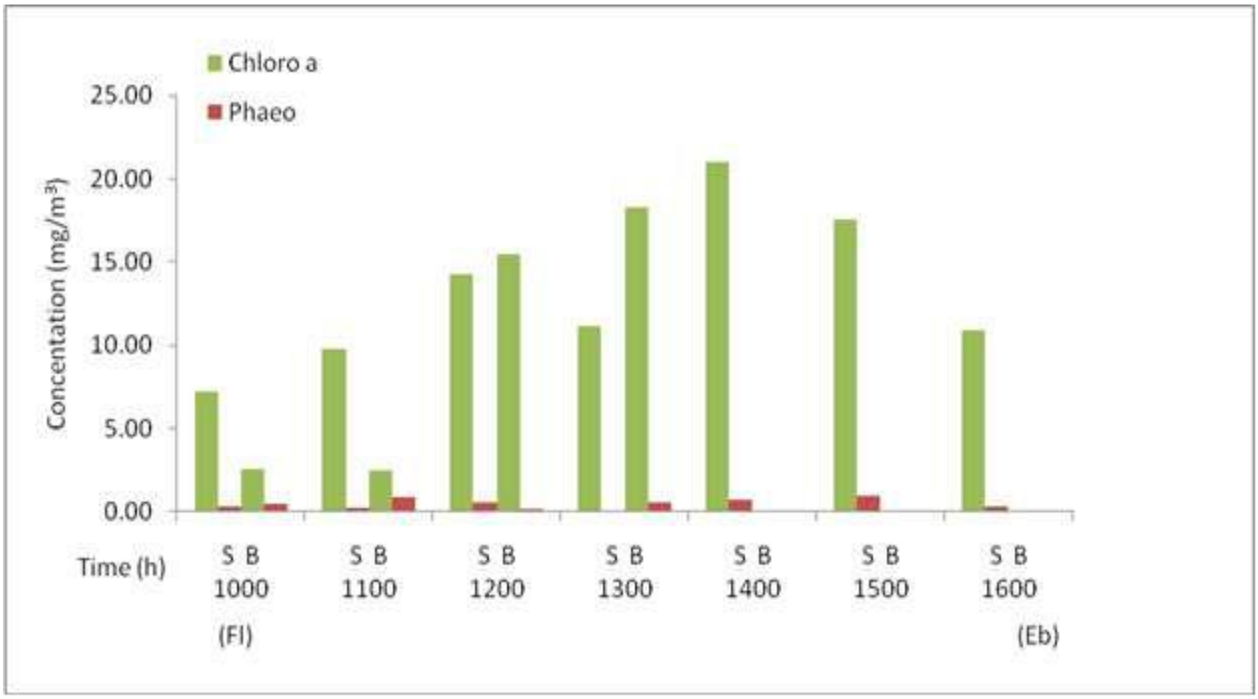


Figure 4.1.8: Temporal Variation of Phytopigments at station DH6 on 18.05.2016.

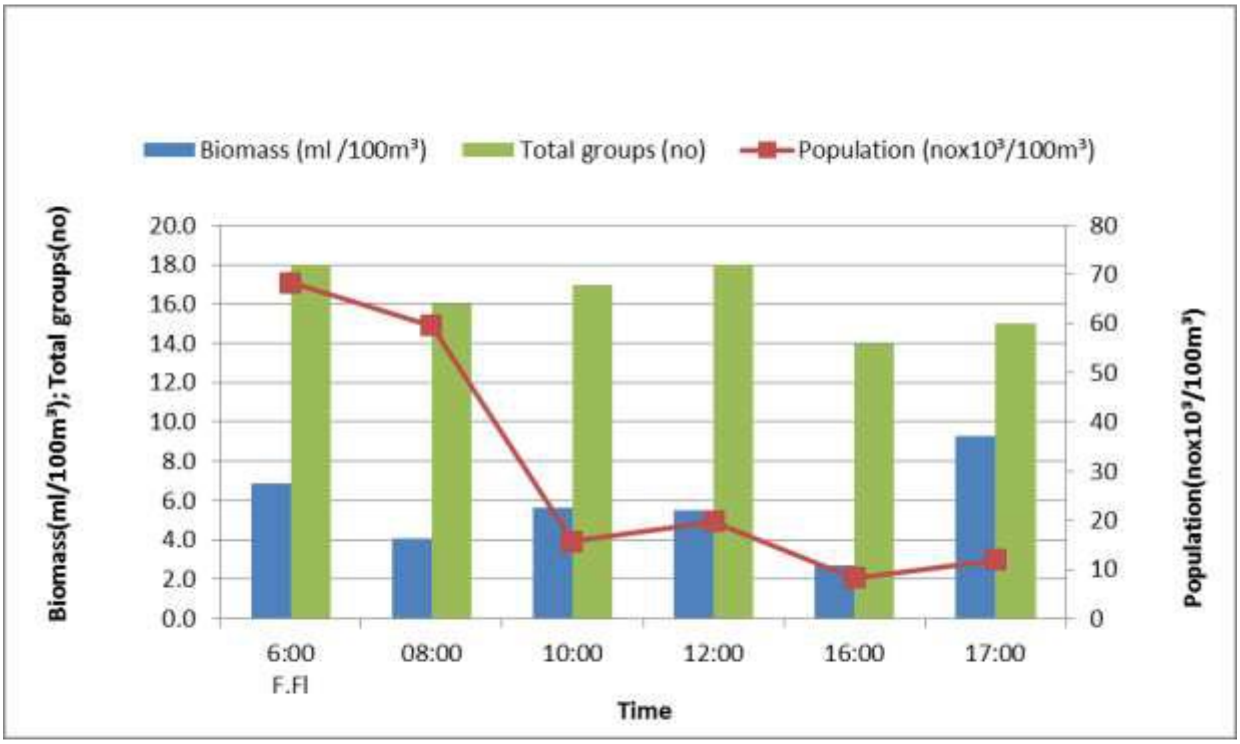


Figure 4.1.9: Temporal Variation of mesozooplankton at station DH4 on 19.11.2015.

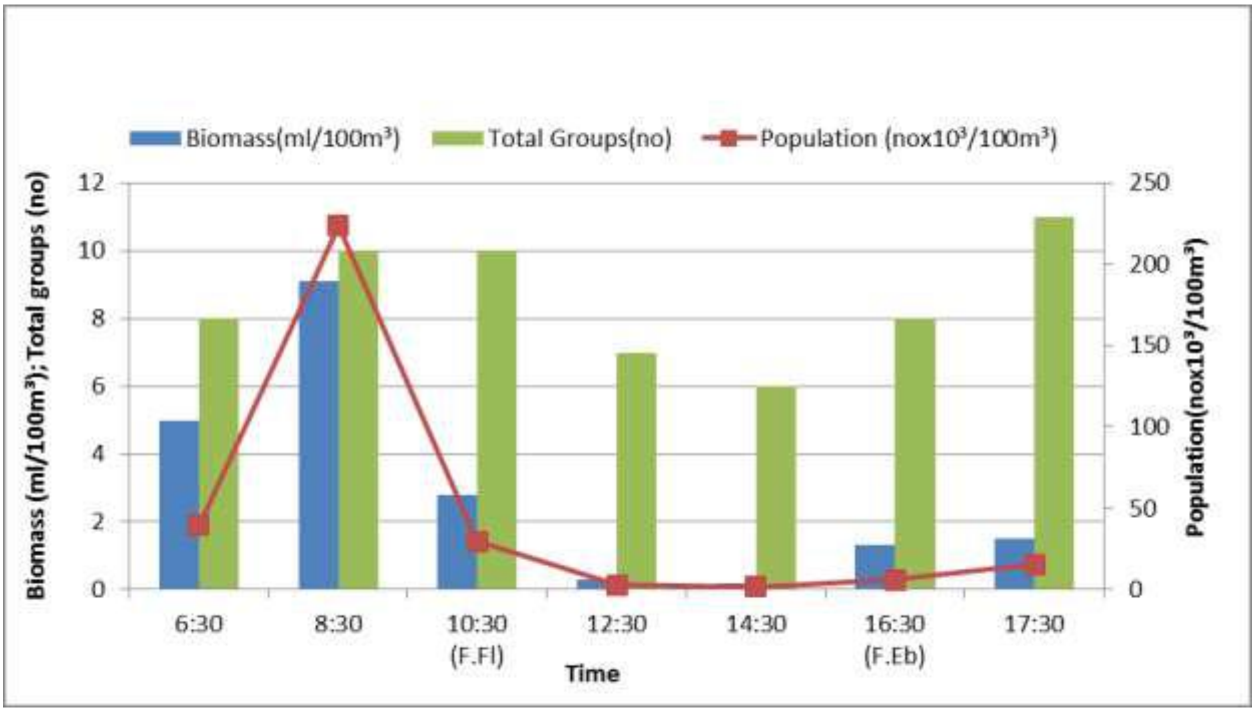


Figure 4.1.10: Temporal Variation of mesozooplankton at station DH4 on 16.05.2016

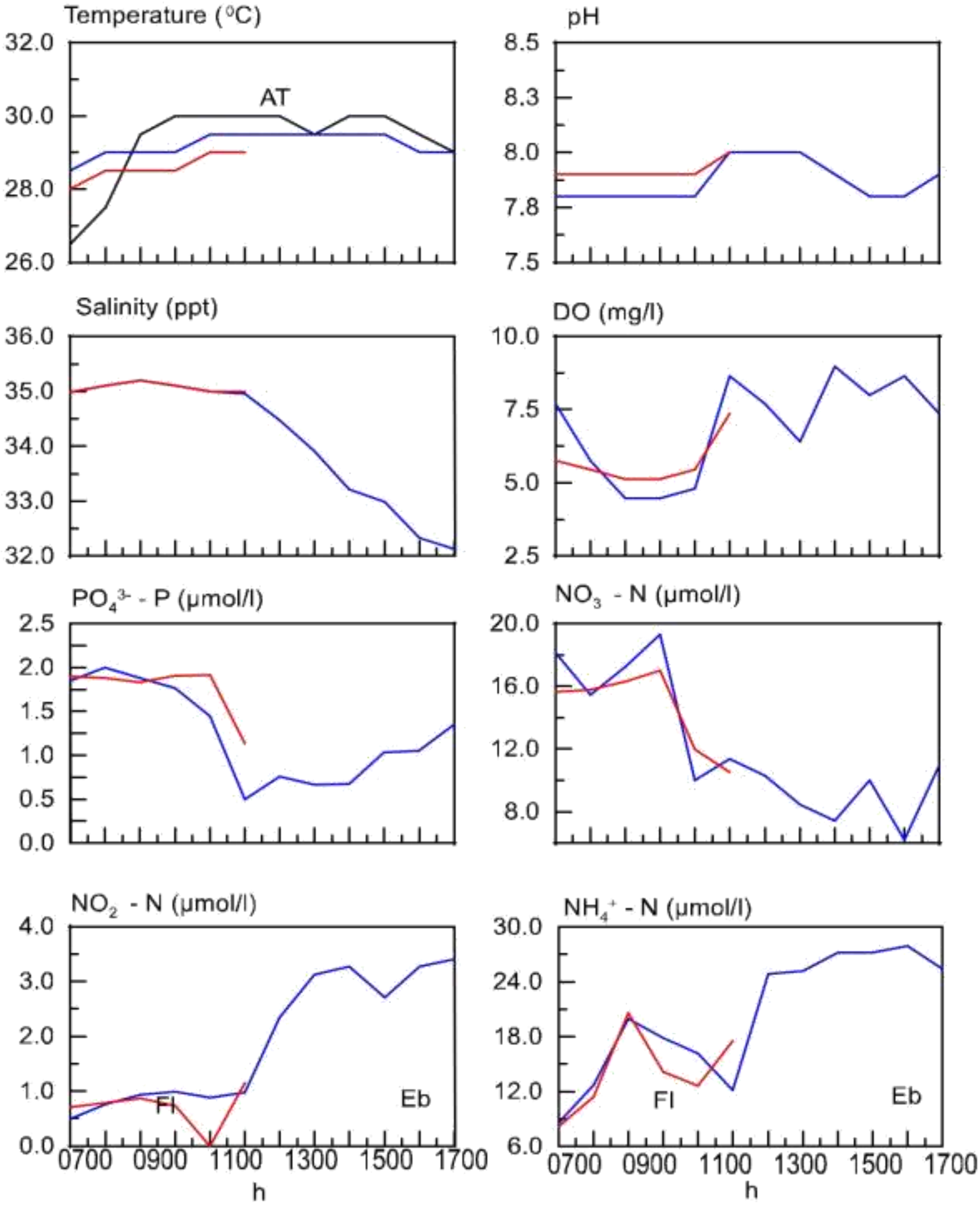


Figure 4.2.1: Temporal Variation of water quality parameters at TP5 (——— S) & (——— B) on 22nd Nov 2015

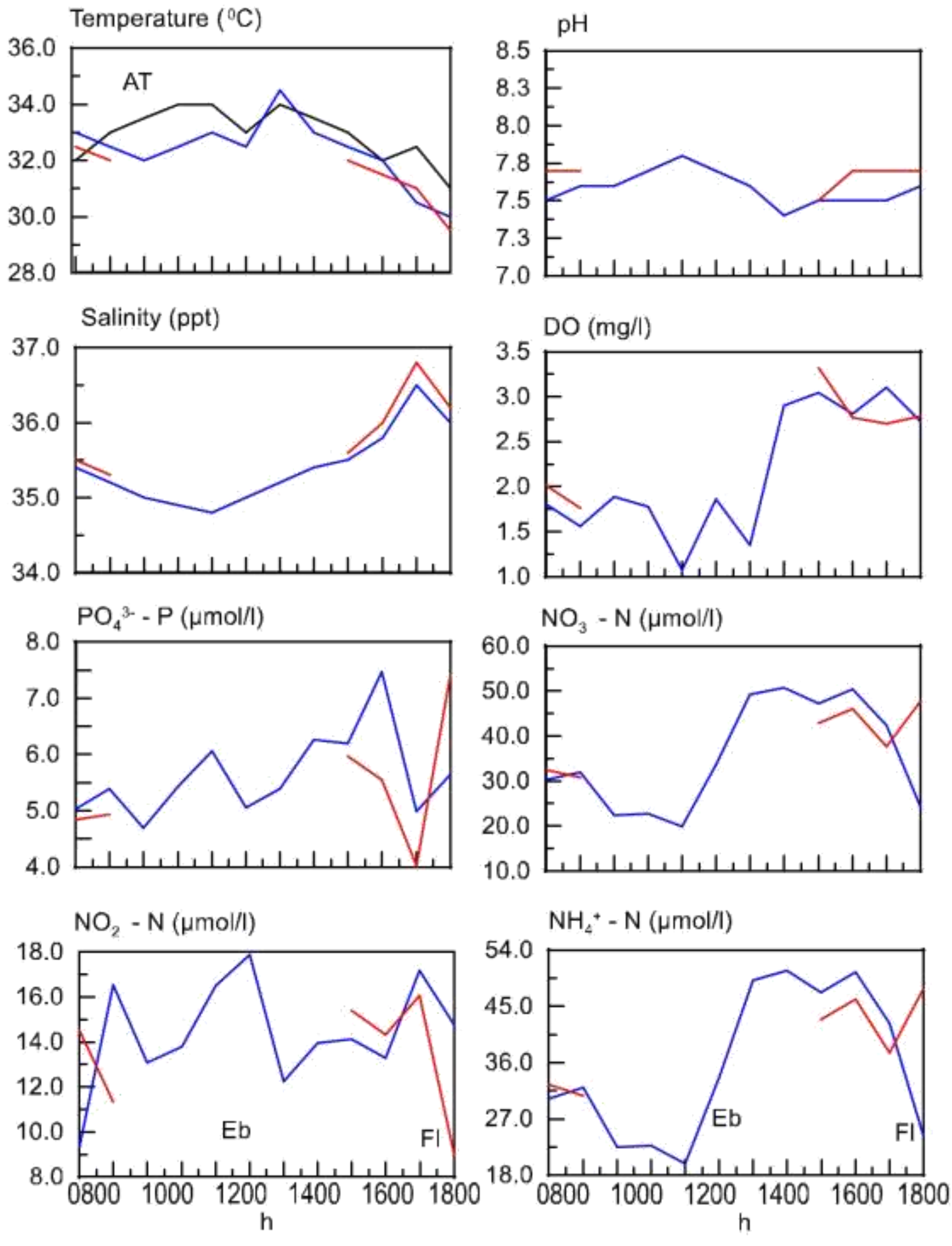


Figure 4.2.2: Temporal Variation of water quality parameters at TP5 (S) & (B) on 13th May 2016

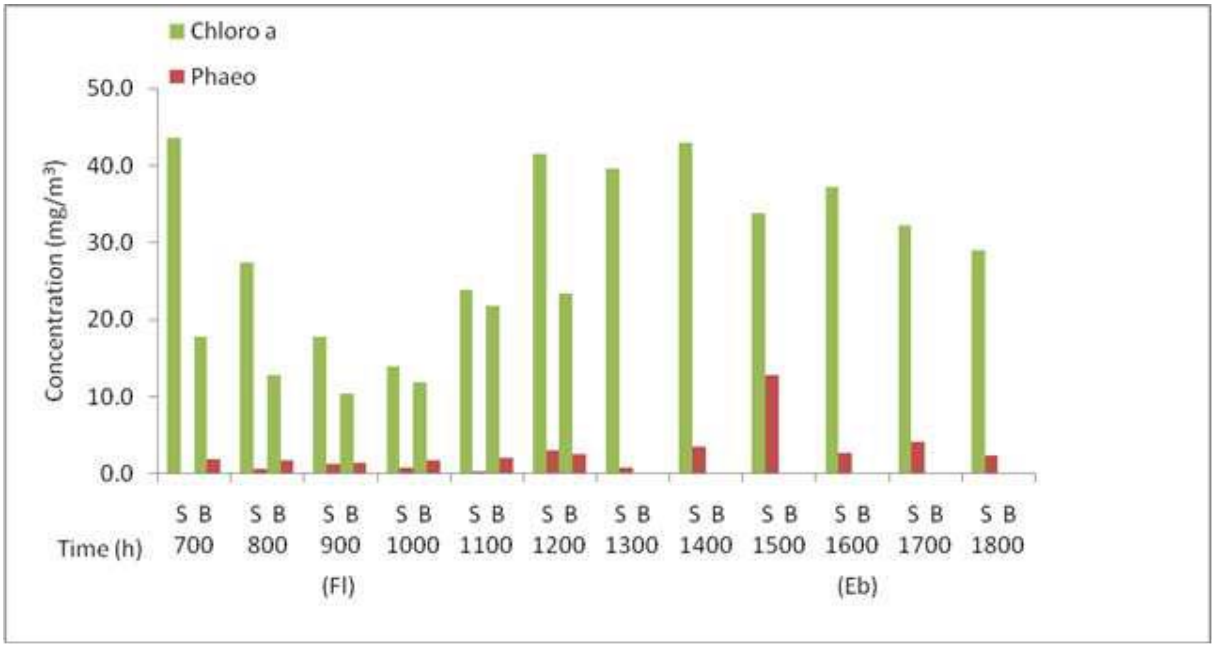


Figure 4.2.3: Temporal Variation of Phytopigments at station TP5 on 22.11.2015.

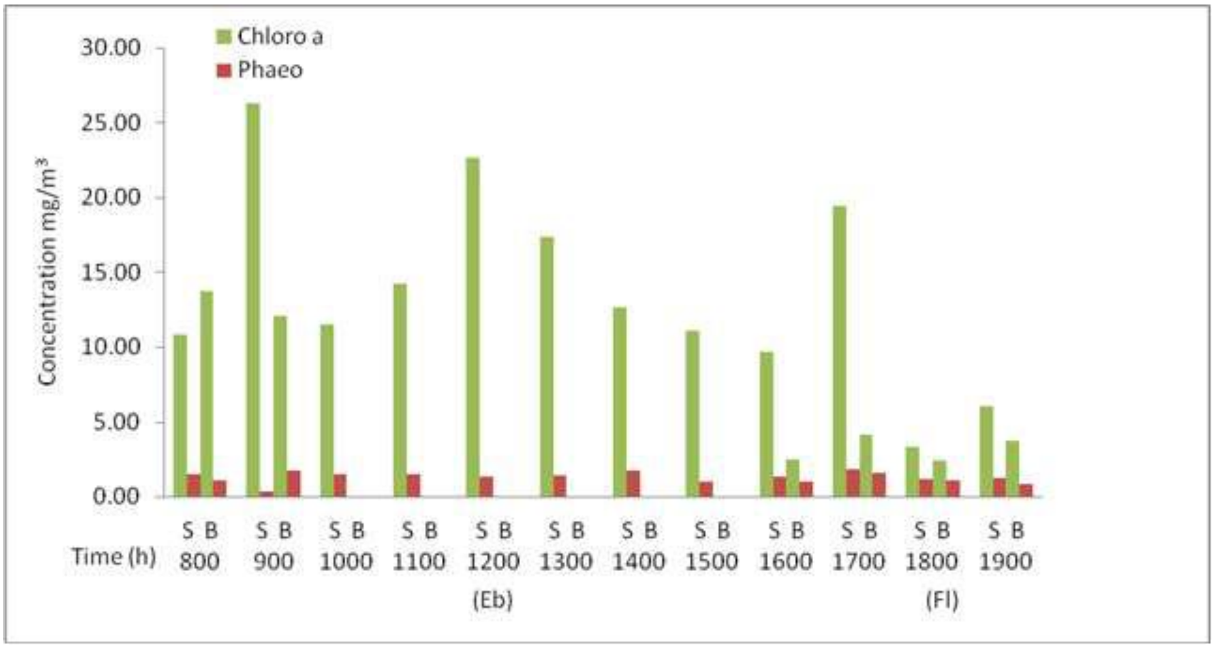


Figure 4.2.4: Temporal Variation of Phytopigments at station TP5 on 13.05.16.

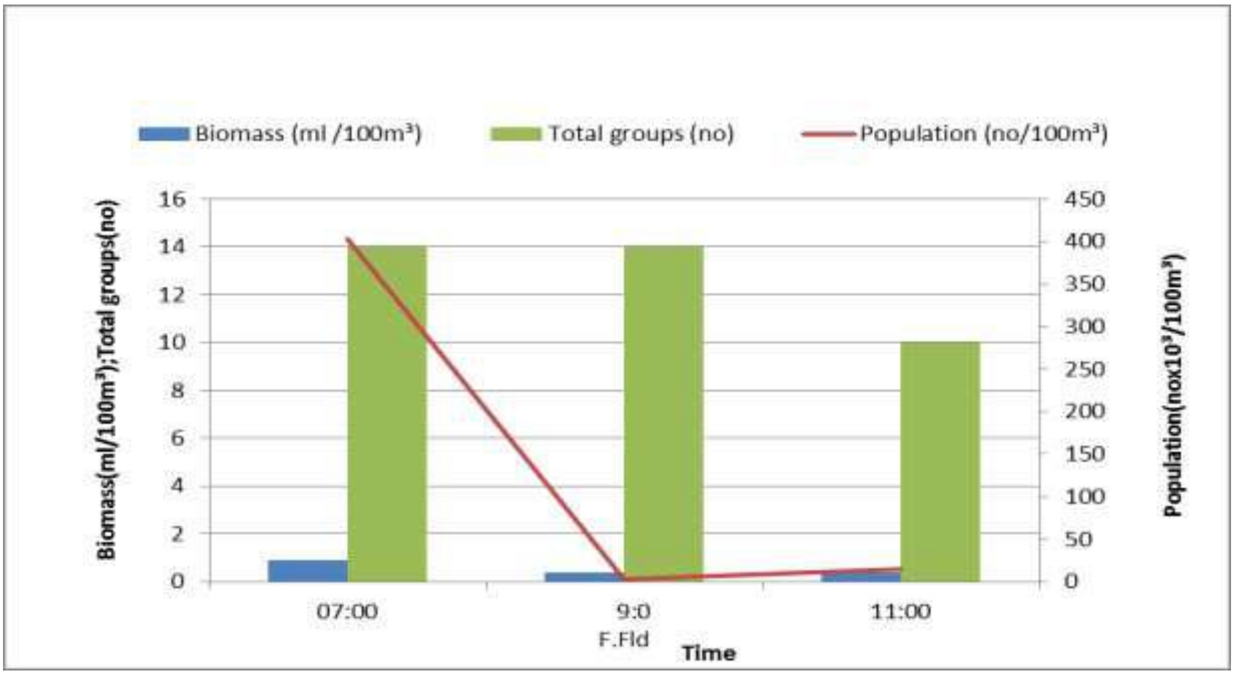


Figure 4.2.5: Temporal Variation of mesozooplankton at station TP5 on 22.11.2015

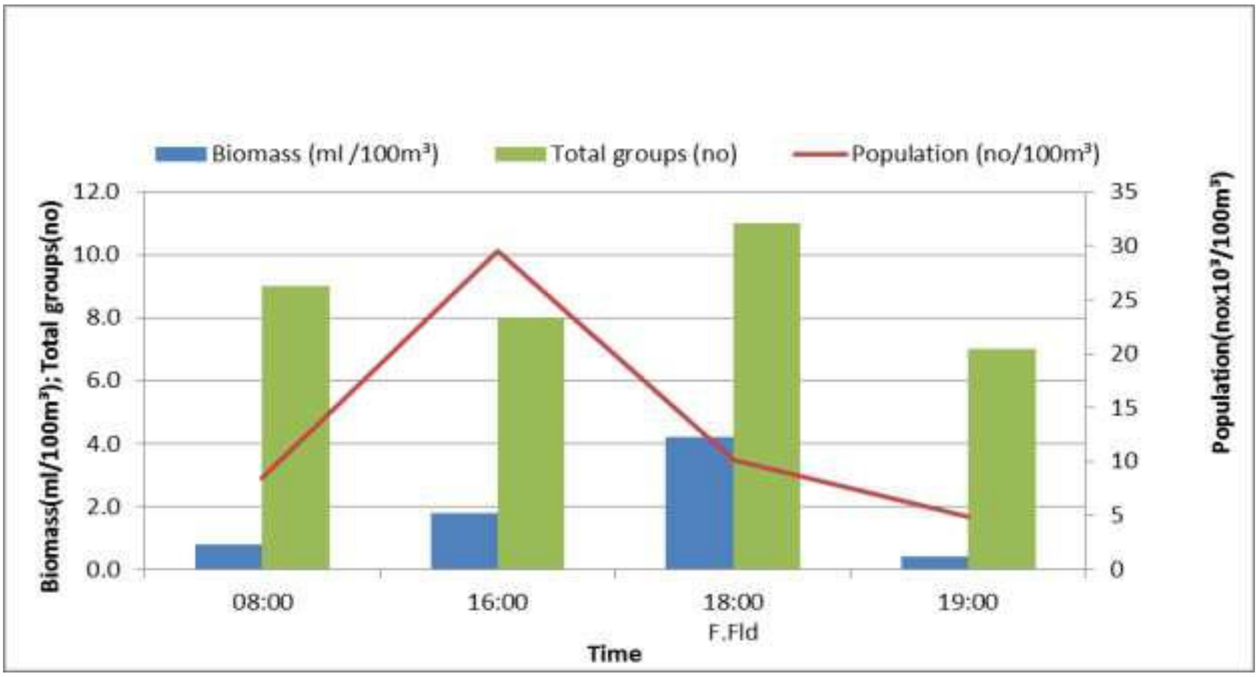


Figure 4.2.6: Temporal Variation of mesozooplankton at station TP5 on 13.05.2016

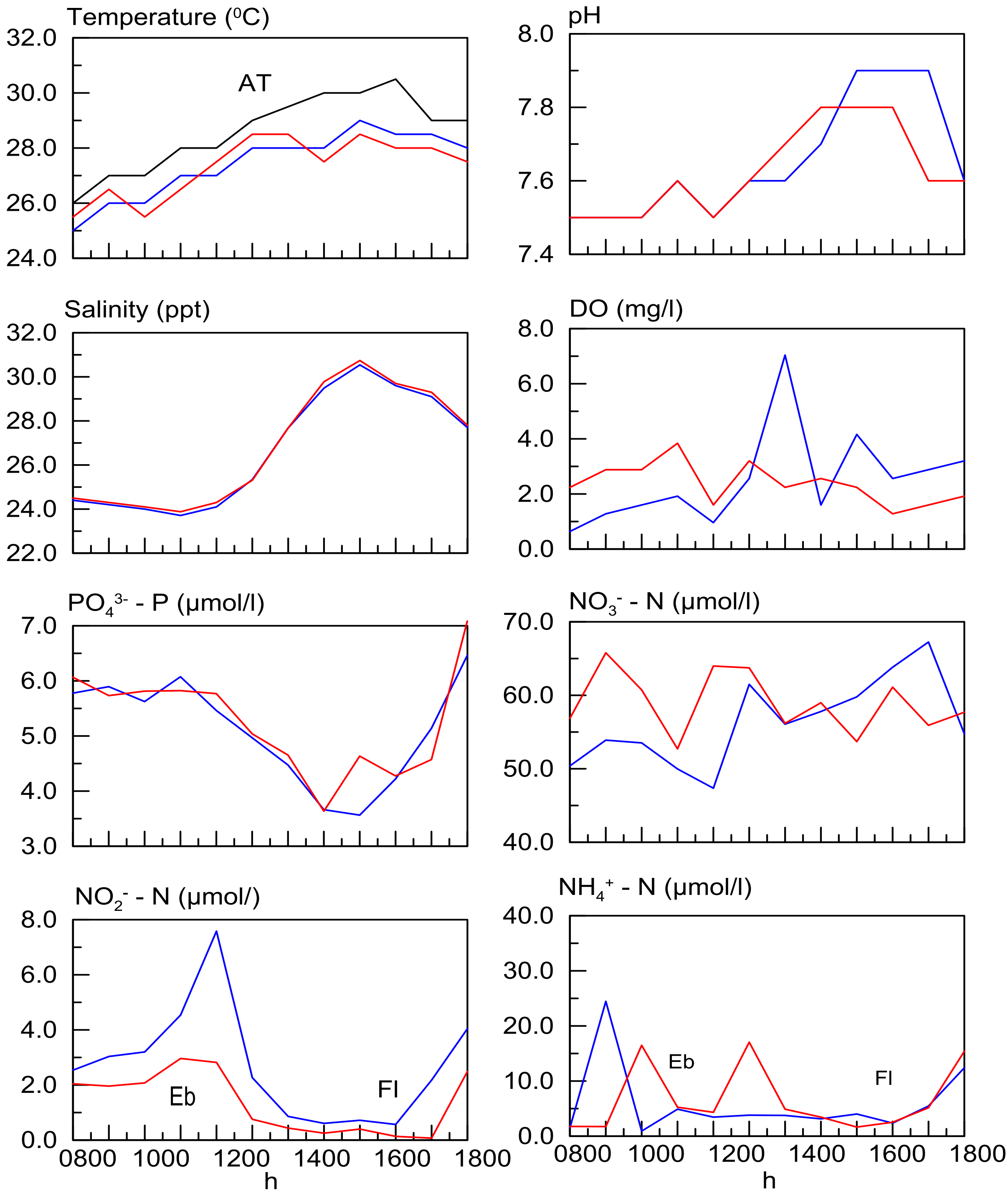


Figure 4.3.1: Temporal Variation of water quality parameters at BS4 (—— S) & (—— B) on 30th Nov 2015

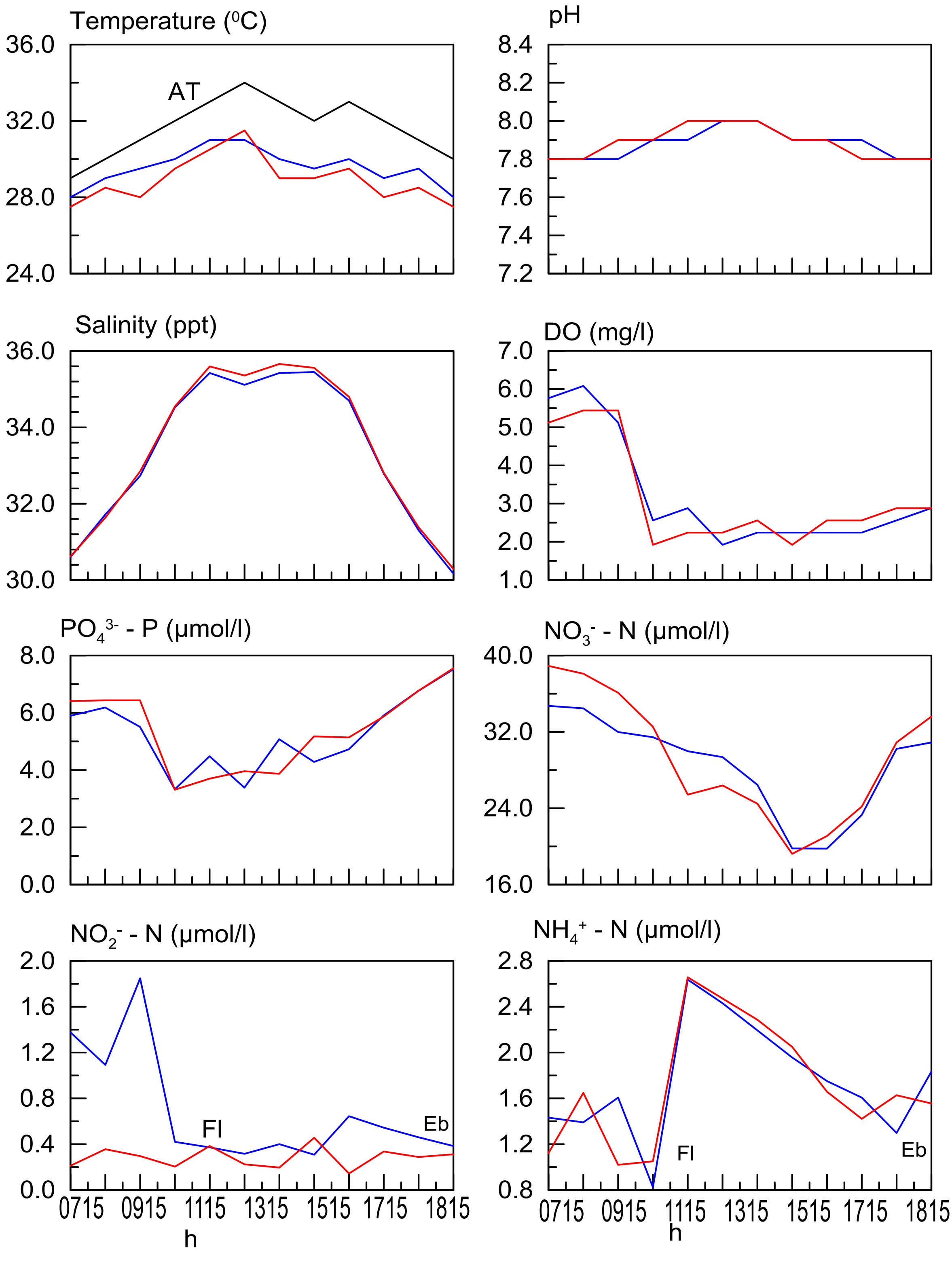


Figure 4.3.2: Temporal Variation of water quality parameters at BS4 (——S) & (——B) on 5th May 2016

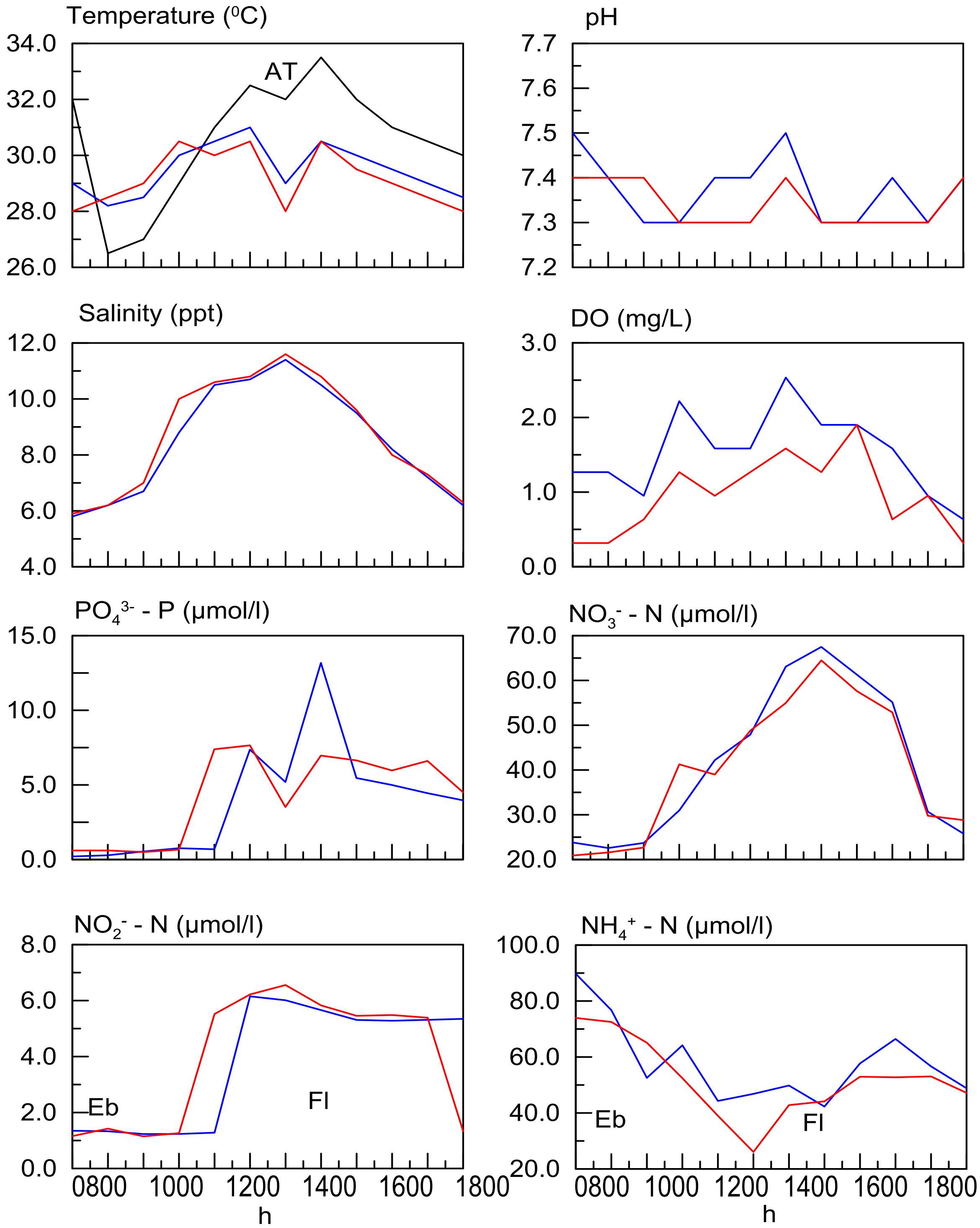


Figure 4.3.3: Temporal Variation of water quality parameters at BS9 (S) & (B) on 26th Nov 2015

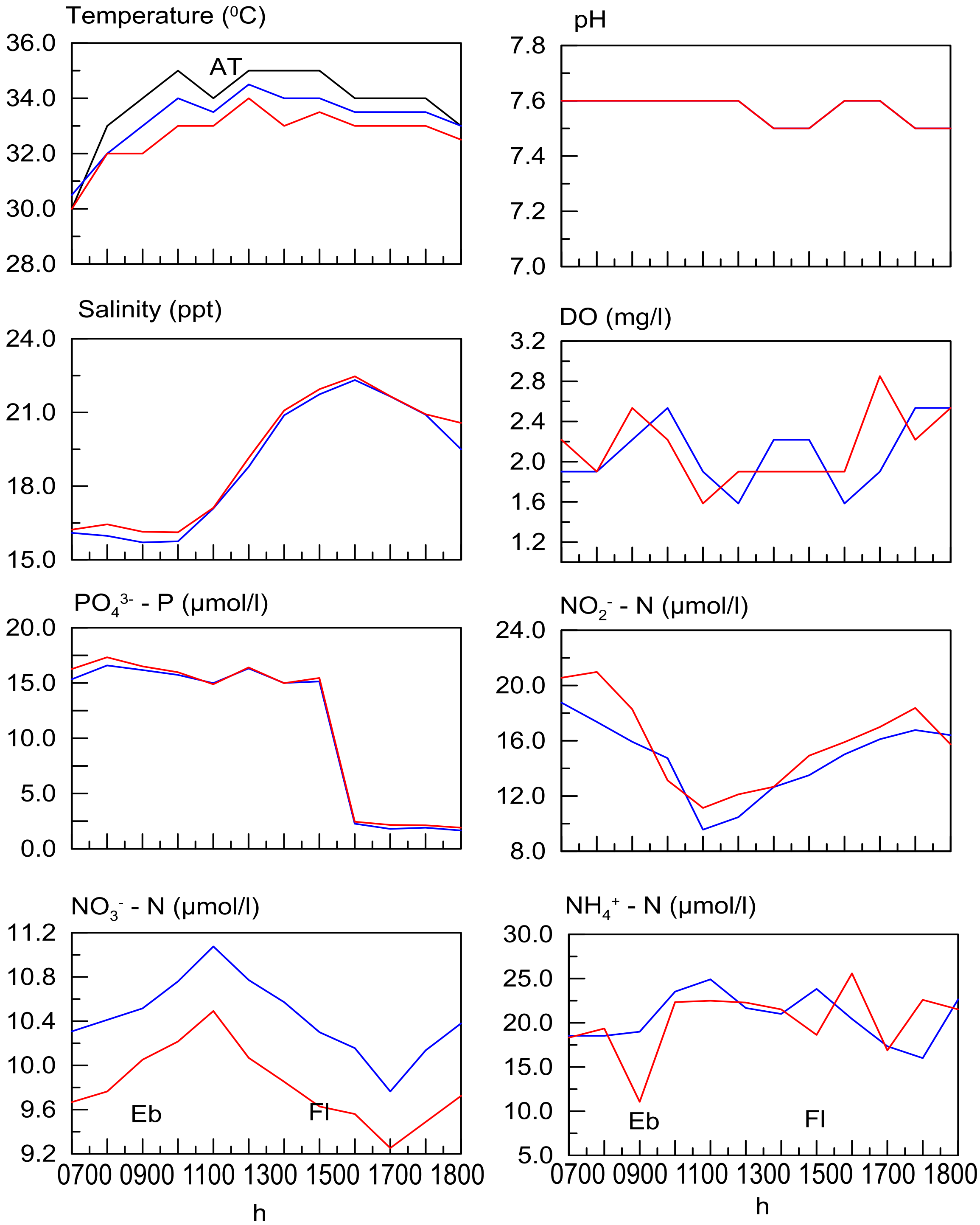


Figure 4.3.4: Temporal Variation of water quality parameters at BS9 (——— S) & (——— B) on 7th May 2016

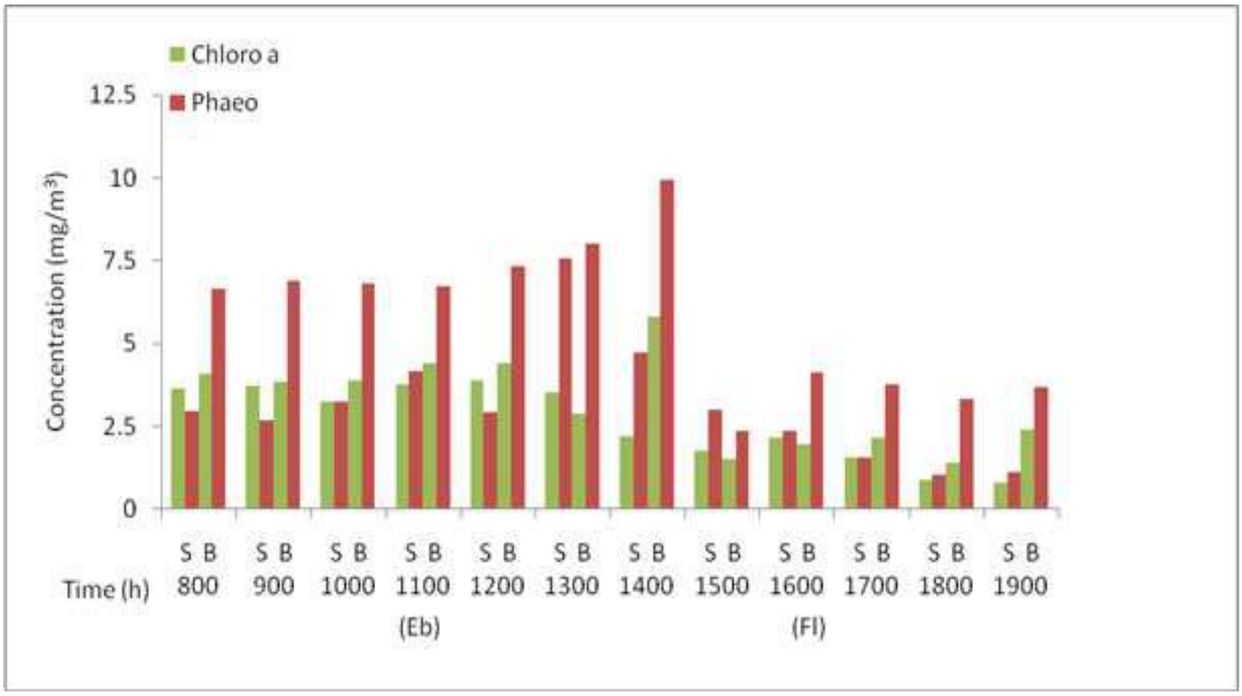


Figure 4.3.5: Temporal Variation of Phytopigments at station BS4 on 30.11.2015.

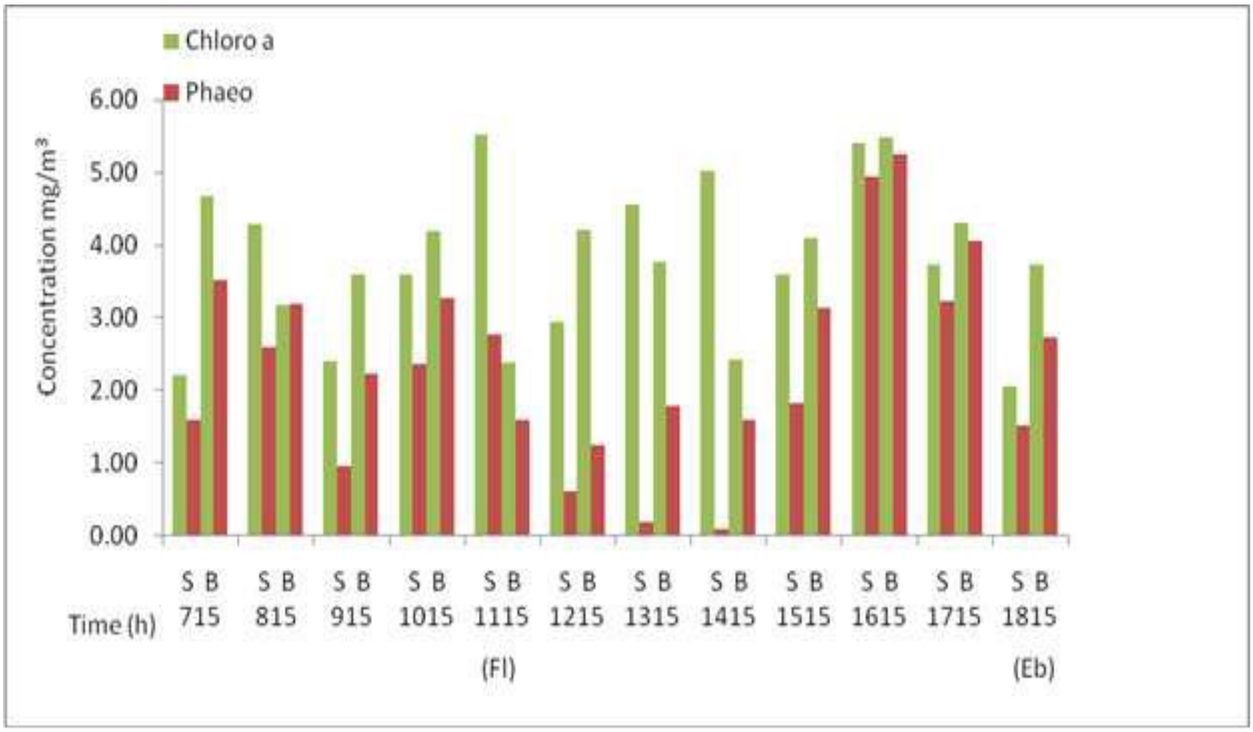


Figure 4.3.6: Temporal Variation of Phytopigments at station BS4 on 05.05.2016.

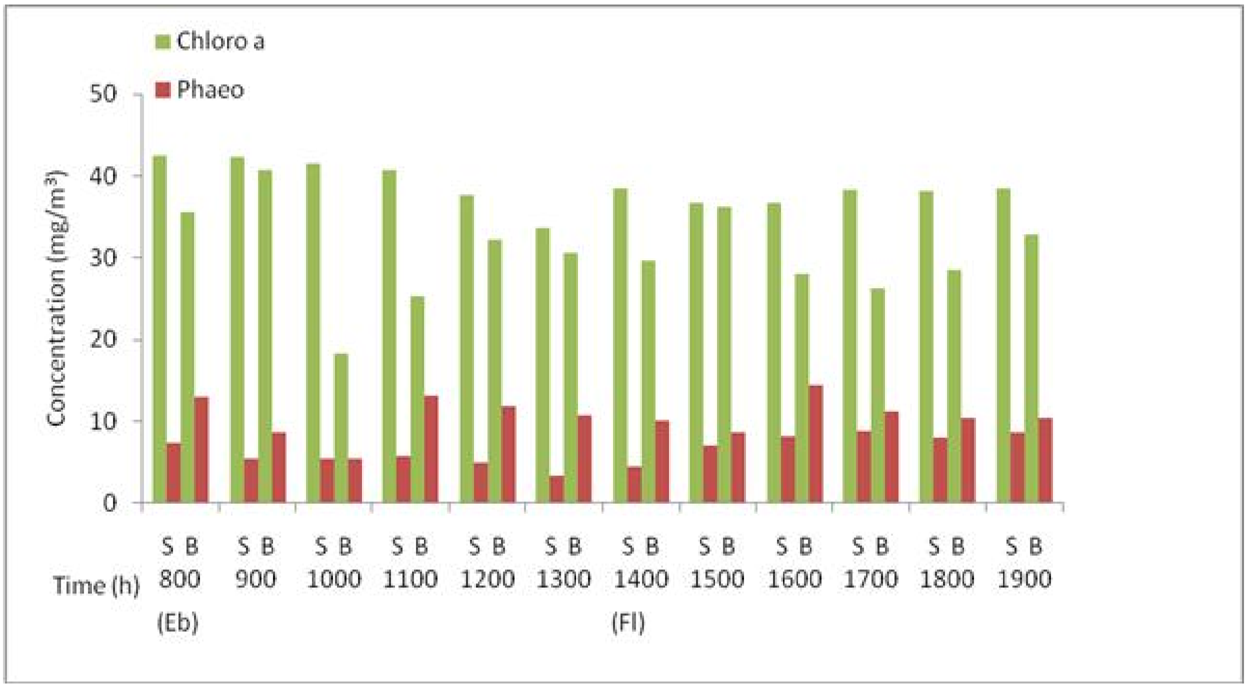


Figure 4.3.7: Temporal Variation of Phytopigments at station BS9 on 26.11.2015.

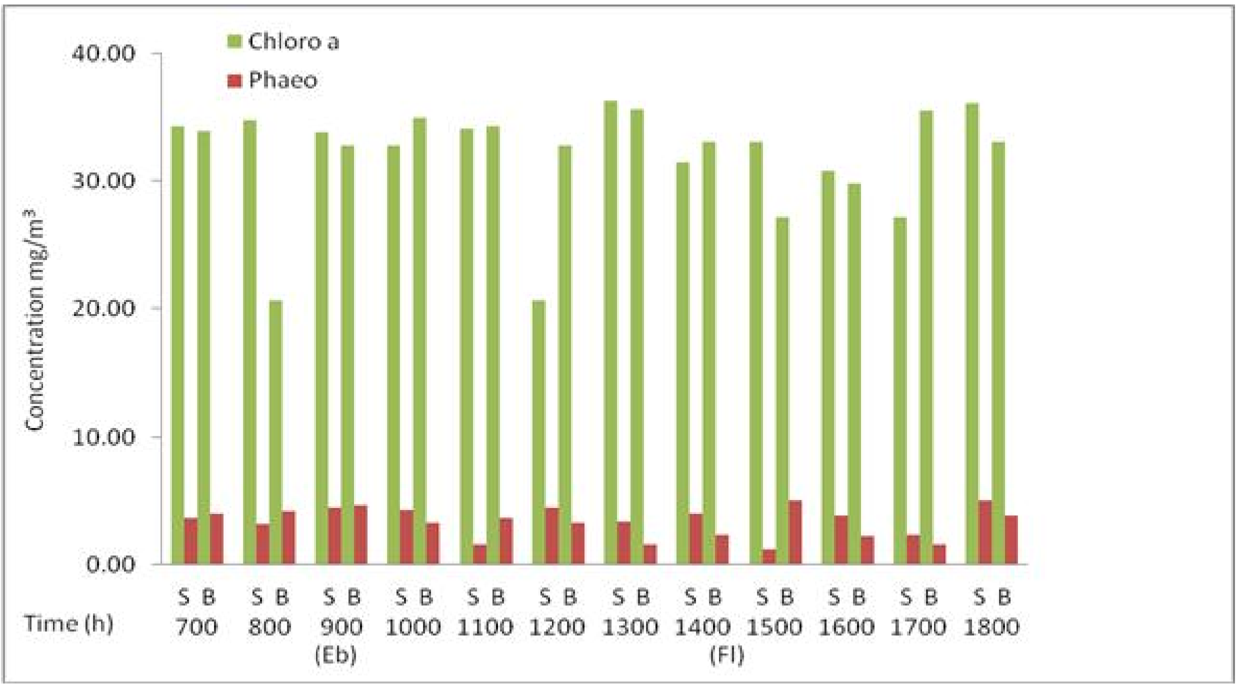


Figure 4.3.8: Temporal Variation of Phytopigments at station BS9 on 07.05.2016.

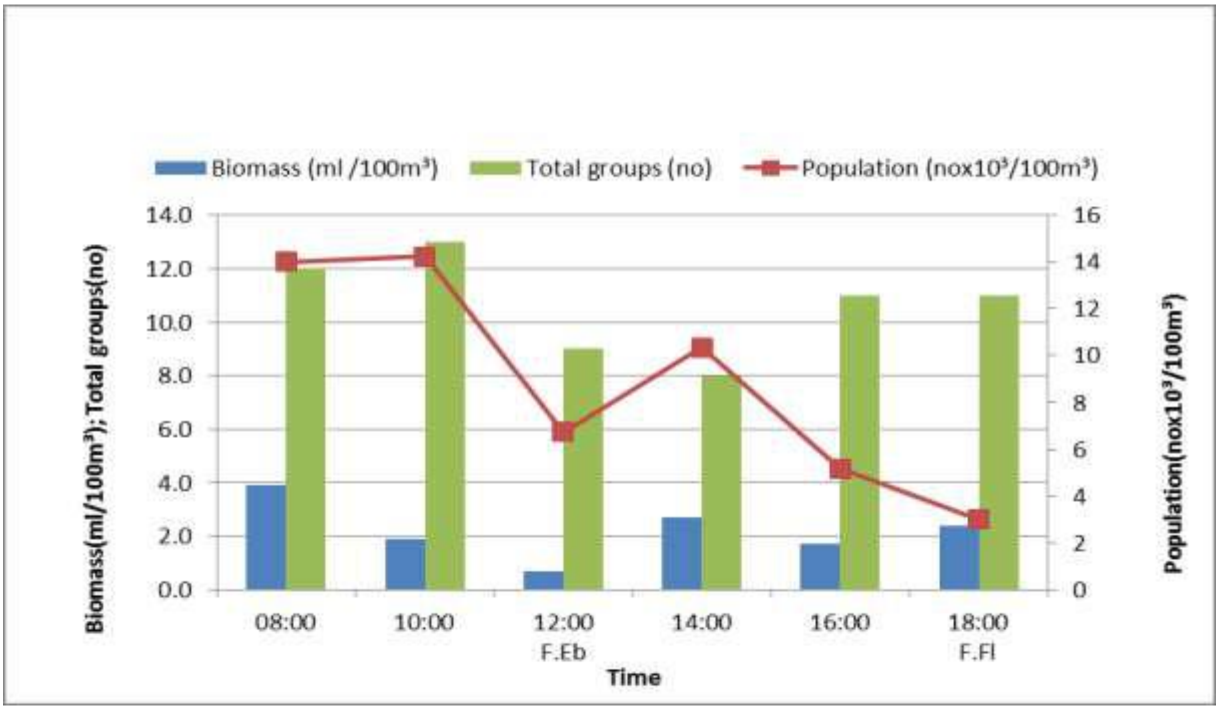


Figure 4.3.9: Temporal Variation of mesozooplankton at station BS4 on 30.11.2015

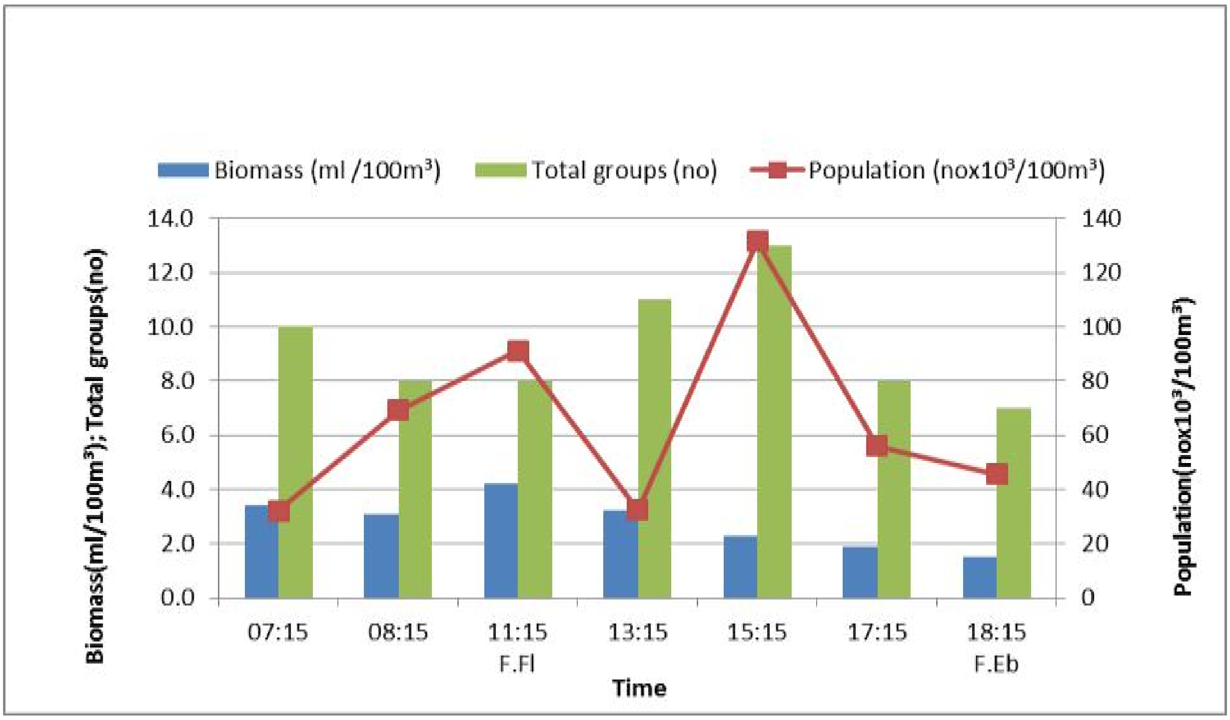


Figure 4.3.10: Temporal Variation of mesozooplankton at station BS4 on 05.05.2016

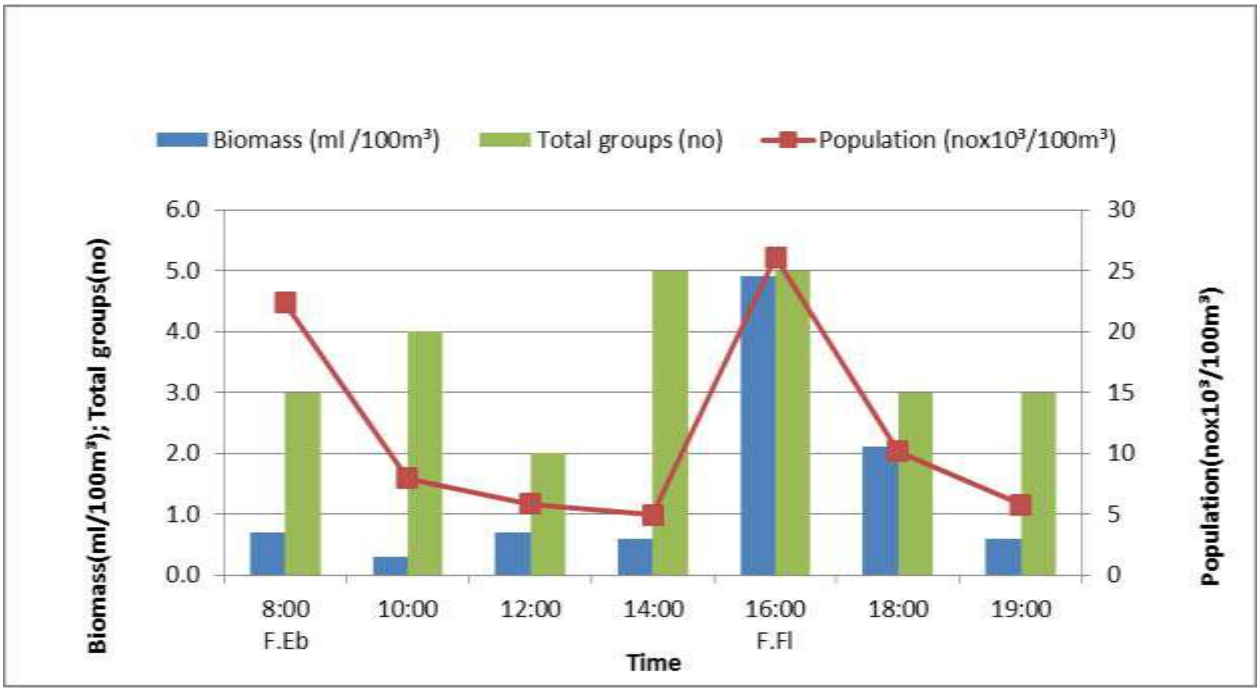


Figure 4.3.11: Temporal Variation of mesozooplankton at station BS9 on 26.11.2015

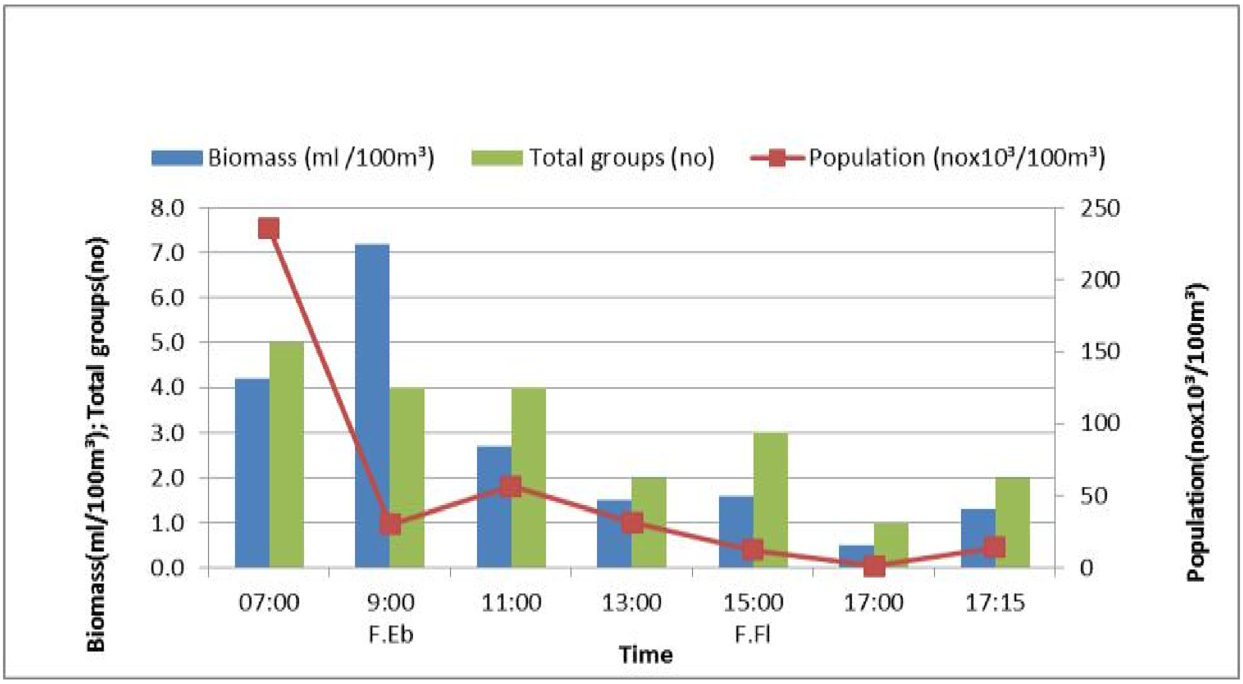


Figure 4.3.12: Temporal Variation of mesozooplankton at station BS9 on 07.05.2016

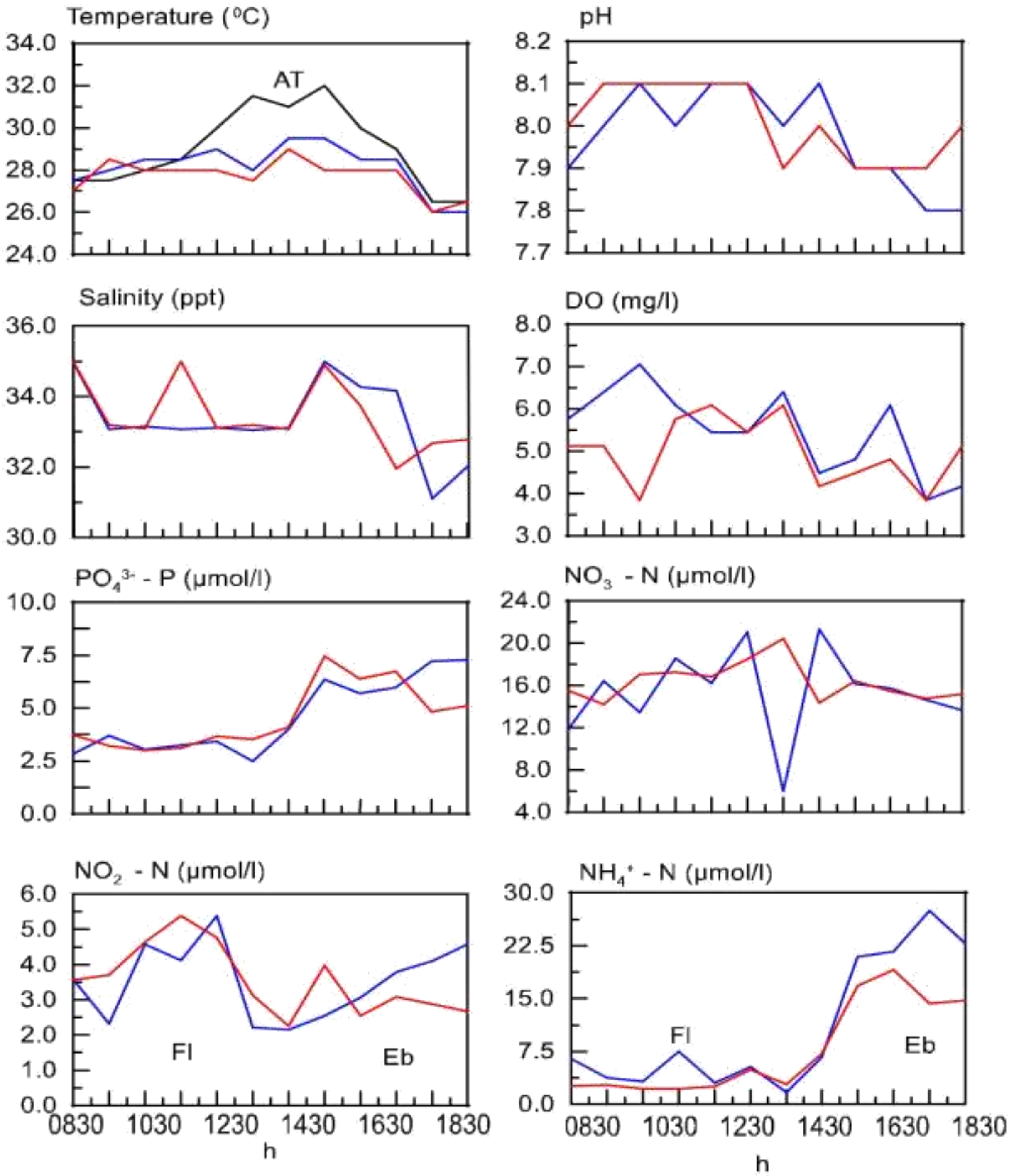


Figure 4.4.1: Temporal Variation of water quality parameters at BYMa4 (——— S) & (——— B) on 11th Dec 2015

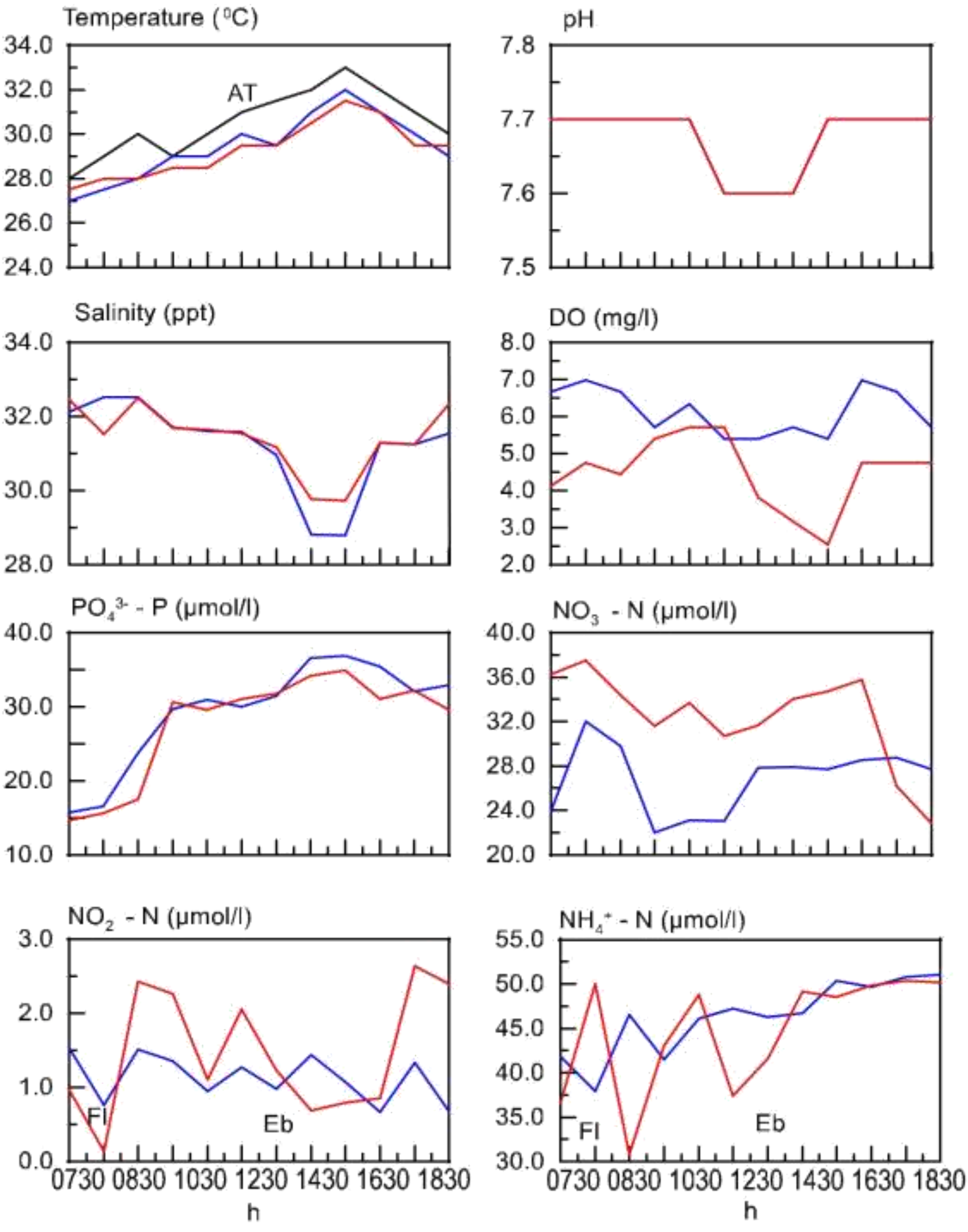


Figure 4.4.2: Temporal Variation of water quality parameters at BYMa4 (——— S) & (——— B) on 3rd May 2016

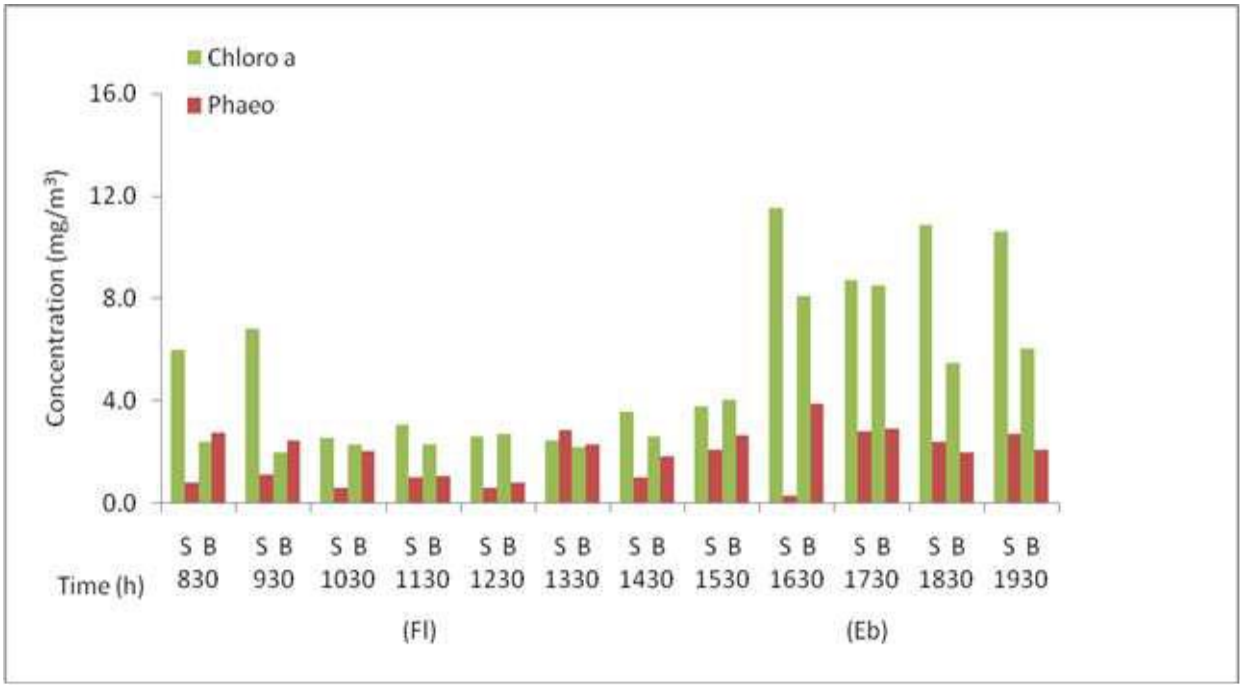


Figure 4.4.3: Temporal Variation of Phytopigments at station BYMa4 on 11.12.2015.

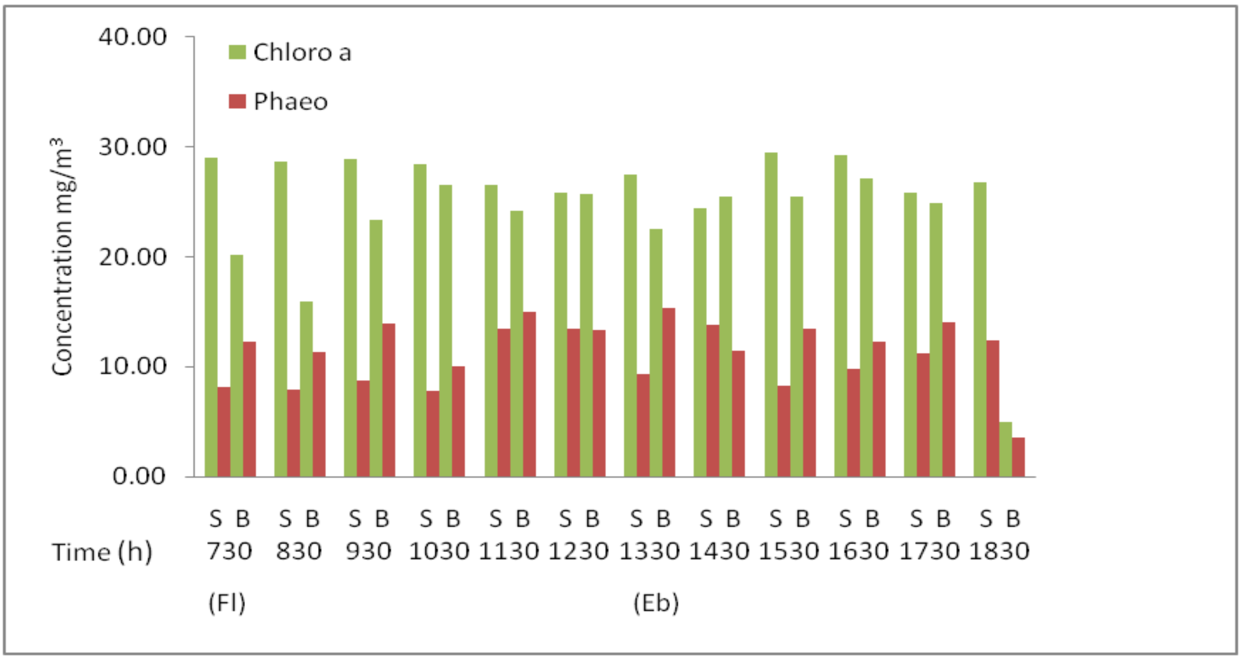


Figure 4.4.4: Temporal Variation of Phytopigments at station BYMa4 on 03.05.2016.

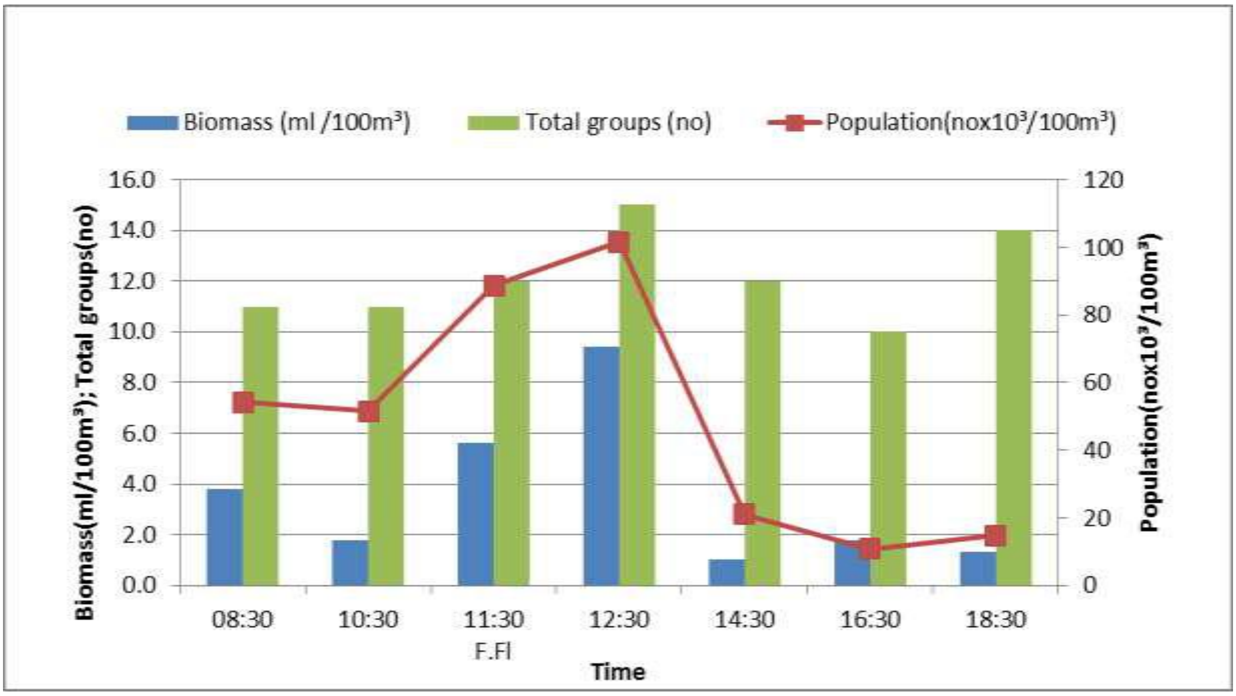


Figure 4.4.5: Temporal Variation of mesozooplankton at station ByMa4 on 11.12.2015

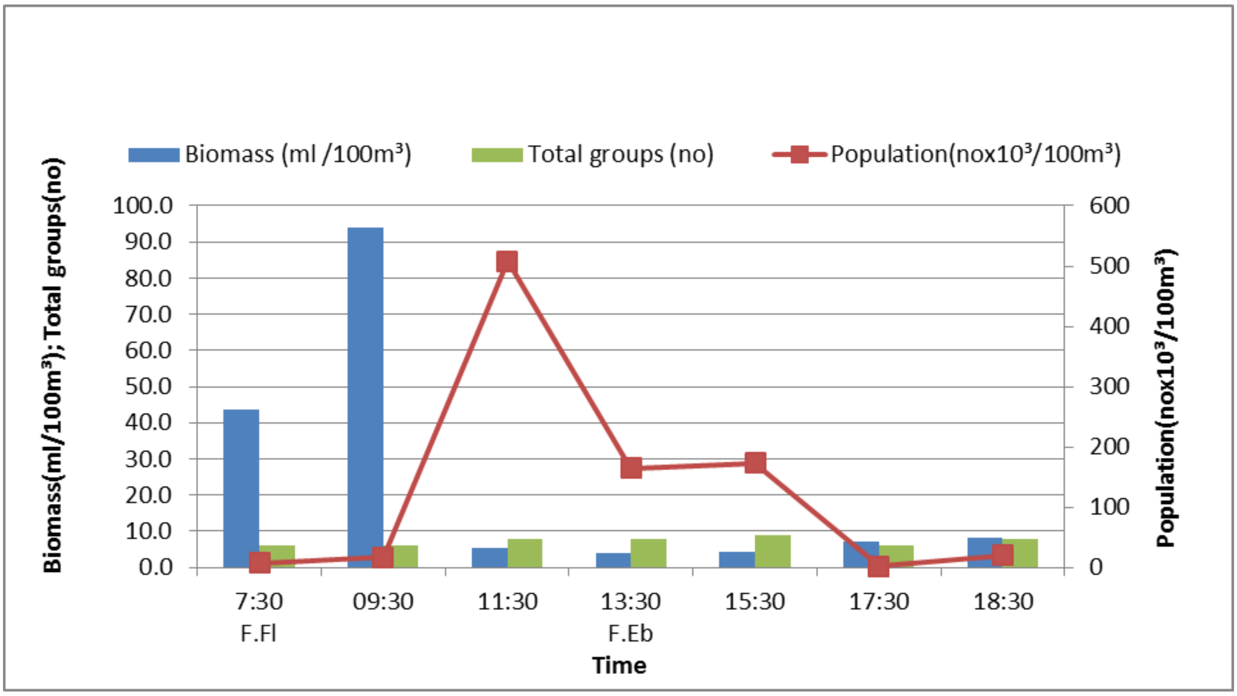


Figure 4.4.6: Temporal Variation of mesozooplankton at station ByMa4 on 03.05.2016

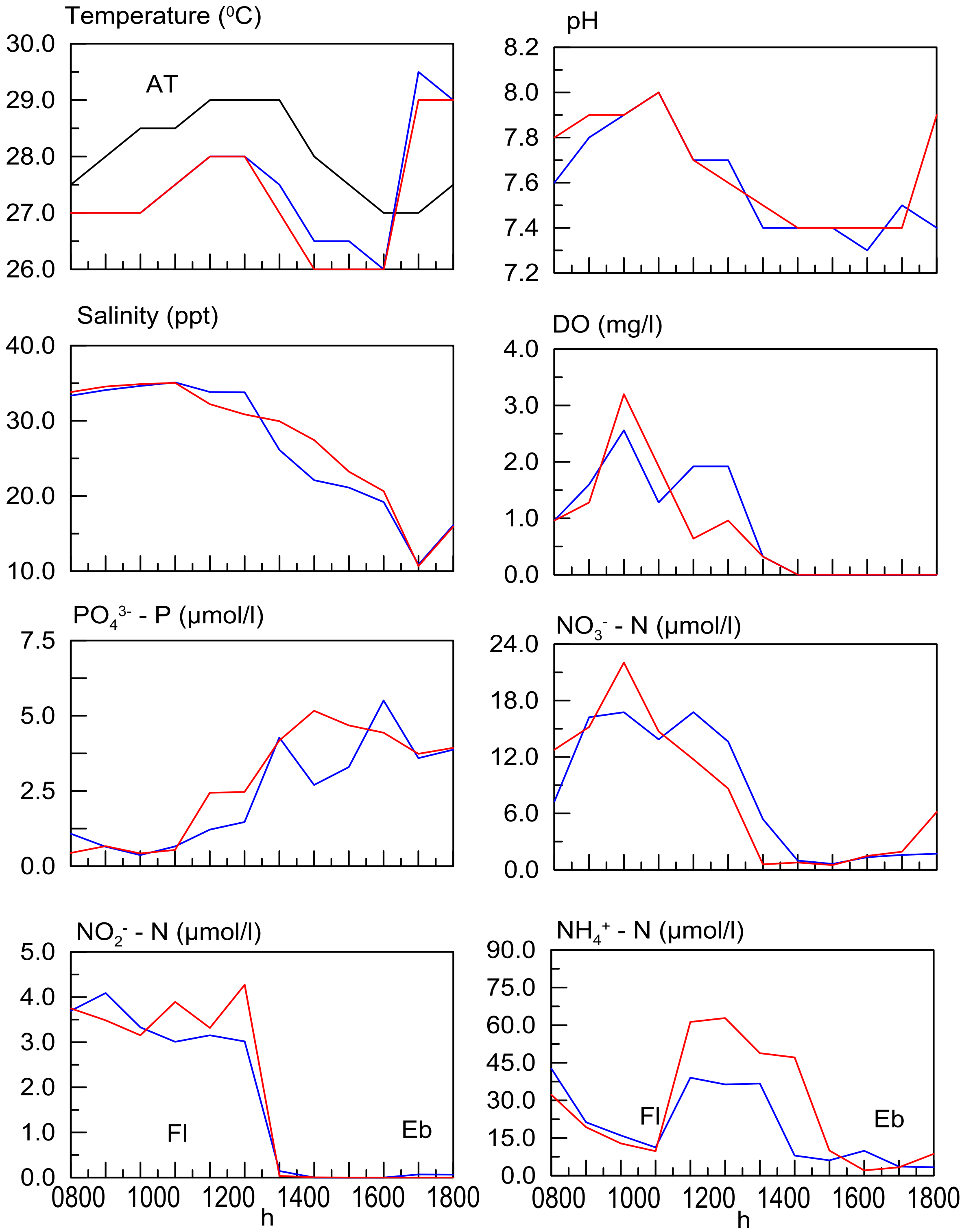


Figure 4.5.1: Temporal Variation of water quality parameters at BYV5 (S) & (B) on 10th Dec 2015

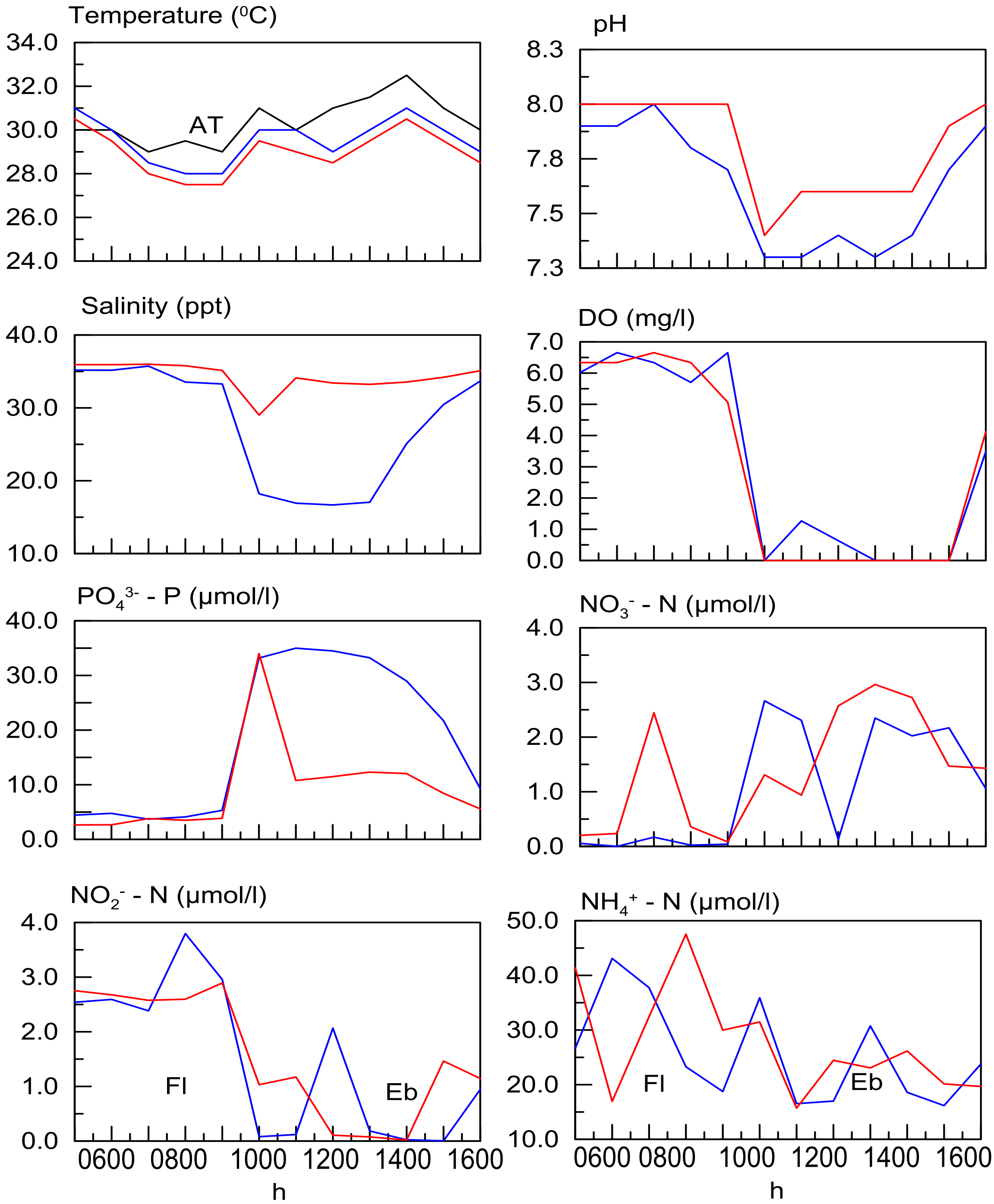


Figure 4.5.2: Temporal Variation of water quality parameters at BYV5 (——— S) & (——— B) on 2nd May 2016

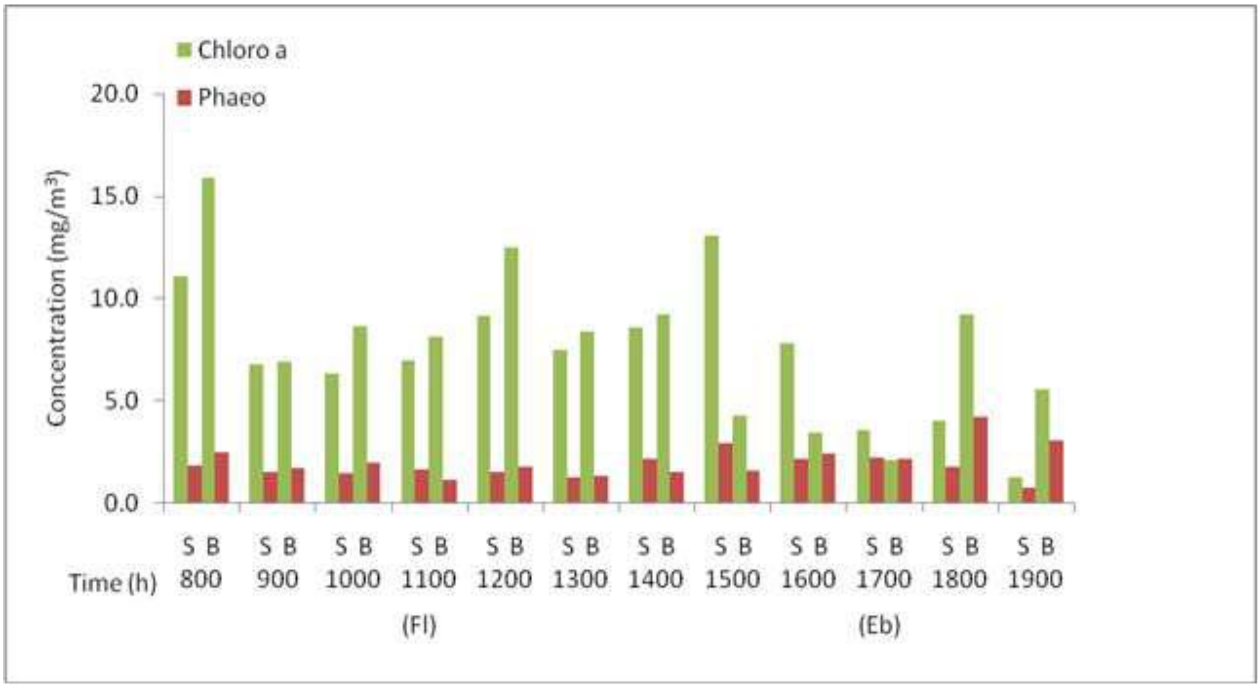


Figure 4.5.3: Temporal Variation of Phytopigments at station BYV5 on 10.12.2015.

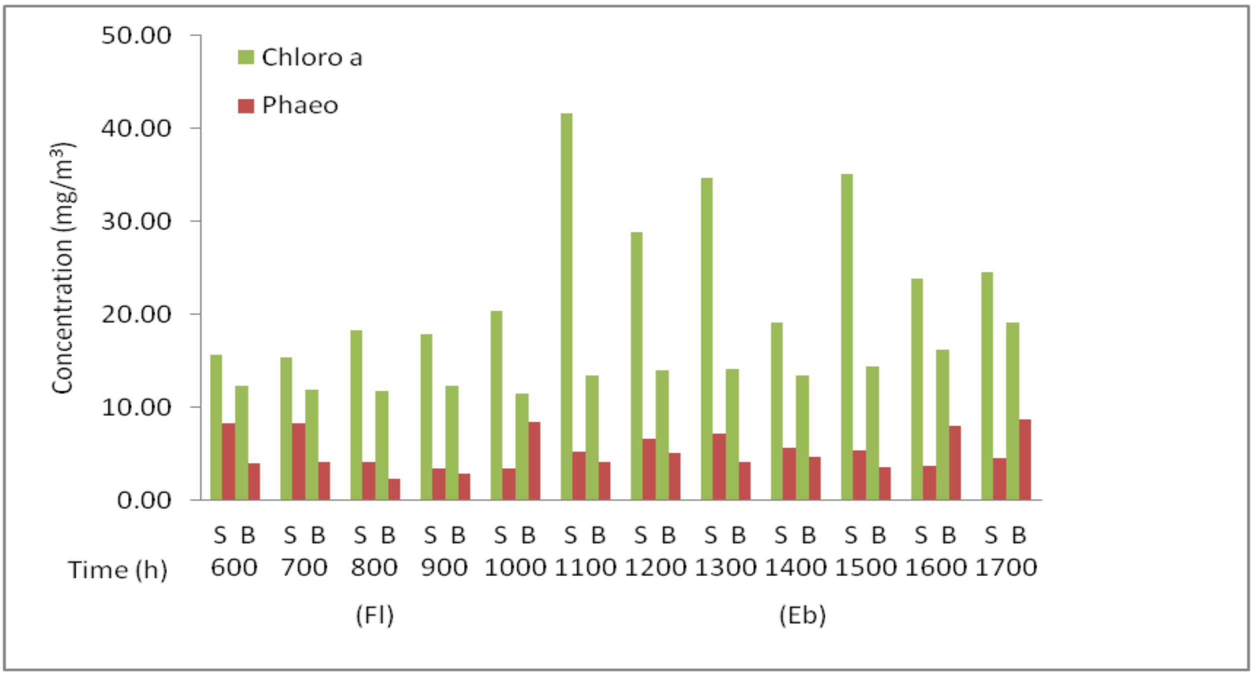


Figure 4.5.4: Temporal Variation of Phytopigments at station BYV5 on 02.05.2016.

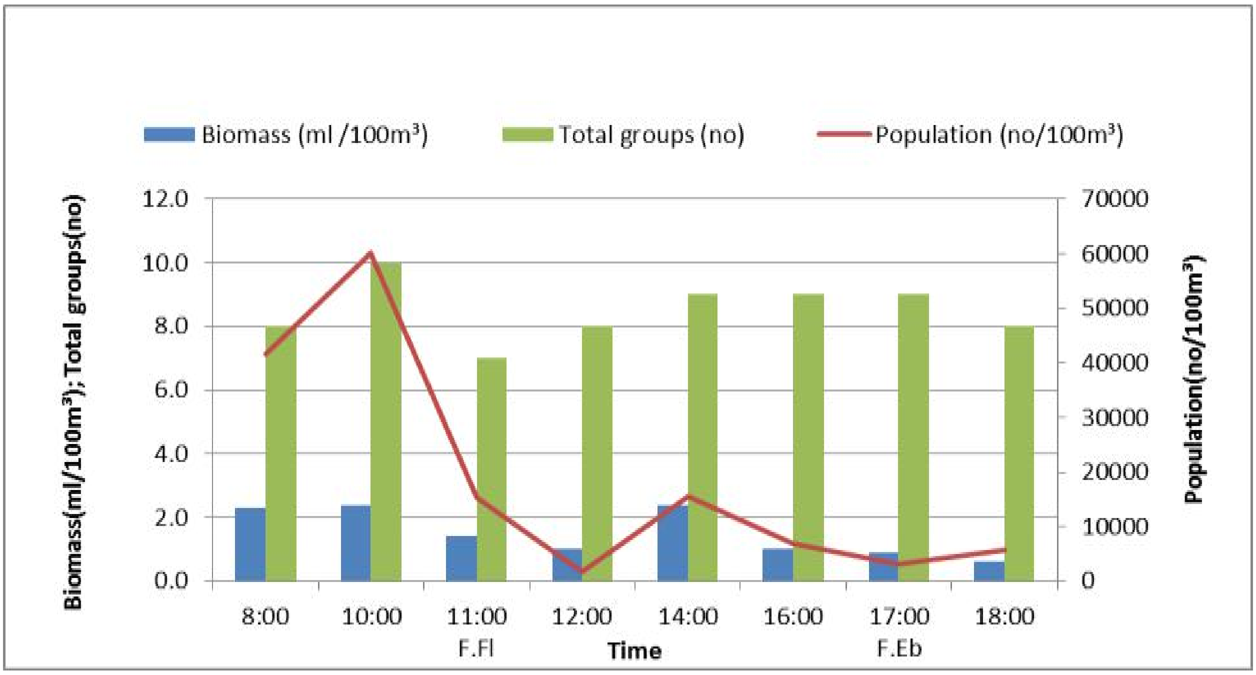


Figure 4.5.5: Temporal Variation of mesozooplankton at station BYV5 on 10.12.2015

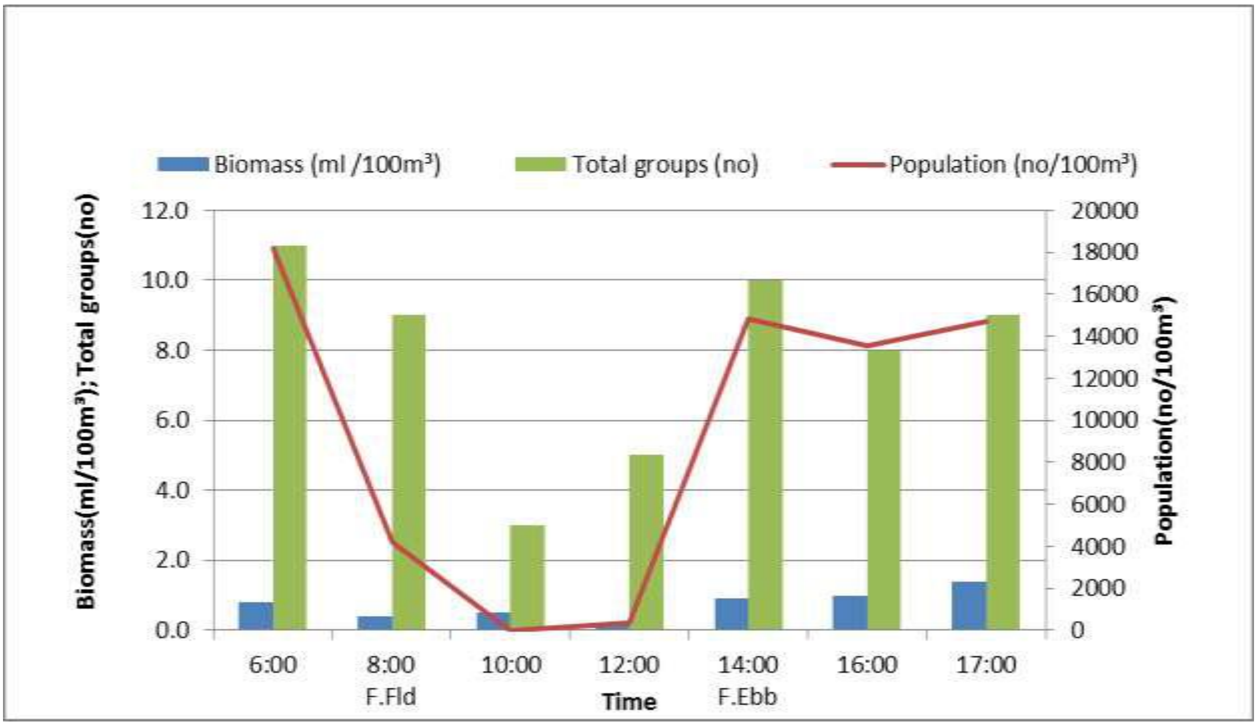


Figure 4.5.6: Temporal Variation of mesozooplankton at station BYV5 on 02.05.2016

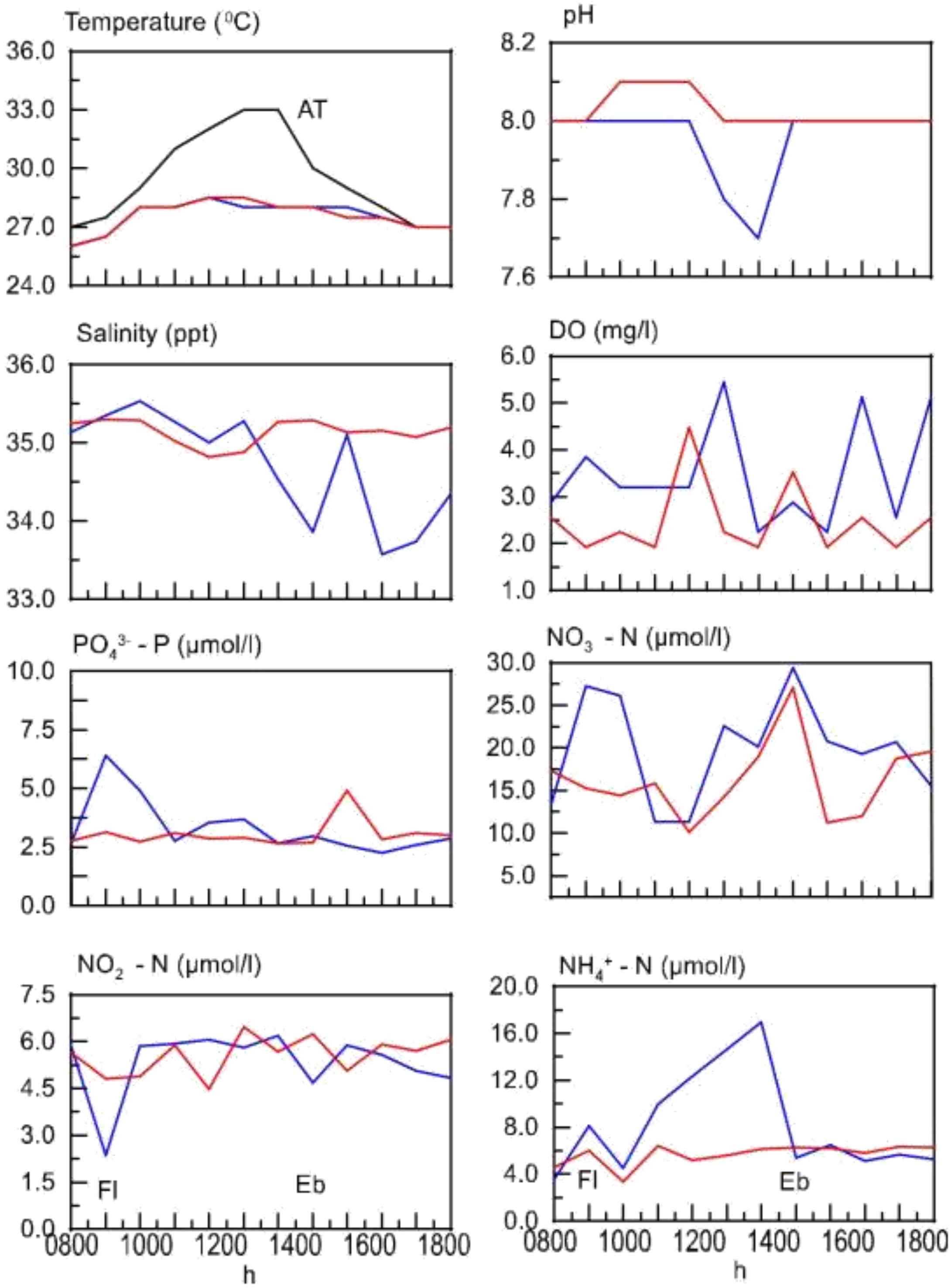


Figure 4.6.1: Temporal Variation of water quality parameters at BYM6 (——— S) & (——— B) on 7th Dec 2015

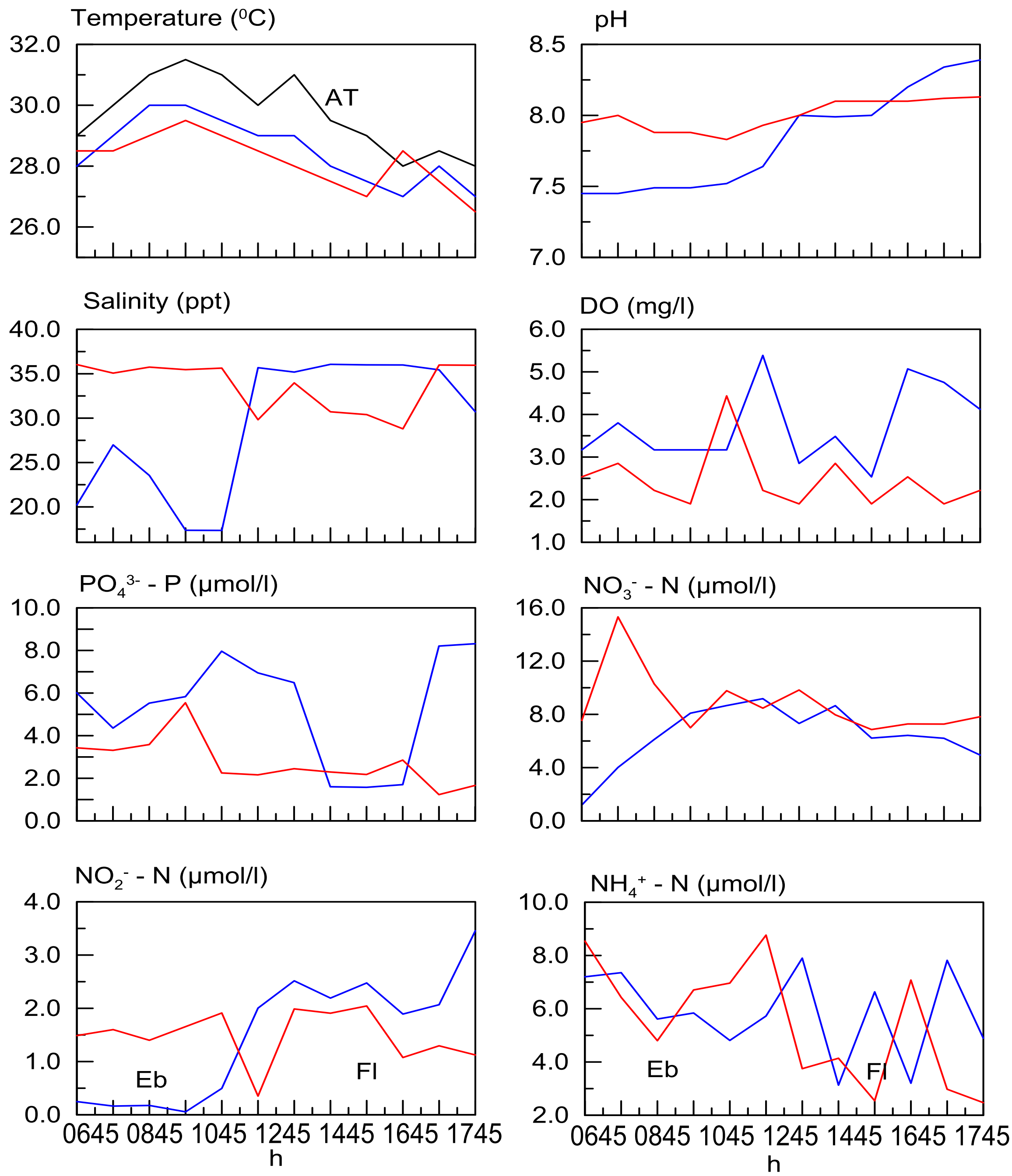


Figure 4.6.2: Temporal Variation of water quality parameters at BYM6 (——— S) & (——— B) on 30th April 2016

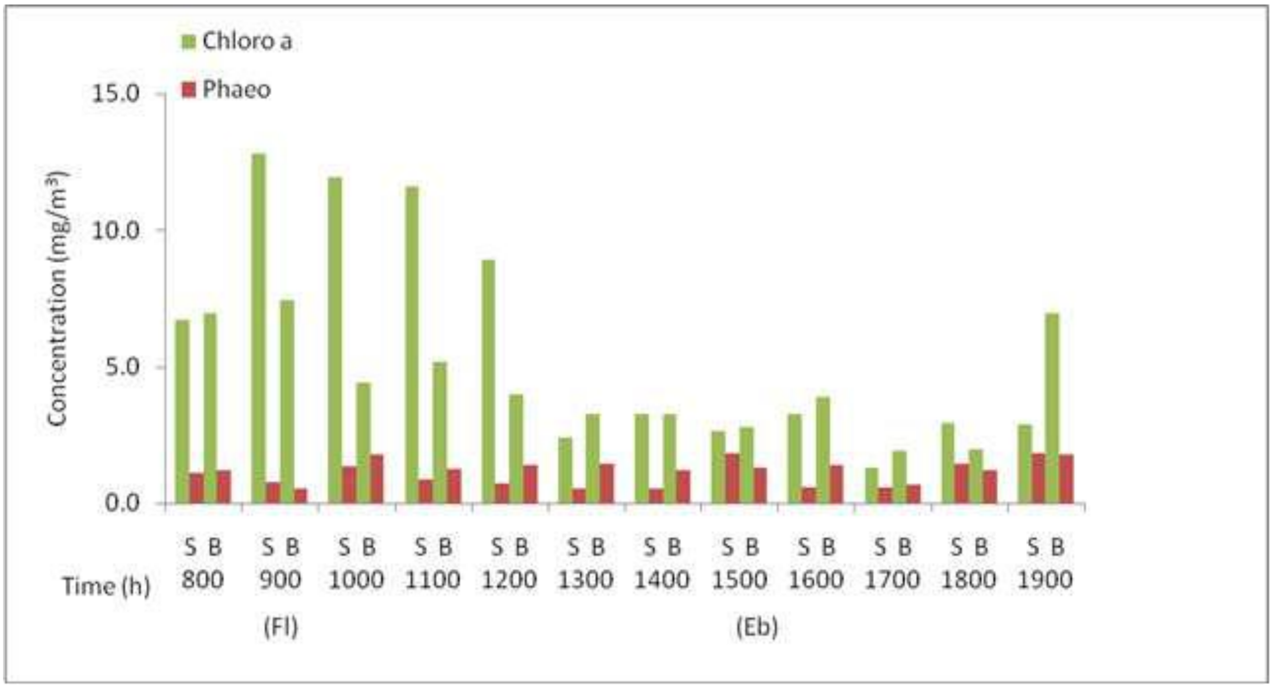


Figure 4.6.3: Temporal Variation of Phytopigments at station BYM6 on 07.12.2015.

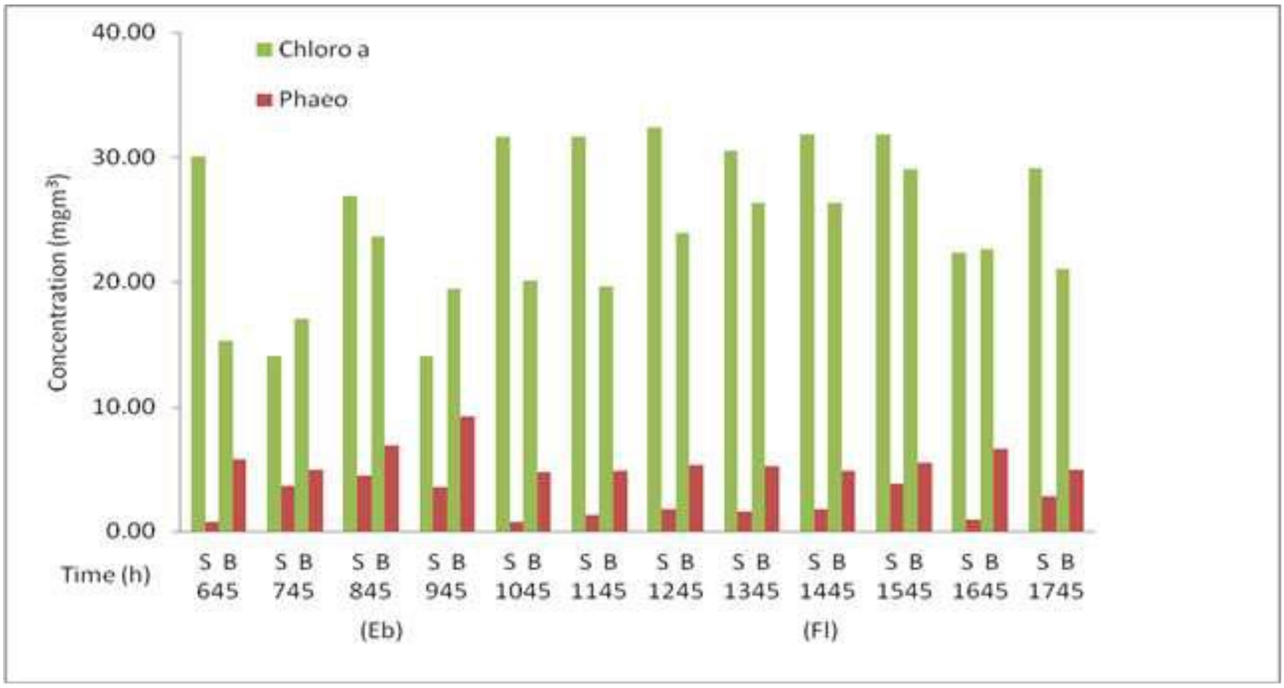


Figure 4.6.4: Temporal Variation of Phytopigments at station BYM6 on 30.04.2016.

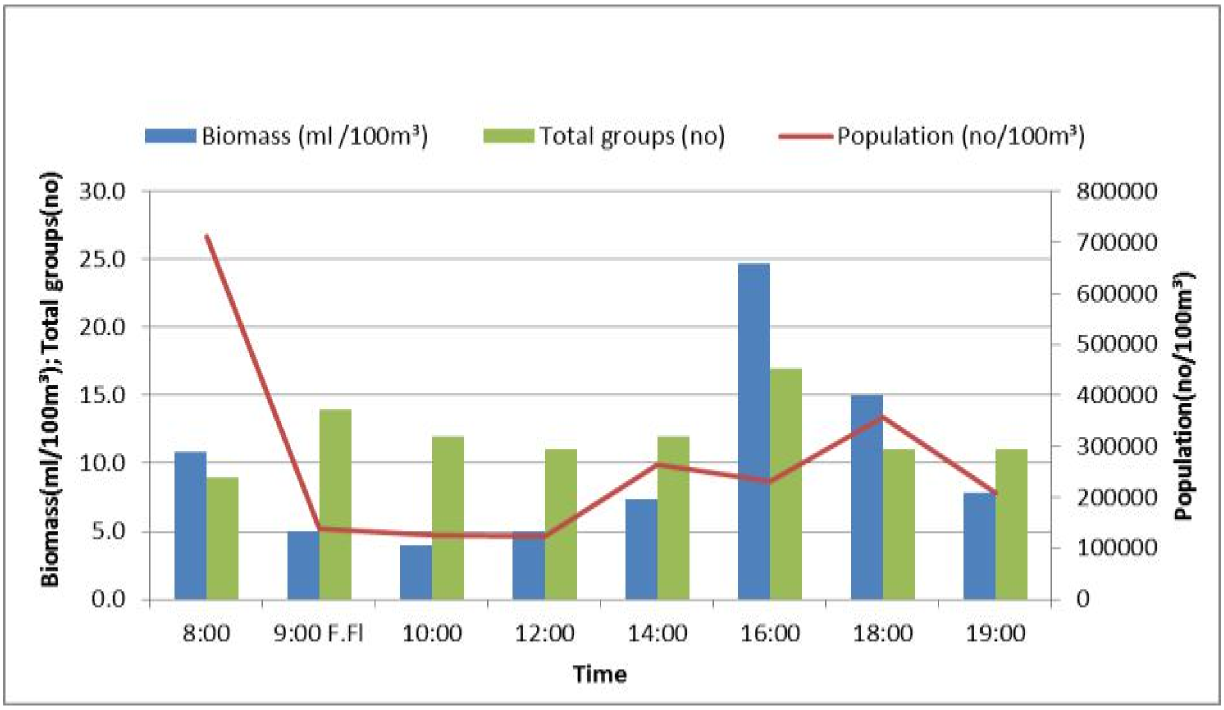


Figure 4.6.5: Temporal Variation of mesozooplankton at station ByM6 on 07.12.2015

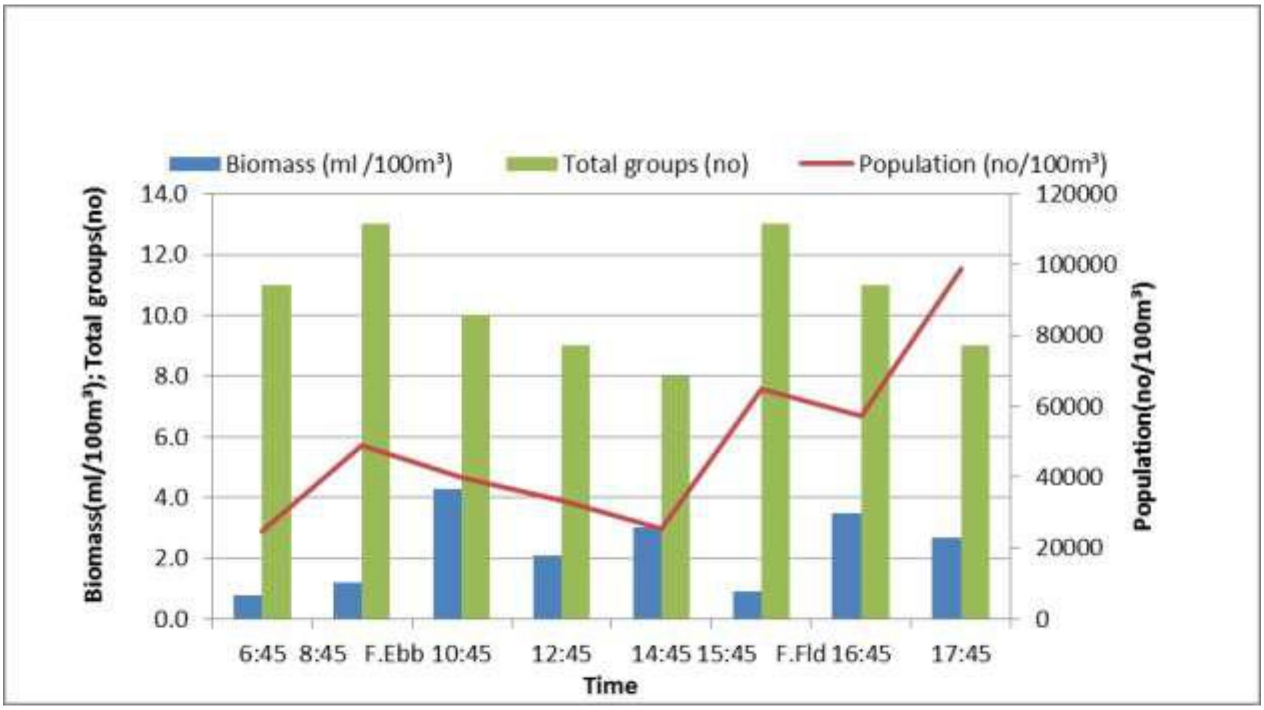


Figure 4.6.6: Temporal Variation of mesozooplankton at station ByM6 on 30.04.2016

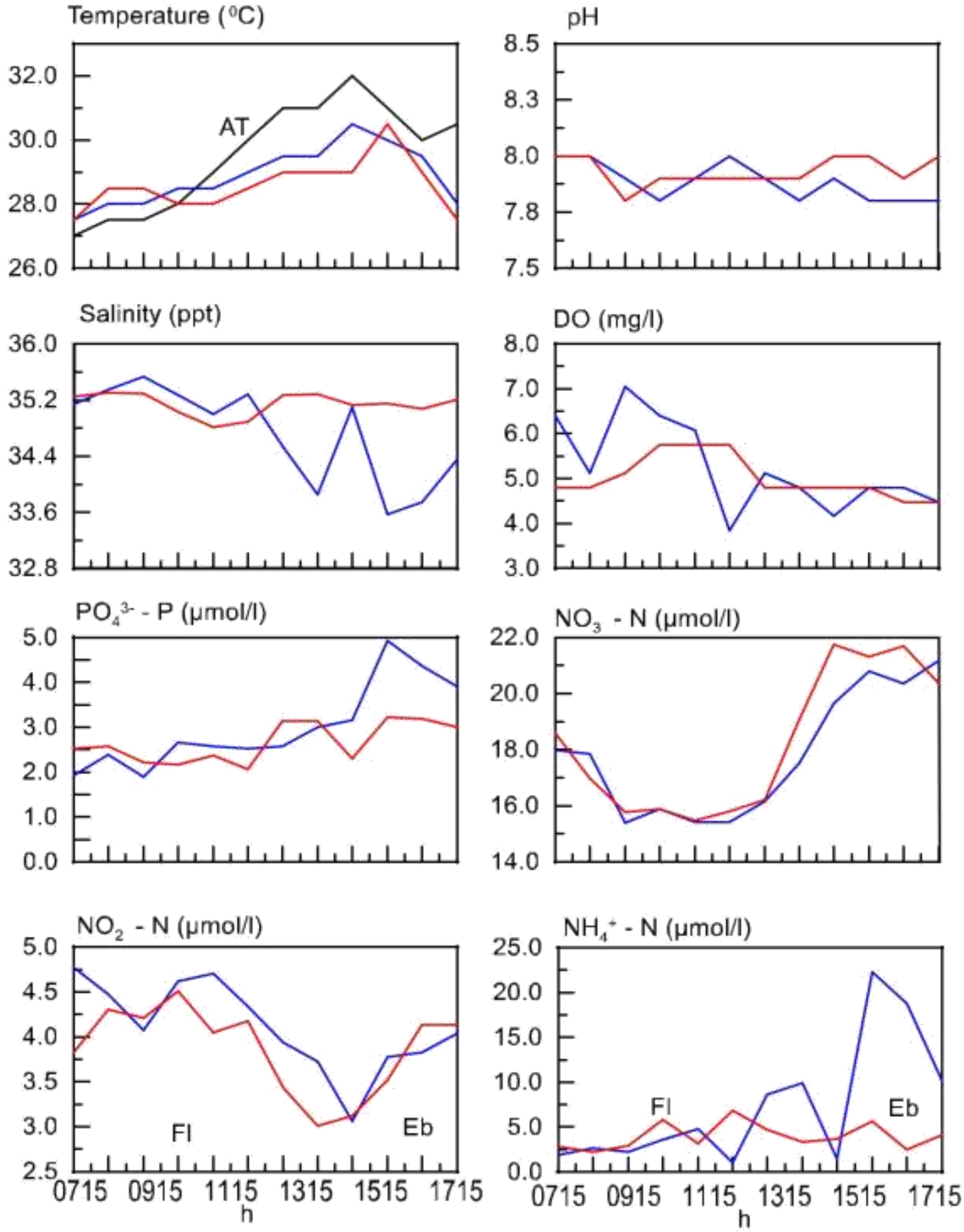


Figure 4.7.1: Temporal Variation of water quality parameters at BYB2 (——— S) & (——— B) on 9th Dec 2015

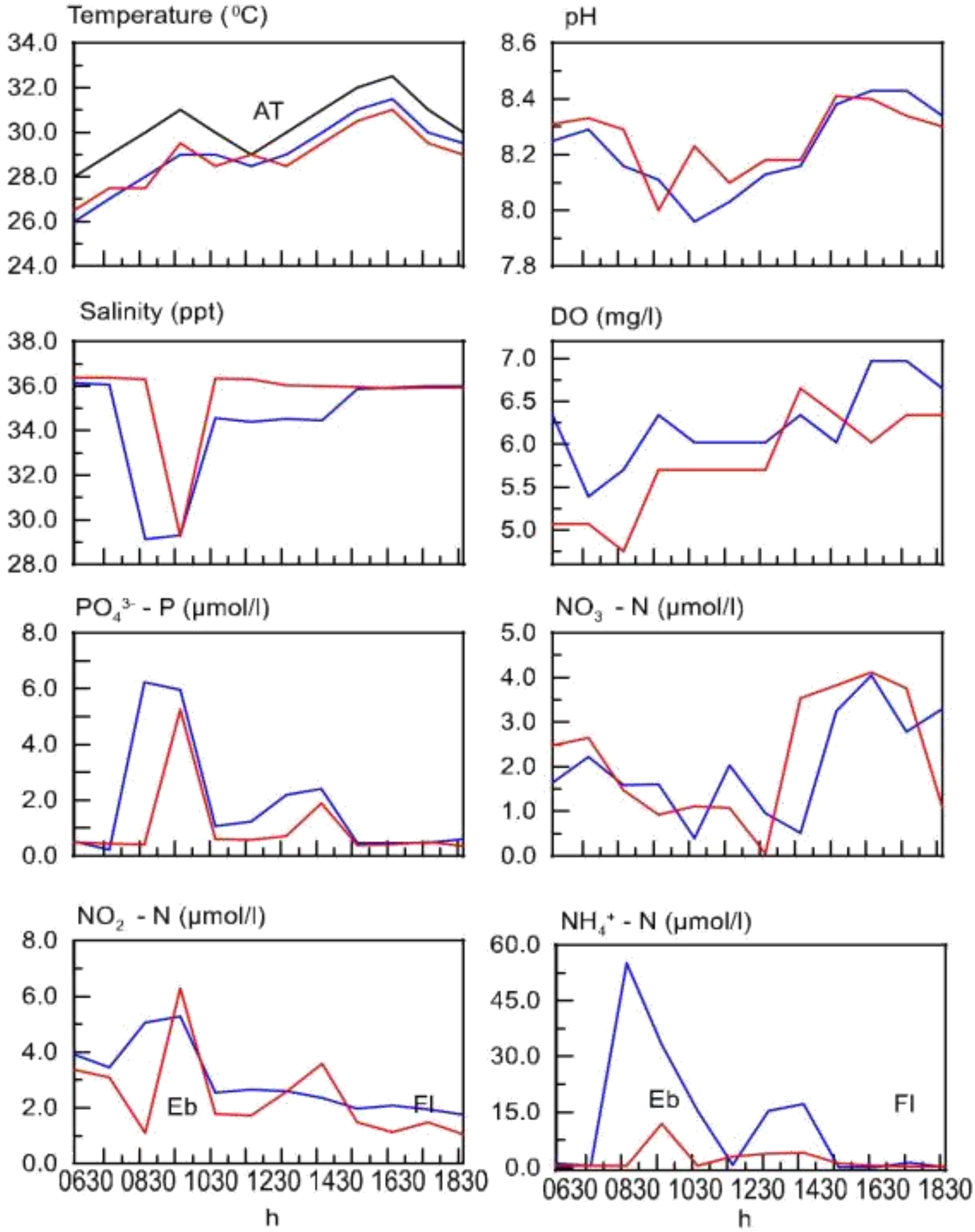


Figure 4.7.2: Temporal Variation of water quality parameters at BYB2 (S) & (B) on 1th May 2016

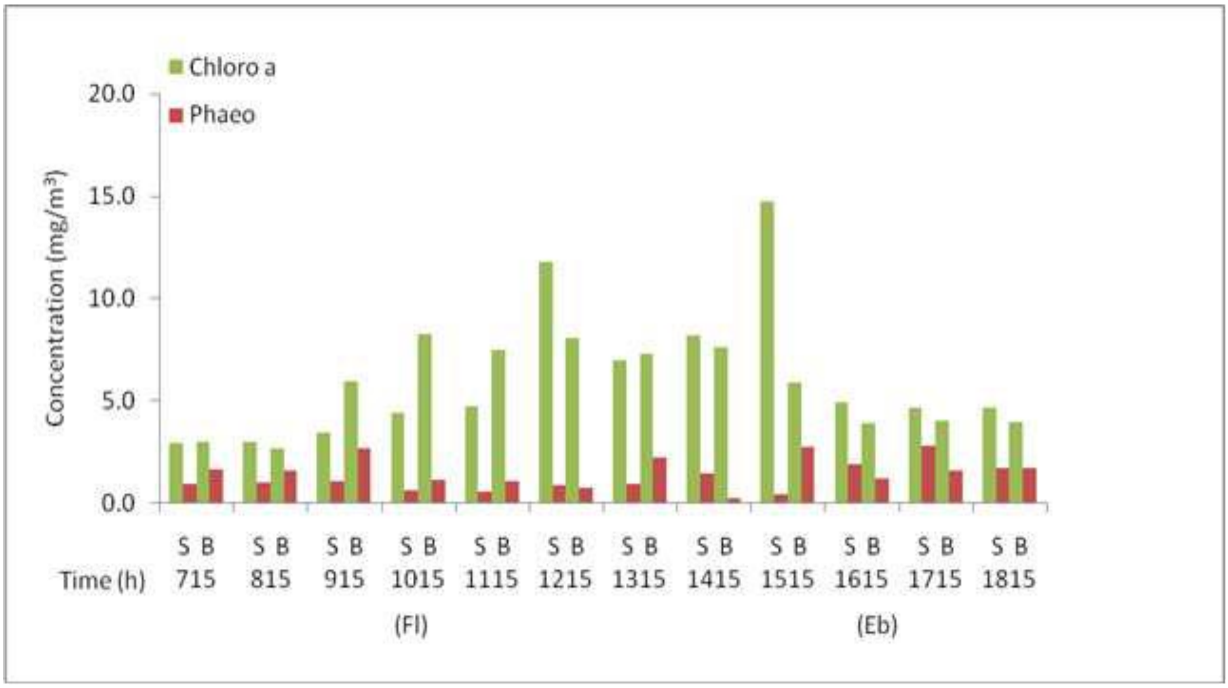


Figure 4.7.3: Temporal Variation of Phytopigments at station BYB2 on 09.12.2015.

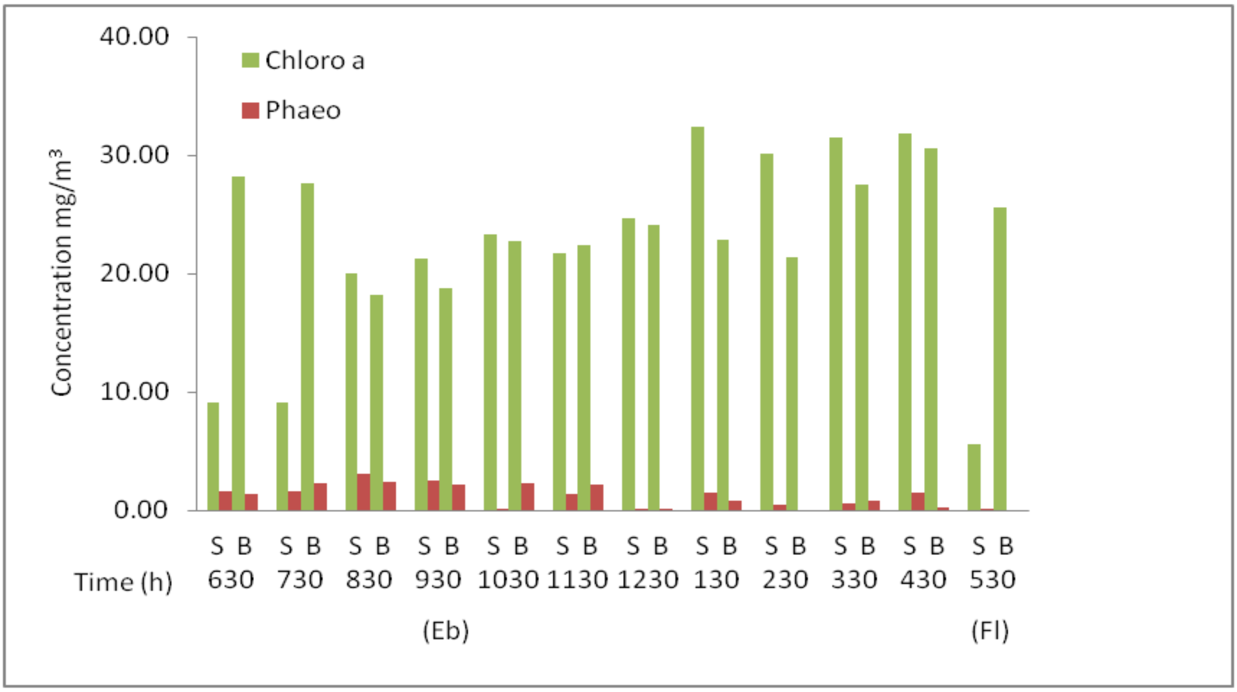


Figure 4.7.4: Temporal Variation of Phytopigments at station BYB2 on 01.05.2016.

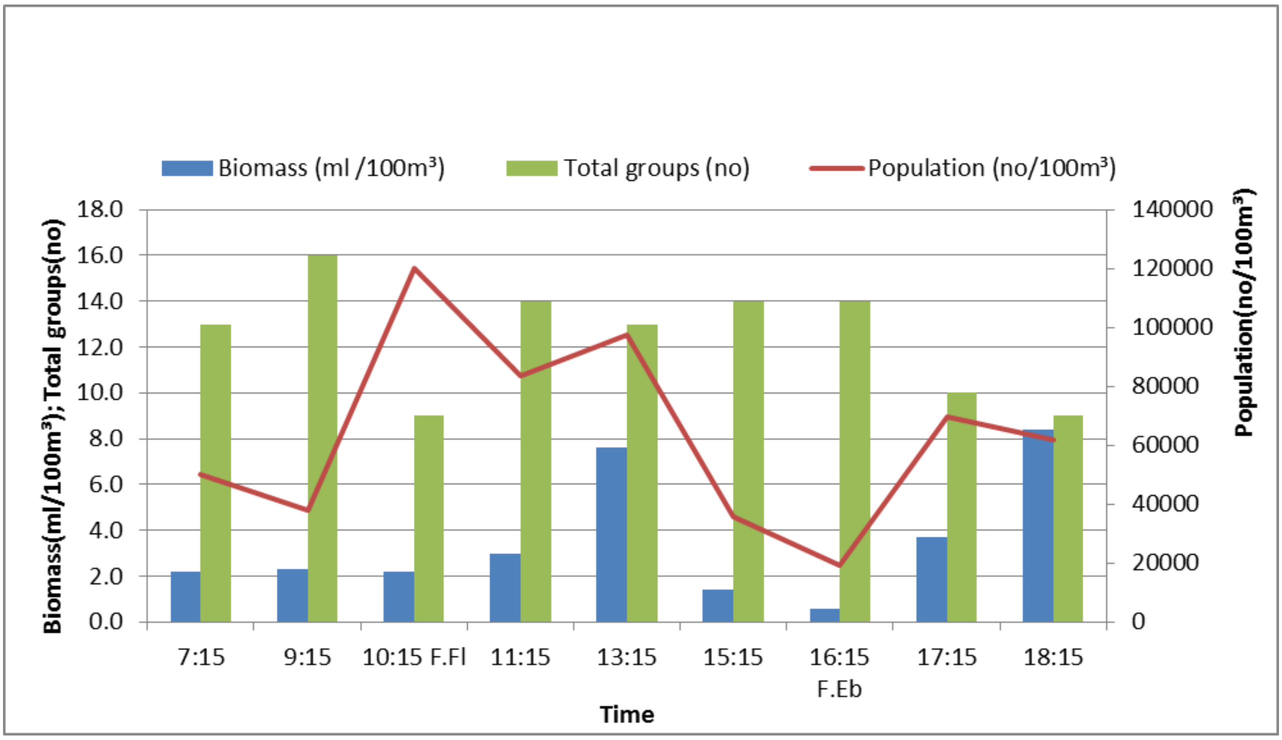


Figure 4.7.5: Temporal Variation of mesozooplankton at station ByB2 on 09.12.2015

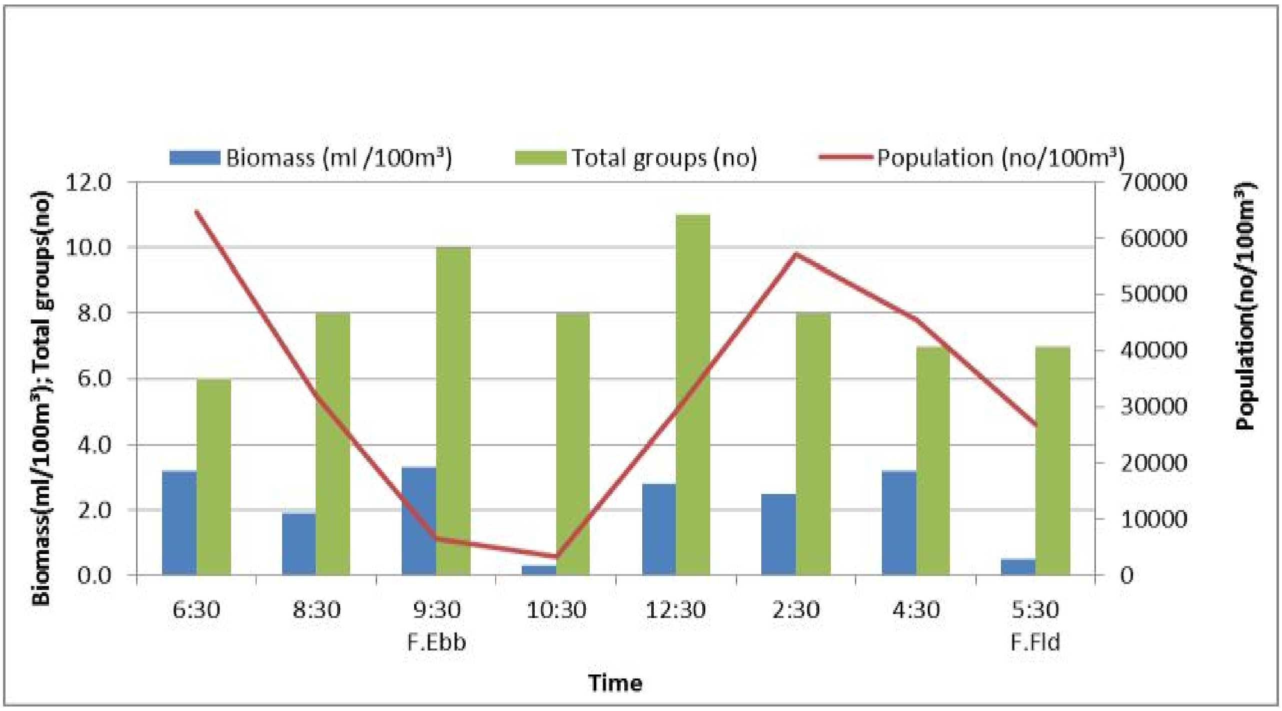


Figure 4.7.6: Temporal Variation of mesozooplankton at station ByB2 on 01.05.2016

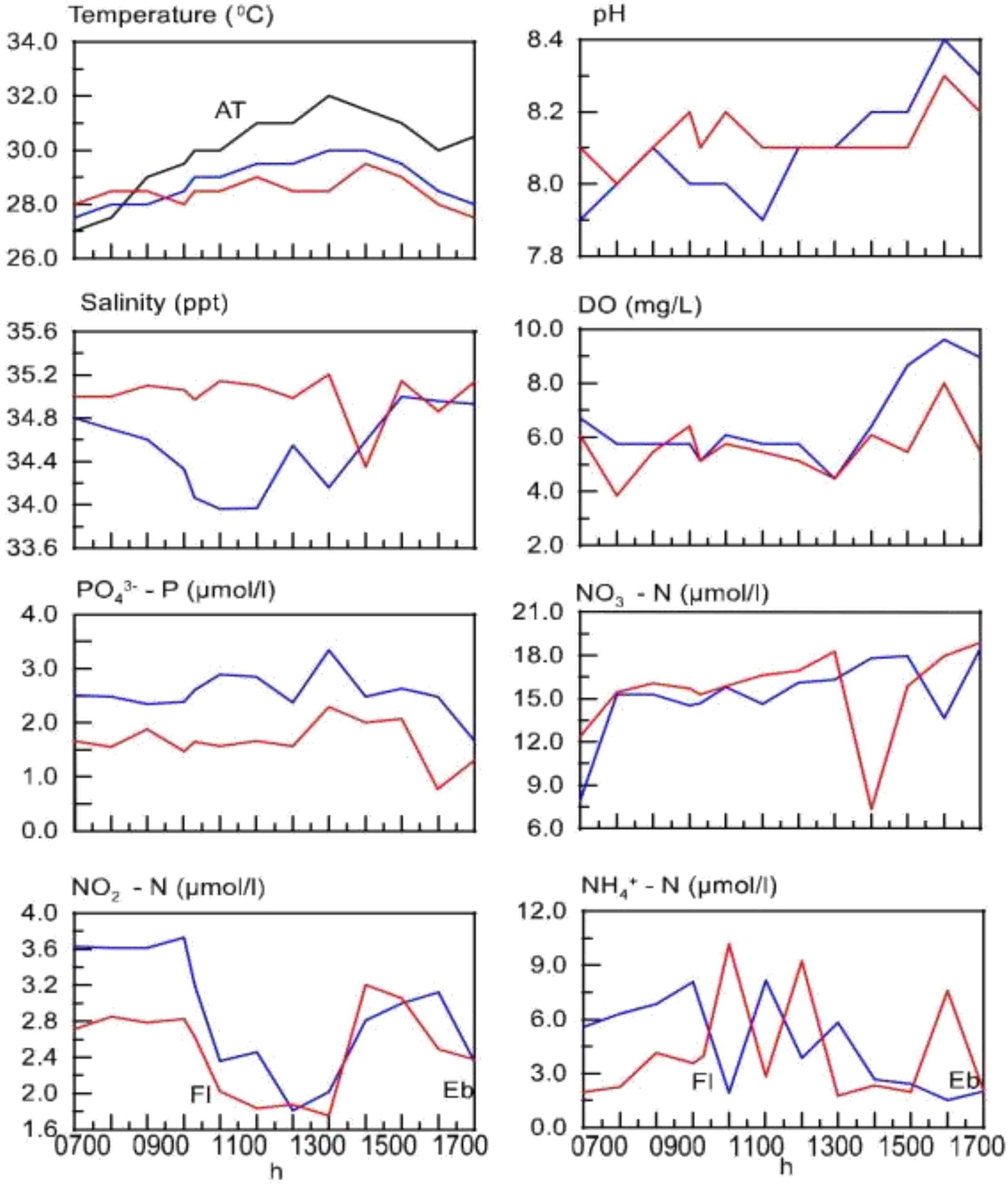


Figure 4.8.1: Temporal Variation of water quality parameters at BYW2 (——— S) & (——— B) on 8th Dec 2015

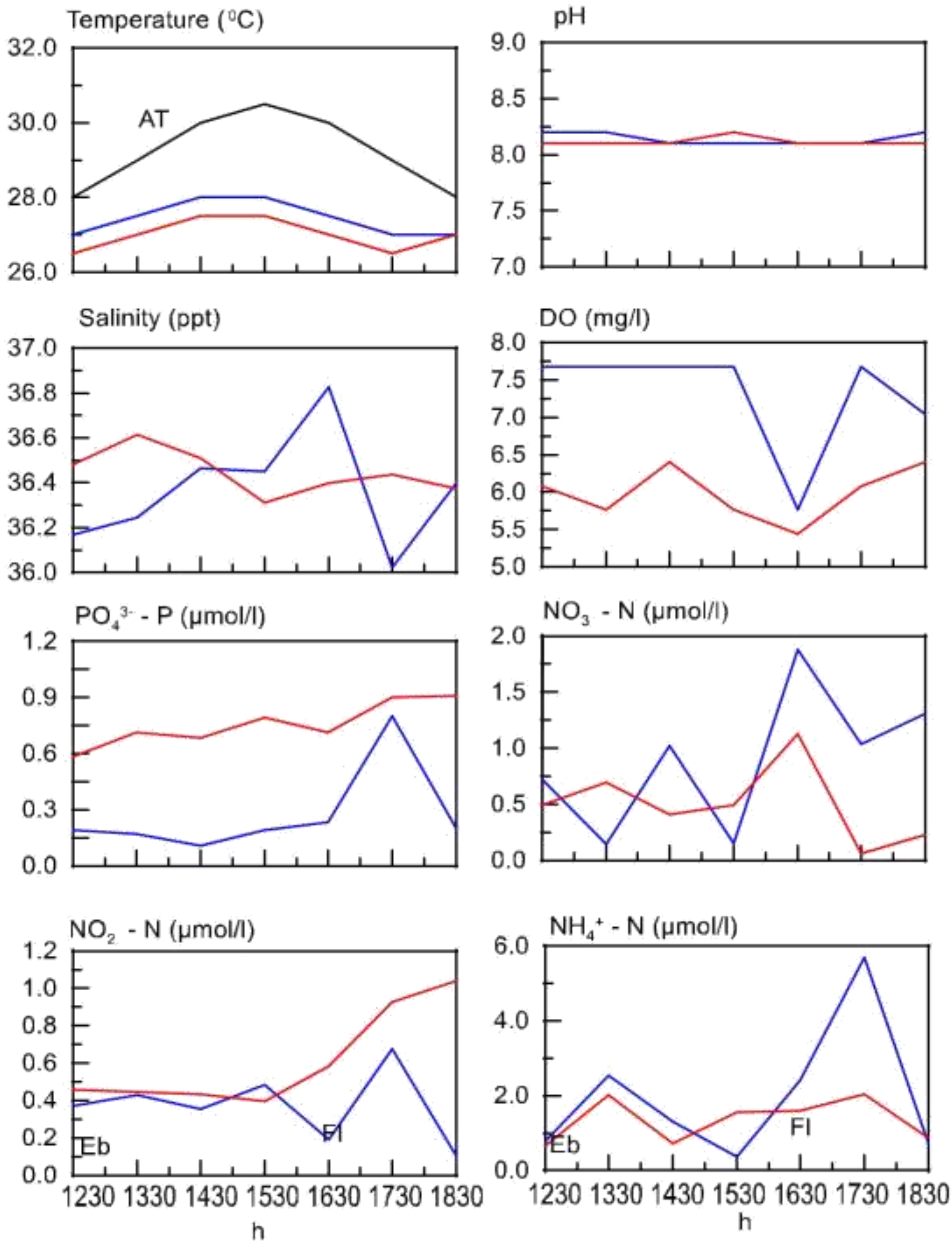


Figure 4.8.2: Temporal Variation of water quality parameters at BYW2 (——— S) & (——— B) on 29th April 2016

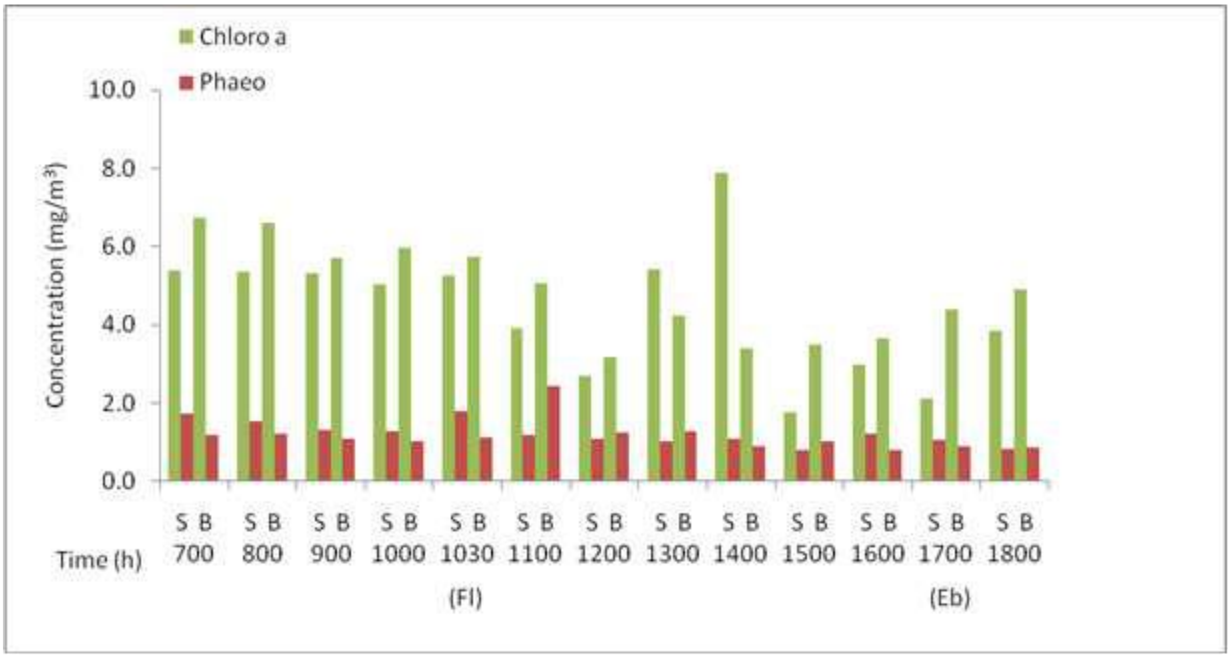


Figure 4.8.3: Temporal Variation of Phytopigments at station BYW2 on 08.12.2015.

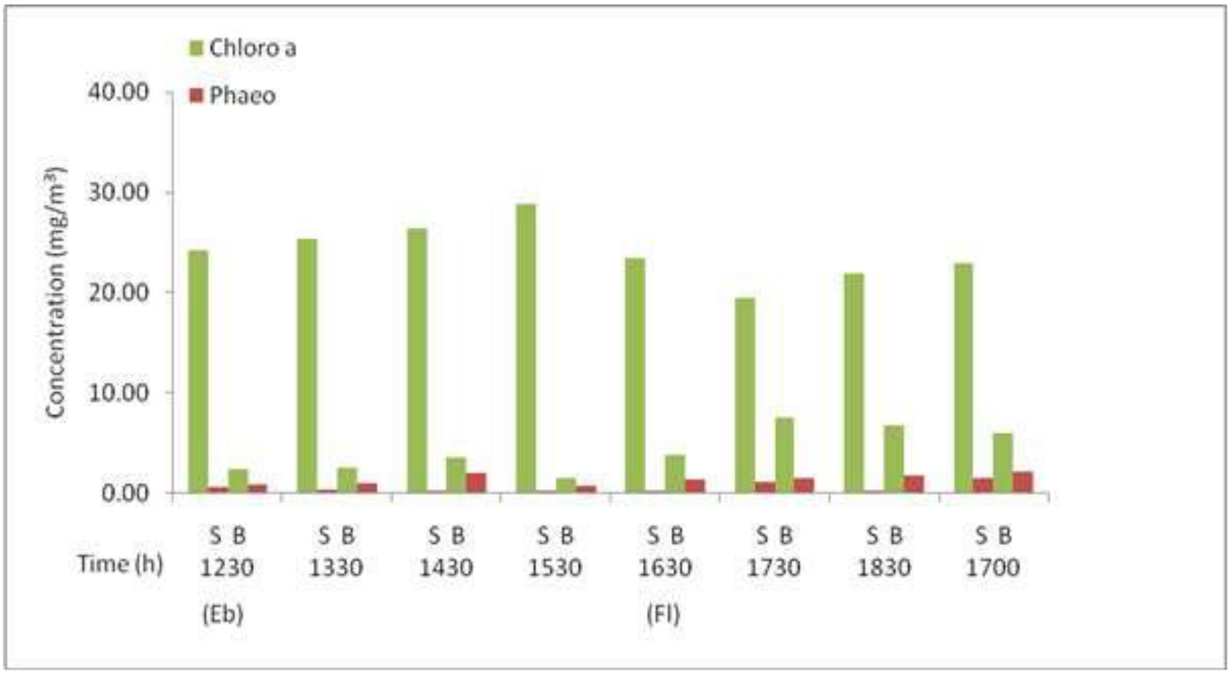


Figure 4.8.4: Temporal Variation of Phytopigments at station BYW2 on 29.04.2016.

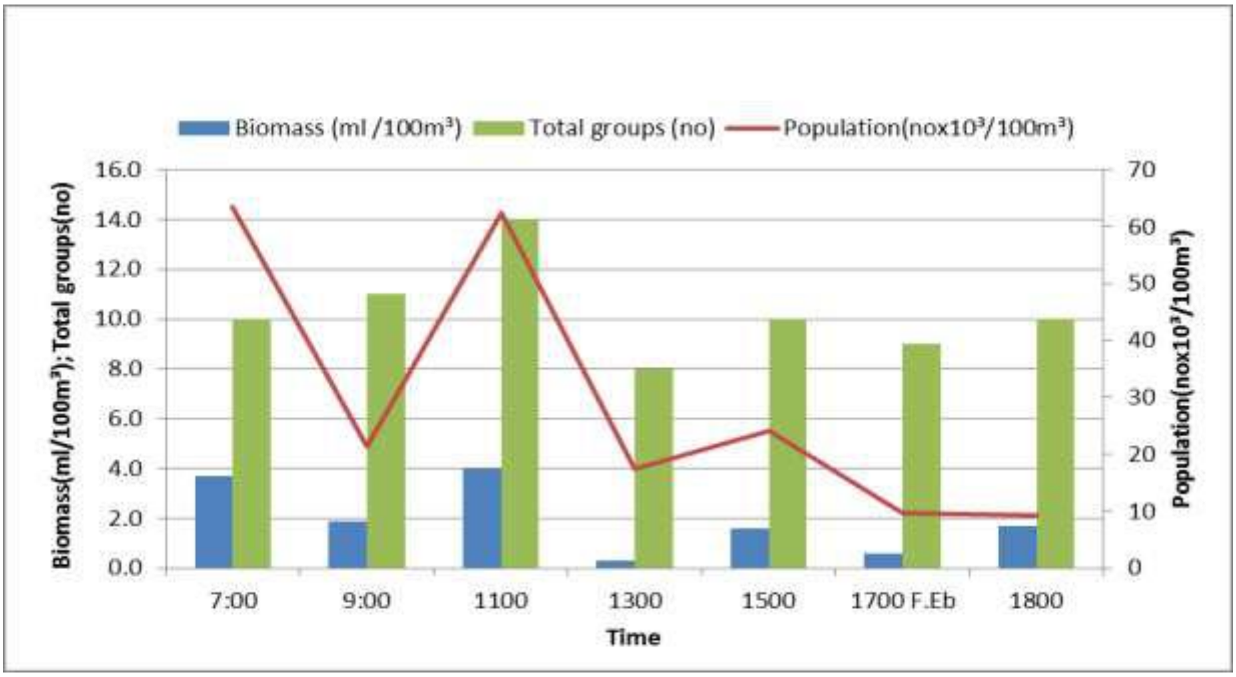


Figure 4.8.5: Temporal Variation of mesozooplankton at station BYW2 on 08.12.2015

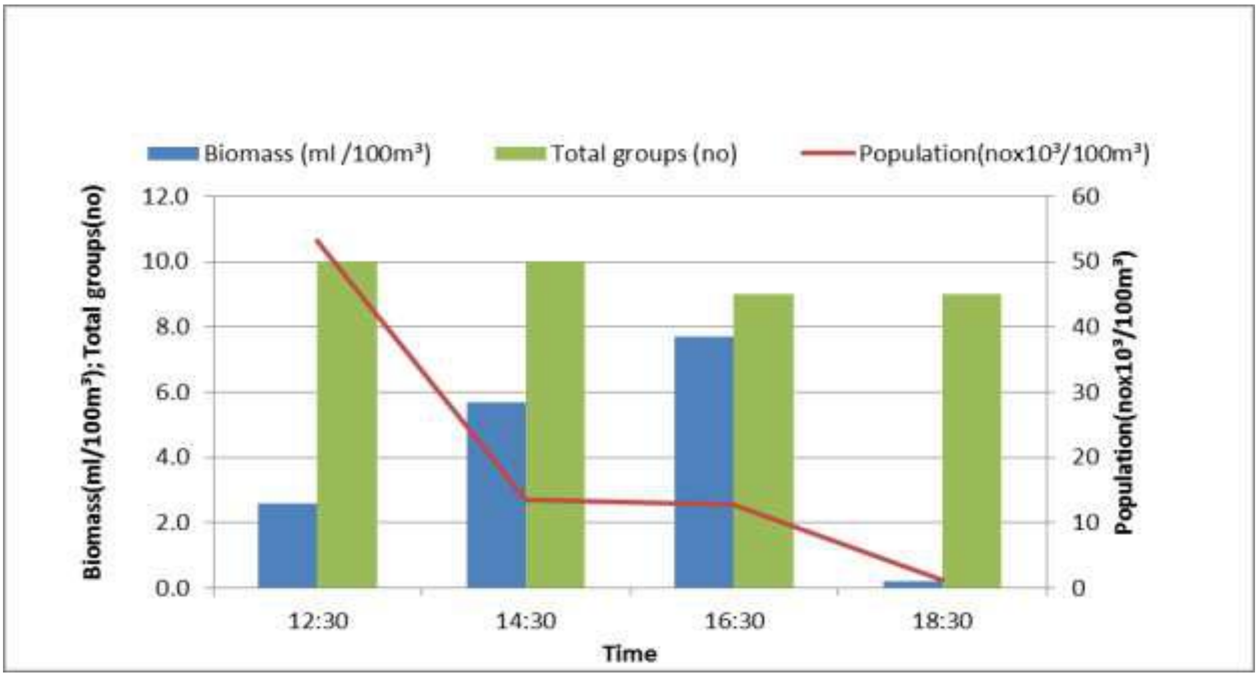


Figure 4.8.6: Temporal Variation of mesozooplankton at station BYW2 on 29.04.2016

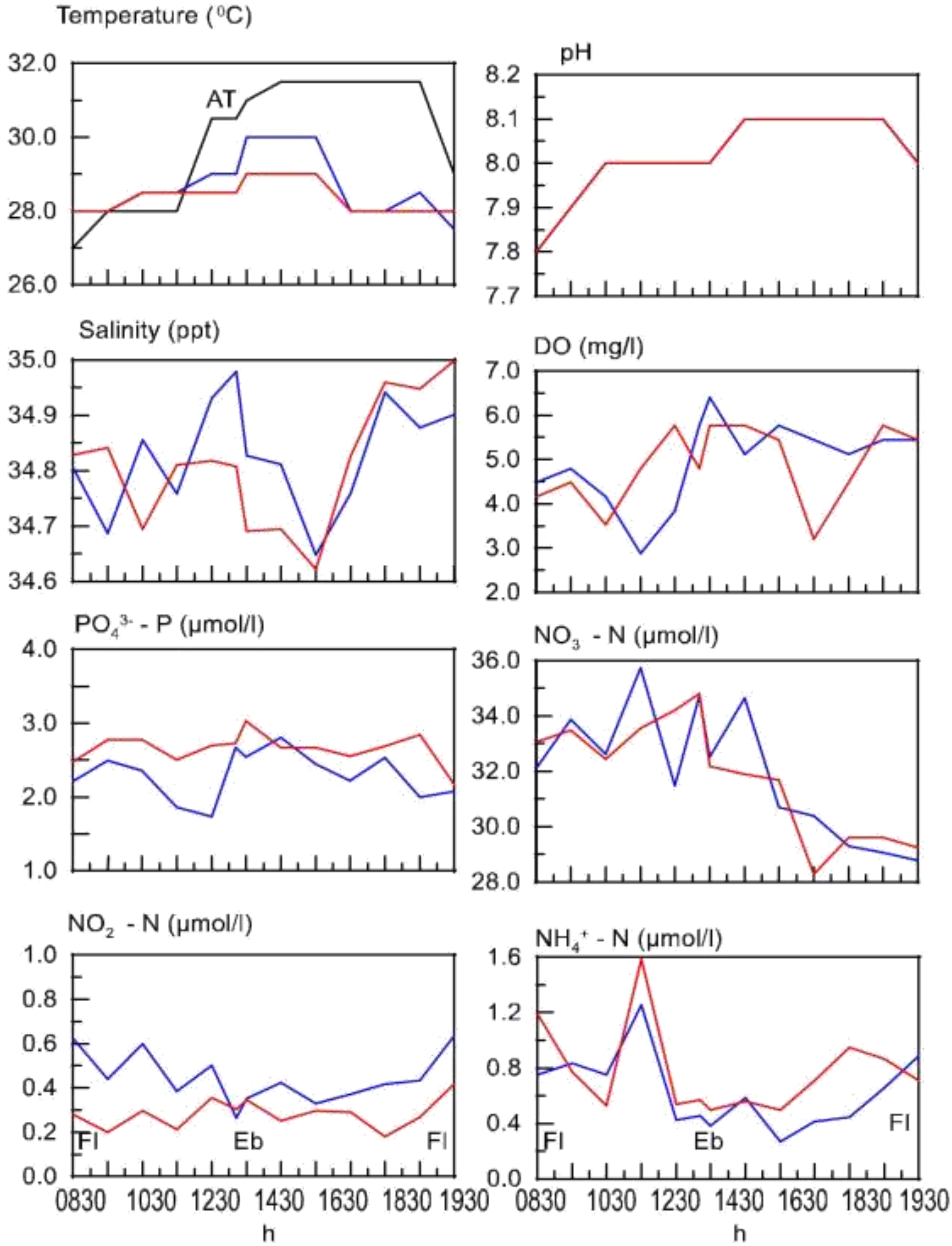


Figure 4.9.1: Temporal Variation of water quality parameters at BY4 (——— S) & (——— B) on 4th Dec 2015

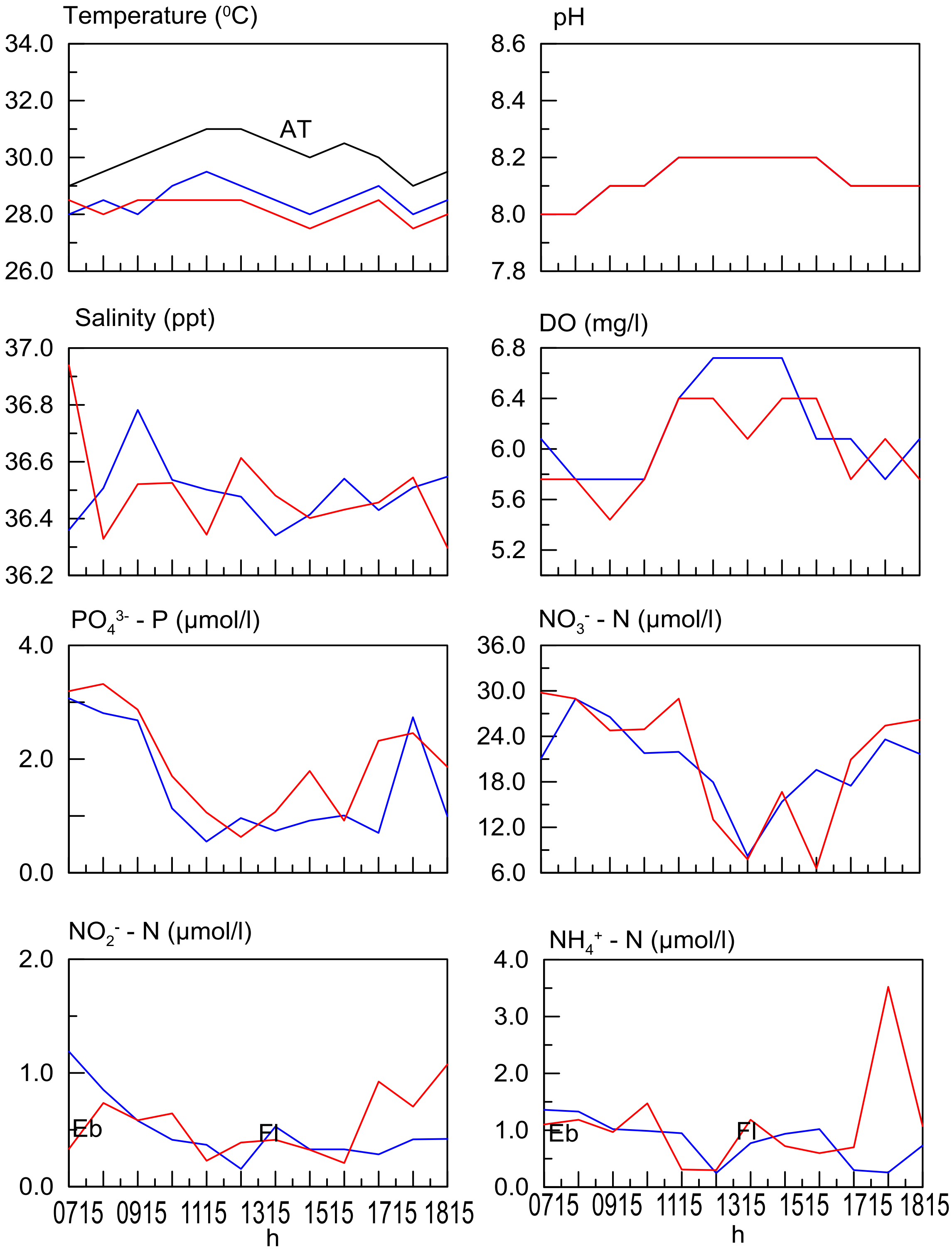


Figure 4.9.2: Temporal Variation of water quality parameters at BY4 (——— S) & (——— B) on 24th April 2016

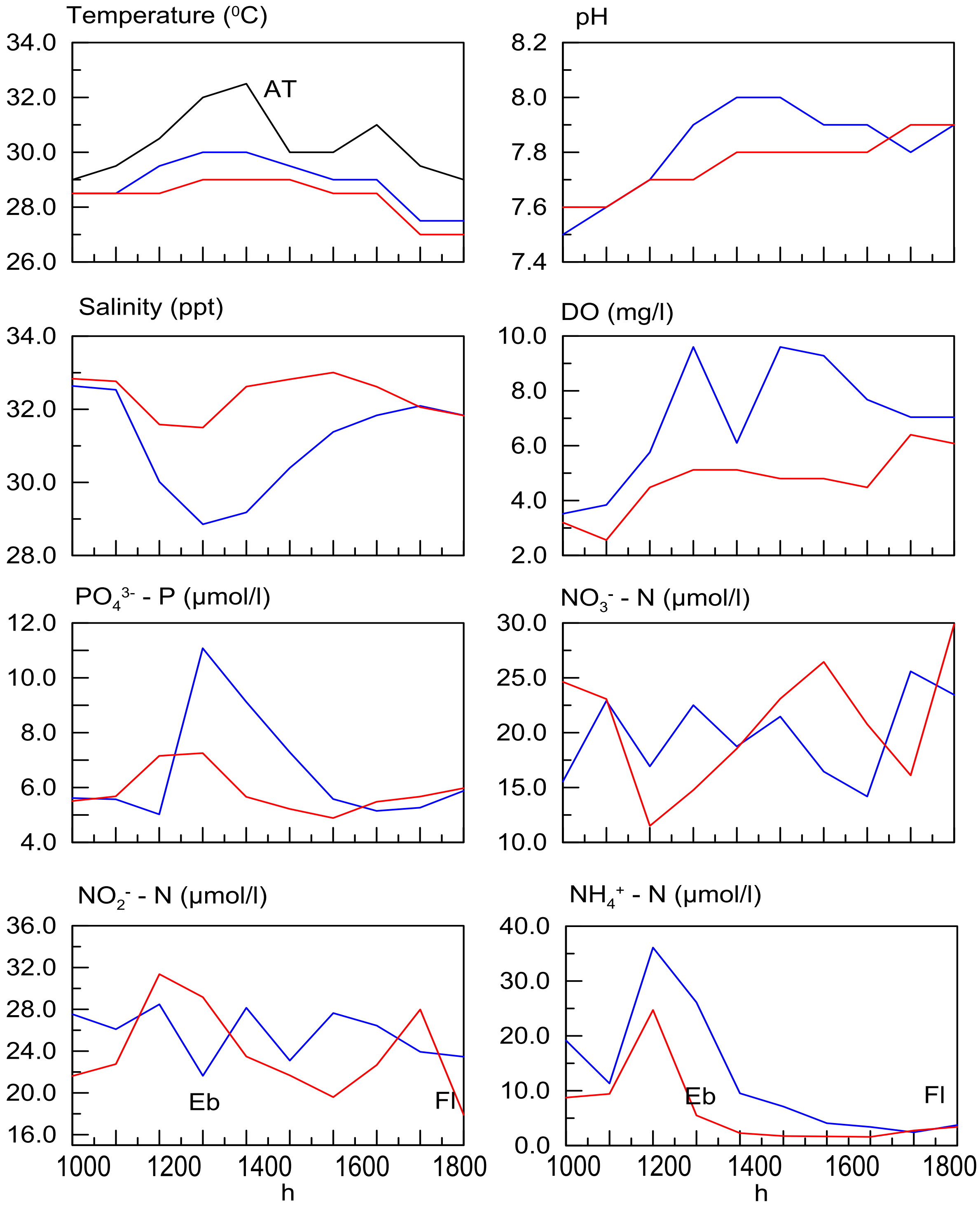


Figure 4.9.3: Temporal Variation of water quality parameters at BY6 (——— S) & (——— B) on 3rd Dec 2015

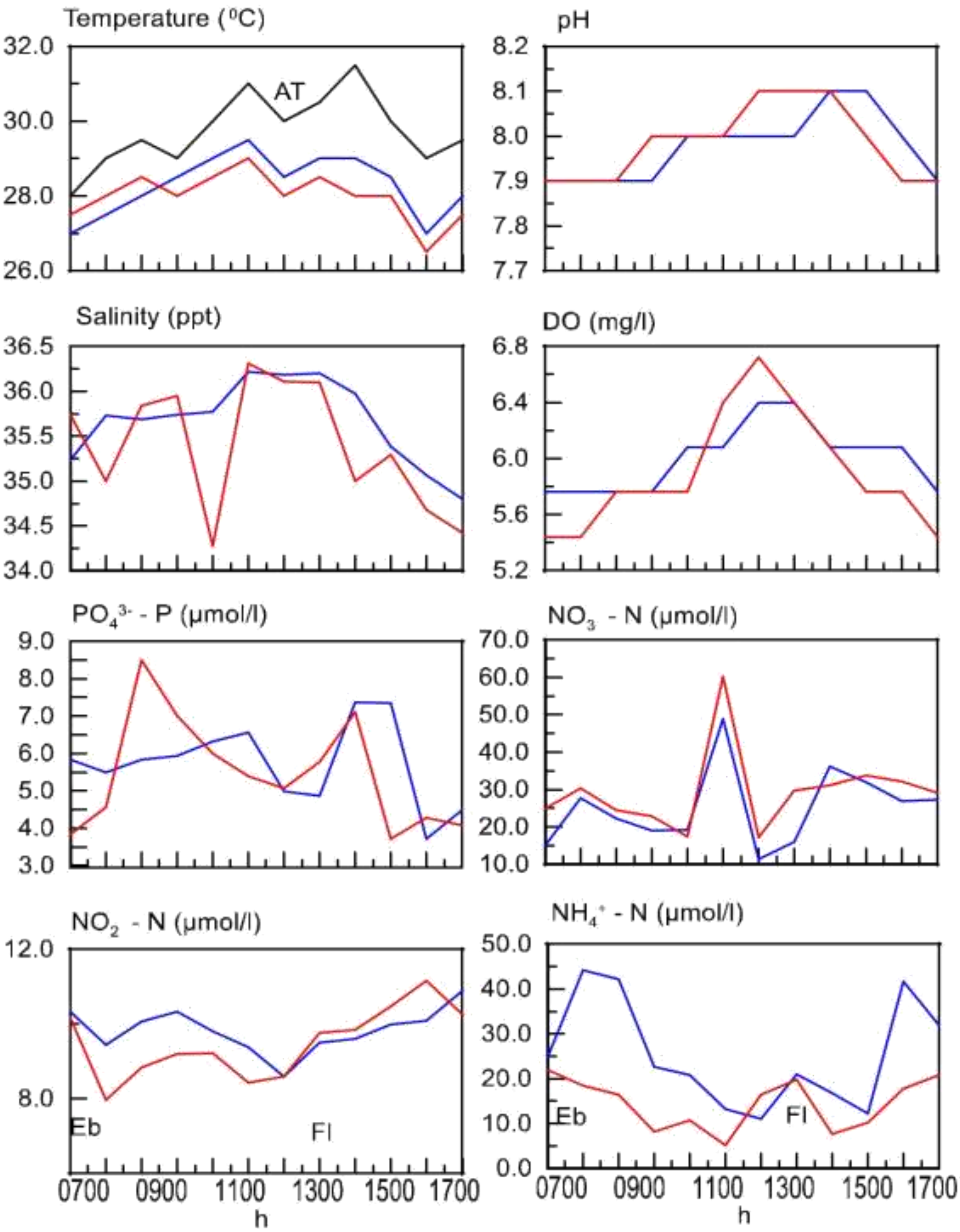


Figure 4.9.4: Temporal Variation of water quality parameters at BY6 (——— S) & (——— B) on 23rd April 2016

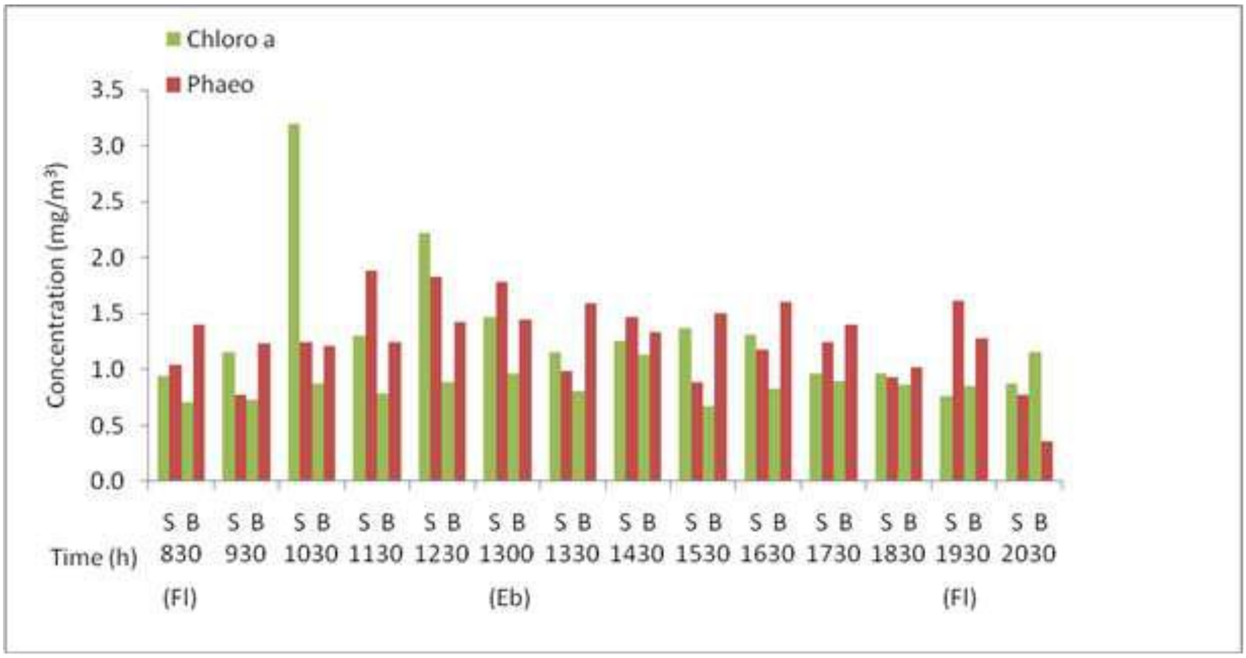


Figure 4.9.5: Temporal Variation of Phytopigments at station BY4 on 04.12.2015.

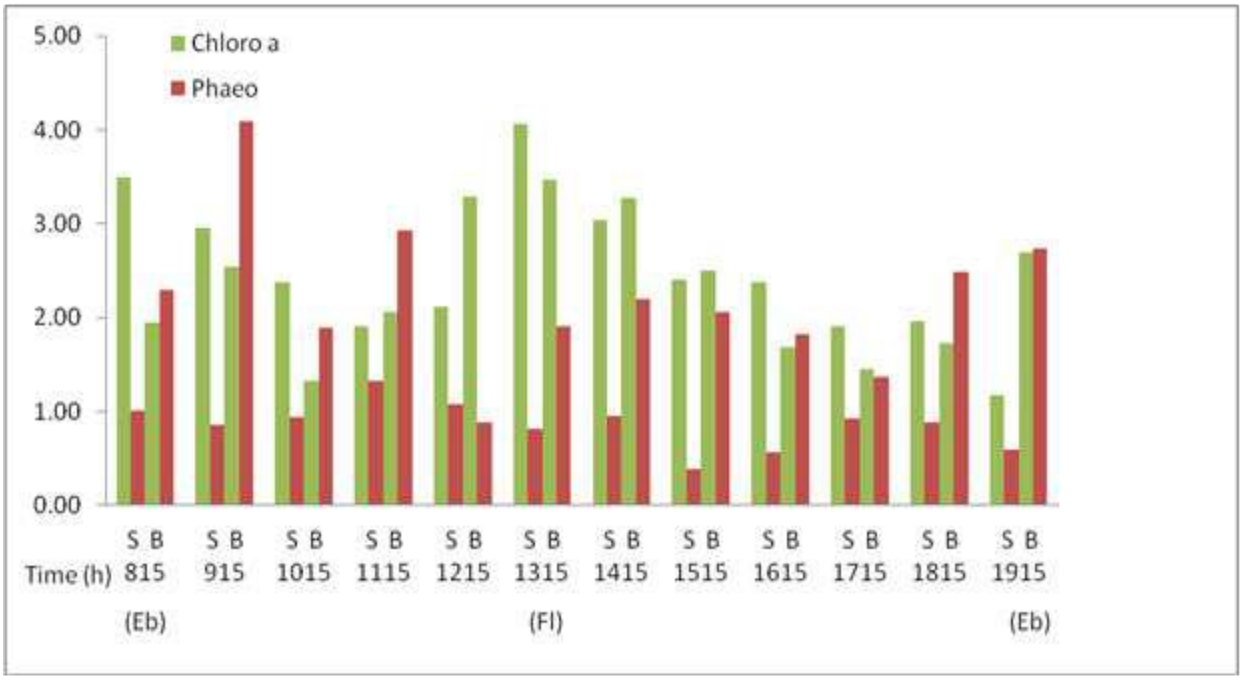


Figure 4.9.6: Temporal Variation of Phytopigments at station BY4 on 24.04.2016.

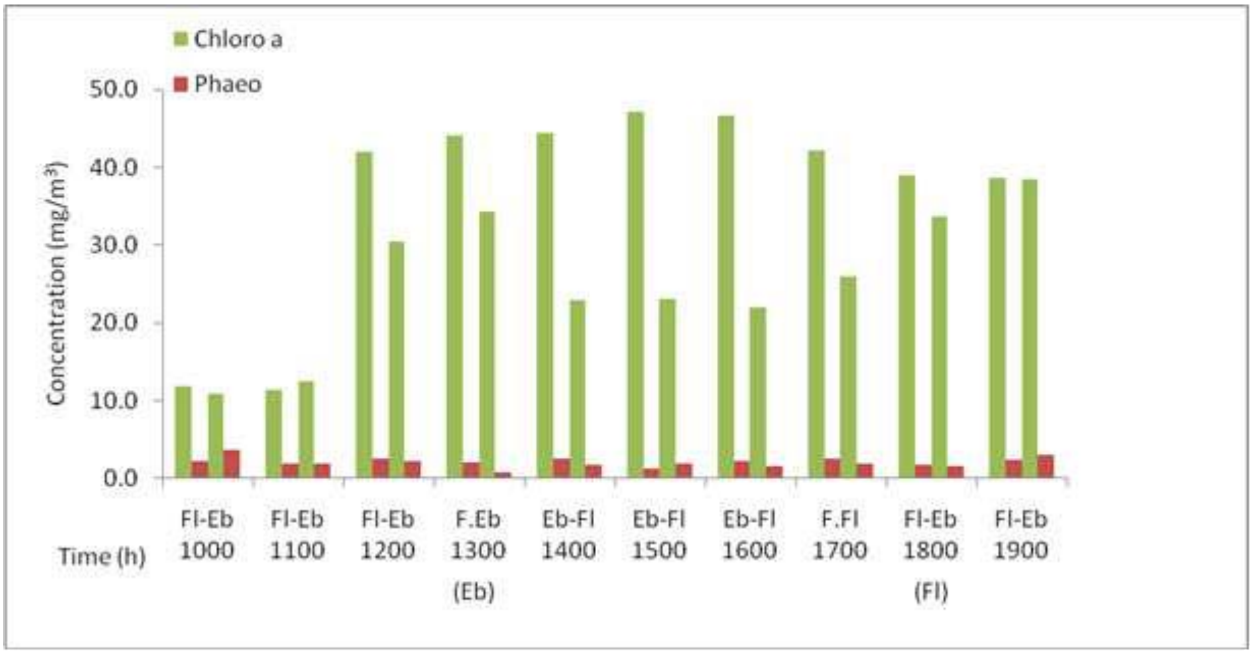


Figure 4.9.7: Temporal Variation of Phytopigments at station BY6 on 03.12.2015.

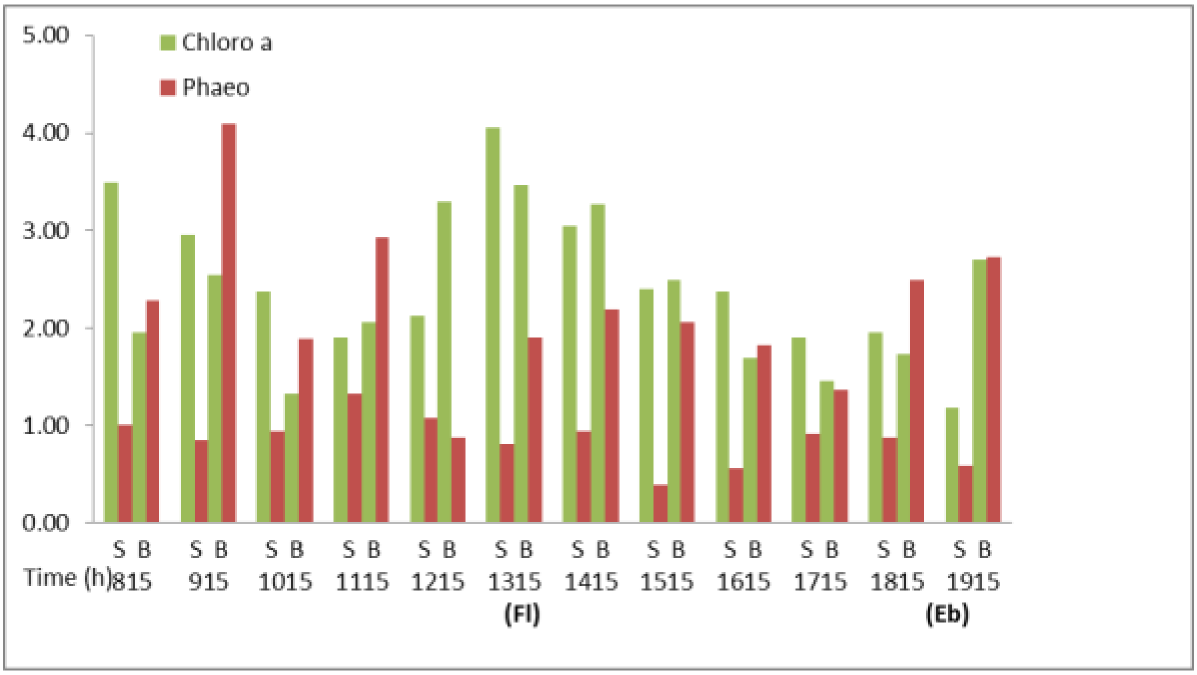


Figure 4.9.8: Temporal Variation of Phytopigments at station BY6 on 23.04.2016.

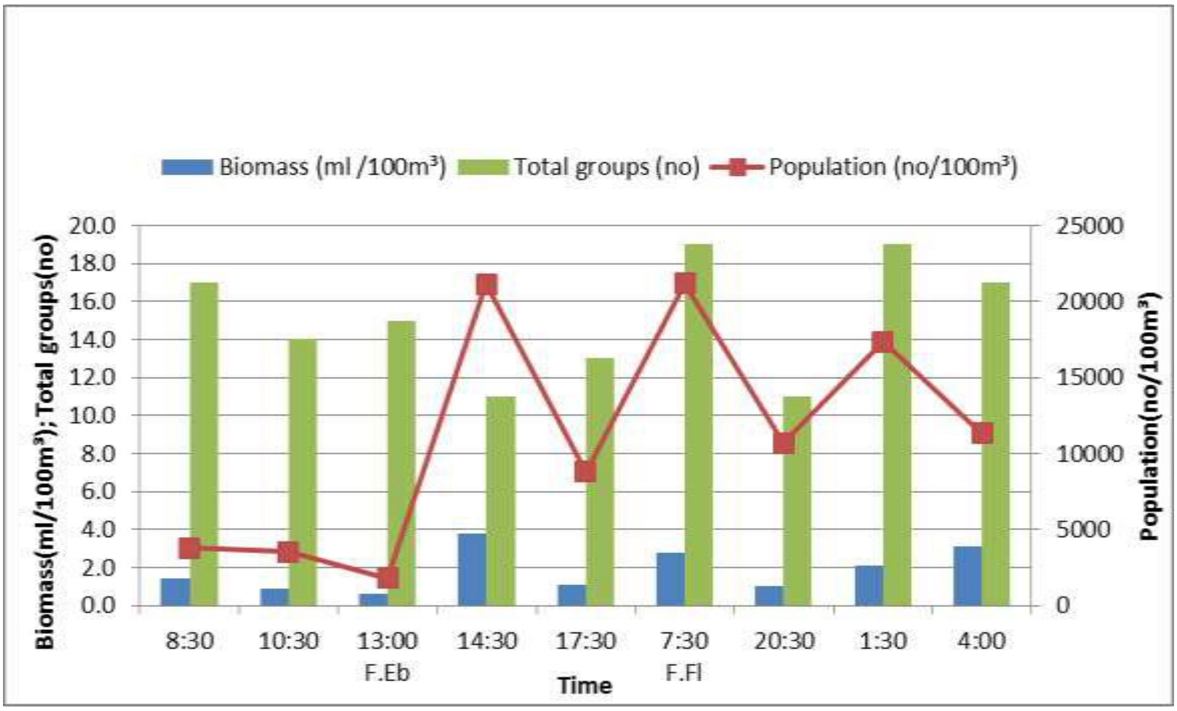


Figure 4.9.9: Temporal Variation of mesozooplankton at station BY4 on 04.12.2015

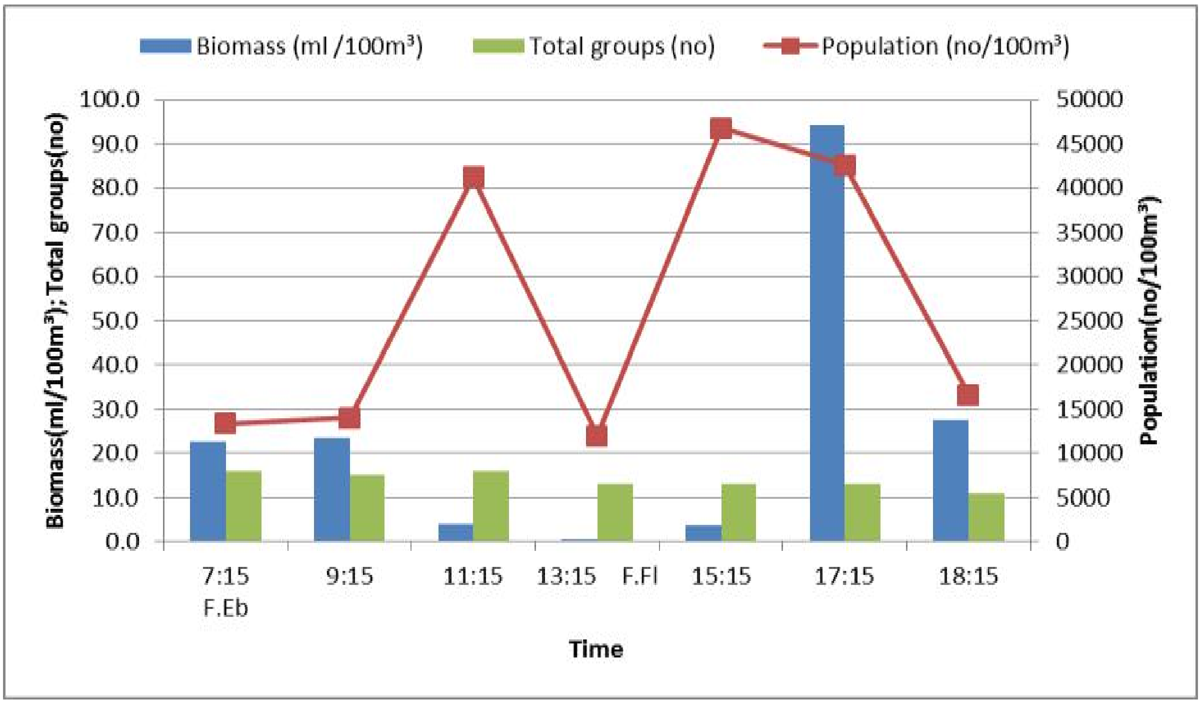


Figure 4.9.10: Temporal Variation of mesozooplankton at station BY4 on 24.04.2016

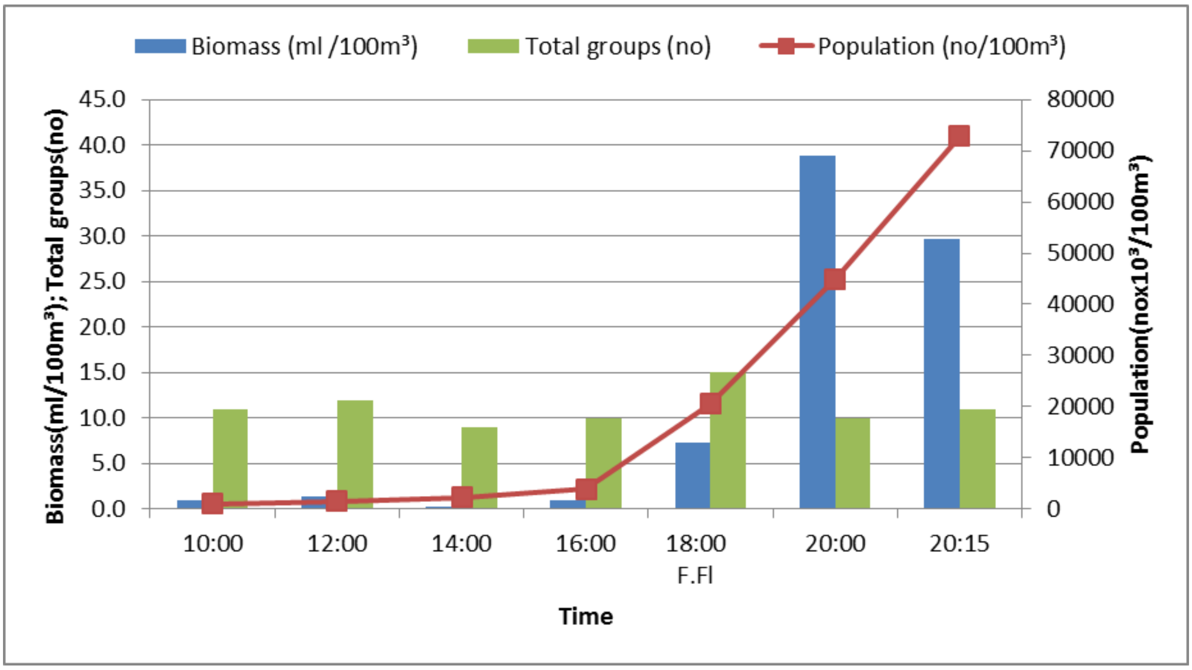


Figure 4.9.11: Temporal Variation of mesozooplankton at station BY6 on 03.12.2015

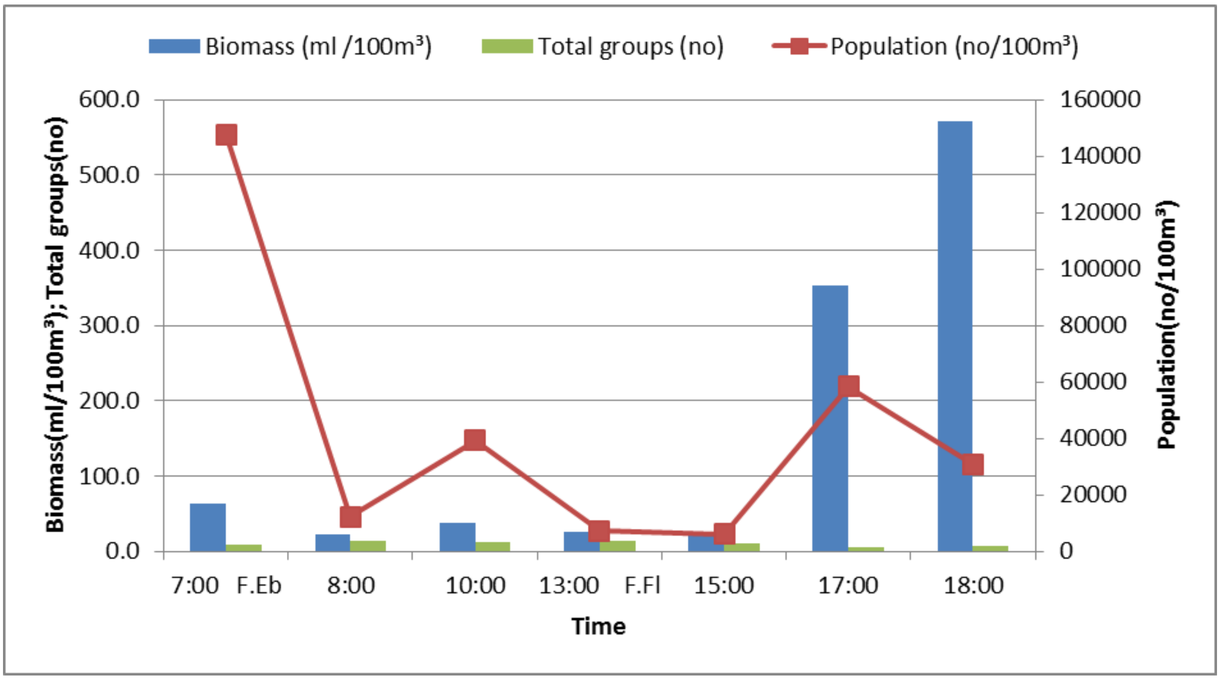


Figure 4.9.12: Temporal Variation of mesozooplankton at station BY6 on 23.04.2016

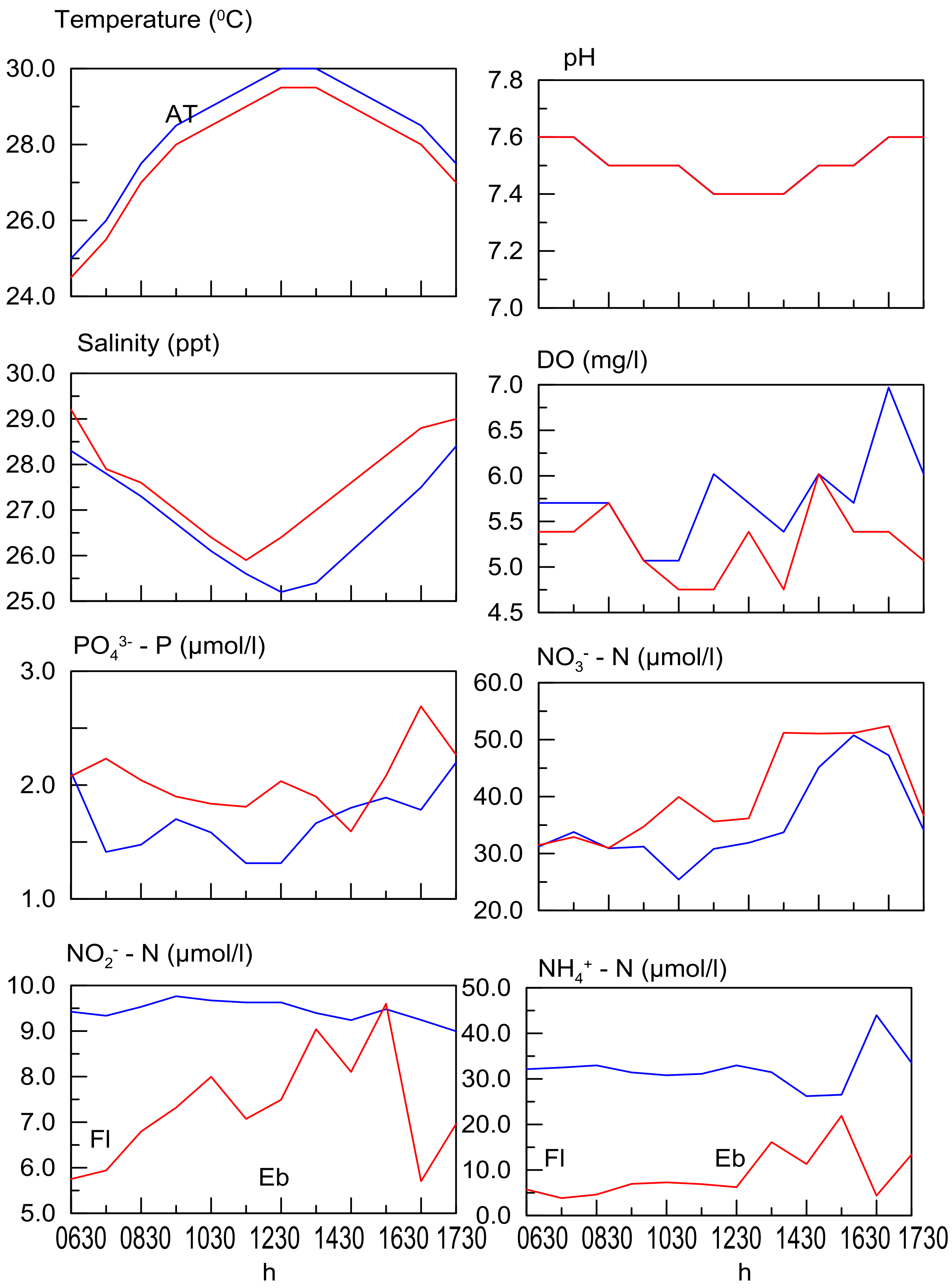


Figure 4.10.1: Temporal Variation of water quality parameters at PT4 (——— S) & (——— B) on 4th Dec 2015

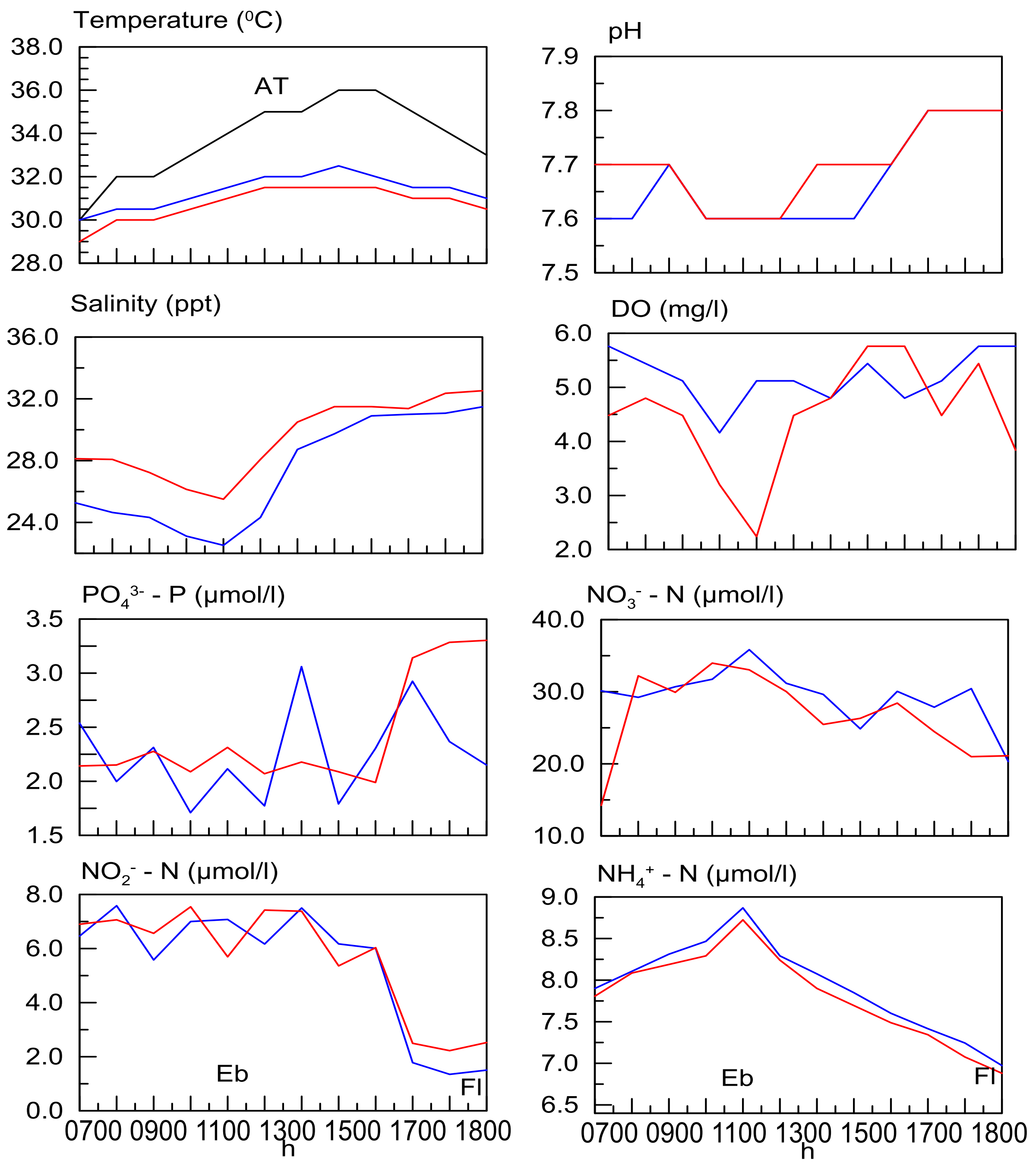


Figure 4.10.2: Temporal Variation of water quality parameters at PT4 (S) & (B) on 14th April 2016

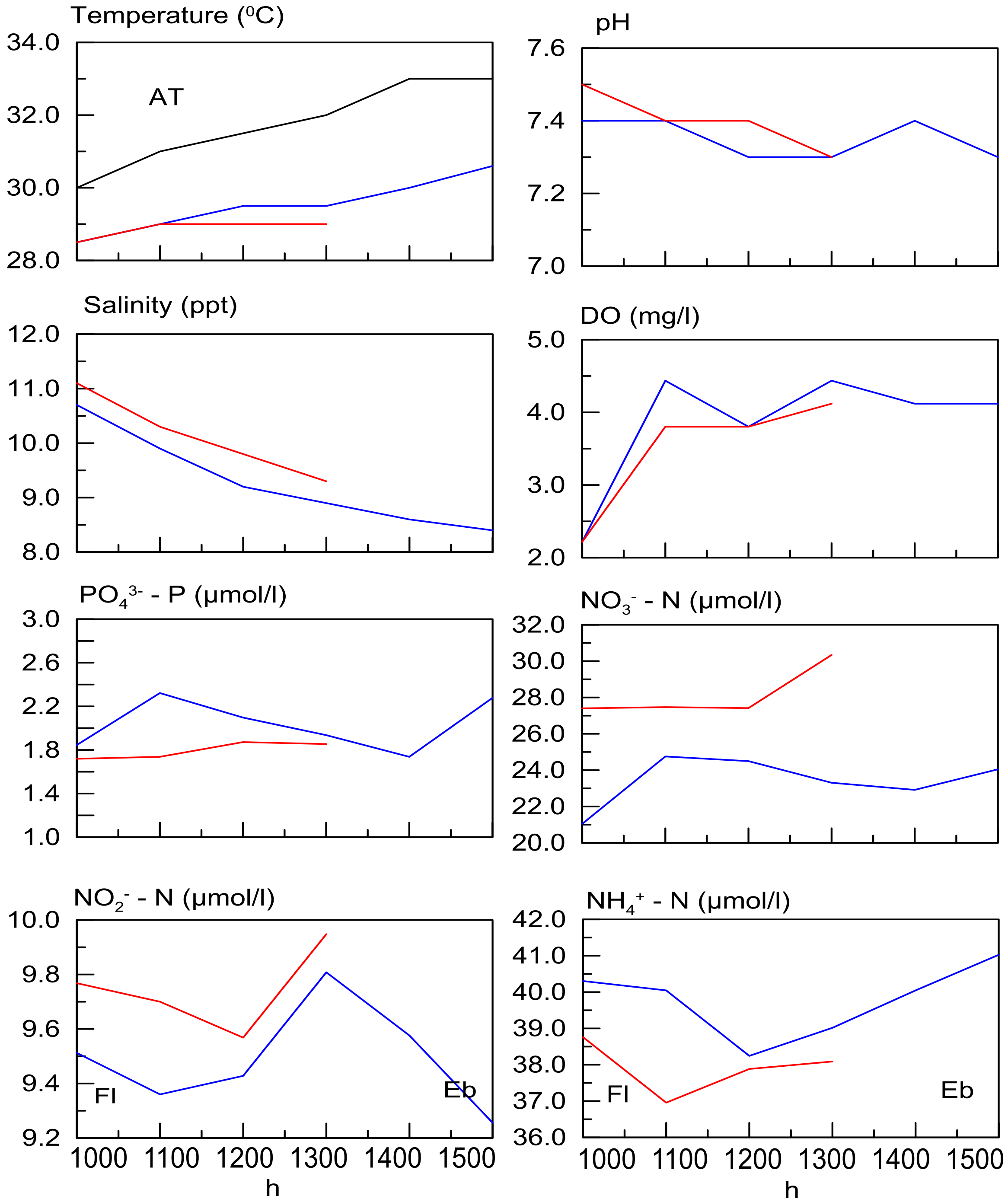


Figure 4.10.3: Temporal Variation of water quality parameters at PT6 (S) & (B) on 7th Dec 2015

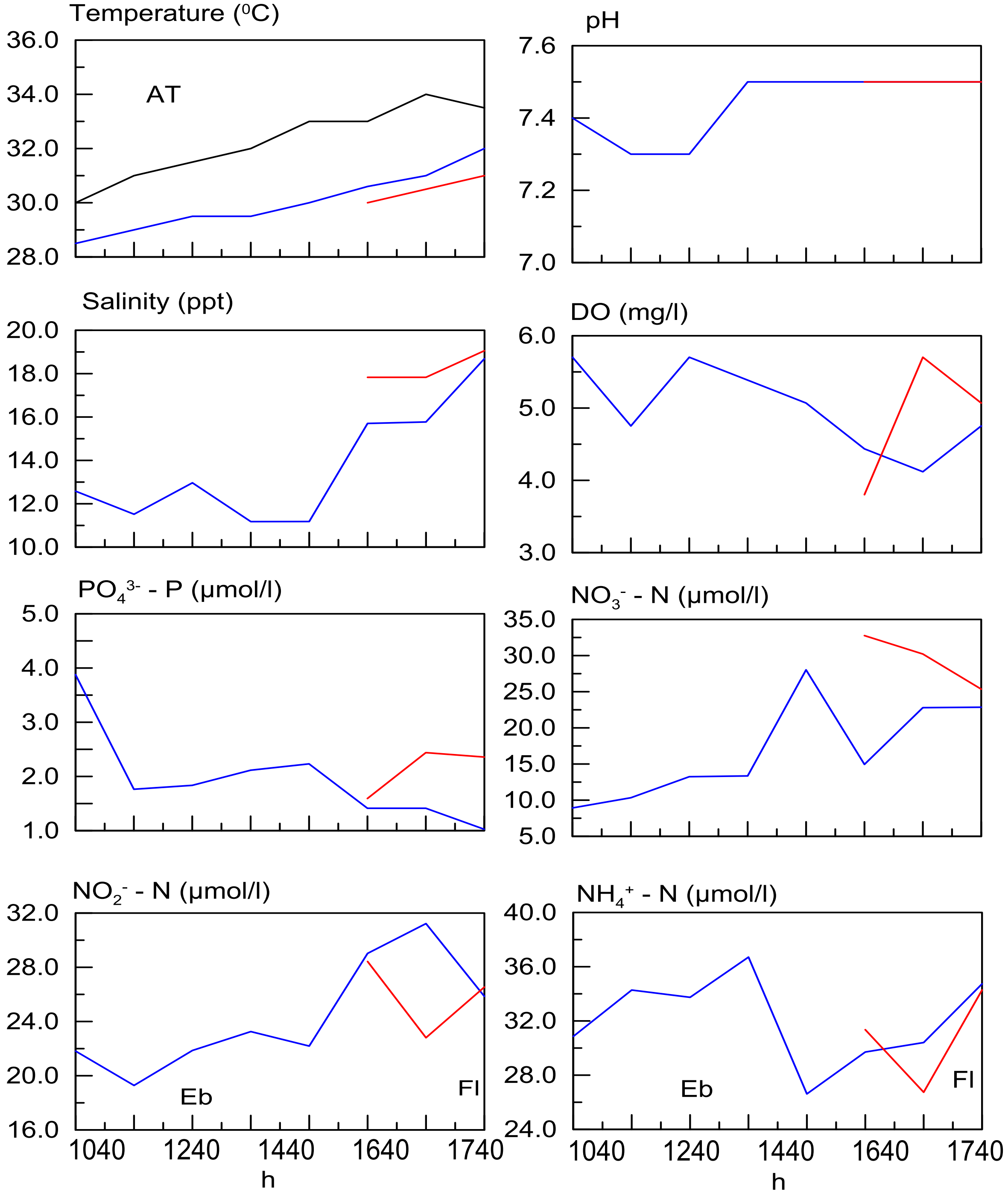


Figure 4.10.4: Temporal Variation of water quality parameters at PT6 (——— S) & (——— B) on 15th April 2016

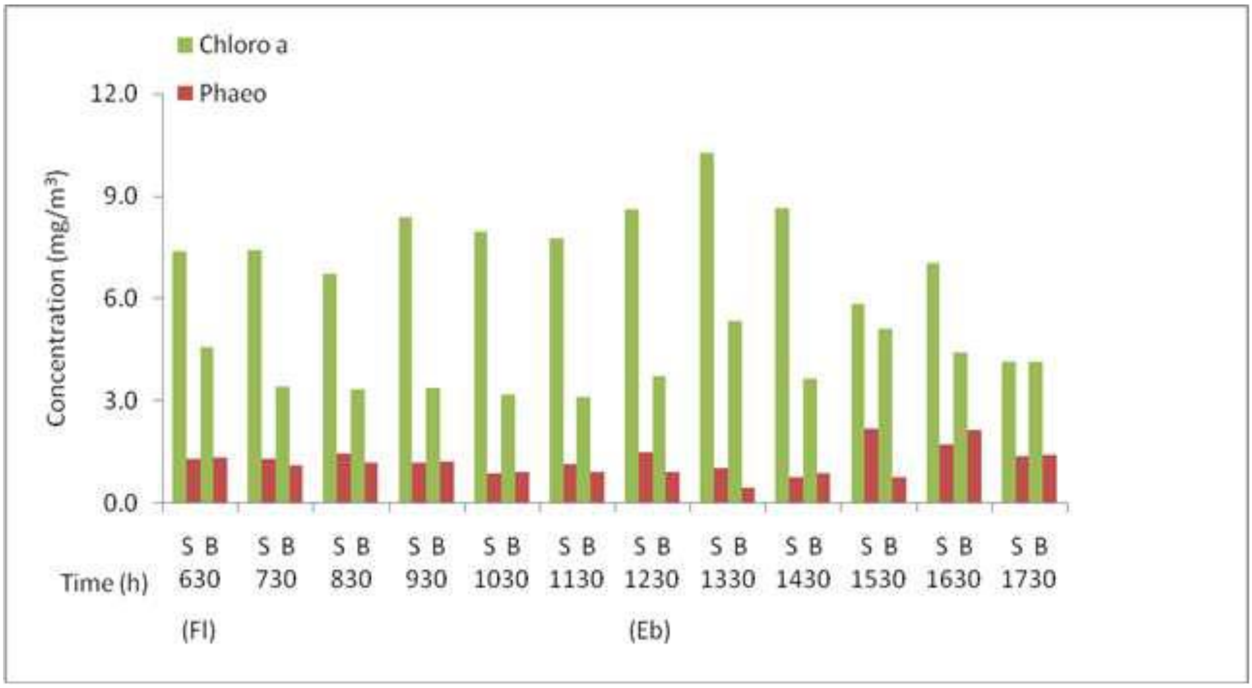


Figure 4.10.5: Temporal Variation of Phytopigments at station PT4 on 04.12.2015.

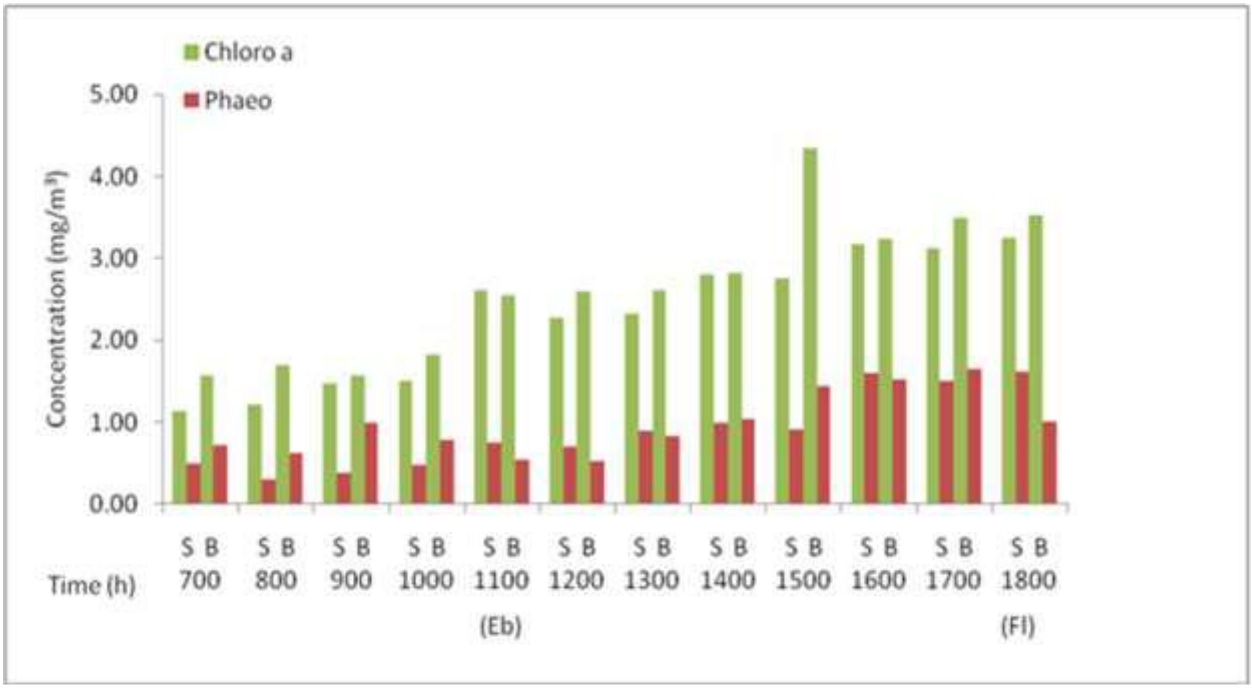


Figure 4.10.6: Temporal Variation of Phytopigments at station PT4 on 14.04.2016.

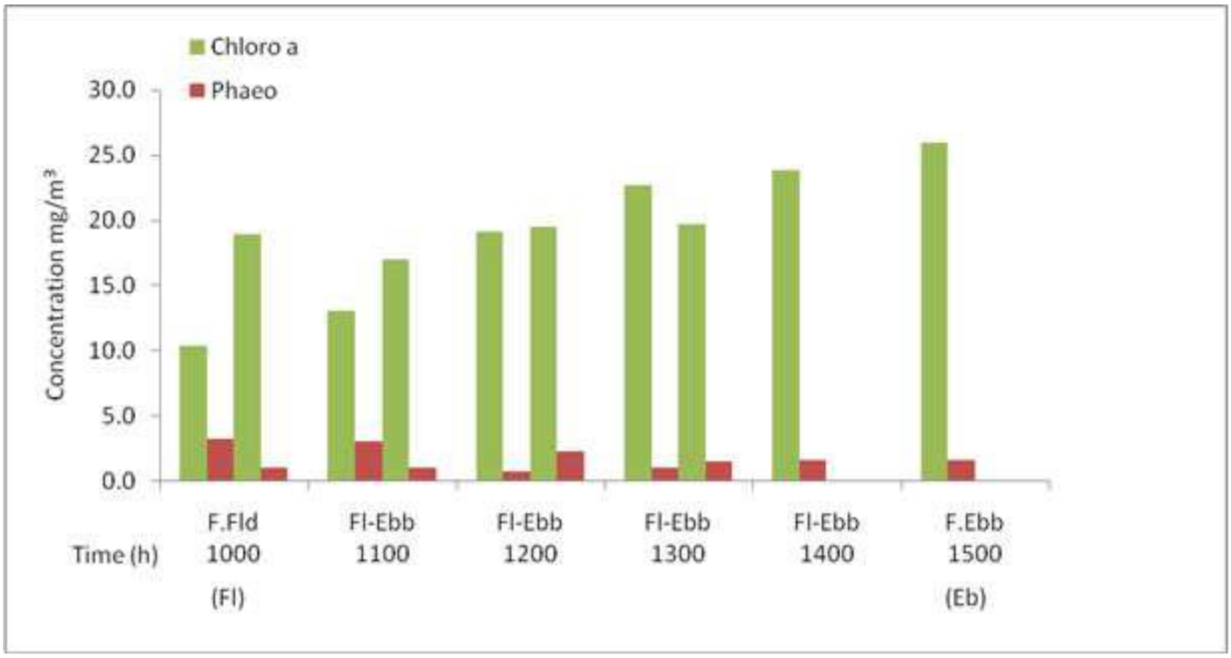


Figure 4.10.7: Temporal variation of phytopigments at station PT6 on 07.12.2015.

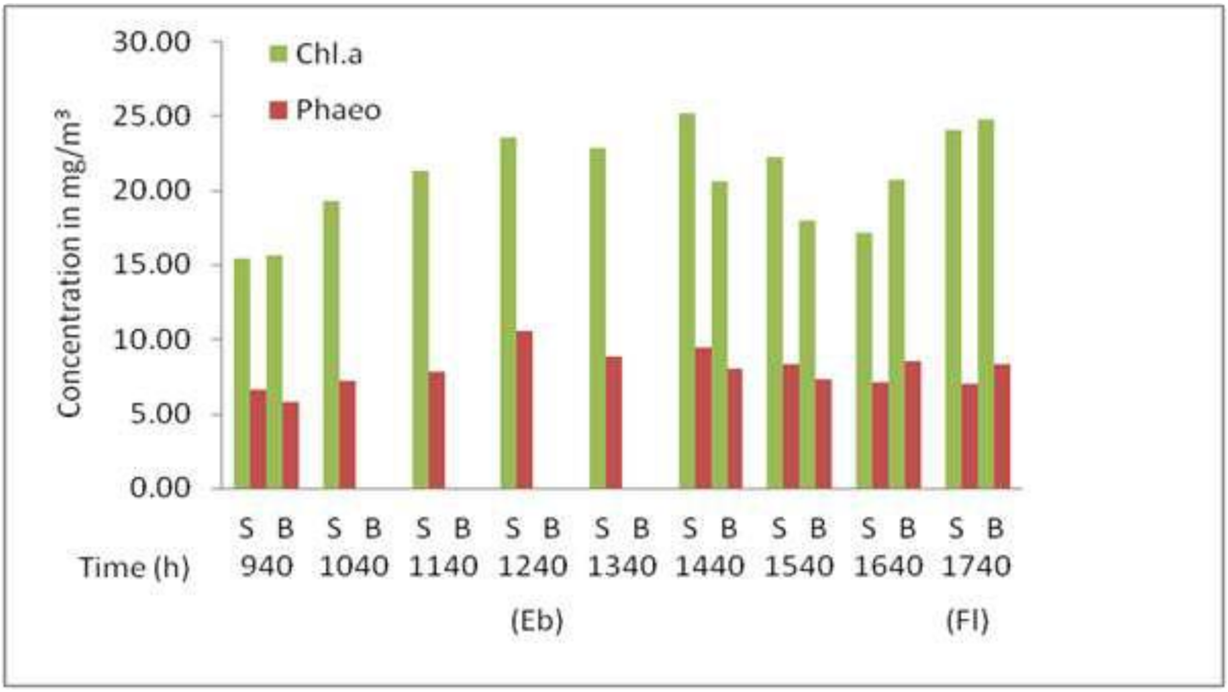


Figure 4.10.8: Temporal variation of phytopigment at station PT6 on 15.04.2016.

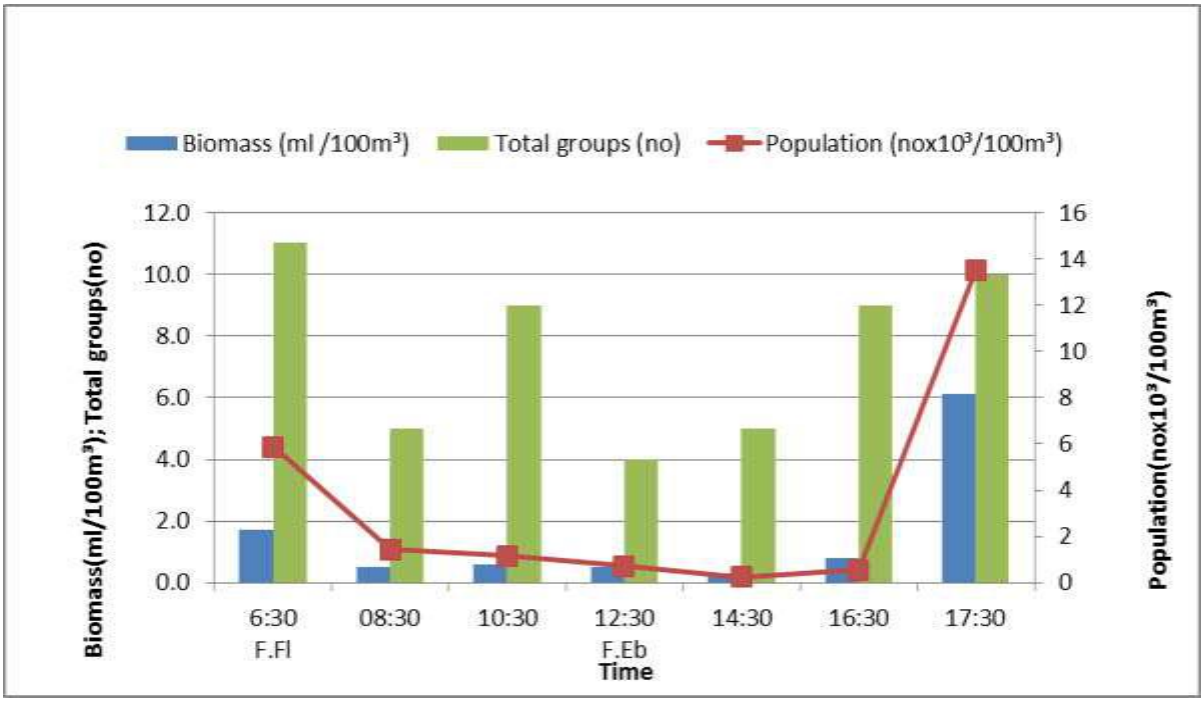


Figure 4.10.9: Temporal Variation of mesozooplankton at station PT4 on 04.12.2015

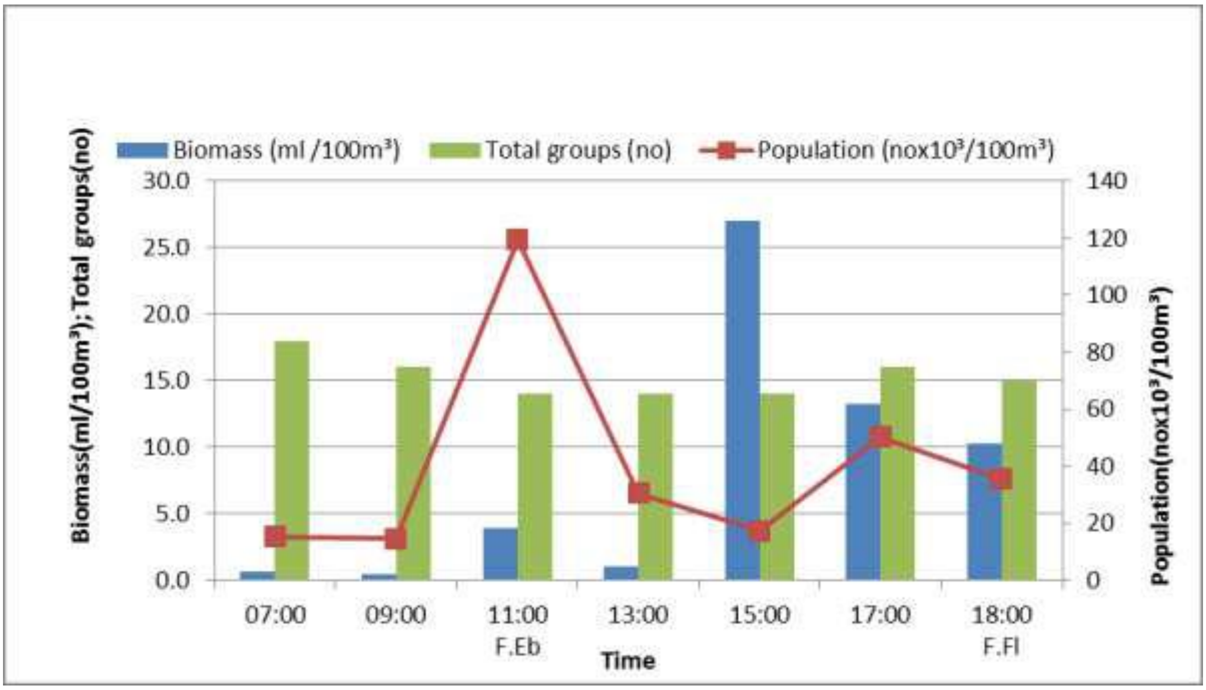


Figure 4.10.10: Temporal Variation of mesozooplankton at station PT4 on 14.04.2016

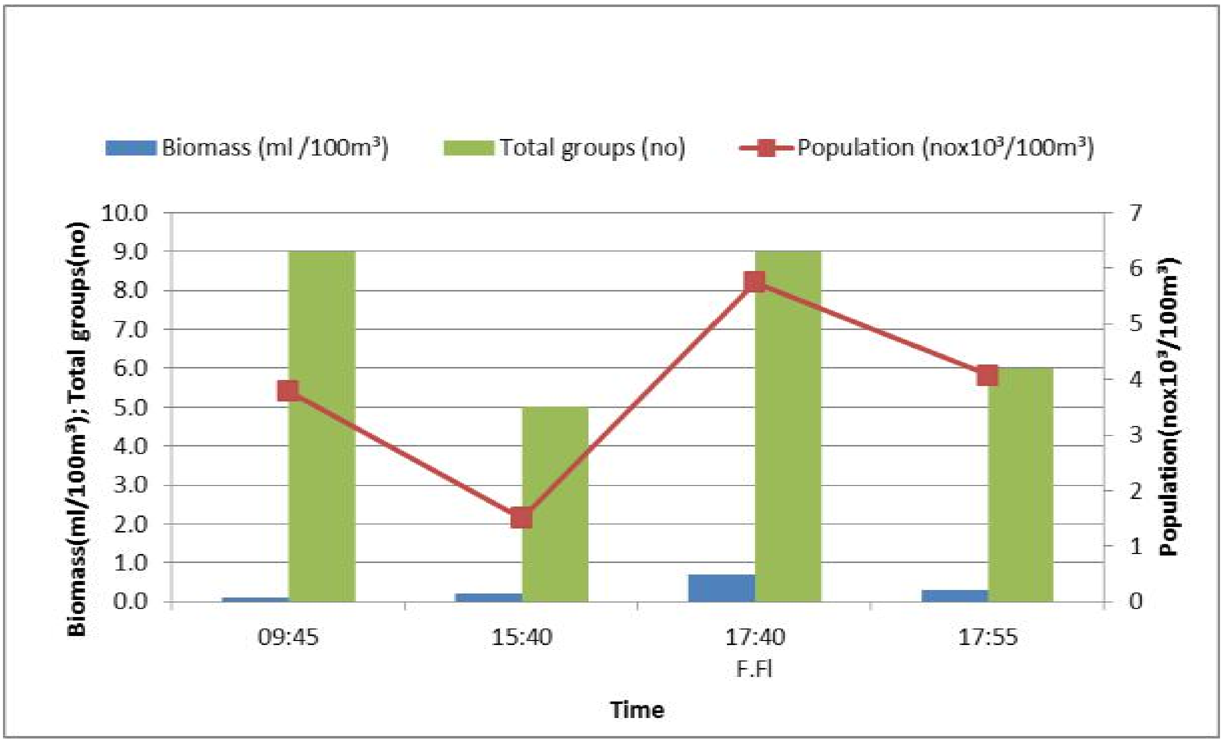


Figure 4.10.11: Temporal Variation of mesozooplankton station PT6 on 07.12.2015.

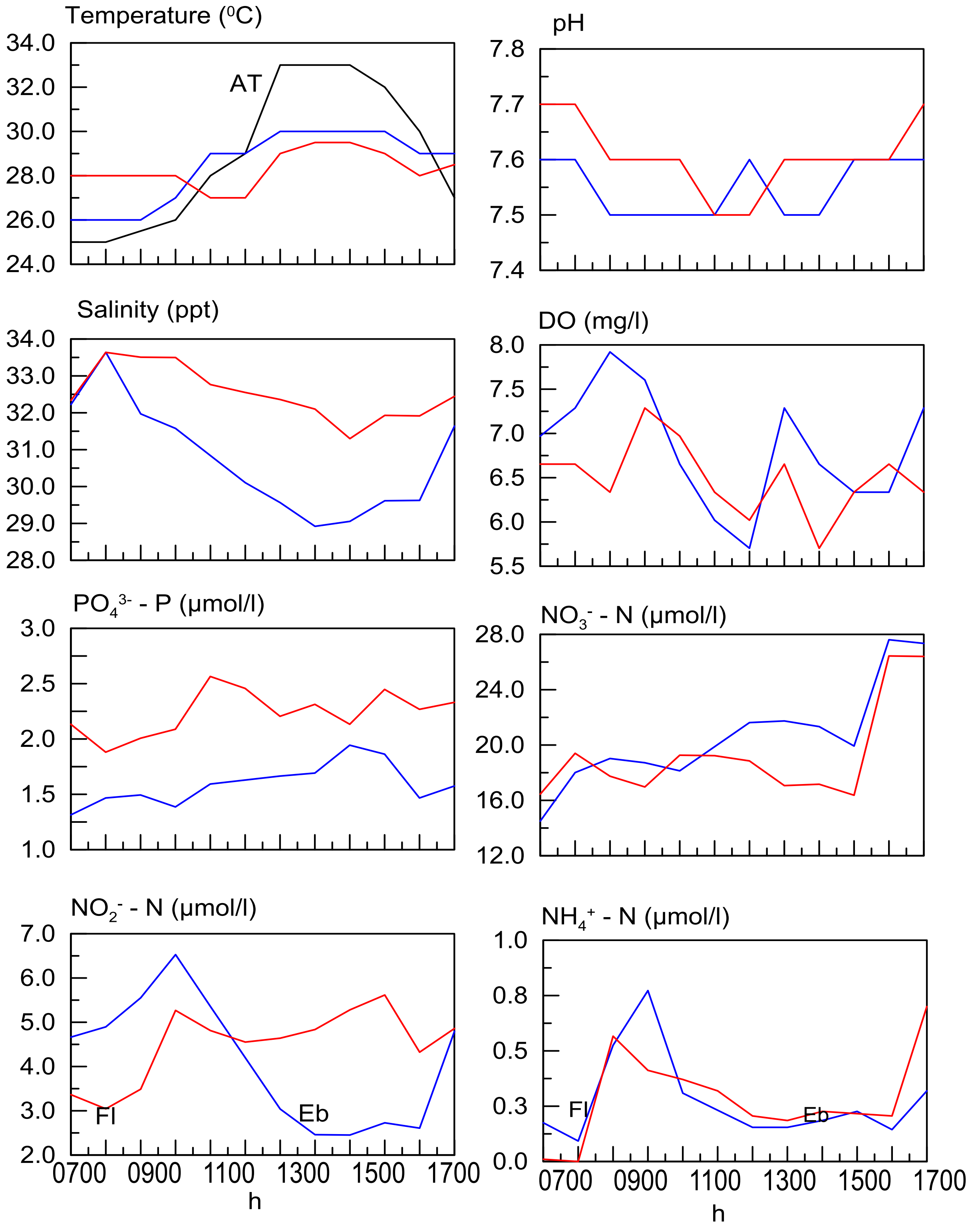


Figure 4.11.1: Temporal Variation of water quality parameters at AB4 (——— S) & (——— B) on 6th Dec 2015

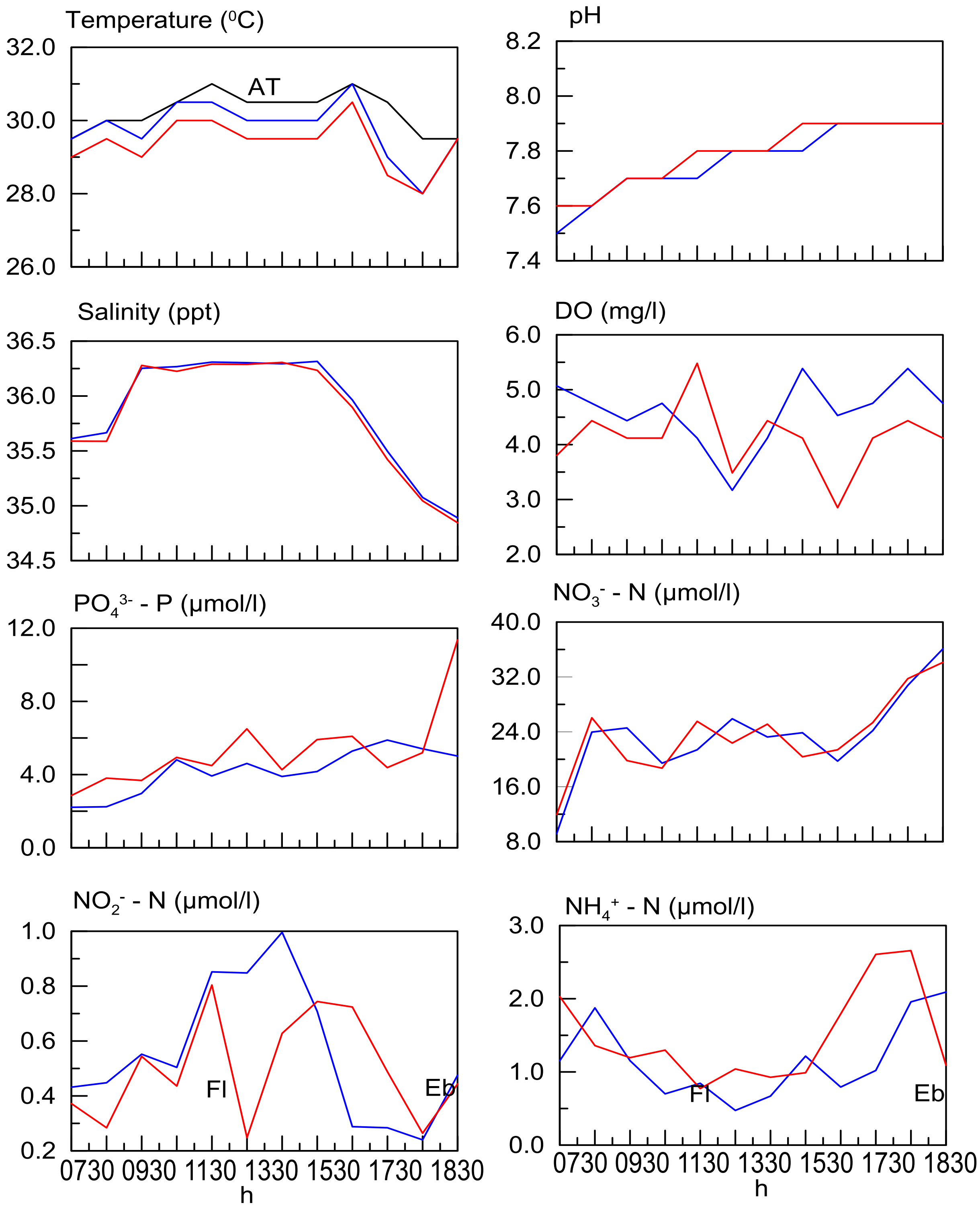


Figure 4.11.2: Temporal Variation of water quality parameters at AB4 (—— S) & (—— B) on 6th May 2016

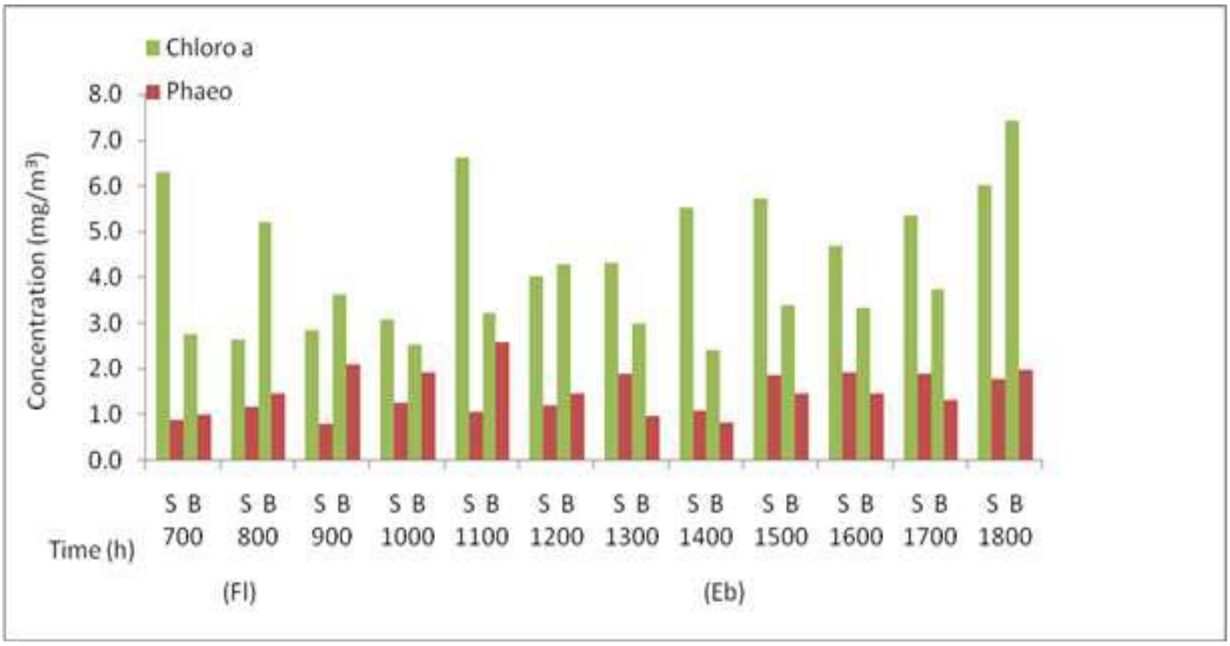


Figure 4.11.3: Temporal Variation of Phytopigments at station AB4 on 06.12.2015.

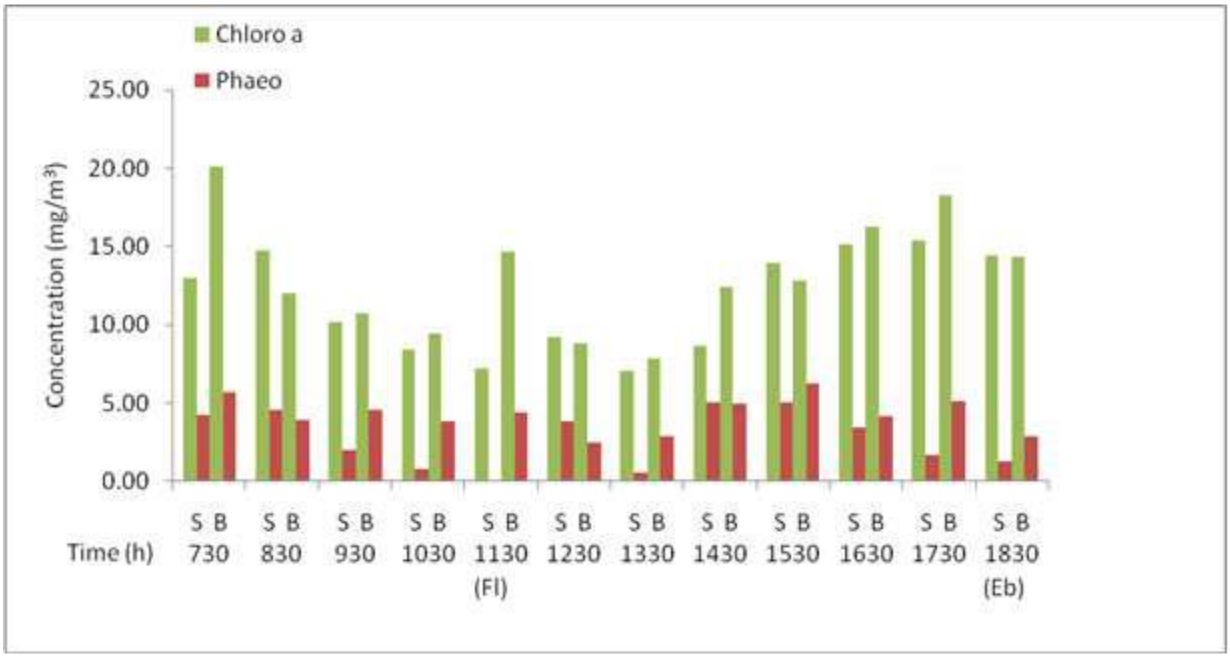


Figure 4.11.4: Temporal Variation of Phytopigments at station AB4 on 06.05.2016.

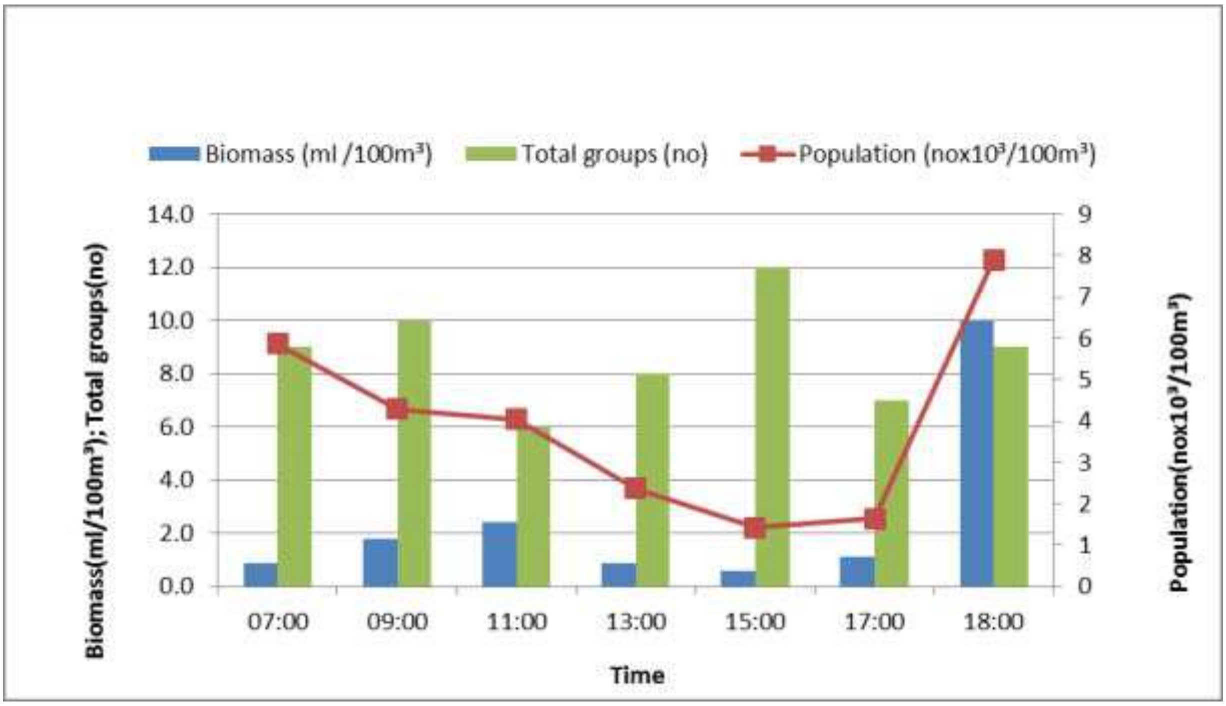


Figure 4.11.5: Temporal Variation of mesozooplankton at station AB4 on 06.12.2015.

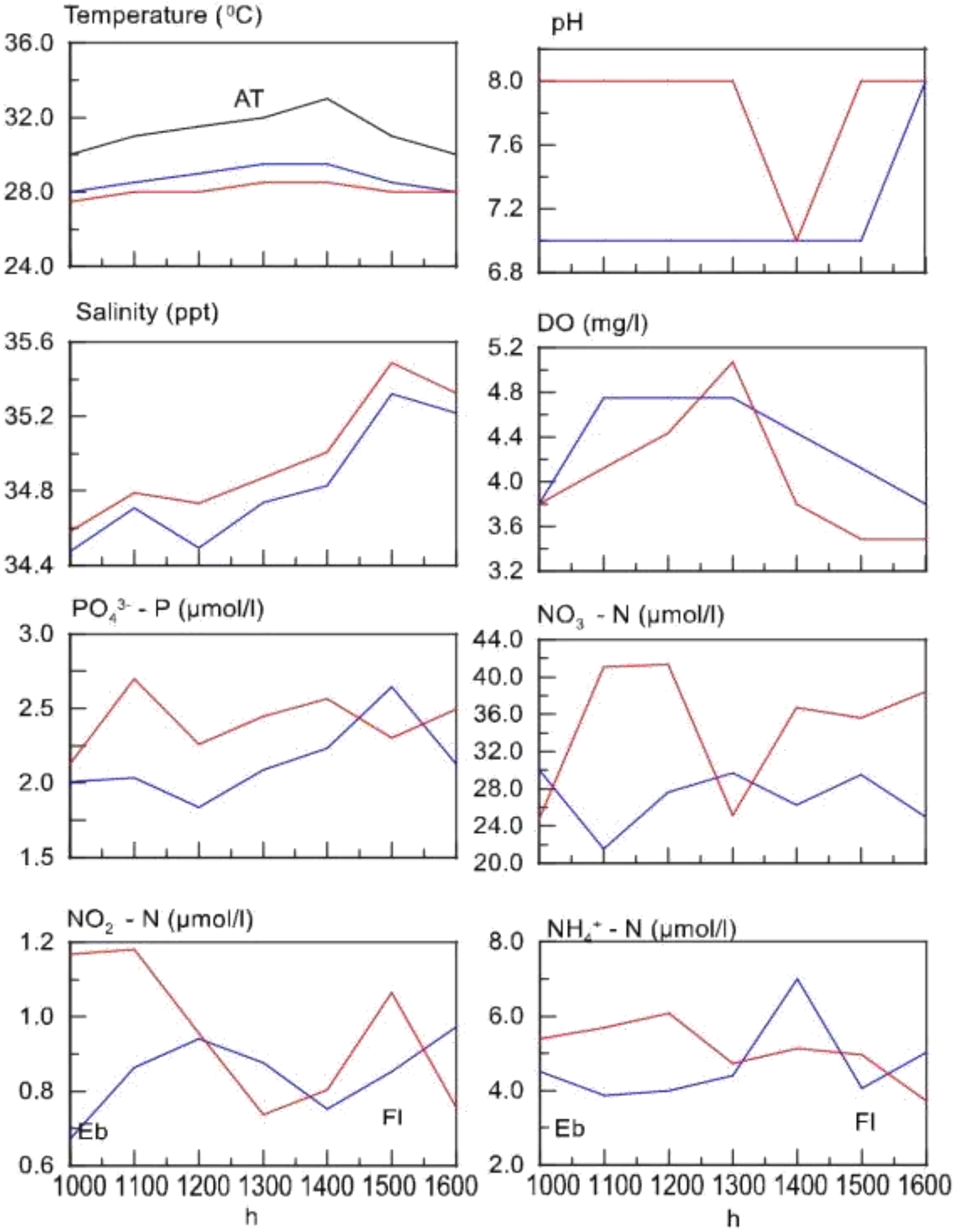


Figure 4.12.1: Temporal Variation of water quality parameters at Thal DP (——— S) & (——— B) on 15th Dec 2015

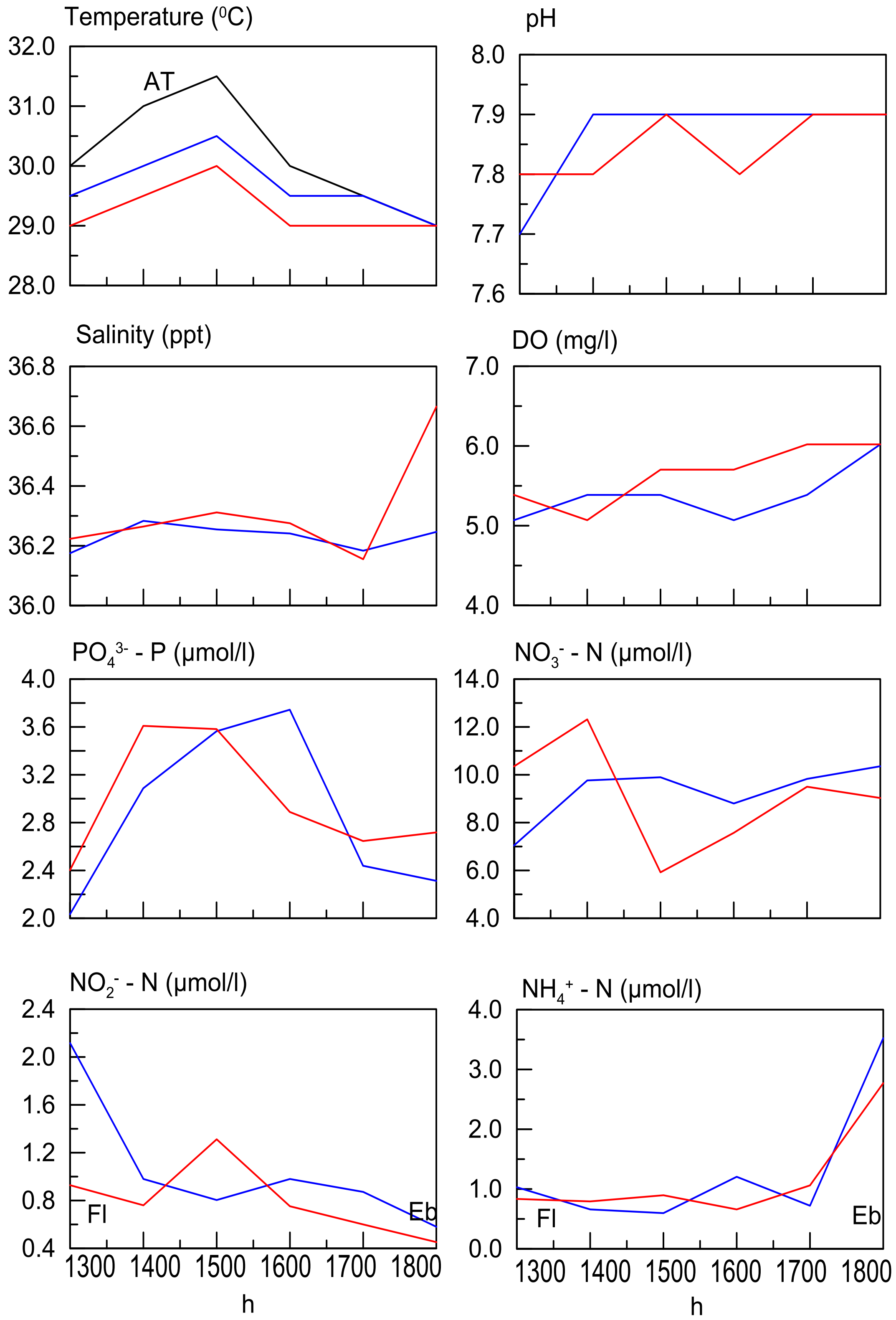


Figure 4.12.2: Temporal Variation of water quality parameters at Thal DP (——— S) & (——— B) on 9th April 2016

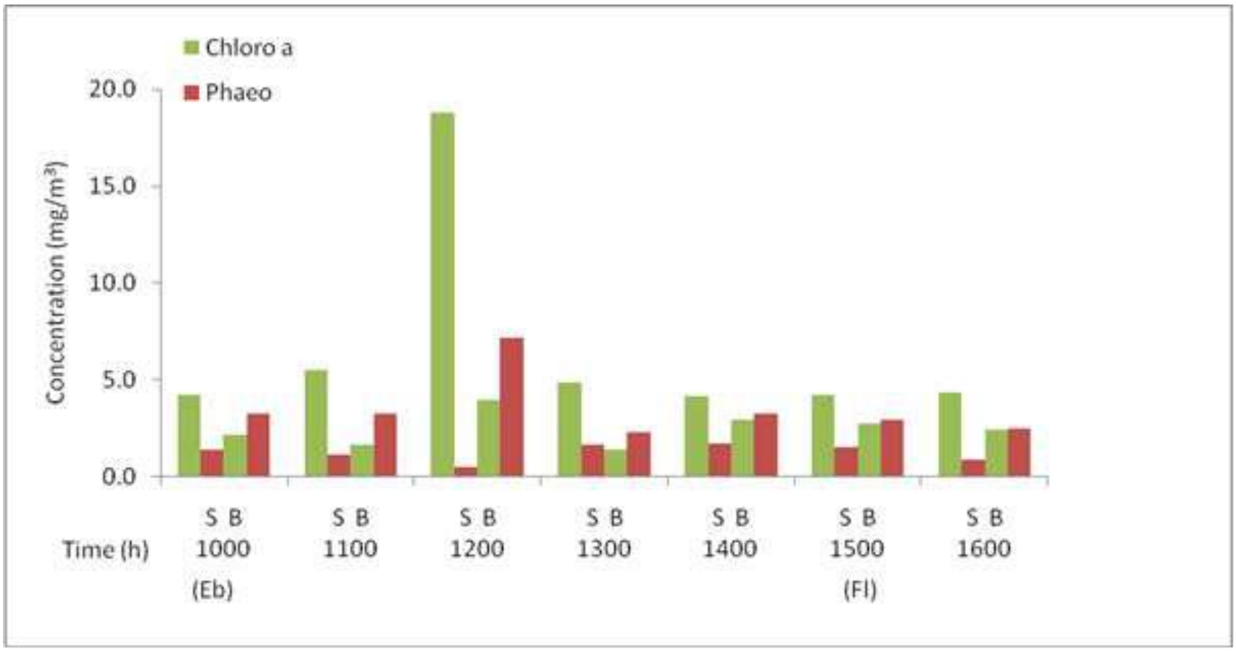


Figure 4.12.3: Temporal Variation of Phytopigments at Thal DP on 15.12.2015.

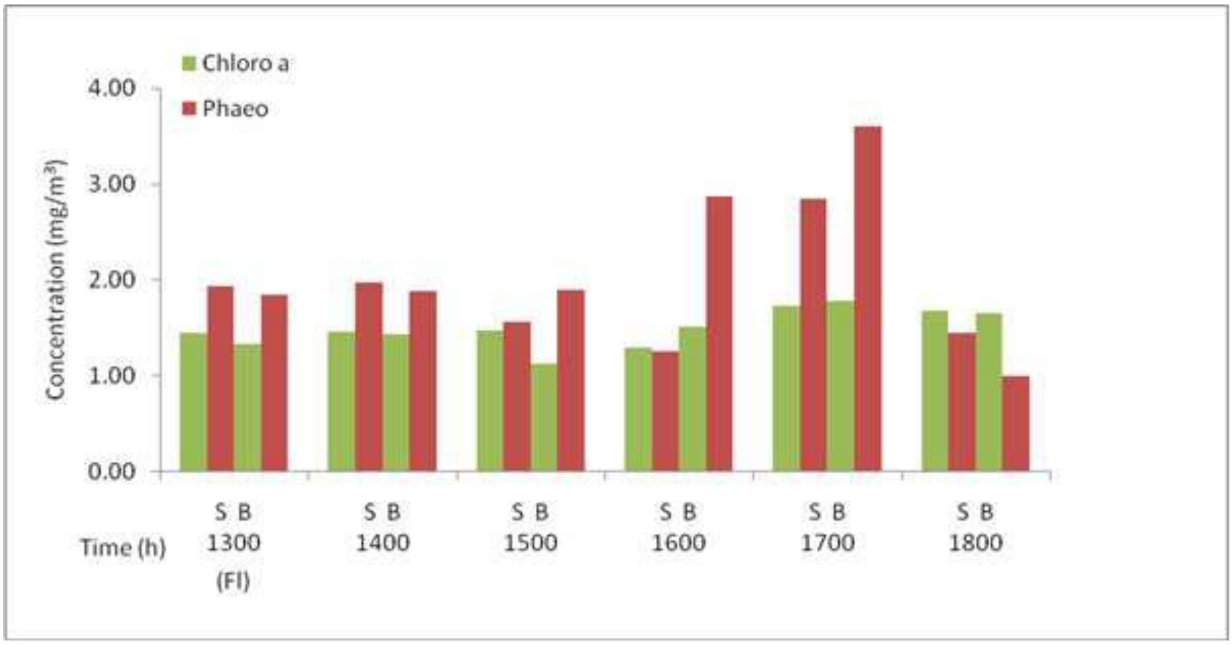


Figure 4.12.4: Temporal Variation of Phytopigments at Thal DP on 09.04.2016.

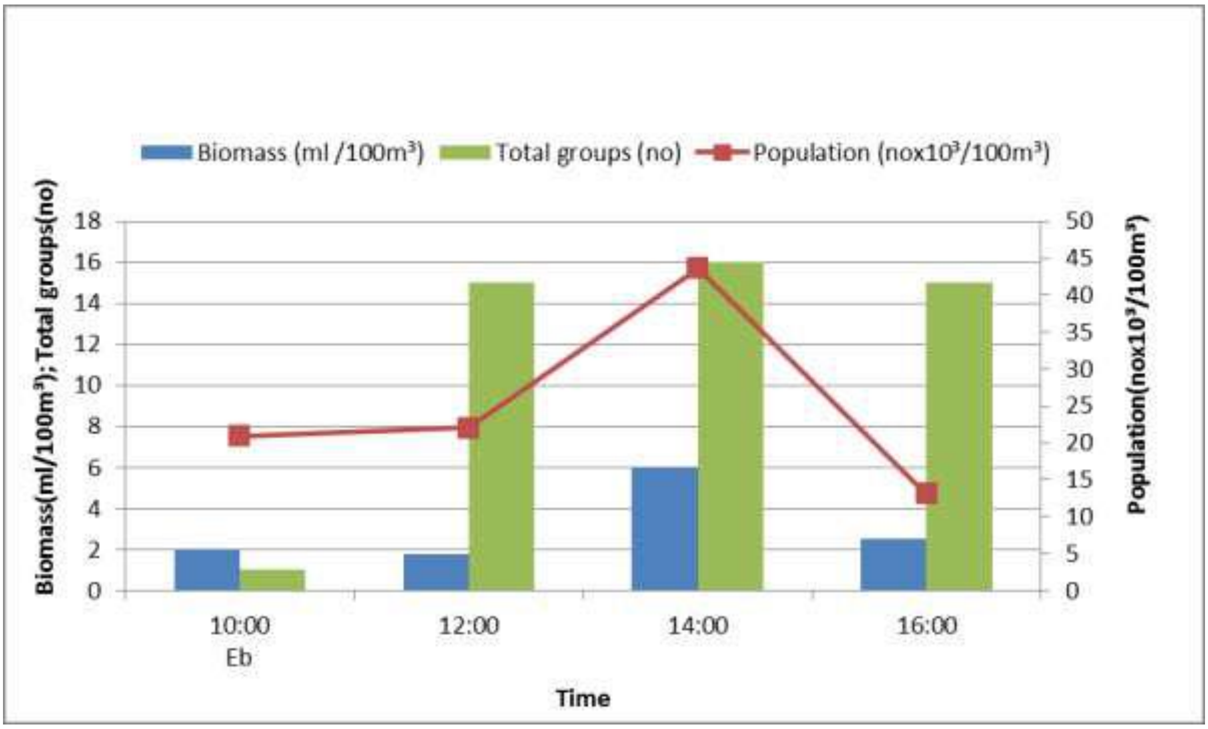


Figure 4.12.5: Temporal Variation of mesozooplankton at Thal DP on 15.12.2015.

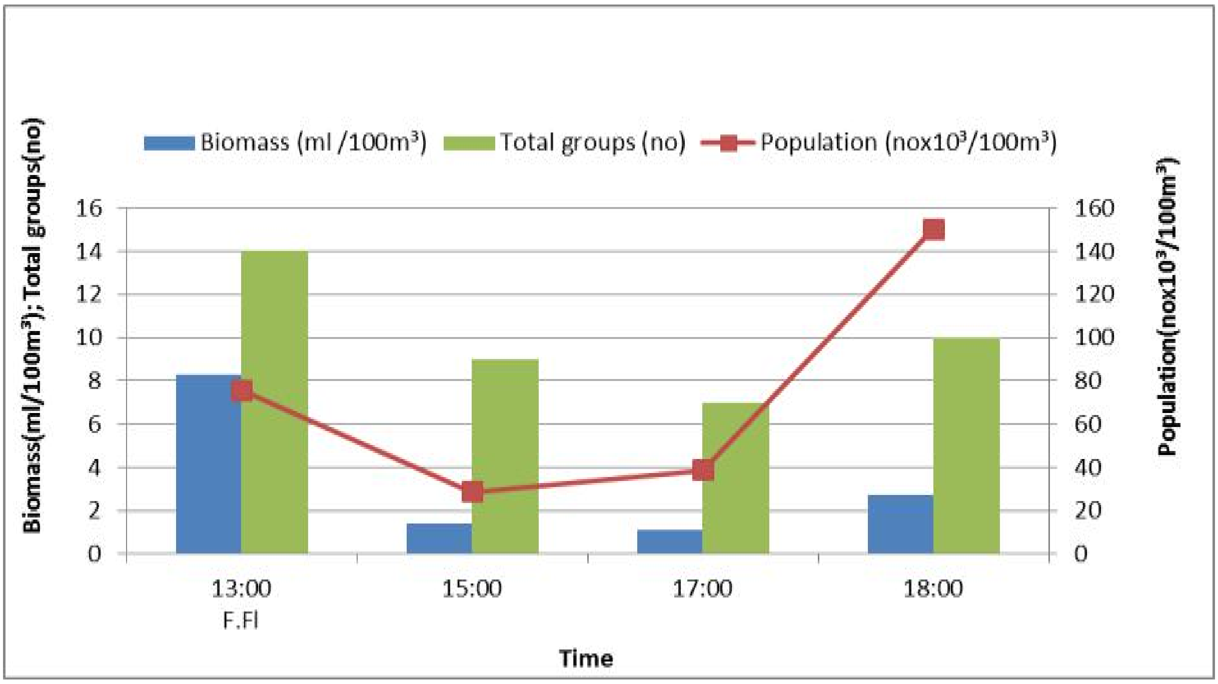


Figure 4.12.6: Temporal Variation of mesozooplankton at Thal DP on 09.04.2016.

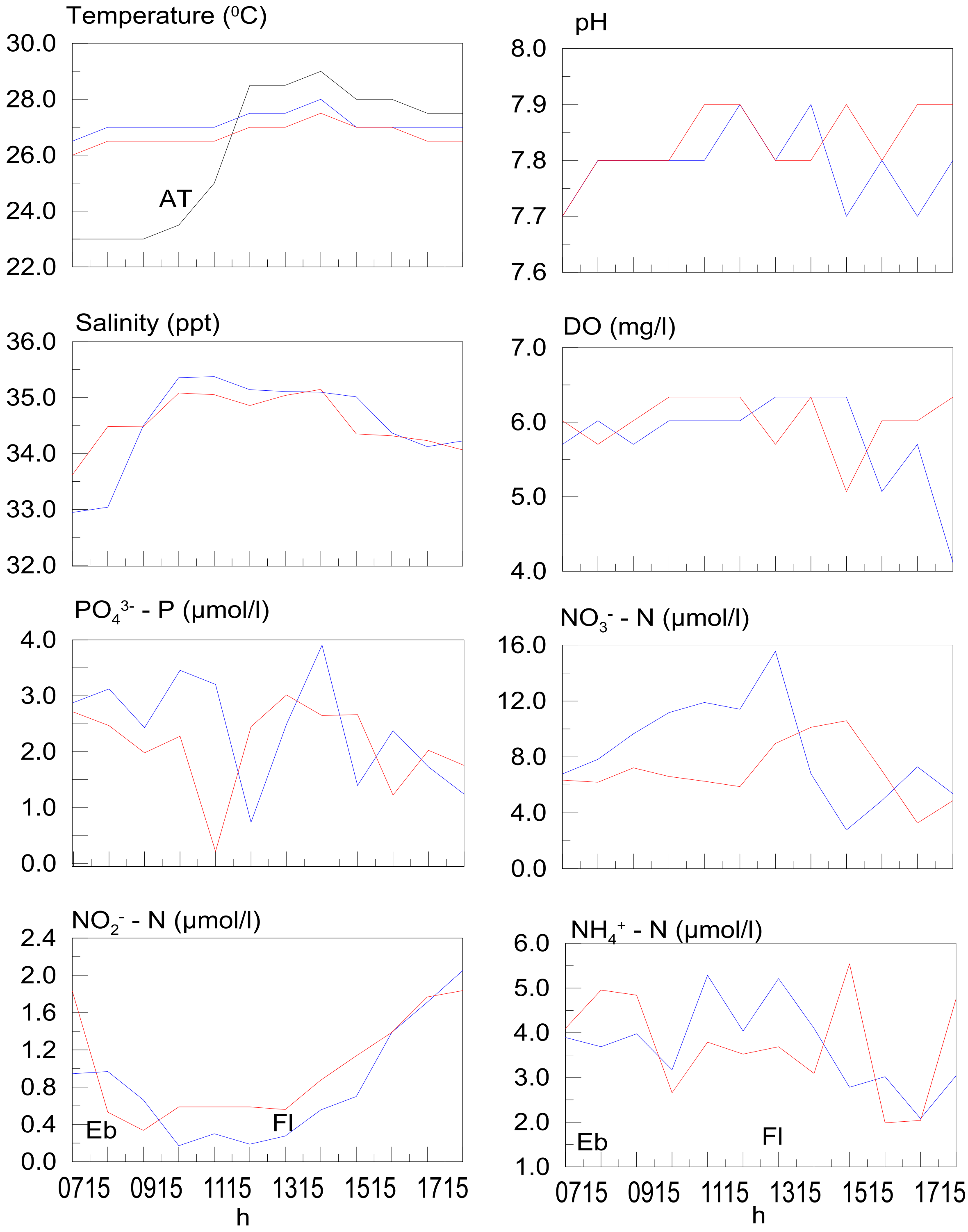


Figure 4.13.1: Temporal Variation of water quality parameters at K4 (——— S) & (——— B) on 14th Dec 2015

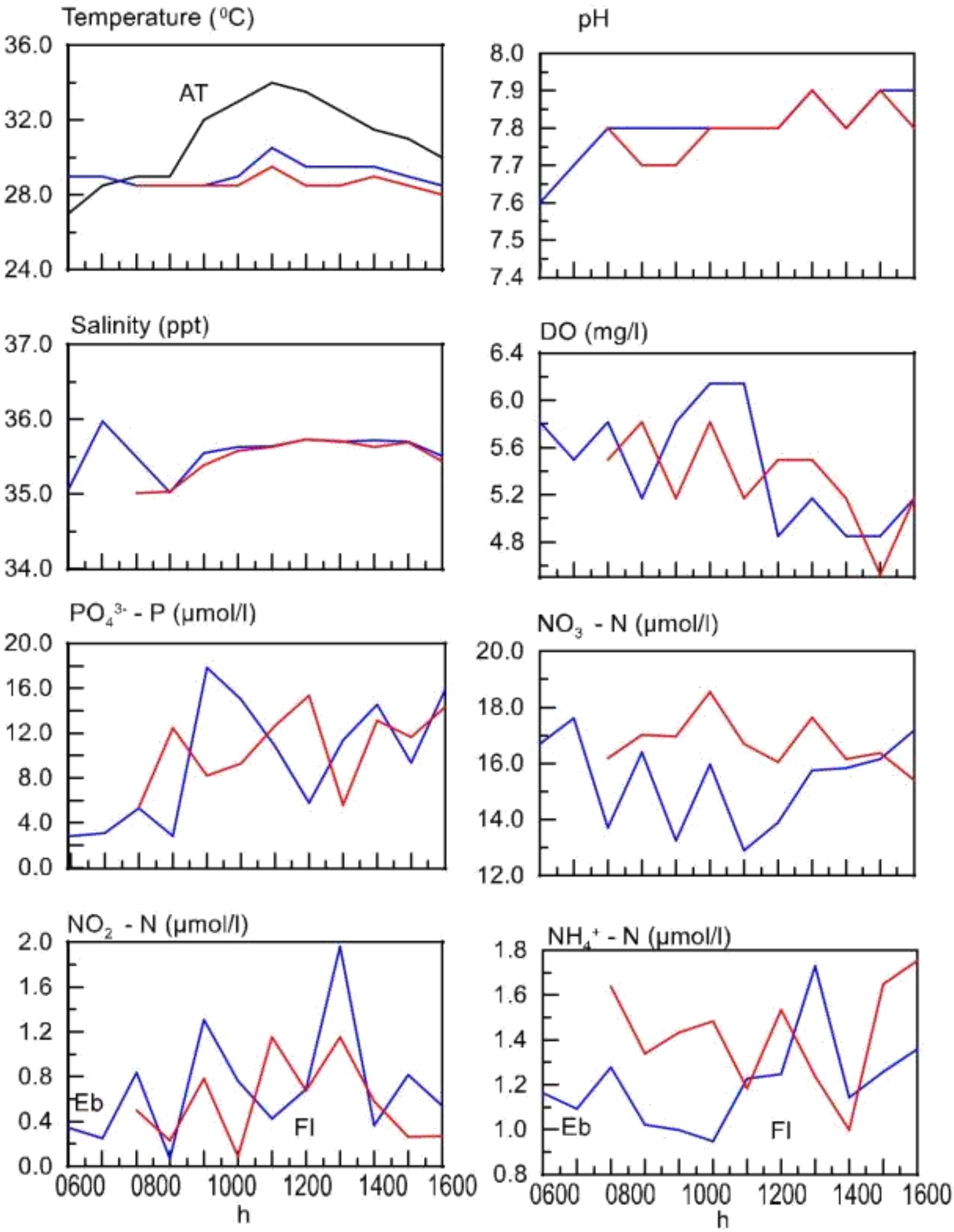


Figure 4.13.2: Temporal Variation of water quality parameters at K4 (——— S) & (——— B) on 8th April 2016

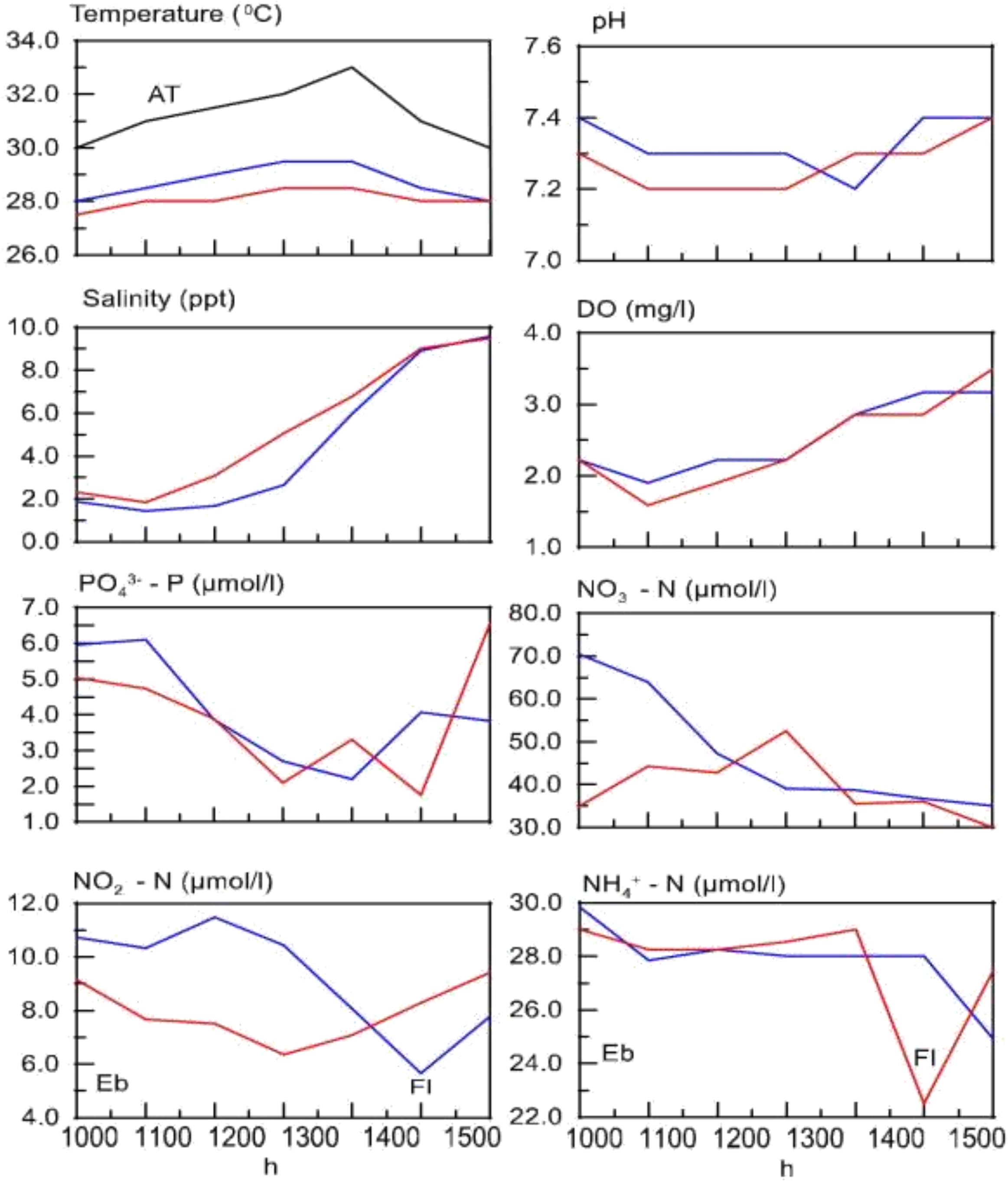


Figure 4.13.3: Temporal Variation of water quality parameters at K8 (——— S) & (——— B) on 17th Dec 2015

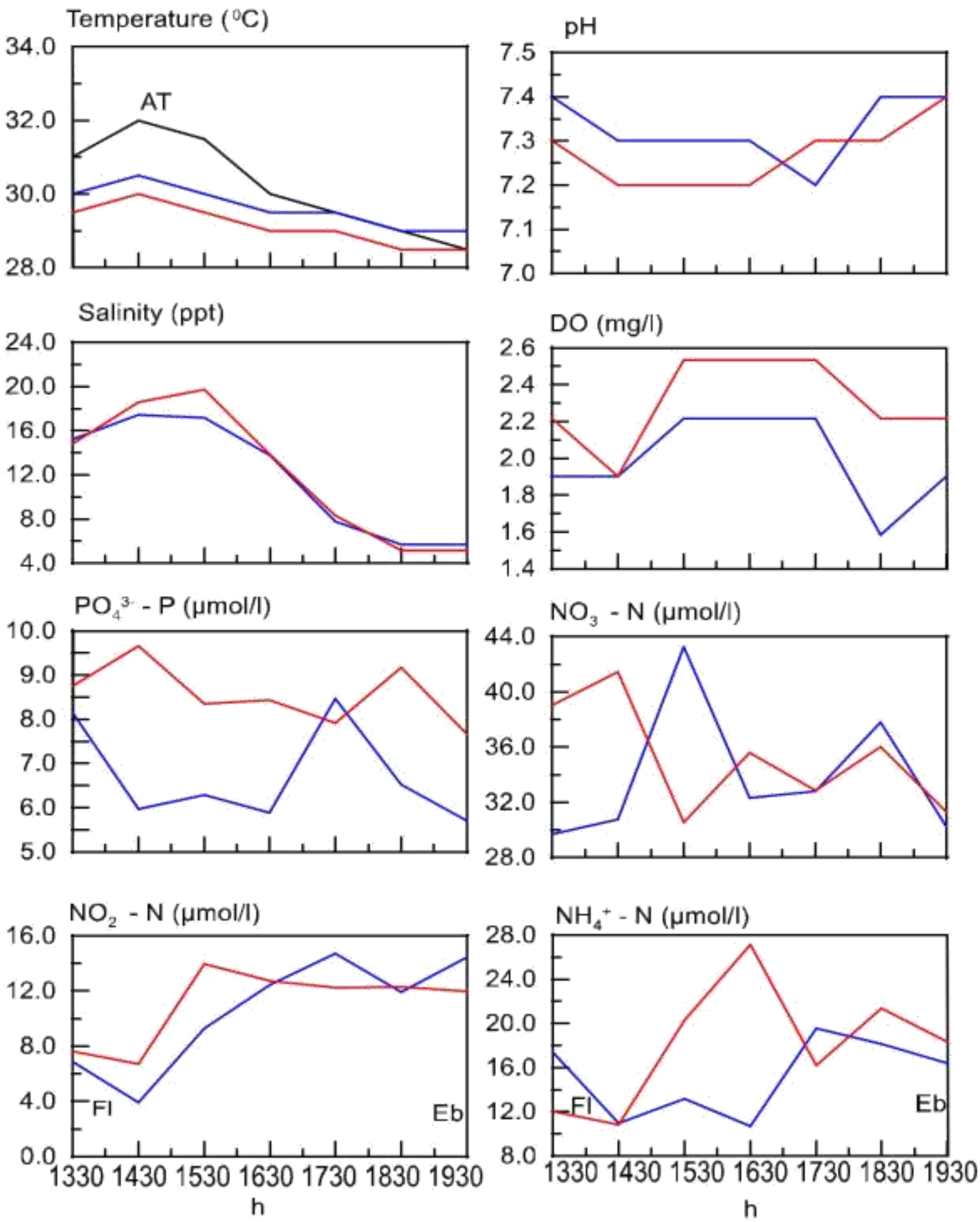


Figure 4.13.4: Temporal Variation of water quality parameters at K8 (——— S) & (——— B) on 9th April 2016

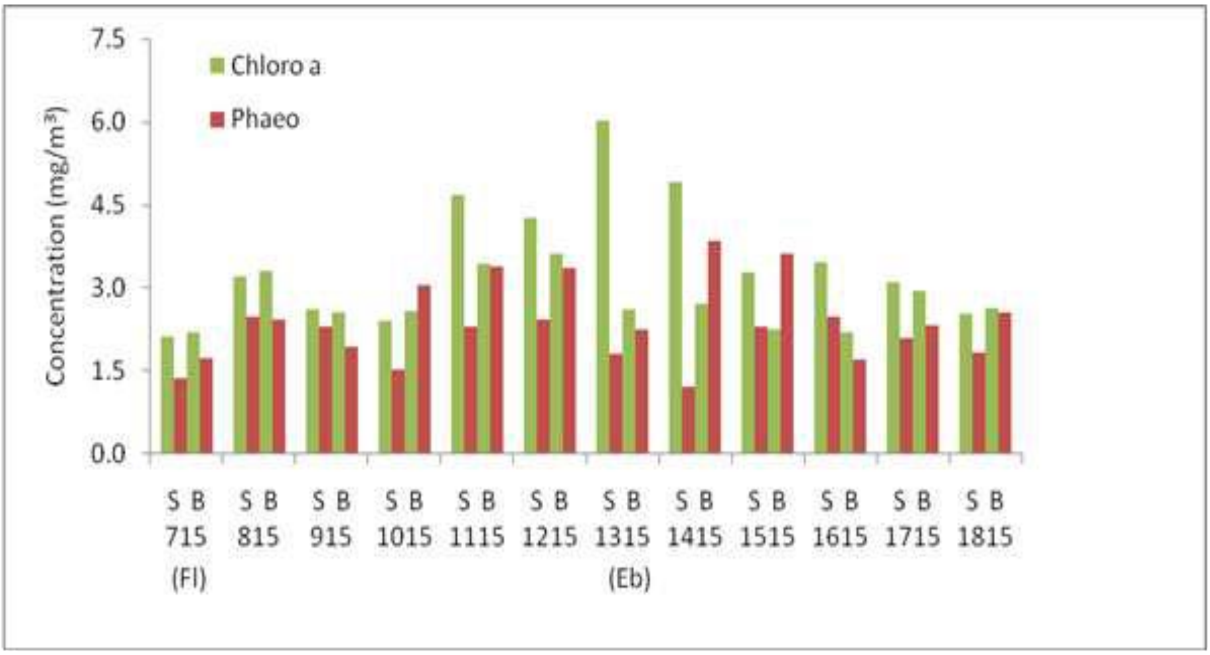


Figure 4.13.5: Temporal Variation of Phytopigments at station K4 on 14.12.2015.

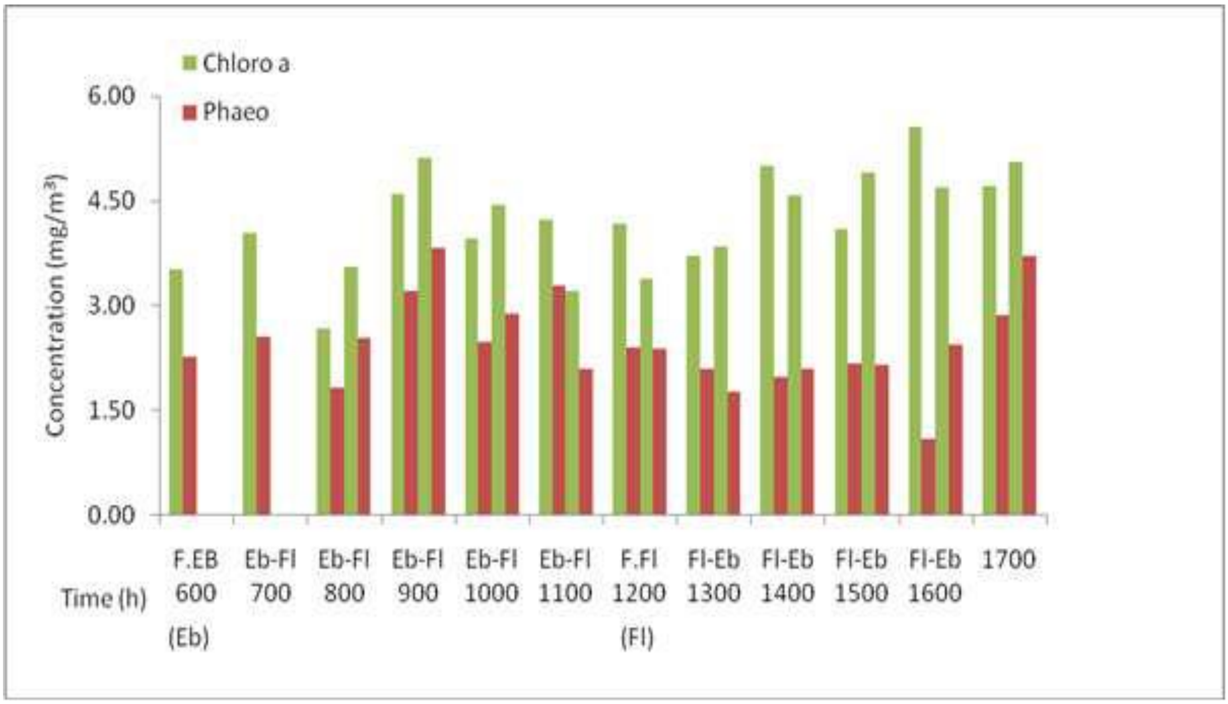


Figure 4.13.6: Temporal Variation of Phytopigments at station K4 on 08.04.2016.

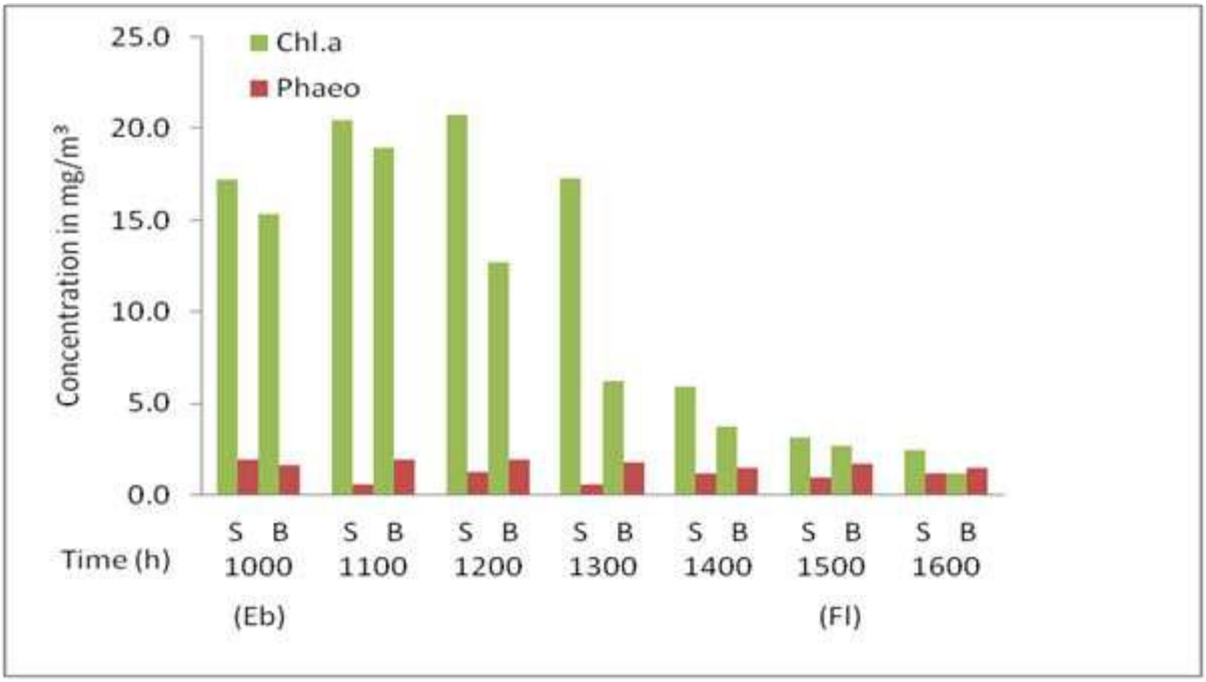


Figure 4.13.7: Temporal variation of phytopigment at station K8 on 17.12.2015.

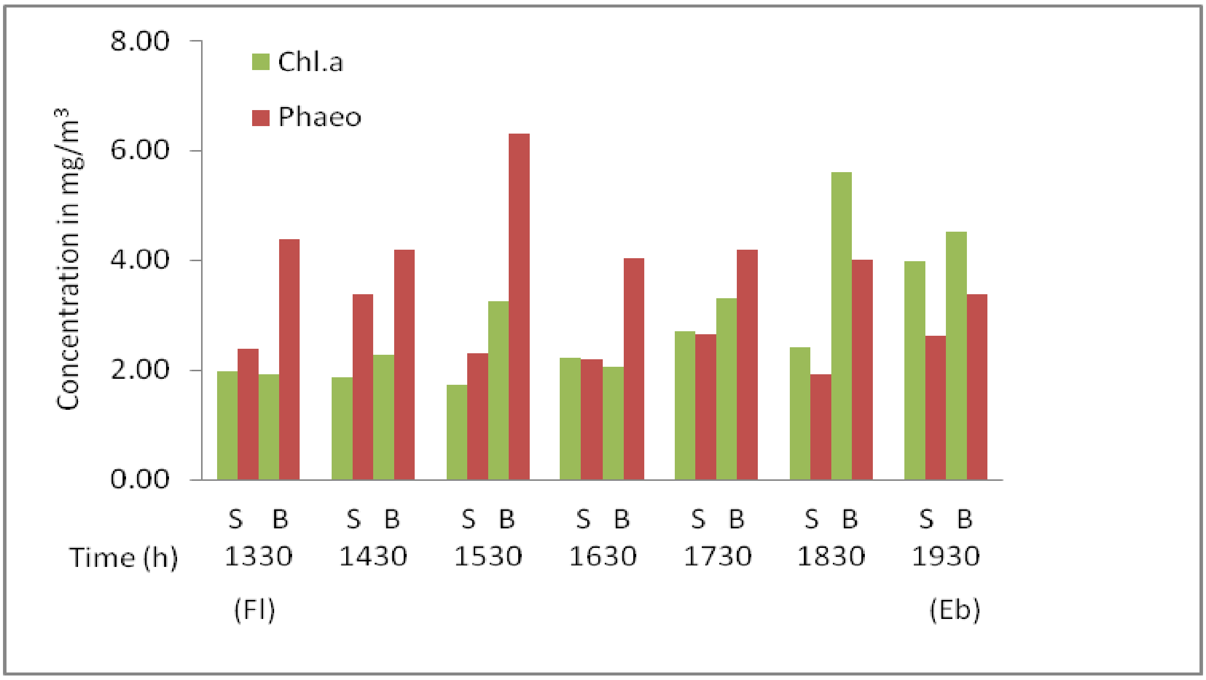


Figure 4.13.8: Temporal variation of phytopigment at station K8 on 09.04.2016.

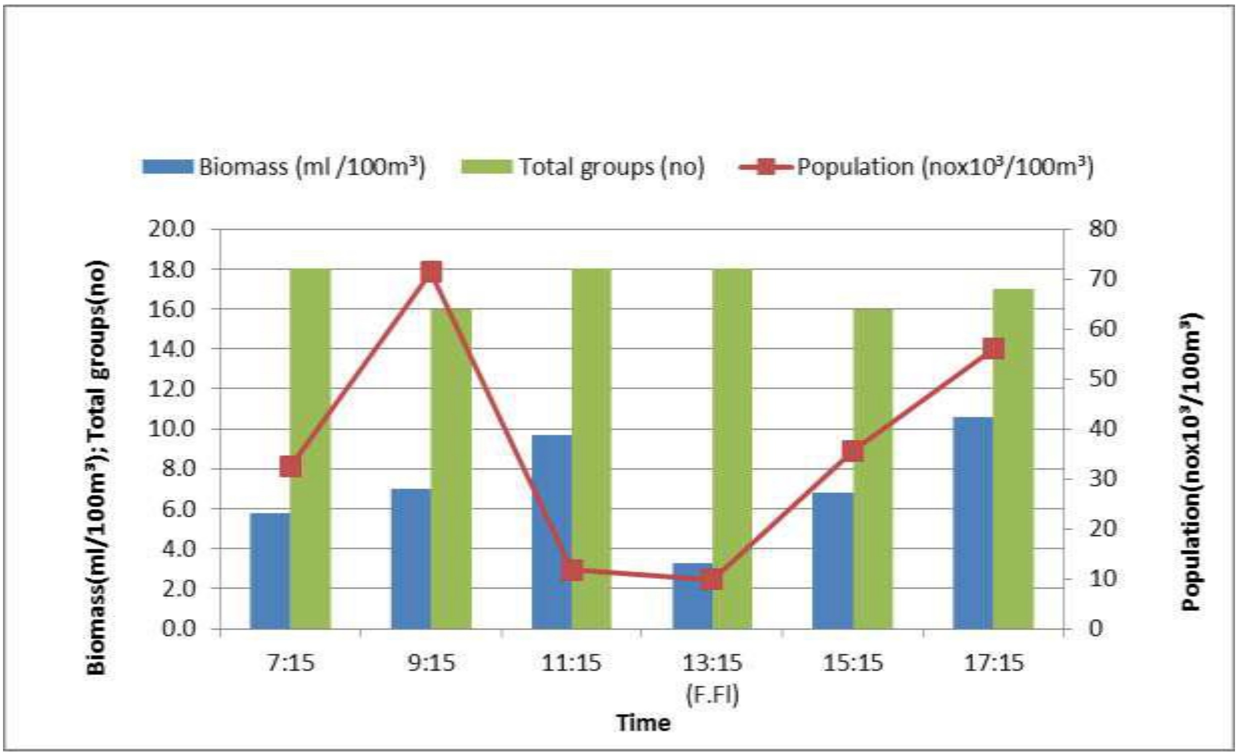


Figure 4.13.9: Temporal Variation of mesozooplankton at station K4 on 14.12.2015

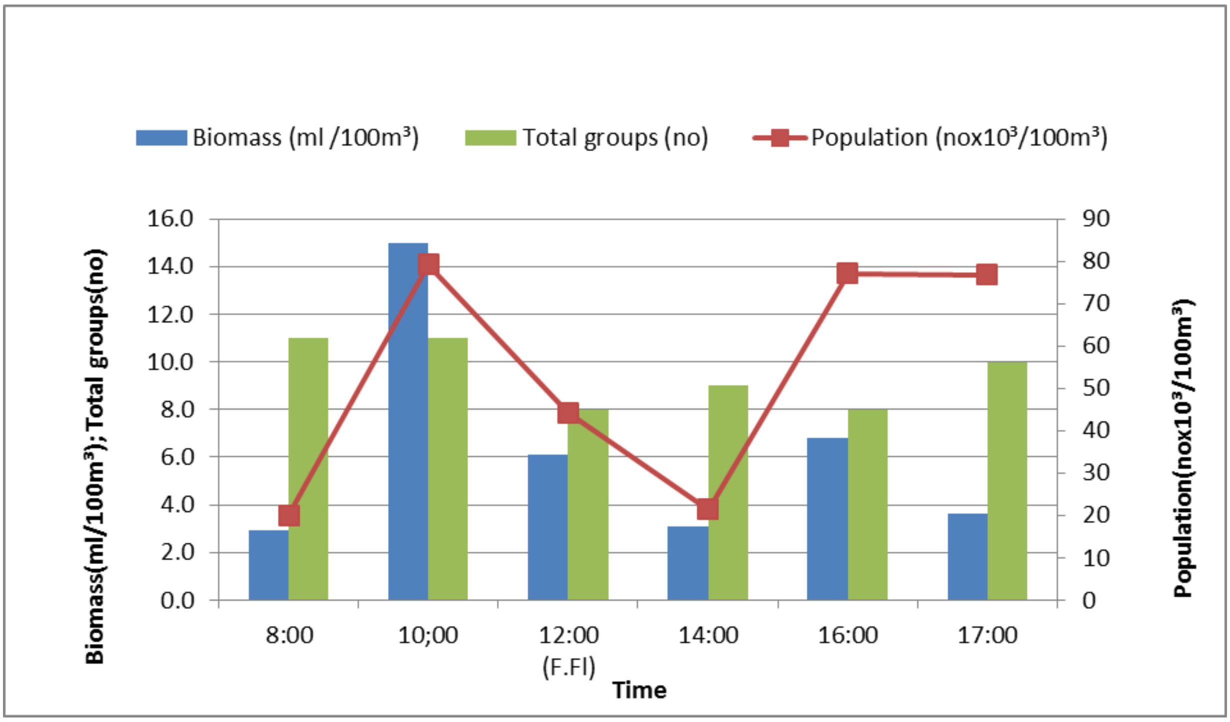


Figure 4.13.10: Temporal Variation of mesozooplankton at station K4 on 08.04.2016

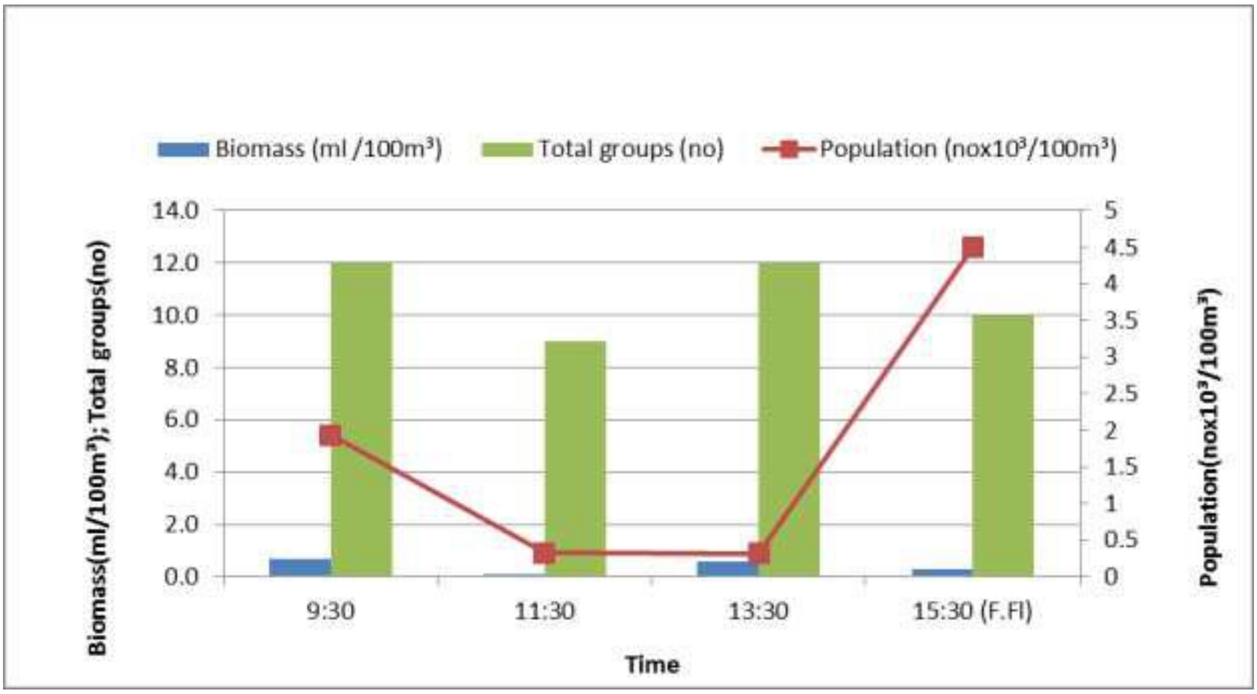


Figure 4.13.11: Temporal Variation of mesozooplankton at station K8 on 17.12.2015

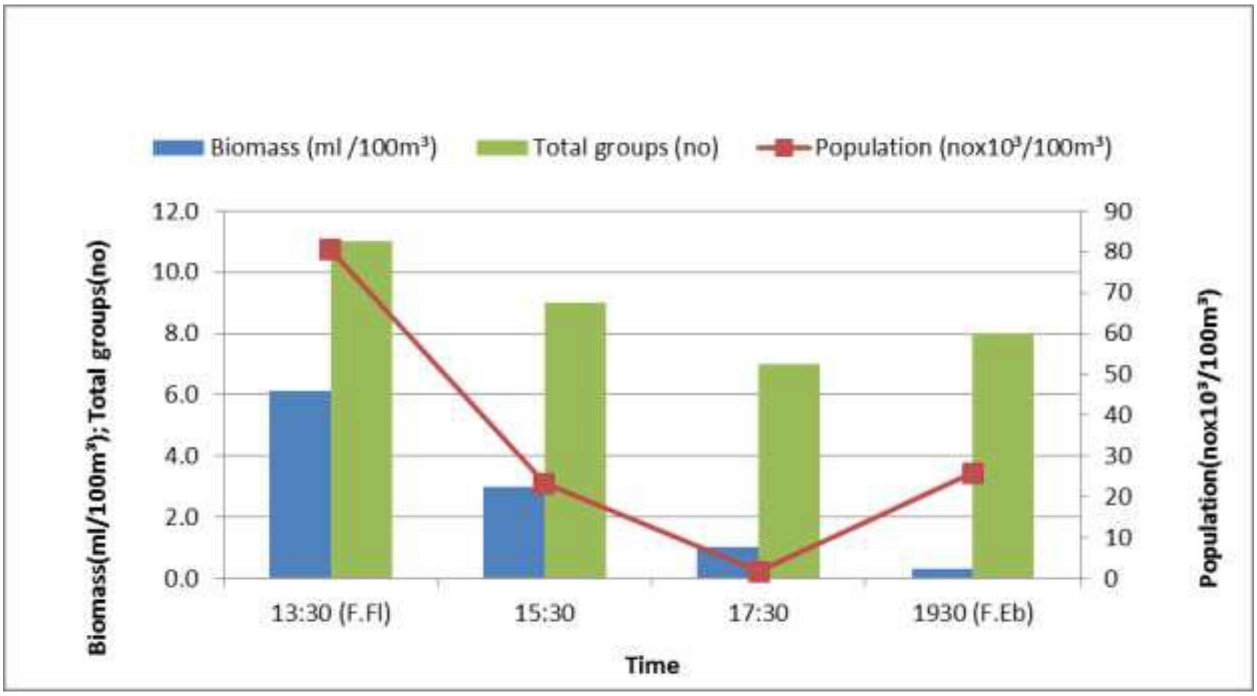


Figure 4.13.12: Temporal Variation of mesozooplankton at station K8 on 09.04.2016

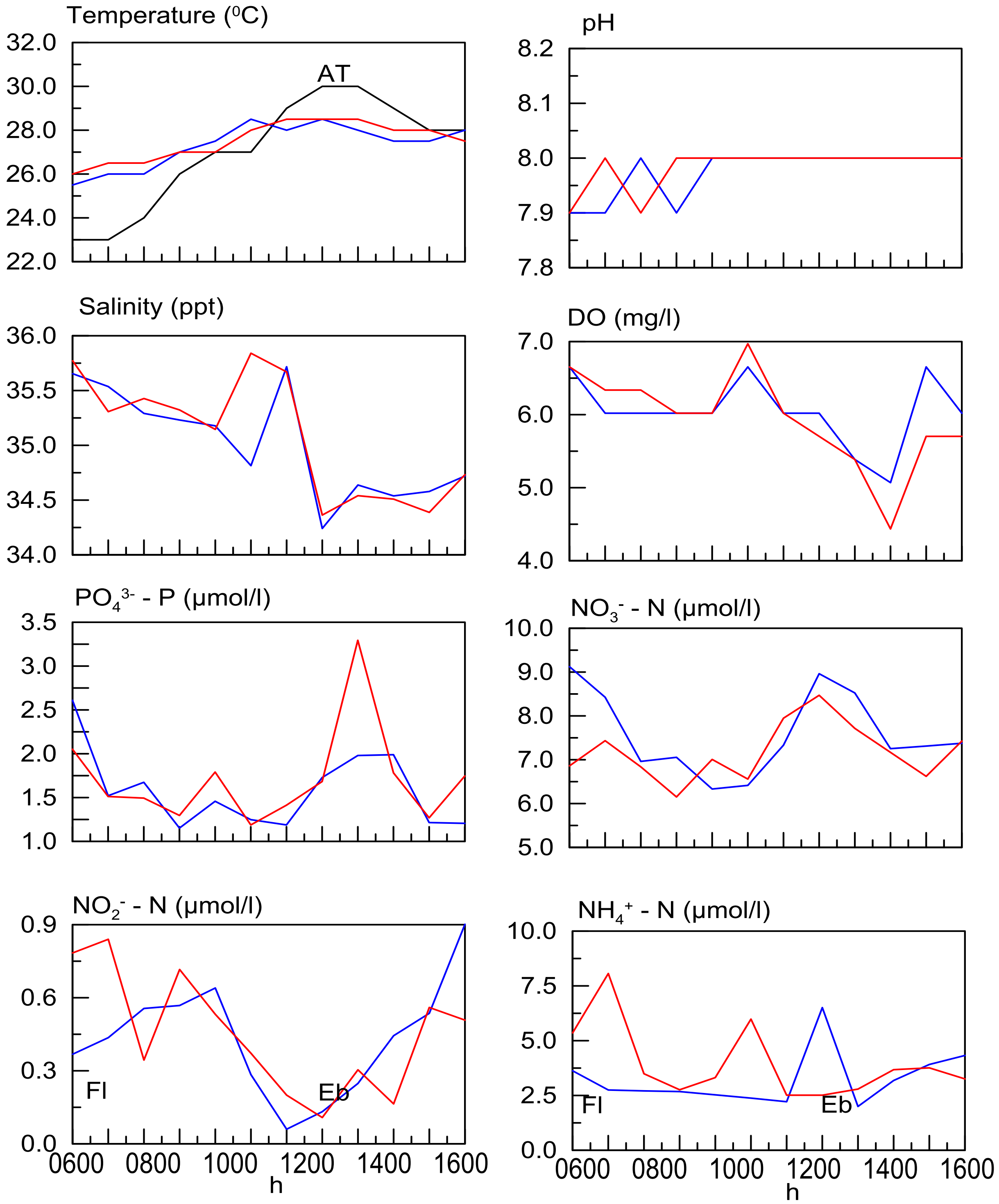


Figure 4.14.1: Temporal Variation of water quality parameters at MR4 (——— S) & (——— B) on 20th Dec 2015

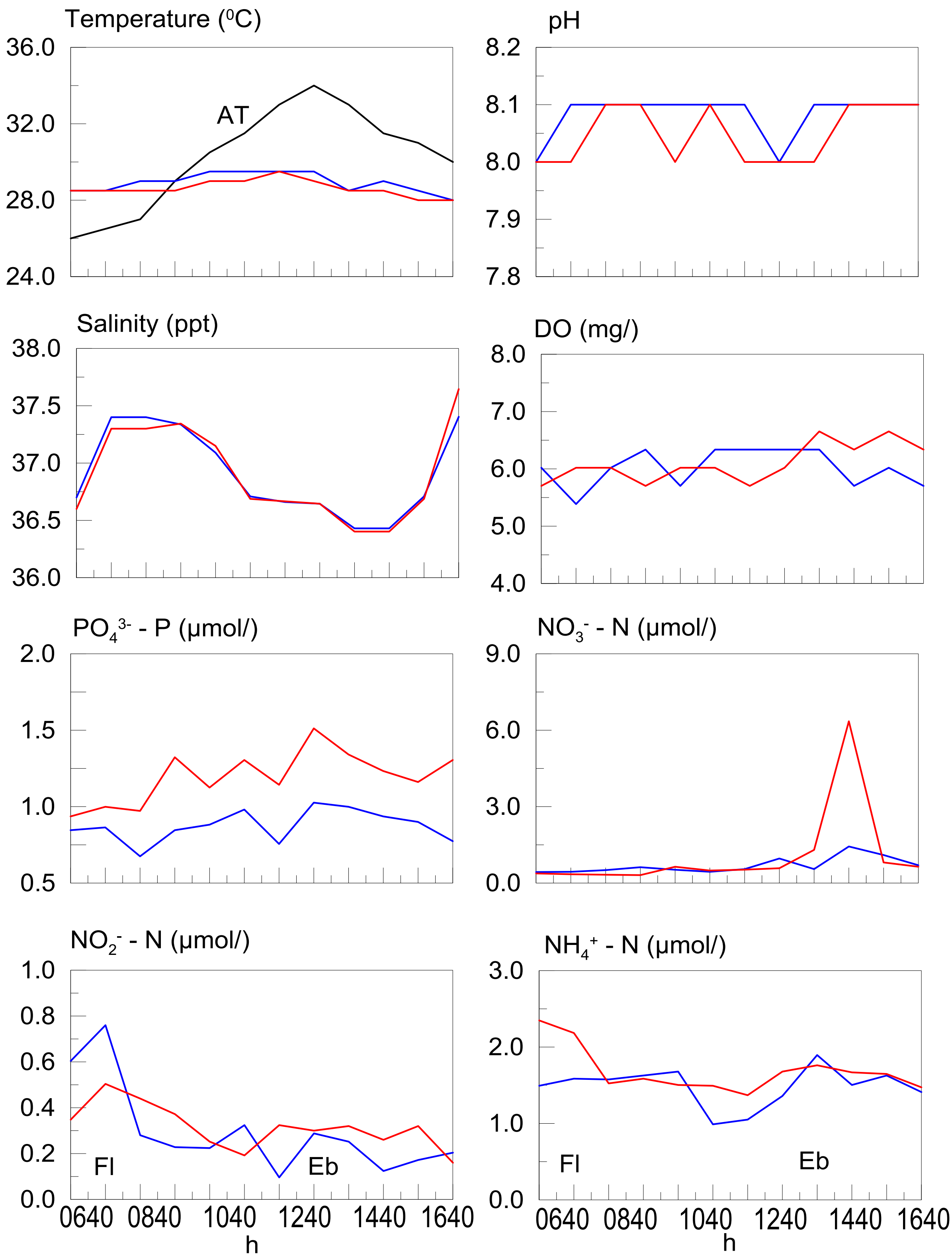


Figure 4.14.2: Temporal Variation of water quality parameters at MR4 (——— S) & (——— B) on 4th April 2016

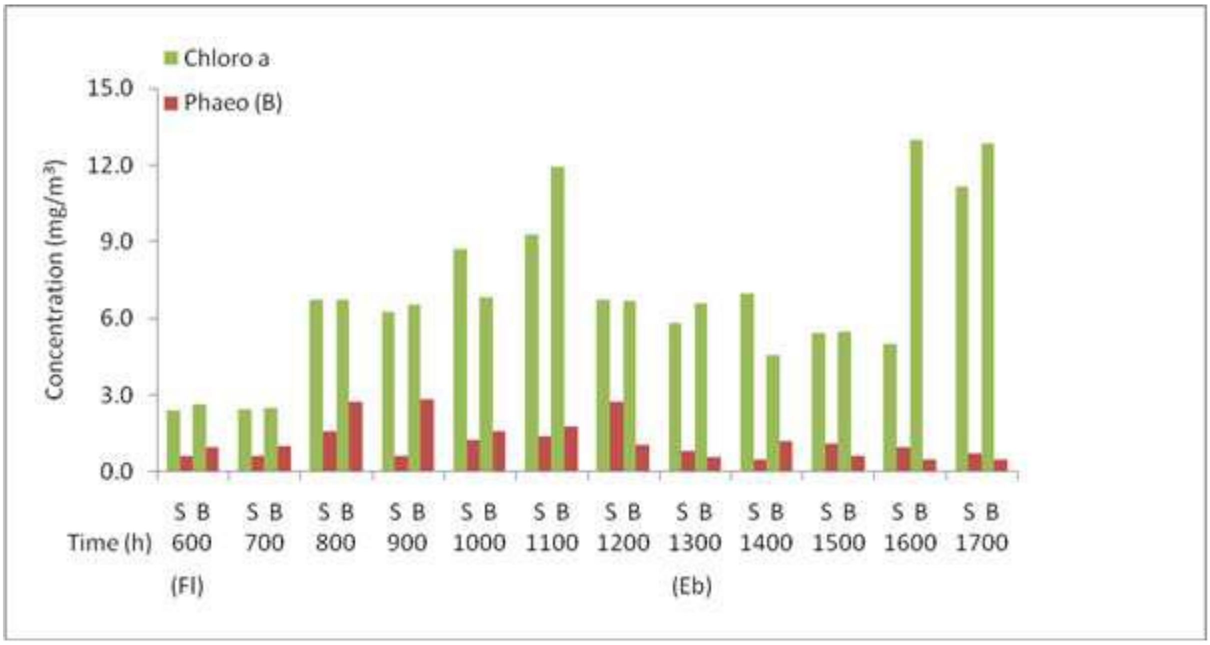


Figure 4.14.3 Temporal Variation of Phytopigments at station MR4 on 20.12.2015.

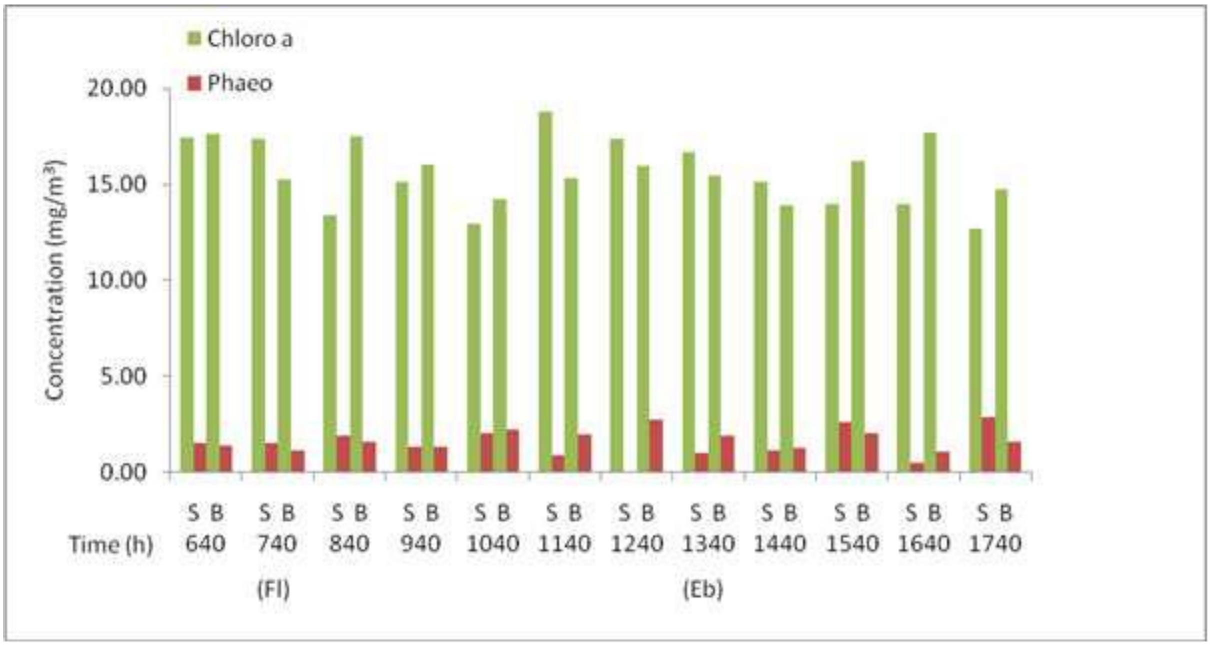


Figure 4.14.4: Temporal Variation of Phytopigments at station MR4 on 04.04.2016.

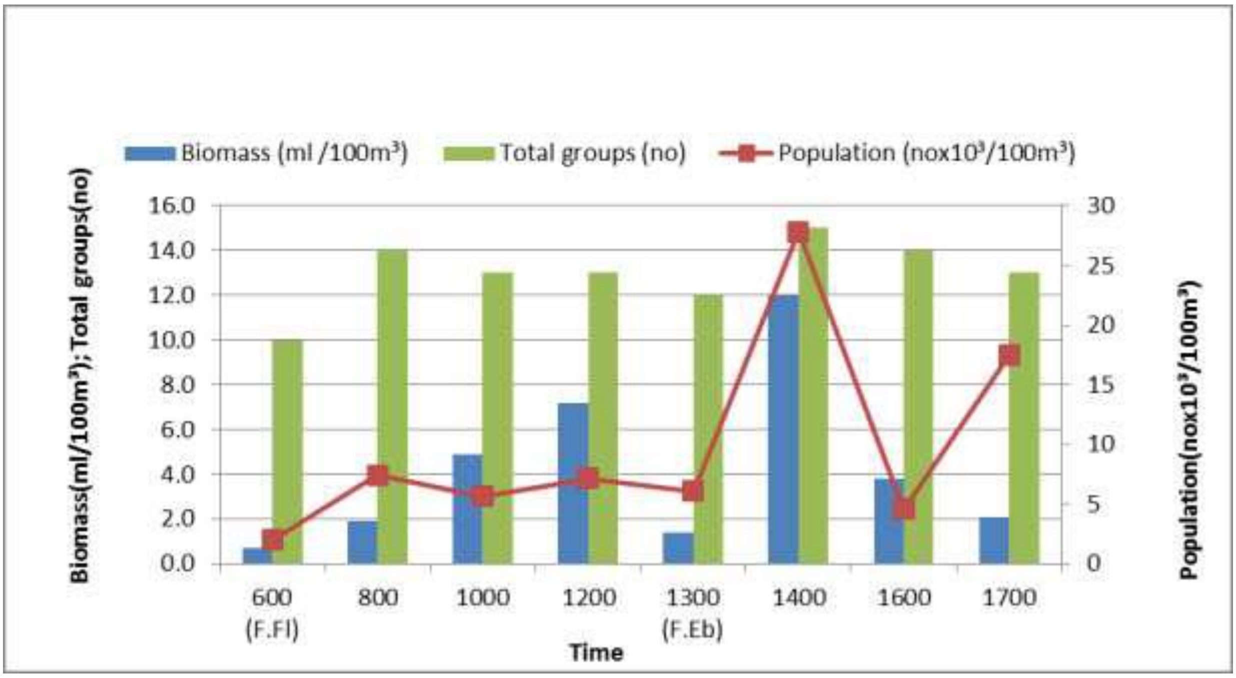


Figure 4.14.5: Temporal Variation of mesozooplankton at station MR4 on 20.12.2015

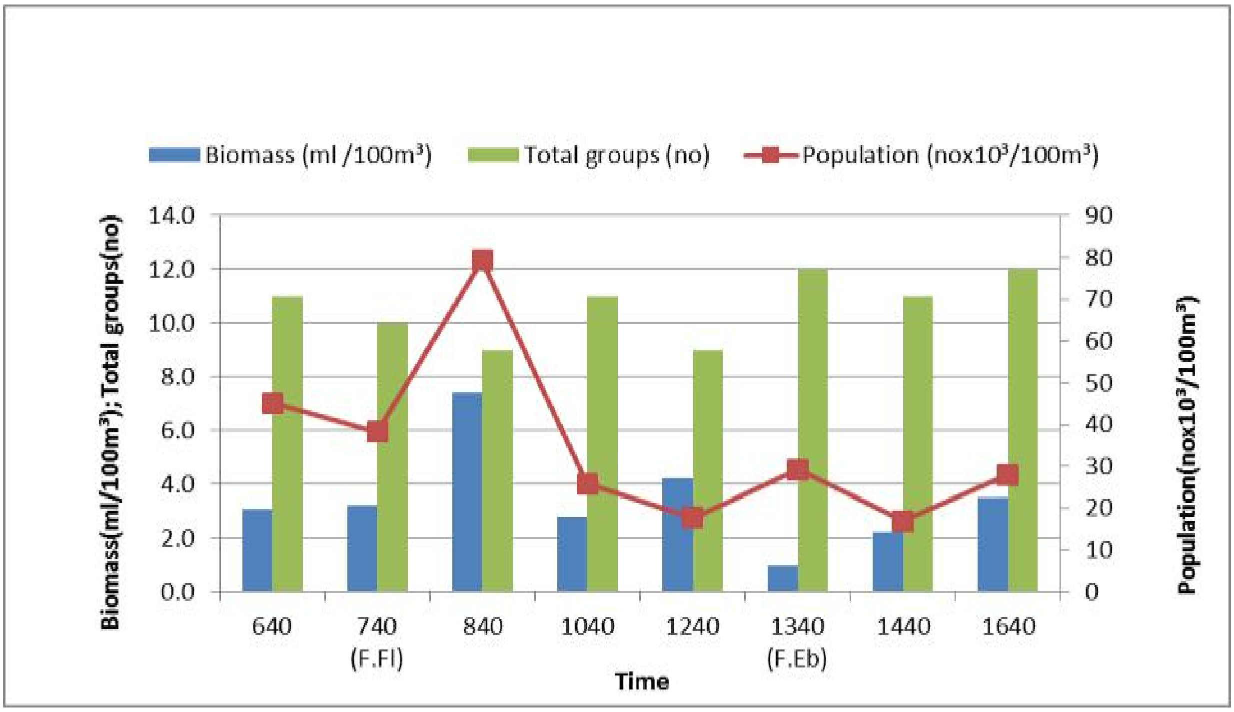


Figure 4.14.6: Temporal Variation of mesozooplankton at station MR4 on 04.04.2016

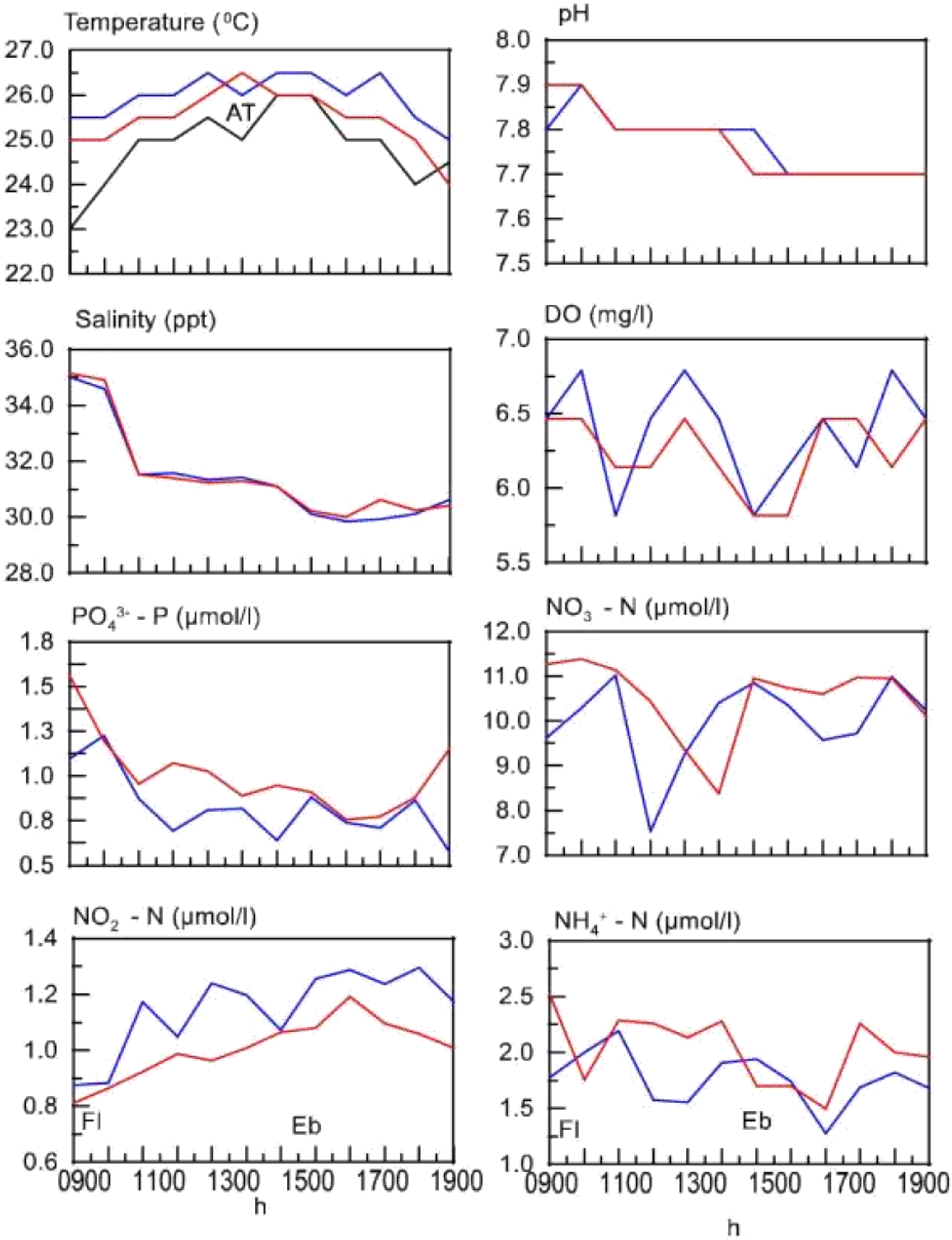


Figure 4.15.1: Temporal Variation of water quality parameters at S4 (——— S) & (——— B) on 23rd Dec 2015

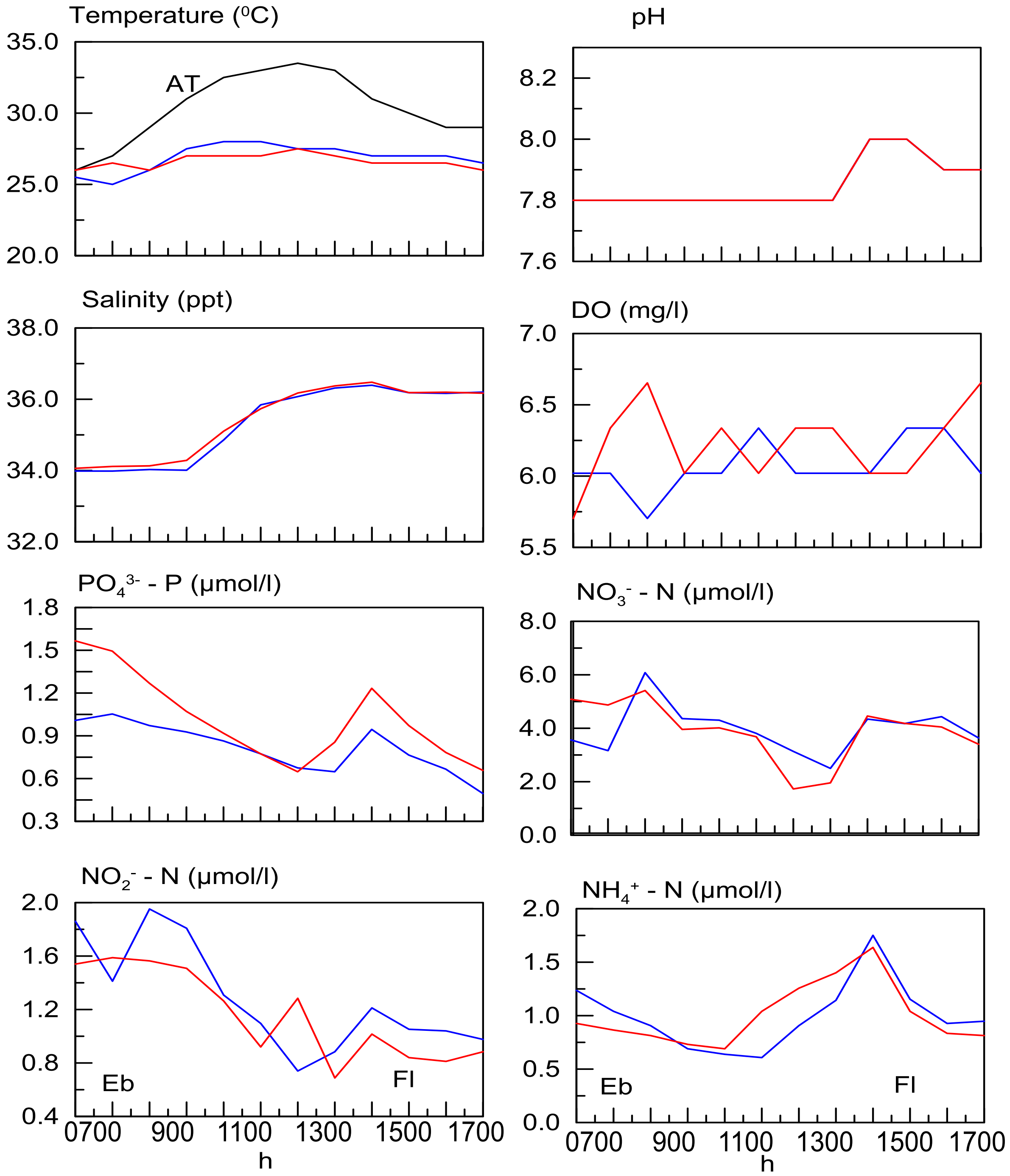


Figure 4.15.2: Temporal Variation of water quality parameters at S4 (S) & (B) on 29th March 2015

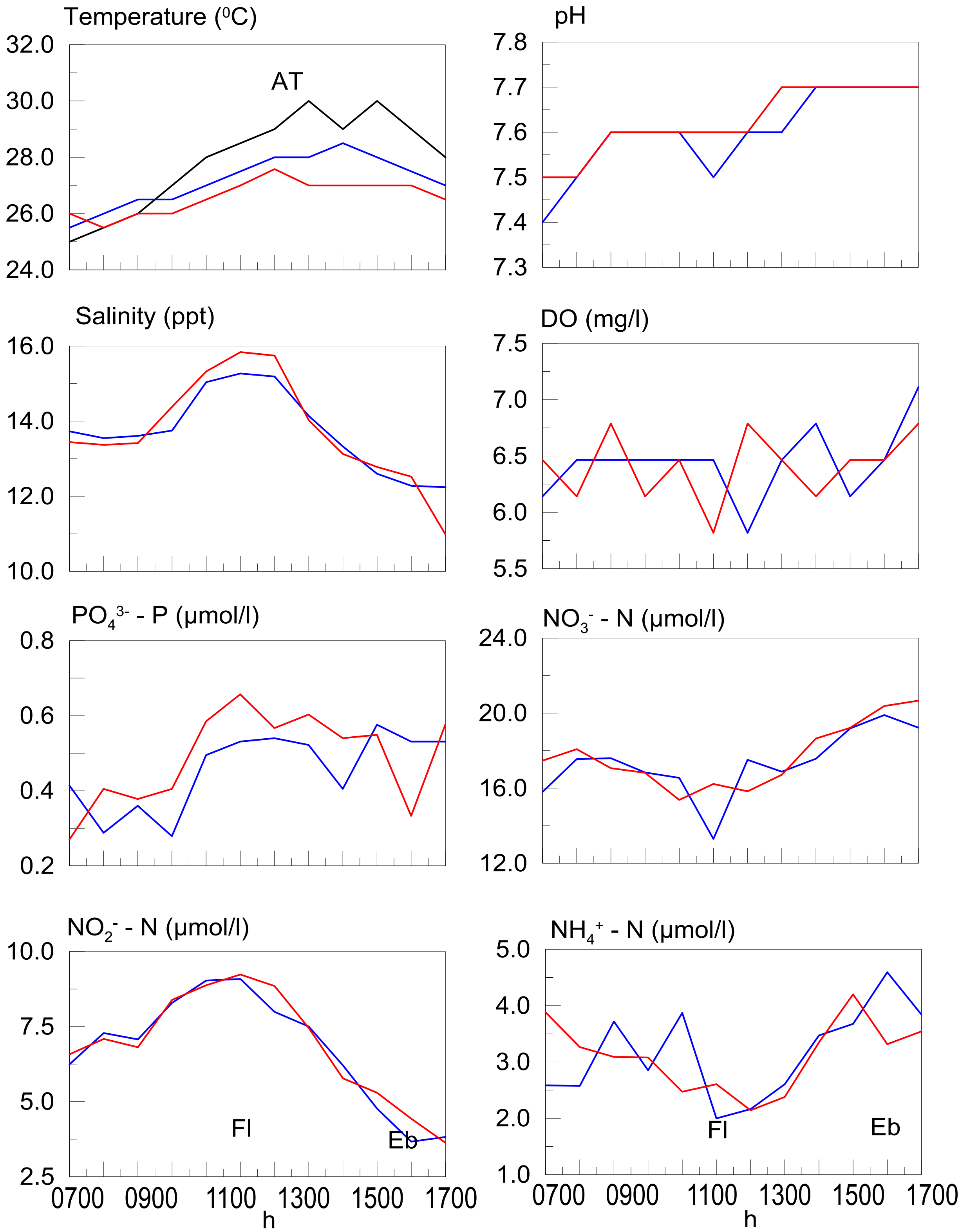


Figure 4.15.3: Temporal Variation of water quality parameters at S8 (——— S) & (——— B) on 25th Dec 2015

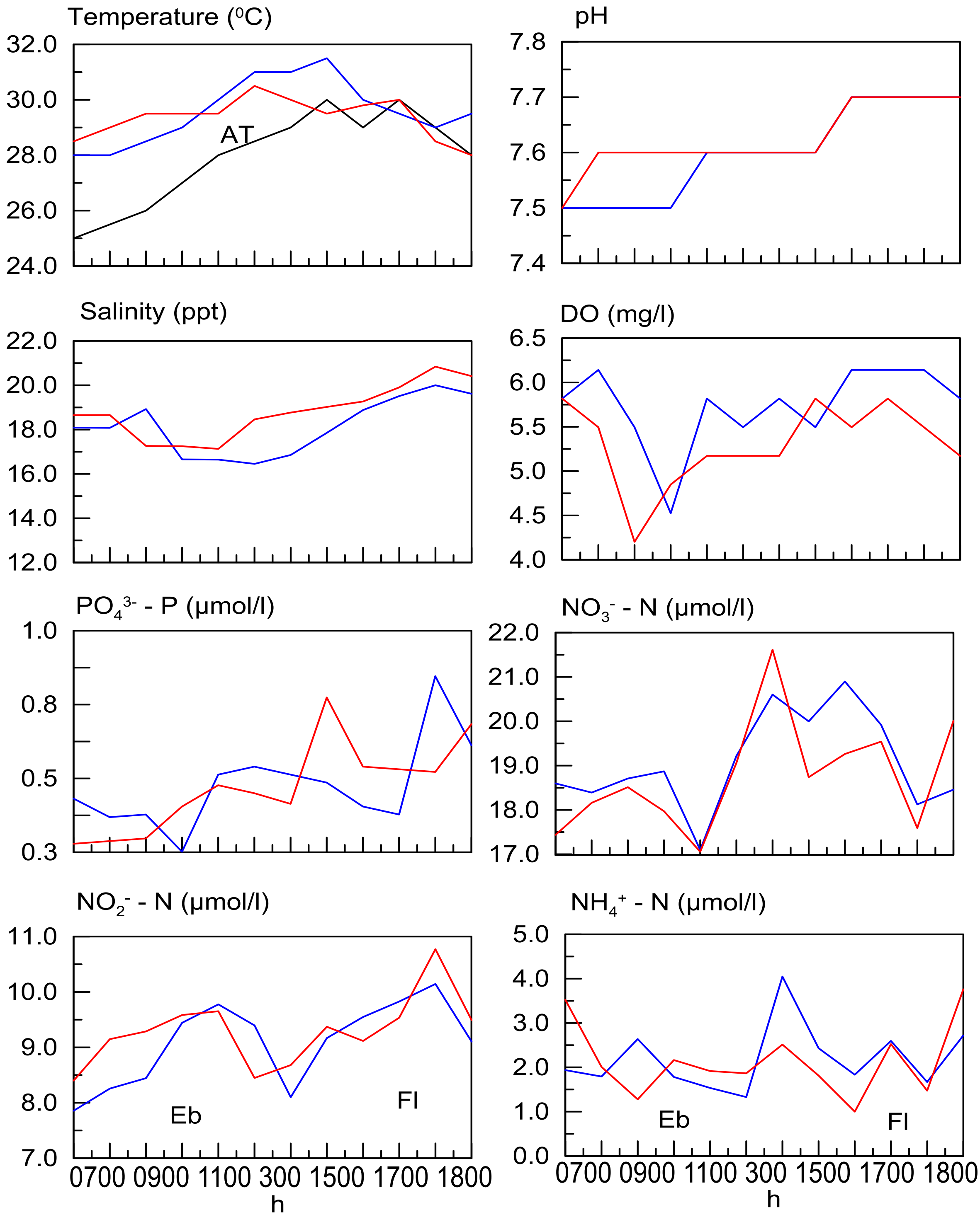


Figure 4.15.4: Temporal Variation of water quality parameters at S8 (S) & (B) on 31st March 2016

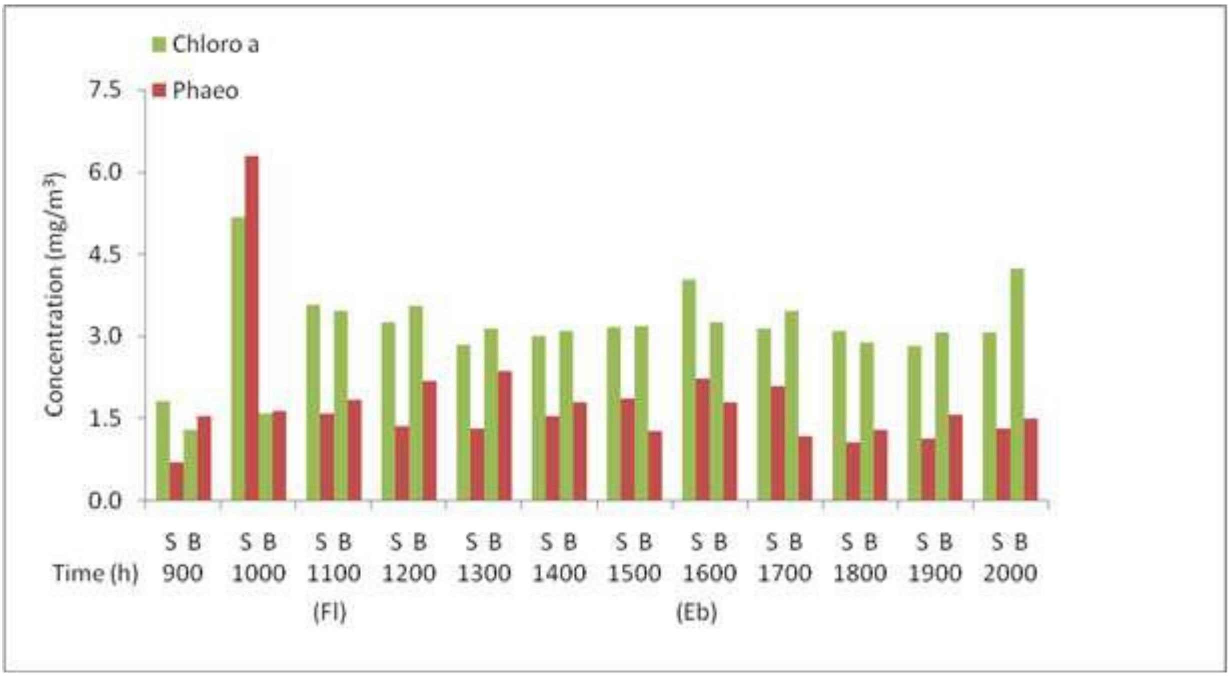


Figure 4.15.5: Temporal Variation of Phytopigments at station S4 on 23.12.2015.

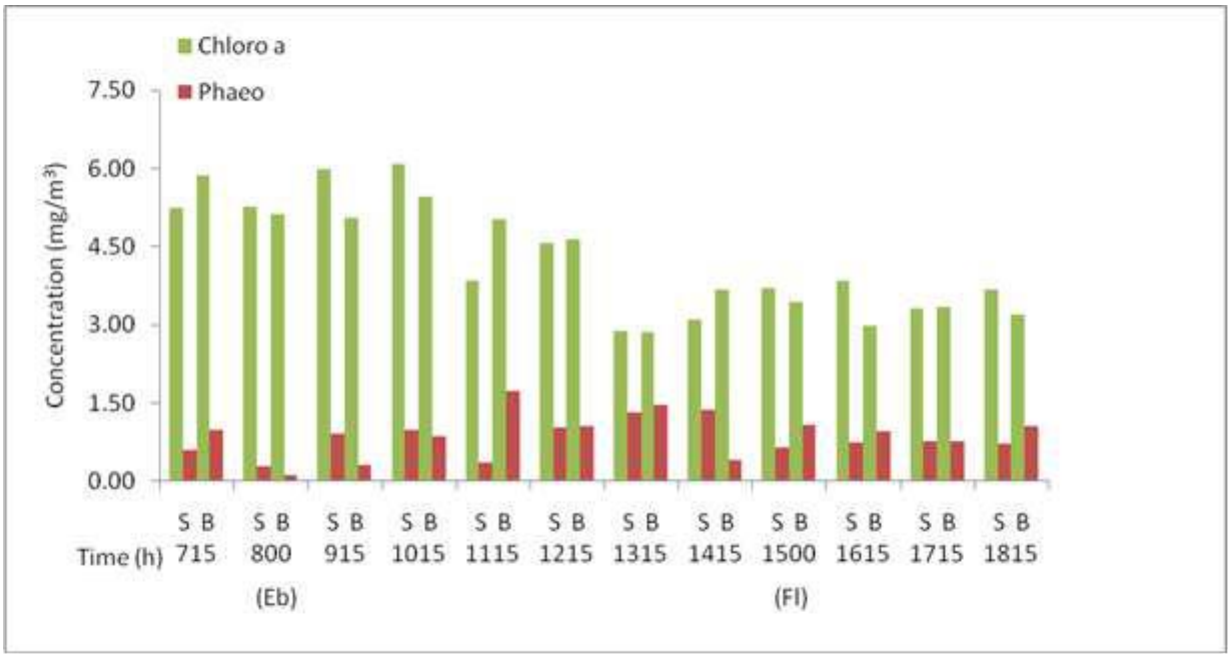


Figure 4.15.6: Temporal Variation of Phytopigments at station S4 on 29.03.2016.

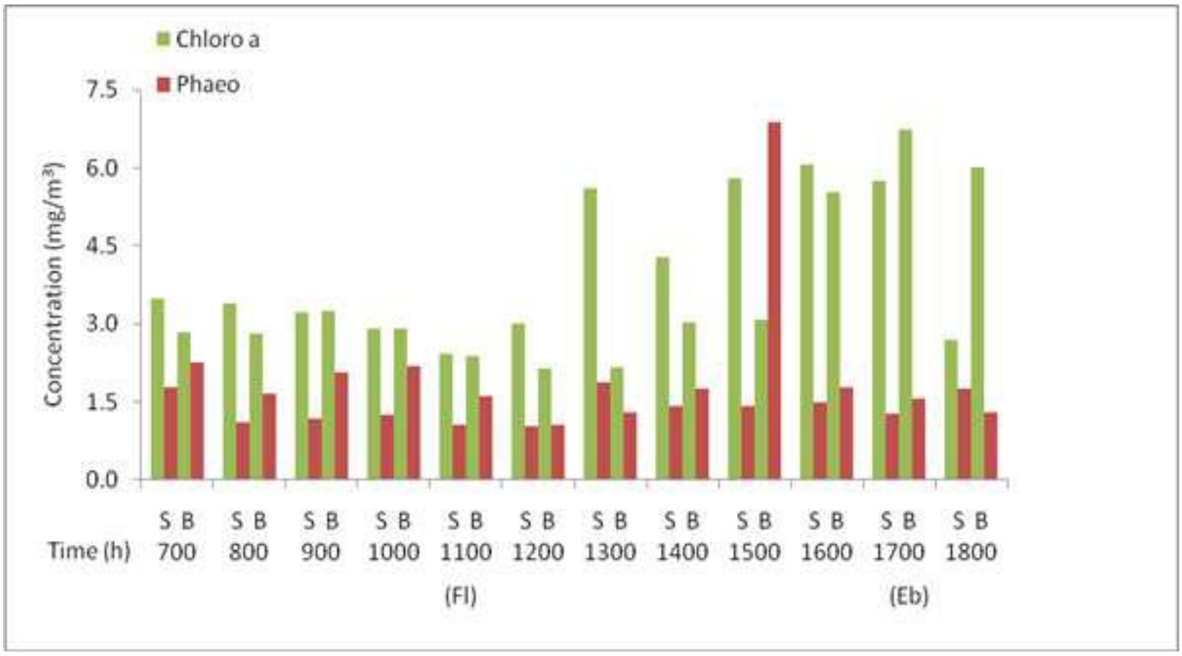


Figure 4.15.7: Temporal Variation of Phytopigments at station S8 on 25.12.2015.

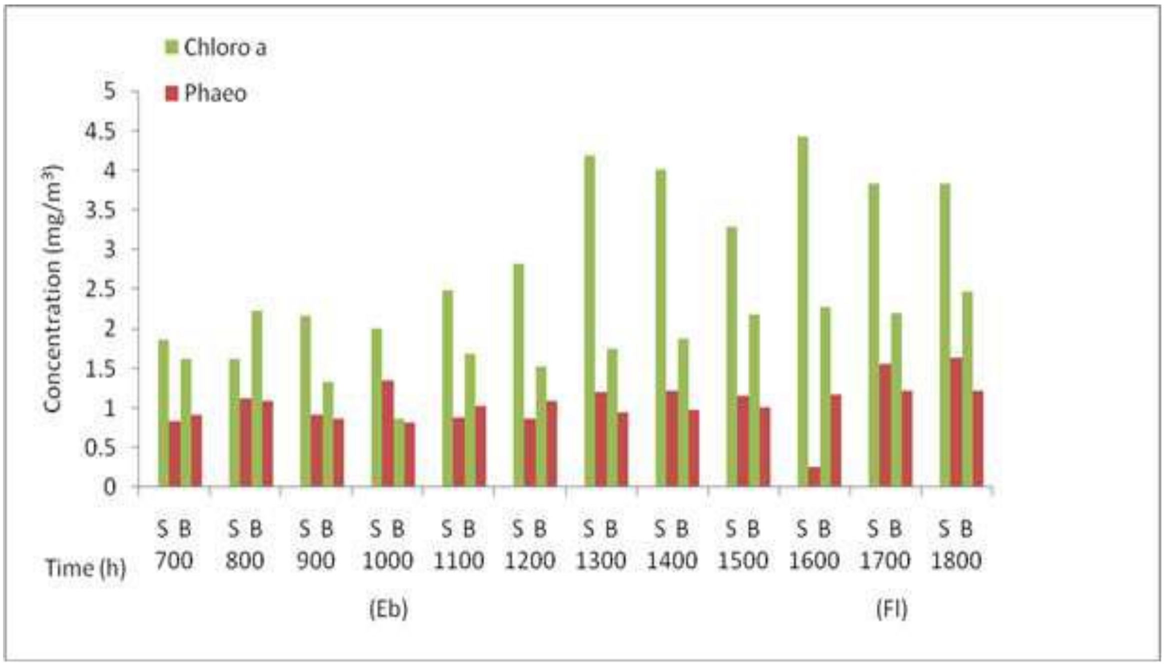


Figure 4.15.8: Temporal Variation of Phytopigments at station S8 on 31.03.2016.

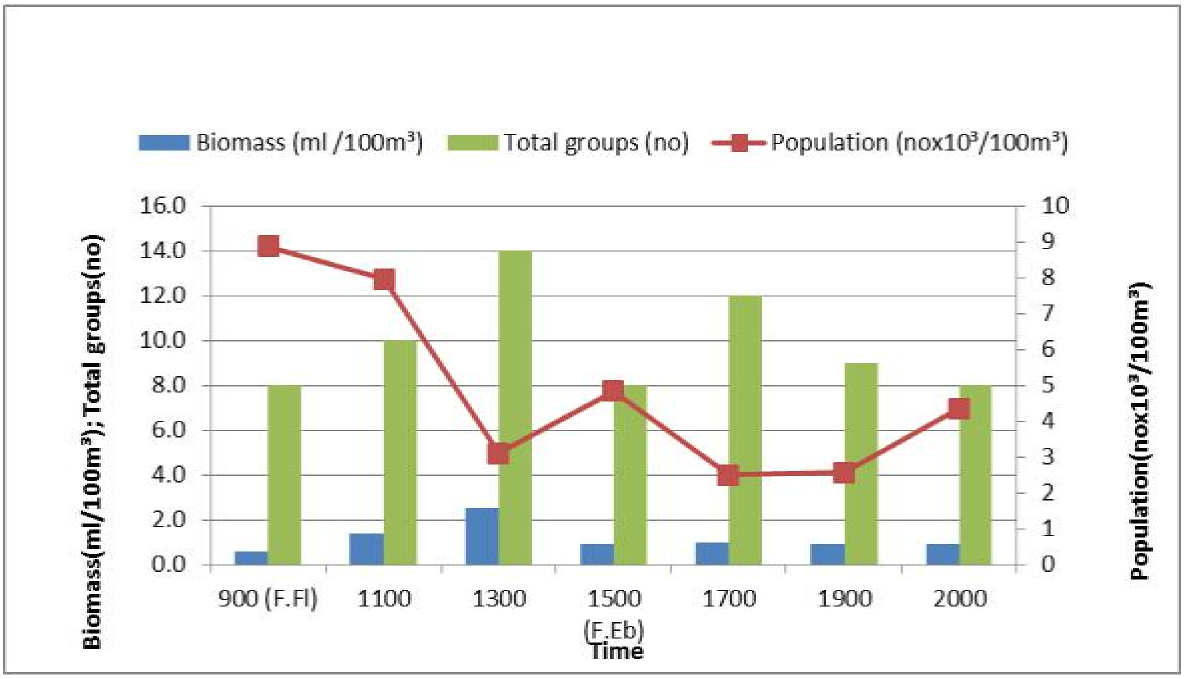


Figure 4.15.9: Temporal Variation of mesozooplankton at station S4 on 23.12.2015

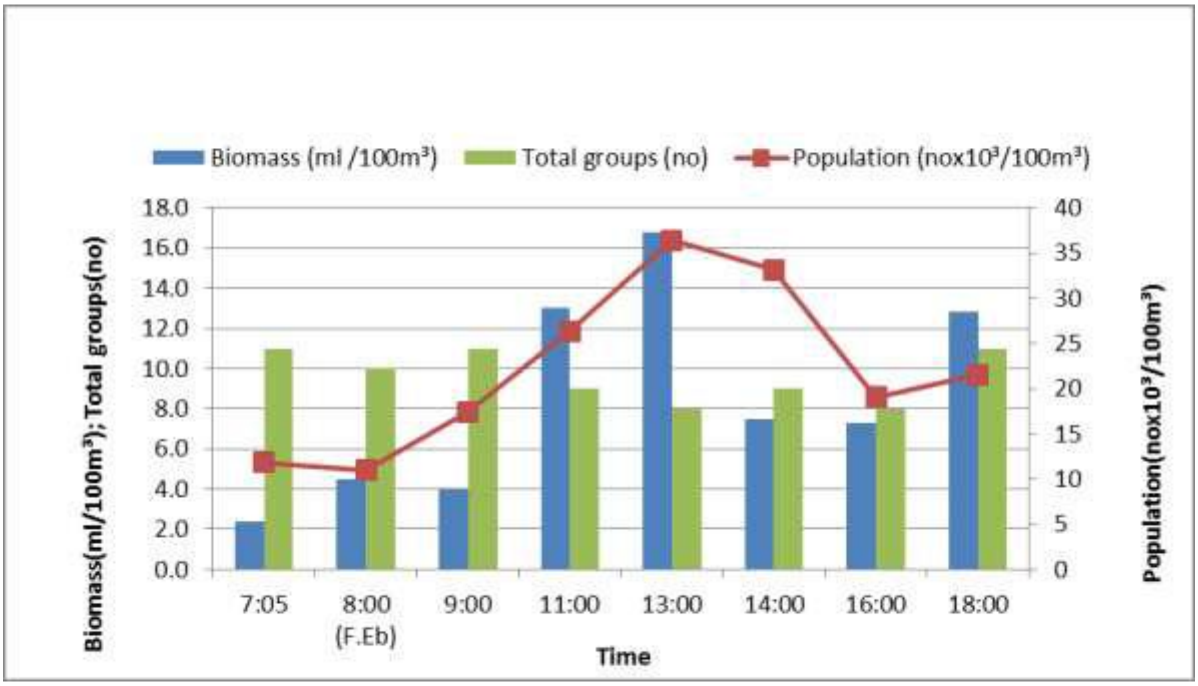


Figure 4.15.10: Temporal Variation of mesozooplankton at station S4 on 29.03.2016

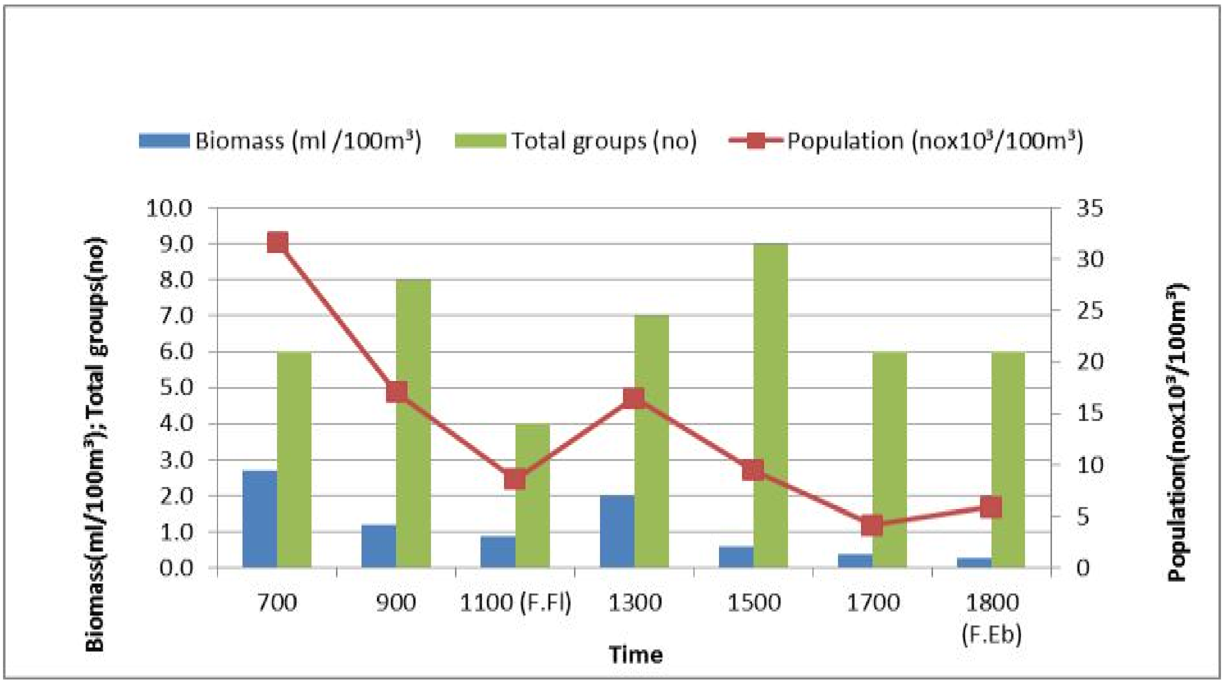


Figure 4.15.11: Temporal Variation of mesozooplankton at station S8 on 25.12.2015

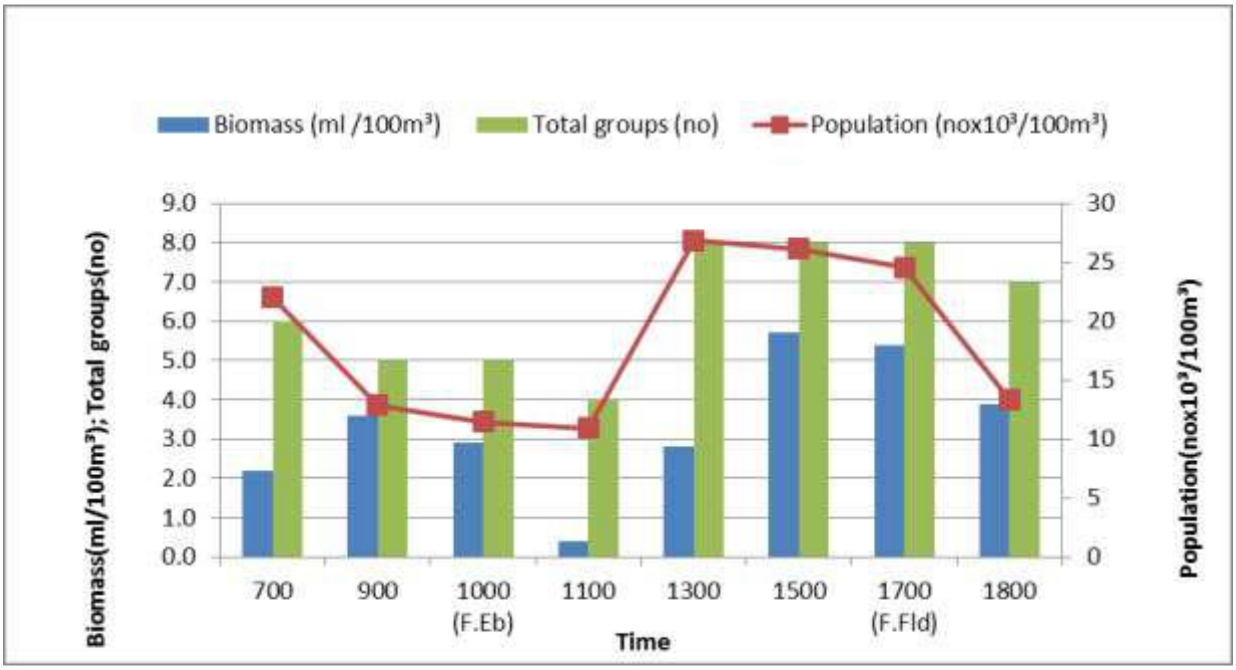


Figure 4.15.12: Temporal Variation of mesozooplankton at station S8 on 31.03.2016

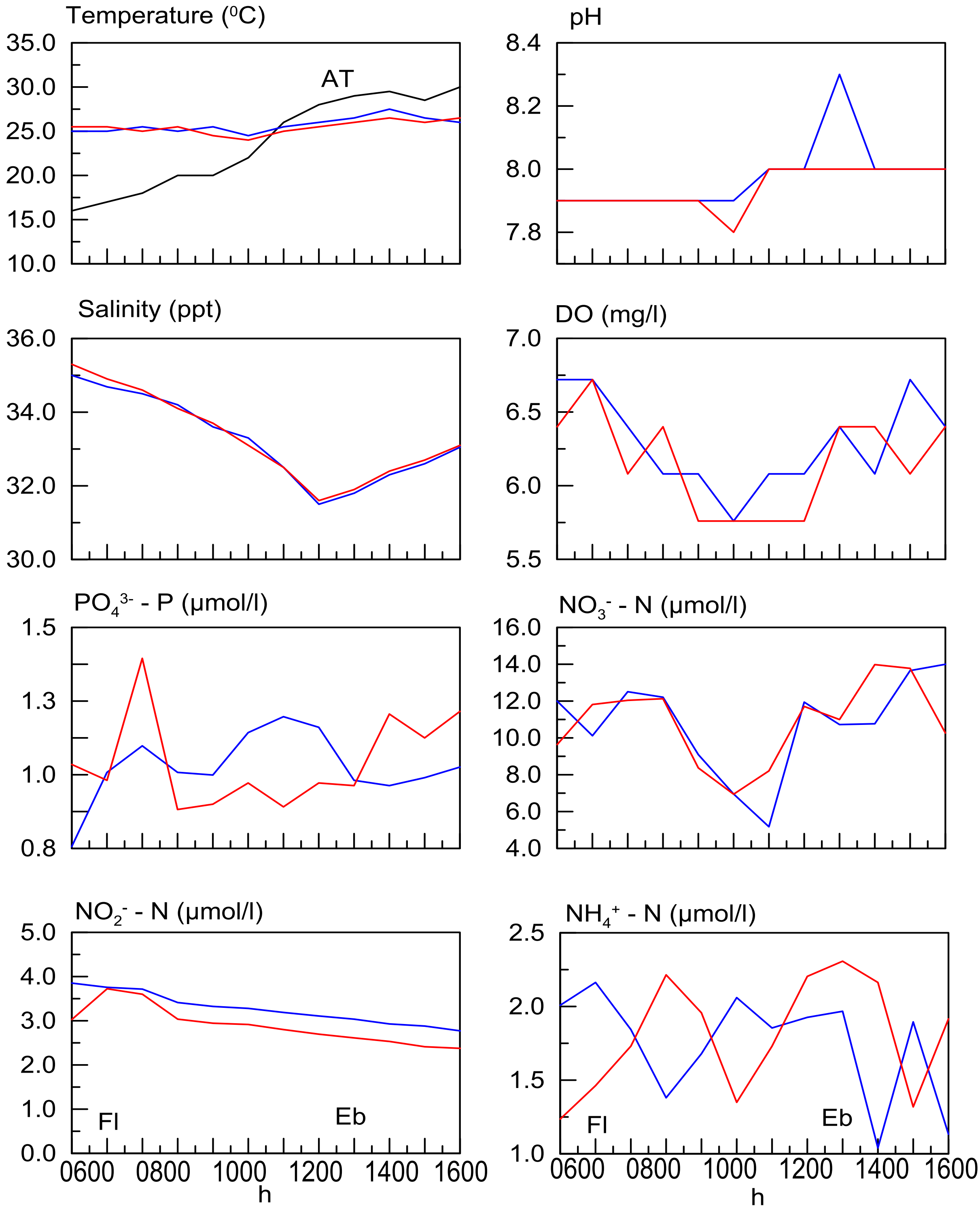


Figure 4.16.1: Temporal Variation of water quality parameters at VS4 (—— S) & (—— B) on 28th Dec 2015

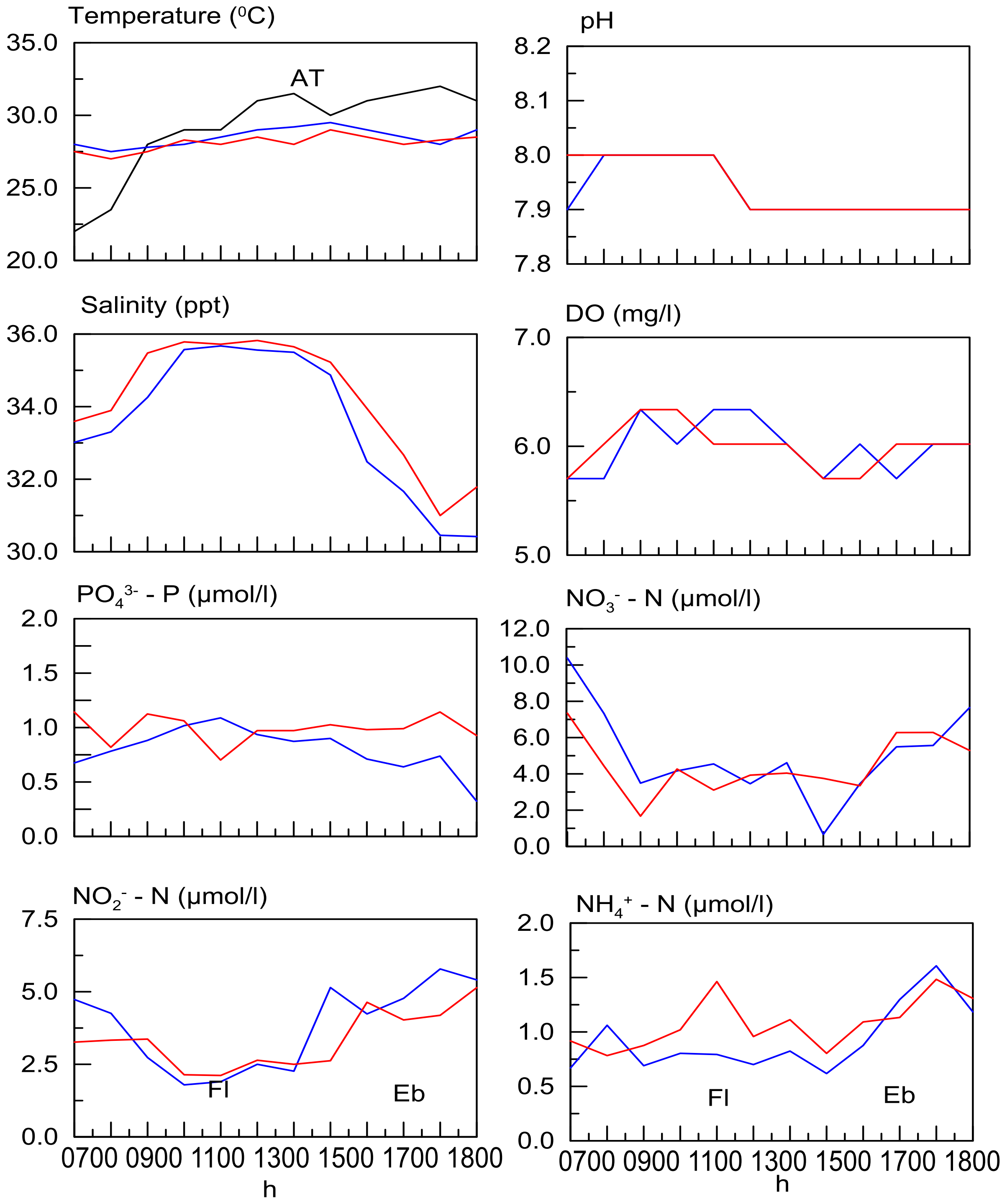


Figure 4.16.2: Temporal Variation of water quality parameters at VS4 (S) & (B) on 22nd March 2016

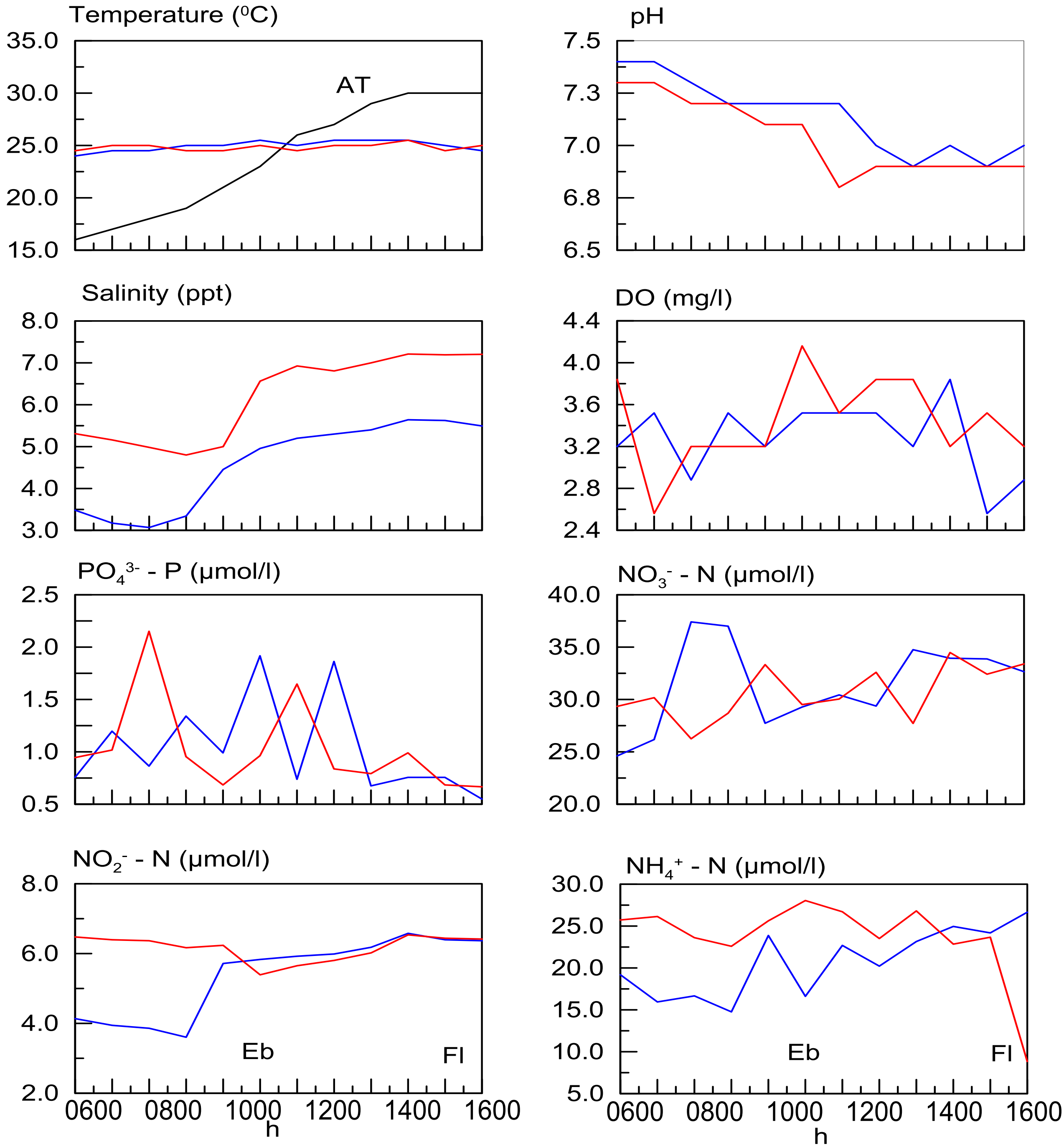


Figure 4.16.3: Temporal Variation of water quality parameters at VS9 (——— S) & (——— B) on 30th Dec 2015

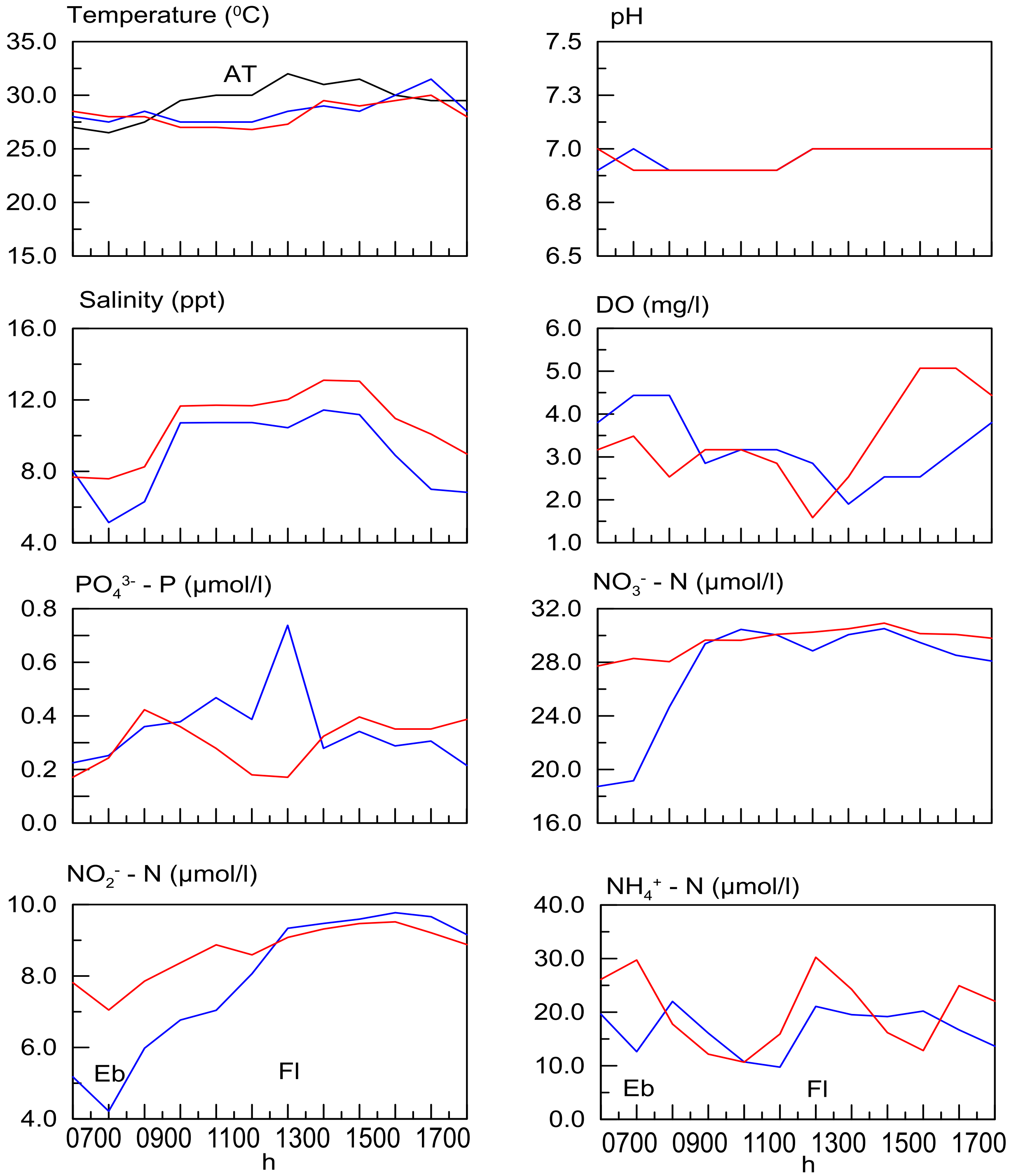


Figure 4.16.4: Temporal Variation of water quality parameters at VS9 (——— S) & (——— B) on 25th March 2016

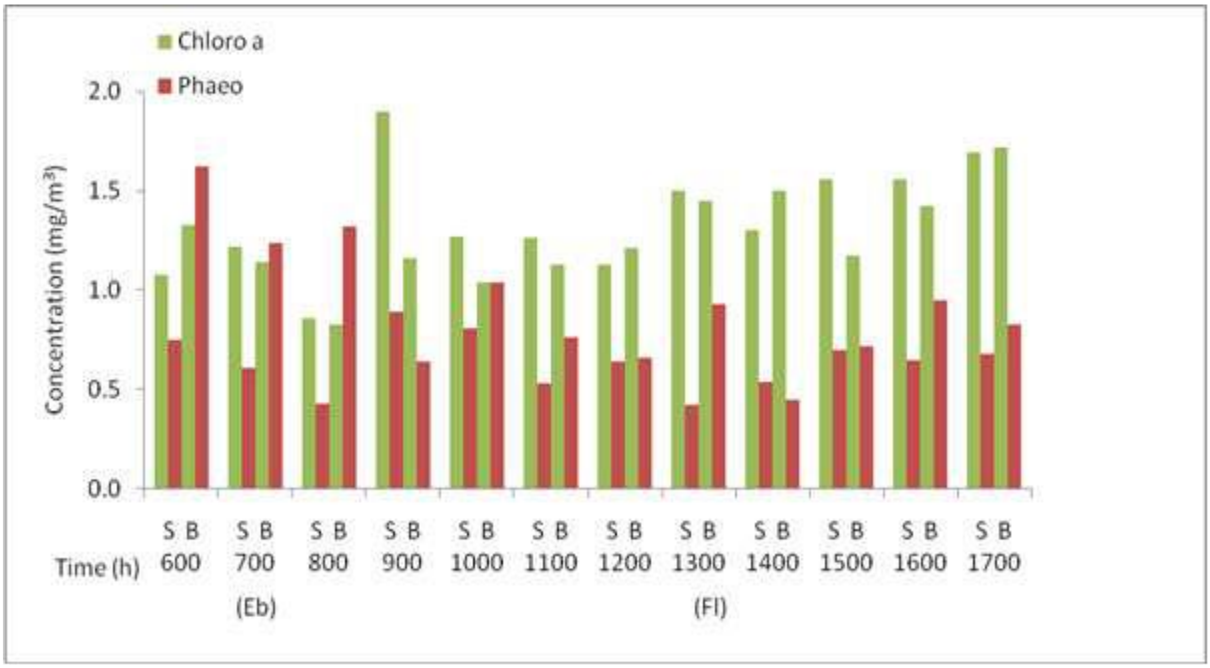


Figure 4.16.5: Temporal Variation of Phytopigments at station VS4 on 28.12.2015.

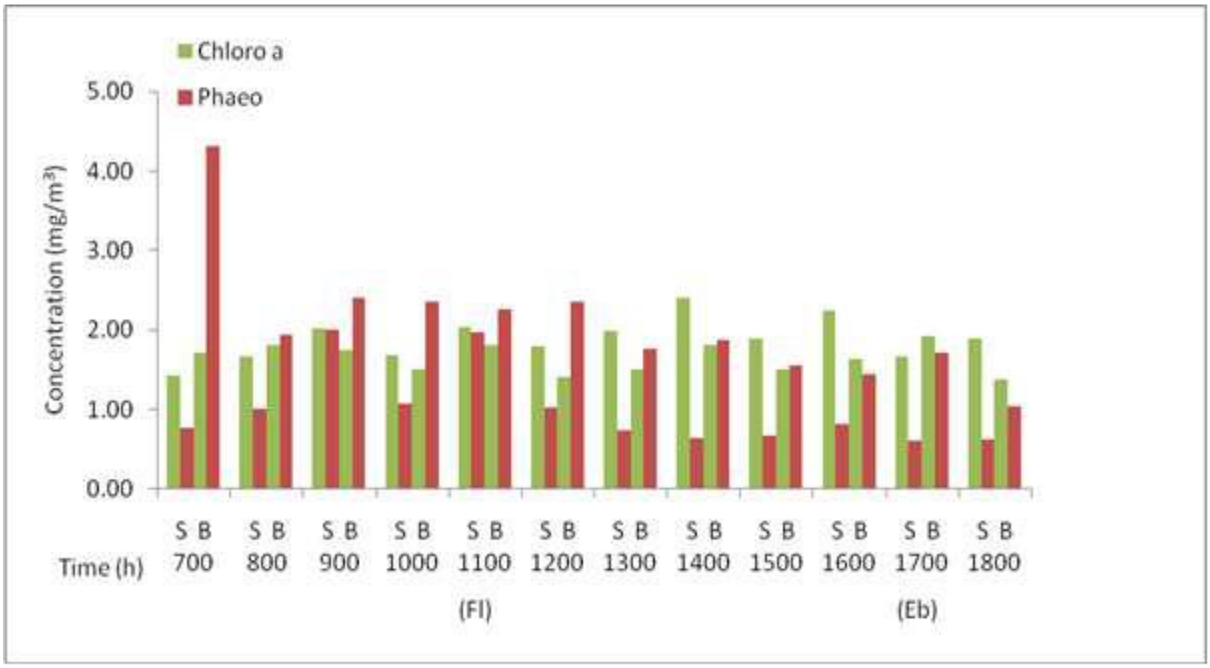


Figure 4.16.6: Temporal Variation of Phytopigments at station VS4 on 22.03.2016.

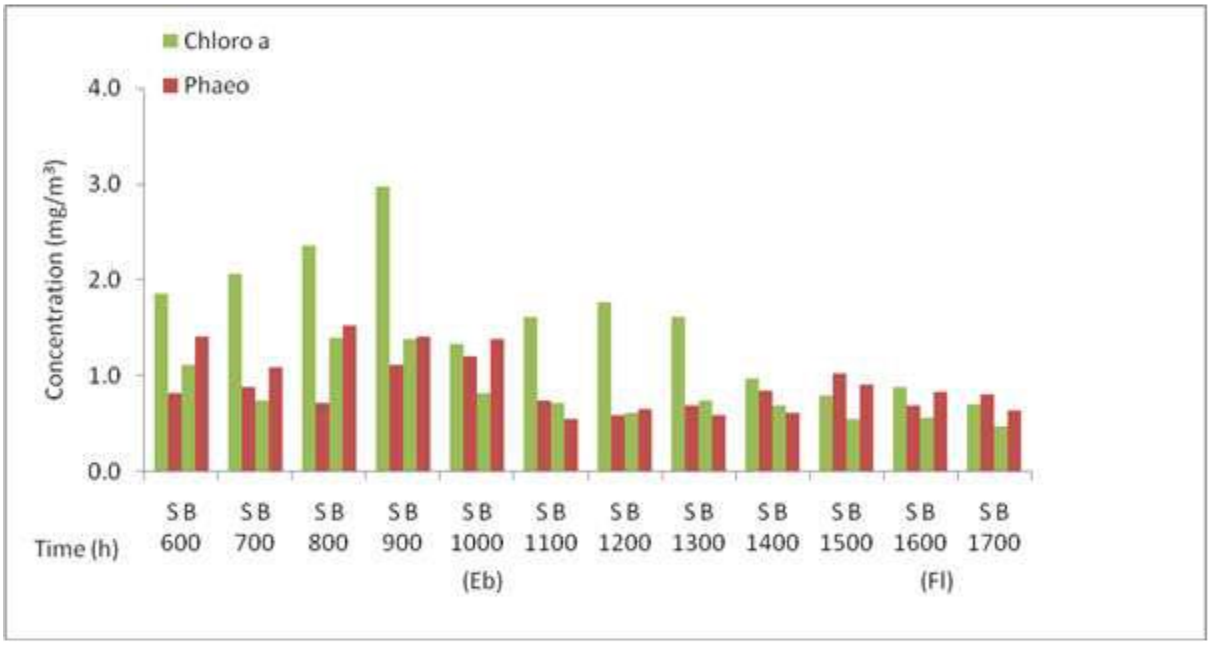


Figure 4.16.7: Temporal Variation of Phytopigments at station VS9 on 30.12.2015.

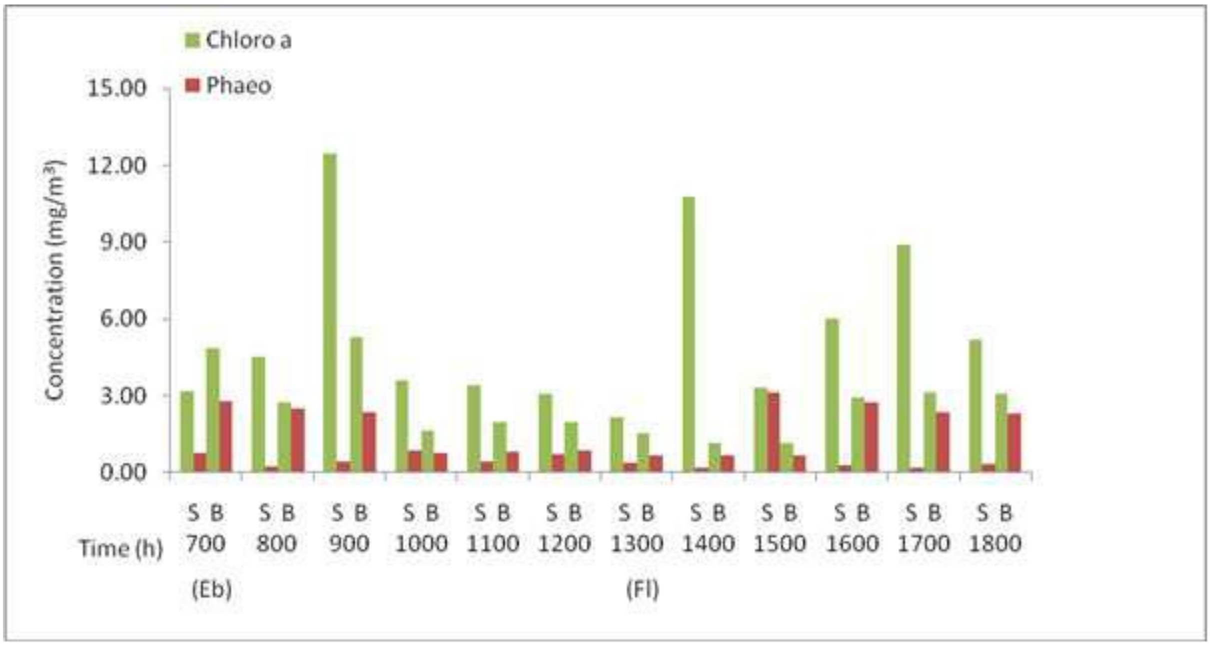


Figure 4.16.8: Temporal Variation of Phytopigments at station VS9 on 25.03.2016.

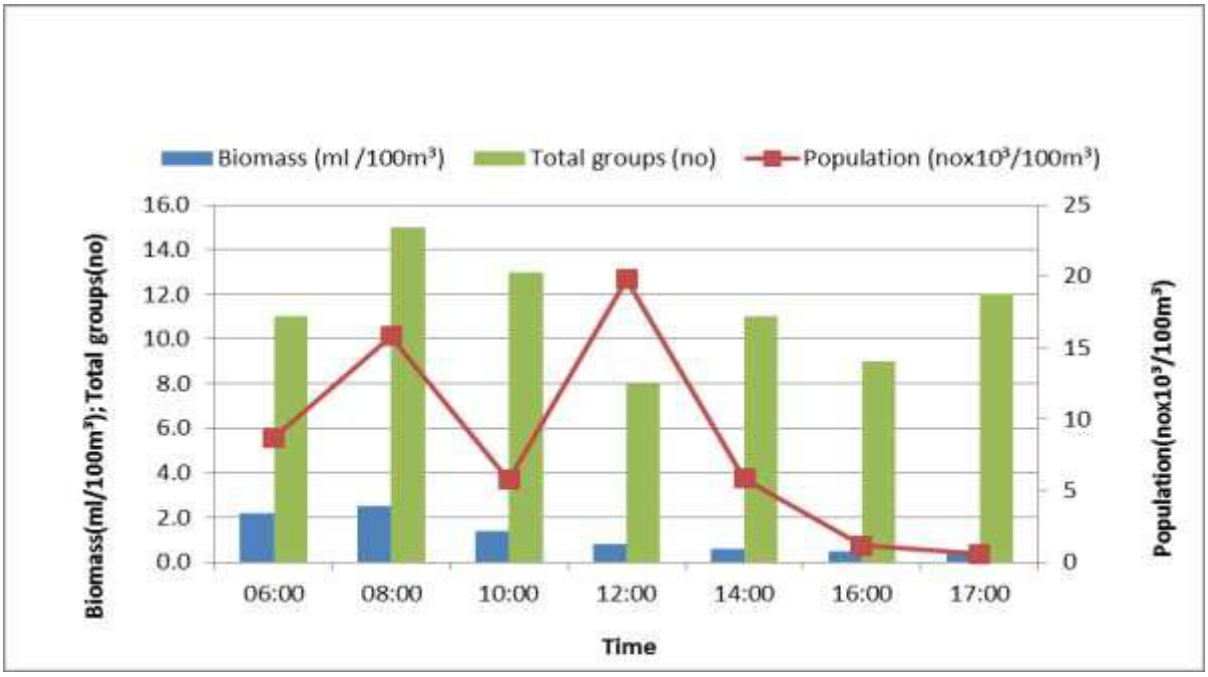


Figure 4.16.9: Temporal Variation of mesozooplankton at station VS4 on 28.12.2015

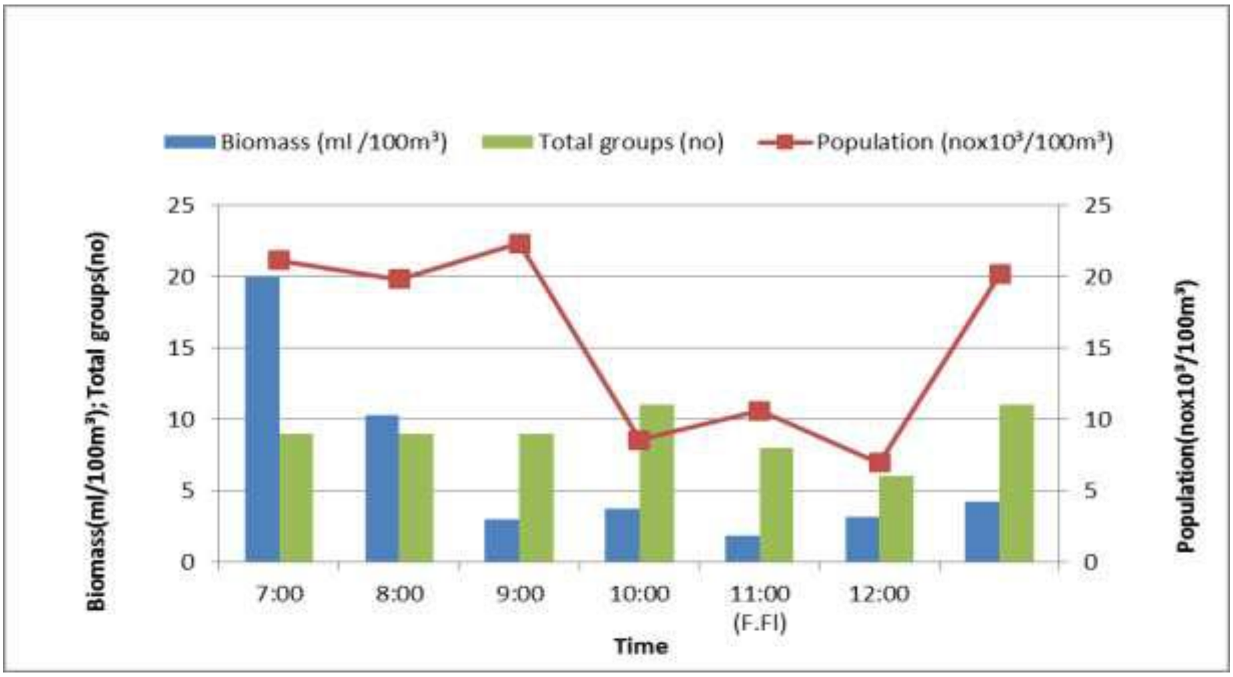


Figure 4.16.10: Temporal Variation of mesozooplankton at station VS4 on 22.03.2016

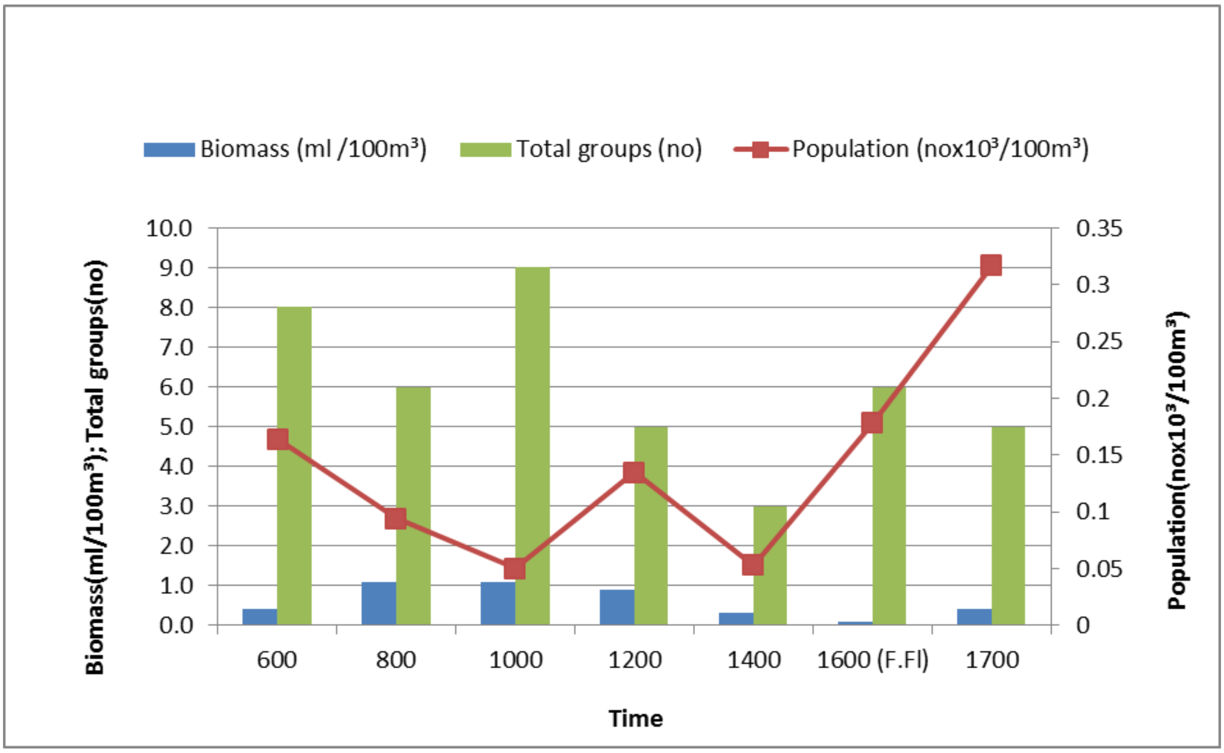


Figure 4.16.11: Temporal Variation of mesozooplankton at station VS9 on 30.12.2015

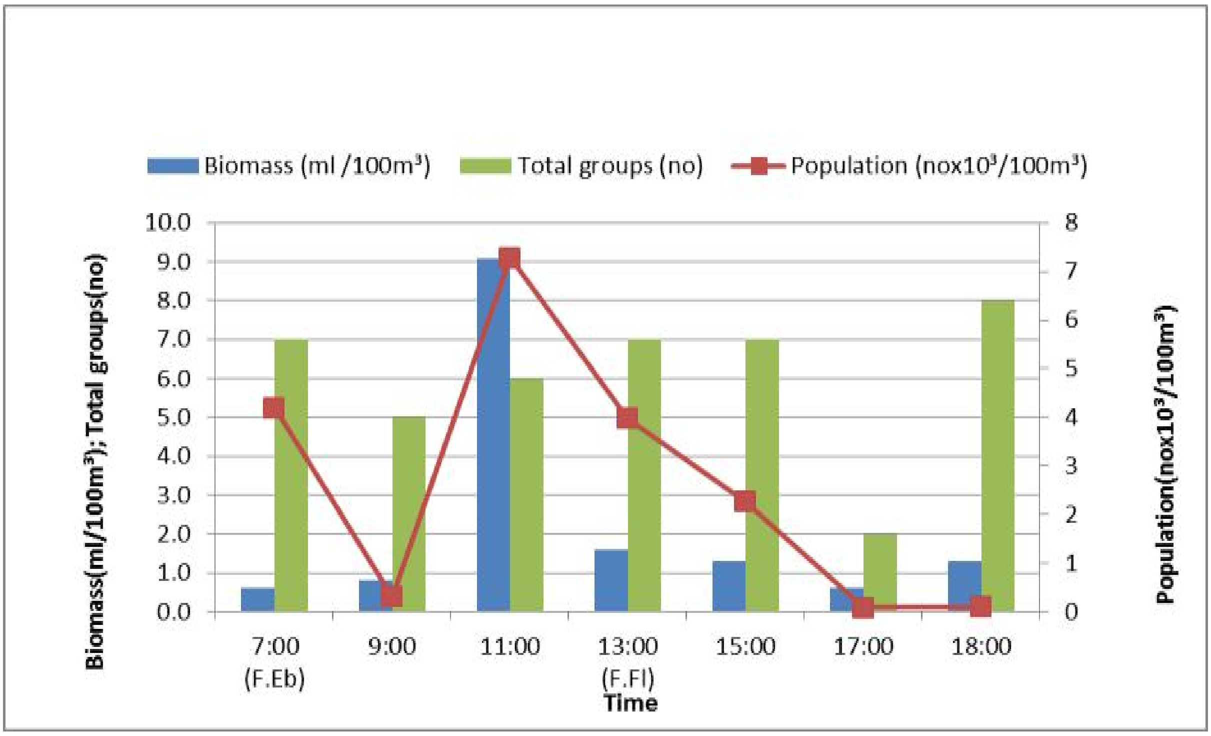


Figure 4.16.12: Temporal Variation of mesozooplankton at station VS9 on 25.03.2016

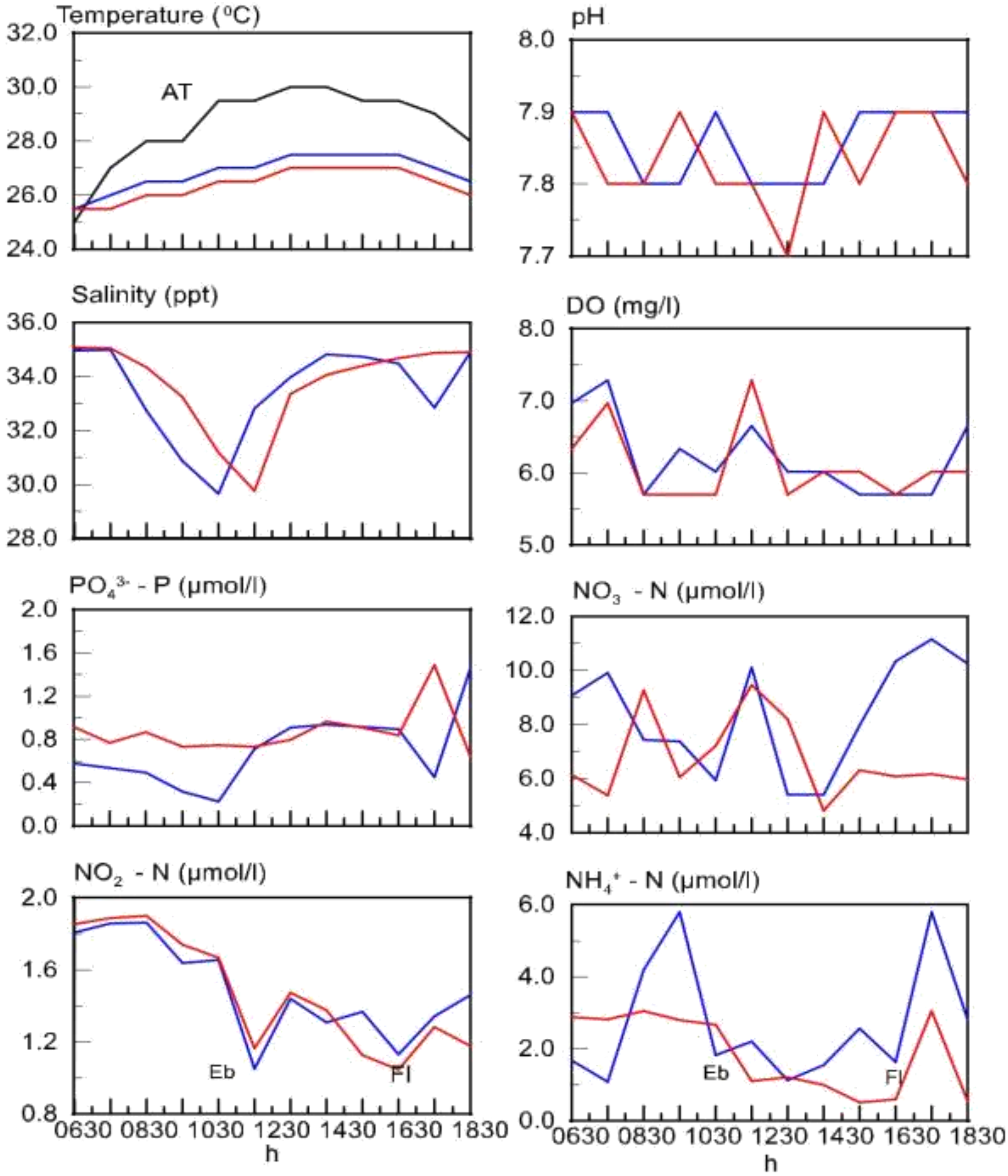


Figure 4.17.1: Temporal Variation of water quality parameters at J5 (—— S) & (—— B) on 3rd Jan 2016

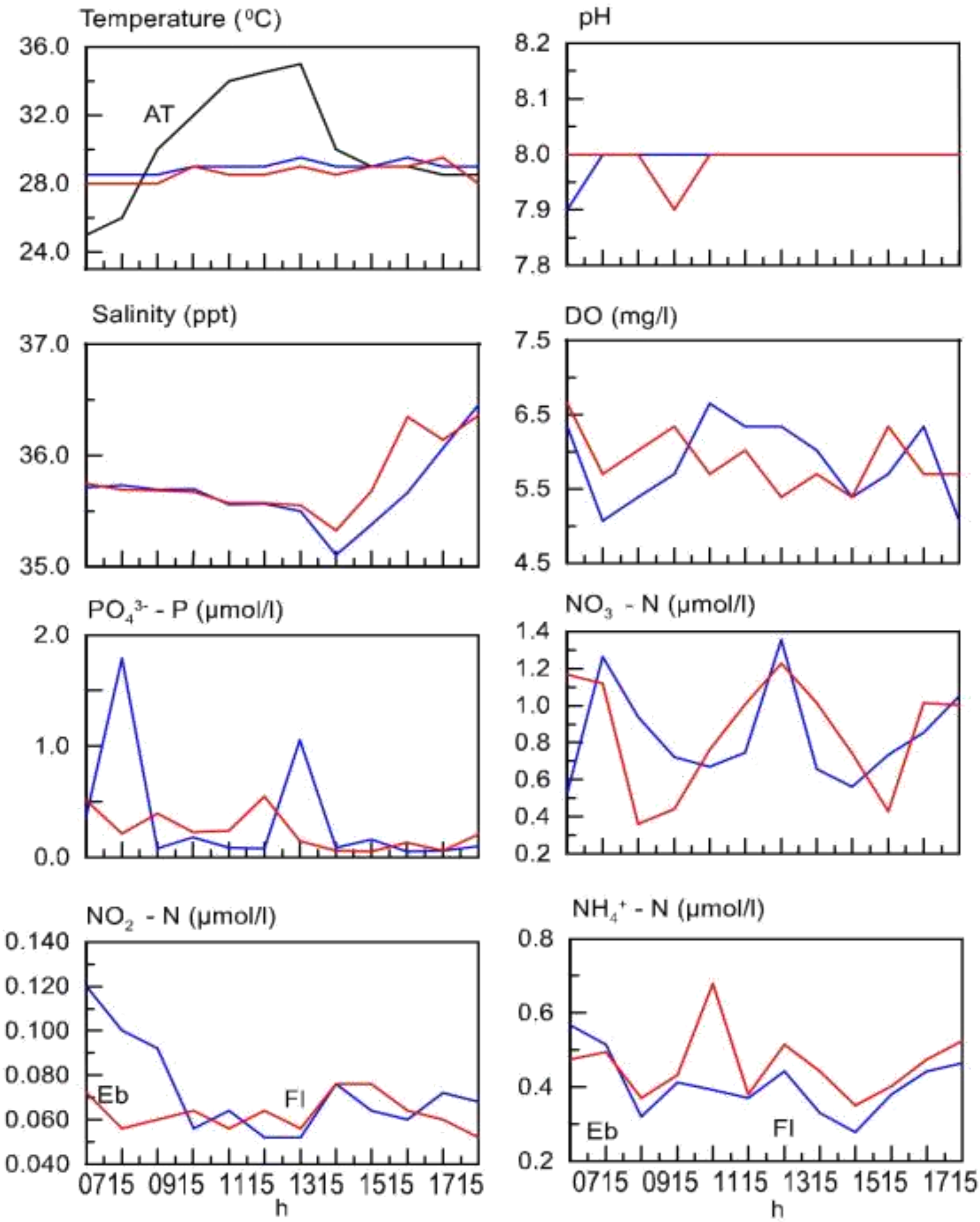


Figure 4.17.2: Temporal Variation of water quality parameters at J5 (——— S) & (——— B) on 18th March 2016

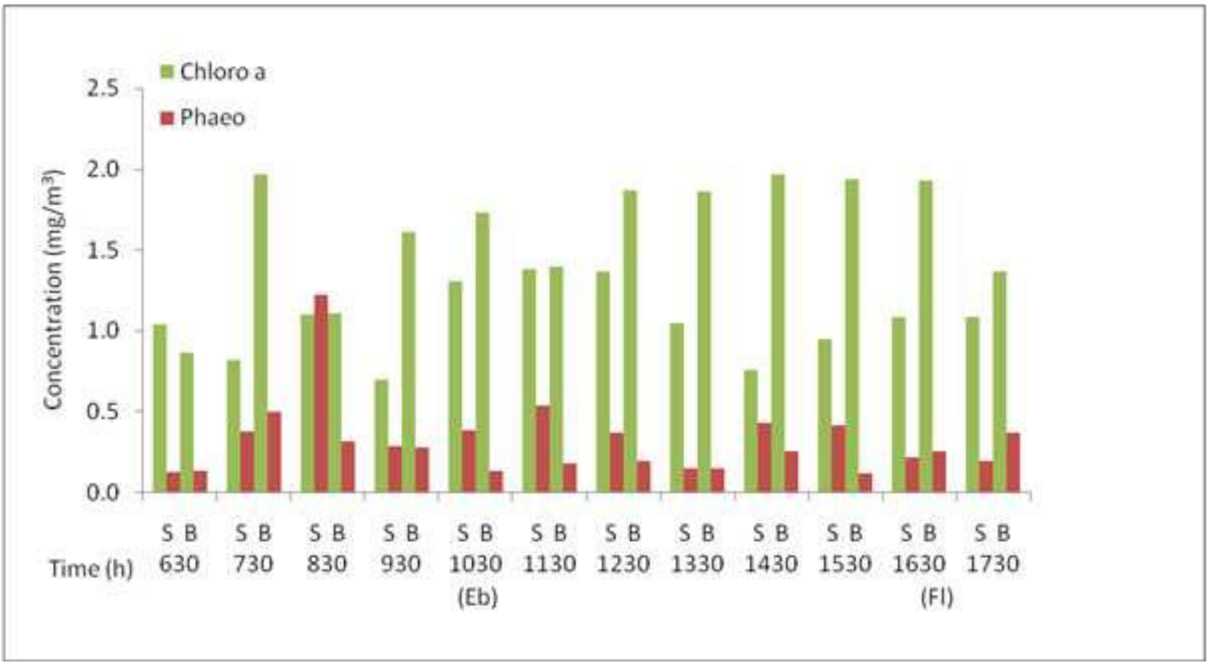


Figure 4.17.3: Temporal Variation of Phytopigments at station J5 on 03.01.2016.

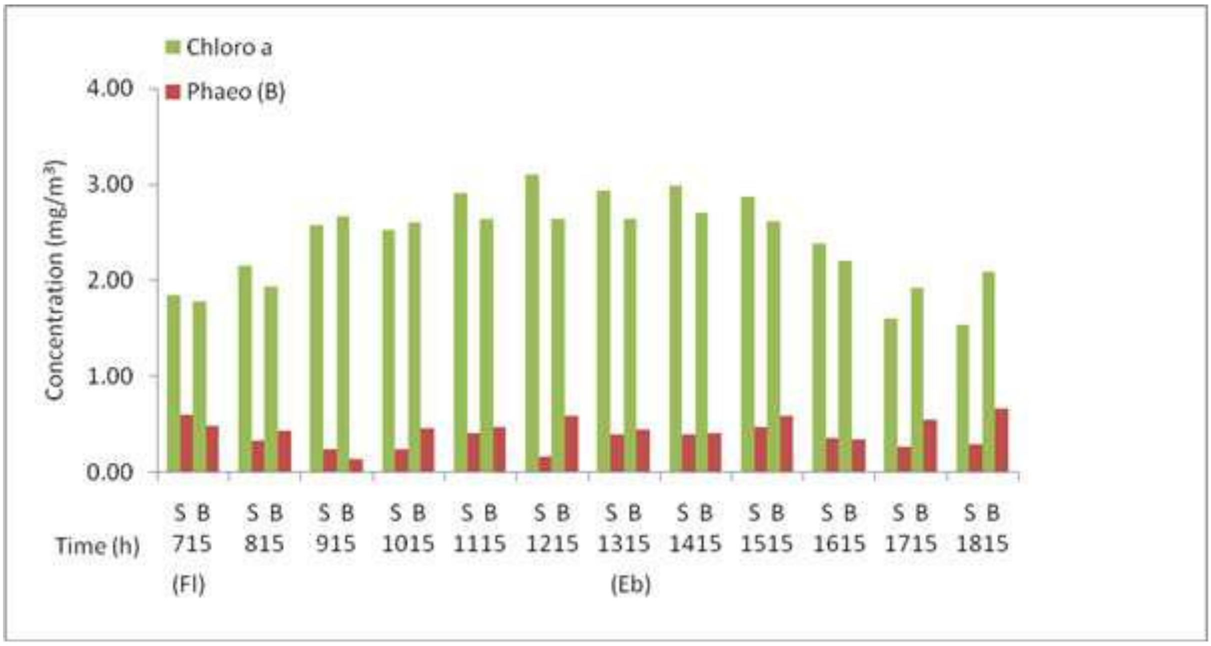


Figure 4.17.4: Temporal Variation of Phytopigments at station J5 on 18.03.2016.

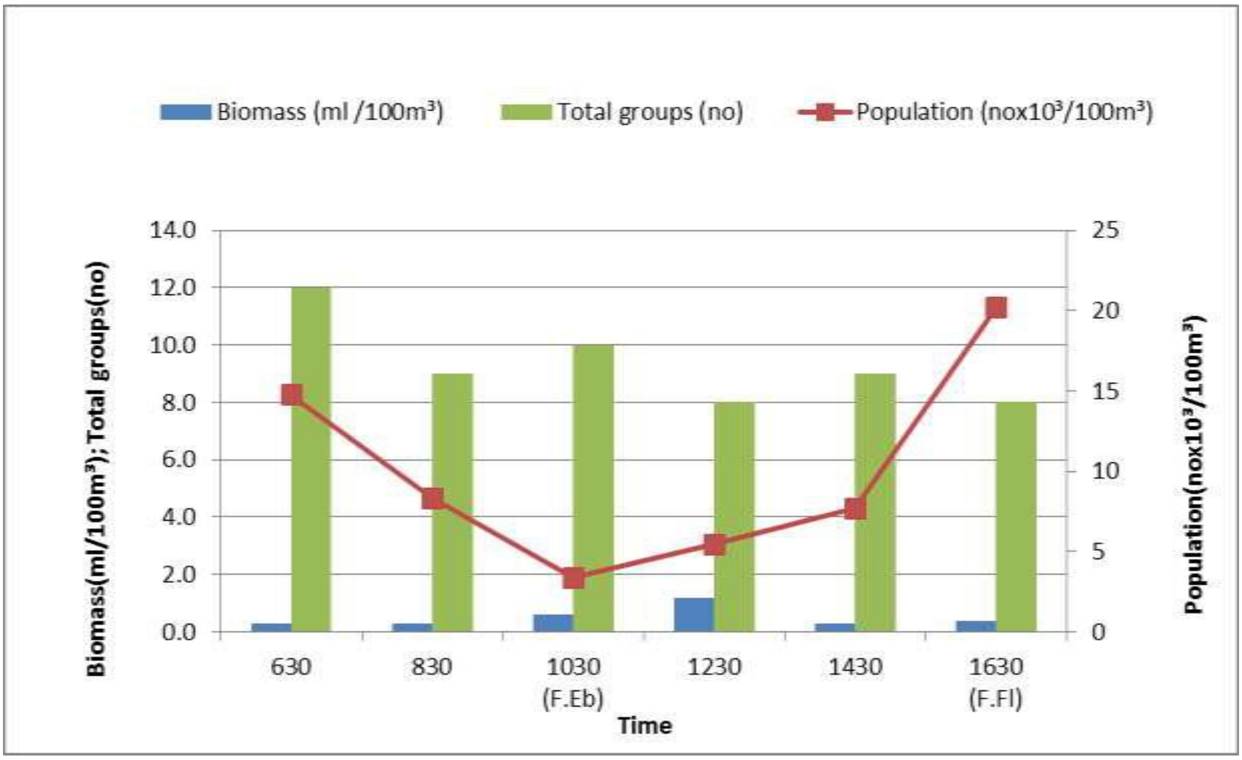


Figure 4.17.5: Temporal Variation of mesozooplankton at station J5 on 03.01.2016

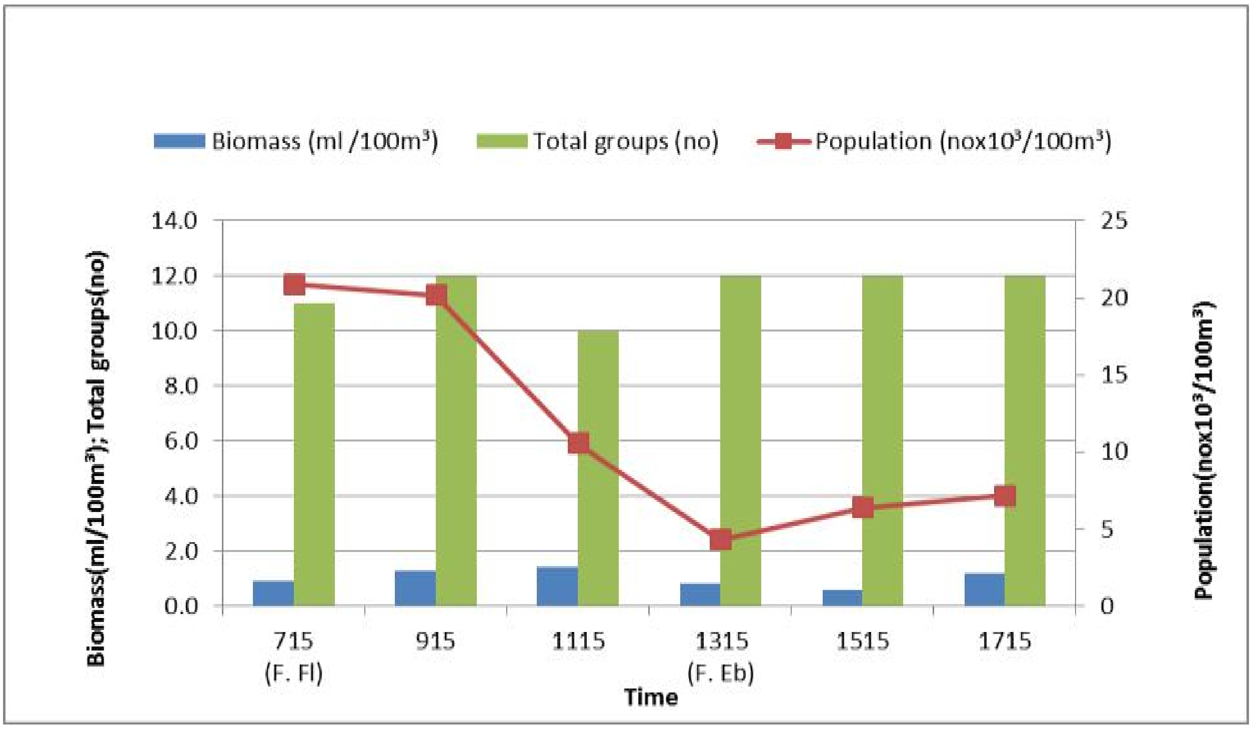


Figure 4.17.6: Temporal Variation of mesozooplankton at station J5 on 18.03.2016

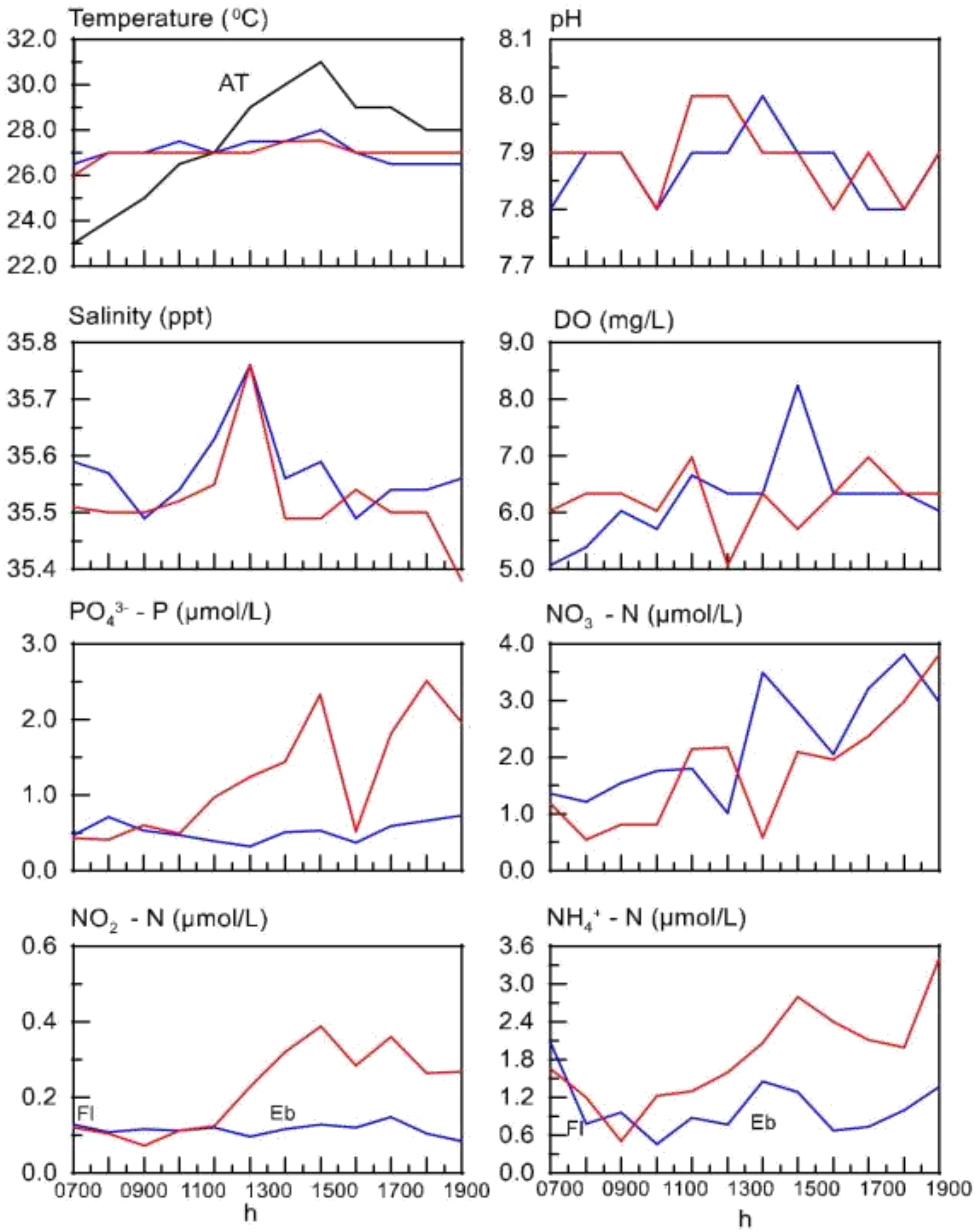


Figure 4.18.1: Temporal Variation of water quality parameters at R4 (——— S) & (——— B) on 6th Jan 2016

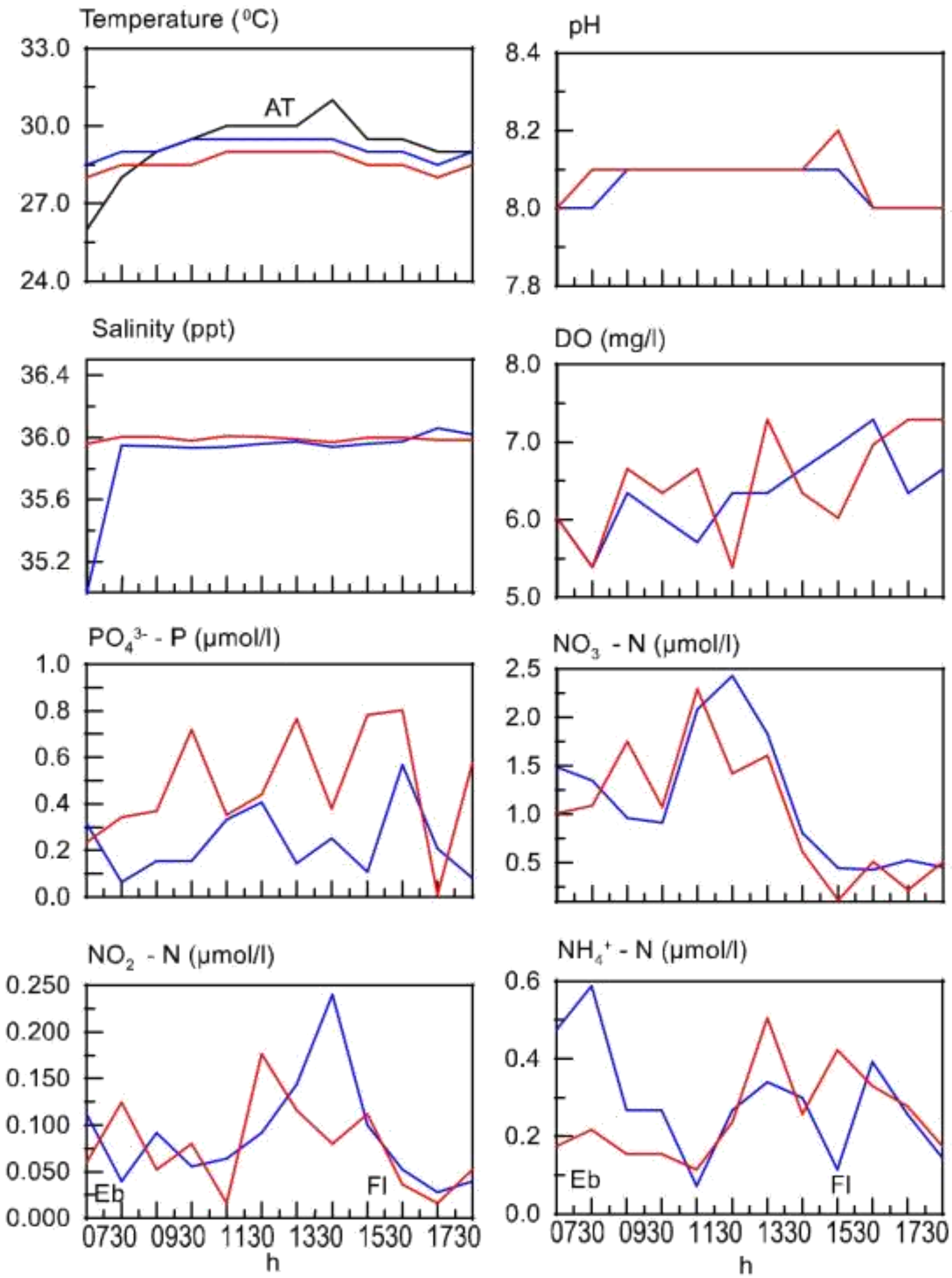


Figure 4.18.2: Temporal Variation of water quality parameters at R4 (——— S) & (——— B) on 14th March 2016

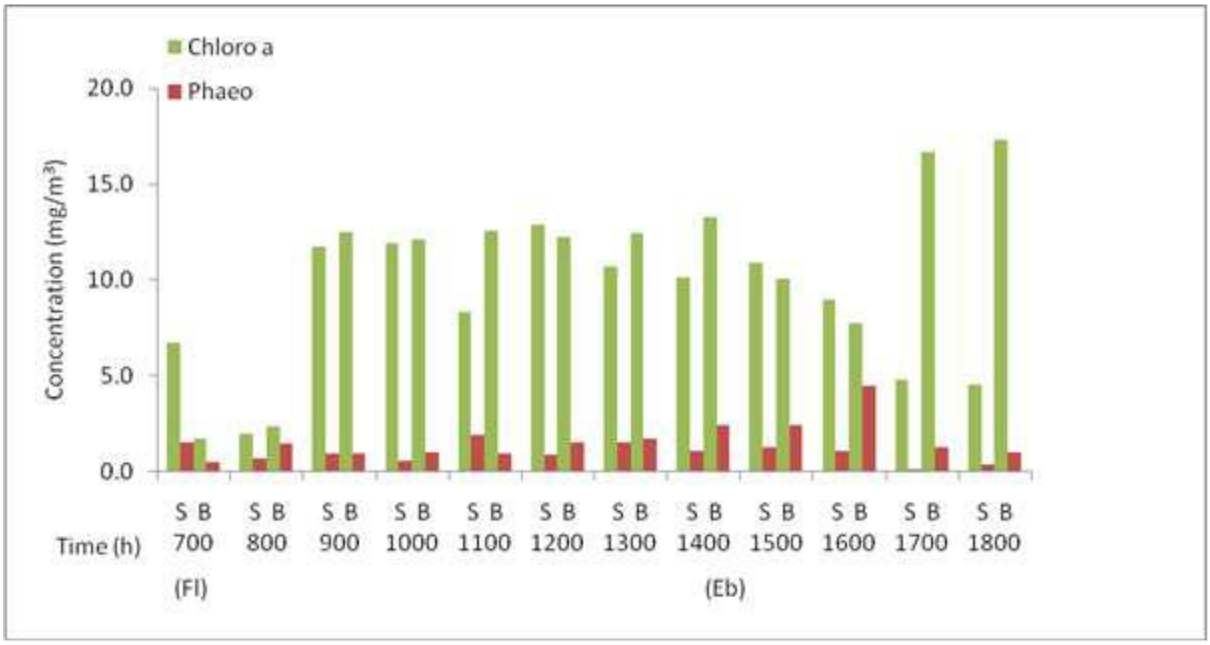


Figure 4.18.3: Temporal Variation of Phytopigments at station R4 on 06.01.2016.

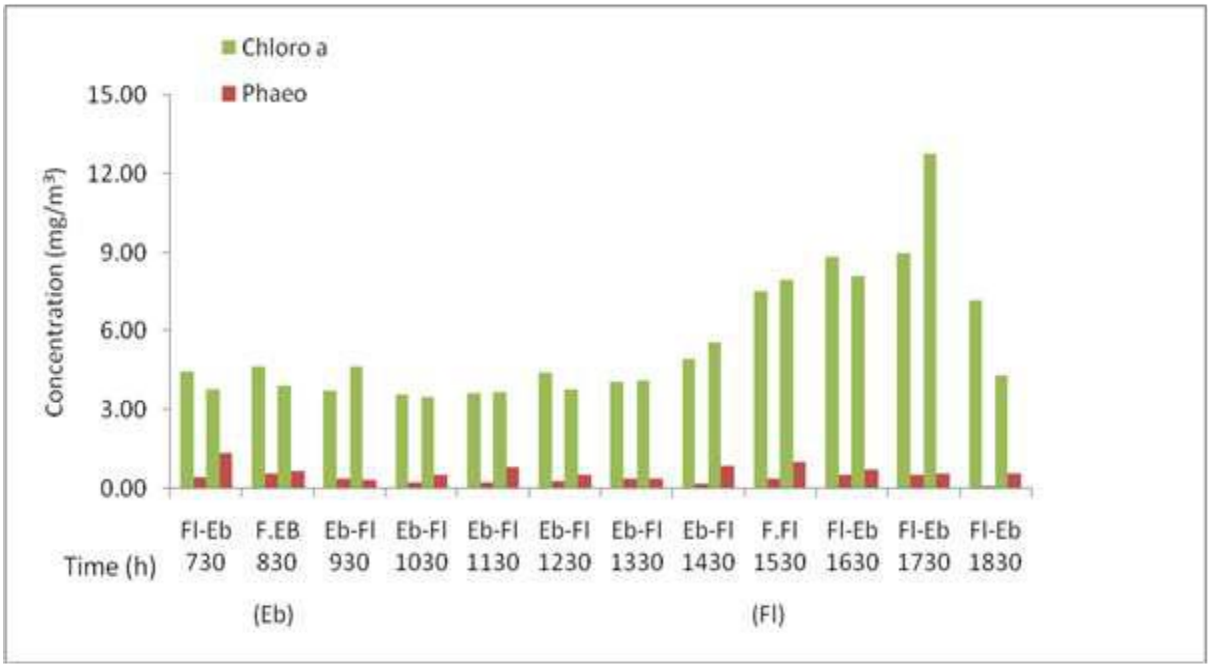


Figure 4.18.4: Temporal Variation of Phytopigments at station R4 on 14.03.2016.

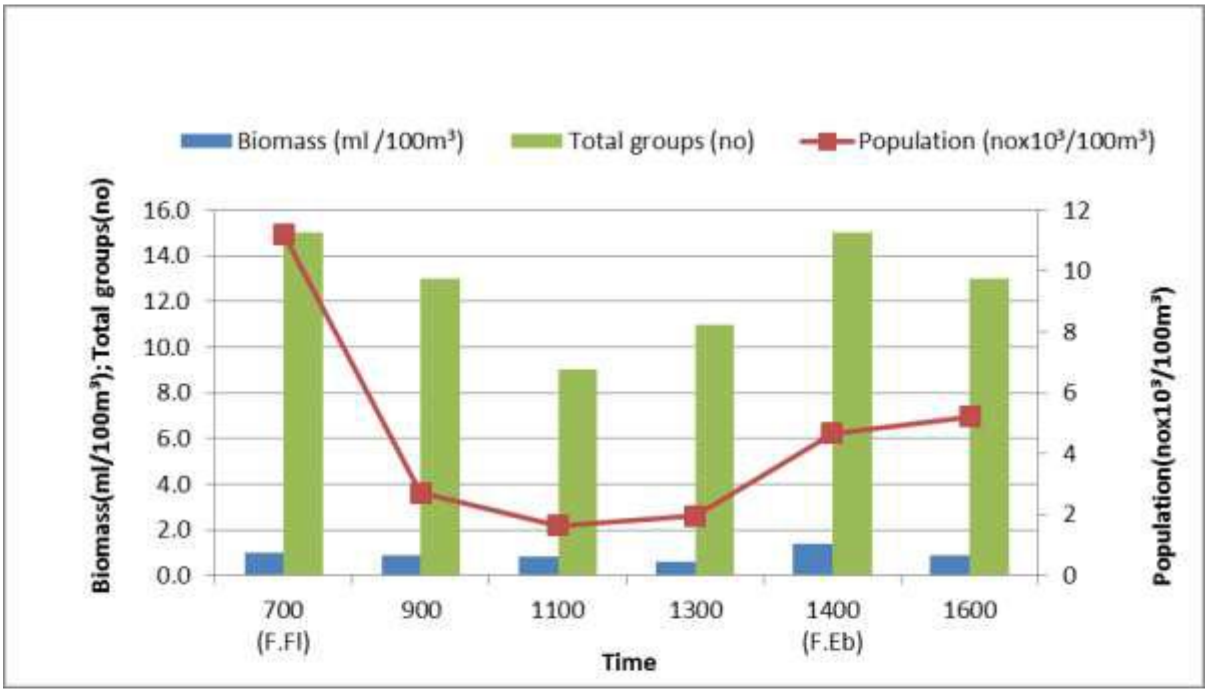


Figure 4.18.5: Temporal Variation of mesozooplankton at station R4 on 06.01.2016

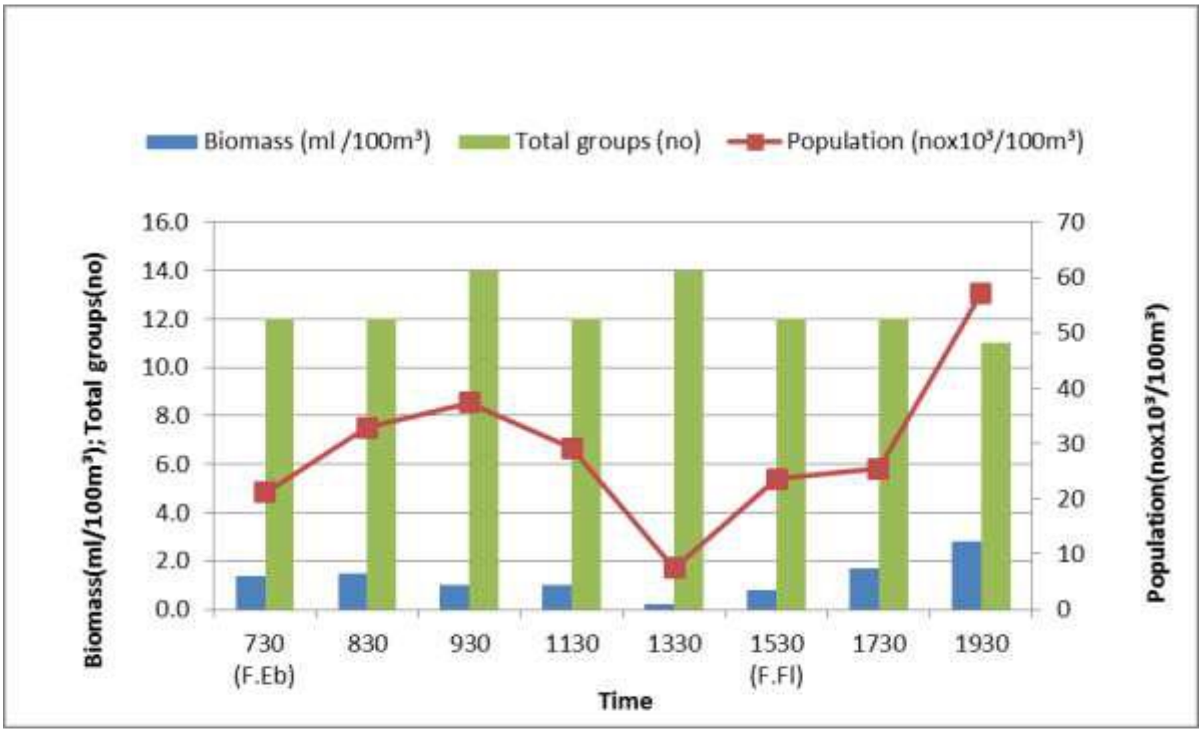


Figure 4.18.6: Temporal Variation of mesozooplankton at station R4 on 14.03.2016

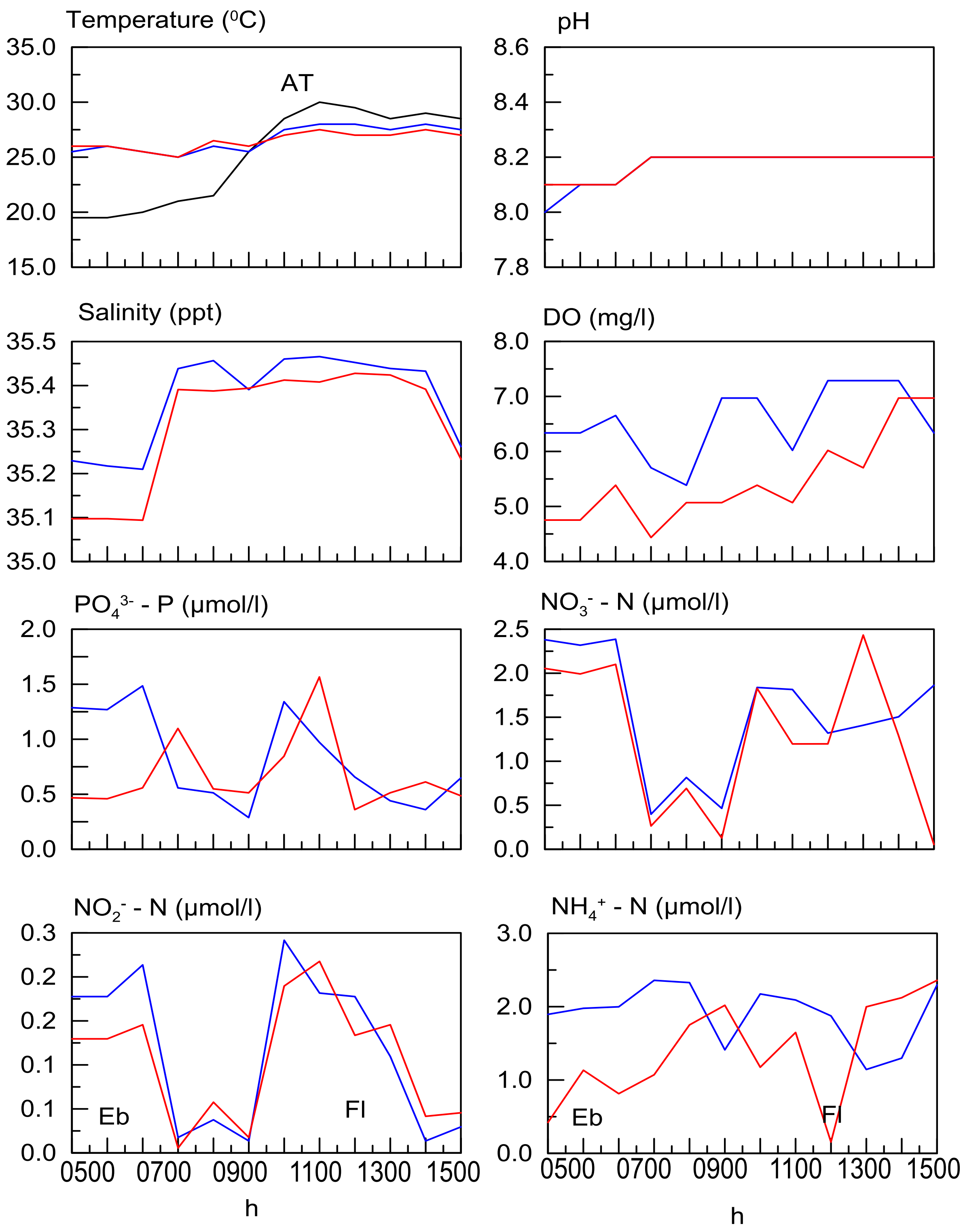


Figure 4.19.1: Temporal Variation of water quality parameters at VJ4 (S) & (B) on 12th Jan 2016

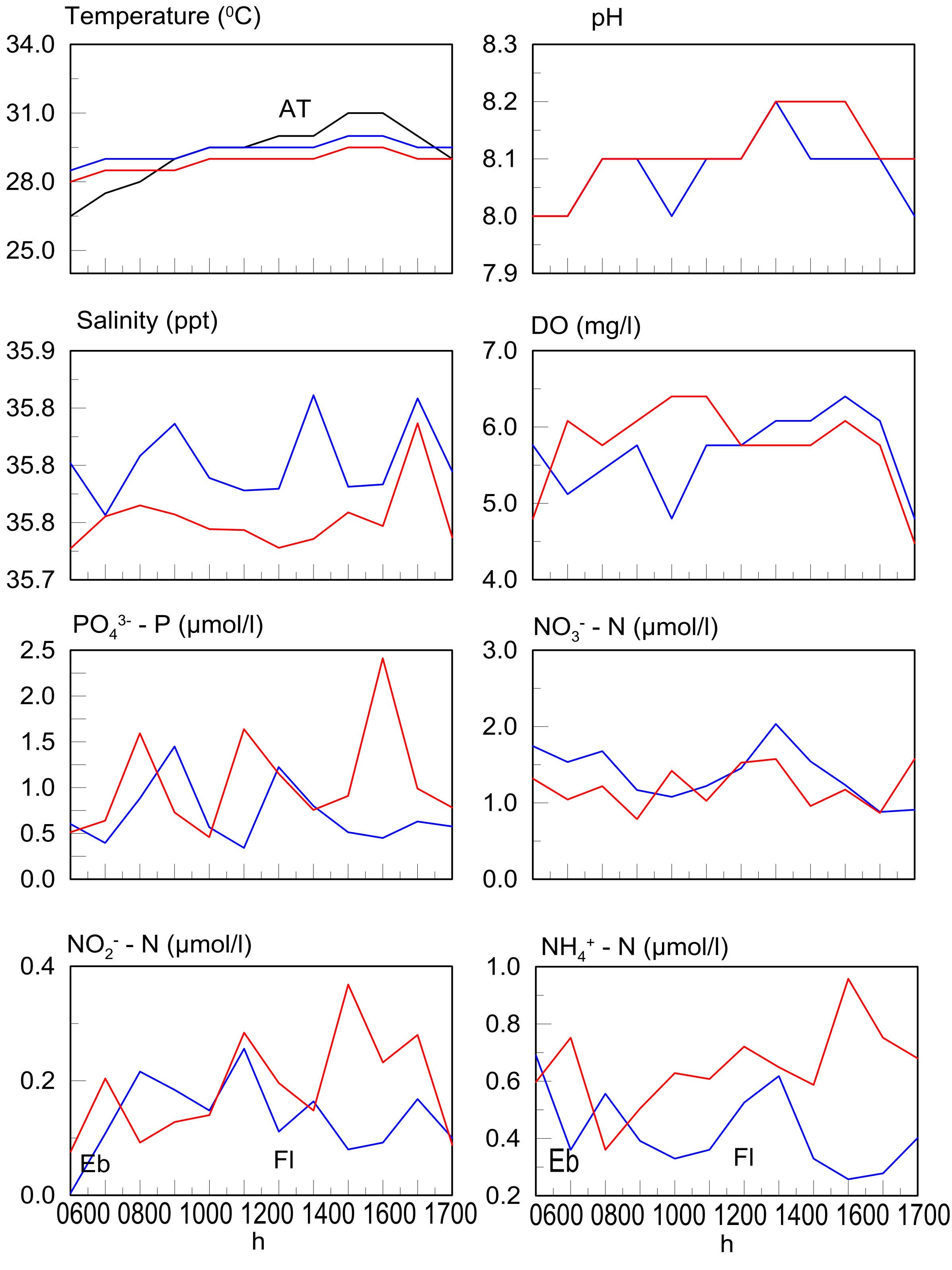


Figure 4.19.2: Temporal Variation of water quality parameters at VJ4 (——— S) & (——— B) on 11th March 2016

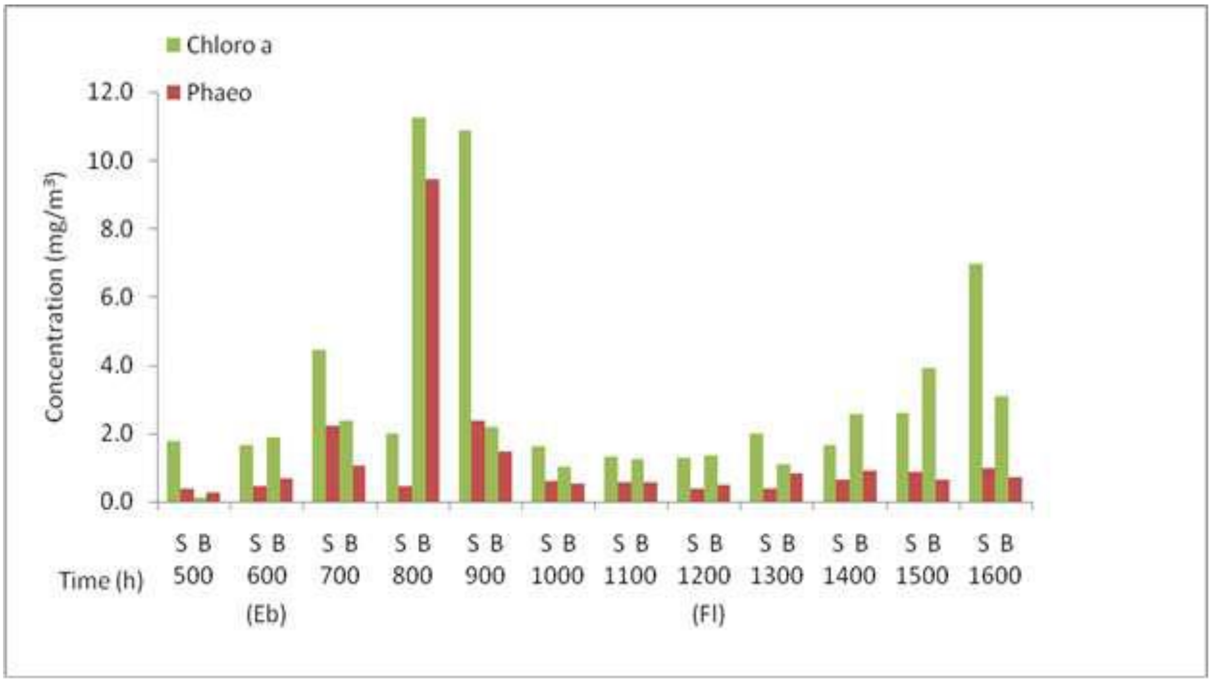


Figure 4.19.3: Temporal Variation of Phytopigments at station VJ4 on 12.01.2016.

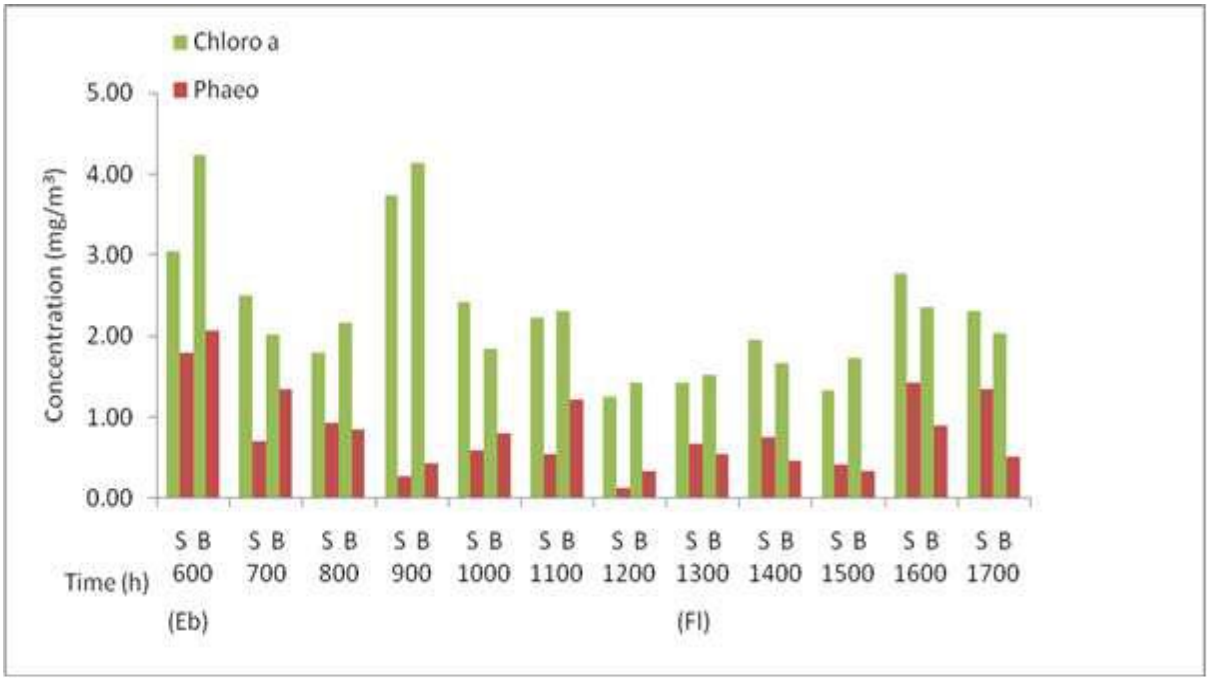


Figure 4.19.4: Temporal Variation of Phytopigments at station VJ4 on 11.03.2016.

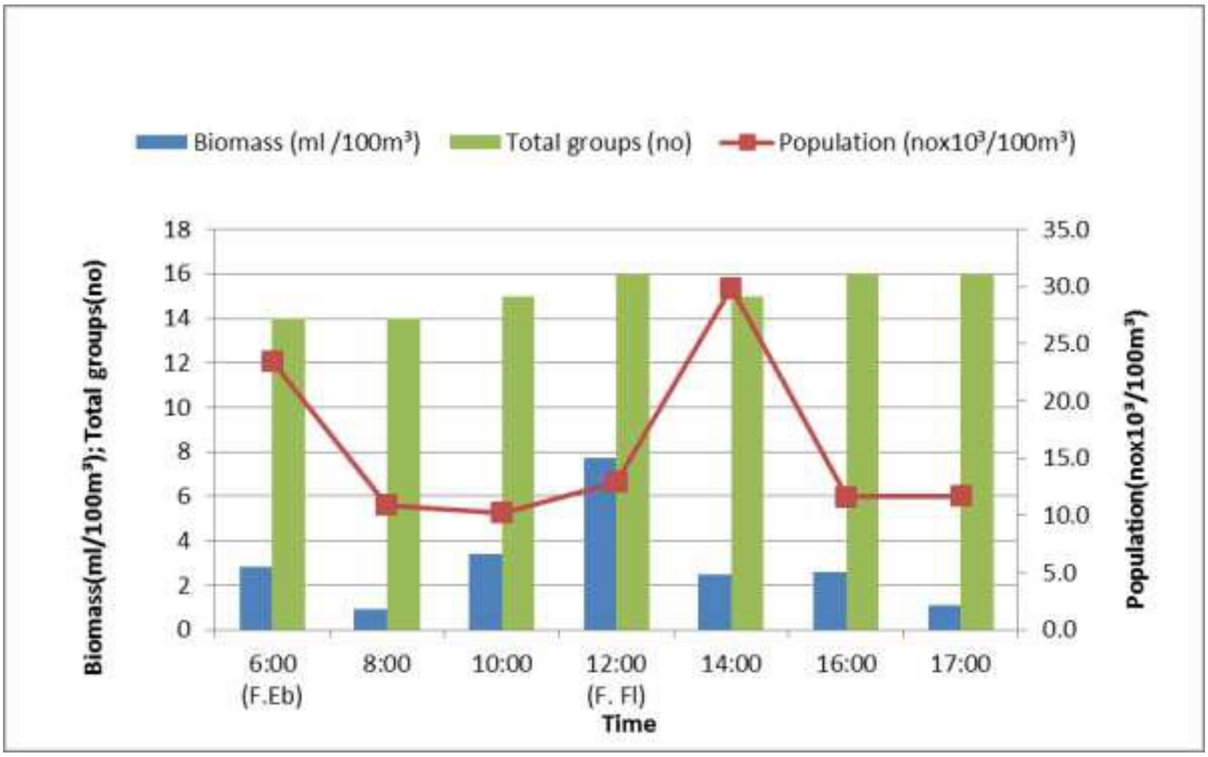


Figure 4.19.5: Temporal Variation of mesozooplankton at station VJ4 on 12.01.2016

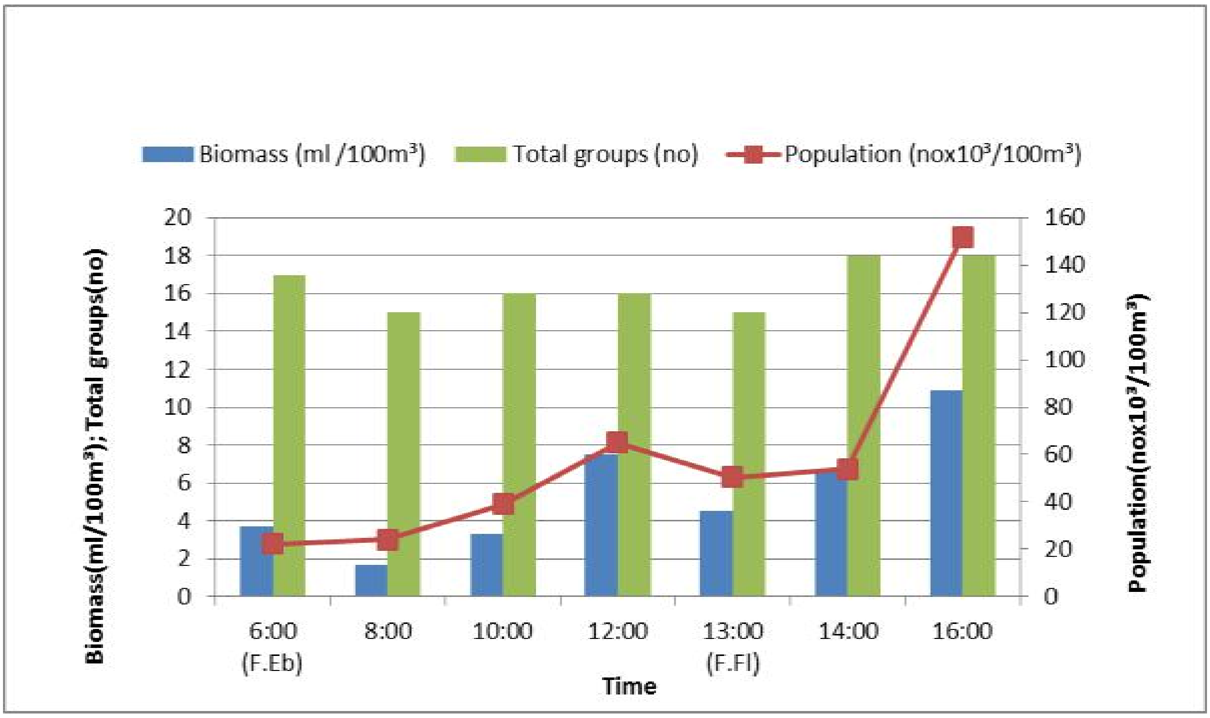


Figure 4.19.6: Temporal Variation of mesozooplankton at station VJ4 on 11.03.2016

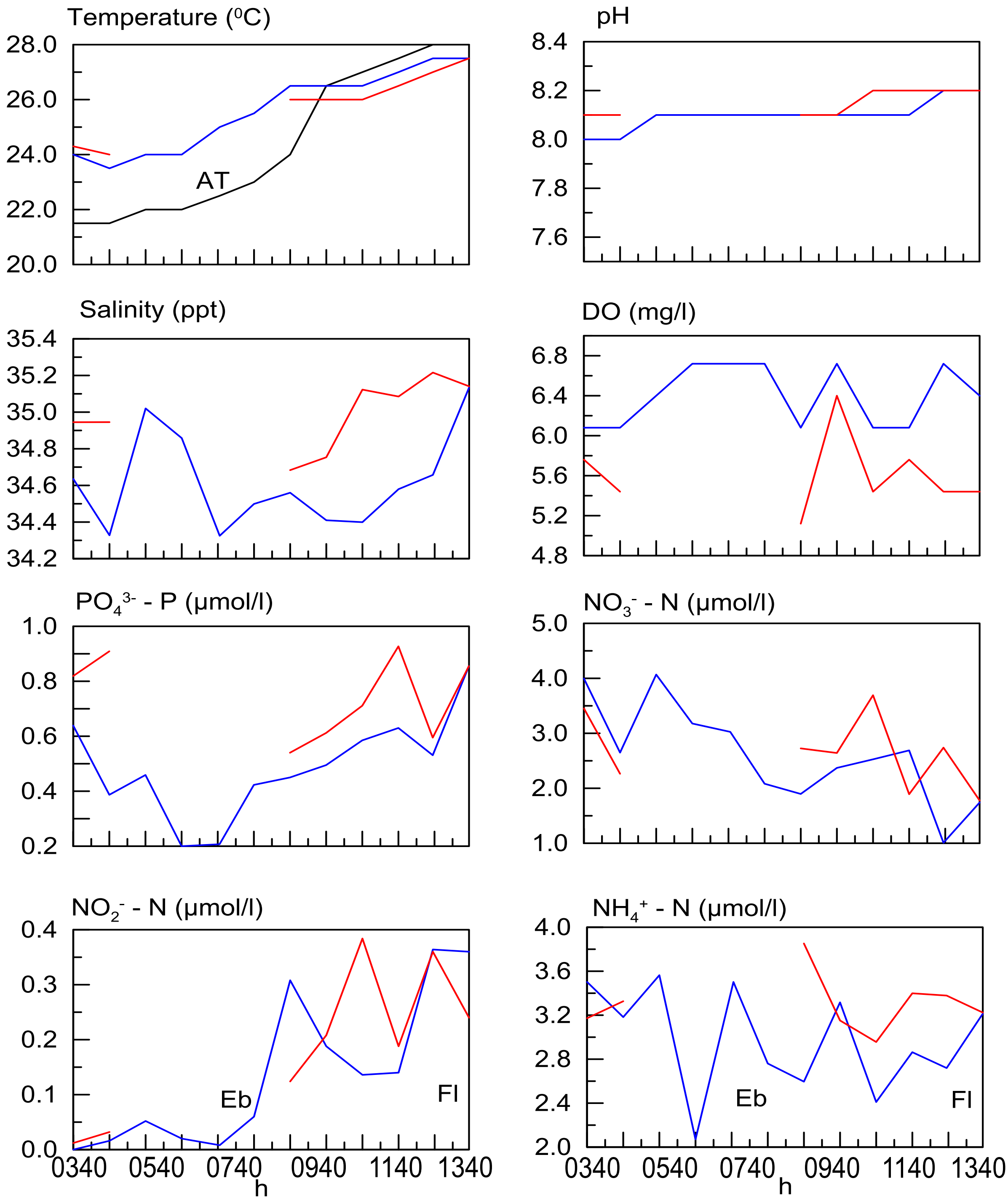


Figure 4.20.1: Temporal Variation of water quality parameters at D4 (S) & (B) on 14th Jan 2016

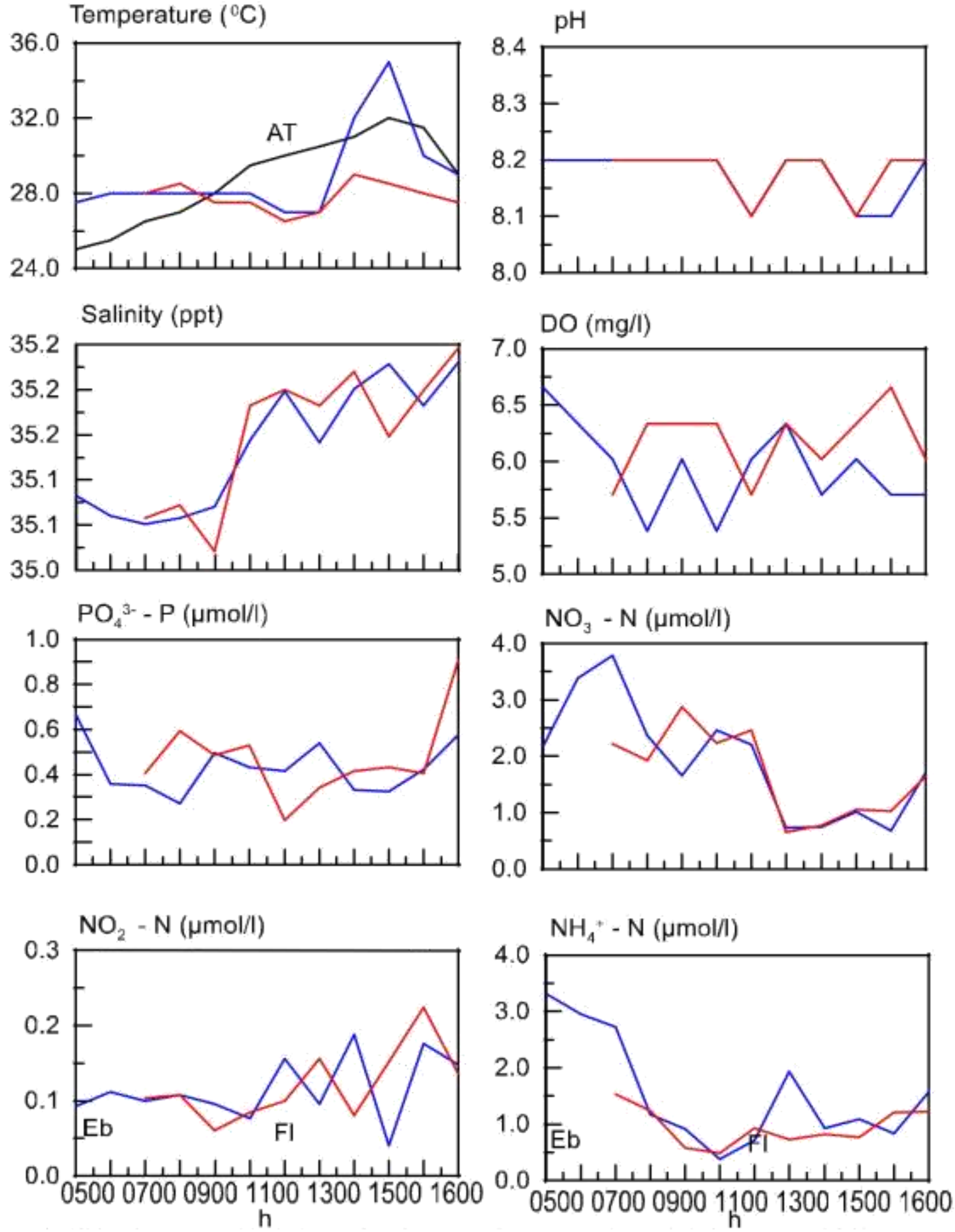


Figure 4.20.2: Temporal Variation of water quality parameters at D4 (S) & (B) on 9th March 2016

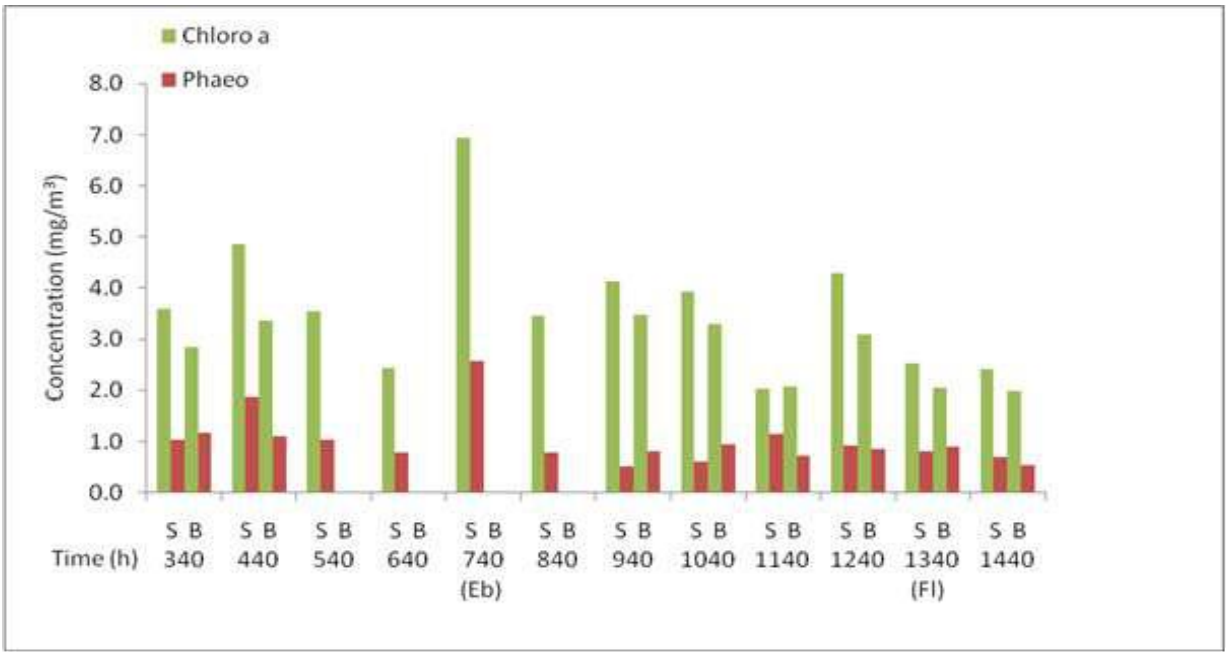


Figure 4.20.3: Temporal Variation of Phytopigments at station D4 on 14.01.2016.

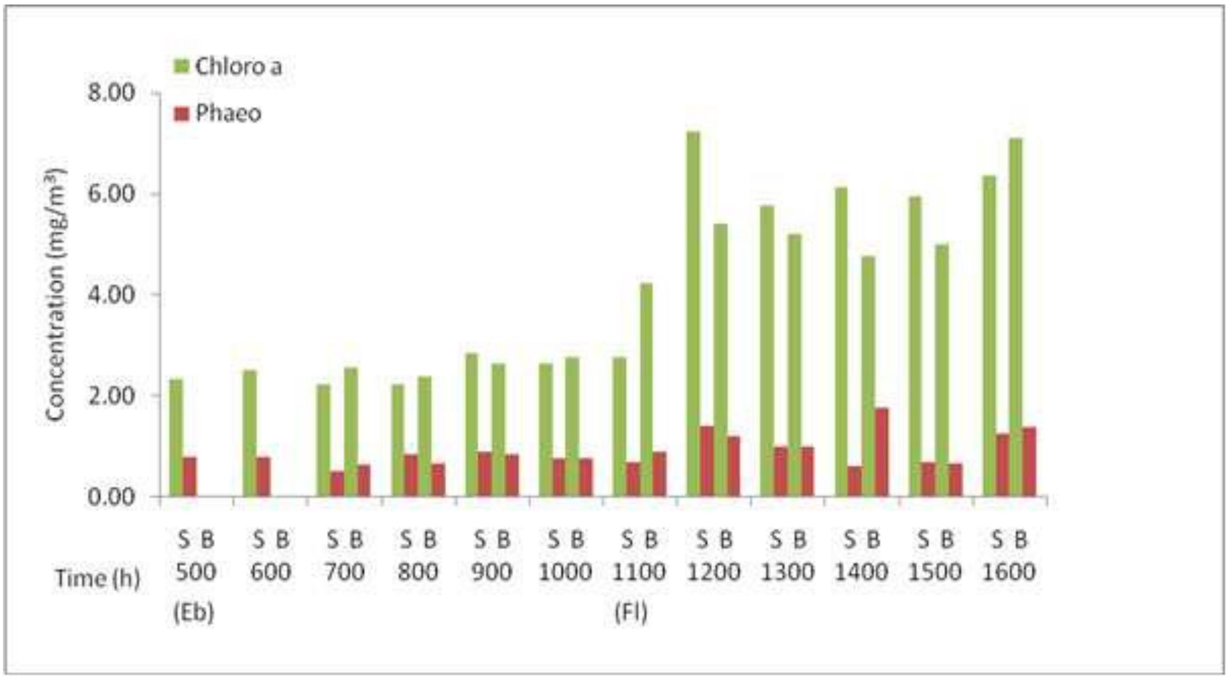


Figure 4.20.4: Temporal Variation of Phytopigments at station D4 on 09.03.2016.

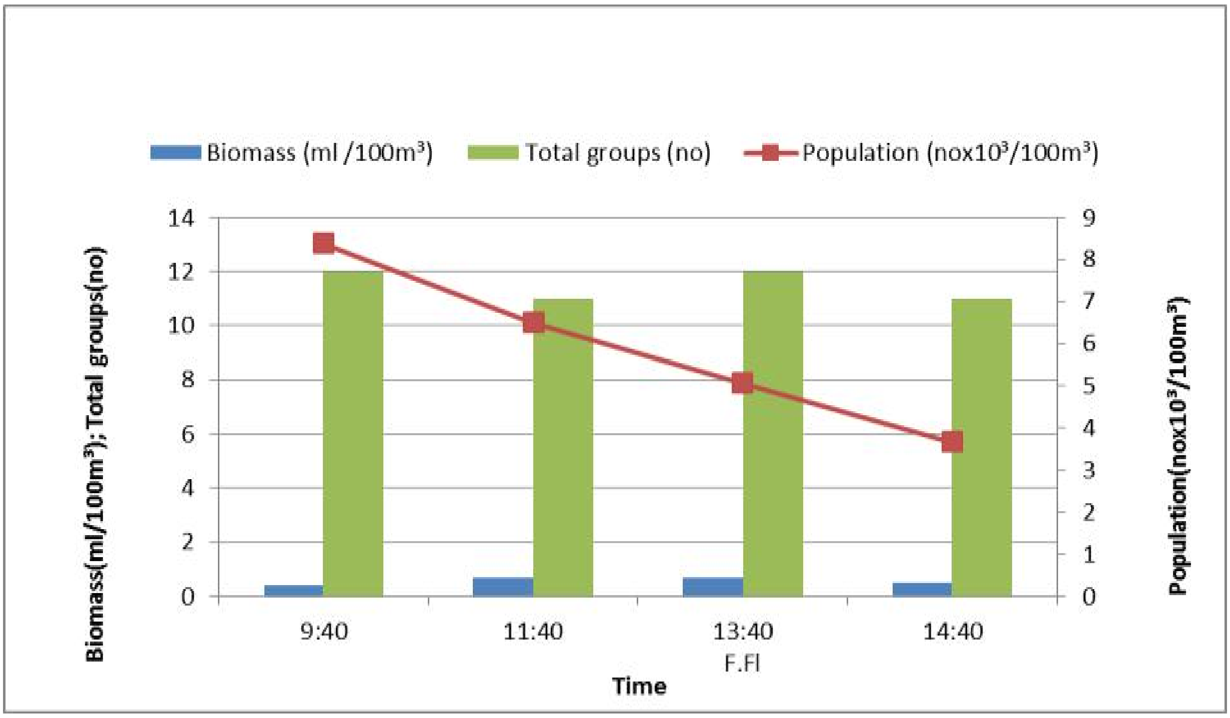


Figure 4.20.5: Temporal Variation of mesozooplankton at station D4 on 14.01.2016

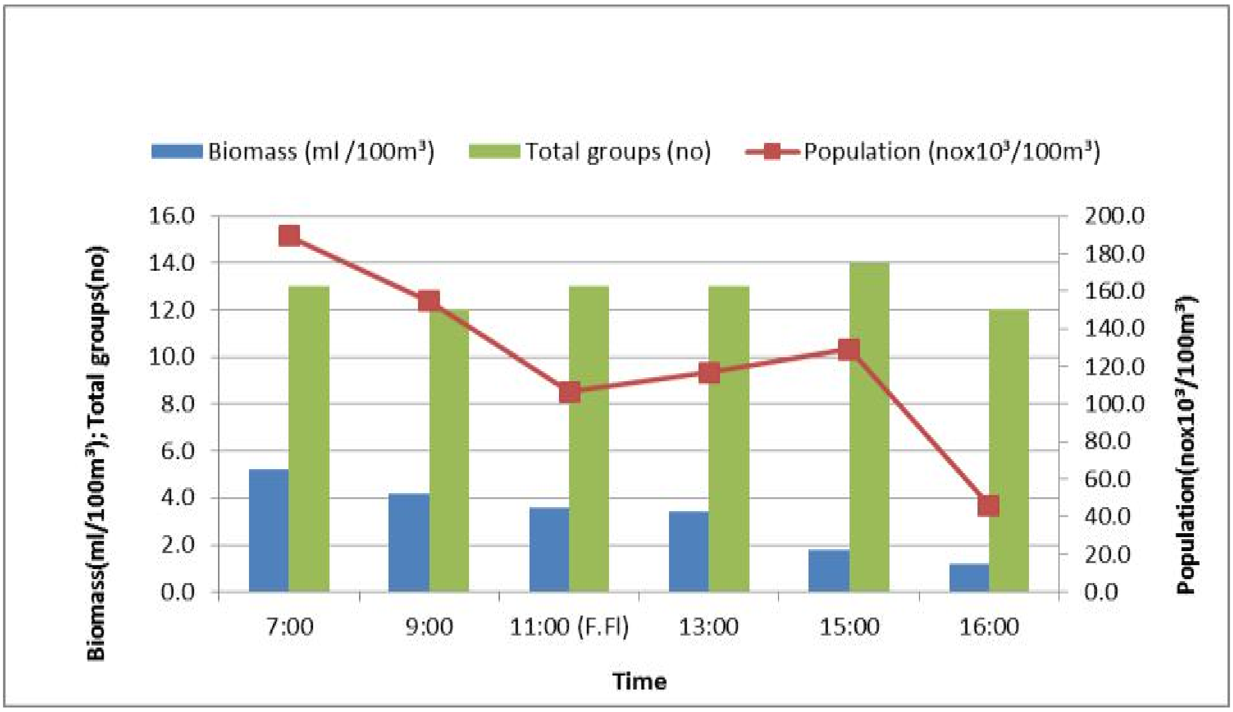


Figure 4.20.6: Temporal Variation of mesozooplankton at station D4 on 09.03.2016

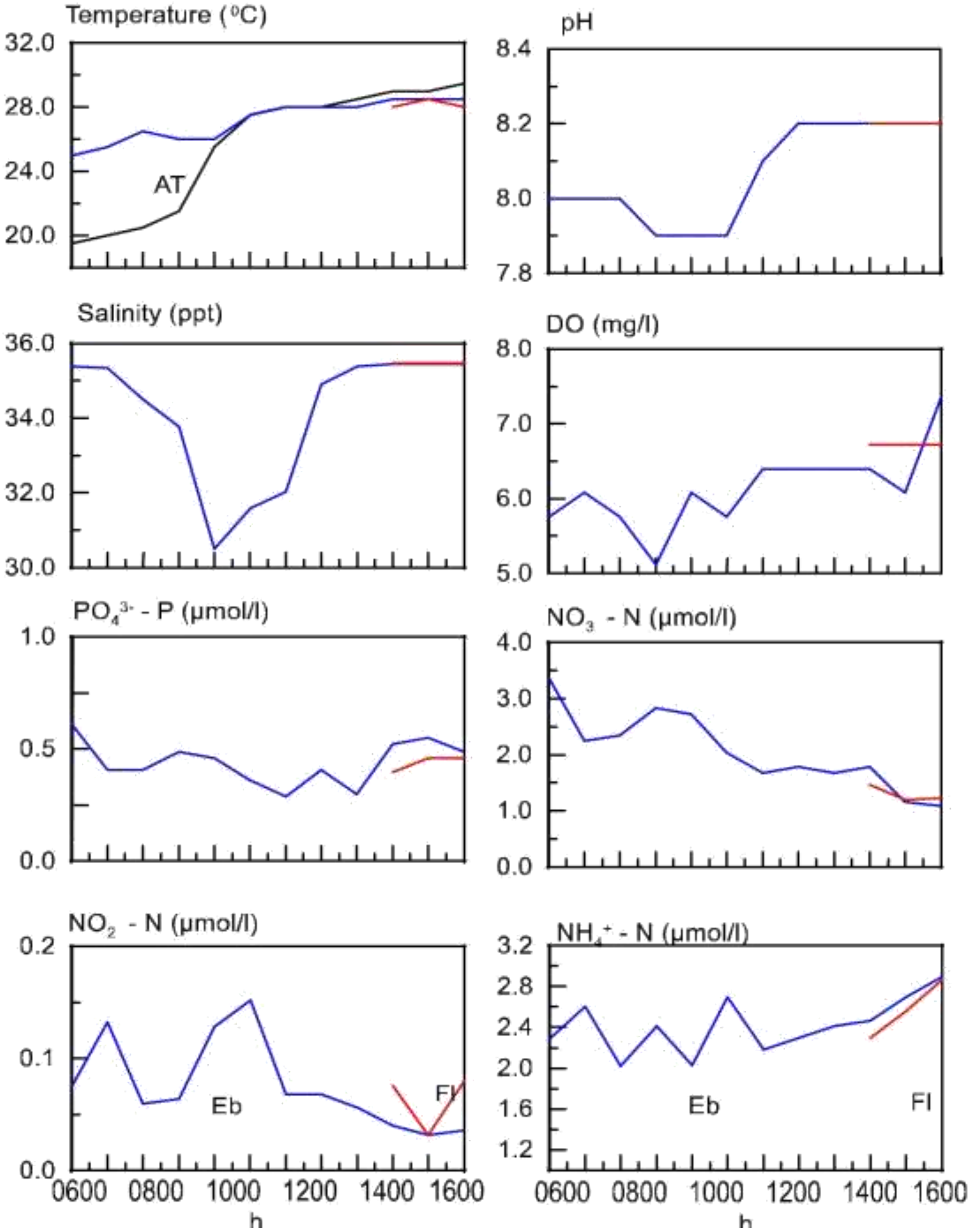


Figure 4.21.1: Temporal Variation of water quality parameters at ACH4 (S) & (B) on 16th Jan 2016

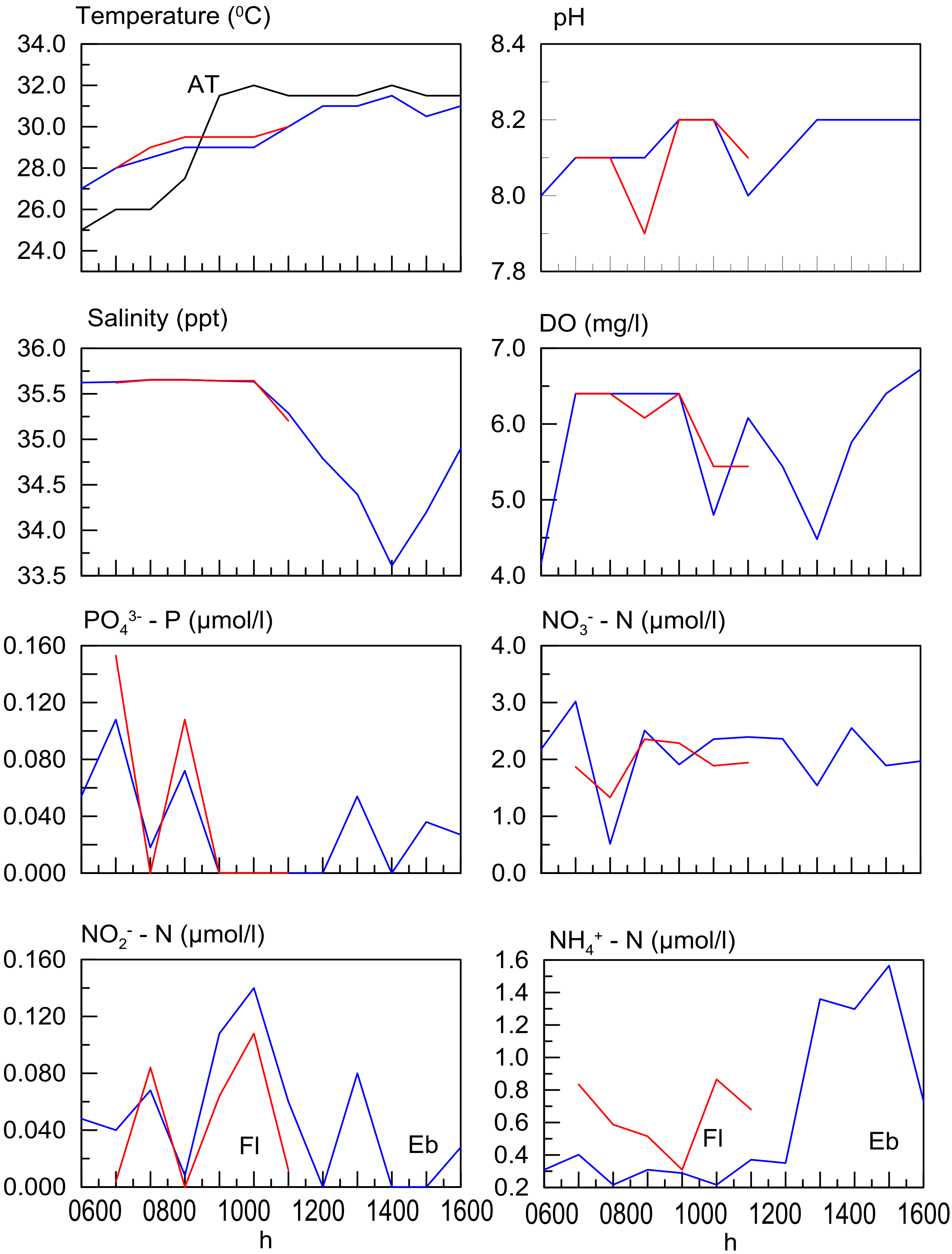


Figure 4.21.2: Temporal Variation of water quality parameters at ACH4 (—— S) & (—— B) on 6th March 2016

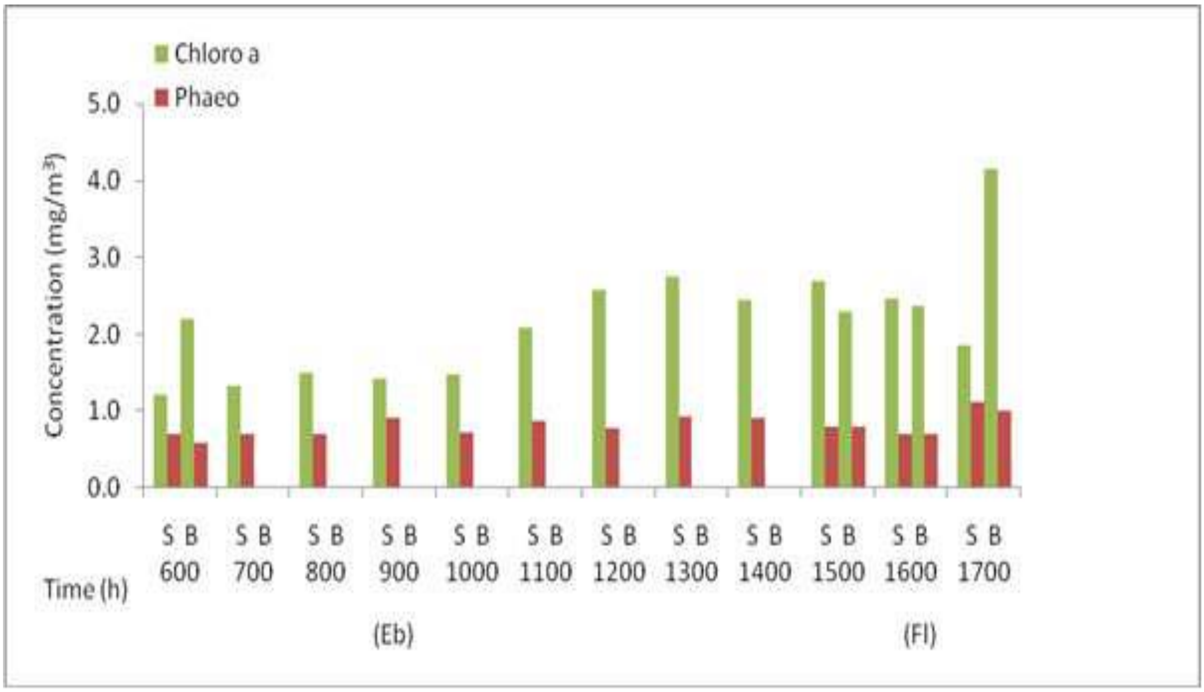


Figure 4.21.3: Temporal Variation of Phytopigments at station ACH4 on 16.01.2016.

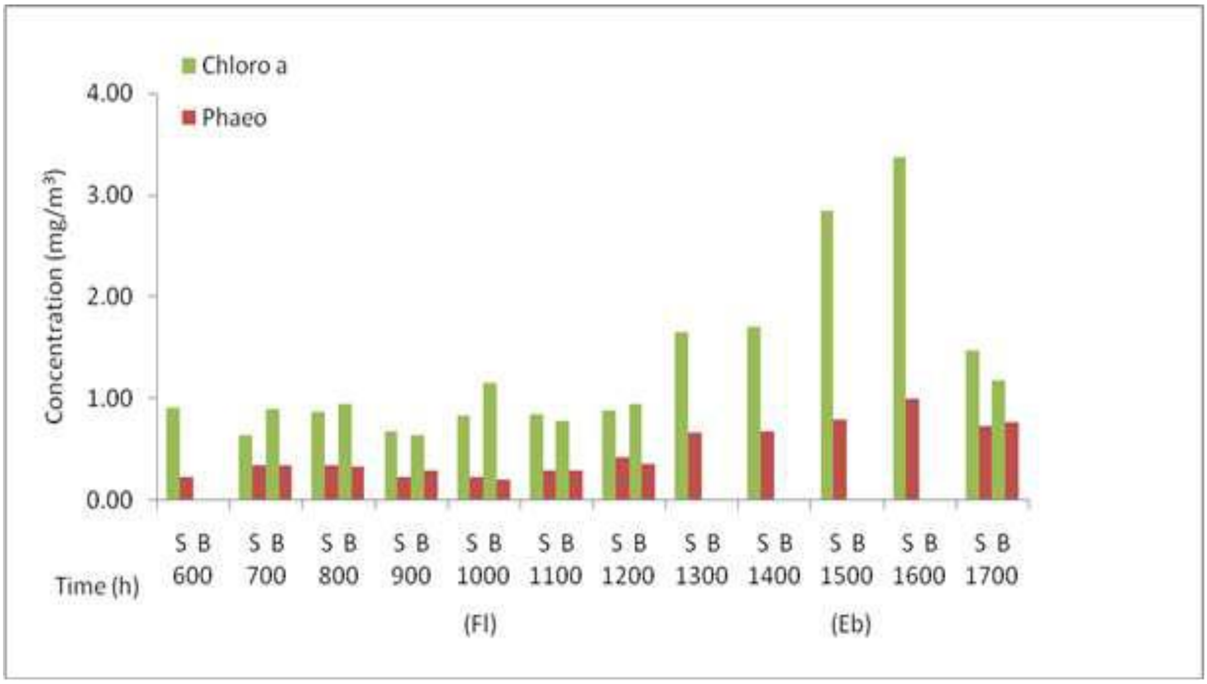


Figure 4.21.4: Temporal Variation of Phytopigments at station ACH4 on 06.03.2016.

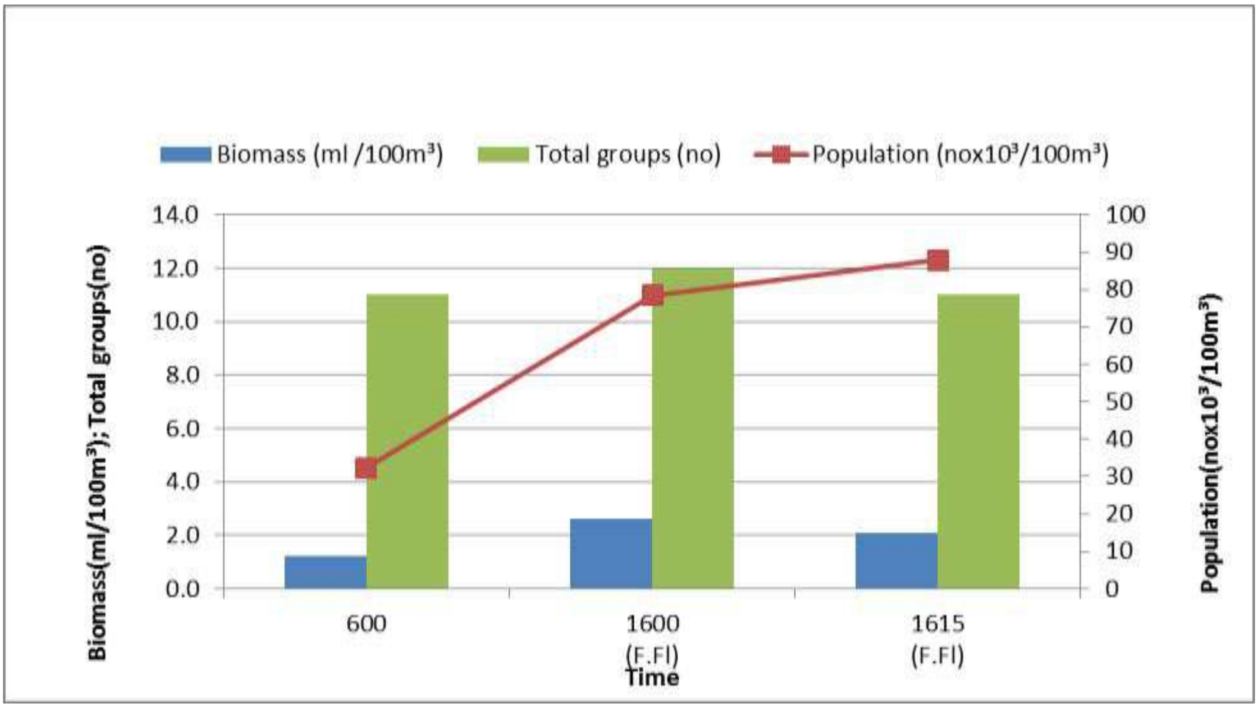


Figure 4.21.5: Temporal Variation of mesozooplankton at station ACH4 on 16.01.2016

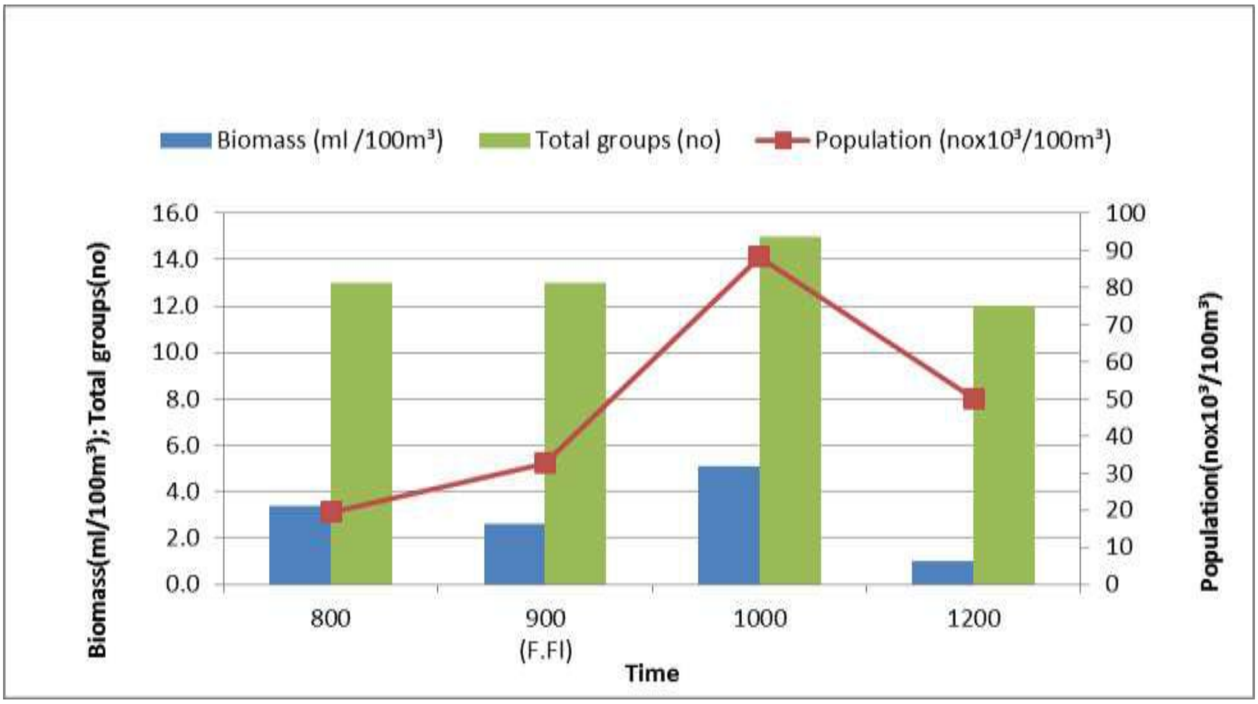


Figure 4.21.6: Temporal Variation of mesozooplankton at station ACH4 on 06.03.2016

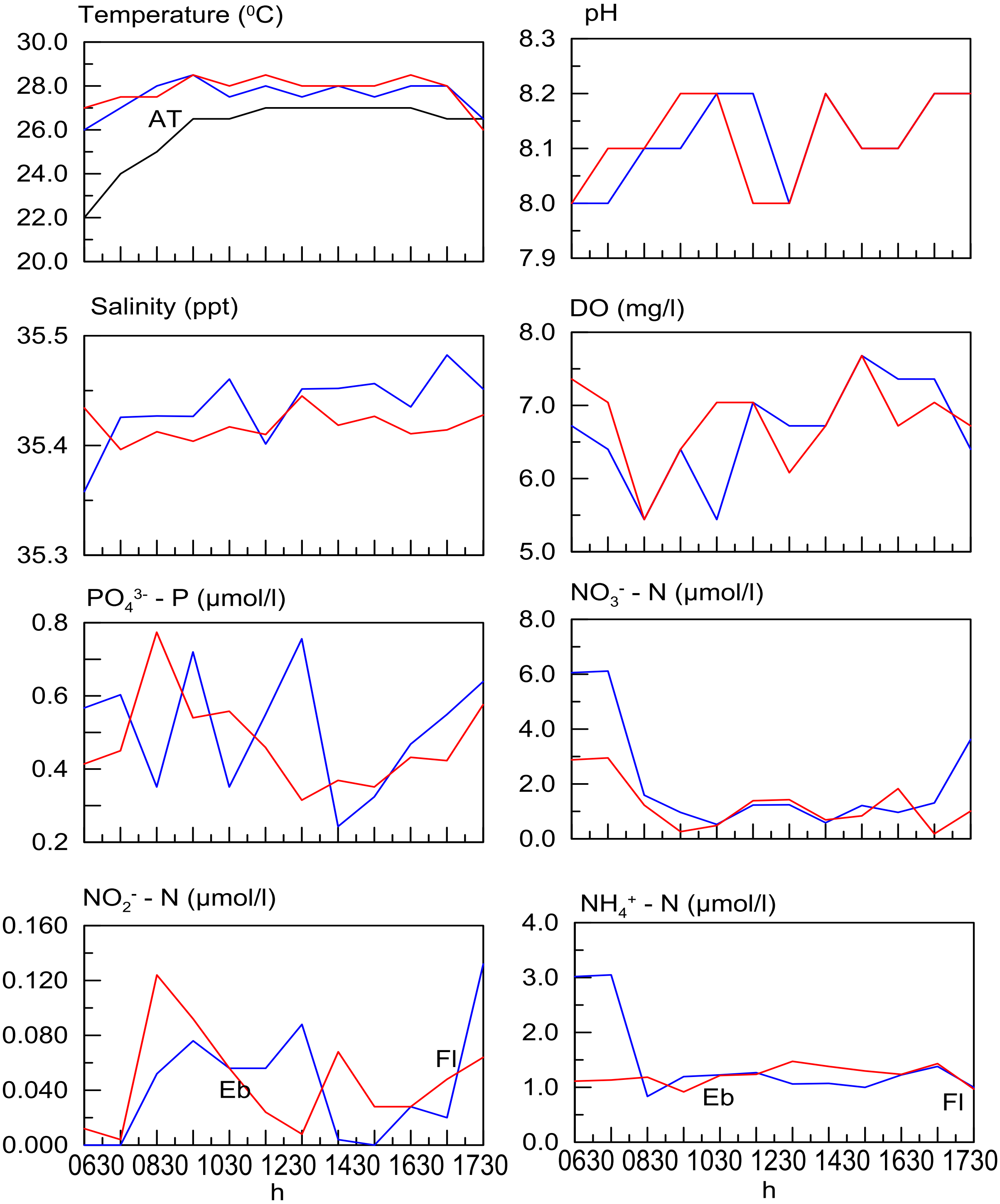


Figure 4.22.1: Temporal Variation of water quality parameters at M4 (——— S) & (——— B) on 17th Jan 2016

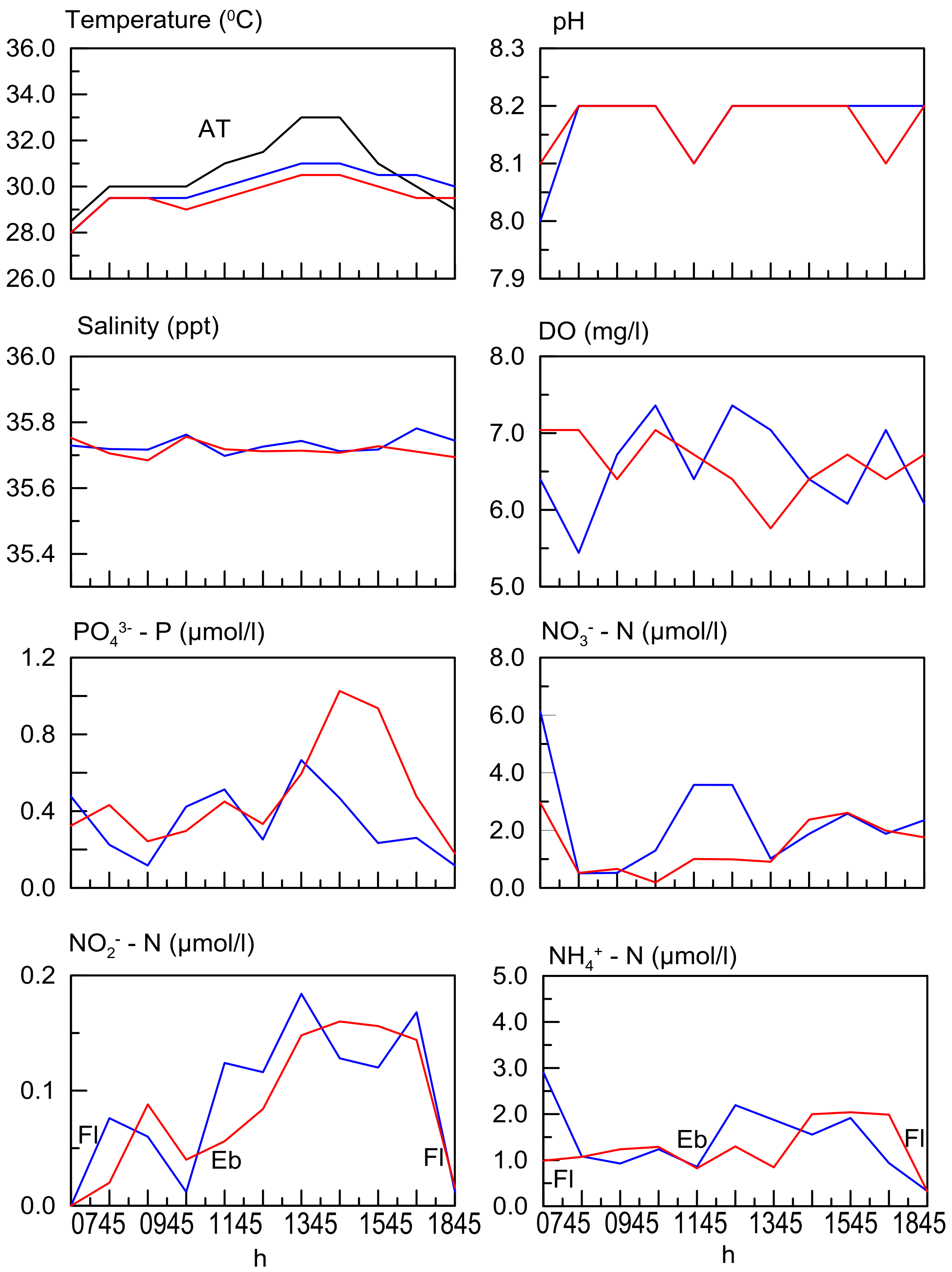


Figure 4.22.2: Temporal Variation of water quality parameters at M4 (——— S) & (——— B) on 3rd March 2016

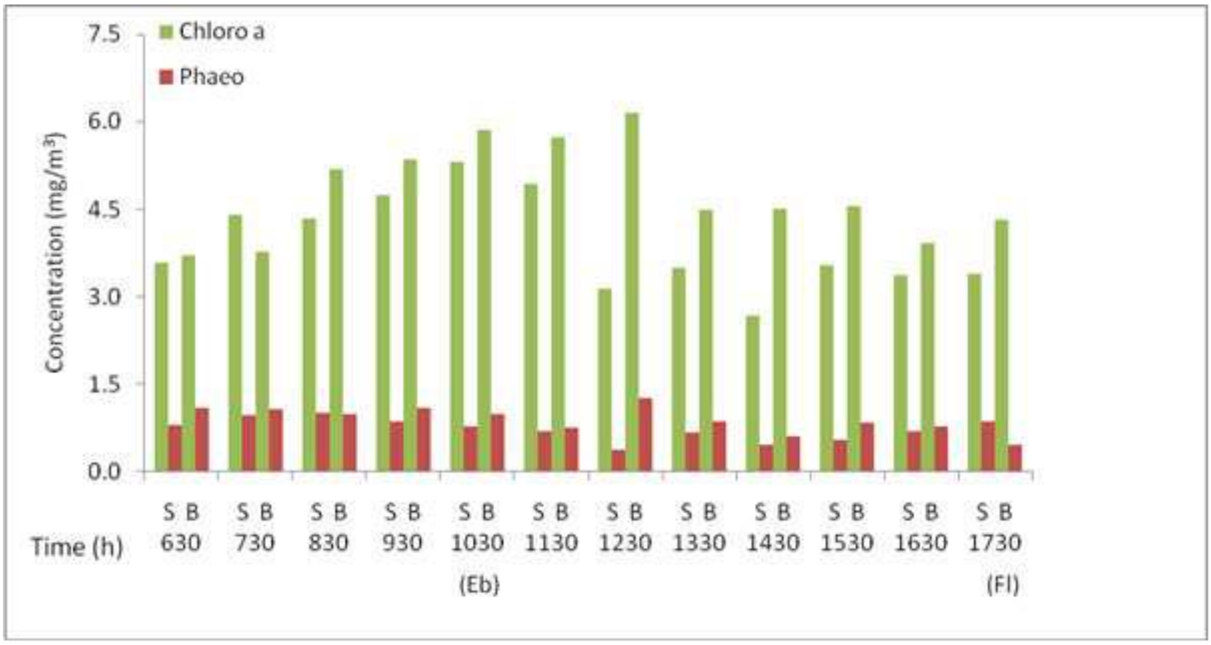


Figure 4.22.3: Temporal Variation of Phytopigments at station M4 on 17.01.2016.

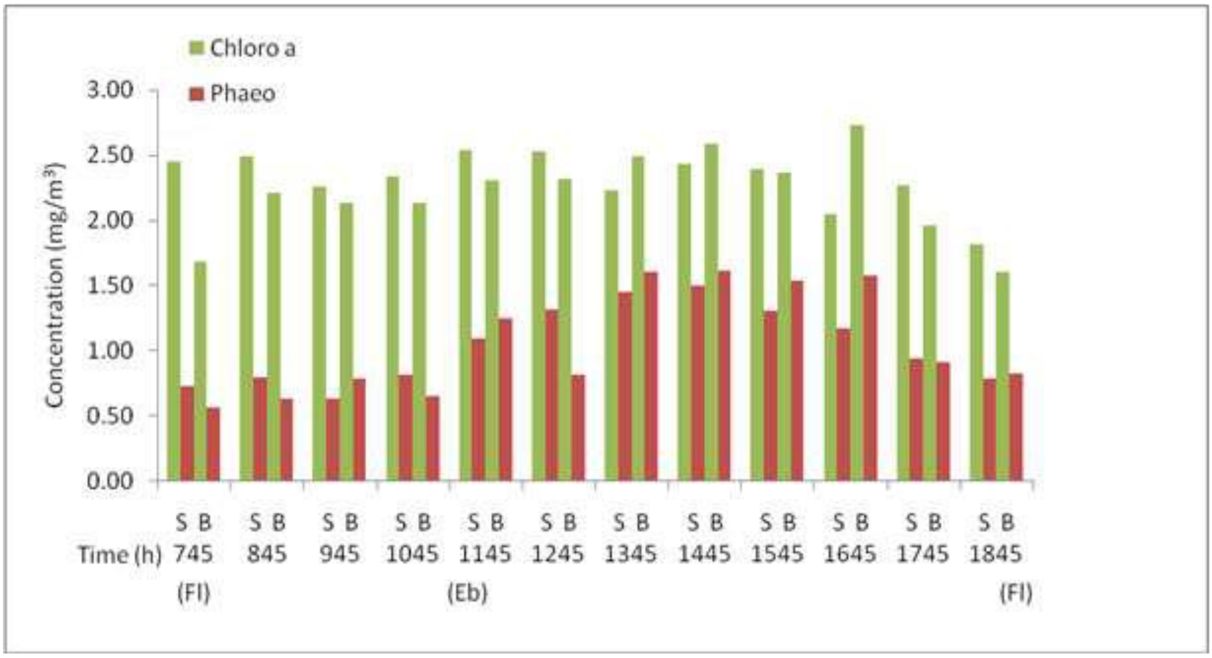


Figure 4.22.4: Temporal Variation of Phytopigments at station M4 on 03.03.2016.

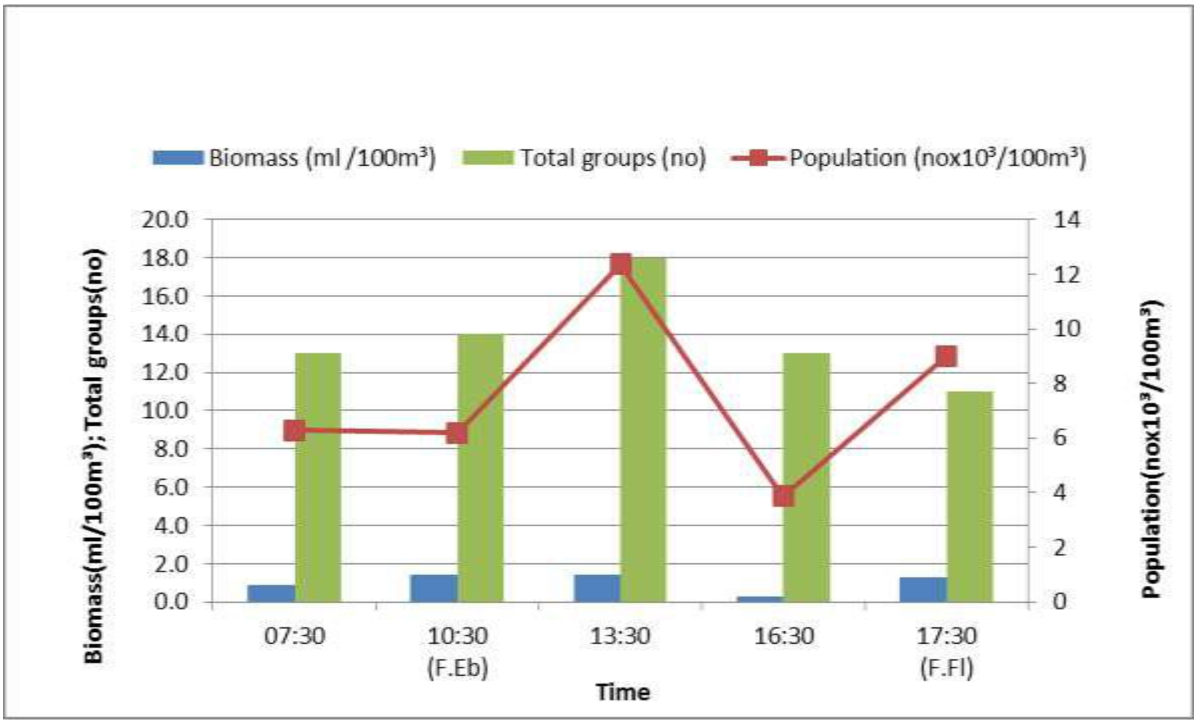


Figure 4.22.5: Temporal Variation of mesozooplankton at station M4 on 17.01.2016

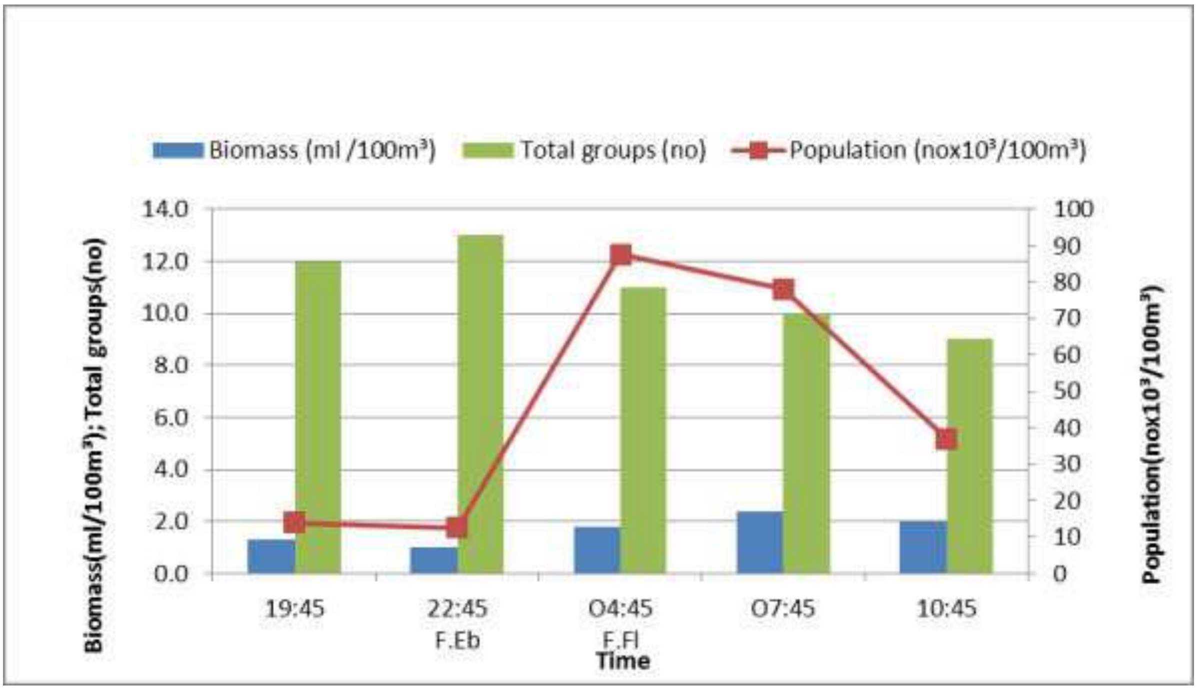


Figure 4.22.6: Temporal Variation of mesozooplankton at station M4 on 03.03.2016

5 ECOLOGICAL ASSESSMENT

The release of treated and untreated effluents into the coastal marine areas including estuaries, bays and creeks can sometimes cause environmental impacts on the prevailing ecology that could be relatively high in the zone of release. However, the intensity of adverse impact would vary depending on several factors such as quality and quantity of effluent, the assimilative capacity of the receiving water and the degree of ecological sensitivity of the area. As the enhancement of levels of pollutants in the receiving water over the natural background is the prime factor controlling the extent of influence on ecology, it was necessary to have adequate information on the prevailing dynamics, water quality, sediment quality and biological characteristics of the monitoring locations.

Assessment of the ecological status of the coastal and inshore waters of Maharashtra is made based on the result of 2015-2016 studies and available baseline data. In this report the assessment is made parameter wise as well as area wise. However, in absence of the baseline data for some regions it is difficult to make a realistic comparison.

5.1 Parameter wise assessment

The parameters considered for the assessment are given below.

Water quality: Temperature, pH, salinity, suspended solids, turbidity, DO and BOD, phosphorus and nitrogen compounds, phenols and PHc

Sediment quality: Texture, Heavy metals, C_{org}, phosphorus and PHc

Biological characteristics: Bacteria, phytoplankton, zooplankton, macrobenthos and meiobenthos.

The data for individual parameters are summarized in Tables 5.1A to 5.1.R as well as the averages for the various segments viz; coastal, creek/bay and estuary are plotted in Figures 5.1.1 to 5.1.92 for discussions. It should be however mentioned here that since the assessment is made on the basis of average values for broadly defined segments of a transect, the conclusions drawn are for an area as a whole. Evidently, when average values are used, the local impacts such as those commonly recorded in a water body in the vicinity of effluent release are missed in such assessments unless the changes are significantly high to influence the average value. Hence the present assessment will bring the general status of a given parameter for different water bodies viz; coastal, bay/creek and estuary of the coastal Maharashtra. The present discussion considers the coastal segments between Dahanu and Murud under north Maharashtra, whereas the area between Savitri and Malvan under south Maharashtra. The micro-level changes would however be reflected in area wise discussion wherein individual values are considered.

Based on the available data as well as recent data along coastal Maharashtra a normal baseline on tentative basis was formulated to compare with present data. Accordingly a general base line for water quality and biological characteristics was prepared as given in Tables 5A. The sediment quality baseline was not available; therefore discussion on sediment quality was made based on present results.

Table 5A: Tentative baseline for water quality of coastal Maharashtra

Water quality	Normal Range
Temperature (^{0}C)	23-32
pH	7.8-8.2
SS (mg/l)	20-50
Salinity (ppt)	32-35
DO (mg/l)	4-10
BOD (mg/l)	1-3
PO_4^{3-}-P (µmol/l)	<3
NO_3^--N (µmol/l)	<5
NO_2^--N (µmol/l)	<3
NH_4^+-N (µmol/l)	<3
PHc (µg/l)	<20
Phenols (µg/l)	<50

5.1.1 Water quality

a) Temperature

Temperature of water is an important parameter that influences chemical processes such as dissolution-precipitation, adsorption-desorption, emulsification -flocculation, oxidation-reduction etc. As a result of absorption of solar radiation, the temperature of a well mixed shallow water body varies in accordance with the prevailing air temperature, while that of waters having restricted vertical mixing a thermal gradient may prevail.

Due to natural changes in climatic conditions the temperature of water fluctuates daily as well as seasonally. These changes often influence the physiological processes and reproductive cycles of aquatic organisms and may affect the prevailing community structure and the geographical distribution of species. An upper threshold limit of 35^{o}C is considered for tropical aquatic species though some may be less tolerant.

In the coastal waters of Maharashtra, the annual temperature range is expected to be 20 to 30^{o}C. But in summer when stagnate condition prevails in the shallow segments, the water temperature may rise to 33 to 35°C in isolated water pools.

As expected for shallow areas, the water temperature varied in accordance with the air temperature as evident from Figures 5.1.1 and 5.1.2 and Table 5.1.A. The average water temperature was higher by 0.8-5.9°C during premonsoon period than in postmonsoon, though at some places postmonsoon season average temperature was slightly higher than premonsoon season, which may be due to time of collection of samples. The difference between coastal and creek temperatures (0.1-1.4°C) was comparable at various segments of the coastal Maharashtra. However, Dahanu creek, Savitri estuary and Achara creek showed 2.5°C, 2.6°C and 2.9°C respectively higher temperature than their respective coastal waters. The temperature in coastal water off Tarapur was higher than the creek water. Such differences may be due to the topography of region and the time of measurement of temperature.Whereas, the estuaries of south Maharashtra revealed marginally higher temperature variations (1-2°C) than that of northern estuaries (0.5-1°C) as compared to respective coastal waters. In general, the coastal segments of north Maharashtra sustained marginally higher average temperature (1.4°C) than that of south Maharashtra. This could be due to difference in time of sampling apart from influence of effluents associated with urbanization and industrialization along north Maharashtra.

b) pH

The pH is the measure of Hydrogen ion activity in water. It is known as master variable since many properties, processes and reactions are pH dependent. The principal system that regulates pH in seawater is the carbonate consisting of CO_2, H_2CO_3, HCO_3^-, and CO_3^{2-}, salt content and alkalinity due to borates. Because of the buffering capacity of seawater, generally seawater pH has limited variability (7.8-8.3). However, the pH of creeks/estuaries may vary depending upon the pH of fresh water inflow, primary productivity and anthropogenic perturbations. The pH range of 5 to 9 is not directly harmful to the aquatic life, however such changes can make many common pollutants more toxic.

As seen in Figures 5.1.3 and 5.1.4, the pH of coastal and creek segments of Maharashtra varied in accordance with vicinity of effluent release (Table 5.1A). The southern coast indicated marginally higher range of pH than that of coastal waters of northern Maharashtra. However the estuaries did not reveal any distinguished regional difference. Thus pH of the estuaries and creeks of north Maharashtra was (7.0-8.4) as compared to south Maharashtra (6.8-8.3) Tarapur (7.4-8.1) and Thal (7.6-7.9) indicated some values lower than expected. Similarly, Manori Creek (7.6-8.1), Versova creek (7.3-8.2), Mahim Creek (7.5-8.4) and Thane Creek (7.5-8.2) revealed occasional low values as compared to other creek systems of Maharashtra.

Also Ratnagiri Bay indicated occasionally low pH. Among the estuaries Ulhas (7.2-8.0), Patalganga (7.6-8.0) and Kundalika (7.2-7.9) of the northern coast and Savitri (7.5-8.0) and Vashishti (6.8-8.3) of the southern coast indicated occasionally low pH.Invariably low pH was recorded at the wastewater release locations and could be associated with the industrial and domestic wastes. The uniform pH values observed vertically as well as laterally on a given segment during the study period indicated that waters were well mixed.

c) Suspended solids

Suspended solids are the descriptive term used for suspended/ settleable particulate matter in the water column. Suspended solids of natural origin mostly contain clay, silt, sand of bottom and shore sediment and planktonic remnants. The major role played by suspended solids is adsorption of constituent as well as contaminants from the water column and transfer them to sediment when they settle. Organic content in suspended solids increases oxygen demand in the water column and its settlement on the bed can make the sediment anoxic.

The immediate effect of suspended solids is an increase in turbidity that reduces light intensity and the depth of photic zone leading to decrease in primary production and fish food.

Suspended particulate were in a range of 7-620 mg/l in the coastal waters of Maharashtra. The higher values of 210 mg/l, 505 mg/l and 363 mg/l occurred at Dahanu, Bassein and Thal respectively. In the other places the suspended solids remained low in the range of 7-250 mg/l. The levels varied widely with the bottom water invariably sustaining relatively higher loads indicating that the SS in coastal regions largely results from the dispersion of the fine particles of bed materials in water by currents.

As evident from Figures 5.1.5 and 5.1.6 and Table 5.1A, the north coast of Maharashtra sustained higher SS as compared to south coast where it was low. The open shore waters off Dahanu, Bassein, Thal, Kundalika and Murud sustained higher SS along north coast. Whereas the SS in the coastal waters of south Maharashtra was below 90 mg/l. The northern creek systems like Dahanu, Manori, Versova, Thane and Murud indicated SS of more than 130 mg/l. The creeks along south had SS values exceeding 26 mg/l. Similarly, all the northern estuaries sustained higher SS upto 620 mg/l, whereas, southern estuaries showed <230 mg/l of SS. The high SS in the northern coastal system of Maharashtra is mainly due to shallow depths, stronger tide-induced currents and bed material composed of silt, clay and sand. Anthopogenic wastes may also be contributing to high SS though the influence is local.

d) Turbidity

Turbidity of water relates to optical clearness of seawater and is affected by dissolved matter and suspended particles.In general turbidity has direct correlation with suspended solids present in water. However, some deviations may occur. SS includes-silt, sediment, nonsettleable solids, bacteria, clay, algae and settleable solids whereas turbidity may be the contribution of these plus dyes, colored dissolved organic matter and humic acids excluding settleable solids. Measurement of turbidity is one of key parameter in deciding the quality of water as high turbidity can harm fish and other aquatic life by reducing food supplies, degrading spawning beds, and affecting gill function.

Turbidity measured in the present monitoring was low in coastal water of south Maharashtra compared to that recorded in the north Maharashtra coastal waters. In general, as shown in Figures 5.1.7 and 5.1.8 and Table 5.1A the highest turbidity was recorded off Bassein (122.7-236.7 NTU), followed by coastal waters off Thane Creek (22.6-106.9 NTU) and Kundalika Estuary (36.5-105.1 NTU). This is due to the high suspended and organic discharge through creek/estuary. Similarly the water of inner Ulhas Estuary was most turbid (34.0-232.7 NTU) among all the estuaries of Maharashtra coast. Among south estuaries Savitri Estuary showed maximum turbidity (0.5-74.5 NTU). Followed by Vashisti (2.2-24 NTU).

e) Salinity

Normally seawater salinity is 35.5 ppt and may vary in coastal areas depending on the difference between evaporation and freshwater addition. Salinity influences several mixing processes such as dissolution, dispersion, dilution etc in seawater due to high dissolved salt content and higher density. Thus DO is relatively low in seawater as compared to freshwater at equivalent water temperature.

Salinity generally remained in the narrow range of 34.0-37.3 ppt all over the coast, except off Bassein and Bandra, where minimum salinity of 24.3 ppt and 29.1 ppt was recorded respectively. The estuarine salinities were tidally variable as expected due to fresh wate influence. Minimum salinity of 0.1 ppt was observed in Patalganga and Kundalika Rivers. However, maximum of 37.7 ppt was recorded at Murud which indicates evaporation exceeding dilution, as there is no freshwater source in the region in dry season (Table 4.4.1).

In general, as shown in Figures 5.1.9 and 5.1.10 and Table 5.1A the salinity was closely comparable between coastal and creek segments of Maharashtra suggesting strong marine influence in the study area. Similarly, the estuaries of coastal Maharashtra were comparable with similar salinity fluctuations indicating appreciable freshwater influx to the estuarine system especially during monsoon. The open coastal system of Maharashtra revealed mostly a stable salinity condition (35-37 ppt) except nearshore segments of Bassein where the average salinity was low (33.3 ppt). The creek like Thane indicated higher variations (8.0 ppt) in salinity suggesting appreciable freshwater influx which could be large volume of sewage effluents released in the creek. Murud Creek (3.6 ppt),Ratnagiri Bay (1.1 ppt), Vijaydurg Creek (1.1 ppt) and Malvan Bay (0.4 ppt) revealed less salinity fluctuations (0.4 to 3.6 ppt) suggesting restricted freshwater influx to these coastal systems. The estuaries of north Maharashtra exhibit a similar salinity trend except Amba Estuary where it was higher during dry period due to negligible freshwater influx to the estuarine system. Along south Maharashtra Shastri Estuary showed less salinity fluctuations with higher values as compared to Savitri and Vashishti suggesting limited freshwater influx to the Shastri Estuary. At most of the places the temporal changes indicated a trend of an increase in salinity around flood tide and a decrease as the ebb tides progressed. Though surface to bottom salinity occasionally varied by about 1 ppt, the waters were well mixed vertically and stratification was absent except in low current regimes.

f) DO and BOD

DO is an important constituent in the protection of aesthetic quality of water as well as maintenance of fish and other aquatic life. Hence, it is an indicator of prevailing water quality and ability of the water body to support a well balanced aquatic life. DO in water is replenished through photosynthesis, dissolution from atmosphere and addition of oxygen rich water. Simultaneously it is consumed during heterotrophic oxidation of oxidisable organic matter and respiration by aquatic flora and fauna as well as oxidation of naturally occurring constituent in water. In the marine environment chronic oxygen deficiency occurs when levels of DO fall between 2.0 and 6.0 mg $l^{-1}$and acute deficiency occurs when DO is <2.0 mg/l respectively. Though the water containing DO concentration <4.0 mg/l is known to be oxygen deficient.

During the study, DO ranged from <0.2-9.6 mg/l with minimum in Bassein and maximum in Worli and Thane Creek (Tables 4.3.1, 4.8.1 and 4.9.1). The lower DO can be due to sewage pollution, whereas, higher DO could be supersaturated with oxygen due to the photosynthetic activity of the algal blooms. Very low or absence of DO was occasionally observed at Tarapur, Bassein, Thane, Mahim, Versova, Manori, Amba, Patalganga, Kundalika, Vashishti and Ratnagiri.

As evident from Figures 5.1.11 and 5.1.12 and Table 5.1B, the coastal waters of Maharashtra had an average DO of >3 mg/l, except off Tarapur suggesting suficient oxidizing potential inspite of organic pollutants reaching the coastal system from urban and industrial areas. Low DO recorded in the open coast off Tarapur during the study period is due to industrial waste disposal near the the coast from MIDC Tarapur. The creek segments, however, revealed deterioration along the coastal Maharashtra. In general, most of the northern creeks indicated occasional low DO levels (<2 mg/l) and Versova Creek with near zero conditions as compared to southern creeks where DO conditions were better (>3.5 mg/l). However, only at Ratnagiri Bay on the south, DO levels occasionally reached as low as 0.6 mg/l suggesting severe deterioration due to port and fishing activities as well as sewage disposals from Ratnagiri town. Persistent low DO was observed in creek systems like Manori, Versova, Mahim and Thane Creek where large sewage releases are made. However, this was confined only to the creek systems and DO increased towards the open sea. Surface to bottom variations were minor as expected for vertically well-mixed waters. In the north, the Ulhas and Patalganga estuaries were severely affected with occasional low DO values (< 0.3 mg/l). Whereas, among southern estuaries, Vashishti was the most affected in the vicinity of effluent release with occasional low DO (<2.0 mg/l). Other estuaries of south Maharashtra sustained better DO conditions (>3.5 mg/l) as compared to north estuaries.

Consumption of DO during heterotrophic degradation of oxidisable organic matter creates oxygen demand popularly termed as the Biochemical Oxygen Demand (BOD). Presence of sufficient DO through replenishment keeps this demand low. However, input of oxidisable organic matter, more than that a water body can assimilate increases BOD with concominent decrease in DO.

Relatively low BOD (<5.0 mg/l) at most of the transect except inner zones of Tarapur, Bassein, Versova, Thane, Patalganga, Kundalika, Vashishti, Ratnagiri and Deogad was indicative of effective consumption of organic matter entering in the creeks, estuaries and in the coastal waters. The BOD of 1-3 mg/l is common for coastal and inshore water and can be upto 5 mg/l in areas of high biological productivity such as the estuarine zones. This is because all natural waters contain some oxidisable organic matter of natural origin that includes a variety of organic compounds in minute quantities, some of which are derived from the land drainage.

As seen in the Figures 5.1.13 and 5.1.14 and Table 5.1B the coastal waters of north (0.3-4.8 mg/l) and south Maharashtra (0.5-5.4 mg/l) revealed good oxidative conditions. In Tarapur coastal water higher BOD (28.5 mg/l) was recorded, due to industrial effluent released in the region which consumed DO leading to its low values. Among the northern creeks Tarapur, Manori, Versova, Thane and Murud indicated BOD of >4 mg/l. Ratnagiri (19.4 mg/l), Vijaydurg and Deogad (5.7 mg/l) /l) in southMaharashtra were above 5 mg/l of BOD.

g) Dissolved nutrients

Dissolved nutrients though in low concentration are essential for production of organic matter by photosynthesis. They tend to be efficiently stripped from the surface water through incorporation into the cells, tissues and extra cellular structures of living organisms. Among several inorganic constituents such as phosphate, nitrogen compounds, silicon, trace metals etc, traditional nutrients namely phosphorus and nitrogen compounds have a major role to play in primary productivity. However, their occurrence in high levels in areas of restricted water exchange can lead to an excessive growth of algae which in extreme conditions result in eutrophication.

h) Phosphorus compounds

Phosphorus as phosphate is one of the major nutrients required for plant nutrition and essential for life though the elemental form is particularly toxic and is subject to accumulation. When in excess however, it stimulates undesirable plant growth when other nutrients are also available. Sources of phosphate in coastal marine environment are mostly land based. These include domestic sewage, detergent, effluent from agro-based and fertilizer industries, agricultural runoff and organic detritus. The sources within marine environment are decomposition of algal plant cells releases through sediment, bacterial action and recycling within the biotic communities. It is difficult to determine the critical levels of phosphate for optimum growth of aquatic life since they may vary from location to location depending upon phosphorus loading and its distribution.

In general, PO_4^{3-}P content varied between0.1 and 49.4 µmol/l with maximum at Thane and minimum at Savitri, Vashishti, Jaigad, Deogad, Achara, and Malvan. The creek exhibited the maximum fluctuation in phosphorus compounds.

As evident from Figures 5.1.15 and 5.1.16 and Table 5.1B, the coastal waters of north (0.1-16.1 µmol/l) indicated elevated levels of PO_4^{3-}-P as compared to that of south Maharashtra (0.1-1.8 µmol/l). Bassein coastal system revealed maximum average (7.1 µmol/l) for the northern region. In general, the northern coastal segments revealed higher variations (0.1-16.1µmol/l) as compared to south (0.1-1.80 µmol/l). Similarly, the creek systems of north and south Maharashtra indicated higher range of PO_4^{3-}-P. Most of the northern creeks viz; Dahanu, Tarapur, Manori, Versova, Mahim and Thane revealed elevated levels of PO_4^{3-}-P (3.2-49.4 µmol/l) suggesting appreciable input of organic load. Whereas, on the south, excepting Ratnagiri Bay (27.6 µmol/l) and Vijaydurg (6.4 µmol/l), the rest of the creeks indicated normal levels of PO_4^{3-}-P (<2 µmol/l) and absence of organic pollution. The northern estuaries like Ulhas (25.6 µmol/l), Patalganga (27 µmol/l), Amba (14.7 µmol/l) and Kundalika (17.9 µmol/l) sustained high levels of PO_4^{3-}-P. Southern estuaries, except Vaishisti (2.2 µmol/l), revealed expected concentration (<2.0 µmol/l) of PO_4^{3-}-P.

i) Nitrogen compounds

Nitrogen cycle involves elementary dissolved nitrogen oxides: NO_3^--N, NO_2^--N; and reduced forms; NH_4^+-N, NH_3-N and plays a significant role in sustaining aquatic life in marine environment. NO_3^--N is the end product of oxidation and the most stable form at pH 7. The principal natural source of nitrogen in marine environment is nitrogen fixation of N_2O and NH_3 via atmosphere.

NO_2^--N occurs in seawater as an intermediate product of nitrate in microbial processes i.e. denitrification at low oxygen levels at which NO_2^--N is further transformed into NH_3 and N_2 in anoxic conditions. Some of the prominent sources of nitrogen compounds are domestic and industrial effluents particularly fertilizer manufacturing units, agricultural runoff, animal wastes and sanitary landfalls.

Natural levels of NO_2^--N are usually low (0.1 µmol/l) but in transition zones between toxic and anoxic layers it may increase to even 2 µmol/l. NH_4^+N concentration though low, considerable variations and rapid changes in its concentrations can occur.

The overall concentrations of NO_2^--N, NO_3^--N and NH_4^+-N varied respectively in the range of 0.1-31.4 (µmol/l), 0.1-71.6 (µmol/l) and 0.2-97.1 (µmol/l) in the coastal and inshore waters of Maharashtra during the study period. The highest concentration of NO_2^--N was observed at Thane whereas the highest concentration of NO_3^--N and NH_4^+-N was recorded at Bassein.

As indicated in Figures 5.1.17 and 5.1.18 and Table 5.1B the values of NO_3^--N varied widely at different coastal segments of Maharashtra with the absence of clear spatial and temporal trends as commonly noted for shallow coastal systems under high tidal influence. Excepting the creeks and estuaries, the open coastal system of south Maharashtra indicated normal range of NO_3^--N (0.1-13.2 µmol/l). However, the coastal waters of Dahanu, Bassein, Bandra, Thane and Thal revealed higher values of NO_3^--N (2.0-62.1µmol/l). The creeks along northern coast indicated higher levels of NO_3^--N (0.2-71.6 µmol/l) than that of southern coast (0.1-39.0 µmol/l). Similarly, the estuaries of north like Ulhas, Patalganga, Amba and Kundalika revealed higher values of NO_3^--N (0.2-71.6 µmol/l). In case of south the Savitri and Vashishti indicated higher levels of NO_3^--N (0.7-39.0 µmol/l). Except a few estuaries and creeks, overall, the southern coastal system indicated normal range of NO_3^--N (ND-13.2 µmol/l).

The results as shown in Figures 5.1.19 and 5.1.20 and Table 5.1C indicated wide variations of NO_2^--N with the absence of clear spatial and temporal trends as commonly noted for shallow coastal waters under high tidal influence. The coastal/inshore systems of north Maharashtra revealed high fluctuations of NO_2^--N as compared to that of south Maharashtra. Normal coastal marine system in general represents less than 1 µmol/l of NO_2^--N. However, coastal waters off Mumbai had higher values for the north Maharashtra. Along south Maharashtra the open coastal systems revealed normal levels, except Vashishti. The creeks like Manori and Thane revealed wide fluctuations with higher values of NO_2^--N. Also Dahanu, Tarapur, Versova and Mahim creeks showed above normal values. Overall, the southern creeks revealed normal trend (0.1-0.4 µmol/l), except Jaigad and Ratnagiri (0.1-2.2 µmol/l) suggesting better conditions. Similarly, higher fluctuations of NO_2^--N were common in northern estuaries as compared to south Maharashtra. The Ulhas, Patalganga and Kundalika estuaries showed higher values in the north. Similarly Savitri and Vashishti showed higher values of NO_2^--N in the south. The Amba estuary revealed values more than normal.

As evident from Figures 5.1.21 and 5.1.22 and Table 5.1C, the NH_4^+-N values highly fluctuated similar to NO_3^--N and NO_2^--N especially along northern coast as compared to that of southern Maharashtra. Normal values are generally <3 µmol/l. Tarapur, Bassein, Bandra, Worli and Thal coastal waters revealed high values for the northern Maharashtra. However, the open coastal system of Thane, Thal and Kundalika revealed above normal values. Elevated concetrations were also observed in the coastal waters of south Maharashtra. The northern creeks indicated higher values of NH_4^+-N as compared to that of southern creeks. Tarapur, Manori, Versova, Mahimand Thane creeks as well as Ratnagiri Bay, Vijaydurg, and Achara revealed elevated values of NH_4^+-N. Similarly, the northern estuaries like Ulhas, Patalganga, Amba and Kundalika showed higher values (32.4-97.1 µmol/l). Among the southern estuaries, Savitri and Vashishti revealed high values (4.8-30.2-15 µmol/l).

j) Dissolved PHc and phenols

Naturally occurring hydrocarbons in marine environment are trace amounts of simple forms produced by Bacteria. PHc derived from crude oil and its products are added to marine environment by anthropogenic activities namely production of crude oil and its products transport through pipelines, ship traffic, tankers etc. Prominent land based sources are domestic and industrial effluents, atmospheric fallout of fuel combustion products, condensed vapour etc.

PHc values varied between 0.2 and 112.8 µg/l with the minimum at Bandra and maximum at Patalganga. In general the PHc varied in narrow ranges (avg 0.2-25.3 µg/l) in coastal waters of Dahanu to Malvan.

As evident from Figures 5.1.23 and 5.1.24 and Table 5.1C, open coastal waters along Maharashtra indicated low concentration (avg 0.2-25.3 µg/l) of PHc during the study period. Coastal waters off Tarapur (25.3 µg/l) showed moderately high contamination for the northern segment. Except at few transects, PHc concentration in the northern and southern Maharashtra was comparable. The northern creeks like Dahanu and Tarapur indicated higher level of PHc (>17.0 µg/l). Creeks of southern Maharashtra revealed PHc concentration <16.5 µg/l. The northern estuaries like Ulhas and Patalganga revealed high values of PHc (72.1-112.8 µg/l) whereas other estuaries of Maharashtra like Kundalika, Amba, Vashishti and Shastri revealed low level contamination of PHc (1.8-24.0µg/l).

These results indicated a variable trend in distribution of PHc in the coastal waters. The variable concentrations of PHc often occur in areas of shipping lanes because the petroleum being sparingly soluble in water, its distribution is often patchy when it enters the aquatic environment through an anthropogenic source such as bilge water.

Phenols include a variety of derivations of phenol (C_6H_5OH) such as monohydric, dihydric, polyhydric, one ring, two ring, polyring and fused aromatic. Phenols in marine environment generally originate through onshore anthropogenic discharges. They are generated as by-products in manufacturing processes of coke, paper and pulp processing, coal gas liquification and produced from hydrocarbons in petrochemical industries. They are produced and used on large scale in fungicides, antimicrobials, wood preservatives, pharmaceuticals, dyes, pesticides, resins etc. Hence, they become important constituent of domestic and industrial effluents.

Overall phenols varied between 2.6 to 922.3 µg/l with maximum at Kundalika estuary.

As evident from Figures 5.1.25 and 5.1.26 and Table 5.1C that the average concentration of phenols in water widely varied with no discernible trends. It was the highest in the coastal water off Kundalika (414.7 µg/l) followed by Dahanu, Tarapur, Bassein, Bandra, and Thane where it was >109 µg/l at south Maharashtra it was more (>90 µg/l) in the open coastal segments between Ratnagiri to Malvan. Northern creeks like Dahanu, Tarapur, Manori, Versova, Mahim and Thane revealed high values (>90 µg/l). Similarly, at south, Ratnagiri Bay, Vijaydurg Creek, Deogad Creek and Achara Creek had high values of phenols (>100 µg/l). Kundalika estuary showed very high values (922.3 µg/l) suggesting the impact of industrial waste disposals in the estuarine system. Other estuaries like Ulhas, Patalganga and Amba also sustained high values (>200 µg/l) suggesting the impact of industrial wastes on water quality. In southern Maharashtra coast, Vashishti had the highest concentration (197.0 µg/l) of phenols, which may be due to the impact of effulent disposal. Other estuaries showed normal range of phenols.

5.1.2 Sediment quality

The pollutants adsorbed by SS are ultimately deposited at the bed sediment on settling. Evidently, concentration of pollutants in sediment increase over a period of time in regions receiving their fluxes. Hence, sediments are useful indicators of pollution by certain contaminants released over a longer span of time.

a) Texture

The open coastal and creek/estuary along coastal Maharashtra revealed either sandy-silt or silty sand substratum with low percentage of clay (Table 5.1D). The creek/estuary of north Maharashtra indicated predominantly silty-sand while the south Maharashtra showed sandy-silt bottom conditions. The percentage of sand in the coastal segments between north and south was comparable; however, northern shore indicated higher percentage of silt and clay than that of the south. The relatively high percentage of clay (>10%) occurred at the transects like Thane, Worli, Thal, and Deogad. The substratum of the Malvan bay was predominantly sandy. The highest percentage of sand (49.4%), silt (86.2%) and clay (33.3%) occurred in the open coastal system of Kundalika, Thane, and Deaogad respectively. Similarly the highest percentage of sand (77.7%), silt (68.1%) and clay (33.7%) in the creek/estuary segments was recorded at Deogad, Thane and Mahim respectively. Thus, the present results indicated high variability in the textural characteristics of sediments along coastal Maharashtra.

b) Metals

Bed sediment in uncontaminated areas has lithogenic metal concentrations which are derived from rocks and soil. However, these levels can get altered when the coastal water received discharges of industrial effluents containing metals. The content largely depends upon the grain size and the composition of bed sediment. Smaller grain size and higher clay matter may result in higher levels of metals in sediment.

The metal content in sediment varied widely along the Maharashtra coast as evident from Tables 5.1E to 5.1G and Figures 5.1.27 - 5.1.48.

Segment-wise (coastal/creek/estuary) dry wt values (range) of Al(%), Fe(%), Cr(µg/g),Co(µg/g), Ni(µg/l), Mn(µg/g), Cu(µg/g), Zn(µg/g), Cd(µg/g), Hg(µg/g) and Pb(µg/g) are summarized in the table below:

Metal	Coastal	Creek/estuary
Al(%)	1.4-9.6	1.4-11.0
Cr(µg/g)	39.0-522.0	8.8-691.0
Mn(µg/g)	396.0-2312.0	183.0-2663.0
Fe(%)	4.8-17.2	1.9-20.9
Co(µg/g)	16.0-134.0	17.0-940.0

Ni(µg/g)	13.0-121.0	14.0-218.0
Cu(µg/g)	17.0-307.0	19.0-488.0
Zn(µg/g)	28.0-239.0	10.0-777.0
Cd(µg/g)	0.1-1.6	0.08-2.8
Hg(µg/g)	0.0-0.40	0.0-0.90
Pb(µg/g)	4.6-24.8	2.4-76.5

Thus, the concentrations of various metals especially the metals of concern such as Cr, Ni, Cu, Zn, Cd, Hg and Pb widely varied in the coastal and creek/estuary sediments along coastal Maharashtra. Except Mn, the other metals showed lower range of concentration in the open coast than that of creek/estuary segments. The average concentration of metals like Al (>9 %), Cr (>200 µg/g), Mn (>1000 µg/g), Fe (>8 %), Co (>50 µg/g), Ni(>100 µg/g), Cu (>120 µg/g), Zn (>120 µg/g), Cd (>0.2 µg/g), Hg (>0.1 µg/g) and Pb (>10 µg/g) was relatively high in many coastal/creek/estuary segments having industrial or domestic waste disposals with anthropogenic accumulation as compared to usually noticed at the clean areas along coastal Maharashtra.

The probable higher concentrations of metals (Al and Fe in %, the rest in µg/g) in various coastal segments of Maharashtra are given in the table below:

Transect	Coastal	Creek/estuary
Dahanu	Mn(1078.0),Co(55.0),Hg(0.2), Cd(0.28),Pb(16.7)	Mn(2153.0), Cd(0.25),Pb(19.4)
Tarapur	Cr(522.0)*, Fe(10.8), Mn (1473.0),Co(76.0),Zn(148.0), Hg(0.2),Cd(0.29),Pb(15.8)	Cr(503.0), Mn(1390.0), Fe(10.2), Co(102.0), Cu(217.0), Zn(253.0),Hg(0.25), Cd(0.75),Pb(28.4)
Bassein	Cr(438.0), Fe(9.8), Mn(2211.0) , Co(69.0), Ni(108.0), Zn(234.0) , Cu(141.0), Hg(0.4)*, Cd(0.21), Pb(21.1)	Cr(691.0)*, Mn(1727.0), Fe(10.0), Co(96.0), Ni(128.0), Cu(231.0), Zn(777.0)*, Hg(0.9), Cd(0.9),Pb(76.5)*
Manori	-	Cr(204.0), Mn(1115.0), Fe(8.5), Cu(126.6), Zn(157.6), Hg(0.3), Cd(2.8),Pb(22.35)
Versova	-	Al(9.7), Cr(226.0), Fe(8.3),Cu(160.0),Zn(180.0),Hg(0.3), Cd(2.72),Pb(28.4)
Mahim	-	Al(9.1), Fe(8.2), Zn(126.0), Hg(0.3), Cd(1.43), Pb(27.0)-
Bandra	Al(9.1),Fe(8.2),Zn(126.0),Cd(1.6)*, Pb(24.8)*	-
Worli	Al(9.3), Fe(8.2), Hg(0.24), Cd(0.54), Pb(21.2)	Fe(8.2), Hg(0.23), Cd(0.94),Pb(17.7)
Thane Creek	Hg(0.2), Cd(0.3), Pb(18.4)	Al(9.3), Cr(208.0), Mn(1153.0), Fe(9.9), Co(54.8), Cu(139.0),Zn(131.0), Hg(0.2), Cd(0.35),Pb(25.7)

Patalganga	-	Cr(525.0), Mn(1512.0), Fe(11.8), Co(940.0)*,Ni(218.0)* Cu(488.0)*,Zn(592.0), Hg(3.64)*, Cd(2.1),Pb(33.6)
Amba	-	Cr(307.0), Mn(1421.0)*, Fe(8.6),Co(67.0), Ni(104.0), Cu(139.0), Hg(0.2), Cd(0.3),Pb(28.7)
Thal	Fe(8.5),Co(68.0),Cu(124.0), Pb(15.8)	-
Kundalika Estuary	Cr(254.0),Fe(9.5),Mn(1397.0),Co(60.0), Cd(0.42), Pb(17.6)	Cr(275.0), Mn(1817.7), Fe(11.2), Co(83.0), Cu(154.0), Hg(0.5), Cd(1.77),Pb(32.0)
Murud	Mn(1082.0), Fe(9.1),Co(60.0), Hg(0.2), Cd(0.25), Pb(13.9)	Fe(8.4), Co(51.0), Hg(0.2),Pb(12.6)
Savitri Estuary	Cr (208.0), Mn(2312.0)*, Fe(12.8), Hg(0.2). Pb(13.7)	Al(9.2), Cr(365.0), Mn(2663.0)*, Fe(15.2), Co(95.0), Ni(105.0), Zn(199.0), Hg(0.3),Cu(273.0), Cd(0.3),Pb(16.3)
Vashishti Estuary	Cr(280.0), Mn(2103.0), Fe(17.2)*,Co(114.0),Cu(307.0)*,Zn(239. 0)*, Cd(0.21), Pb(14.1)	Cr(283.0), Mn(2428.0), Fe(16.5), Co(105.0), Cu(465.0), Zn(210.), Hg(0.4), Cd(0.27),Pb(19.8)
Jaigad/Shastri Estuary	Cr(245.0), Mn(1987.0), Fe(16.1),Co(134.0)*, Cu(261.0),Zn(192.0), Hg(0.3), Cd(0.22), Pb(12.6)	Al(11.0)*, Cr(341.0), Mn(2371.0), Fe(20.9)*, Co(147.0), Ni(129.0), Cu(415.0), Zn(290.0), Hg(0.3),Pb(12.8)
Ratnagiri	Mn(1285.0), Fe(11.8),Co(72.0), Cu(170.0)*, Hg(0.2) Pb(12.6)	Mn(1019.0), Fe(8.4), Co(60.0),Pb(10.3)
Vijaydurg Creek	Al(9.6)*, Cr(255.0), Mn(2138.0),Co(96.0), Fe(17.1), Cu(298.0),Zn(218.0), Hg(0.2),Ni(121.0)*, Cd(0.21), Pb(14.0)	Al(9.1), Cr(309.0), Mn(2153.0),Co(162.0), Fe(18.7), Ni(133.0), Cu(319.0),Zn(251.0), Hg(0.2), Pb(10.4)
Deogad	Al(9.5),Cr(234.0), Fe(8.3), Hg(0.2), Pb(17.7)	Cr(222.0), Mn(1375.0), Fe(14.4),Co(90.0), Cu(208.0),Zn(147.0), Pb(19.0)
Achara	Cr(227.0), Mn(1098.0), Fe(10.3),Co(90.0), Pb(18.5)	Cr(367.0),Fe(12.8),Co(77.0), Pb(11.3)
Malvan	Cr(233.0), Hg(0.2), Pb(16.6)	Pb(15.0)

*Highest value

The rest of coastal areas of Maharashtra, due to the absence of any major industrial activity represent the lithogenic concentrations of metals. Tthe estuaries and creeks along coastal Maharashtra revealed vide variability in distribution of metals. High value for Fe in the coastal segment from Savitri to Achera appeared to be more of lithogenic origin than of anthropogenic nature. Therefore, it appears that the lithogenic source plays a vital role in the distribution of metals in the coastal sediments of Maharashtra. Variations in lithogenic fraction of metals in sediment of the west coast of India is common due to various factors such as variable inputs of SS through land drainage, littoral transport, sediment movement due to currents, tides etc apart from strong monsoonal influence. The variations in the concentration of trace metals can also be due to changing levels of Aluminium and Iron which generally influence the concentration of trace metals.

However, the higher levels of Cr, Hg and Pb in Tarapur creek, Cr, Ni, Zn and Hg in Ulhas estuary, the Cr, Co, Ni, Zn, Hg and Pb in Patalganga and the Cr, Cd and Pb in Kundalika Estuary revealed anthropogenic source. It is also evident from above results that the creek/estuaries of north Maharashtra had higher levels on metals as compared to the southern coast.

Overall, the results indicated enrichment of selected metals in various coastal segments of Maharashtra.

c) Organic carbon (C_{org})

Generally, organic matter in natural coastal sediment originates from terrestrial runoff and remains of organism’s habitating the region. Their decay is one of the important sources of nutrients in the water column. Anthropogenic organic inputs however can increase the content of organic matter to abnormal levels disturbing equilibrium of the ecosystem. Organic matter settling on the bed is scavenged by benthic organisms to a large extent. The balance is decomposed by the heterotrophic microorganisms that require DO.

As evident from Table 5.1H and Figures 5.1.49 and 5.1.50 the percentage of C_{org} content in the sediments along Maharashtra varied in a narrow range (ND to 4.5%) with comparable trend between coastal and creek/estuary. These concentrations were low and compared well with rest of the area of the west coast of India, though few segments of creek/estuary sustained extensive mangrove that are known to contribute appreciable organic matter. The highest value for the coastal (3.4%) and creek/estuary (4.5%) was at Deogad and Jaigad estuary respectively. Most of the segments along coastal Maharashtra showed av. >1% suggesting good carbon turnover for the coastal areas of Maharashtra.

d) Phosphorous (P)

Lithogenic phosphorous in the sediment is derived from the geological source. However, anthropogenic phosphorous in sediment is derived from organic loading of sewage. Settling of particulate matter (bio decomposition product) including sediment to which phosphorous is bound is also a prominent source of sediment enrichment by phosphorous.

As noticed from Table 5.1H and Figures 5.1.51 and 5.1.52, the concentration of P in sediments widely varied from 156 to 3908 µg/g with comparable trend between coastal and creek/estuary along Maharashtra. The highest value for the coastal (2268 µg/g) and creek/estuary (3908 µg/g) was recorded at Murud and Patalganga Estuary respectively. Most of the coastal/creek/estuary segments along Maharashtra indicated average values >1000 µg/g. The open coastal segments of south, similar to C_{org}, showed higher values than that of north, whereas, the creek/estuary of north coast had higher values than that of south. The above trend in the distribution of P could be related to relatively high biological productivity in the open coastal segments of south as supported by high values of C_{org} than that of north. The observed concentrations though variable to those recorded in the sediment of other areas of the west coast, do not indicate much enrichment in the study area.

e) Petroleum hydrocarbon (PHc)

Generally, PHc, contaminant in sediment occurs through water by settling of heavier petroleum residues and the portion adsorbed onto SS. In shallow coastal water tidal disturbance may result in reintroduction of the residue into the overlying water. The sediment contamination largely depends upon composition of the residue, SS content of water and the extent of tidal disturbance. It is evident from Table 5.1H and Figures 5.1.53 and 5.1.54 that the concentration of PHc in sediment varied (0.1-13.9 µg/g) with clearly higher concentration of PHc in creek/estuary (0.1-13.9 µg/l) compare to coastal (0.1-2.8 µg/g) area of Maharashtra. The open coastal segments of Kundalika (2.8 µg/g) and the Patalganga (13.9 µg/g) indicated the highest value for the offshore and inshore segments respectively. Most of the segments along coastal Maharashtra revealed <3 µg/g of PHc in sediment suggesting absence of noticeable petroleum contamination in the study area excepting a few selected locations. In general, the north shore of Maharashtra indicated higher values of PHc than that of south, which could be associated with hectic port traffic and industrial activities along north as compared to the south. The coastal waters off Bassein and Kundalika revealed higher values (>2 µg/g) suggesting the possible area of petroleum contamination of the coastal Maharashtra. Similarly, the inshore segments like creek/estuary of Tarapur, Bassein, Manori, Thane, Patalganga, Kundalika and Vashishtiestuary indicated higher values (>4 µg/g) associated with industrial, port and fishery activities at these coastal segments. In general, the observed petroleum contamination was purely localized and any severe implication of PHc on the coastal sediment ecosystem of the study area was not evident.

5.1.3 Biological characteristics

Many processes control distribution of life in the coastal water. Some are similar to those we know on land, but others are quite different. Due to constant interaction of sea with atmosphere and inshore segments like estuaries/creeks/bays and associated turbulence, the coastal water forms a highly variable and dynamic environment. The environmental factors which influence distribution of flora and fauna are circulation, tides, freshwater flow, depth, salinity, temperature, DO, CO_2, sunlight, nutrients, nature of sea bed etc.

In aquatic environment, organisms experience natural stress which varies in magnitude and frequency depending on the changes in physicochemical characteristics of the water mass. Though organisms have evolved to withstand such changes, they may not be well adapted to anthropogenic induced stress and this may even affect their capacity to adopt the natural variations.

Aquatic plants and animals depend on one another to provide the conditions and materials that make life possible in the water bodies. Organisms exchange matter and energy with each other and with the waters around them. Ecosystem includes autotrophic organisms (usually plants or bacteria) that produce food from inorganic substances. Heterotrophic organisms (animals and bacteria) eat this food, thereby obtaining needed energy. Outside this arrangement are the omnivores, who eat both plants and animals. The food chain relationship is the study of organic production of the whole ecosystem interms of flow of energy through it. The results of biological characteristics (averages) are summarized in the Figures 5.1.55 to 5.1.92 as well as their ranges are given in the Tables 5.1.I to 5.1.R.

a) Microbiology

Microbes adapted to both water and sediment environment constitute the microbiology of aquatic systems. A Total viable count (TVC) is not a specific micro-organism but rather a test which estimates total numbers of viable individual micro-organisms present in a set volume of sample. The level of TVC in the water and sediment samples gives the indication of load of all the viable bacteria prevailing in the area under study. Fecal coliforms are the indication of fecal contamination in the sample influenced by anthropogenic activities. *Escherichia coli* and *Streptococcus fecalis* are the index organisms indicating the presence or absence of other pathogenic organisms present in the environment; it has to be noted that absence of these index organisms does not necessarily indicate the area is not contaminated with pathogenic organisms. The bacterial characteristics in a polluted versus unpolluted coastal segment is given in Table 5B.

Table 5B

Characteristics	Coastal segment	
	Polluted	Unpolluted
Bacterial population	Abnormally high	Normal
Diversity	High	Normal
Faecal coliform	High	Low
Pathogens	High	Low or absent
Community structure	Dominance of decomposers/ Faecal coliform pathogens	Normal and balanced

i) Bacteria in water

The bacterial counts in water viz; TVC, TC and FC along coastal Maharashtra are given in Table 5.1.I and Figures 5.1.55- 5.1.60. The comparative Table (values in CFU/ml) of TVC, TC and FC for the year 2007-2008 (NIO, MPCB report, 2007-08) and 2015-2016 is summarized below:

Year	Place	Coastal			Creek/Estuary		
		TVC	TC	FC	TVC	TC	FC
2007-2008	North Maharashtra	500-42600	62-16000	20-9240	500-38200	80-15378	26-9864
	South Maharashtra	350-16200	26-2592	18-1866	500-13500	74-2980	14-1900
Year	Place	Coastal			Creek/Estuary		
		TVC	TC	FC	TVC	TC	FC
2015-2016	North Maharashtra	4250-23500	2-3087	2-2044	15000-194000	10-885	4-383
	South Maharashtra	1650-59200	8-195	8-172	3150-45000	58-899	67-606

The coastal and creek/estuary along coastal Maharashtra revealed high variations in bacterial counts viz; TVC, TC and FC in surface water as evident from above data. In general, the bacterial counts in the creek/estuary segments were broadly comparable with open coastal waters of the respective segments of north and south Maharashtra. However, the coastal water of South Maharashtra indicated higher counts of TVC and lower counts of TC and FC as compared to North Maharashtra; whereas reverse scenario was recorded in waters of creek and estuaries. TVC counts recorded in North Maharashtra and South Maharashtra were abnormally high as compared to TVC counts recorded earlier in 2007-2008, whereas counts of TC and FC suggested a decrease in fecal pollution as compared to results recorded in 2007-2008. Also, the load of total coliforms and fecal coliforms recorded in creeks and estuaries of North Maharashtra was comparatively less than load obtained in coastal waters. Whereas, along South Maharashtra coastal waters had less counts of total coliforms and fecal coliforms as compared to creeks/Estuaries and bays.

North Maharashtra

TVC counts were abnormally high (av.>100000 CFU/ml) in the open coastal waters of Tarapur, Bassein and Thal as compared to the open coastal system of Dahanu, Bandra, Worli, Thane and Kundalika (av>10000 CFU /ml). Among the creek/estuary the transects like Tarapur, Ulhas (Bassein), Patalganga and Kundalika showed abnormal values (av.> 100000 CFU/ml) as compared to the rest. The highest TVC counts were obtained in estuarine region of Patalganga followed by creek region of Tarapur, whereas in the coastal segment the highest counts of TVC occurred off Thal. Thus the counts obtained for Tarapur, Patalganga and Thal in current monitoring period is much higher than total viable counts recorded in 2007-2008.

In case of TC, the open coastal waters off Bassein, Bandra,Thal,Kundalika, Murud and Tarapur indicated abnormally high values (av>200 CFU/ml) as compared to the rest, whereas among transects of creek and estuarine system, Bassein, Mahim, Kundalika and Patalganga showed abnormally higher values (av.> 500 CFU/ml). As compared to results recorded in 2007-2008, the counts of TC has increased in Patalganga and Kundalika while decreased in rest of the transects.The FC counts were abnormally high (av >200 CFU/ml) in the open coastal areas of Tarapur, Bandra, Thal, Murud and Kundalika and in the creek/estuarine system of Dahanu, Tarapur, Bassein, Versova, Mahim, Kundalika and Patalganga. As compared to results recorded in 2007-2008, the counts of FC had increased in Dahanu, Patalganga and Kundalika while they decreased in rest of the transects monitored along North Maharashtra. (NIO, MPCB report, 2007-08)

South Maharashtra

TVC counts were abnormally high (av. >10000 CFU/ml) in the open coastal waters of Shastri, Ratnagiri, Vijaydurg and Malvan as compared to rest of the transects whereas it was high among all the transects of creek and estuarine system (except Savitri). Overall Malvan recorded the highest counts of total viable bacteria. On comparing the data for total viable counts recorded in current monitoring period with counts obtained in 2007-2008, it is found that the counts have increased in Savitri, Jaigad, Ratnagiri, Vijaydurg, Deogad and Malvan. ((NIO, MPCB report, 2007-08).

In case of TC, the open coastal waters off Ratnagiri, Vijaydurg, Deogad and Malvan indicated high values (av. >150 CFU/ml) as compared to the rest whereas creek and estuarine systems showed high values (av. >200 CFU/ml) (except Savitri). As compared to results recorded in 2007-2008, the counts of TC were increased in Vashishti and Ratnagiri while they decreased in rest of transects monitored along South Maharashtra. ((NIO, MPCB report, 2007-08).

Similar to TC counts, the FC counts were abnormally high (av. >200 CFU/ml) in the open coastal areas of Malvan and Vijaydurg and in the all transects of creek/estuarine system except Savitri. As compared to results recorded in 2007-2008, the counts of FC had increased in Ratnagiri, Vashishti, Vijaydurg and Malvan and decreased in rest of transects monitored along South Maharashtra.

The pathogens like ECLO, PKLO, VPLO, VCLO, PALO, SHLO and SFLO were also recorded in varying counts in the polluted areas of coastal Maharashtra.

Overall, the results indicated higher environmental deterioration at different segments along north Maharashtra than that of south Maharashtra as evident from high to abnormally high counts of TVC, TC and FC in surface waters. This was mainly attributed to continuous indiscriminate discharge of domestic wastes over a prolonged period in the coastal system of north Maharashtra as compared to the south coast.

ii) Bacteria in sediment

The bacterial counts (CFU/g) in sediment viz; TVC, TC and FC along coastal Maharashtra are given in Table 5.1.J and Figures 5.1.61-5.1.66. The comparative Table (values in CFU/g) of TVC, TC and FC for the year 2007-2008 and 2015-2016 is summarized below:

Year	Place	Coastal			Creek/Estuary		
		TVC	TC	FC	TVC	TC	FC
2007-2008	North Maharashtra	1800-196200	190-46150	130-22460	1200-242200	380-46280	90-22630
	South Maharashtra	2300-32100	510-18490	110-12680	1900-30000	110-17820	920-8500
Year	Place	Coastal			Creek/Estuary		
		TVC	TC	FC	TVC	TC	FC
2015-2016	North Maharashtra	16500-1045000	23-545	7-2044	77000-133901	1500-108800	14000-775000
	South Maharashtra	119900-772500	8-2169	500-1503	175000-767500	125-33244	176-24821

Bacterial counts viz; TVC, TC and FC in sediment were much higher than in water and varied widely in various segments viz; coastal, creek and estuary of coastal Maharashtra as noticed from above data. Again, the counts of TVC, TC and FC were much higher in the sediments of open coastal, creeks and estuaries along the northern shore as compared to southern shore of Maharashtra.

North Maharashtra

TVC counts were abnormally high (av.>1000000 CFU/g) in the sediment of open coastal system of Dahanu and Tarapur as compared to the open coastal system of Bandra, Murud, Thal and Kundalika (av.>200000 CFU /g). Among the creek/estuary, the transect like Tarapur, Bassein, Patalganga, Kundalika and Amba showed abnormally high values (av. >1000000 CFU/g) as compared to the rest. The highest TVC counts were confined to estuarine sediment of followed by creek region of Tarapur and Bassein whereas in the coastal segment the highest counts of TVC were obtained off Dahanu.

On comparing the current monitoring data with that of 2007-2008, it was found that the TVC at Dahanu, Tarapur, Patalganga, Amba, Thal, Kundalika and Murud was much higher than the corresponding counts in 2007-2008. (NIO, MPCB report, 2007-08).

In case of TC, the sediment of open coastal system off Dahanu, Bandra and Murud sustained abnormally high values (av. >300 CFU/g) as compared to the rest whereas among creek and estuarine systems, Dahanu, Tarapur, Bassein and Manori sustained abnormally high values (av. >1000 CFU/g). As compared to the results of 2007-2008, the counts of TC had increased in Tarapur, but declined in rest of the transects monitored along North Maharashtra. (NIO, MPCB report, 2007-08).

The FC counts were abnormally high (av. >1000 CFU/ml) in the sediment of open coastal areas as well as in the creek/estuarine system of Dahanu, Tarapur, Bassein and Manori. As compared to results of 2007-2008, the counts of FC had increased inTarapur, while declined in rest of the transects monitored along North Maharashtra. (NIO, MPCB report, 2007-08).

South Maharashtra

TVC counts were abnormally high (av. >100000 CFU/g) in all of the transects monitored along south Maharashtra. The highest counts of TVC were recorded in sediment of Vashishti from the coastal zone and in sediment of Savitri Estuary. On comparing the data for total viable counts recorded in current monitoring period with counts obtained in 2007-2008, it is found that the counts have increased in all the transects monitored. (NIO, MPCB report, 2007-08).

In case of TC, the sediment of open coastal zone off Ratnagiri, Vijaydurg Achara and Malvan indicated high values (av. >2000 CFU/g) and Vashishti, Ratnagiri, Deogad and Achara regions from estuary/Bay. Abnormally high value (approx. 60000 CFU/g) was recorded in the sediment of Ratnagiri. As compared to results recorded in 2007-2008, the counts of TC had increased in Ratnagiri while decreased in rest of transects. (NIO,MPCB report,2007-08).

Similar to TC counts, the FC counts were abnormally high (av. >1000 CFU/g) in the sediment of open coastal areas of Ratnagiri, Vijaydurg, Achara and Malvan and in the creek/estuarine system of Vashishti, Ratnagiri, Achara and Deogad (av.> 1000 CFU/g). As compared to results of 2007-2008, the counts of FC had decreased in all of the transects monitored along South Maharashtra. (NIO,MPCB report,2007-08).

The counts of pathogens like ECLO, PKLO, VPLO, VCLO, PALO, SHLO and SFLO were variable in the coastal sediments of Maharashtra but generally increased in polluted areas. Overall, the results indicated high to very high counts of TVC, TC and FC in the sediments of northern coastal system as compared to the southern coastal areas. Thus, the results clearly revealed higher degree of bacterial contamination and deterioration in the coastal, creek and estuarine sediments of north Maharashtra and these results closely followed the trend of bacterial counts in water. This trend is primarily attributed to voluminous sewage disposal and hectic port activities in the north than south Maharashtra for the last one decade.

b) Phytoplankton

Phytoplanktons are vast array of minute and microscopic plants passively drifting in natural waters and mostly confined to the illuminated zone. In an ecosystem these organisms constitute primary producers forming the first link in the food chain.

Phytoplanktons have long been used as indicator of water quality (Table 5C). Some species flourish in highly eutrophic waters while others are very sensitive to organic and/or chemical wastes. Some species develop noxious blooms, sometimes creating offensive tastes and odours or anoxic or toxic conditions resulting in animal death or human illness. Because of their short life cycles, phytoplankton responds quickly to environmental changes. Hence their standing crop interms of biomass, cell counts and species composition are more likely to indicate the quality of the watermass in which they are found.

Table 5C: Phytopigments/population as indicator of pollution

Characteristics	Coastal segment	
	Polluted	Unpolluted
Chlorophyll *a*, phaeophytin and phyto-population	Wide variability and abnormally high values (>60 mg/m^3 for Chl *a*; >10 mg/m^3 for Pheophytin)	Low variability and normal values (<60 mg/m^3 for Chl *a*; <10 mg/m^3 for Pheophytin)
Ratio of chl *a:* Phaeo	<1	>1
Sensitive species	Disappearance or mortality	Appearance and survival
Community structure	Dominance of stress tolerant and opportunistic species	Normal and balanced composition

Generally, phytoplankton standing crop is studied interms of biomass by estimating chlorophyll *a* and primary productivity and also interms of population by counting total number of cells and their generic composition. When under stress or at the end of their life cycle, chlorophyll in phytoplankton decomposes with phaeophytin as one of the major products. The results of phytoplankton (range and averages) are summarized in the Tables 5.1.K and 5.1.L and Figures 5.1.67 to 5.1.74.

It is evident from Figures 5.1.67 and 5.1.68 and Tables 5.1.K and 5.1.L that the concentration of chlorophyll *a* (av. 0.96 – 19.5mg/m^3) in the coastal system of Maharashtra varies widely suggesting high seasonal variability and patchiness in the distribution of phytoplankton. Northern segments indicated higher values than that of south Maharashtra. Bandra, open shore waters revealed very high values (>10 mg/m^3). Whereas the rest of the northern segments showed higher values than normal (<10 mg/m^3). In the south, the openshore segments indicated normal trends.

Majority of the creeks and estuaries along coastal north Maharashtra revealed very high values of chlorophyll *a*. Except Dahanu, Thane, and Amba, the rest of the creeks and estuaries of north Maharashtra indicated abnormally high average values (>10 mg/m^3) of chlorophyll *a*. The highest chlorophyll *a* value (av 19.5 mg/m^3) was noticed at Bassein. The wide variations in the values of chlorophyll *a* could be related to regional and seasonal differences, environmental conditions like organic input to the coastal system and grazing pressure on phytoplankton by secondary producers.

The results revealed that similar to chlorophyll *a* the phaeophytin values also varied widely and ranged between 0 to 23.3 mg/m^3 with the maximum at Bassein (Figures 5.1.67 and 5.1.69). The trends of northern and southern open shore segments, in general, were comparable. The coastal transect of Dhanu, Worli and Thal indicated high phaeophytin values (max.) while the rest showed normal values along north. The estuary/creek areas of Tarapur, Bassein, Manori and Patalganga showed abnormally high values (max. >10 mg/m^3) for the coastal Maharashtra.

In general, the phaeophytin values along coastal Maharashtra were moderate suggesting high phytoplankton production. Such trends are commonly noticed in a highly productive coastal marine ecosystem associated with high organic input either through natural or anthropogenic source. However, the ratios of chlorophyll *a* to phaeophytin (>1 mg/m^3) mostly suggested a delicate balance between growth and mortality of phytoplankton in the coastal segments of Maharashtra.

The variations in phytoplankton population apply not only to difference in density, but to distinction in floristic composition. Phytoplankton composition also varies considerably with time and space. Thus, a very few species may be overwhelmingly common during blooms, while a large number of species may occur without clear dominance under normal conditions. These latter populations are said to have high species diversity, in contrast to low diversity populations where there are only a few dominant species. Massive blooms may be related to eutrophication, resulting from natural or anthropogenic addition of nutrients which may be abundantly available.

As evident from Figures 5.1.71 and 5.1.72 and Tables 5.1.K and 5.1.L that the cell counts of phytoplankton also revealed wide variations in accordance with the distribution of phytopigments along coastal Maharashtra. All the open shore coastal transects of north except Thal (max. 150.4 x 10^3/ml) revealed abnormally high cell counts (>200 x 10^3/ml). In the south many of the open shore segments showed normal values except Ratnagiri and Malvan where the average values were high. The creeks and estuaries along coastal Maharashtra revealed either high or abnormally high values suggesting very good primary production in the inshore segments as compared to the open coastal waters. Most of the transects along north clearly indicated human induced high primary production due to organic pollution. Whereas such trends were noticed only at selected bay/creek or estuaries along south Maharashtra.

The generic composition of phytoplankton at different coastal segments of Maharashtra widely varied (Figures 5.1.73 and 5.1.74 and Tables 5.1.K and 5.1.L) in accordance with trends in phytopigments and population. The generic diversity of phytoplankton was in general, high in the open coastal, creek and estuaries along coastal Maharashtra except certain transects like Malvan, Worli, Bandra, Murud and Thal. Overall, the generic diversity of phytoplankton was good along the coastal Maharashtra supporting high primary production of the region. The low diversity and high population in Malvan may be indicative of selective generic dominance and bloom-like conditions.

The composition of phytoplankton genera widely varied from 3 to 52 at individual stations along coastal Maharashtra (Tables 5.1.K and 5.1.L). In general, the dominant genera of phytoplankton between northern and southern coastal segments of Maharashtra were comparable. However, the order of dominance between them noticeably varied depending upon the place and season. The most dominant genera along northern segment were *Navicula*, *Skeletonema*, *Guinardia*, *Nitzschia*, *Peridinium*, *Cyclotella*, *Bacteriastrum*, *Oscillatoria*, *Chaetoceros*, *Pleurosigma, Biddulphia* and *Thalassionema*. Similarly, the southern segments were represented by the generic dominance in the order of *Bacteriastrum*, *Biddulphia*, *Thalassiosira*, *Thalassionema*, *Navicula*, *Nitzschia*, *Amphiprora, Chaetoceros, Aulocoseira*, *Coscinodiscus*, *Peridinium*, *Cyclotella*, *Ceratium* and *Dictyocha*. The open shore coastal waters of the north Maharashtra were represented by the most dominant genera like *Thalassiosira*, *Thalassionema*, *Pleurosigma,Guinardia*, *Skeletonema*, *Chaetoceros*, *Navicula*, *Nitzschia*, and *Cyclotella*. Whereas, the general like *Asterionella*, *Amphiprora*, *Mallomonas*, *Navicula*, *Nitzschia*, *Thalassiosira*, *Thalassionema*, *Chaetoceros, Cylindrotheca* and *Coscinodiscus* were dominant along the openshore coastal system of the south Maharashtra. *Thalassiosira*, *Navicula*, *Skeletonema*, *Nitzschia*, *Guinardia* and *Cyclotella* were the dominant genera noticed along the northern creeks, whereas the dominant genera of the southern creeks were *Navicula*, *Nitzschia*, *Chaetoceros*, *Biddulphia*, *Coscinodiscus* and *Ceratium*.

The genera like *Thalassiosira*, *Skeletonema*, *Navicula*, *Nitzschia*, *Peridinium*, *Bacteriastrum* and *Cyclotella* were dominant along the northern estuaries. Whereas the southern estuaries indicated the dominance of genera like *Thalassiosira*, *Cylindrotheca*,*Thalassionema*, *Navicula*, *Nitzschia, Amphipora* and *Cyclotella*. The dominance of *Thalassiosira* and *Bacteriastrum* in the coastal segments of north and south Maharashtra was evident from above results. However, the southern creeks were predominated by the genera like *Navicula* and *Nitzschia* than that of northern creeks. Thus, specific generic dominace of phytoplankton was evident at different coastal segments of Maharashtra. Phytoplankton bloom of *Skeletonema* occurred at Thane Creek and this could be recurring phenomena around Mumbai. The genera like *Skeletonema*, *Guinardia*, *Thalassiosira*, *Chaetoceros* and *Navicula* may be considered as pollution tolerant phytoplankton since they were most dominant in the coastal system of MumbaI as well along the polluted estuaries/creek of Maharashtra.

c) Zooplankton

Zooplankton is myriads of organisms that drift with currents. By virtue of sheer abundance and intermediate role between phytoplankton and fish, they are considered on the chief index of utilization of aquatic biotope at the secondary trophic level. The herbivorous zooplanktons are efficient grazers of the phytoplankton population and have been referred to as living machines transforming plant material into animal tissue. The zooplankton can be used as the indicator organisms for the physical, chemical and biological processes in the aquatic body. They occur at different depths and constitute a complicated ecological system.

Zooplankton characterised by their faunal diversity includes arrays of organisms varying in size from the microscopic protozoan to jellyfish. The physico-chemical boundaries play an important role in the distribution of zooplankton in the sea as there are usually strong gradients interms of light, temperature and salinity from surface to bottom layers. Besides light, food availability, inter and intra species competition, predation pressure, niche selection, energy conservation and physiological state are the major biological factors responsible for distribution aided by the physical factors like tides, waves, currents and circulation of water mass. The zooplanktons are dispersed according to the scales of water turbulence.

The zooplankton standing stock in terms of biomass and population ranged widely from 0.1 to 571 ml/100m^3 and 0.02 to 693 x 10^6 nos./100m^3 respectively. The results of zooplankton (range and averages) are summarized in Tables 5.1.M and 5.1.N and Figures 5.1.75 to 5.1.80.

The zooplankton biomass (ml/100m^3) as evident from Figures 5.1.75 to 5.1.76 varied widely along the coastal Maharashtra suggesting patchiness in their distribution associated with spatial, temporal and seasonal variability. The distribution of average biomass indicated low to high values at different segments of coastal Maharashtra. The open coastal segments off Tarapur, Murud, Vashishti and Vijayadurg indicated low values of zooplankton biomass. Among the bay/creek/estuary system except Manori, Thane, Amba and Murud the rest of them indicated low to average biomass values and the former it was normal. Thane creek revealed abnormally high biomass for the study area inspite of polluted nature and the occurrence of such big values especially during premonsoon could be related to dominance of carnivore predators like decapods, *Acetes* sp. and medusae in the middle and upperCreek. Such congregation of zooplankton in the lower estuarine segments can be related to estuarine hydrodynamics as well as ecosystem modification aided by anthropogenic waters.

The faunal group diversity of zooplankton (Figures 5.1.77 to 5.1.80) at different segments viz. coastal/creek/estuary along Maharashtra was closely comparable. Many of the open shore segments along Maharashtra showed comparatievely high values while the rest of them were low. Similarly, most of the creeks and estuaries along coastal Maharashtra indicated comparatievely higher groupdiversity of zooplankton except a few where it was less. The faunal groups like copepods, decapods, chaetognaths, foraminiferans, gastropods, lamellibranchs, medusae and fish eggs were dominant along northern coast. Whereas, copepods, decapods, siphonophores, cladocerans, *Lucifer* sp., gastropods, lamellibranchs, chaetognaths, appendicularians and fish eggs and fish larvae were dominant along southern coast. The above results indicated clear cut difference in group dominance between the north and south coastal systems of Maharashtra. Also the present results clearly revealed that faunal groups like copepods, decapods, gastropods, lamellibranchs, foraminiferans, medusae and chaetognaths had shown differential tolerance to various pollutants especially in the coastal system of Maharashtra.

It is evident from the results that the zooplankton productivity interms of biomass, population and faunal diversity varied widely in the region, as commonly observed for coastal areas under high tidal influences and normal patchiness in the distribution of various groups. The faunal diversity was maximum at Vijayadurg and minima at Bassein.

Overall the present study found that the zooplankton biomass has been found decreased in comparison with previous study in 2007-08 along the North and South Maharashtra coast.

Benthic fauna

Benthic fauna refers to various organisms found on (epifauna) and in (infauna) the bottom floor of aquatic body. These animals are divided into three categories i.e.microfauna (<63µm), meiofauna (>63µm and <500µm) and macrofauna (>500µm) based on their size differences. Benthic community responses to environmental perturbations are useful in assessing the impact of anthropogenic perturbations on environmental quality. The viability of particular faunal group or species in an area will be a result of combined impact of multiple factors including biotic and abiotic. Three situations for which patterns of benthic community structure change have been documented viz. organic loading, substrate alterations, and toxic chemical pollution in the present study. Severe organic pollution usually results in the decreased diversity of benthic organisms to the dominance of most tolerant ones.

Assessing the impact of a pollution source generally requires the comparison of benthic communities and their physical habitats at sites influenced by pollution with those from adjacent unaffected sites. The benthic communities can be characterized and compared accordingly to community structure such as density, biomass and diversity or other analyses.

In the present study macro and meiobenthic communities have been studied for the purpose of understanding the status of the coastal ecosystems along Maharashtra.

d) Macrobenthos

The subtidal macrobenthic standing stock in terms of population and biomass range vary from 0 to 23950 Ind./m^2 and 0 to 513.06 g/m^2; wet wt respectively with the highest population and biomass at Manori. The results of macrobenthos (range and averages) are summarized in the Tables 5.1.O and 5.1.P and Figures 5.1.81 to 5.1.86.

The benthic biomass was highly varied in the coastal system of Maharashtra (Figures 5.1.81 and 5.1.82). The open coastal waters indicated wider range of benthic biomass in the north than south Maharashtra. The coastal waters off Dahanu, Tarapur, Bassein, Bandra, Thane, Thal, Kundalika, and Vashishti sustained low biomass; out of which all transects, except Vashishthi, are from north Maharashtra. In general, the open shore coastal system of south Maharashtra revealed better benthic production than north Maharashtra. The creek/estuaries of coastal Maharashtra showed good benthic potential for the study area. The benthic biomass in the creeks and estuaries have also revealed the same results as in case of coastal waters i.e. northern segments showed wide range of spatial variation in biomass as compared to southern coast of Maharashtra. The highest value was noticed at

Manori, Thane, Murud transects. Among the estuaries, Ulhas (Bassein) showed lowest average benthic biomass (1.85 g/m^2).

The population of macrobenthos along the coastal Maharashtra widely varied and also followed a similar trend that of biomass (Figures 5.1.83 and 5.1.84). In general, the open coastal waters sustained normal to high population counts suggesting good benthic potential for the study area especially along southern coastal segments. The open shore coastal system of Dahanu, Tarapur, Ulhas (Bassein), Bandra and Thal revealed low benthic population. These results suggest lower productivity in coastal areas of north Maharashtra than south Maharashtra.

The population density of creeks and estuaries along coastal Maharashtra indicated normal to high values. All the estuaries, along Maharashtra revealed high values except Amba which showed normal values. In general, the estuaries of coastal Maharashtra revealed good benthic potential in terms of population density. However, in comparison of north to south, more fluctuation in macrobenthic population was recorded in the northern segment than southern segment.

The faunal group diversity of macrobenthos widely varied in the study area suggesting better diversity along south than north coastal Maharashtra (Figures 5.1.85 and 5.1.86). Mostly low diversity of benthos in the open coastal waters of north Maharashtra was found except Murud, where it was normal. In case of south Maharashtra, the open coastal waters showed mostly normal diversity except Savitri, Vashishti and Deogad, where it was low. Among the creeks, Murud, Vijaydurg, Deogad and Achara indicated high diversity of macrobenthos. Whereas the rest of the creeks along coastal Maharashtra revealed low diversity; mostly low diversity creeks are situated along the northern coastline of Maharashtra. All the estuaries sustained low diversity of macrobenthos. Overall, the north coastal segment of Maharashtra revealed low faunal group diversity of benthos suggesting the impact of various abiotic and biotic factors like physico-chemical, nature and stability of substrate, strong currents, monsoonal influence, and prey predator relationship together with human induced anthropogenic changes such as, industrial and organic pollution.

In general, Polychaetes were the most dominant group along coastal Maharashtra. Polychaeta, Amphipoda, Pelecypoda, Nemertea and Brachyurans were most common along the coastal Maharashtra, whereas groups like Polychaeta, Pelecypoda, Gastropoda, Amphipoda, Tanaidacea and Cumacea were more common along south Maharashtra. Polychaeta, Amphipoda, Nemertea, Oligochaeta and Turbellaria were common along north coast of Maharashtra. Hence, the order of dominance of selected faunal groups varied between north and south segments of coastal Maharashtra. This could be related to various factors as mentioned above. Thus, the groups like Polychaeta, Gastropoda, Pelecypoda, Nemertea and Amphipoda indicated tolerance to coastal pollution of the study area. The group like Tanaidacea, Ostracoda and Cumacea which were noticed more frequently with good counts along south than north Maharashtra suggesting their preference to cleaner environment.

The overall results reveal wide spatial variations in the subtidal macrobenthic standing stock with 0-15 faunal groups.

Overall the present study found that the macrobenthic population density has been decreased while biomass has been increased with comparing previous study in 2007-08 along the Maharashtra coast. Group diversity of benthic macrofuan has been increased in the south Maharashtra while decreased trend observed in the north Maharashtra with comparing the studies conducted in 2007-08.

The composition and density of benthos in marine coastal area are reasonably stable from year to year in unpolluted environments. However, seasonal fluctuations associated with life cycle dynamics of individual species, can result in extreme conditions at specific sites within any calendar year.

e) Meiobenthos

The subtidal meiobenthic standing stock interms of population vary from 0 (Bassein) to 7691 Ind./10 cm^2 (Patalganga). The meiofaunal biomass ranged from 0.0 (Bassein) to 47374.56 µg/10cm^2 (Manori). The results of meiobenthos (range and averages) are summarized in the Tables 5.1.Q and 5.1.R and Figures 5.1.87 to 5.1.92.

It is evident from Figures 5.1.87 and 5.1.88 that the meiobenthic biomass varied widely in the coastal system of Maharashtra. The open coastal waters indicated higher variations in the south whereas in north Maharashtra the biomass was comparable and low. The coastal waters off Dahanu, Tarapur, Bassein (Ulhas), Worli, Thane creek and Murud showed lower biomass values than other transects of North Maharashtra. In general, the open shore coastal system of south Maharashtra revealed normal to high values suggesting better benthic production for south than north Maharashtra, except Achara where coastal biomass was low. The creek/estuaries of coastal Maharashtra showed normal to high values suggesting good benthic potential for the study area, except for Dahanu, Mahim, Thane and Savitri. The highest coastal biomass value was noticed at Shastri, whereas among the inshore waters Manori showed highest benthic production. It is important to note here that the exceptionally high biomass at Manori in premonsoon was due to the large number of large body sized Polychaetes. This may be indicative of flourish of opportunistic species that can survive flourish in high abundance at a moderate to high polluted regions.

The population of meiobenthos along coastal Maharashtra showed wide variations (Figures 5.1.89 and 5.1.90). In general, the open coastal waters indicated low to moderate population counts suggesting below average benthic potential for the area along northern coastal segments. The open shore coastal system of Dahanu, Tarapur and Bassein showed low benthic population among the north Maharashtra transects, whereas the other transectsshowed normal meiofaunal density. In the south transects, meiofaunal population in coastal waters were normal to high, except Achara where coastal waters showed low meiofaunal density, which may be due to high currents and sandy substratum in the open coastal region.

Among the creeks and estuaries of north Maharshtra most of them recorded normal meiofaunal counts, except Mahim which showed low meiofaunal density, and Tarapur, Manori and Patalganga where counts were very high as a result of nematode dominance in the region. Of the south Maharashtra transects except Savitri, all other areas showed normal population of meiofauna in inshore waters. Savitri, Vashishthi, Shastri, Ratnagiri and Vijaydurg showed higher meiofauna count in the coastal waters than in the inshore region. The south transects showed lesser variation in meiofaunal population than the north transects, indicating healthier ecological condition than at north Maharashtra.

Benthic fauna are found to be abundant in soft oxygenated mud. Thus the benthic communities are poor near sewage disposal areas but rich sufficiently away from the disposal location but within the same water system, which may result in high overall density, and may be mistaken to represent healthy ecosystem. Thus, meiofaunal diversity is also a major factor in deciding the quality of an ecosystem.

In the study area faunal group diversity showed great variation especially in the northern segments than the southern segment of Maharashtra (Figures 5.1.91and 5.1.92). In coastal waters, Tarapur and Thane showed lowest average faunal group diversity from northern segment, whereas Savitri and Achara showed lowest diversity from southern segments. Among the creeks, Murud and Achara indicated high diversity of meiobenthos comprising of 8 faunal groups on average. Whereas, the rest of the creeks along coastal Maharashtra revealed low diversity. All the estuaries sustained low diversity of meiobenthos except Patalganga, Amba and Shastri. Overall coastal waters from north coast of Maharashtra showed less diversity as compared to inshore waters like estuaries or creeks whereas in southern region coastal diversity was observed to be slightly higher than inshore waters.

Groups like cumaceans, kinorhynchs, tardigrades which are sensitive to environmental perturbations have been recorded mostly from the south transects and rarely from the north. Among the north transects, the diversity at

Murud is noticeable with groups like, brachiopods, cladocerans, ophiuroids and rotifers. This suggests that environmental condition of the southern Marashtra coast is better than northern Maharashtra.

5.1.4 Metals in Biota

The major environmental issues concerning metals are their potential availability and bioaccumulation in the aquatic life. Some metals are essential for metabolic functions in the living organisms; some of the metals such as Hg have no known metabolic importance and their concentration even in trace quantity becomes toxic for the living organisms. Heavy metal contamination may have devasting effects on the ecological balance of the recipient environment and a diversity of aquatic organisms. Many aquatic organisms have the ability to accumulate and biomagnify contaminants like heavy metals. The ingestion of these contaminants may affect not only the productivity but ultimately affect the health of man who depends on these organisms as major source of proteins. Results of metals anlysed in fishes collected from different area is given in table 5.1.4. Average values of elements of concern are summarized in the Table below:

Table 5.1.4: Concentration of heavy metals and PHc in fish tissue collected from coastal Maharashtra.

Transect	Species	Element (µg/g)							
		Cr (µg/g)	Co (µg/g)	Ni (µg/g)	Cu (µg/g)	Zn (µg/g)	Hg (µg/g)	Pb (µg/g)	PHc (µg/g)
Dahanu	Arius maculatus	1.2	0.02	ND	1.2	19.9	0.05	ND	3
	Lutjanusrusselli	1.9	0.9	ND	4.6	59	0.06	ND	1.1
	Pennahiaanea	1.55	0.46	ND	2.9	39.6	ND	ND	1.5
Tarapur	Liza parsia	0.2	0.04	ND	14.48	32.99	0.04	0.17	4.9
	Ilisha megaloptera	0.27	0.03	ND	1.25	31.76	0.05	0.15	3
Ulhas	Opisthopterustardoore	0.31	0.81	1.31	2.97	43.04	0.03	0.18	1.35
	Thryssamalabarica	0.34	0.83	1.14	2.13	55.77	0.015	0.15	0.85
	Coilia dussumieri	0.1	0.42	1.84	ND	75.76	0.02	0.21	3.2
	Pampusargenteus	1.23	0.04	ND	2.86	69.81	0.09	0.11	0.3
	Otolithoidesbiauritus	0.72	0.1	ND	0.86	26.42	0.04	0.2	2.1
	Gopidae	0.4	0.04	ND	7.94	57.72	0.06	0.14	1.8
	Liza parsia	0.2	0.06	ND	0.7	27.16	0.01	0.17	0.5
Patalganga	Ilishamegaloptera	0.1	0.09	ND	6.82	59.1	0.07	0.17	1
	Pennahiaanea	0.4	0.02	ND	1.5	53.5	0.06	0.14	0.8
	Coiliadussumieri	0.54	0.1	ND	2.86	55.94	ND	0.17	2.5

	Arius maculates	0.24	0.08	ND	1.7	91.95	0.02	0.11	0.9
	Johniusbelangerii	0.32	0.1	ND	1.58	30.18	0.03	0.1	0.9
	Panuliruspolyphagus	0.17	0.11	ND	8.31	72.07	ND	0.14	0.4
	Stingray (himanturachaophraya)	0.7	0.06	ND	2.5	49.17	ND	0.1	2.2
	lishamegaloptera	0.49	0.02	ND	1.8	65.29	0.01	ND	0.5
Murud	Thryssamystax	0.24	0.02	ND	1.13	30.79	0.06	ND	2
	Pellonaditchella	0.4	0.05	ND	3.7	36.99	0.03	ND	3
	Trichiurussavala	0.69	0.33	ND	9.71	31.2	0.01	ND	1.8
	Portunuspelagicus	0.3	0.1	ND	5.27	36.6	0.05	ND	1.5
	Charybdis cruciata	0.55	0.16	ND	7.18	39	0.03	ND	0.8
	Coiliadussumieri	0.24	0.04	ND	1.17	31.7	ND	ND	2.2
	Johniusaeneus	0.25	0.07	ND	1.61	25.96	0.04	ND	1.9
Kundalika	Liza parsia	0.14	0.03	ND	9.85	22.44	0.04	ND	0.8
	Johnieops aneus	0.2	0.03	ND	0.99	21.21	0.06	ND	0.9
	Carangoides malabaricus	0.19	0.03	ND	1.03	20.11	ND	ND	1.2
	Coila dussumeiri	0.22	0.03	ND	1	25.41	0.05	ND	2.3
Savitri	Arius jella	0.5	0.4	ND	1.2	36.4	ND	ND	1.2
	Cynoglossussp	0.87	0.18	ND	1.61	27.82	0.04	ND	1.2
	Megalaspiscordyla	0.68	0.12	ND	1.73	25.59	0.03	ND	1.5
	Scatophagusargus	0.99	0.39	ND	1.44	24.8	0.05	ND	1.4
	Epinephelussp	0.41	0.08	ND	1.34	34.97	0.01	ND	1.8
	Harpadonnehereus	0.55	0.06	ND	0.76	22.52	0.01	ND	2
	Pampusargenteus	0.44	0.03	ND	0.91	31.71	ND	ND	0.4
	Otolithoidesbiauritus	0.22	0.49	ND	1.8	34.02	ND	ND	1.1
Vashishthi	Ambassis ambassis	ND	0.15	ND	0.93	12.62	ND	ND	1
	Coila dussumeiri	ND	0.14	ND	2.6	23.14	0.04	ND	1.5
	Johniops aneus	ND	0.13	ND	3.96	30.64	0.06	ND	0.9
	Thryssa malabarica	ND	0.16	ND	1.95	30.52	0.03	ND	0.8
	Liza parsia	ND	0.05	ND	0.34	10.12	0.01	ND	0.6
Jaigad	Otolithoidesbiauritus	0.09	0.01	ND	1.31	19.97	0.01	ND	0.6
	Harpadonnehereus	0.65	0.01	ND	2.7	27.15	ND	ND	1.2
	Loligoduvauceli	0.41	0.05	ND	1.1	33.22	0.01	ND	1
	Metapenaeusbrevicornis	0.41	ND	ND	6.91	21.45	ND	ND	0.8
	opisthopterus tardoore	0.33	0.01	ND	1.76	20.73	ND	ND	1.2

Jaigad	Megalaspis cordyla	0.29	0.04	ND	3.3	36.63	ND	ND	0.9
	Lactarius lactarius	0.41	0.05	ND	9.01	32.34	ND	ND	0.8
	Coiliadussumieri	0.96	0.18	0.05	2.26	24.09	ND	ND	1.1
	Loligo	0.6	0.15	ND	2.64	30.61	0.01	ND	0.9
	Cynoglossusarel	0.28	0.03	ND	0.34	10.56	ND	ND	1.2
	Johnieopsaneus	0.96	0.12	ND	0.86	16.5	ND	ND	0.6
	Epinephelusdiacanthus	0.74	0.08	ND	0.84	19.9	ND	ND	0.5
Ratnagiri	Caranxpara	ND	0.15	ND	7.13	29.06	ND	ND	0.6
	Rastrelligerkanagurta	ND	0.12	ND	1.31	19.79	ND	ND	1.4
	Loligoduvauceli	ND	0.21	ND	1.08	26.29	ND	ND	1.3
Deogad	Trichiurussavala	0.37	0.06	ND	1.62	23.8	0.02	ND	0.8
	Ilishamegaloptera	0.96	0.14	ND	1.82	22.47	0.02	ND	0.5
	Sardinellagibbosa	0.23	0.1	ND	2.51	33.58	0.03	ND	0.2
	Johniusaeneus	0.44	0.12	0.43	1.01	38.47	0.02	ND	0.9
Vijaydurg	Epinephalusareolatus	0.87	0.07	ND	0.71	24.07	0.03	ND	1.5
	Caranxpara	0.2	0.06	ND	3.36	27.15	ND	ND	1.2
	Lutjanusrusselli	0.06	0.04	0.01	4.98	34.14	ND	ND	1
	Sphyraenajello	0.33	0.02	ND	1.31	21.68	0.03	ND	0.8
USEPA Limit		8.0	-	1.0	120	120	0.5	4.0	-
WHO Limit		-	-	0.5-0.6	30	40	0.5	0.5	-

From the above results of metal (Cr, Co, Ni, Cu, Zn, Hg and Pb) analysis in the edible tissues of different species of fishes/prawns, it was found that the concentration of Cr varied in the range from ND to 1.9 µg/g; dry wt, which is below the permissible limit set by USEPA (8.0 µg/g; wet wt) for Cr in edible tissues. Chromium was not detectable in the fishes collected from Ratnagiri and Vashishti estuary and highest concentration was at Dahanu during postmonsoon season. Similarly Co was high (0.42-0.83 µg/g; dry wt) in Ulhas Estuary during postmonsoon season. However, during premonsoon, the concentration was low (0.03-0.83 µg/g; dry wt), even in the same species (Opisthopterustardoore and Thryssamalabarica). Fishes of all other area showed Co concentration <0.94 µg/g (dry wt). Concentration of Ni was also high (1.14-1.84 µg/g; dry wt), in Ulhas Estuary during postmonsoon season.However, above value is below the permissible level, when compared to dry and wet wt ratio. In other areas and season the concentration of Ni in fishes was low (ND-0.43 µg/g; dry wt). The concentration of Cu (ND-14.48 µg/g; dry wt) and Hg (ND-0.09 µg/g; wet wt) at almost all the locations was below the USEPA permissible level of 120 µ/g; dry wt and 0.5 µg/g; wet wt respectively. Pb was not detectable at all locations except at Ulhas and Patalganga estuaries, where the concentration varied from 0.01 to 0.04 µg/g;

dry wt. Concentration of Zn was high (10.12-91.95 µg/g; dry wt) in patalganga region. Concentration of 91.95 µg/g; dry wt and 72.07 µg/g; dry wt found in Arius maculates *and* Panuliruspolyphagus respectively from patalganga region, though high, but not exceeding permissible limit when compared on dry and wet weight ratio, as the analysis based on dried fish tissues. Overall, the results indicate that the fishes collected from different sites of Maharashtra coast are relatively free from contamination by toxic metals (Cr, Co, Ni, Co, Zn, Hg and Pb) as compare to the permissible limit.

5.1.5 Petroleum hydrocarbon (PHc) in biota

Estuaries are among the most productive ecosystems on the earth and more than 50% of the world population lives along the estuaries and coastlines (Bincy et al., 2013). Estuarine regions are very prone to contamination by PHc originated from domestic and industrial effluents, boating and shipping activities, and marine operations including tanker traffic and oil product ion. Although a significant portion of petroleum hydrocarbons entering the marine environment is removed by evaporation, a portion gets disseminated in water, accumulated in sediment and transferred to biota. PHc has received special attention because it is readily adsorbed onto particulate matter and settles to the bottom sediment ultimately act as a reservoir for hydrophobic contaminations. Predominance of hydrocarbons including several types such as normal alkanes (saturated, n-alkanes), unsaturated hydrocarbons, non-symmetric cyclic hydrocarbons (terpanes) and polycyclic aromatic hydrocarbons (PAHs), in the environmental samples indicate petroleum pollution. Some of the petroleum compounds are magnified through food chain. These hydrocarbon components belong to the family of carcinogens and neurotoxic organic pollutants which affect a variety of biological processes and entities. Petroleum pollutants tend to accumulate more in the organisms than in the environment since fishes are at the top of the food web in the aquatic ecosystem. Hence they accumulate substantial amount of PHc, if exposed to the contaminated area. Oil comes in direct contact with fish and contaminates their skin or gills, whereas toxic and volatile components of oil, present in the water column are absorbed by their eggs, larvae, and fishes at juvenile stages may eat contaminated food and accumulate toxins in their tissues. Therefore it is used as a bio-indicator to assess the PHc contamination levels in environment. It has been reported that the PHc concentration of as low as 0.1 ppm can be toxic to larvae of some of species in the sea. Human consuming large quantity of fish become ultimate target of these carcinogenic organic compounds.

Fishes caught through experimental trawling and collected from local fishermen were analysed for the PHc concentration in tissue and the results are presented in Table 5.1.4.From the table it is evident that the PHc concentration was maximum in *Arius maculatus* (3.0 µg/g; wet wt) *Liza parsia* (4.9 µg/g; wet wt),*Ilisha megaloptera* (3.0 µg/g; dry wt),*Coilia dussimieri* (3.2 µg/g; wet wt) and *Pellonaditchella* (3.0 µg/g; wet wt) caught from Dahanu, Tarapur creeks, Ulhas Estuary and Murud. PHc concentration in fishes, caught from different locations was in the range 0.3-2.2 µg/g; wet wt. These values are below the recommended safe limit (maximum10 µg/g; wet wt).

Table 5.1.A: Range of water quality parameters (physico-chemical) along Maharashtra coast during 2015-2016.

Transect	Coastal					Creek/Estuary				
	WT (ºC)	pH	SS (mg/l)	Turbidity (NTU)	Salinity (ppt)	WT (ºC)	pH	SS (mg/l)	Turbidity (NTU)	Salinity (ppt)
Dahanu	26.0-34.0	7.7-8.2	20-210	3.1-22.2	35.0-37.3	26.0-38.0	7.5-8.2	20-191	20.5-76.7	32.7-37.2
Tarapur	29.0-34.5	7.4-8.1	14-70	4.6-9.2	34.2-37.1	28.0-34.5	7.4-8.1	12-82	1.5-11.3	32.1-36.8
Bassein	26.5-33.0	7.7-8.2	219-505	122.7-236.7	24.3-36.8	25.0-35.0	7.2-8.0	69-620	34-232.7	0.4-35.7
Manori	-	-	-	-	-	26.0-32.0	7.6-8.1	28-156	14.4-32.5	28.8-35.0
Versova	-	-	-	-	-	26.0-31.0	7.3-8.2	38-139	13.2-31.5	10.7-36.7
Mahim	-	-	-	-	-	26.0-30.0	7.5-8.4	39-131	10.2-58.1	17.4-36.1
Bandra	26.0-31.5	7.8-8.4	46-168	1.9-16.8	29.1-36.4	-	-	-	-	-
Worli	26.5-30.0	7.9-8.4	68-109	10.4-21.2	34.0-36.8	-	-	-	-	-
Thane	27.5-30.0	8.0-8.2	58-290	22.6-106.9	34.4-36.5	26.5-30.0	7.5-8.2	22-389	16.3-118.2	28.9-36.9
Patalganga	-	-	-	-	-	24.5-32.5	7.0-8.0	9-181	4.7-42.8	0.1-32.5
Amba	-	-	-	-	-	26.0-32.5	7.4-8.0	23-117	1.1-15.2	0.3-36.5
Thal	27.5-30.5	7.6-7.9	104-363	23.5-78.0	34.5-36.7	-	-	-	-	-
Kundalika	26.5-29.5	7.7-8.0	88-193	36.5-105.1	34.1-36.7	26.0-30.5	7.2-7.9	56-327	25.4-149	0.1-36.1
Murud	26.0-29.5	7.9-8.0	15-251	10.4-29.3	34.4-36.8	25.5-29.5	7.9-8.2	9-274	1.4-18.5	34.1-37.7
Savitri	25.0-27.5	7.9-8.0	16-93	1-17	35.0-36.2	24.0-31.5	7.5-8.0	17-228	0.5-74.5	10.0-36.5
Vashishti	23.5-28.5	8.0-8.1	44-148	2.2-24	35.0-36.2	24.0-31.5	6.8-8.3	13-186	1.2-34.8	0.6-35.8
Jaigad	27.5-29.5	7.9-8.1	15-20	0.6-2.2	35.3-35.8	25.5-29.5	7.7-8.0	18-36	0.3-2.3	27.2-36.5
Ratnagiri	26.5-29.5	7.8-8.2	10-21	0.5-2.0	35.4-36.0	26.0-29.5	7.6-8.2	11-28	0.8-3.4	35.0-36.1
Vijaydurg	27.0-29.5	8.0-8.1	28-35	1.7-7.0	35.3-35.8	24.5-30.0	8.0-8.2	23-179	1-2.6	34.7-35.8
Deogad	27.5-29.0	8.2-8.2	17-21	1.1-2.6	35.3-35.7	23.5-35.0	8.0-8.2	14-26	1.5-3.9	25.2-35.7
Achara	23.5-29.5	8.1-8.2	17-35	1.2-2.3	34-35.7	24-31.5	7.7-8.2	12-31	1.1-5.9	29.8-35.8
Malvan	25.0-30.5	8.1-8.2	7-19	1.2-2.4	35.3-35.7	27.5-31.0	8.0-8.2	17-34	1.1-2.5	35.4-35.8
North Maharashtra	**26.0-34.5**	**7.4-8.4**	**12-505**	**1.9-236.7**	**24.3-37.3**	**24.5-38.0**	**7.0-8.4**	**9-620**	**1.1-232.7**	**0.1-37.7**
South Maharashtra	**23.5-30.5**	**7.8-8.2**	**7-168**	**0.5-24.0**	**34.0-36.2**	**23.5-35.0**	**6.8-8.3**	**11-228**	**0.3-74.5**	**0.6-36.5**

Table 5.1.B: Range of water quality parameters (physico-chemical) along Maharashtra coast during 2015-2016.

Transect	Coastal				Creek/Estuary			
	DO (mg/l)	BOD (mg/l)	PO_4^{3-}-P (µmol/l)	NO_3^--N (µmol/l)	DO (mg/l)	BOD (mg/l)	PO_4^{3-}-P (µmol/l)	NO_3^--N (µmol/l)
Dahanu	3.5-6.7	1.0-3.5	0.6-2.3	12.2-34.3	4.5-7.4	1.9-4.2	0.5-3.2	2.0-20.3
Tarapur	1.6-7.0	1.6-28.5	0.4-2.3	0.7-16.9	0.6-9.0	2.2-25.3	0.5-3.3	0.7-19.3
Bassein	2.5-6.2	0.6-4.4	1.2-16.1	2.0-62.1	<0.2-7.0	0.3-69.2	0.2-25.6	0.2-68.5
Manori	-	-	-	-	1.9-7.0	0.3-4.8	2.5-36.9	6.0-37.5
Versova	-	-	-	-	<0.2-6.7	0.6-30.6	0.1-35.0	0.5-22.0
Mahim	-	-	-	-	1.9-5.4	0.6-2.9	0.1-8.3	1.2-29.4
Bandra	3.5-7.0	0.6-2.6	0.2-13.8	4.7-31.3	-	-	-	-
Worli	3.8-9.6	1.0-4.8	0.1-3.3	3.9-18.9	-	-	-	-
Thane	5.1-6.7	0.3-3.8	0.4-2.4	4.6-34.8	2.6-9.6	1.0-9.0	0.5-49.4	6.6-60.3
Patalganga	-	-	-	-	0.3-7.0	0.9-35.6	0.6-27.0	0.5-59.3
Amba	-	-	-	-	2.9-7.9	0.9-5.0	1.3-14.7	5.2-71.6
Thal	3.5-6.0	1.9-3.8	1.8-3.7	5.9-41.4	-	-	-	-
Kundalika	4.8-6.7	1.9-4.7	0.7-4.4	6.4-18.7	1.6-7.0	0.9-19.4	0.2-17.9	2.8-70.4
Murud	5.7-7.0	1.3-3.8	0.4-3.0	5.1-16.9	4.4-7.0	0.3-4.9	0.4-3.3	0.3-9.1
Savitri	5.5-6.8	1.0-3.9	0.6-1.4	2.1-13.2	3.8-7.1	1.3-4.1	0.2-1.6	1.7-21.6
Vashishti	5.4-7.0	2.2-4.8	0.6-1.8	3.8-8.7	1.6-6.7	1.0-15.4	0.2-2.2	0.7-39.0.
Jaigad	5.7-6.8	1.0-2.9	0.2-0.7	1.2-5.8	4.8-7.3	0.6-3.8	ND-1.9	0.2-11.1
Ratnagiri	5.1-7.3	0.5-3.3	0.1-1.8	0.4-3.7	0.6-8.2	0.8-19.4	0.1-27.6	0.1-19.0
Vijaydurg	5.5-7.8	1.3-5.4	0.1-1.2	1.0-3.1	3.5-7.3	1.6-5.1	0.3-6.4	0.1-2.4
Deogad	5.8-7.2	2.9-4.5	0.1-0.7	1.1-2.2	5.1-7.7	2.2-5.7	0.2-1.4	0.7-4.1
Achara	5.8-7.0	1.9-3.1	0.1-0.8	0.7-2.0	4.2-7.4	0.6-3.6	ND-0.7	0.5-3.9
Malvan	6.3-7.7	1.0-4.1	0.1-0.8	ND-3.2	5.4-7.7	2.3-3.6	0.1-1.0	0.2-6.1
North Maharashtra	**1.6-9.6**	**0.3-28.5**	**0.1-16.1**	**0.7-62.1**	**<0.2-9.6**	**0.3-69.2**	**0.1-49.4**	**0.2-71.6**
South Maharashtra	**5.1-7.8**	**0.5-5.4**	**0.1-1.8**	**ND-13.2**	**0.6-8.2**	**0.6-19.4**	**ND-27.6**	**0.1-39.0**

Table 5.1.C: Range of water quality parameters (physico-chemical) along Maharashtra coast during 2015-2016.

Transect	Coastal				Creek/Estuary			
	NO_2^--N (µmol/l)	NH_4^+-N (µmol/l)	PHc (µg/l)	Phenols (µg/l)	NO_2^--N (µmol/l)	NH_4^+-N (µmol/l)	PHc (µg/l)	Phenols (µg/l)
Dahanu	0.3-1.3	0.8-3.3	2.0-7.9	49.9-134.3	0.1-1.3	0.6-7.3	3-17.0	57.6-145.0
Tarapur	0.1-1.9	0.6-26.9	3.0-25.3	82.8-118.1	0.3-9.8	8.2-50.7	6.2-19.1	82.8-206.9
Bassein	0.1-8.8	1.8-12.8	1.4-8.3	59.3-109.2	0.1-15.0	0.8-97.1	1.5-72.1	53.8-209.3
Manori	-	-	-	-	0.1-5.6	1.6-51	1.6-5.5	43.2-112.6
Versova	-	-	-	-	ND -4.5	2.1-62.8	0.8-4.7	29.3-185.8
Mahim	-	-	-	-	0.1-6.6	2.5-17.0	1.2-4.5	20.4-95.8
Bandra	0.1-6.3	0.2-41.6	0.2-2.5	31.2-135.8	-	-	-	-
Worli	0.1-3.7	0.4-12.9	1.2-2.4	46.1-72.5	-	-	-	-
Thane	0.1-1.0	0.9-5.2	1.2-3.3	28.1-138.4	0.2-31.4	0.2-36.1	1.8-7.4	22.3-333.8
Patalganga	-	-	-	-	ND -31.2	0.6-73.8	1.0-112.8	41.3-346.8
Amba	-	-	-	-	0.1-9.5	ND -32.4	3.1-8.7	2.6-592.1
Thal	0.5-2.1	3.6-35.5	9.2-12.3	84.5-367.7	-	-	-	-
Kundalika	0.3-2.2	0.7-7.4	2.1-9.6	20.6-414.7	0.1-14.7	0.9-35.1	1.8-24.0	10.8-922.3
Murud	0.2-1.7	1.3-3.4	0.6-7.0	40.1-117.6	0.1-0.9	0.8-6.5	1.0-8.2	23.0-117.6
Savitri	0.3-1.0	0.5-2.4	1.9-4.7	59.8-80.4	0.3-10.8	0.5-4.8	0.8-19.9	12.6-104.4
Vashishti	0.6-2.6	0.8-6.3	2.8-5.3	45.1-84	1.6-17.8	0.6-30.2	2.7-15.8	61.9.7-197.0
Jaigad	0.1-1.2	0.4-3.9	1.8-6.4	35.8-64.1	ND -2.2	0.3-5.8	1.2-16.4	54.7-98.4
Ratnagiri	ND -0.2	0.2-2.6	1.7-11	35.3-114.6	ND -2.2	0.1-28.0	2.4-9.1	64.3-117.6
Vijaydurg	0.1-0.2	0.7-6.8	4.1-17.2	51.1-127.7	ND -0.4	0.2-19.4	2.2-14.2	80.9-144.0
Deogad	0.1-0.4	0.3-2.1	1.0-3.0	23.8-92.4	ND -0.4	0.4-3.9	2.6-12.2	8.4-117.4
Achara	ND -0.5	0.4-1.9	4.2-6.0	44.4-119.5	ND -0.4	0.2-9.5	2.2-13.4	48.7-131.8
Malvan	ND -0.4	0.2-1.9	2.8-14.5	42-187.7	ND -0.2	0.3-3.0	2.5-15.9	24.0-85.4
North Maharashtra	**0.1-8.8**	**0.2-41.6**	**0.2-25.3**	**20.6-414.7**	**ND -31.4**	**ND -97.1**	**0.8-112.8**	**2.6-922.3**
South Maharashtra	**ND -2.6**	**0.2-6.8**	**1.0-17.2**	**23.8-187.7**	**ND -17.8**	**0.1-30.2**	**0.8-19.9**	**8.4-197.0**

Table 5.1.D: Range of sediment quality parameters (dry wt) along Maharashtra coast during 2015-2016.

Transect	Coastal			Estuary		
	Sand (%)	Silt (%)	Clay (%)	Sand (%)	Silt (%)	Clay (%)
Dahanu	0.0-7.4 (2.8)	60.0-95.0 (83.1)	5.0-32.6 (13.9)	1.7-85.3 (36.7)	6.3-83.5 (50.5)	5.6-17.8 (12.8)
Tarapur	0.1-86.1 (40.9)	4.7-88.6 (36.7)	9.2-44.8 (22.4)	0.1-94.4 (54.7)	1.6-94.8 (36.7)	0.3-26.6 (8.6)
Bassein	8.7-98.4 (42.2)	1.1-48.3 (29.7)	0.4-46.3 (28.2)	0.6-59.6 (15.3)	25.8-93.9 (54.4)	2.4-53.1 (30.4)
Manori	-	-	-	5.5-39.5 (18.1)	34.6-79.5 (59.0)	15.0-49.6 (22.9)
Versova	-	-	-	1.7-4.4 (3.0)	80.1-87.7 (83.6)	8.6-17.6 (13.4)
Mahim	-	-	-	0.4-16.0 (5.3)	43.4-81.1 (61.0)	13.4-55.7 (33.7)
Bandra	0.5-10.2 (3.9)	66.8-95.3 (80.6)	4.2-23.1 (15.6)	-	-	-
Worli	0.8-5.0 (2.9)	76.0-88.3 (81.0)	6.7-23.2 (16.2)	-	-	-
Thane	2.8*	86.2*	11.0*	0.6-9.3 (3.7)	43.6-88.3 (68.1)	6.7-55.8 (28.2)
Patalganga	-	-	-	2.6-67.4 (25.0)	5.5-87.1 (48.9)	2.2-87.1 (26.1)
Amba	-	-	-	0.9-44.6 (8.8)	27.6-89.9 (64.5)	9.2-56.4 (26.8)
Thal	1.5-2.6 (2.05)	81.8-85.3 (83.55)	13.2-15.6 (14.4)	-	-	-
Kundalika	0.3-94.6 (49.4)	1.8-90.0 (39.7)	1.2-30.5 (10.9)	1.2-98.0 (32.7)	1.2-88.5 (52.8)	0.8-33.8 (14.4)
Murud	0.4-94.2 (45.7)	1.2-94.4 (42.3)	4.6-32.9 (12.0)	1.9-55.6 (22.1)	20.2-88.6 (60.7)	6.4-40.7 (17.0)
Savitri	0.4-96.4 (21.1)	2.6-91.8 (69.9)	1.0-17.0 (9.0)	14.4-97.4 (65.0)	1.0-74.5 (28.7)	0.6-15.2 (6.3)
Vashishti	0.1-73.6 (16.3)	17.4-98.7 (75.1)	1.2-17.4 (8.7)	7.8-98.6 (49.0)	0.8-82.9 (40.0)	0.6-29.9 (11.0)
Jaigad	4.2-78.8 (31.4)	15.0-90.7 (57.6)	5.1-20.8 (11.0)	1.6-96.6 (55.7)	1.2-88.2 (37.1)	2.2-12.4 (7.3)
Ratnagiri	0.2-88.9 (41.3)	4.5-87.6 (42.0)	6.6-37.6 (16.6)	8.6-92.2 (66.0)	1.8-67.8 (24.1)	2.4-23.6 (10.0)
Vijaydurg	1.1-84.4 (29.0)	6.4-79.2 (46.4)	9.2-51.7 (24.7)	14.4-95.4 (75.9)	3.4-69.0 (18.5)	1.2-16.6 (5.6)
Deogad	0.4-37.2 (10.2)	35.0-83.6 (56.5)	12.6-62.9 (33.3)	40.4-97.8 (77.7)	0.8-51.0 (16.3)	1.2-10.4 (6.0)
Achara	6.2-94.6 (48.4)	3.8-80.1 (39.5)	1.6-23.7 (12.1)	6.7-92.0 (71.0)	5.4-82.1 (24.4)	2.2-11.2 (4.6)
Malvan	0.0-2.2 (1.2)	84.8-89.4 (87.8)	9.6-13.0 (11.0)	1.0-96.2 (48.6)	1.8-85.6 (43.7)	2.0-13.4 (7.7)
North Maharashtra	**0.0-98.4**	**1.1-95.3**	**0.4-46.3**	**0.1-98.0**	**1.2-94.8**	**0.3-87.1**
South Maharashtra	**0.0-96.4**	**2.6-98.7**	**1.0-62.9**	**1.0-97.8**	**0.8-88.6**	**0.6-40.7**

*Single Value

Table 5.1.E: Range of sediment quality parameters (dry wt) along Maharashtra coast during 2015-2016.

Transect	Coastal				Estuary			
	Al (%)	Cr (µg/g)	Mn (µg/g)	Fe (%)	Al (%)	Cr (µg/g)	Mn (µg/g)	Fe (%)
Dahanu	6.9-7.3 (7.0)	127.0-165.0 (146.0)	939.0-1078.0 (1008.5)	6.7-7.2 (7.1)	3.1-7.2 (6.2)	118.0-159.0 (139.0)	899.0-2153.0 (1264.0)	5.1-7.3 (6.5)
Tarapur	3.1-7.1 (5.7)	125.0-522.0 (262.7)	840.0-1473.0 (1109.0)	6.6-10.8 (8.0)	1.4-6.4 (4.0)	184.0-503.0 (273.8)	821.0-1390.0 (1006.1)	2.4-10.2 (7.0)
Bassein	5.4-7.6 (6.5)	148.0-438.0 (285.3)	822.0-2211.0 (1337.7)	7.3-9.8 (8.2)	6.3-8.2 (7.1)	187.0-691.0 (329.6)	862.0-1727 (1204.8)	6.5-10.0 (8.0)
Manori	-	-	-	-	6.3-8.1 (7.4)	142.0-204.6 (175.6)	592.0-1115.0 (842.3)	5.9-8.5 (7.5)
Versova	-	-	-	-	4.8-9.7 (6.8)	123.0-226.0 (165.0)	700.0-983.0 (877.0)	6.2-8.3 (7.0)
Mahim	-	-	-	-	5.0-9.8 (7.4)	134.0-162.0 (151.6)	887.0-1157.0 (986.4)	6.3-8.5 (7.2)
Bandra	7.9-9.1 (8.6)	136.0-152.0 (145.7)	900.0-989.0 (943.0)	7.5-8.2 (7.9)	-	-	-	-
Worli	6.9-9.3 (8.0)	122.0-154.0 (141.5)	685.0-932.0 (834.0)	6.5-8.2 (7.4)	-	-	-	-
Thane	8.0*	136.0*	796.0*	7.3*	5.5-9.3 (7.6)	94.0-208.0 (148.4)	549.0-1153.0 (880.8)	5.0-9.9 (7.7)
Patalganga	-	-	-	-	5.5-8.3 (6.7)	148.0-525.0 (290.1)	689.0-1512.0 (1079.9)	6.7-11.8 (8.4)
Amba	-	-	-	-	2.3-8.1 (6.5)	95.0-307.0 (178.3)	183.0-1421.0 (873.1)	3.7-8.6 (7.0)
Thal	6.9-7.1 (7.0)	182.0-193.0 (187.5)	882.0-973.0 (927.5)	8.2-8.5 (8.35)	-	-	-	-
Kundalika	4.0-7.5 (5.3)	107.0-254.0 (173.8)	610.0-1397 (993.8)	5.9-9.5 (8.0)	4.7-8.4 (6.8)	138.0-275.0 (193.8)	767.0-1817.0 (1167.7)	7.0-11.2 (8.6)
Murud	1.4-7.3 (4.8)	39.0-183.0 (128.5)	668.0-1082.0 (928.5)	4.8-9.1 (7.2)	4.5-8.0 (6.2)	144.0-169.0 (158.1)	548.0-822.0 (683.3)	5.6-8.4 (7.2)
Savitri	5.6-7.2 (6.5)	144.0-208.0 (164.3)	631.0-2312.0 (1074.3)	6.7-12.8 (8.5)	6.5-9.2(7.8)	204.0-365.0 (258.8)	1146.0-2663.0 (1689.9)	9.9-15.2 (12.0)
Vashishti	5.3-7.5 (6.5)	113.0-280.0 (165.8)	599.0-2103.0 (1059.7)	6.2-17.2 (9.6)	6.1-9.0 (7.4)	151.0-283.0 (200.9)	962.0-2428.0 (1532.6)	9.9-16.5 (12.2)
Jaigad	4.7-7.3 (6.5)	186.0-245.0 (206.8)	1138.0-1987.0 (1361.0)	10.1-16.1 (12.2)	5.3-11.0 (7.4)	178.0-341.0 (261.8)	1222.0-2371.0 (1718.3)	10.2-20.9 (15.0)
Ratnagiri	3.7-8.2 (5.5)	95.0-162.0 (142.5)	582.0-1285.0 (968.7)	6.5-11.8 (9.1)	1.4-6.1 (3.7)	47.0-123.0 (84.8)	482.0-1019.0 (732.0)	3.3-8.4 (5.8)
Vijaydurg	6.0-9.6 (7.9)	182.0-255.0 (210.0)	863.0-2138.0 (1317.3)	8.8-17.1 (12.5)	5.9-9.1 (7.7)	226.0-309.0 (261.3)	1782.0-2153.0 (1980.7)	16.6-18.7 (17.6)
Deogad	6.8-9.5 (8.2)	182.0-234.0 (203.8)	471.0-565.0 (521.0)	7.7-8.3 (8.0)	2.4-7.1 (4.9)	158.0-222.0 (185.1)	701.0-1375.0 (997.8)	6.8-14.4 (10.5)
Achara	3.9-8.5 (6.2)	140.0-227.0 (189.5)	447.0-1098.0 (729.3)	6.0-10.3 (8.3)	1.7-5.6 (3.6)	58.0-367.0 (164.2)	203.0-861.0 (453.0)	1.9-12.8 (6.5)
Malvan	6.8-8.7 (7.5)	159.0-233.0 (198.5)	396.0-664.0 (552.5)	6.3-7.5 (7.1)	4.7-5.5 (5.1)	8.8-134.0 (111.0)	472.0-785.0 (628.5)	4.3-6.0 (5.2)
North Maharashtra	**1.4-9.3**	**39.0-522.0**	**610.0-2211.0**	**4.8-10.8**	**1.4-9.8**	**94.0-691.0**	**183.0-2153**	**2.4-11.2**
South Maharashtra	**3.7-9.6**	**95.0-280.0**	**396.0-2312.0**	**6.0-17.2**	**1.4-9.2**	**8.8-367.0**	**203.0-2663.0**	**1.9-20.9**

*Single Value

Table 5.1.F: Range of sediment quality parameters (dry wt) along Maharashtra coast during 2015-2016.

Transect	Coastal				Estuary			
	Co (µg/g)	Ni (µg/g)	Cu (µg/g)	Zn (µg/g)	Co (µg/g)	Ni (µg/g)	Cu (µg/g)	Zn (µg/g)
Dahanu	40.0-55.0 (47.0)	57.0-75.0 (65.3)	91.0-104.0 (97.3)	80.0-104.0 (91.0)	29.0-50.0 (41.0)	58.0-76.0 (63.6)	58.0-110.0 (86.8)	42.0-101.0 (84.4)
Tarapur	38.0-76.0 (52.7)	57.0-94.0 (71.7)	87.0-102.0 (92.5)	82.0-148.0 (108.3)	17.0-102.0 (62.0)	26.0-90.0 (71.2)	19.0-217.0 (85.1)	100.0-253.0 (157.8)
Bassein	34.0-69.0 (57.7)	60.0-108.0 (84.2)	44.0-141.0 (92.5)	105.0-234.0 (136.5)	37.0-96.0 (58.9)	68.0-128.0 (90.2)	97.0-231.0 (135.1)	95.0-777.0 (230.2)
Manori	-	-	-	-	26.0-42.4 (34.2)	45.0-59.5 (52.0)	85.0-126.6 (101.4)	114.0-157.6 (133.0)
Versova	-	-	-	-	24.0-50.0 (38.8)	61.0-80.0 (70.5)	104.0-160.0 (138.0)	116.0-180.0 (149.0)
Mahim	-	-	-	-	34.0-52.0 (42.0)	53.0-79.0 (65.2)	91.0-114.0 (105.2)	98.0-131.0 (117.8)
Bandra	34.0-38.0 (35.3)	49.0-58.0 (53.7)	85.0-107.0 (95.3)	93.0-126.0 (107.0)	-	-	-	-
Worli	36.0-50.0(43.0)	57.0-87.0(70.0)	94.0-112.0 (102.5)	97.0-116.0(105.8)	-	-	-	-
Thane	34.0*	52.0*	81.0*	90.0*	24.0-54.8 (45.8)	36.0-85.0 (70.1)	56.0-139.0 (101.1)	62.0-131.0 (101.3)
Patalganga	-	-	-	-	31.0-940.0 (154.9)	55.0-218.0 (93.5)	77.0-488.0 (220.3)	72.0-592.0 (164.8)
Amba	-	-	-	-	25.0-67.0 (48.5)	26.0-104.0 (76.9)	34.0-139.0 96.3)	10.0-109.0 (82.0)
Thal	63.0-68.0 (65.5)	69.0-73.0 (71.0)	123.0-124.0 (123.5)	92.0-93.0 (92.5)	-	-	-	-
Kundalika	29.0-60.0 (45.5)	55.0-85.0 (69.0)	53.0-101.0 (72.7)	60.0-82.0 (75.2)	34.0-83.0 (54.9)	51.0-99.0 (73.3)	74.0-154.0 (112.3)	73.0-116.0 (94.3)
Murud	16.0-60.0 (40.3)	13.0-68.0 (49.0)	17.0-108.0 (73.7)	28.0-77.0 (64.5)	28.0-51.0 (42.3)	41.0-76.0 (59.8)	62.0-109.0 (88.4)	55.0-83.0 (75.4)
Savitri	33.0-50.0 (41.0)	52.0-58.0 (55.3)	61.0-92.0 (74.3)	80.0-86.0 (82.7)	66.0-95.0 (77.5)	78.0-105.0 (90.5)	114.0-273.0 (179.7)	117.0-199.0 (152.2)
Vashishti	38.0-114.0 (61.3)	62.0-92.0 (76.5)	89.0-307.0 (157.7)	76.0-239.0 (121.5)	68.0-105.0 (83.4)	70.0-100.0 (86.9)	183.0-465.0 (255.6)	128.0-210.0 (151.6)
Jaigad	55.0-134.0 (77.2)	70.0-92.0 (76.3)	158.0-261.0 (188.3)	105.0-192.0 (133.2)	52.0-147.0 (94.0)	84.0-129.0 (101.7)	192.0-415.0 (280.2)	104.0-290.0 (178.3)
Ratnagiri	33.0-72.0 (56.8)	45.0-89.0 (67.8)	93.0-170.0 (137.5)	71.0-117.0 (98.5)	21.0-60.0 (42.3)	14.0-64.0 (42.3)	29.0-104.0 (70.0)	31.0-71.0 (51.0)
Vijaydurg	57.0-96.0 (71.3)	82.0-121.0 (95.8)	122.0-298.0 (203.8)	98.0-218.0 (140.8)	79.0-162.0 (120.2)	97.0-133.0 (118.5)	267.0-319.0 (296.5)	191.0-251.0 (217.0)
Deogad	43.0-50.0 (46.8)	80.0-100. (88.3)	86.0-94.0 (89.3)	87.0-95.0 (90.3)	38.0-90.0 (67.5)	46.0-81.0 (59.3)	56.0-208.0 (118.8)	51.0-147.0 (102.8)
Achara	41.0-90.0 (60.0)	65.0-95.0 (75.8)	74.0-117.0 (96.3)	62.0-113.0 (92.0)	23.0-77.0 (47.0)	25.0-57.0 (42.4)	28.0-88.0 (60.6)	11.0-82.0 (45.0)
Malvan	36.0-49.0 (43.3)	69.0-97.0 (84.5)	68.0-86.0 (78.8)	69.0-89.0 (81.8)	32.0-48.0 (40.0)	35.0-53.0 (44.0)	41.0-73.0 (57.0)	49.0-71.0 (60.0)
North Maharashtra	**16.0-76.0**	**13.0-108.0**	**17.0-141.0**	**28.0-234.0**	**17.0-940.0**	**26.0-218.0**	**19.0-488.0**	**10.0-777.0**
South Maharashtra	**33.0-134.0**	**45.0-121.0**	**61.0-307.0**	**62.0-239.0**	**21.0-147.0**	**25.0-133.0**	**28.0-465.0**	**11.0-290.0**

Table 5.1.G: Range of sediment quality parameters (dry wt) along Maharashtra coast during 2015-2016.

Transect	Coastal			Estuary		
	Cd (µg/g)	Hg (µg/g)	Pb (µg/g)	Cd (µg/g)	Hg (µg/g)	Pb (µg/g)
Dahanu	0.10-0.28 (0.17)	0.11-0.20 (0.15)	8.6-16.7 (13.1)	0.11-0.25 (0.17)	0.01-0.11 (0.06)	14.1-19.4 (16.9)
Tarapur	0.11-0.29 (0.20)	0.01-0.2 (0.13)	9.2-15.8 (13.3)	0.14-0.75 (0.34)	0.03-0.25 (0.112)	4.2-28.4 (13.57)
Bassein	0.15-0.21 (0.18)	0.05-0.44 (0.22)	8.1-21.1 (14.5)	0.19-0.9 (0.386)	0.04-0.91 (0.4)	9.03-76.5 (23.6)
Manori	-	-	-	1.08-2.8 (1.57)	0.20-0.34 (0.26)	18.2-28.8 (22.35)
Versova	-	-	-	1.1-2.72 (2.2)	0.11-0.30 (0.20)	20.1-28.4 (23.75)
Mahim	-	-	-	0.32-1.43 (0.8)	0.17-0.30 (0.2)	16.1-27.0 (20.9)
Bandra	1.1-1.6 (1.3)	0.20-0.27 (0.23)	17.1-24.8 (20.60	-	-	-
Worli	0.17-0.54 0.362	0.18-0.24 (0.2)	4.6-21.2 (17.4)	-	-	-
Thane	0.3*	0.17*	18.4*	0.16-0.35 (0.24)	0.09-0.21 (0.2)	14.3-25.7 (18.6)
Patalganga	-	-	-	0.2-2.1 (0.7)	0.04-3.64 (0.7)	9.2-33.6 (20.94)
Amba	-	-	-	0.2-0.3 (0.2)	0.04-0.15 (0.10)	8.4-28.7 (18.9)
Thal	0.15-0.17 (0.16)	0.02-0.06 (0.04)	13.3-15.8 (14.55)	-	-	-
Kundalika	0.18-0.42 (0.31)	0.02-0.12 (0.08)	10.4-17.6 (13.7)	0.11-1.77 (0.50)	0.02-0.50 (0.18)	4.7-32.0 (15.8)
Murud	0.14-0.25 (0.19)	0.005-0.18 (0.09)	5.5-13.9 (9.6)	0.14-0.2 (0.17)	0.04-0.16 (0.10)	7.3-12.6 (9.67)
Savitri	0.1-0.2 (0.2)	0.04-0.18 (0.12)	6.6-13.7 (10.6)	0.1-0.3 (0.2)	0.04-0.26 (0.13)	2.7-16.3 (8.3)
Vashishti	0.12-0.21 (0.17)	0.10-0.14 (0.12)	7.3-14.1 (9.8)	0.08-0.27 (0.18)	0.06-0.41 (0.17)	2.9-19.8 (8.73)
Jaigad	0.06-0.22 (0.15)	0.09-0.30 (0.18)	7.1-12.6 (10.8)	0.08-0.19 (0.14)	0.07-0.29 (0.17)	7.1-12.8 (9.2)
Ratnagiri	0.14-0.19 (0.16)	0.01-0.17 (0.08)	6.9-12.6 (9.8)	0.11-0.17 (0.14)	0.02-0.07 (0.04)	4.7-10.3 (7.175)
Vijaydurg	0.14-0.21 (0.17)	0.10-0.21 (0.15)	9.5-14.0 (11.03)	0.1-0.18 (0.135)	0.04-0.16 (0.10)	2.4-10.4 (7.3)
Deogad	0.12-0.15 (0.11)	0.06-0.19 (0.14)	11.9-17.7 (15.1)	0.08-0.2 (0.14)	0.02-0.12 (0.07)	4.8-19.0 (12.4)
Achara	0.1-0.2 (0.2)	0.07-0.14 (0.11)	14.7-18.5 (16.1)	0.1-0.2 (0.2)	0.03-0.07 (0.06)	6.8-11.3 (9.2)
Malvan	0.13-0.20 (0.16)	0.13-0.18 (0.15)	13.0-16.6 (14.7)	0.08-0.1 (0.09)	0.06-0.10 (0.08)	12.9-15.0 (13.9)
North Maharashtra	**0.10-1.6**	**0.01-0.44**	**4.6-24.8**	**0.11-2.8**	**0.01-0.91**	**4.2-76.5**
South Maharashtra	**0.06-0.22**	**0.01-0.30**	**6.6-18.5**	**0.08-0.3**	**0.02-0.41**	**2.4-19.8**

* Single value

Table 5.1.H: Range of sediment quality parameters (dry wt) along Maharashtra coast during 2015-2016.

Transect	Coastal			Estuary		
	C_{org} (%)	P (µg/g)	PHc (µg/g)	C_{org} (%)	P (µg/g)	PHc (µg/g)
Dahanu	0.9-1.5 (1.1)	667.0-820.0 (775.8)	0.6-1.8 (1.3)	0.2-1.2 (0.9)	176.0-1020.0 (609.4)	1.1-3.2 (2.3)
Tarapur	0.1-1.2 (0.68)	250.0-1224.0 (850.7)	0.3-2.1 (1.3)	0.1-1.3 (0.54)	156.0-2209.0 (976.9)	0.8-4.5 (2.9)
Bassein	0.0-2.6 (1.1)	488.0-1319.0 (964.2)	0.3-2.5 (1.3)	0.4-3.7 (1.9)	858.0-2224.0 (1532.3)	0.9-8.8 (4.1)
Manori	-	-	-	1.5-2.1 (1.8)	234.0-320.0 (288.5)	3.4-12.2 (6.6)
Versova	-	-	-	2.2-2.4 (2.3)	622.0-1449.0 (1031.3)	1.2-2.7 (1.9)
Mahim				1.3-2.2 (1.6)	866.0-1624.0 (1276.4)	0.9-1.7 (1.2)
Bandra	1.0-1.2 (1.1)	273.9-463.0 (346.0)	0.7-1.0 (0.9)	-	-	-
Worli	1.4-1.6 (1.5)	960.0-1558.0 (1314.3)	0.2-0.9 (0.5)	-	-	-
Thane	2.2*	1296.0*	0.3*	0.9-2.2 (1.5)	796.0-1744.0 (1288.2)	0.2-10.1 (1.9)
Patalganga	-	-	-	0.3-4.1 (2.2)	869.0-3908.0 (1908.9)	0.9-13.9 (5.2)
Amba	-	-	-	0.8-2.6 (2.0)	1000.0-1548.0 (1172.7)	0.3-3.0 (1.6)
Thal	1.2-1.3 (1.25)	1625.0-1715.0 (1670.0)	1.0-1.6 (1.3)	-	-	-
Kundalika	0.1-1.7 (0.8)	786.0-2123.0 (1550.5)	0.6-2.8 (1.8)	0.1-2.7 (1.7)	1182.0-1803.0 (1512.0)	0.7-6.1 (2.7)
Murud	0.2-2.0 (1.1)	1221.0-2268.0 (1881.2)	0.2-1.9 (0.8)	1.2-2.2 (1.6)	1205.0-2769.0 (1635.6)	0.2-0.7 (0.4)
Savitri	0.4-2.4 (1.8)	918.0-1578.0 (1400.8)	0.2-0.8 (0.4)	0.2-3.8 (1.9)	686.0-2143.0 (1338.0)	0.3-3.9 (1.7)
Vashishti	0.8-2.6 (2.0)	1014.0-1807.0 (1436.5)	0.2-1.1 (0.5)	0.2-4.1 (1.7)	712.0-1892.0 (1371.8)	0.1-8.2 (4.1)
Jaigad	0.3-2.3 (1.2)	198.0-1149.0 (725.3)	0.1-0.4 (0.3)	0.1-4.5 (1.7)	255.0-1516.0 (708.2)	0.2-2.8 (1.1)
Ratnagiri	0.3-2.7 (1.4)	510.0-2111.0 (1273.5)	0.4-0.9 (0.6)	0.3-2.2 (0.9)	980.0-3777.0 (1764.5)	1.4-3.0 (2.3)
Vijaydurg	1.0-3.0 (2.0)	364.0-1961.0 (1020.5)	0.3-0.8 (0.6)	0.3-1.8 (1.0)	498.0-2306.0 (1285.2)	0.5-2.7 (1.4)
Deogad	2.8-3.4 (3.1)	452.0-2125.0 (1155.0)	0.2-1.3 (0.7)	0.1-2.3 (0.9)	416.0-1798.0 (1140.3)	0.8-1.9 (1.2)
Achara	1.6-2.9 (2.3)	670.0-2217.0 (1519.5)	0.5-1.0 (0.8)	0.0-2.6 (1.3)	200.0-2126.0 (781.4)	08-1.8 (1.1)
Malvan	2.4-3.3 (2.9)	368.0-435.0 (413.3)	0.4-0.9 (0.6)	1.3-2.1 (1.7)	242.0-330.0 (286.0)	0.5-0.8 (0.7)
North Maharashtra	**0.0-2.6**	**25.0-2268.0**	**0.2-2.8**	**0.1-4.1**	**156.0-3908.0**	**0.2-13.9**
South Maharashtra	**0.1-3.4**	**198.0-2217.0**	**0.1-1.3**	**0.0-4.5**	**200.0-3777.0**	**0.1-3.9**

*Single Value

Table 5.1.I: Range and average (parenthesis) of TVC, TC and FC counts (expressed in CFU/ml) of water along Maharashtra coast during 2015-2016.

Transect	Coastal			Creek/Estuary		
	TVC X 10^3	TC	FC	TVC X 10^3	TC	FC
Dahanu	1-45 (23)	10-370 (190)	10-200 (105)	1-60 (30.5)	10-600 (305)	10-600 (305)
Tarapur	4-308 (156)	10-2500 (1255)	10-2080 (1045)	4-800 (402)	20-490 (255)	10-440 (225)
Bassein	4-240 (122)	10-480 (245)	10-370 (190)	1.0-200 (100)	10-2000 (1005)	10-1800 (905)
Manori	-	-	-	1-30 (15.5)	10-300 (155)	10-350 (180)
Versova	-	-	-	1-40 (20.5)	10-480 (245)	10-420 (215)
Mahim	-	-	-	2-33 (17.5)	10-1220 (615)	10-610 (310)
Bandra	0.2-20 (10.1)	20-400 (210)	10-400 (205)	-	-	-
Worli	3-22 (12.5)	20-100 (60)	10-70 (40)	-	-	-
Thane	4-50 (27)	10	10	2-64 (33)	10-100 (55)	10-100 (55)
Patalganga	-	-	-	7-3000 (1503)	40-5500 (2770)	30-1500 (765)
Amba	-	-	-	5-110 (57.5)	10-130 (70)	10-110 (60)
Thal	28-430 (229)	140-430 (285)	70-400 (235)	-	-	-
Kundalika	12-37 (24.5)	50-740 (395)	30-630 (345)	1-560 (280.5)	30-990 (525)	10-980 (495)
Murud	0.9-16 (8.5)	20-500 (260)	20-400 (210)	1-50 (25.5)	10-90 (50)	10-50 (30)
Savitri	2.9-4.9 (3.9)	10-130 (70)	10-80 (45)	1.5-6.1 (4.5)	10-200 (105)	10-200 (105)
Vashishti	0.2-3.0 (1.6)	10-120 (65)	10-100 (55)	1.8-23.9 (12.75)	10-15200 (7605)	10-7700 (3855)
Jaigad	6-21 (13.5)	40-70 (55)	40-60 (50)	8-32 (20)	10-900 (455)	10-450 (230)
Ratnagiri	0.6-27 (13.8)	50-400 (225)	50-300 (175)	1-45 (23)	100-2980 (1540)	70-1900 (985)
Vijaydurg	9.1-30 (19.5)	20-500 (260)	10-500 (255)	6-170 (88)	10-15200 (7605)	10-7700 (3855)
Deogad	4-15 (9.5)	20-200 (110)	20-200 (110)	1-82 (41.5)	10-900 (455)	10-800 (405)
Achara	0.02-16 (8)	10-80 (45)	10-60 (35)	3-70 (36.5)	20-400 (210)	10-400 (205)
Malvan	1-320 (160.5)	50-2000 (1025)	40-1800 (920)	2.0-220 (111)	400-1200 (800)	300-900 (600)
North Maharashtra	**0.2-430**	**10-2500**	**10-2080**	**1-3000**	**10-5500**	**10-1800**
South Maharashtra	**0.02-30**	**10-2000**	**10-1800**	**1-220**	**10-15200**	**10-7700**

Table 5.1.J: Range and average (parenthesis) of TVC, TC and FC counts (expressed in CFU/g) of sediment along Maharashtra coast during 2015-2016.

Transect	Coastal			Creek/Estuary		
	TVC X 10^3	TC	FC	TVC X 10^3	TC	FC
Dahanu	5-2800 (1402.5)	40-3000 (1520)	30-2600 (1315)	2-400 (201)	10-3000 (1505)	10-2500 (1255)
Tarapur	5-200 (1025)	10-220 (115)	10-120 (65)	30-5000 (2515)	40-4000 (2020)	20-4000 (2010)
Bassein	60-280 (170)	200	100	30-4000 (2015)	32-5000 (2516)	20-4200 (2110)
Manori	-	-	-	2-1500 (751)	80-7000 (3540)	50-6000 (3025)
Versova	-	-	-	1-490 (246)	10-80 (45)	20-70 (45)
Mahim	-	-	-	2-200 (101)	50-60 (55)	30-40 (35)
Bandra	2-800 (401)	2000	1500	-	-	-
Worli	2-120 (61)	40-100 (70)	10-70 (40)	-	-	-
Thane	100	200	100	5-800 (403)	10	ND
Patalganga	-	-	-	12-9000 (4506)	50-1900 (975)	10-360 (185)
Amba	-	-	-	38-3000 (1519)	30-100 (65)	10-90 (50)
Thal	320-1000 (660)	50-360 (205)	10-190 (100)	-	-	-
Kundalika	150-1800 (975)	30-40 (35)	10-30 (20)	3-3000 (1502)	10-330 (170)	10-200 (105)
Murud	80-500 (290)	500-1000 (750)	400-1000 (700)	100-1200 (650)	200	200
Savitri	100-900 (500)	50	30	80-1800 (940)	30-1100 (565)	10-900 (455)
Vashishti	150-1700 (925)	ND	ND	5.1-800 (403)	10-15200 (7605)	20-7700 (3860)
Jaigad	100-800 (450)	ND	ND	120-400 (260)	ND	1000
Ratnagiri	9.2-400 (204)	979-6000 (3489.5)	516-4000 (2258)	10.9-800 (405.45)	2010-120000 (61005)	972-90000 (24821)
Vijaydurg	40-1880 (920)	10-7000 (3505)	10-6000 (3005)	100-400 (250)	1000	1000
Deogad	30-700 (365)	ND	ND	100-1200 (650)	400-8000 (4200)	1000-4000 (2500)
Achara	30-1000 (515)	1000-4000 (2500)	1000-2000 (1500)	40-1700 (870)	40-6000 (3020)	10-6000 (3005)
Malvan	80-1500 (790)	1200-8000 (4600)	1000-5000 (3000)	70-1400 (735)	ND	ND
North Maharashtra	**2-2800**	**10-3000**	**10-2600**	**1-9000**	**10-7000**	**10-6000**
South Maharashtra	**9.2-1700**	**10-8000**	**10-6000**	**5.1-1800**	**10-120000**	**10-90000**

Table 5.1.K: Range and average (parenthesis) of phytoplankton along North Maharashtra coast during 2015-2016.

Transect	Coastal				Bay/Creek/Estuary			
	Chl *a* (mg/m^3)	Phaeo (mg/m^3)	Cell count (nox10^3/l)	Total genera (no)	Chl *a* (mg/m^3)	Phaeo (mg/m^3)	Cell count (nox10^3/l)	Total genera (no)
Dahanu	0.5-25.4 (4.2)	0.1-9.8 (1.0)	4.4-22340 (1790)	4-14 (9)	1.3-30.6 (8.3)	(1.45)	3.2-9545 (1891.5)	3-12 (9)
Tarapur	0.8-31.5 (4.5)	0.2-5.3 (0.8)	19-955 (148.5)	7-23 (14)	1.6-43.6 (15.4)	0.1-12.7 (1.5)	49-2561 (649.95)	7-25 (16)
Bassein	1-5.8 (2.9)	0.1-11 (2.1)	19-377 (116.1)	6-18 (12)	0.8-42.4 (19.5)	0.1-23.3 (6.2)	14.2-45996 (3610.6)	3-24 (12)
Manori	-	-	-	-	2-32.2 (16.7)	0.3-15.3 (5.8)	44.4-2815 (583.52)	7-20 (13)
Versova	-	-	-	-	1.3-41.6 (11.6)	0.8-8.7 (3.6)	38-2059 (717.25)	8-20 (16)
Mahim	-	-	-	-	1.3-32.4 (16.4)	0.2-9.3 (2.2)	38.8-8719 (2480.95)	9-21 (13)
Bandra	2.7-32.4 (11.89)		56.6-5642 (1628.65)	11-20 (16)	-	-	-	-
Worli	1.5-28.8 (9.9)	0.3-9.3 (0.8)	106.4-1650.6 (599.47)	12-23 (18)	-	-	-	-
Thane	1.5-6.8 (2.4)	0-1.7 (0.9)	31.2-932 (176.22)	11-22 (15)	0.7-47 (8.3)	0.7-1.7 (0.9)	35-13343.4 (1954.3)	8-23 (17)
Patalganga	-	-	-	-	0.98-30.7 (12.69)	0.3-10.58 (4.07)	103.8-96607 (9232.5)	15-52 (28)
Amba	-	-	-	-	2-24.5 (7.2)	0.1-6.4 (2.2)	21-2866.4 (281.09)	8-32 (19)
Thal	1.1-18.8 (3.02)	0.5-7.2 (2.2)	24.8-150.4 (68.9)	9-22 (15)	-	-	-	-
Kundalika	1.6-4.4 (2.8)	0.6-4.4 (2.1)	58-268 (111.87)	11-19 (14)	1.1-25.4 (10.0)	0.3-6.3 (1.9)	97-2941.8 (842.82)	9-22 (14)
Murud	1-12.6 (4.1)	0.3-4 (1.5)	17.4-2082 (356.07)	10-27 (18)	2.4-18.8 (11.2)	0.1-2.9 (1.3)	332.7-2382 (779.14)	18-33 (25)

Table 5.1.L: Range and average (parenthesis) of phytoplankton along South Maharashtra coast during 2015-2016.

Transect	Coastal				Bay/Creek/Estuary			
	Chl *a* (mg/m^3)	Phaeo (mg/m^3)	Cell count (nox10^3/l)	Total genera (no)	Chl *a* (mg/m^3)	Phaeo (mg/m^3)	Cell count (nox10^3/l)	Total genera (no)
Savitri	1.11-4.33 (2.1)	0.3-3.4 (1.4)	11.4-106.6 (50.3)	8-26 (14)	0.2-9.5 (3.4)	0.13-6.9 (1.4)	10.2-1614.4 (200.4)	6-21 (15)
Vashishti	0.7-2.21 (1.2)	0.3-2.73 (0.9)	12.8-35 (19.7)	9-12 (10)	0.5-12.46 (2)	0.17-4.31 (1.1)	13-152.4 (47.01)	8-17 (13)
Jaigad	0.5-1.7 (0.96)	0-0.7 (0.29)	6.6-26.2 (13.7)	5-10 (7)	0.2-3.1 (1.92)	0-2.5 (0.5)	10.8-96.4 (37.2)	8-16 (9)
Ratnagiri	1.42-3.18 (2.4)	0.2-2.2 (0.73)	23-648 (141.1)	6-25 (14)	1.7-17.3 (7.4)	0.2-2.2 (1.3)	37-2351.8 (699.4)	13-22 (17)
Vijaydurg	0.7-4.2 (1.6)	0.1-1.8 (0.52)	12.2-67 (31.7)	7-15 (10)	0.1-11.2 (3.3)	0.3-9.5 (1.2)	15.4-300 (99.7)	9-18 (14)
Deogad	1.1-2.03 (1.43)	0.13-1.2 (0.5)	10.8-60.6 (33.1)	6-14 (10)	1.4-13.6 (3.9)	0.17-2.6 (0.8)	46.4-3747.2 (467.4)	10-21 (16)
Achara	1.1-2.79 (1.8)	0.22-1.37 (0.8)	43.0-188.4 (108.8)	10-20 (14)	0-4.1 (1.7)	0-1.52 (0.5)	0-590.6 (181.5)	6-20 (11)
Malvan	0.62-6.2 (4.1)	0.09-1.62 (0.8)	47-3746.6 (1600.1)	9-24 (20)	0.48-4.04 (2.1)	0-3.94 (0.8)	64-292.8 (209.7)	13-26 (19)

Table 5.1.M: Range and average (parenthesis) of zooplankton along North Maharashtra coast during 2015-2016.

Transect	Coastal			Bay/Creek/Estuary		
	Biomass ($ml/100m^3$)	Population ($nox10^3/100m^3$)	Total Groups (no)	Biomass ($ml/100m^3$)	Population ($nox10^3/100m^3$)	Total Groups (no)
Dahanu	0.1-18.2 (2.9)	0.3-73.1 (12.4)	9-17 (14)	0.2-9.1 (3.7)	1.7-223.6 (30.3)	9-18 (12)
Tarapur	0.1-3.7 (1.2)	0.5-74.9 (16.2)	8-16 (13)	0.3-4.2 (0.9)	1.5-29.5 (8.4)	8-13 (11)
Bassein	0.3-7.6 (2.3)	1.8-68.7 (25.7)	1-15 (11)	0.2-12.3 (2.7)	1.4-258.9 (32.5)	1-13 (6)
Manori	-	-	-	0.4-94.1 (6.9)	1.0-507.9 (51.5)	6-16 (12)
Versova	-	-	-	0.2-5.2 (2.0)	0.02-144.6 (36.8)	3-16 (10)
Mahim	-	-	-	0.4-9.4 (2.9)	1.0-101.5 (56.8)	8-16 (12)
Bandra	0.3-8.4 (2.6)	2.0-120.2 (42.9)	6-14 (9)	-	-	-
Worli	0.2-7.7 (3)	1.1-63.4 (32.5)	8-14 (10)	-	-	-
Thane	0.5-6.2 (2.8)	2.3-25.7 (19.6)	9-20 (14)	0.2-570.8 (35.8)	0.6-147.6 (22.6)	6-19 (13)
Patalganga	-	-	-	0.3-27.0 (4.3)	0.3-283.3 (25.3)	4-18 (10)
Amba	-	-	-	0.9-16.8 (35.8)	2.2-99.0 (28.1)	9-15 (12)
Thal	1.1-8.3 (4.3)	20.9-150.3 (49.1)	7-17 (13)	-	-	-
Kundalika	0.3-26.1 (6.9)	1.3-692.9 (163.7)	11-17 (13)	0.1-18.1 (3.1)	0.3-346.1 (75.6)	7-18 (10)
Murud	0.2-2.1 (0.8)	1.4-25.3 (6.3)	9-13 (11)	0.7-24.2 (5.5)	1.5-83.0 (16.3)	9-15 (12)

Table 5.1.N: Range and average (parenthesis) of Zooplankton along South Maharashtra coast during 2015-2016.

Transect	Coastal			Bay/Creek/Estuary		
	Biomass (ml/100m^3)	Population (nox10^3/100m^3)	Total Groups (no)	Biomass (ml/100m^3)	Population (nox10^3/100m^3)	Total Groups (no)
Savitri	0.1-50.0 (5.9)	0.04-137.6 (21.1)	3-13 (10)	0.2-16.8 (2.9)	1.3-36.3 (11.4)	4-14 (8)
Vashishti	0.5-3.8 (2.0)	9.1-30 (19.0)	7-13 (10)	0.1-14.3 (2.2)	0.05-22.3 (7.0)	2-15 (8)
Jaigad	0.7-5.3 (2.6)	8.8-50.1 (29.1)	8-14 (12)	0.1-1.4 (0.7)	3.3-20.9 (9.6)	8-15 (10)
Ratnagiri	0.3-24.1 (2.9)	2.2-331.4 (37.5)	11-18 (14)	0.2-2.8 (0.4)	1.6-57.2 (10.7)	9-14 (12)
Vijaydurg	0.3-4.0 (2.3)	9.6-75.1 (27.0)	13-17 (15)	0.9-10.9 (2.6)	8.1-151.8 (33.8)	13-19 (16)
Deogad	1.0-8.6 (5.3)	18.6-47.5 (36.7)	11-16 (14)	0.4-5.2 (2.4)	3.2-189.0 (59.0)	11-16 (13)
Achara	0.3-5.7 (3.0)	10.1-90.5 (44.6)	4-15 (11)	0.6-6.0 (2.7)	11.6-88.2 (55.3)	10-15 (12)
Malvan	1.4-32.7 (7.9)	6.1-154.9 (32.0)	8-19 (13)	0.9-2.4 (1.1)	6.2-78.1 (26.7)	9-18 (13)

Table 5.1.O: Range and average (parenthesis) of Macrobenthos along North Maharashtra coast during 2015-2016.

Transect	Coastal			Creek/Estuary		
	Biomass (g/ m^2; wet weight)	**Population (Ind./ m^2)**	**Total groups (No.)**	**Biomass (g/ m^2; wet weight)**	**Population (Ind./ m^2)**	**Total groups (No.)**
Dahanu	0.01-0.41 (0.17)	25-1325 (236)	1-2 (1)	0.03-3.07 (0.81)	25-1550 (656)	1-5 (3)
Tarapur	0.00-3.27 (0.44)	0-700 (119)	0-5 (2)	0.01-37.83 (4.96)	50-3350 (558)	1-6 (2)
Bassein	0.00-7.50 (1.01)	0-625 (172)	0-7 (2)	0.00-401.00 (1.85)	0-14200 (1450)	0-5 (2)
Manori	-	-	-	0.01-513.06 (88.55)	25-23950 (4138)	0-8 (4)
Versova	-	-	-	0.00-22.03 (3.68)	0-3275 (750)	0-7 (3)
Mahim	-	-	-	0.01-56.46 (9.70)	25-4350 (721)	1-7 (3)
Bandra	0.04-17.35 (2.53)	25-875 (269)	1-5 (3)	-	-	-
Worli	0.20-26.50 (30.28)	175-2450 (631)	1-10 (2)	-	-	-
Thane	0.62-3.54 (1.93)	275-1675 (813)	2-3 (2)	0.10-217.80 (21.21)	50-4550 (1156)	1-9 (4)
Patalganga	-	-	-	0.01-25.51 (3.63)	25-15725 (1775)	1-8 (2)
Amba	-	-	-	0.00-24.30 (2.02)	0-1875 (495)	0-8 (3)
Thal DP	0.1 – 1.1 (0.405)	75 – 625 (216)	1 – 2 (2)	-	-	-
Kundalika	0.00-9.30 (1.84)	0-2400 (503)	0-6 (3)	0.00-27.00 (5.55)	0-3075 (745)	0-7 (2)
Murud	0.02-133.05 (27.82)	50-1900 (783)	1-11 (4)	0.00-279.60 (21.57)	0-4700 (1861)	0-15 (9)

Table 5.1.P: Range and average (parenthesis) of macrobenthos along South Maharashtra coast during 2015-2016.

Transect	Coastal			Creek/Estuary		
	Biomass (g/ m^2; wet weight)	Population (Ind./m^2)	Total groups (No.)	Biomass (g/ m^2; wet weight)	Population (Ind./ m^2)	Total groups (No.)
Savitri	0.0-43.3 (6.3)	50-5125 (839)	1-4 (2)	0.00-19.90 (3.72)	0-9700 (1350)	0-6 (2)
Vashishti	0.0-12.8 (3.0)	50-3150 (523)	1-4 (2)	0.03-116.30 (15.32)	25-10825 (2065)	1-6 (3)
Jaigad	1.4-20.0 (7.5)	875-13175 (3513)	3-7 (5)	0.40-105.00 (10.44)	175-7275 (1817)	2-7 (5)
Ratnagiri	1.0-157.1 (22.7)	525-12500 (3508)	3-11 (6)	0.04-65.10 (12.75)	225-12475 (4468)	1-10 (5)
Vijaydurg	0.0-28.1 (5.4)	0-7000 (1294)	0-12 (5)	0.02-26.40 (3.52)	25-3350 (960)	1-10 (6)
Deogad	0.0-49.2 (9.0)	0-1200 (547)	0-13 (4)	0.09-78.73 (12.82)	175-7225 (1643)	3-12 (6)
Achara	0.2-95.4 (8.4)	275-2450 (1116)	4-11 (7)	0.07-33.07 (7.80)	50-3550 (1625)	2-12 (7)
Malvan	0.0-20.3 (5.0)	50-2475 (945)	1-10 (5)	0.70-22.90 (6.60)	625-5375 (2207)	3-6 (5)

Table 5.1.Q: Range and average (parenthesis) of Meiobenthos along North Maharashtra coast during 2015-2016.

Transects	Coastal			Estuary/Creek/Bay		
	Biomass ($\mu g/10cm^2$)	Population ($Ind./10cm^2$)	Total groups (No.)	Biomass ($\mu g/10\ cm^2$)	Population ($Ind./10\ cm^2$)	Total groups (No.)
Dahanu	3.41-131.51 (57.72)	7-112 (35)	1-5 (3)	9.66-921.08 (195.16)	10-1901 (321)	2-8 (4)
Tarapur	9.48-695.17 (164.63)	11-451 (97)	1-5 (2)	69.72-11934 (2827.44)	55-5248 (1233)	3-8 (5)
Ulhas	70.36-304.55 (168)	18-306 (95)	1-4 (3)	0-8666.88 (567.47)	0-7313 (411)	0-9 (3)
Manori	-	-	-	7.28-47374.56 (3890.77)	10-1114 (202)	2-8 (5)
Versova	-	-	-	4.06-2564.74 (458.49)	14-974 (220)	2-5 (3)
Mahim	-	-	-	13.96-236.42 (53.105)	20-362 (128)	2-6 (3)
Bandra	9.29-557.88 (259.74)	65-413 (168)	3-6 (4)	-	-	-
Worli	60.68-155.58 (105.69)	92-386 (215)	2-5 (3)	-	-	-
Thane	41.32-73.98 (57.65)	116-128 (149)	2-3 (2)	1.24-169.34 (50.72)	1-326 (84.14)	1-5 (2)
Patalganga	-	-	-	2.85-22651.8 (2973.34)	10-7691 (1691)	2-9 (6)
Amba	-	-	-	11.34-948.6 (312.84)	28-978 (264)	2-12 (5)
Kundalika	3.14-1314.8 (314.18)	16-885 (250)	1-7 (4)	0.64-3777.12 (378.14)	1-856 (180)	1-8 (5)
Thal	101.25-597.27 (233.55)	35-327 (209)	2-7 (4)	-	-	-
Murud	25.89-341.36 (113.525)	61-330 (172)	4-9 (6)	113.06-1627.3 (533.68)	44-1019 (351)	4-13 (8)

Table 5.1.R: Range and average (parenthesis) of Meiobenthos along South Maharashtra coast during 2015-2016.

Transects	Coastal			Estuary/Creek/Bay		
	Biomass (µg/10 cm^2)	Population (Ind./10 cm^2)	Total groups (No.)	Biomass (µg/10 cm^2)	Population (Ind./ 10cm^2)	Total groups (No.)
Savitri	68.74-482.77 (256.02)	35-836 (289)	2-6 (3)	4.26-280.47 (91.62)	7-515 (179.3)	1-7 (4)
Vashishthi	12.36-626.83 (266.09)	8-1059 (441)	2-10 (4)	12.36-968.36 (201.96)	17-893 (228)	2-9 (4)
Jaigad	42.35-3612.17 (1044.75)	99-1496 (722)	2-12 (6)	11.02-1118.76 (274.86)	64-892 (367)	2-10 (5)
Ratnagiri	44.19-1423.78 (511.71)	37-1737 (637.5)	2-9 (5)	161.59-2039.36 (734.55)	44-1335 (406)	1-8 (4)
Vijaydurg	28.54-2918.56 (931.39)	40-1021 (450)	2-9 (5)	63.96-1537.93 (671.43)	41-1042 (279)	2-8 (5)
Deogad	9.61-755.88 (230.92)	28-1081 (505)	2-7 (4)	10.65-2121.11 (593.72)	7-3114 (793)	1-9 (5)
Achara	8.4-316.62 (117.42)	13-335 (156)	1-5 (3)	12.16-4097.67 (1337.99)	58-986 (539)	2-14 (8)
Malvan	9.69-649.5 (214.46)	597-1022 (470)	3-5 (4)	9.69-834.93 (328.21)	299-1190 (533)	3-6 (5)

5.2 Areawise assessment

General features of monitoring locations and their water quality, sediment quality as well as biological characteristics are briefly discussed under the chapter 4 **"Prevailing environment"**. The parameter-wise status of the coastal ecosystem of Maharashtra is discussed earlier under Section 5.1. The ecological status of the monitoring locations of the Maharashtra coast is individually discussed in this section vis a vis the pollution loads received by them. The assessments are based on two season's site specific data (premonsoon and postmonsoon) and other available information.

5.2.1 Dahanu

Dahanu, a small town lies at the north side of the entrance to Khondha (Dahanu) Creek which further bifurcates into Savata Creek and Danda Creek. The creek being located at the north of the Maharashtra coast experiences strong tidal influence in the mouth zone that decreases considerably with the distance from the mouth. The creek receives effluent release (presently 80000 m^3/h of combined FGD and coolant water, which was only 22000 m^3/h before the commissioning of FGD system) from a power plant in the vicinity of station DH6. The results (2015-2016) of water quality, sediment quality and biological characteristics are discussed below.

i) Water quality (Figures 5.2.1 to 5.2.4)

The water temperature of the coastal/creek system varied in accordance with the air temperature except in the vicinity of the warm discharge of the power station. The water temperature at this location was higher by 4°C in reference to the ambient water temperature. As evident from above table that the creek (26.0-38.0°C) indicated higher temperature than that of coastal water (26.0-34.0°C) suggesting noticeable impact of power plant release on the temperature of the creek system.The temperature recorded during premonsoon season exceeded the upper tolerance limit (35°C) for tropical aquatic larvae. The pH, DO and BOD varied in a normal ranges.The SS and turbidity indicated elevated levels than normal. DO conditions were fairly good excepting occasional low values in the inner creek and BOD was low. The salinity in the coastal waters was normal. The high salinity noticed in the inner creek could be due to impact of power plant release coupled with high evaporation. Nutrients in the coastal system of Dahanu were in the normal range excepting PO_4^{3-}-P in the creek where it was high. The levels of PHc and phenols suggested some petroleum contamination in the coastal system. Overall, the water quality indicated low level pollution in the coastal system of Dahanu.

The comparison of earlier data indicated that the parameters like temperature, pH and DO were comparable over the years along this transect. However, nutrients revealed high variations with a noticeable reduction in NO_3^--N and PO_4^{3-}-P and increase in NH_4^+-N over the years especially in the creek system suggesting increase in the input of organic wastes to the creek system.

ii) Sediment quality (Tables 5.1.D to 5.1.H)

The sediment texture varied spatialy and was silty-clay (coastal), silty-sand (station D5) and clayey-silt (station D6). The increase in clay contents reflected in higher percentage of Al (6.9-7.3%) in the coastal system. The concentrations of heavy metals in sediment were in the range expected for uncontaminated sediment of the central west coast of India and hence largely lithogenic. Phosphorus and C_{org} concentrations were also low and did not show significant enrichment. However, PHc showed minor elevation in the creek region indicating contamination by petroleum, which may be due to the traffic of boats.

iii) Flora and Fauna (Tables 5.1.I to 5.1.R, Figures 5.2.5 to 5.2.7)

Dahanu Creek sustained higher count of TVC, TC, FC and VLO as compared to coastal segment which suggested contamination of the region by sewage.As compared to results of 2007-08, TC and FC counts were higher in creek region than coastal waters. Bacterial counts in sediment were several time higher than in water as expected. Also the creek sustained relatively higher counts of TVC, TC and FC in sediment than that of coastal area. Noticeable counts of pathogens like PKLO, VPLO, VCLO and PALO in the creek segment indicated pathogenic contamination of the creek system. The microbial counts like, TVC FC and TC were high in numbers at creek and coastal segments in both water and sediment.But on comparison with 2007-08 report it was found that coastal sediment of Dahanu creek sustained higher counts of TVC,TC and FC than creek regions.

The phytopigments viz chlorophyll *a*, phaeophytin, cell counts of phytoplankton and their generic composition widely varied in the study area suggesting high patchiness and seasonal trend in their distribution. The creek sustained high concentration of chlorophyll *a*, cell counts and normal community structure of phytoplankton especially during premonsoon as compared to the coastal waters. This was also supported by elevations in nutrients like PO_4^{3-}-P associated with organic pollution of the creek system during the same period. Therefore, organic pollution induced primary production was evident at Dahanu Creek during premonsoon period. This was further supported by dominance of pollutant tolerant genera like *Skeletonema, Thalassiosira Nitzschia* and *Navicula* during premonsoon period. The other common genera recorded were *Chaetoceros,* *Thalassiothrix, Melosira* and *Guinardia, Pleurosigma, Coscinodiscus, Cyclotella, Peridinium, Gyrosigma.*

Good standing stock of phytoplankton supported the zooplankton stock in the creek system. The community structure of zooplankton was dominated by decapods, copepodsand lamellibranchs. The results suggested that during premonsoon upper estuary exhibited low primary productivity in Dahanu. The impact of pollution if any on the creek system seemed to be minor.

Overall, except for increase in temperature in the segment of effluent release, the creek ecology was largely free from gross impact due to release of effluents. However, organic pollution induced primary production without adequate support of secondary producers especially during dry periods, was evident.

In Dahanu, the standing stock of macrobenthos varied widely in the study area suggesting high unevenness in their distribution. According to 2007-08 report, the coastal area sustained better standing stock and group diversity as compared to the creek region. In contrast the present study showed better standing stock and group diversity in the creek region than the coastal segment.

The coastal segment supported poor benthic potential for the study area. Postmonsoon sustained better standing stock and diversity than premonsoon. Though very clear status of benthic community structure could not revealed, but overall it can be stated that the community pattern has been found little detoriated over the years.

Meiobenthic standing stock was found to be low in the creek except for the upper creek region in premonsoon, associated with increased phytoplankton which is a food source for benthic detritivores. The poor meiobenthic diversity (av. 4 groups) was indicative of polluted environment, with the dominance of only pollution tolerant groups such as nematodes in both seasons.

5.2.2 Tarapur

Tarapur Creek is a minor creek with poor tidal flushing and received industrial effluents which had a potential to influence the nearshore environment negatively. Also nearshore coastal waters receive power plant release which can influence temperature regime of the area. The results of water quality, sediment quality and biological characteristics are discussed below:

i) Water quality (Figures 5.2.8 to 5.2.11)

The temperature was on a normal range and no evidence of increase of temperature due power plant was evident. The temperature was below the upper threshold of 35°C for tropical aquatic larvae. Although the pH was in the normal range in the coastal waters, creek waters revealed occasional low pH, which may be due to the influence of industrial as well domestic wastes. SS and turbidity were comparable in coastal and creek waters. The average salinity varied in a narrow range and was closely comparable between coastal and creek segments suggesting negligible freshwater influx to the creek. DO widely varied with occasional low values (<0.6 mg/l) especially in the creek supported by elevated levels of BOD suggesting the influence of organic pollution in the creek. Similarly, the high values of NO_3^--N, NO_2^--N and NH_4^+-N in the creek system revealed the influence of organic load at the creek and their values were normalized in the open coastal waters excepting NH_4^+-N. The levels of PHc and phenols suggested minor petroleum contamination in the creek system of Tarapur which could be due to releases from fishing boats as well as industrial units.

The comparison of earlier data indicated that the salinity and pH were found stable with noticeable increase in temperature over the years. High variability in DO was evident. In general, the nutrients especially NO_2^--N and NH_4^+-N had increased over the years suggesting an increasing trend of the waste disposals.

ii) Sediment quality (Tables 5.1.D to 5.1.H)

The sediment texture was largely sandy-silt in coastal and creek regions. The concentrations of heavy metals in sediment were in the range expected for uncontaminated sediment of the central west coast of India and hence largely lithogenic. However, the concentration of Zn (97-253 μg/g) and Cr (125-522 μg/g) were relatively high as compared to normal coastal areas of Maharashtra. Phosphorus and C_{org} concentrations were also low and did not show significant enrichment. However, concentration of PHc was high in creek. The sediment collected from shore showed high concentration of PHc indicating that the PHc released from fishing boats and industrial wastes settles on the bed sediment.

iii) Flora and Fauna (Tables 5.1.I to 5.1.R, Figures 5.2.12 to 5.2.14)

Tarapur creek sustained high counts of TVC in water than that of coastal segment. Similar to Dahanu, the counts of TC and FC were comparable between creek and coastal water. Bacterial counts in sediment were much higher than that of water and broadly comparable with the levels in the Dahanu Creek. Tarapur Creek sediment sustained higher count of TVC, TC, FC, VLO and PKLO than coastal stations. PKLO and VLO were high in numbers at coastal station.The occurrence of TC, FC, ECLO, SHLO, SLO, PKLO; VCLO organisms were high at coastal water. The count of TC, FC, ECLO, SHLO, VLO, PKLO in the middle of the creek (Station TP5) were in high number as compared to lower creek, upper creek and coastal water.This indicates enrichment of bacterial counts due of receiving wastes from domestic, industrial and power plant. Whereas in sediment,TVC was high and TC and FC were in the normal range. The presence of organisms like FC, ECLO, SHLO, SLO, PKLO, and VCLO was higher at creek. The pathogens like SHLO, SLO, PKLO and VCLO in the creek system revealed pathogenic contamination of water and sediment.Also, on comparing with 2007-08 report it was found that TC and FC counts in water were higher in coastal waters as compared to creek region and reverse scenario was observed for sediment.

The creek sustained lower values of phytopigments compare to Dahanu and high standing stock of macrobenthos as compared to that of open coastal waters. The phytoplankton cell counts were very high at the creek compared to coastal area during both pre- and post-monsoon .However total genera were in normal range at both the regions. Therefore, the grazing pressure on phytoplankton was considerably reduced leading to higher mortality of phytoplankton with an increase in phytopigment concentration as evident from above results. However, the benthic detrital feeders and filter feeders can make use of this opportunity feeding the high organic remains of phytoplankton on settlement to the bottom. A similar trend was noticed at the Tarapur creek and its coastal system.The community structure of phytoplankton was mainly dominated by *Thalassiosira* and *Peridinium* followed by *Streptotheca, Cyclotella*. *Astemophalus* and *Navicula.*

Zooplankton biomass was low in the creek area when compare with offshore. However, the community structure of phytoplankton and zooplankton between coastal and creek was closely comparable. The community structure of zooplankton was mainly dominated by decapods, copepods and lamellibranchs. During 2007-08 the higher zooplankton biomass were observed in the creek area. The high primary productivity as noticed in the creek could be related to organic pollution. Such organic pollution induced abnormally high productivity in general was not adequately supported by secondary producers.

In Tarapur, benthic faunal group diversity did not vary appreciably between the seasons, but upper creek showed marked increase in biomass and population in postmonsoon. Upper and middle creek segments sustained better standing stock of macrobenthos in both seasons. The standing stock of the coastal segments was comparable to results of 1998 and 2001 while population and biomass standing stock were higher in 2007-08 with compared to the present study. Population of macrobenthos showed trend similar to biomass. Low standing stock in coastal segments can be due to unsuitable substratum like sand.

Meiobenthic standing stock was highest in the upper creek region in both seasons. Meiofaunal density and biomass showed an abrupt increase in the upper creek in postmonsoon season, due to increase in nematode density. Overall group diversity was lower in postmonsoon than premonsoon.

5.2.3 Bassein/Ulhas Estuary

The Ulhas Estuary is one of the largest estuary of Maharashtra and received various industrial and domestic discharges from Kalyan-Thane-Ulhasnagar belt. The water quality, sediment quality and biological characteristics of the estuary (averages) are summarized below.

i) Water quality (Figures 5.2.15 to 5.2.18)

The most of the water quality parameters widely varied suggesting spatial and seasonal trends at Bassein. The average estuarine temperature was 1 to 2^{o}C higher than that of the open coastal waters and followed the trends of air temperature. Although pH was constant, the estuary indicated low pH than that of coastal waters. SS and turbidity were high, varied and comparable between the coastal and estuarine segments. Salinity revealed typical estuarine trend within the estuary (0.3-36.8 ppt) however, the coastal waters indicated seasonal fluctuations with occasional low salinity and values were comparable with other openshore coastal system of Mumbai. The coastal waters in general, sustained better DO (average >4.0 mg/l) inspite of considerable organic input to the estuary. Though the middle and upper estuary sustains high BOD (av 2.2-73.2 mg/l) load due to sewage and industrial wastes, the BOD values in the coastal Bassein showed normal value (avg 1.6 mg/l). The enrichment of nutrients like PO_4^{3-}-P, NO_3^--N, NO_2^--N and NH_4^+-N especially at the inner estuary as compared to the coastal waters was evident and it could be attributed to organic loading through industrial and domestic waste disposals at the inner estuary as well as the inadequate tidal flushing. Low freshwater input to the estuarine system, especially during the dry periods coupled with regular waste disposals resulted in build-up of organic pollutants which are generally responsible for high nutrients in the inner estuary. During insufficient DO availability for an aquatic system, the active nitrification of organic load by bacterial population gets affected resulting high NH_4^+-N and NO_2^--N in such aquatic ecosystem. A similar situation was noticed in the inner segment of the Ulhas Estuary. Impact of estuarine organic load was observed in terms of increased NH_4^+-N concentration (av 3.6 µg/l) in coastal water off Bassein during the recent study. Therefore, the inner estuary revealed severe organic pollution due to indiscriminate and regular waste disposals. Elevations in PHc and phenols than normal revealed noticeable petroleum contamination in Bassein/Ulhas estuary.

The comparison of present results with earlier data revealed that the parameters like temperature, salinity and pH in the estuarine system varied widely without any specific trend. However, the decrease in DO levels in the estuarine segments over the years had occurred. Although, PO_4^{3-}-P and NO_3^--N varied widely, the values were broadly comparable over the years. However, the increasing trend in NO_2^--N and NH_4^+-N of the estuary over the years was evident and this could be due to the increasing input of organic load to the estuarine system.

ii) Sediment quality (Tables 5.1.D to 5.1.H)

The sediment texture widely varied from clayey-silty-sand (coastal) to clayey-sandy-silt (estuary) in the coastal system of Bassein.The concentrations of selected metals showed elevated values as given below.

Coastal	Estuary
Cr(438.0), Fe(9.8), Mn(2211.0) , Co(69.0), Ni(108.0), Zn(234.0) , Cu(141.0), Hg(0.4)*, Cd(0.21), Pb(21.1)	Cr(691.0)*, Mn(1727.0), Fe(10.0), Co(96.0), Ni(128.0), Cu(231.0), Zn(777.0)*, Hg(0.9), Cd(0.9), Pb (76.5)*

* High values

As evident from the above data the concentration of selected metals varied widely with elevated levels in the open coastal and estuarine system of Bassein. The levels of Cr, Mn and Ni were the highest for the openshore coastal system of Maharashtra. Similarly, Cr and Co concentrations were the highest for the creek/estuary along coastal Maharashtra. The rest of the metals mentioned above showed elevated values than normally noticed among the openshore and creek/estuary of coastal Maharashtra.

Most of the metals (Al, Mn, Fe, Ni and Cu) revealed concentrations falling within the range of catchment soil at the coastal/estuarine system of Bassein suggesting possibility of lithogenic origin. However, the metals like Cr, Zn and Hg indicated elevated levels as compared to catchment soil suggesting their anthropogenic source. Phosphorus also indicated elevated levels as compared to catchment soil.

The baseline for Hg in Mumbai sediments has been reported to be 0.1 µg/g based on analysis of sediments deposited before industrialization of Mumbai and region around. The observed concentrations were in the range (0.04 – 0.91 µg/g) with markedly high values (0.91 µg/g) in the inner estuary. Comparison of these results with those reported for the inner estuary during 2007-08 indicated considerable increase in the sediment Hg in 2015-16. The concentration of Hg in upper estuary was considerably high compare to the values reported during 2007-08 because the sampling in the inner most part of estuary was missed during 2007-08. Prior to 1999, a Hg-cell based chlor-alakli plant was releasing Hg laden effluent in the inner part of Ulhas Estuary. Hence, this anthropogenic Hg was settling in the upper segment of the estuary, thus increasing Hg in the sediment of this segment. However, after scrap down of the chlor-alkali plant, concentration of Hg has decreased drastically as compare to 1996-97 values.The values of C_{org}, P and PHc were relatively higher in the estuarine region as compared to the coastal waters. Hence, the coastal system of Bassein especially the estuary indicated enrichment of selected metals.

iii) Flora and Fauna (Tables 5.1.I to 5.1.R, Figures 5.2.19 to 5.2.21)

Bassein/Ulhas estuary sustained higher count of TVC, TC, FC SLO, PKLO PALO and SFLO compared to coastal areas in both water and sediment due to contamination of the region by sewage. Presence of fecal pollution indicator bacteria FC and other pathogenic organisms like VLO and SFLO were high at estuarine regions. TVC, TC, FC, ECLO, PKLO, VCLO, PALO were high at coastal region compare to other region of estuary.Occurrence of pathogens like PKLO, VPLO, PALO, SFLO and SHLO in the estuary/coastal segments indicated contamination of both water and sediment through sewage.Also, on comparing with 2007-08 report it was found that FC and TC were higher in creek regions than coastal water and sediment samples.

Ulhas estuary showed a wide range of spatio- temporal distribution pattern of phytoplankton. The distribution of chlorophyll a and Phaeophytin were high at the estuary compared to the coastal areas off Bassein. Cell counts were also in high number at the creek but the total genera were in the normal range at both the region. The most common pollution tolerant genera found at Ulhas estuary were Thalassiosira, Chaetoceros, Cylindrotheca, Merimopedia and Navicula. The Diversity of phytoplankton did not reveal any clear cut trend.The comparison of present results with earlier data indicated that the standing stock of phytoplankton had decreased.

Zooplankton standing stock indicated no significant variations from coastal to the middle and the upper estuary. The above trends in the biotic distribution clearly indicated the organic pollution induced high primary production supported by high benthic and zooplankton stock especially at the upper and middle estuarine segments. However, the high zooplankton standing stock noticed at the upper estuary as compared to the rest could be related to their tolerance to high environmental stress. Hence, organic pollution induced high primary production was supported by secondary producers like zooplankton is well supported especially at the upper estuary. Such changes within the marine food chain are common in the polluted ecosystems where high input of organic load through anthropogenic or natural sources occurs. In such modified ecosystems mostly the opertunistic species proliferate to make use of such alterd environmental conditions. The major zooplankton groups were copepods, lamellibranchs and gastropods.

The macrobenthic standing stock of costal and lower segment of the estuary has remained similar since year 1998, whereas middle and upper zones showed decreasing trend. Overall health of the estuary has depleted according to macrobenthic data (figure 5.2.13). The group diversity of macrobenthos was low compared to other transect studied throughout the time scale. It has also been observed that the macrobenthic faunal group diversity remained low over the years.

Meiobenthic faunal count was poor throughout the Ulhas estuary, except for BS5 (lower estuary) in premonsoon. The anomalous count at BS5 was due to very high nematode density (99.6%), yet all other meiofaunal groups (except copepods, 0.4%) were absent. Ulhas shows typical meiofaunal density distribution pattern of a disturbed estuary (unpredictable wide variability and low diversity).

5.2.4 Manori

Manori-Gorai Creek is a part of Mumbai Metropolitan Region and carries domestic and other wastewaters. The creek is considered to have limited tidal flushing.The results of water quality, sediment quality and biological characteristics (averages) are summarized below.

i) Water quality (Figures 5.2.22 to 5.2.25)

The variation in water temperature was in the expected range. The pH in the range of seawater. The SS which was high and largely of natural origin made the waters turbid and muddy. DO was undersaturated and low values of DO were recorded in many instances. Salinity was occasionally low and comparable with other creek system of Mumbai. An increase in the values of nutrients viz; PO_4^{3-}-P, NO_3^--N, NO_2^--N and NH_4^+-N was associated with domestic waste disposals. Low DO with elevated levels of NO_2^--N and NH_4^+-N clearly indicated the impact of organic pollution in the creek system. The concentration of PHc did not reveal gross contamination. However, some elevated values of phenols were observed indicating minor contamination. During present study avrage concentration of DO was lower than that of the 2007-08 results. Similarly concentration of phenols have increased in recent years. However, other parameters were in the same ramge as recorded during 2007-08.

ii) Sediment quality (Table 5.1.D to 5.1.H)

The texture of creek sediment was silty-clay in nature. The levels of metals in sediment did not indicate any serious contamination though Cr (204.6 μg/g), Hg (0.34 μg/g and Pb (28.8 μg/g) seemed to be elevated.

Though the region received large quantity of domestic effluents, there was no signature of accumulation of C_{org} and P in sediment. However, elevated concentration (3.4-12.2 µg/g; wet wt) of PHc was recorded. Concentration of Cd and Hg was higher than the values recored during 2007-08, indicating there anthropogenic inputs.

iii) Flora and fauna (Tables 5.1.I to 5.1.R; Figures 5.2.26 to 5.2.28)

The Manori Creek sustained very high counts of TVC, TC and FC both in water and sediment. The counts of VLO were also high in water (Table 4.4.5). The overall microbial counts at upper creek were higher as compared to lower creek and comparable to those in the Ulhas estuary though the counts were much higher in the sediment of the former. The counts of TC, FC, PKLO, and VLO were much higher in the lower creek. The results suggested severe bacterial and pathogenic contamination associated with domestic sewage released to the creek system beyond its assimilative capacity. On comparing with 2007-08 report, it was found that TC and FC counts decreased throughout the study area.

The creek system revealed higher concentration of phytopigments and cell counts. However chlorophyll a and phaeophytin counts were lesser than other stations like Dahanu, Tarapur, and Bassein. The high concentration at Manori is due to elevated levels of nutrients associated with organic pollution. The generic diversity of phytoplankton was normal. The upper creek segment with high organic pollution stress revealed better standing stock of phytoplankton and macrobenthos as compared to the lower segment. Overall, the creek system revealed conditions of optimal pH and DO associated with high nutrients suggesting considerable input of organic waste into the creek system.

The creek sustained comparably low standing stock of zooplankton commonly noticed in many other creek systems with organic pollution. The upper creek segment with high organic pollution stress revealed better standing stock of phytoplankton as compared to the lower segment. Whereas the standing stock of zooplankton was comparatively better at the lower segment.

The standing stock of macrobenthos was relatively high at the lower creek as compared to the rest in postmonsoon, contrastingly highest biomass was found at upper creek in the premonsoon due to large density of pelecypods. High values for macrobenthos in the creek could be due to enrichment of nutrients. Phoronida group was dominant in the creek, probably due to organic enrichment. Overall macrobenthic production showed increasing trend as compared to earlier study in the Manori creek.

Meiobenthos of Manori Creek varied widely with very high biomass (avg 6508.62 µg/10cm^2) in premonsoon. Upper creek sustained better meiobenthic potential than the lower creek in postmonsoon, whereas the reverse trend occurred in premonsoon due to environmental stress. Such variability is due to changes in physico-chemical parameters in the creek system - spatially as well as temporally. Polychaetes were the most dominant group, followed by nematodes. Gastropods were also fairly common.

5.2.5 Versova

Versova, an important fishing village is a part of the Mumbai Metropolitan Region and located on the southern bank of the Malad Creek. The creek dries during low tide except for a narrow channel extending 5-6 km inland from the entrance. The creek receives voluminous sewage inflow from the Versova sewage treatment plant. The results of water quality, sediment quality and biological characteristics are summarized below.

i) Water quality (Figures 5.2.29 to 5.2.32)

The salinity and pH was occasionally low while SS and turbidity were high with normal range of temperature. The DO fluctuated widely with high values of BOD especially during the ebb tide. The high concentrations of nutrients like PO_4^{3-}-P, NO_3^--N, NO_2^--N and NH_4^+-N and variable DO falling to near zero at low tides in some instances clearly indicated the severity of degradation of the creek environment.

The comparison of present values with earlier data revealed that the parameters like temperature, pH, salinity and DO varied but broadly comparable over the years. The creek sustained low DO conditions all these years suggesting deteriorated creek ecology. The nutrients like PO_4^{3-}-P, NO_3^--N, NO2$^-$-N showed high variability without any clear trend. However, the increase in NH_4^+-N over the years was evident suggesting severity deterioration of the system and no much difference was recorded as compared to 2007-08 results, instead increased of BOD were recored in the present study.

ii) Sediment quality (Tables 5.1.D to 5.1.H)

The sediment texture was silty-clay in nature with low percentage of sand. The concentrations of trace metals in sediment indicated possible contamination of Cr (226 µg/g), Cu (160 µg/g), Zn (180 µg/g), Hg (0.30 µg/g) and Pb (28.4 µg/g) in the creek system of Versova. The C_{org} (2.4%) and P (1449 µg/g) contents in sediment did not reveal accumulation, however, PHc (2.7µg/g) showed elevated values suggesting petroleum contamination possibly through fishing boats. No much variation in the sediment quality was discernible is present study and almost all the paremeters were recored in similar range as during 2007-08.

iii) Flora and fauna (Tables 5.1.I to 5.1.R; Figures 5.2.33 to 5.2.35)

The Versova Creek harboured very high counts of TVC, TC and FC both in water and sediment. The bacterial counts both in water and sediment were somewhat higher in the Versova creek as compared to the adjacent Manori Creek. Overall, the Versova creek showed the highest average bacterial counts both in water and sediment for the coastal Maharashtra. But as compared to results of 2007-08, FC and TC counts are found to be decreased.

The phytoplankton standing stock interms of chlorophyll a and cell counts, as well as generic diversity were in the higher range. The chlorophyll a and phaeophytin were high during premonsoon.The dominant phytoplankton genera were *Skeletonema, Nitzschia, Navicula Thalassiosira, Gunardia* and *Peridinium* which are tolerant to organic pollution.The comparison of present values with earlier data showed that the standing stock of phytoplankton and zooplankton varied erratically without any specific trends. Overall, the creek system indicated deteriorated water quality viz; sub-optimal DO, high nutrients and very high bacterial counts associated with organic load. The phytoplankton standing stock was normal with high biomass of zooplankton and normal standing stock of benthos.

The zooplankton population was low in the area while the costal segment exibited relatively high standing stock. Middle segment of the creek also sustained good standing stock and diversity of zooplankton when comparing with the rest. The faunal groups like copepods, gastropods and lamellibranchs were more dominant in the creek system.The comparison of present values with previous studies revealed that the standing stock of phytoplankton and zooplankton varied randomly without any specific trends.

The macrobenthic faunal standing stock revealed a decrease over the years except post monsoon of the present study. The fauna was mostly constituted by Polychaetes.

Versova creek sustained low meiofaunal standing stock except in the upper creek region in premonsoon where meiofaunal density and biomass were multiple times higher than its counterparts. This could be due to organic load in the upper segments of the creek.

5.2.6 Mahim

Mahim Creek which received high volume of domestic wastewater as well as industrial effluents continued to exhibit highly deteriorated environment. The results of water quality, sediment quality and biological characteristics (averages) are summarized below.

i) Water quality (Figures 5.2.36 to 5.2.39)

The temperature, salinity, SS, BOD and NO_3^--N were in normal range. High turbidity was due to organic load turning the water blackish. The salinity of the MahimBay was largely influenced by land drainage during monsoon and by wastewater discharges during the dry periods. Reduction in DO (<2 mg/l) and increase in PO_4^{3-}-P, NO_2^--N and NH_4^+-N at the inner creek could be associated with organic load entering the bay PHc and phenols were low indicating moderate petroleum contamination. The impact of anthropogenic release was minor in the open coastal waters.

The comparison of present results with earlier data indicated that the parameters like temperature, pH, salinity and DO were broadly comparable over the years. However, the variation in NO_3^--N, PO_4^{3-}-P and NH_4^+-N was random and seasonal. But the values of NO_2^--N were low and comparable over the years.

ii) Sediment quality (Tables 5.1.D to 5.1.H)

The sediment texture was silty-caly in nature. The concentration of heavy metals in sediment varied considerably with enhanced levels of Hg (0.30 µg/g), Cadmium (1.43 µg/g), Pb (27 µg/g), Cr (162 µg/g) and Zinc (131 µg/g). Recorded values of organic content and PHc were low as compared to Versova Creek. However, build up of phosphorus was recored in the resent study.Though the mahim Creek receives large volume of sewage, the results suggest good flushing of the Mahim bay.

iii) Flora and fauna (Tables 5.1.I to 5.1.R; Figures 5.2.40 to 5.2.42)

The bacterial counts viz; TVC, TC and FC in water and sediment of the creek system of Mahim widely varied but the average counts were much lower than that of Versova Creek. However, the counts of TVC, TC and FC both in water and sediment were abnormally high for the coastal system of Maharashtra. Mahim Creek sustained high count of TVC, TC, and FC at all the station. The overall microbial counts at upper creek were higher as compared to lower creek.The microbial counts of sediments were high at upper creek region than lower part of the creek. The presence of pathogens like ECLO, VCLO and VPLO in high numbers showed contamination of the creek system by sewage. But as compared to results of 2007-08, FC and TC counts are found to be decreased in creek regions.

The phytopigments revealed enhanced values than normal indicating induced primary production associated with organic load with high values during premonsoon.The chlorophyll a, phaeophytin, cell counts and number of genera were high during premonsoon as compared to post monsoon. The Mahim creek sustained relatievely high phytoplankton diversity.

The comparison of present results with earlier data showed that the values of chlorophyll *a* varied with an increase in phytoplankton population and generic diversity over the years.

The zooplankton standing stock interms of biomass, and population was low in the study area. The inner creek showed low standing stock during premonsoon.This trend closely followed other polluted creek systems around Mumbai. The group diversity of zooplankton was normal with copepods, gastropods, lamellibranchs and decapods dominanting the population.

The macrobenthic standing stock was high two decades ago, however, a decreasing trend was observed since 1990. Relatively, postmonsoon of the present study showed better standing stock than premonsoon. The group diversity of macrobenthos has not varied much over the years. Polychaeta was the dominant group of macrobenthos followed by Amphipoda and Pelecypoda with occasional occurrence in both the seasons. Phoronida was the second dominant group followed by Polychaeta in premonsoon.

In Mahim creek meiofuna was generally low, although it was slightly higher in premonsoon than postmonsoon.

5.2.7 Bandra

The marine sewage outfall off Bandra is operational since about two decades. The sewage after grit separation is released through large diffusers at a depth of 7 m CD. The results of water quality, sediment quality and biological characteristics (averages) are summarized below.

i) Water quality (Figures 5.2.43 to 5.2.46)

The most of the water quality parameters were in normal range during the study period. However, elevations in PO_4^{3-}-P, NH_4^+-N and SS as well as occasional drop in DO (3.5-7.0 mg/l), as compared to 2007-08 were noticed probably due to the influence of sewage reaching the coastal areas.

ii) Sediment quality (Tables 5.1.D to 5.1.H)

The coastal segments of Bandra represented silty bottom condition. The concentration of most trace metals in the sediment did not reveal increase and values were in the range expected for the lithogenic background. However, selected metals like Cr (152 μg/g), Cd (1.6 μg/g), Hg (0.27 μg/g) and Pb (24.8 μg/g) indicated elevated level. Organic carbon, phosphorus and PHc contents were also in the expected ranges and lower than at the Mahim Creek. A marginal increase in Cr, Cd, Hg and Pb in sediment value as compare to 2007-08 may be due to the build up of these elements through sewage and fluxes from Mahim Bay, which receives effluents from several small scale industries.

iii) Flora and fauna (Tables 5.1.I to 5.1.R; Figures 5.2.47 to 5.2.49)

The Bandra openshore coastal system revealed lower bacterial counts in water and sediment as compared to Bassein openshore. Bandra zone sustained higher count of TVC, TC, FC, PKLO, VLO and SFLO due to waste disposal.The microbial counts in sediment were higher than in water as expected. The marine outfall area indicated lower bacterial counts as compared to the adjacent nearshore waters. This could be due to higher influence of adjacent creeks like Versova and Mahim on the nearshore watermass. Counts of TVC, TC, FC and VLO in sediment of coastal stations of Bandra were high. Most of the pathogens were common both in water and sediment. But as compared to results of 2007-08, FC and TC counts are found to be decreased.

The overall distribution of phytoplankton viz. chlorophyll a, phaeophytin and cell counts were high during premonsoon, however total genera were in the same range during pre- and post-monsoon. In general, organic load induced phytoplankton production was evident off Bandra. The standing stock of zooplankton was low with the community structure mainly dominated by copepods and lambellibranchs. The zooplankton biomass was found decreased when compared with earlier data.

Overall, deterioration in water quality and induced primary productivity associated with sewage disposals in the coastal waters off Bandra especially around DP were evident.

The biomass of macrobenthos was low compared to other regions in Maharashtra with low diversity. In postmonsoon, low population with high biomass was due to the dominance of small Polychaetes which accounted for numbers rather than biomass. The present macrobenthic production is comparable with earlier study.

Bandra zone showed higher density and lower biomass in postmonsoon, than premonsoon, although overall average meiofaunal standing stock was low.

5.2.8 Worli

The coastal area of Worli receives domestic sewage through a large submarine outfall. The results of water quality, sediment quality and biological characteristics (averages) are summarized below.

i) Water quality (Figures 5.2.50 to 5.2.53)

Temperature, pH, DO, BOD, NO_3^--N and PO_4^{3-}-P were in the normal ranges and comparable with other coastal areas of north Maharashtra. Though the concentration of SS, turbidity, NO_2^--N and NH_4^+-N were higher as compare to coastal water away from the anthropogenic inputs, the values were lower than that recorded during 2007-08. The results suggest no significant impact of release of sewage in the coastal water off Worli.

ii) Sediment quality (Tables 5.1.D to 5.1.H)

The sediment texture was clayey-silt in nature. The metal contents in sediment did not indicate any serious contamination except for Hg (0.24 µg/g) which was high. However, the value was lower than the 2007-08 values. Organic carbon and PHc values were in the expected ranges and comparable with Bandra. However, concentration of phosphorus (1558 µg/g) was high as cmprared to Bandra and Bassein indicating its accumulation in the region.

iii) Flora and fauna (Tables 5.1.I to 5.1.R; Figures 5.2.54 to 5.2.56)

The bacterial counts viz; TVC, TC and FC in water and sediment were much lower as compared to the coastal zone of Bandra. Population of microbes water off Worli was low in comparison with that of Mahim and Versova creeks. Presence of faecal indicator bacteria like TC, FC, ECLO were more during postmonsoon and pathogenic bacteria like SHLO, SLO, VLO, VPLO and VCLO were in low numbers or absent during premonsoon. The microbial counts of sediments showed almost similar distribution for the study period except VLO which was higher in Postmonsoon 2015. But as compared to results of 2007-08, FC and TC counts are found to be decreased.

In Worli, chlorophyll *a* values in pre-monsoon (April 2016) have shown significant increase in comparison to previous years' data, although post-monsoon (December 2015) showed a slight decrease. Phytoplankton cell count has increased considerably whereas phytoplankton genera count showed only minor fluctuations in comparison to previous data. The results are indicative of increased nutrient enrichment, especially NO_3^-, as also evident in figure 5.2.52 in Worli region which has led to increased phytoplankton growth. The most dominant genera during the previous study were *Guinardia, Thalassiosira, Skeletonema, Thalassionema, Nitzschia, Chaetoceros* and *Navicula*. In the present study *Thalassiosira, Chaetoceros, Skeletonema, Cylindrotheca* were dominant.

The zooplankton standing stock and faunal group diversity were low durind post monsoon and mainly dominated with copepods, appendicularians and lamellibranchs. A similar trend was noticed for macrobenthos with normal standing stock and poor diversity as that of Bandra. The Polychaeta was the most dominant group off worli. Worli showed low to moderate meiofaunal standing stock. Nematodes were the most dominant group. Cnidarians were observed only during postmonsoon.

5.2.9 Thane Creek-Mumbai Harbour

Thane Creek-Mumbai Harbour receives multiple wastewaters which include domestic, industrial and port-based wastes from Mumbai, Thane, Navi Mumbai and Thane-Taloja-Uran-Panvel industrial belt. The Thane Creek is a 24 km long, V-shaped semi-enclosed basin that opens to the Arabian Sea at its south-west approach and connected at its northern extremity to the Ulhas Estuary through a narrow channel. The impressive tidal influence generates swift water movements with excursion lengths of 5-11 km and average current speeds of 25-55 cm/s. Modelling of the residual circulation indicates that the western side of the Bay has ebb dominated flow as against flood dominated currents along the eastern segment. The results of water quality, sediment quality and biological characteristics (averages) are summarized below.

i) Water quality (Figures 5.2.57 to 5.2.60)

The temperature and pH varied on a normal range with occasional low pH at the lower and upper creek segments. SS and turbidity were high along this transect. The salinity varied considerably even in dry season especially the upper creek due to wastewater discharges and influx from the Ulhas estuary. The tide dependant DO levels often falling to <3mg/l especially during low tides at the upper creek segment were common. The drop in salinity and DO levels was also noticed in the lower creek segment. The coastal waters however revealed stable salinity and DO conditions. From the pattern of DO and BOD distribution, it appeared that the organic load entering every day (8.7×10^4 kg/day of BOD) was being effectively dispersed by the tidal currents and assimilated in the coastal waters itself and their transport offshore was low. The nutrients like PO_4^{3-}-P, NO_3^--N, NO_2^--N and NH_4^+-N were all high along the transect especially the creek segments which revealed relatively much higher values than coastal waters.

It appeared that due to high oxygen demand the oxidation of organic matter was only partial in the creek (NO_2^--N - 0.2-31.4μmol/l, NH_4^+-N - 0.2–36.1μmol/l) and better mineralization occurred only when the wastes reached the open coast (NO_2^--N 0.1-1.0μmol/l; NH_4^+-N 0.9–5.2μmol/l). The differential deterioration in water quality between the lower and the upper creek could be related to poor flushing of the creek system and subsequent building of pollutants within the creek for a period of time. Apart from this, the Colaba marine outfall also may be responsible for the deterioration of water quality in the lower segment of the creek. The PHc concentration (1.2-7.4 µg/l) were normal suggesting absence of any severe petroleum contamination of the area inspite of hectic port activities. However, elevated concentration of phenol indicated impact of sewage in the region.

The comparison of present results with earlier data indicated that the temperature and pH were stable and comparable over the years. Whereas the salinity and DO did not have any specific trend over the years. The concentrations of PO_4^{3-}-P, NO_3^--N were lower than the 2007-08 results, however, elevated concentrations of NO_2^--N and NH_4^+-N, especially in upper creek region were recorded during the present study as compared to earlier data.

ii) Sediment quality (Tables 5.1.D to 5.1.H)

The sediment texture varied from silty (coastal) to clayey-silt (creek) along Thane transect. Heavy metal contents of sediment indicated wide spatial and temporal variability. This may be due to the influence of the particulate load associated with the runoff during monsoon. High monsoonal precipitation in the region transports voluminous detritus to the creek. A yearly load of 8.4 x 10^5 m^3 of fine-grained sediment is estimated to be transported, largely during monsoon, to the Bay via Thane, Panvel and Dharmatar creeks. Under the dynamic creek environment the native bed sediment disturbed by turbulence mixes with the load delivered through the land runoff and the oscillating tidal movements probably spread this material fairly uniformly over the 240 km^2 area of the Bay. The openshore segments of the Thane Creek did not show elevated concentration of trace metals. The creek segment indicated high content of Cr (208 µg/g), Hg (0.21µg/g) and Pb (25.7 µg/g) suggesting possible metal enrichment in the sediment along Thane transect. However a decrease in the concentration of Hg and Pb, as compared to 2007-08 values may be due to the restriction on the industrial uses and waste discharges. Organic carbon, phosphorus and PHc contents were mostly low in coastal sediment; however PHc showed occasional elevations suggesting minor petroleum contamination of sediments.

iii) Flora and fauna (Tables 5.1.I to 5.1.R; Figures 5.2.61 to 5.2.63)

In general, the counts of TVC, TC and FC in sediments were abnormally high compare to counts in water at the coastal system of Thane. The bacterial counts viz; TVC, TC and FC in the surface water were more in the open coastal segment than that of creek areas.The overall microbial counts at lower creek were higher than coastal, middle and upper creek and during Premonsoon 2016, upper creek and lower creek had higher microbial counts as compared to coastal and middle creek. The average counts of TVC in water were more in the open coastal segments of Thane than that of Bassein. Also the Thane openshore segment indicated the highest counts of TVC for the coastal areas of Maharashtra. The relative counts of bacteria in sediment were 3 - 4 times higher than in the overlying water. The creek sediments sustained relatively higher counts of TVC, TC and FC as compared to the open coastal zone suggesting highly bacterial contaminated creek sediments due to sewage disposals and port activities.

The microbial counts of sediments were higher in Postmonsoon 2015 and counts of VLO were high at the lower creek. Such high bacteria counts in the openshore waters of Thane could also be influenced by the cumulative impact of discharges from Patalganga and Amba estuaries. The high counts of selected pathogens like PKLO, VPLO, and PALO etc showed pathogenic contamination of the coastal system of Thane. On comparing with 2007-08 report, Thane creek was found to sustain low counts of TC and FC both in water and sediment.

Thane creek region has shown major variations in phytoplankton records. During the present study, the upper creek segment showed the highest chlorophyll a and cell count values during post-monsoon, indicating bloom formation, whereas in the previous study, similar high values of chlorophyll a and phytoplankton cell count was observed in pre-monsoon. *Skeletonema, Chaetoceros, Thalassiosira, Prorocentrum,* were the most frequented genera during the present study as was also observed in the previous study

The zooplankton standing stock interms of biomass and population along this transect widely varied. The highest biomass (240 ml/100 m^3) (Figure 5.2.62) were recorded at the upper creek, recorded in previous studied also. The faunal group diversity of zooplankton was high with dominance of copepods, decapods larvae and *Acetus sp*.

Although, the organic load induced phytoplankton production supported equally high succession of zooplankton standing stock, the grazing pressure was low as indicated by high phaeophytin (3.2 mg/m^3) suggesting higher mortality in the bloom. Therefore, these results suggest that the organic pollution induced high primary production unlikely to yield healthy and desired secondary production of the food chain in most cases.

The macrobenthic standing stock was better in creeks than in the coastal segment.This can be attributed to organic enrichment and nutrient availability. Similar trend was observed in faunal group diversity of benthos that is high values in the creek than open coastal segment. This can be related to unstable substrata in the coastal segments due to physical stress.

Polychaetes, pelecypods and gastropods were dominant in the benthic environment of the study area. An increase in benthic standing stock with a decrease in group diversity was noticed during the present study as compared to earlier data.

The region was very low in meiofaunal density, which was droped to a minimum of 1 ind./cm^2 in premonsoon (station BY5). However, overall meiobenthic standing stock ranged from low to moderate. Postmonsoon recorded slight increase in meiofaunal density.

5.2.10 Patalganga Estuary

Patalganga is a minor river/estuary joining the Amba Estuary there by forming the Dharmatar Creek. The zone below the weir experiences strong tidal influence via the Dharamtar Creek. Treated effluents (15000 m^3/d) from the MIDC Patalganga are being discharged at Apta just below the weir (station PT9). Some industries located outside MIDC area release their effluents in the upstream of weir - the freshwater zone of Patalganga. The results of water quality, sediment quality and biological characteristics (averages) are summarized below.

i) Water quality (Figures 5.2.64 to 5.2.67)

The water quality varied at different segments of the river depending on the prevailing tidal regime. Low salinity and pH occurred especially at the inner estuary associated with freshwater and effluent releases. SS and turbidity were high due to tidal influence. Concentration of DO revealed anthropogenic stress through out the creek with values occasionally falling <0.3 mg/l in the middle lower estuarine segments. The BOD was high suggesting the impact of organic load. The nutrients like NO_3^--N, NO_2^--N and NH_4^+-N were more than normal in the lower and middle estuary. More than normal values of NH_4^+-N and NO_2^--N in the estuarine segment associated with drop in DO and high primary productivity indicated deterioration in the environmental quality associated with effluent release in the estuarine segments. PHc and phenols were more than normal range indicating significant deterioration due to effluent release.

The comparison of present results with earlier data revealed that the parameters like temperature, pH and salinity were comparable over the years. Also, the DO values though varied indicated a decrease over the years in the lower and the middle estuary. The nutrients like PO_4^{3-}-P, NO_3^--N and NO_2^--N showed wide fluctuations without any specific trend. However, NH_4^+-N had high concentration at the middle estuary as compared with the past data.

ii) Sediment quality

The sediment texture in the Patalganga estuary was mostly a mixed type representing clayey-silty-sand.The heavy metal distribution in sediment varied widely with elevated levels of Cr (525 μg/g), Co (940 μg/g), Ni (218 μg/g), Cu (488 μg/g), Zn (592 μg/g), Hg (3.64 μg/g) and Pb (33.6 μg/g). The levels of Co and Hg were the highest for the creek/estuary of coastal Maharashtra and indicated possible metal enrichment in the sediments of the Patalganga estuary. The values recored for Cr, Co, Cd, Hg and Pb during present study were higher than the 2007-08 results in the upper segment, indicating discharge of these metals through industrial wastes. Organic carbon, phosphorus and PHc also varied widely with relatively higher content in the lower and the middle segments of the estuary suggesting possible accumulation due to industrial discharges.

iii) Flora and fauna (Tables 5.1.I to 5.1.R; Figures 5.2.68 to 5.2.70)

In general, the counts of TVC, TC and FC in sediments were high compared to counts in water in the estuary. The estuary is highly contaminated by faecal indicator bacteria like TVC, TC, FC, ECLO and pathogenic microbes like, SHLO, PKLO, VPLO and VCLO. During Postmonsoon season the count were high as compared to pre-monsoon. The counts in water and sediment were comparable with Dahanu Creek system. Bacterial counts in sediment were 3-4 times higher than in water. Abnormal counts of TVC, TC and FC were found to be present in Patalganga water and sediment samples as compared to results obtained in 2007-08.

Patalganga estuary shows marginal variations in all phytoplankton parameters except in December 2015 (post-monsoon), when the middle segment had an abrupt increase in phytoplankton cell density reaching the highest value of 37108.4×10^3/l. The upper segment also showed significantly high cell count during the same season. This can be attributed to monsoonal land run-off, leading to an increased content of nitrogen compounds which created conditions favourable for unprecedented phytoplankton growth. Such high phytoplankton densities can be harmful for other aquatic life forms including fishes as they lead to hypoxia when the population dies off. *Skeletonema* and *Thalassiosira* were the most dominant genera.

The zooplankton standing stock was high in the middle segment during premonsoon; thereby supporting high secondary production. The faunal group diversity was normal but reduced during pre-monsoon as compared to post-monsoon. The faunal groups like copepods, decapod larvae and medusae were dominant.

The comparison of present results with earlier data indicated that the biological parameters like the diversity of phytoplankton as well as population counts of zooplankton did not exhibit any trend.

The estuary sustained low standing stock of macrobenthos during postmonsoon and it was relatively better during premonsoon. The faunal group diversity of benthos was low during the study period and it was almost same in the preveious years. The fauna was mainly represented by Polychaeta and Oligochaeta. Usually, salinity decreases in the postmonsoon season so it would be expected that oligochaeta will be dominant. In the present study Polychaeta and Oligochaeta were dominant in the postmonsoon and premonsoon respectively. This can be due to organic enrichment in the upper estuarine stations where oligochaeta usually found dominant. The biomass of the present study did not show much variation as compared to earlier study, while population was observed with an increasing trend in the entire estuarine segment except the upper segment which was comperable.

A very wide fluctuation in meiofauna community was apparent in Patalganga during both the seasons, and no trend was observed in the distribution of meiofauna. Although a total of 18 and 14 groups were observed during postmonsoon and premonsoon respectively, not all were found at any one station. This could be due to uneven spatial distrtibution of environmental parameters throughout the estuary.

5.2.11 Amba Estuary

AmbaRiver joins MumbaiHarbour and receives effluents mainly from petrochemical industries. The tidal excursion is very high in the estuary and its influence can be seen upto Nagothane village where the ingress is stopped by a weir constructed to store freshwater. The results of water quality, sediment quality and biological characteristics (averages) are summarized below.

i) Water quality (Figures 5.2.71 to 5.2.74)

The pH was lower in the estuarine system as compared to the normal coastal system which could be due to effluent releases and freshwater influx to the estuary. Salinity was on a normal range during dry period, however, it was low at the upper segments during postmonsoon suggesting measurable freshwater influx. SS was in the range, generally recorded in estuaries of Maharashtra with no clear spatial and seasonal trend. DO was in the normal range with occasional increase in BOD suggesting good oxidation potential for the estuary inspite of effluent releases. PO_4^{3-}-P and NO_3^--N showed values more than normal in the estuary during different season. NH_4^+-N was more than normal at different segments during both seasons. PHc was normal suggesting absence of noticeable petroleum contamination even though PHc is a vital pollutant from RIL. Concentration of phenol was high during postmonsoon suggesting land based contamination. Temporal variations suggested that the parameters like pH, salinity and DO increased during flooding while nitrite, nitrate and ammonia increased during ebbing revealing their sources through the tidal water and upstream drainage respectively. An increase in the concentration of nutrients (PO_4^{3-}-P, NO_3^--N, NO_2^- -N, and NH_4^+-N) as compared to the 2007-08 results, which may be due to the increase in the swage discharge.

ii) Sediment quality (Tables 5.1.D to 5.1.H)

The texture of the sediment was mostly clayey-silt in nature. The content of trace metals, C_{org}, P and PHc revealed considerable scatter but there was no evidence for their accumulation in the estuarine sediments

(Tables 5.1.D - 5.1.H). The estuary did not reveal any petroleum contamination inspite of receiving effluents from petrochemical industry at Nagothane. There was not much elevation in the concentration of the metals and values were almost similar to that reported during 2007-08.

iii) Flora and fauna (Tables 5.1.I to 5.1.R; Figures 5.2.75 to 5.2.77)

The bacterial counts showed spatial and temporal variations in Amba estuary. Amba estuary sustained higher count of TVC, TC, FC and VLO during ebb period than that of flood. However, organisms such as SFLO, PALO, SHLO, PKLO and SLO were either absent or recorded in very low numbers while organisms like TC, FC, ECLO, SHLO, PKLO, VPLO and VCLO were relatively higher. The bacterial counts, in general, were broadly comparable with Patalganga estuary. Incidentally, the Amba estuary revealed the lowest counts of TC among the estuaries along Maharashtra. The bacterial counts were more during postmonsoon than premonsoon. On comparing with 2007-08 report, Amba estuary was found to sustain low counts of TC and FC both in water and sediment.

Long term data from Amba estuary reveals considerable fluctuations in all phytoplankton parameters. The present study showed increased chlorophyll *a*concentrations during pre-monsoon, in comparison to all previous years' data. The increased values are comparable to the results from year 2001. The phytoplankton generaalso showed increasing trend. *Skeletonema, Thalassiosira, Cylindrotheca, Nitzschia, Navicula* were dominant in the present study.

The standing stock of zooplankton was higher during premonsoon than postmonsoon. During pre-monsoon, the middle segment sustained better standing stock than the rest. Such trend associated with organic pollutant was uniformly noticed in many creek and estuarine systems around Mumbai. The dominant faunal groups of zooplankton were copepods, chaetognaths, *Lucifer* sp and decapode larvae.

Overall macrobenthic standing stock have shown decreasing trend over the years. The faunal diversity was the most impacted in the recent years. However, the present study revealed similar benthic production at all the segments of Amba estuary. Such trend associated with organic pollution was uniformly noticed in many creek and estuarine systems. The faunal group diversity of benthos was found lowest in the recent years. Polychaeta, Pelecypoda and Amphipoda were the dominant benthos. Amba estuary recorded low to moderate meiofauna biomass and density. The middle and lower stuary sustained highest meiofauna standing stock in postmonsoon and premonsoon respectively.

5.2.12 Thal

Thal transect represent single sampling station in the vicinity of the effluent disposal site of RCF. The results of water quality, sediment quality and biological characteristics (averages) are summarized below.

i) Water quality (Figures 5.2.78 to 5.2.81)

The most of the water quality parameters indicated normal range as compared with clean open coastal waters along Maharashtra. However, elevated levels of SS, turbidity, NO_3^--N, NH_4^+N and phenols than normal clearly showed the impact of waste disposals both locally as well as the polluted coastal water mass moving down the coast of Thal from Mumbai due to strong ebb tidal currents prevailing in the region. Temporal variations revealed no marked variations in water temperature, pH and salinity in the coastal system of Thal. The waters were well-mixed vertically and temporal variations were not significant.

The comparison of present results with earlier data shows that the temperature, pH, and salinity were stable and comparable over the years. However, fluctuation in DO associated with varying values of essential nutrients over the years was noticed.

ii) Sediment quality (Tables 5.1.D to 5.1.H)

The texture of sediment was silty in nature. Phosphorus and C_{org} contents in sediment were low suggesting absence of enrichment. The trace metals were in the expected ranges as noticed for the normal coastal system of Maharashtra and were comparable with earlier results. The values indicated lithogenic source and no gross anthropogenic contamination.

iii) Flora and fauna (Tables 5.1.I to 5.1.R; Figures 5.2.82 to 5.2.84)

In general, Thal coastal system revealed lower bacterial counts viz; TVC, TC and FC both in sediment and water as compared to the openshore segments of Mumbai. Counts of TC in sediments were the lowest for the openshore segments of Maharashtra. The pathogens like ECLO, VLO and PALO were common indicating low level pathogenic contamination due to the influence of sewage.

In Thal, although chlorophyll *a* concentrations had remained camparable over the past few years, both phytoplankton cell count and genera count showed increasing trend and aslo comparable with 2007-08 data. But population of phytoplankton in Thal was low in comparison to other coastal regions along north Maharashtra. *Prorocentrum, Thalassiosira, Gymnodinium and Nitzschia* were the most frequently observed genera.

The zooplankton standing stock and diversity were in normal comparable range over the years though temporal variations were high as expected for areas with tide dependant circulation. The faunal groups like copepods, foraminifera and lamellibranches were more common. In comparison with earlier studies the present study recorded less zooplankton groups.

The standing stock of macrobenthos was low with poor diversity suggesting unstable substrate (silty) conditions associated with siltation in the area. Faunal groups like Polychaetes in post-monsoon (76%) and premonsoon (96.4%) were dominant in the area.

The comparison of present results with earlier data indicated that the biomass of macrobenthos had decreased in recent years which could be due to silt suspended bottom conditions. In general, 2 faunal groups have been recorded from this riegion which is lowest among the areas studied. Meiofaunal density and biomass showed reverse trends, as density was higher in postmonsoon whereas, biomass was higher in premonsoon.

5.2.13 Kundalika Estuary

Kundalika is a shallow estuary with a fishing port and Ispat unit at Revadanda. It received wastes from the CETP of MIDC near Dhatav (St K9) situated on the southern bank of the upper estuary. During 2007-08 study the effluent was flowing on the shore through a broken pipeline. However, during the present study, the effluent was release through a diffuser in the estuary near satation K9. During 2007-08 the green coloured wastewater entered the estuary and spread in the receiving water depending on the tidal stage. In the present study also the estuary water around the effluent release area was coloured. The water quality, sediment quality, biological characteristics (averages) are summarized below.

i) Water quality (Figures 5.2.85 to 5.2.88)

Water quality of Kundalika Estuary varied widely but indicated considerable degradation of upper and middle segments. However, the coastal waters revealed normal water quality that was comparable with the adjacent coastal sites excepting occasional increase in SS, turbidity, NH_4^+-N and phenols values which could be the influence of contaminated estuarine water flowing in the coast during ebb tide. Estuarine segments sustained variable pH and salinity, frequently low DO and often high BOD with high nutrients, PHc and phenols associated with release of industrial effluents and sewage in the upper estuary.

The comparison of present results with earlier data revealed that the parameters like temperature, pH, salinity and DO varied widely but comparable over the years. Fluctuations in nutrients were high with the high value for NO_3^--N and comparable concentration of NH_4^+-N in the estuarine region.

Temporal variations at D.P. (station 9) suggested that the effluent receiving water was freshwater or water with low salinity throughout the tidal cycle in both the study periods. Though pH, which was low, varied randomly, DO decreased and nitrite and ammonia increased during ebb tide. Phosphae and nitrate varied randomely. Results indicated the impact of effluent release on the water quality of Kundalika Estuary.

It appears that the effluent released at St K9 was not effectively diluted and sluggishly transported downstream due to limited assimilative capacity and poor flushing. The deviations in the water quality in respect of high phosphate, nitrate, nitrite, ammonia, PHc and phenols were clearly evident at the effluent disposal site. Incidentally, the effluent also had high contents of phosphate, nitrite, ammonia, PHc and phenols.

ii) Sediment quality (Tables 5.1.D to 5.1.H)

The sediment texture of the estuary varied widely and composed of mainly silt, sandy-silt and clayey-silt respectively at the coastal area, estuary mouth and the upper segment of the estuary respectively. The substratum at station K10, which represented maily freshwater zone was mainly sand.The trace metal contents were variable with relative high values of Hg (0.50 μg/g) and Pb (32.0 μg/g) at the effluent release site (upper estuary) indicating contamination due to ongoing effluent disposal. Increase in the Hg concentration in the estuarine region, as compared to the 2007-08 values indicated its discharge through the industrial wastes. The estuarine sediment however, by and large was free from anthropogenic contamination by other trace metals excepting minor enhancement of Cr (275 μg/g) and Cu (154 μg/g). Organic carbon and phosphorus were low and comparable between the coastal and the estuarine segments and did not indicate their accumulation in sediments of the region. The concentration of PHc was high in the effluent release area, indicating its anthropogenic source.

iii) Flora and fauna (Tables 5.1.I to 5.1.R; Figures 5.2.89 to 5.2.91)

The Kundalika coastal system revealed higher bacterial counts viz; TVC, TC and FC both in water and sediment in the estuarine segments as compared to the openshore areas. The estuary sustained higher count of TVC, TC, FC and VLO during ebb period than that of flood suggesting contamination by sewage. Presence of TVC, TC, FC ECLO, PKLO, VCLO, and PALO were recorded at coastal, lower and upper regions of the estuary. The pathogens like ECLO, SHLO, VLO, VPLO, VCLO and PALO were in high numbers especially in the inner estuarine segment indicating influence of sewage. The sediment of the upper estuary also had high microbial counts than the coastal area and the lower estuary.Similar results were obtained in 2007-08.

Chlorophyll a, phytoplankton cell count and genera (no) revealed an an increasing trend in the Kundalika estuary over the years; especially the upper estuary sustained significant increase in chlorophyll a values. Total genera count in Kundalika was also high with *Thalassiosira* and *Pseudo-nitzschia* dominating during postmonsoon and *Cyclotella, Thalassiosira* and *Aulacoseira* during postmonsoon. The present study is comparable with 2007-08 data.

The zooplankton standing stock indicated wide variation in biomass and population with spatial and temporal variability over the years. The faunal groups like copepods, decapods, foraminiferans and *Lucifer* sp were dominant.

The macrobenthic standing stock showed decreasing trend as compared to earlier study. The benthic productivity was relatively low in the coastal water and increased in the mid and upper estuary. Upper estuary sustained low population and faunal diversity with high biomass. This can be due to low density of large body sized Polychaeta, Oligochaeta and Fish larvae. The faunal groups like Polychaeta and Oligochaeta were dominant.

In both the seasons, average meiofauna density in Kundalika was lowest in the lower estuary, and comparable between the coastal and upper segments. Meiofaunal biomass showed much greater fluctuations than density.

5.2.14 Murud

Murud area was sampled at the mouth of the Rajpuri and is being monitored since 1989 under the COMAPS programme. This area is free from known point discharges except minor land base anthropogenic pollutants entering the bay and discarded organic wastes resulting from fishery operation. Hence, the marine environment is expected to be largely uncontaminated and to represent the baseline for the region. The results of water quality, sediment quality and biological characteristics (averages) are summarized below.

i) Water quality (Figures 5.2.92 to 5.2.95)

Water quality results indicated natural marine environment by and large free from contamination. Temporal variations revealed variation of water temperature in a narrow range and stable pH, as expected. Variations in salinity and DO were not marked with nitrite, nitrate and phosphate remaining low throughout the tidal cycle. Enhanced concentration of ammonia may be due to its production from decomposition of detritus material as the area sustained dense mangroves. The high salinity (>37 ppt) in the area, especially during dry periods, could be due to high evaporation at the creek segment resulting in high saline regime.

The comparison of present results with earlier data showed that the temperature, pH, salinity and DO values though varied were broadly comparable over the years. In general an increase in NO_3^--N and NH_4^+-N concentration was recorded, though the variation was not systematic. Reduction in PO_4^{3-}-P and NO_2^--N over the years suggested assimilation of organic load and production of NH_4^+-N, which further gets oxidized to NO_3^--N in the presence of oxygen.

ii) Sediment quality (Tables 5.1.D to 5.1.H)

The sediment was mainly sandy-silt with low percentage of clay content and was comparable between the coastal and the creek segments. The trace metals represented the lithogenic concentrations. Relative high phosphorus content suggested enrichment through mangrove ecosystem as well as attributed to high biological productivity of the coastal system. Organic carbon and PHc were low in sediment indicating absence of their enrichment. The results of sediment quality were comparable with that of the 2007-08 results.

iii) Flora and fauna (Tables 5.1.I to 5.1.R; Figures 5.2.96 to 5.2.98)

Bacterial populations in water were low with narrow spatial and temporal variations as compared with sediments. Higher counts of TC, FC, ECLO, PKLO and VLO occurred at the coastal region compare to lower creek. The overall microbial counts of the upper creek were higher than the coastal and the lower creek during premonsoon season. Pathogens were in low numbers or absent suggesting unpolluted nature of coastal system. Sediments also sustained low counts.

Chlorophyll *a*, phytoplankton cell count and genera (no) indicated an overall increasing trend in Murud over the past three decades. The highest cell count occurred in the lower segment during Decemeber 2015 (postmonsoon), whereas the highest chlorophyll a concentration was noted in the same segment but during April 2016 (premonsoon). *Thalassiosira, Skeletonema* and *Cylindrotheca* were the most abundant groups in the present study.

The zooplankton standing stock varied widely with spatial and temporal fluctuations over the years. The creek sustained better standing stock than that of coastal waters. The community structure was comparable during the two phases of monitoring with high faunal diversity. The faunal groups like copepods, decapods, foraminiferans, lamellibranchs and *Lucifer* sp were dominant.

The standing stock of macrobenthic fauna varied widely with substantial temporal and spatial variations over the years. The creek sustained better standing stock than the coastal zone in postmonsoon season. In premonsoon similar results have been observed in terms of population density, but biomass showed reversed trend i.e. coastal segment recorded the higher value than the creek. Since 1989, Murud creek showed relative increasing trend in biomass, wheras the population density varied over the time scale. The macrobenthic faunal diversity was low in the open coastal system whereas it was high in the creek and populations mainly represented by Polychaeta, Amphipoda and Ophiuroidea. Overall faunal group diversity has increased in recent years.

Similar to the macrobenthos, the Murud creek sustained better meiobenthic stock than the open coastal region, in both seasons with moderate meiofaunal density through out. The group diversity was also high in the region, with a total of 22 groups recorded including brachiopods.

5.2.15 Savitri Estuary

Savitri River originates in the Sahyadri Hills and meets the Arabian Sea near Bankot. Savitri estuary receives industrial effluents from Mahad MIDC which houses chemical and pharmaceuticals units. Treated effluent from the CETP of MIDC is discharged on the south bank of the estuary in the vicinity of St S8. The CETP effluent which was black in colour was advected along the south bank of the estuary. Untreated sewage from Mahad town also enters the estuary in the upstream of station S8. Tidal influence was observed upto station S9, which is around 70-80 km upstream from the estuary mouth. The water quality, sediment quality and biological characteristics (averages) are summarized below.

i) Water quality (Figures 5.2.99 to 5.2.102)

The upper segment of the Savitri Estuary (Station S8 and S9) was under the influence of freshwater flow through the Savitri River as evident from low salinity (av 13.1 ppt). The water temperature and SS was generally in the normal range in the coastal system of Savitri. Lower segment of the estuary had comparatively higher SS and turbidity.The pH was in the normal range in the open coastal system; however it was comparatively low in the middle and upper estuary. The average DO values was comparable between open coastal system and the estuary, however occasional low values in the upper segment due to anthropogenic influence, was evident. The estuary revealed high values of nitrogen bearing nutrients associated with anthropogenic influxes.The nutrients levels decreased considerably from the inner to the outer segment of the estuary. Concentration of nutrient in the coastal waters indicated normal values. The concentration of NO_2^--N was higher than NH_4^+-N, indicating its build up prior to the oxidation to NO_3^--N in the savitri Estuary. Relatively higher concentration of PHc and phenols in the upper estuary indicated moderate petroleum pollution prabaly through industrial wastes. Thus, the water quality at the inner estuary was distinctly different from that of the lower estuary with deviations in respect of nitrate, nitrite and ammonia as observed at the effluent disposal site. Ammonia and nitrate increased as the ebb progressed at station S8 during postmonsoon indicating their source in the effluent. However, there was no particular trend during Premonsoon season. The normalization of nutrients in the open coastal system clearly showed the high assimilative capacity of coastal waters of Savitri estuary.

The comparison of present results with earlier data showed that the parameters like temperature, pH and salinity though varied were broadly comparable over the years. However, the DO revealed a noticeable reduction in the upper estuary over the years. The nutrients like PO_4^{3-}-P varied on a lower range and broadly comparable over the years. However, present results of NO_3^--N, NO_2^--N and NH_4^+-N indicated their enhancement towards the lower estuarine region suggesting spread of the organic load towards downstream of the estuary. The values of PO_4^{3-}-P were low, varied and comparable over the years. The nutrients like NO_3^--N, NO_2^--N and NH_4^+-N had noticeably increased especially in the estuarine segments over the years.

ii) Sediment quality (Tables 5.1.D to 5.1.H)

The sediment texture along this transect varied from clayey-silt (coastal) to silty-sand. Phosphorus, organic carbon and PHc were in general low in the coastal area with marginal increase in estuarine segment indicating their source from the estuarine region.

The concentrations of selected metals like Cr (208 μg/g), Mn (2312 μg/g) and Fe (12.8%), in the coastal sediments were relatively higher as compared to the coastal areas of Murud. The estuarine sediment showed elevated levels of Cr (365 μg/g), Mn (2663 μg/g), Fe (15.2%), Ni (105 μg/g), Cu (273 μg/g) and Hg (0.26 μg/g). This is unlikely to be associated with the effluents entering the estuary since high concentrations in sediment are wide spread. Results of present monitoring indicated similar results as in the 2007-08. However, in the coastal region decrease in Co, Ni, Cu, Zn and Pb indicates no anthropogenic input in the region.

Results indicated the high concentrations of these metals in the adjacent Vashishti estuary also. These high concentrations were invariably associated with the high levels of iron and / or manganese probably indicating their lithogenic source. For a better understanding of metals, a detailed study is essential. This issue needs to be settled by analyzing sediment from the riverine segments and selected catchment soils and rocks.

iii) Flora and fauna (Tables 5.1.I to 5.1.R; Figures 5.2.103 to 5.2.105)

Savitri estuary is less polluted than other estuaries like Patalganga, Amba, and Manori. The presence of faecal indicator bacteria like TVC, TC, FC, ECLO and pathogenic microbes like, SHLO, PKLO, VPLO and VCLO were in the same range and were in low counts compare to other estuaries. SHLO, SLO, PALO and SFLO were mostly absent. In sediment, the TVC counts were high at all the three regions of the estuary compare to water sample. Except TVC, TC and FC other microbial community were absent.The pathogens like ECLO, VLO and VCLO were common but low in numbers suggesting that the coastal system was under moderate human influence. On comparing with 2007-08 report, Savitri estuary was found to sustain low counts of TC and FC both in water and sediment.

The phytopigments revealed temporal and spatial variation with marginally higher values during postmonsoon. Within the estuary, the premonsoon sustained the highest values at the lower estuary whereas it was the highest at the upper estuary during postmonsoon. These results indicated severity of the pollution during dry periods. The phytoplankton generic diversity was high during premonsoon than postmonsoon. The genera like *Amphora, Chaetoceros, Cosinodiscus, Nitzschia, Thalassiosira, Cylindrotheca, Skeletonema* and *Prorocentrum* were most common.

The zooplankton standing stock varied widely and no regular trend in their distribution was discernible over the years as often observed for estuaries and nearshore waters under tidal influences. However, the estuary sustained high biomass and diversity of zooplankton as compared to the open coastal waters during premonsoon period. Within the estuary the faunal diversity varied widely with low diversity at the upper segment. Phytoplankton production induced zooplankton standing stock was noticed in the estuary. The most common groups were copepods, decapods, chaetognaths, lamellibranches, *Lucifer* sp, Polychaetes and gastropods. The results are comparable with earlier studies.

Macrobenthic distribution also indicated wide fluctuations in standing stock over the years. Postmonsoon period encountered higher benthic biomass, population and faunal diversity due to high production in the upper estuary. In premonsoon coastal segment showed highest benthic stock. The estuarine segment sustained high benthic standing stock with low diversity could be due to adverse effect of effluent on estuarine ecology. Polychaeta, Tanaidacea and Amphipoda were the most common groups in the study area.

The historical analysis of benthic macrofaunal standing stock showed some variations but did not indicate any clear-cut trend. The faunal group diversity was reduced since 1991.

Meiobenthic standing stock was also higher in postmonsoon than premonsoon. In postmonsoon, a decreasing trend was observed in meiofaunal density and biomass from coastal to upper segment; whereas in premonsoon middle estuary showed highest meiofaunal standing stock. Group diversity was low.

5.2.16 Vashishti Estuary

Vashishti is a fairly large estuary of south Maharashtra and experiences excellent flushing due to the large quantity of fresh water released upstream and considerable tidal influence. The upstream segment of the estuary receives effluent in the vicinity of St VS9 from an industrial agglomeration at Lote Parshuram. The results of water quality, sediment quality and biological characteristics (averages) are summarized below.

i) Water quality (Figures 5.2.106 to 5.2.109)

The water quality which was normal in the coastal waters off Vashishti Estuary had not changed appreciably over the years and comparable with clean coastal areas of coastal Maharashtra. However, the estuary revealed low pH and salinity with occasional decrease in DO coupled with high NO_2^--N and NH_4^--N mainly associated with effluent disposals in the upper estuary. The low salinity indicated adequate freshwater influx to the estuary even during dry periods. The entire estuary indicated higher deterioration due to tidal oscillations as compared to the open coastal waters which had very good assimilative capacity for pollutants.

Temporal observations at the effluent disposal point also indicated wide variations in water quality parameters suggesting deterioration during ebb periods.

The comparison of present values with earlier data showed that the water temperature varied and comparable over the years. The salinity and pH were low at the upper estuary and the trend was comparable over the years. However, the DO levels varied and continued to be low in recent years. The values of PO_4^{3-}-P were low, varied and comparable over the years. The nutrients like NO_3^--N, NO_2^--N and NH_4^+-N had noticeably increased especially in the estuarine segments over the years.

ii) Sediment quality (Tables 5.1.D to 5.1.H)

The sediment texture varied from silty-sand (coastal) to sandy silt estuary) along this transect. The metals like Fe (17.2%) and Cu (307μg/g) showed elevated levels in the coastal sediments. Whereas the estuarine sediment revealed high values of Cr (283 μg/g), Mn (2428 μg/g), Fe (16.5%), Co (105 μg/g), Cu (465 μg/g), Zn (210 μg/g) and Hg (0.41 μg/g). Very high percentage of Fe and Mn indicated the lithogenic source of these metals rather than anthropogenic activities. However, the formulation of baseline for these metals is necessary for reliable comparison. The levels of C_{org} and P in the sediment were low suggesting absence of their accumulation. High concentration of PHc in the vicinity of effluent discharge indicates some contamination form the industrial effluent. However elevated concentration of PHc in the lower estuary may be attributed to the contamination from fishing boats.

iii) Flora and fauna (Tables 5.1.I to 5.1.R; Figures 5.2.110 to 5.2.112)

The bacterial counts in the coastal system of Vashishti estuary revealed wide spatial and temporal variations but was less polluted than estuary like Patalganga, Amba, and Manori. TVC, TC, FC, ECLO were present at all the three regions like coastal, lower estuary and upper estuary. SHLO, SLO, PALO and PKLO were mostly absent. The bacterial counts in water were relatively high in the coastal area than that of estuarine segments. Whereas a reverse trend was noticed in sediment with higher values confined to the estuarine segments. Except TVC, TC and FC other microbial community were absent at all stations. Also on comparing with 2007-08, FC and TC were found to increase in water and decrease in sediment samples.

Phytopigments were low and varied over the years. The chlorophyll a, phaeophytin and cell counts values were higher in the estuary than that of open coastal waters. The trend in the distribution of cell count was comparable with phytopigments. The seasonal variability in phytopigments, cell counts and composition was noticed with relatively higher values during premonsoon. The generic diversity was normal. The genera like *Cyclotella, Mallomonas, Prorocentrum, Coscinodiscus, Cylindrotheca, Guinardia and Navicula* were found dominant in the estuary.

The zooplankton standing stock varied widely over the years and indicated an overall low secondary production in the estuary with spatial and temporal variability. The estuary region sustained low diversity of zooplankton especially in the post-monsoon season. The open coastal waters sustained normal standing stock and diversity of zooplankton. The faunal groups like copepods, chaetognaths, *Lucifer* sp, decapods and gastropods, were dominant. Whereas the standing stock was high is in pre-monsoon compared to post-monsoon.

In Vashishti, macrobenthic standing stock also exhibited wide spatial and temporal variation over the years. The inner segment sustained higher macrobenthic standing stock during both the seasons. In general, the estuary sustained better standing stock with normal diversity as compared to the open coastal system. Faunal diversity was uniform between two periods and two segments with dominance of Polychaeta, Amphipoda and Pelecypoda.

Macrobenthic standing stock in terms of biomass was noticeably high especially in the upper estuary during December 2007, December 2015 and March 2016 as compared to earlier data.

Meiofaunal distribution showed wide variations in Vashishti, and no clear trend was observed. Group diversity ranged from 2 (low) to 10 (moderate).

5.2.17 Jaigad/Shastri Estuary

The estuary does not receive any effluent from point sources and harbours luxuriant mangroves. The fishing port is an active centre at this coastal transect. The results of water quality, sediment quality and biological characteristics (averages) are summarized below.

i) Water quality (Figures 5.2.113 to 5.2.116)

Overall assessment indicated that the Jaigad coastal and estuary were free from any anthropogenic input and sustained good water quality. The pH was constant and in the expected range. SS were below 36 mg/l with low turbidity. Salinity was low in the estuary than that of coastal waters where it was almost constant. DO content was above 4.5 mg/l and consequently BOD was low. Phosphate was uniformly in the normal range and seasonal as well as spatial variations were absent. However, elevated concentration of nitrate, nitrite and ammonia was recorded during postmonsoon season. Such seasonal variation may be due terrestrial and shore based (mainly mangrove based organic load) influence on water quality. PHc and phenol concentrations were also in the normal ranges. The water quality did not reveal any deterioration although natural organic load reached the estuarine system through a vast mangrove forest along the estuary.

ii) Sediment quality (Tables 5.1.D to 5.1.H)

The sediment texture varied from silty-sand (coastal) to sandy-silt (estuary) along this transectorganic carbon and PHc varied as per the lithology of the sediment. Relative high organic carbon content in marine sediments off the southern Maharashtra coast is typical of the region and is of natural occurrence associated with coastal wetland and high primary productivity. The metals showed considerable spread of the concentrations without any spatial variations. The metals like Cr (245 μg/g), Fe (16.1%), Co (134 μg/g), Cu (261 μg/g), Zn (192 μg/g) and Hg (0.30 μg/g) in the coastal system of Jaigad revealed elevated levels. Similarly, the estuarine sediment indicated elevated values for Al (11%), Cr (341 μg/g), Fe (20.9%), Co (147 μg/g), Ni (129 μg/g), Cu (415μg/g),Zn (290μg/g) and Hg (0.29 μg/g). The concentration of copper was invariably high in sediments not only of Jaigad area but also upto Vijaydurg. These levels can be of lithogenic origin associated with the basalts of the catchments. The concentrations of iron were also high as expected along coastal south Maharashtra. The concentration of mercury was relatively high at the coastal and estuary in March 2016 but indicated almost baseline in January 2016. Similar trend of mercury was also recorded during 2007.In the absence of a known source of anthropogenic mercury, occasional high value could be a sporadic occurrence.

iii) Flora and fauna (Tables 5.1.I to 5.1.R; Figures 5.2.117 to 5.2.119)

The presence of faecal indicator bacteria TVC were in the same range and counts were low compare to counts in sediment sample along the transect. SHLO, SLO, PALO and SFLO were mostly absent. The pathogens like ECLO, VLO, VCLO, SHLO, SLO and PKLO in noticeable counts showed pathogenic contamination of the estuarine and coastal system of Jaigad.
Also on comparing with 2007-08, FC and TC were found to decrease in water and sediment samples.

In sediment sample the TVC counts were high at all the three regions of the estuary. Except TVC, TC and FC other microbial community were absent.

The distribution of phytopigments did not show wide variation spatially as well as temporally over the years. Phytoplankton cell counts and generic diversity also behaved normally in line with the variation of phytopigments. However, the estuary especially at the upper segment revealed high values of phytopigments, cell counts and generic diversity than that of lower estuary and open coastal water. The genera like *Thalassiosira, Mallomonas, Guinardia, Gonyaulax, Cyclotella, Navicula,* and *Ceratium* were most common.

Zooplankton standing stock population and faunal diversity exhibits wide seasonal and spatial variation over the years. However, the standing stock was comparatively high in premonsoon coastal segment than postmonsoon. During 2007-08 postmonsson period recorded high standing stock. The community structure was with the dominance of copepods, chaetognaths, appendicularians and lamellibranchs.

Subtidal macrobenthic standing stock indicated wide variation in the region and no clear seasonal and spatial trend in their distribution was distinct in comparision to historical data. However, the highest standing stock was noticed in the coastal as well as lower estuary during both the seasons due to the presence of silt and clay in higher percentage, which are more stable substrata than sand. The faunal distribution revealed normal diversity with less seasonal tends. Polychaeta, Amphiopoda and Pelecypoda were the most common groups in the area.

In both seasons, coastal segment sustained highest meiofaunal standing stock. Highest nematode biomass was also observed in the coastal segment in both seasons. Nematodes were the most dominant in both seasons, followed by hydrozoans in premonsoon, and harpacticoids in postmonsoon.

5.2.18 Ratnagiri

Ratnagiri Port and fishery harbour is located inside the Mirya Bay which lies between GalesPoint and Miyet Point. There is no river opening in the bay. Apart from domestic wastewater from the Ratnagiri town, the bay is influenced by fishery operation and Bhagawati Port operation. The results of water quality and biological characteristics (averages) are summarized below.

i) Water quality (Figures 5.2.120 to 5.2.123)

The openshore water off Ratnagiri was relatively free from anthropogenic fluxes of pollutants and the water quality represented natural background. However, inner Mirya bay was severely degraded due to release of untreated domestic wastewater and organic wastes from fish landings. The inner bay had very low DO and high BOD, PO_4^{3-}-P and $NH4^+$-N.

The comparison of earlier data indicated that the water temperature had increased over the years. However, the values of pH and salinity varied and comparable over the years. The DO indicated lower values at the bay than coastal waters during recent studies. An increase in PO_4^{3-}-P ,NO_3^--N and NH_4^+-N as compared to 2007-08 was evident in the in the inner bay of Ratnagiri.

ii) Sediment quality (Tables 5.1.D to 5.1.H)

Sediment off Ratnagiri was silty sand with low content of clay. C_{org} and PHc were generally low. High concentration of phosphorus recorded in the sediment near the fishing harbor indicated its accumulation due to the organic waste. The coastal sediment revealed elevated levels of Fe (11.8%), Cr (162μg/g), Cu (170μg/g) and Zn (117μg/g). Whereas the bay sediment indicated low values for Fe (3.3%), Mn (482 μg/g) and Cu (29 μg/g) as compared to other metals but comparable with the 2007-08 results. The above said levels of metals could be probably associated with the catchment soil. In fact the relative high concentrations of Cu were associated with the coastal sediments from Jaigad to Deogad and in view of no known anthropogenic source they could be of lithogenic origin. Analysis of sediment from the catchment would help in resolving this issue.

iii) Flora and fauna (Tables 5.1.I to 5.1.R; Figures 5.2.124 to 5.2.126)

The open coastal waters of Ratnagiri sustained the lowest counts of TVC and FC for the coastal Maharashtra suggesting clean coastal system.

However, Ratnagiri Bay sustained much higher counts of TVC, TC and FC in water and sediment as compared to the openshore areas. SHLO, SLO, PALO and SFLO were absent at inner, outer and coastal bay region. The higher bacterial contamination in the inner bay could be related to sewage disposals and port as well as fish landing activities. In sediments TVC, TC, FC and ECLO counts were quite high during premonsoon as compared to postmonsoon throughout the region. Abnormally higher counts of TC and FC were found to be present in sediment of bay regions as compared to 2007-08.

Phytoplankton standing stock both interms of phytopigments and population was normal to high and revealed wide seasonal and spatial variations over the years with increasing trend from coastal water towards the bay. Bay region sustained higher phytopigments, population and the most common genera were *Cylindrotheca,Chaetoceros, Guinardia, Navicula* and *Skeletonema* as compared to the rest of the coastal segments suggesting organic pollution induced primary production in the deteriorated bay areas.

Zooplankton standing stock was an indicative of an overall normal secondary productivity with temporal and spatial variations over the years. The standing stock and group diversity showed gradual reduction from open coastal waters to the inner bay suggesting less tolerance of zooplankton to pollution. The groups like copepods, decapods, lamellibranches, foraminiferans, and siphonophores were dominant. The composition of zooplankton diversity was comparably low in the bay region.

Macrobenthic standing stock varied spatially and temporally over the years. The standing stock was low in the inner bay during the entire study period. The faunal group diversity was relatively more at the outer bay and the middle bay. The inner bay sustained poor diversity due to high sand parcentage, this has been aslo supported by low zooplankton biomass, which means low food availability for benthic organism. The faunal groups like Polychaeta, Tanaidacea, Pelecypoda and Amphipoda were more common. In this bay, the substratum could be assumed as one of the major players than organic pollution in deciding the distribution and abundance of benthic standing stock. Macrobenthic production in lower segment increased as compared to earlier studies.

The outer bay was the richest in meiobenthic standing stock in Ratnagiri, in terms of both density and biomass, whereas inner bay was the poorest. This was also supported by observation of benthic macrofauna. Significant spatial and temporal variation was also noted in the region, with premonsoon sustaining better benthic potential than postmonsoon. Nematodes and foraminiferans were most abundant. Echiurans were encountered in both seasons and kinorhynchs in postmonsoon.

5.2.19 Vijaydurg Creek

Vijaydurg Creek joins with Vaghotan River. Though the creek does not receive any effluent directly handling of molasses and fish handling at the Vijaydurg port have the potential to influence environmental quality of this coastal system. The results of water quality, sediment quality and biological characteristics (averages) are summarized below.

i) Water quality (Figures 5.2.127 to 5.2.130)

The coastal and creek environment off Vijaydurg sustained good water quality comparable to that of unpolluted coastal area of south Maharashtra. Water temperature, salinity, pH and SS varied mostly in normal range. However, elevated concentration SS was recorded during premonsoon season, which may be due to increased turbulence during premonsoon season. DO and BOD values were normal. Relatively low DO (3.5 mg/l) was recorded occasionally in the nearshore waters. Elevated concentration of PO_4^{3-}-P, NH_4^+-N and and phenols in the upper estuarine segmens and low concentration of NO_3^--N indicated some inputs of the organic load to the system probably associated with fisheries and port activities.

ii) Sediment quality (Tables 5.1.D to 5.1.H)

The sediment texture varied from clay-silt (coastal) to silty-sand (creek) with low levels of P indicating uncontaminated nature. However, C_{org} varied as per the nature of sediment texture. Elevated concentration of PHc was recorded in creek in some instances. The coastal segments of Vijaydurg revealed elevated levels of Al (9.6%), Mn (2138 μg/g), Fe (17.1%) and Cu (298 μg/g). The levels of Al were the highest for the open coastal segment of Maharashtra. The concentration of Cr (309 μg/g), Fe (18.7%), Mn (2153 μg/g), Co (162 μg/g), Ni (133 μg/g), Cu (319 μg/g) and Zn (251 μg/g) were relatively high and comparable with 2007-08 values in the creek segment and appeared to be natural associated with the catchment soil similar to the creeks of south Maharashtra.

iii) Flora and fauna (Tables 5.1.I to 5.1.R; Figures 5.2.131 to 5.2.133)

Counts of faecal indicator bacteria TC, FC were low in water compare to counts in sediment. SHLO, SLO, and SFLO were mostly absent during premonsoon. Populations of bacteria like TVC and TC in water and sediment were relatively high in the open coastal system than that of the creek segments. The bacterial counts were comparable with that of adjacent coastal systems.In sediment the TVC counts were high at all the three regions of the creek. TVC, TC, FC and ECLO were present during postmonsoon at only coastal region and lower estuary (Stations VJ4) during premonsoon. Other microbial community were absent during the study period.On comparing with 2007-08 results, TC and FC counts were much higher in creek regions.

The distribution of phytopigments and population indicated wide spatial and temporal variations over the years with higher average cell counts and generic diversity during post-monsoon period. The standing stock of phytoplankton and diversity were comparable between different segments suggesting strong marine influence in the creek system. The generic diversity was normal. *Mallomonas, Pseudo-nitzschia, Navicula, Cyclotella, Pleurosigma, Cylindrotheca and Bellorachea were* common genera in the area.

Zooplankton standing stock both interms of biomass and population revealed mostly comparable with occasionally high secondary production with wide temporal and spatial fluctuations over the years. The creek sustained better standing stock than that of open coastal system during the pre-monsoon period. The group diversity of zooplankton varied between different segments. The major groupsof zooplankton present were copepods, chaetognaths, cladocerans and siphonophoes e standing stock was high comparatively in lower segment in pre-monsoon than in post-monsoon.

The macrobenthic distribution indicated wide spatial and seasonal variations with higher benthic standing stock over the years. No obious trend was observed in the creek. In coastal and lower segment, biomass and population decreased from postmonsoon to premonsoon. The area sustained good faunal diversity. The faunal groups like Polychaeta, Tanaidacea, and Amphipoda were more common in the creek, whereas, Turbellaria and Pelecypoda were dominant in premonsoon season.

In Vijaydurg, meiofaunal standing stock was normal to high throughout the creek (except premonsoon lower creek), and comparatively higher in postmonsoon than premonsoon, which may be due to the increased organic content from land runoff. Nematodes were the most abundant followed by foraminifera.

5.2.20 Deogad

Deogad Bay is connected with Deogad Creek in turn upstream with Deogad River and does not receive much freshwater except in monsoon. Apart from a small volume of untreated sewage from Deogad town and wastes from Anandwadi fishery harbor, the region is free from gross anthropogenic influences. The results of water quality, sediment quality and biological characteristics (averages) are summarized below.

i) Water quality (Figures 5.2.134 to 5.2.137)

The openshore water of Deogad were characterised mostly by normal range of water quality parameters suggesting clean water quality. BOD values were mostly in the normal range excepting occasion deviations indicating minor stress associated with port and fish landing activities. Similarly elevated concentration of NH_4^+-N and phenols were also recorded in the creek water. However, PHc levels were in the normal range indicating absence of noticeable petroleum contamination. Elevated concentration of phenol as compared to 2007-08 results may be attributed to the non point discharge of sewage.

ii) Sediment quality (Tables 5.1.D to 5.1.H)

Sediment texture was highly variable and ranged from sandy-silt (coastal) to silty-sand (creek) with a comparable trend as that of Vijayadurg. Relative high concentrations of C_{org} especially in the openshore was probably natural and such concentrations have been reported off the south Maharashtra coast. Occasional elevated levels of PHc especially in the creek segments indicated some accumulation of oily residues which were likely to be associated with the fishing port and fishing vessels operating in the region. The levels of heavy metals in sediment did not indicate abnormal values except occasional elevated levels of Fe (14.4 μg/g), Cu (208 μg/g) and Zn (147 μg/g) especially in the creek segment which appear to be lithogenic and broadly comparable between the creek of Vijayadurg. Similarly, the concentrations of various metals in the openshore were comparable with open coastal areas of Ratnagiri. Concentration of Cr continues to be high in coastal as well as creek area in the line with other area of south Maharashtra, indicating lithogenic characteristics.

iii) Flora and fauna (Tables 5.1.I to 5.1.R; Figures 5.2.138 to 5.2.140)

The bacterial counts in coastal waters of Deogad were comparable with that of Vijaydurg. TVC, TC, FC, ECLO, PKLO, VCLO, and PALO were recorded at all the three segments. TVC counts were high in sediment during pre- and post-monsoon at all the three region. Except TC, FC and ECLO other microbial community were absent at other region of the creek. Also TC and FC counts were higher in sediment as compared to 2007-08.

Phytoplankton standing stock both interms of phytopigments and cell count were in the normal range excepting occasional deviations and indicated wide spatial and temporal variations over the years. Segment wise distribution of phytoplankton indicated higher production in the inner estuary. Overall the generic diversity was normal with the absence of spatial or seasonal trends. The genera like *Skeletonema, Cosinodiscus, Gyrosigma, Pinnularia, Cylindrotheca, Navicula, Nitzschia and Pleurosigma* were the most dominant in the study area.

The zooplankton standing stock was comparable with occasional increase and without any specific trends over the years. However, premonsoon sustained better standing stock than postmonsoon. The biomass was better in the coastal sgment while population was comparable between the different segments. The groups like copepods, lamellibranches, cladocerans, chaetognaths and gastropods were more common.

High macrobenthic standing stock was indicative of good benthic productivity with spatial and seasonal variations over the years. In postmonsoon, all the segments sustained better faunal standing stock, however in premonsoon decrease in macrobenthic standing stock occurred in the coastal segment. The faunal diversity was normal with a wide variability and comparable between different segments. The groups like Polychaeta, Tanaidacea, Amphipoda and Pelecypoda were common. Overall macrobenthic production has been increased as compared to earlier studies.

In postmonsoon, Deogad recorded an overall high meiofaunal standing stock, whereas in premonsoon it was significantly low. Station D4 harboured the lowest meiofaunal density during the study period. Nematodes were the most dominant fauna in both seasons although frequency of occurrence of harpacticoid was also significantly high in premonsoon.

5.2.21 Achara

The Achara Creek is surrounded by lush healthy mangroves. Sand deposition at the mouth of the creek makes navigation difficult especially during ebb. There is no known anthropgenic discharge in the creek. However, due to attaractive natural beach, some disturbance due to tourism may be expected, apart from Achara village and a small fishing port. The results of water quality, sediment quality and biological characteristics (averages) are summarized below.

i) Water quality (Figures 5.2.141 to 5.2.144)

Coastal water of Achara revealed the natural background for SS, turbidity, pH, salinity, DO, BOD, phosphate, nitrate, nitrite and PHc. However, elevated concentration of ammonia and phenols indicated some organic load in the region. Sililarly creek water also indicated high concentration of ammonia and phenols. Temporal variation of salinity near the mouth of Achara Creek revealed substantial dercease in salinity during ebb tide, indicating influx of freshwater even during dry season. However, other parameters did not show any particular tidal trend. Such observations indicate that there is no organic source in the upper region of the creek and whatever variation in chemical parameters observed may be due to local perturbations.

ii) Sediment quality

Texture of the sediment of the Achara region was sandy-silt. Concentration of C_{org} was low with elevated concentration of phosphorus, as in other parts of the south Maharashtra coast. Cr and Fe remained high in line with Vijaydurg region. However, other metals were low in concentration.

iii) Flora and fauna (Tables 5.1.I to 5.1.R; Figures 5.2.145 to 5.2.147)

Achara Creek sustained relatively high count of TVC, TC, FC and VLO during premonsoon which suggested sewage contamination by fishing port. The TVC counts of the creek at lower region were very high than the coastal and the upper creek. TC, FC, ECLO, SHLO, PKLO, VPLO and VCLO counts were high at lower and upper creek. At coastal region microbial community like TC, FC, ECLO, SLO, PKLO, VLO and SFLO were absent. The microbial counts of sediments indicated significantly high numbers of TVC, TC and FC. Distribution of Microorganisms like TVC, TC and FC were quite high during premonsoon time. At study region during postmonsoon the microbial community like TC, FC, ECLO, SLO, PKLO, VLO and SFLO were absent.

The distribution of phytopigments and cellcount indicated wide spatial and temporal variations with higher average cell counts and generic diversity during premonsoon period. The standing stock of phytoplankton and diversity were comparable between different segments suggesting strong marine influence in the creek system. The generic diversity was normal. *Pseudo-nitzschia, Plagioselmis, Cylindrotheca, Alexandrium, Cosinodiscus, Navicula,* and *Pleurosigma* were common genera in the study area.

Zooplankton standing stock both interms of biomass and population were normal with occasionally high secondary production and wide temporal and spatial fluctuations. The creek sustained better standing stock than that of open coastal system. The group diversity of zooplankton varied and represented more than normal range with comparable trend between different segments. The major components of zooplankton were copepods, chaetognaths, lamellibranchs and cladocerans were more common.

In Achara creek, macrobenthic standing stock was found to be normal. Lower creek and upper creek sustained low and high macrobenthic standing stock respectively. The faunal diversity was normal with less variation between the the segments. The groups like Polychaeta and Pelecypoda were common and dominant in the area during the study period. The faunal groups varied from 1-10 numbers in the study area.

As at Deogad, in Achara, postmonsoon showed higher meiofaunal standing stock. Upper creek sustained the highest meiofaunal density and biomass. Nematodes were most abundant in both seasons.

5.2.22 Malvan

Malvan Bay is also under the influences of minor pollution stress associated with port operations and fishery harbour activities. The results of water quality, sediment quality and biological characteristics (averages) are summarized below.

i) Water quality (Figures 5.2.148 to 5.2.151)

The water quality of the coastal bay systems of Malvan was good with minor spatial and temporal variations. The pH, SS, salinity and temperature were in the normal ranges and indicated a typical marine area with low freshwater inflow. The water was well-oxygenated and the BOD was low as expected for areas free from organic pollution. Selective nutrients namely phosphate (PO_4^{3-}-P), nitrate NO_3^--N), nitrite (NO_2^--N) and ammonia (NH_4^+-N) were uniformly low with normal ranges. However, inner bay sustain comparatively high NH_4^+-N, indicating some anthropogenic perturbations, mainly through sewage. The PHc and phenols showed moderate petroleum contamination, which may be due to fishing and port activities. The present data was comparable with the past study.

ii) Sediment quality (Tables 5.1.D to 5.1.H)

Bottom of most of the inner stations were rocky. The texture of sediment in the coastal waters was mostly silty with low percentage of clay, whereas the bay was mostly sandy. The concentration of organic carbon was occasionally elevated in the openshore segments than that of bay but unlikely to be due to external perturbations. These values indicated the source of high biological productivity in the coastal system of Malvan. Phosphate and PHc were low in sediment, as compared to the 2007-08 results. The concentrations of trace metals were comparable with adjacent coastal segments of Deogad and sediments of the region. In general, the concentrations of metals were relatively high in the openshore as compared to the bay and well corresponded with the sediment texture.

iii) Flora and fauna (Tables 5.1.I to 5.1.J; Figures 5.2.152 to 5.2.154)

During premonsoon counts of faecal indicator bacteria TVC, TC, FC were high at all the three regions of Malvan compared to postmonsoon. TVC, TC and FC in water and sediment were relatively high in the bay than the open coast. TC, FC and ECLO, SHLO, SLO, VCLO, PALO and SFLO counts were absent at all the three station of Malvan Bay during postmonsoon. Highest microbial counts in sediments were recorded at Coastal region during pre monsoon time. However, their high populations in the bay indicated human influence through port and fishery activities. The pathogens like ECLO, PKLO, PALO and SFLO were recorded in low numbers and indicated low levels of pathogenic contamination especially in the bay. Sediment also revealed results comparable to water samples. In sediment sample also the counts were highest at the coastal region during premonsoon. On comparing with 2007-08, TC and FC counts were increased in water and sediment of Malvan study area.

Phytopigments revealed spatial as well as seasonal variability with the bay sustaining higher content of phytopigments. The values of chlorophyll a were higher during postmonsoon than premonsoon whereas phaeophytin was more during postmonsoon than that of premonsoon suggesting higher mortality of phytoplankton during postmonsoon. Phytoplankton cell count did not show any specific trend. However, the bay sustained higher cell counts than the coastal waters. But composition and generic diversity were comparable between the two segments. The genera like *Chaetoceros, Pseudo-nitzschia, Cylinrotheca, Plagioselmis, Bacteriastrum, Navicula and Pleurosigma* were common in the coastal system of Malvan.

The overall distribution of zooplankton indicated wide spatial and seasonal variability over the years. Coastal segment sustained relatively higher biomass and population in comparison to the bay. Comparing with earlier data the present study recorded high biomass during premonsoon period. Faunal diversity was high at the coastal station. The groups like copepods, chaetognaths, decapods larve and *Lucifer sp* were more common.

In Malvan bay, macrobenthic standing stock decreased in comparision to the results of 2007. The faunal diversity was normal with more or less similar values in the bay and the coastal system. The groups like Polychaeta, Amphipoda, Pelecypoda, Cumacea, Tanaidacea and Brachyuran were common in the area. The faunal groups varied in the range of 2-12 no.

During postmonsoon meiofaunal standing stock was significantly high in Malvan, compared to premonsoon. The bay region sustained highest meiobenthic standing stock in both seasons. Nematodes were the most abundant in both seasons, followed by foraminiferans in postmonsoon and harpacticoids in premonsoon.

5.3 Water Quality Index

Water quality index (WQI) as a means of water quality assessment through the determination of physico-chemical and microbial parameters of water, can act as an indicator of water pollution because of natural inputs and anthropogenic activities. WQI is one of the most effective tools to provide feedback on the quality of water to the policy makers and environmentalists. It provides a single number expressing overall water quality status of a certain time and location. It is actually the categorization counting the combined influence of different important water quality parameters; as it is calculated based on the concentration of several important attributes. The objective of the study was to assess the WQI as an indicator to evaluate the water pollution status of the sites investigated. Water quality variables such as temperature, pH, DO (percent saturation), BOD, turbidity, nitrate (mg/l), total phosphorous (mg/l), and fecal coliform (CFU/100 ml) are the health indicators of a coastal environment. Nevertheless, the large datasets created are often complex to understand. Thus, in an attempt to present the complex datasets in a more comprehensive approach, a single indicatorof WQI was attempted. The WQI is a dimensionless number that combines multiple water quality variables.

Factors and weights considered for Water quality index (WQI) calculation are given in the table below:

Factor	Weight
pH	0.12
Temperature(°C)	0.11
DO(% saturation)	0.18
BOD(mg/l)	0.12
Turbidity(NTU)	0.09
Total Phosphorus(mg/l)	0.11
Nitrate Nitrogen(mg/l)	0.10
Fecal coliform(CFU/100ml)	0.17

The 100 point index can be divided into several ranges correspondingto the general descriptive terms shown in the table below:

Water Quality Index Legend	
Range	**Quality**
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very bad

In the present study spatial variation of water quality index was calculated taking average measured values of parameters listed above. Thus from the Figures 5.3.1 to 5.3.20, it is evident that the water quality index off Dahanu was between 71 to 76, with maximum value obtained in coastal water, which indicates medium to good water quality of the Dahanu transect. Coastal and creek water of Tarapur showed good quality during postmonsoon, but was in the bad to medium range during premonsoon season, indicating increased load during this period in the creek. Coastal water quality off Bassein was in the medium range, whereas the estuarine water quality upto mouth was in the bad range during both the seasons due to high industrial as well as domestic waste discharges. WQI of Thane Creek appeared to be in medium to good category. Versova and Mahim Creeks were in the bad to medium range WQI. WQI in the mouth region of Patalganga was in medium range, upper estuary was bad range. However, the freshwater zone was in the good range. Amba Estuary appeared in medium to good WQI range, with lower values during premonsoon season. Kundalika estuary showed bad to medium WQI, with bad values in the vicinity of the effluent release location, indicating pollution load through industrial waste. The water quality index obtained in the Murud Creek was in good range throughout the study period, indicating largely free from anthropogenic load.

Among the estuaries of south Maharashtra, Savitri and Vaishisti estuaries showed lower WQI in the effluent discharge area. Thus the Savitri Estuary was in medium range in effluent release area and in good category in the in down and upstream of effluent release location. Similarly, WQI in Vashishti Estuary was medium to good range. The WQI from Shastri Estuary to Malvan area was in good range, but the mouth of Ratnagiri Creek indicated bad WQI, which was due to sewage discharge and waste from fishing activities in the Ratnagiri harbor.

From the above WQI values it appears that none of the transects of Maharashtra coastal (Upto 5 km from shore) showed excellent water quality index and inner segments of some of the estuaries are under bad WQI category, indicating impact of human perturbation.

5.4 Effluent quality of different CETP

During monitoring period effluents were collected in the presence of MPCB officials from different CETPs, discharging effluent to nearshore water bodies of Maharashtra coast and the results are presented in Tables 5.4.1 & 5.4.2. From the results, it is evident that only CETP of Mahad MIDC (20.2 mg/l of BOD) and CETP at Ambernath (Chemical) (44.8 mg/l of BOD) met BOD criteria specified by MPCB, during postmonsoon season. This is because the inlet BOD of effluent at CETP of Ambernath (96.0 mg/l) and CETP Mahad (60.2 mg/l) itself was lower. However, BOD of other CETPs was above 120 mg/l and some of them exceeded 800 mg/l in the final effluent. Similarly, COD values of final effluents were multifold above the specified criteria of MPCB for CETPs and some are discharging effluent containing COD value above 31000 mg/l, which was recorded in the effluent of Lote Parshuram CETP during December 2015. Concentration of metals analysed in the effluent of different CETP were within the specified criteria of MPCB. Similarly values of PHc were below the specified criteria in terms of oil and grease. Concentration of phenols also was within the limit given by MPCB for effluent discharge of CETP.

Based on results obtained from effluent analyses and quantity of effluent discharge from different CETPs, total daily and annual load discharged to the receiving water bodies were calculated and the results are given in the Table 5.4.3. Thus the water off Tarapur receives $6.5x10^6$t BOD, $24x10^4$t COD, 0.6 t, Cr, 4.9 t Mn, 31 t Fe, 1.1 t Ni, 0.7 t Cu, 0.9 t Zn, 8.2 t PHc, and 5.5 t phenols per annum. Ulhas Estuary receives $4.4x10^3$ t BOD, $4.1x10^4$ COD, 0.4 t Cr, 2.9 t Mn, 15.8 t Fe, 0.7 t Ni, 1.1 t Cu, 2.4 t Zn, 1.6 t PHc and 2.6 t phenols annualy. Patalganga Estuary receives $0.7x10^4$ t BOD, $0.3x10^4$ COD, 0.6 t Cr, 9.8 t Mn, 27.5 t Fe, 0.8 t Co, 0.2 t Ni, 0.9 t Zn, 2.4 t PHc and 0.8 t of phenols in a year. $1.1x10^3$t BOD, $5.4x10^4$ t COD, 0.3 t Cr. 2.2 t Mn, 0.5 t Fe, 0.5 t Cu, 0.2 t Zn, 0.3 t PHc and 0.6 t Phenols are released to Kundalika estuary per year. Among south Maharashtra estuaries, Savitri Estuary receives $0.04x10^3$ t BOD, $0.1x10^4$t COD, 0.2 t Mn, 0.3 t Fe, 0.2 t Zn, 0.15 t PHc and 0.3 t phenols in a year. The load released through MIDC Lote Parsuram MIDC to the Vaishisti Estuary are $1.3x10^3$t BOD, $6.0x10^4$ t COD, 0.3 t Mn, 0.2 t Fe. 1.0 t Cu, 0.2 t Zn, 0.5 t PHc and 0.3 t Phenols.

Apart from above point sources of industrial wastes, there are many none-MIDC industries, which discharge their effluent to the creeks and estuaries of the Maharashtra coast. However, quality and quantity of these effluents are not known. Also large volume of sewage from point and none-point sources are released to the creeks and estuaries, which contribute more than the industrial load of pollution, particularly BOD in the coastal waters.

Table 5.4.1: Effluent quality (final disposal) of different CETPs during November - December 2015

Sample ID	Cr (µg/l)	Mn (µg/l)	Fe (µg/l)	Co (µg/l)	Ni (µg/l)	Cu (µg/l)	Zn (µg/l)	Hg (µg/l)	Pb (µg/l)	BOD (mg/l)	COD (mg/l)	PHc (µg/l)	Phenol (µg/l)
Tarapur CETP	22.6	168.2	1083.0	3.1	37.9	25.4	31.5	0.26	42.5	224	8480	282.1	187.2
CETP AMBERNATH Chemicals	17.0	191.1	1004.	3.3	86.9	162.9	650.9	1.22	37.8	44.8	4400	217.3	251
Additional Ambernath CETP	41.1	499.4	1806.0	2.6	31.1	23.7	90.5	0.28	24.0	192	10800	73.7	289
ACMA CETP Ambernath	128	489	2718	17.4	54.5	342.9	732.6	0.10	25.6	244	4400	96.0	251
Badlapur CETP	9.3	98.0	93.8	3.8	112.8	26.9	45.3	0.26	20.8	192	8000	197.3	221
MIDC CMET (chikroli) Badlapur	2.5	742.5	266.1	6.8	127.4	41.1	75.5	0.29	41.9	224	2560	103.9	312
Wadalgaon STP Ulhasnagar	ND	52.7	69.9	ND	2.2	1.7	5.3	0.08	4.2	64	3200	53.6	158
Ulhasnagar STP	ND	13.0	8.9	0.4	4.1	2.0	10.5	0.10	2.6	51	800	242.4	186
Dombivali DBESA CETP	16.2	96.3	459.8	0.7	22.9	34.9	14.1	0.02	30.1	224	7680	101.6	368
Dombivali DCETP	34.0	76.4	1815.0	1.7	43.7	84.7	198.2	0.02	43.2	320	7200	86.7	242
MIDC Patalganaga	103	1787	5031	139	39	16.0	166	0.020	22.7	120	560	436	142
MIDC Roha (Kundalika)	92	608.0	125	35.1	14.4	149.0	65.0	0.165	36.6	288	14800	82.0	153.6
MIDC Lote	22.2	58.0	32.6	9.2	21.5	189.0	36.5	0.21	115.5	448	31200	94.0	75.6
MIDC Mahad CETP	12.0	54.0	73.0	4.2	2.1	8.2	5.5	0.575	2.4	20.2	573	42.5	76.6

Table 5.4.2: Effluent quality (final disposal) of different CETPs during April - May 2016

Sample ID	Cr (µg/l)	Mn (µg/l)	Fe (µg/l)	Co (µg/l)	Ni (µg/l)	Cu (µg/l)	Zn (µg/l)	Hg (µg/l)	Pb (µg/l)	BOD (mg/l)	COD (mg/l)	PHc (µg/l)	Phenol (µg/l)
Additional Ambernath CETP	142.3	543.3	3020.0	19.3	60.5	369.9	814.0	0.24	28.2	887.1	1296	474.0	124.8
ACMA CETP Ambernath	2.2	110.1	409.1	0.7	42.8	19.4	78.3	0.10	39.7	190.1	1120	100.2	178.0
Badlapur CETP	12.5	356.9	590.2	33.5	119.7	99.0	399.3	ND	57.2	570.3	1412	96.4	204.0
MIDC CMET (chikroli) Badlapur	3.0	478.9	1646.0	0.3	109.0	68.9	15.4	0.14	40.9	458.4	1063	117.2	154.8
Dombivali DBESA CETP	19.6	116.5	556.4	0.8	27.7	42.2	17.1	0.08	70.5	697	1930	120.0	117.6
Dombivili DCETP	17.0	109.7	2369.0	0.3	18.9	78.7	87.8	0.02	89.1	190.1	746	130.2	135.6
MIDC LOTE	2.5	93.1	91.2	1.9	9.3	341.5	95.0	ND	36.3	253.5	1920	176.7	75.6
MIDC Mahad CETP	3.8	146.0	165.0	1.4	5.2	72.3	215.8	0.20	3.0	20.2	573.0	91.9	187.0

Table 5.4.3: Total Load Through industrial waste

Sample ID	Cr (Kg/day)	Cr (Kg/year)	Mn (Kg/day)	Mn (Kg/year)	Fe (Kg/day)	Fe (Kg/year)	Co (Kg/day)	Co (Kg/year)	Ni (Kg/day)	Ni (Kg/year)	Cu (Kg/day)	Cu (Kg/year)	Zn (Kg/day)
Tarapur CETP	1.81	659.90	13.46	4911.40	86.64	31623.60	0.25	90.50	3.03	1106.70	2.032	741.700	2.520
Ambernath CETP	0.64	232.40	6.21	2266.80	20.75	7574.20	0.16	59.10	1.32	483.40	2.070	755.700	5.166
Dombivali DCETP	0.38	138.60	1.75	637.00	22.75	8304.10	0.02	5.60	0.50	180.80	1.052	384.000	1.388
MIDC Patalganaga	1.55	563.90	26.81	9783.80	75.47	27544.70	2.09	761.00	0.59	213.50	0.240	87.600	2.490
MIDC Roha (Kundalika)	0.92	335.80	6.08	2219.20	1.25	456.30	0.35	128.10	0.14	52.60	1.490	543.900	0.650
MIDC Mahad CETP	0.05	17.30	0.60	219.00	0.71	260.60	0.02	6.10	0.02	8.00	0.242	88.100	0.664
MIDC LOTE	0.12	45.10	0.76	275.80	0.62	225.90	0.06	20.30	0.15	56.20	2.653	968.200	0.658

Sample ID	Zn (Kg/year)	Pb (Kg/day))	Pb (Kg/year)	Hg (Kg/day)	Hg (Kg/year)	BOD (Kg/day)	BOD (Kg/year)	COD (Kg/day)	COD (Kg/year)	PHc (Kg/day)	PHc (Kg/year)	Phenol (Kg/day)	Phenol (Kg/year)
Tarapur CETP	919.800	3.40	1241.0	0.021	7.600	17920	6540800	678400	247616000	22.568	8237.300	14.976	5466.200
Ambernath CETP	1885.500	0.57	208.8	0.005	1.700	5647	2061038	58038	21183870	2.677	977.000	3.442	1256.200
Dombivali DCETP	506.500	1.02	371.9	0.001	0.200	6261	2285288	76808	28034738	1.918	700.200	3.777	1378.400
MIDC Patalganaga	908.900	0.34	124.3	0.000	0.100	1800	657000	8400	3066000	6.540	2387.100	2.130	777.500
MIDC Roha (Kundalika)	237.300	0.37	133.6	0.002	0.600	2880	1051200	148000	54020000	0.820	299.300	1.536	560.600
MIDC Mahad CETP	242.300	0.02	5.9	0.002	0.800	121	44238	3438	1254870	0.403	147.200	0.791	288.600
MIDC LOTE	240.000	0.76	277.0	0.002	0.800	3508	1280238	165600	60444000	1.354	494.000	0.756	275.900

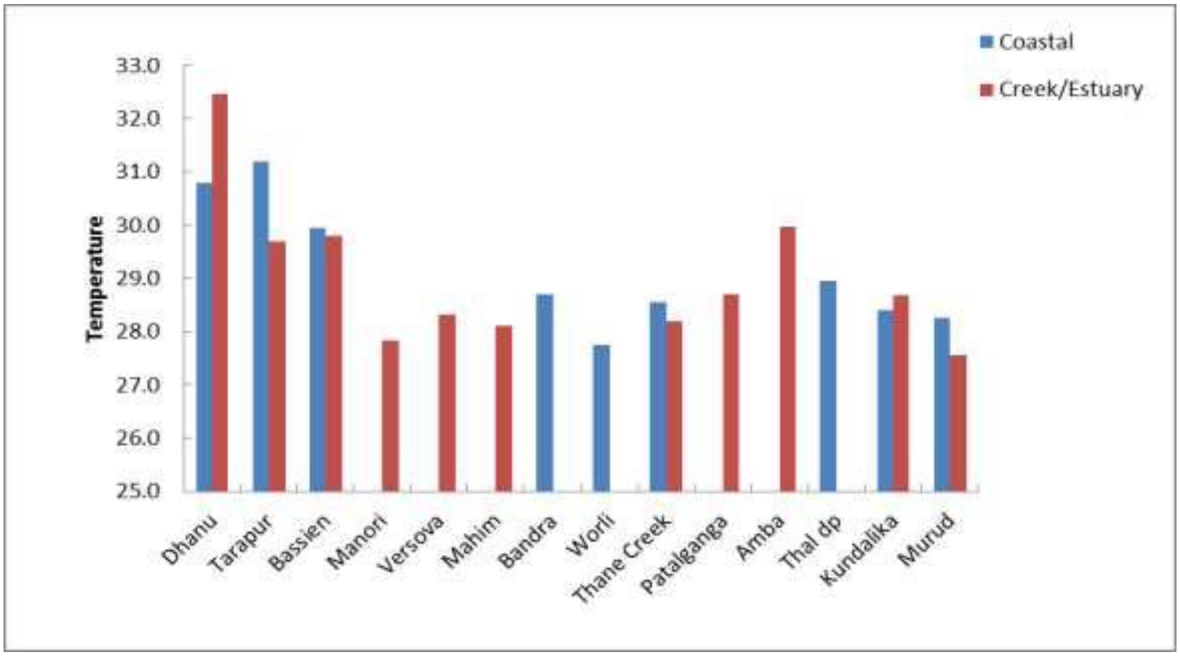


Figure 5.1.1: Water temperature along North Maharashtra coast.

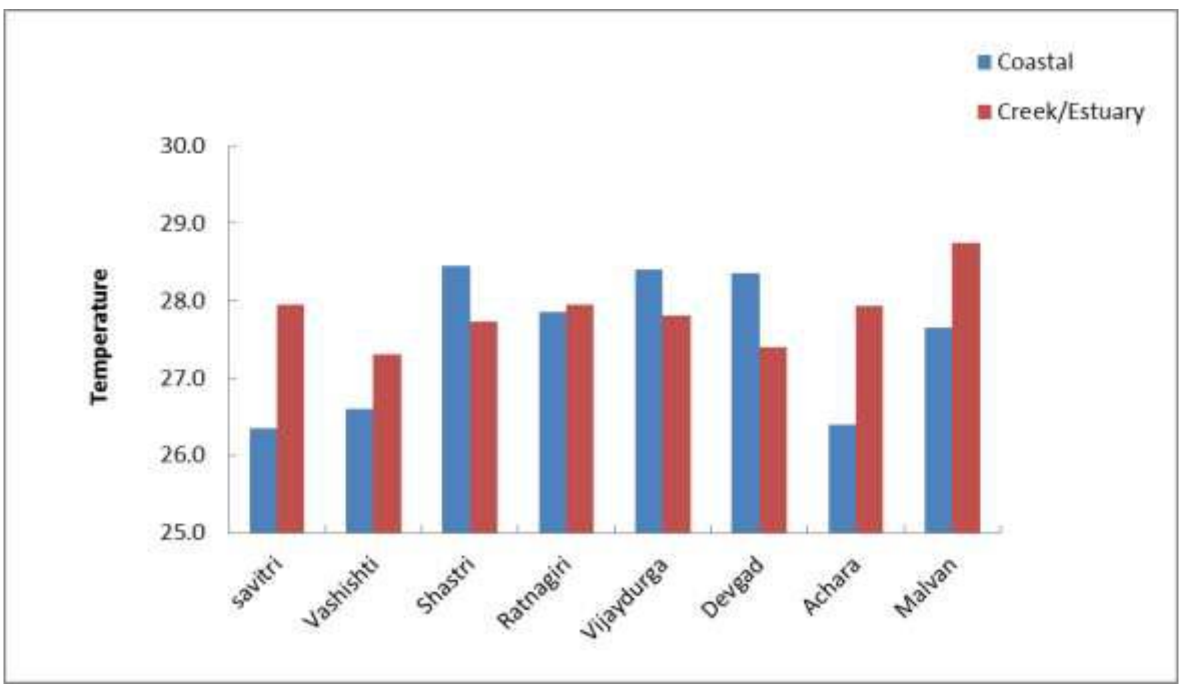


Figure 5.1.2: Water temperature along South Maharashtra coast.

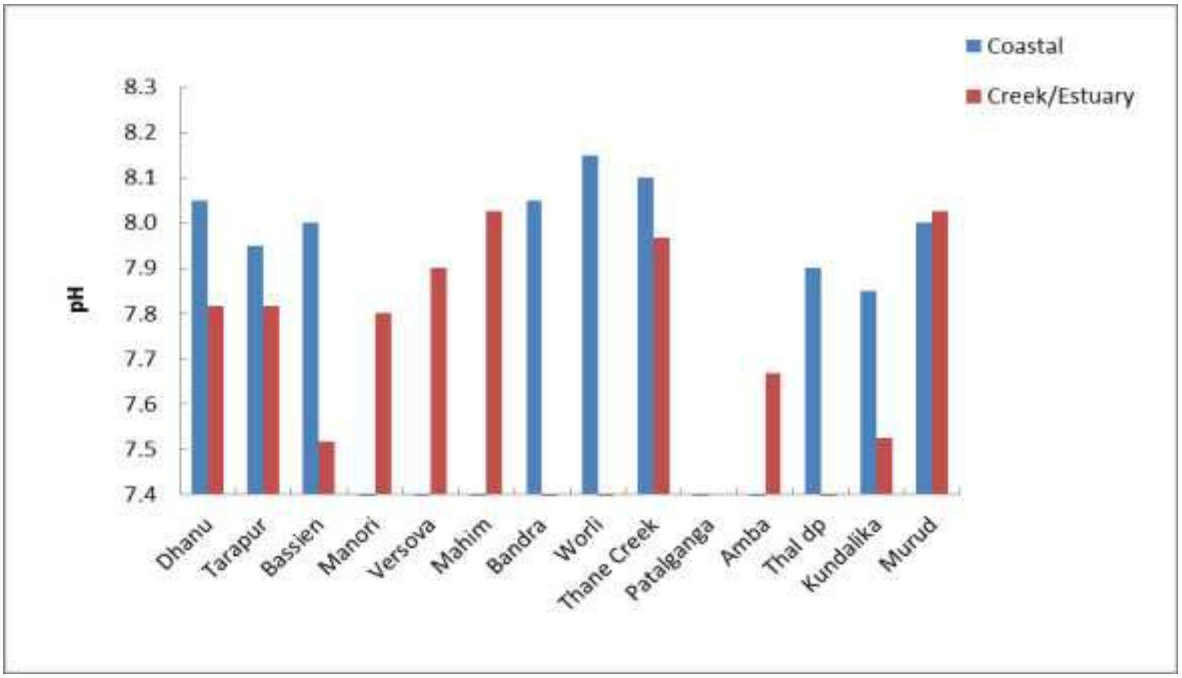


Figure 5.1.3: pH along North Maharashtra coast.

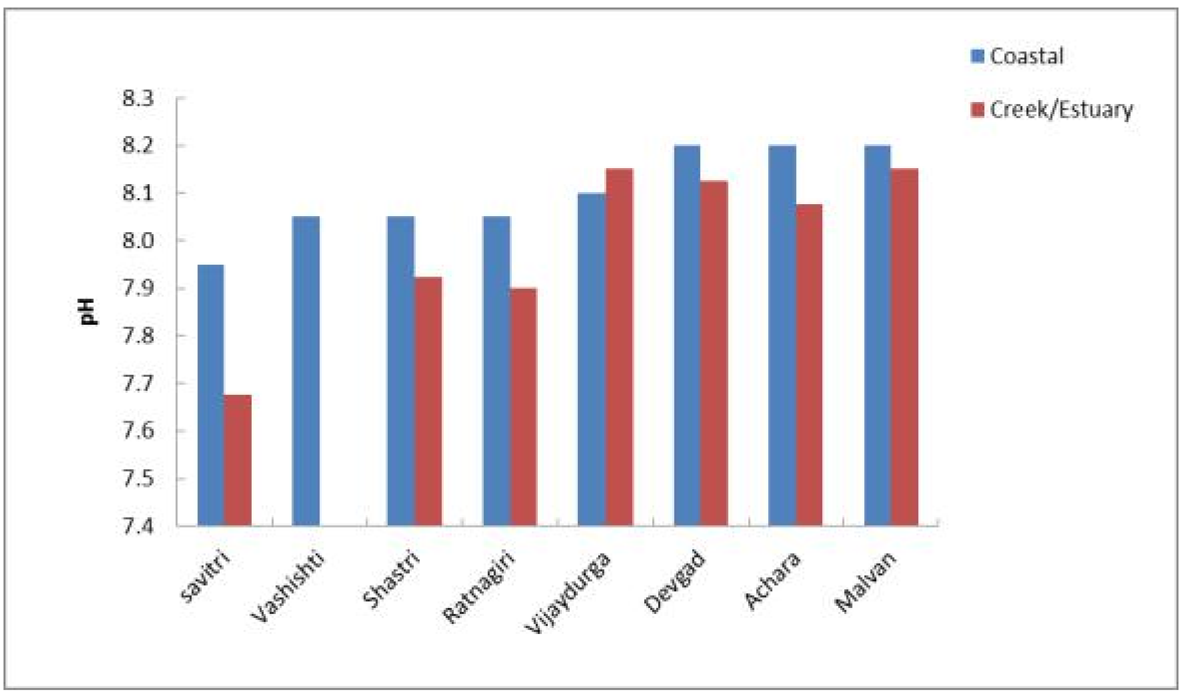


Figure 5.1.4: pH along South Maharashtra coast.

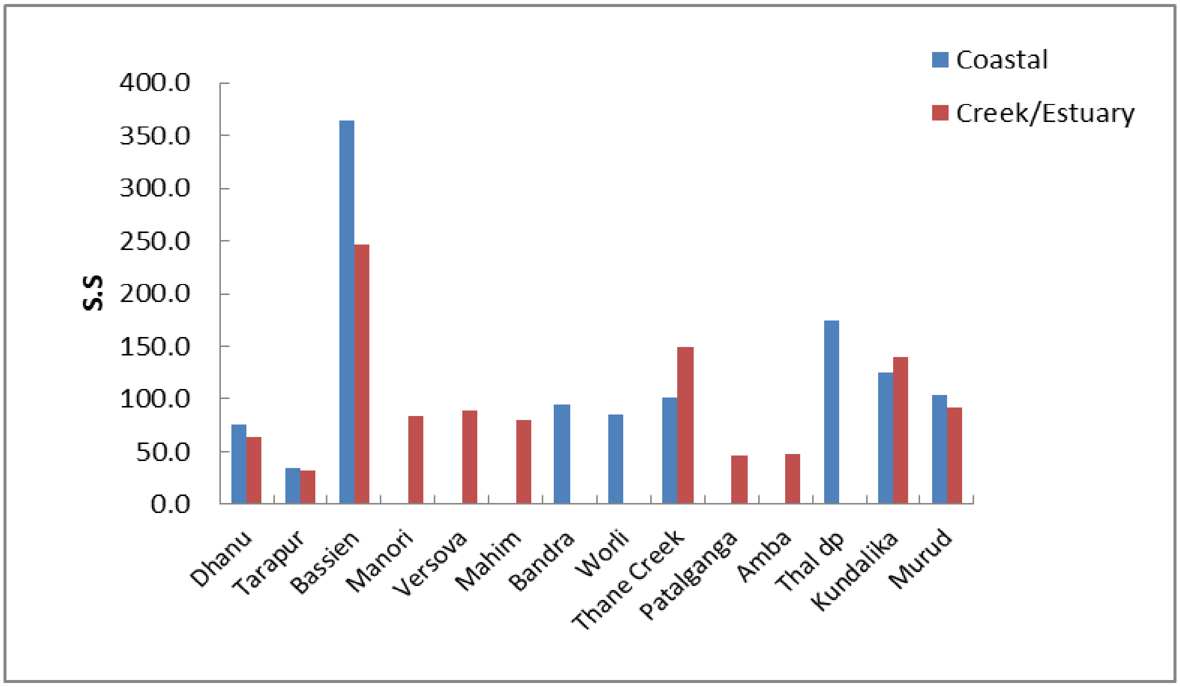


Figure 5.1.5: Suspended Solids along North Maharashtra coast.

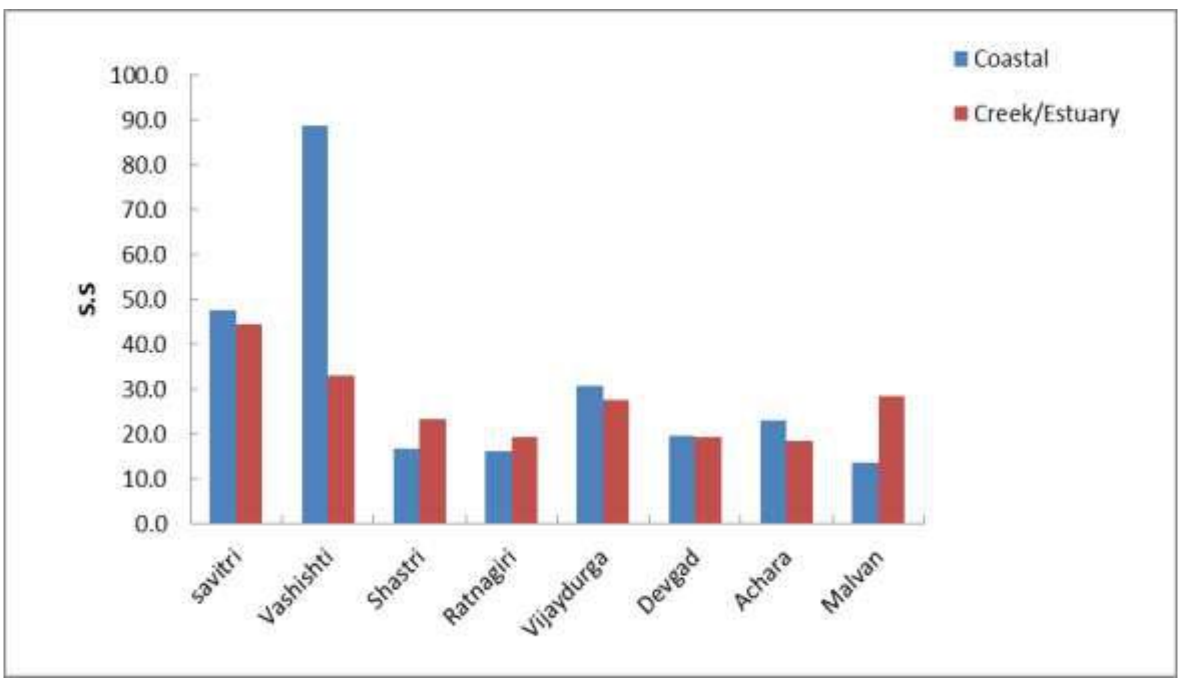


Figure 5.1.6: Suspended Solids along South Maharashtra coast.

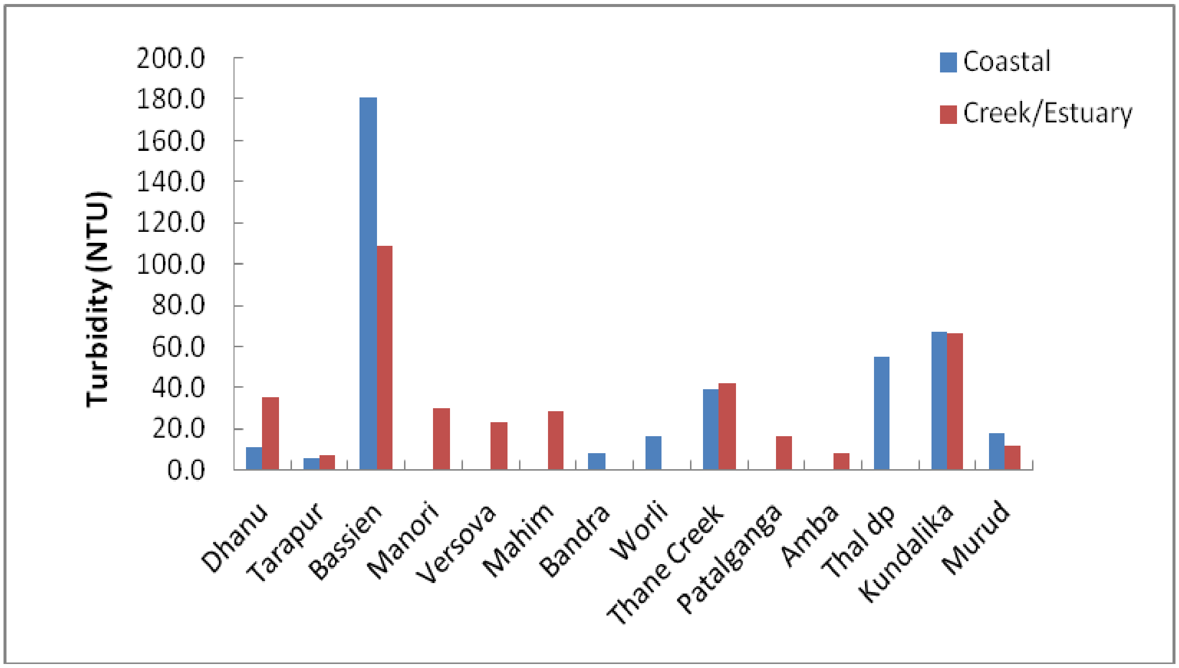


Figure 5.1.7: Turbidity along North Maharashtra coast.

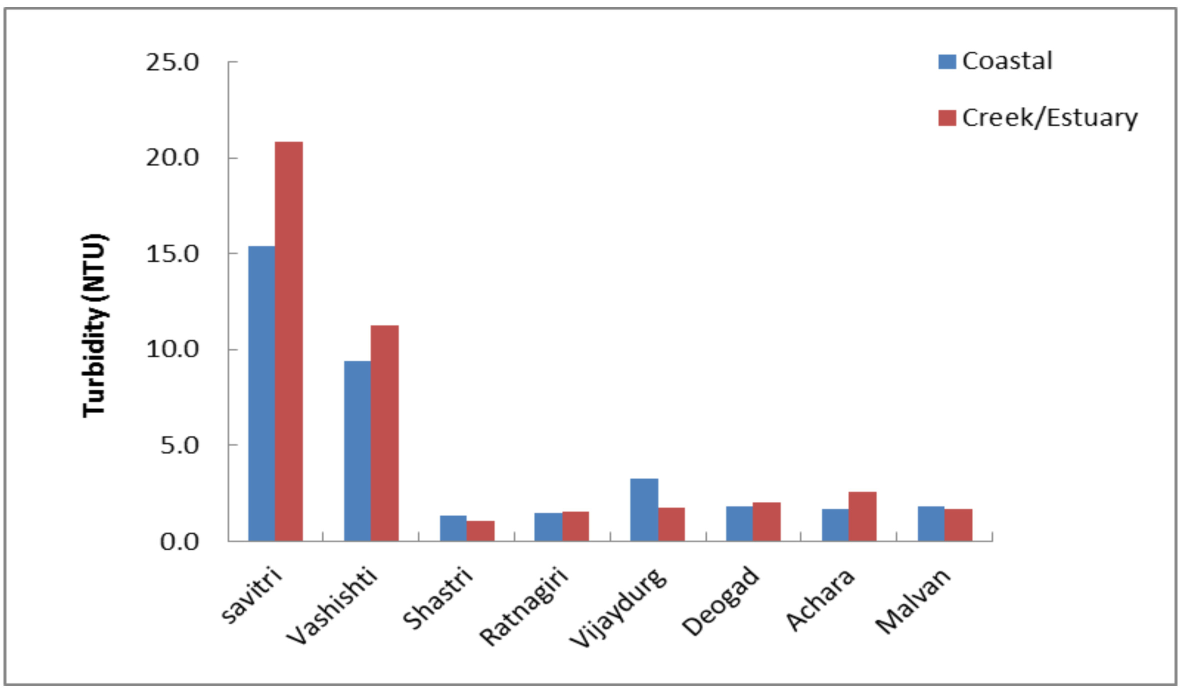


Figure 5.1.8: Turbidity along South Maharashtra coast.

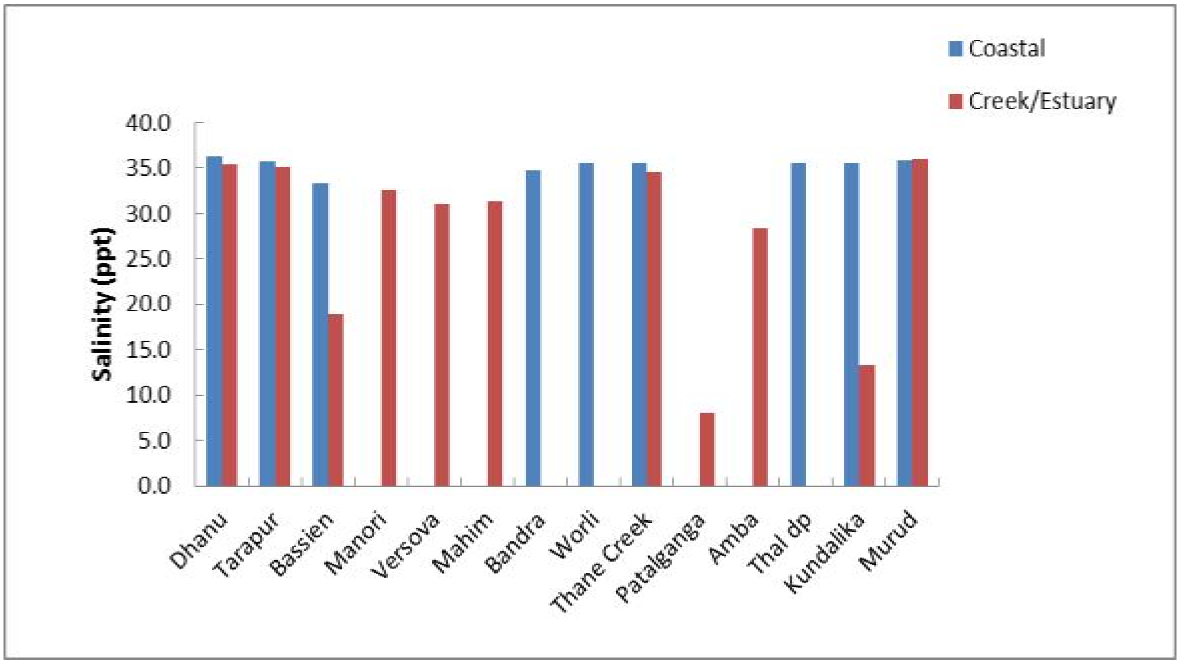


Figure 5.1.9: Salinity along North Maharashtra coast.

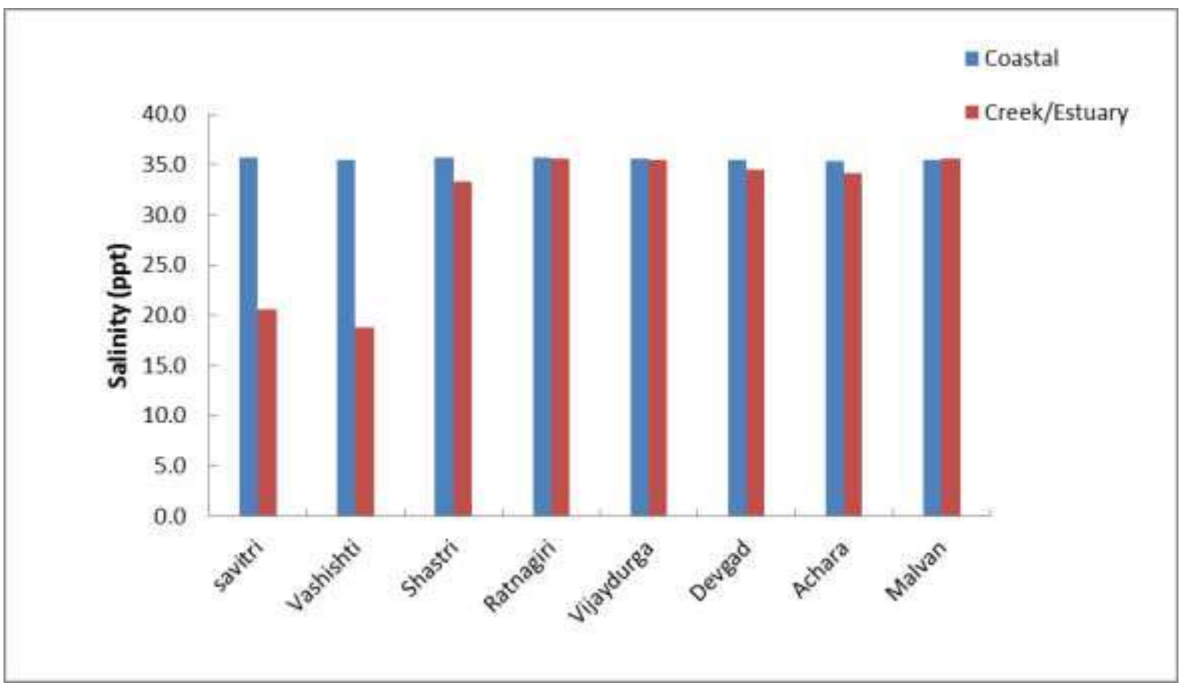


Figure 5.1.10: Salinity along South Maharashtra coast.

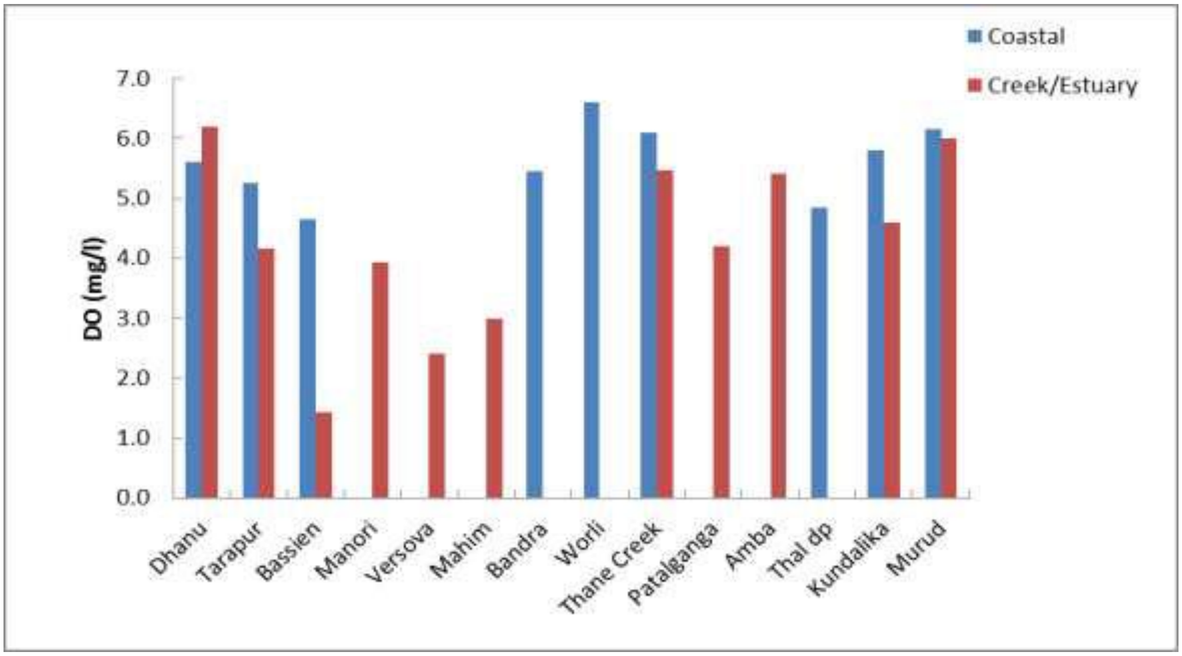


Figure 5.1.11: Dissolved Oxygen along North Maharashtra coast.

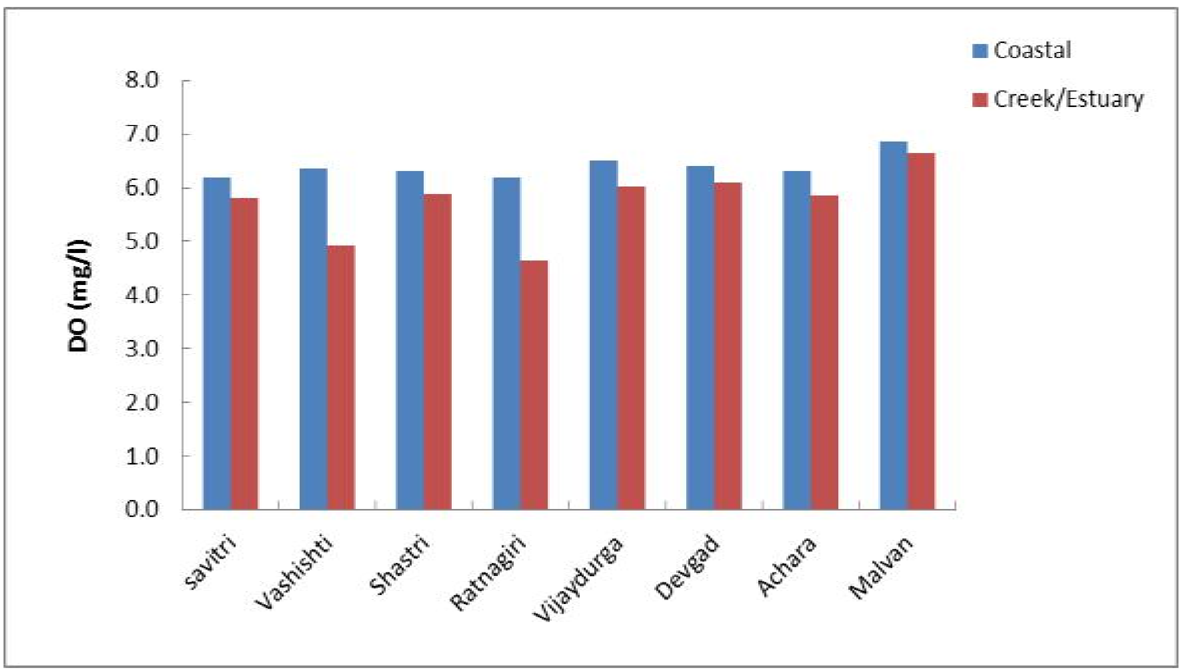


Figure 5.1.12: Dissolved Oxygen along South Maharashtra coast.

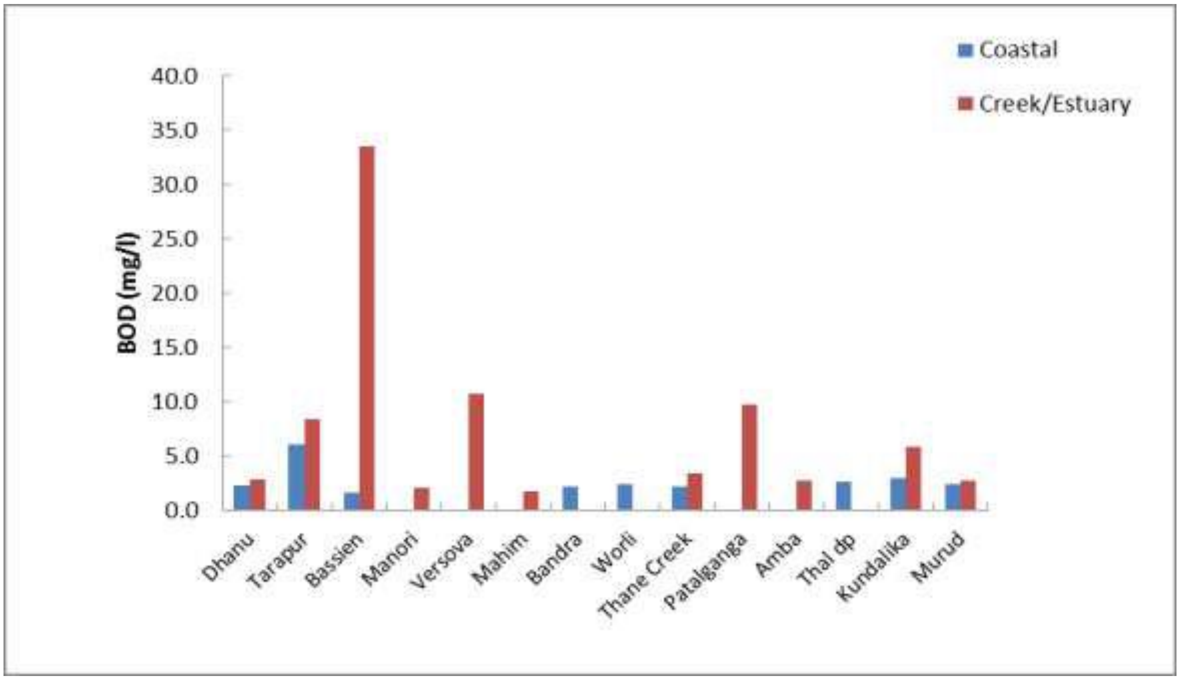


Figure 5.1.13: Biochemical Oxygen Demand along North Maharashtra coast.

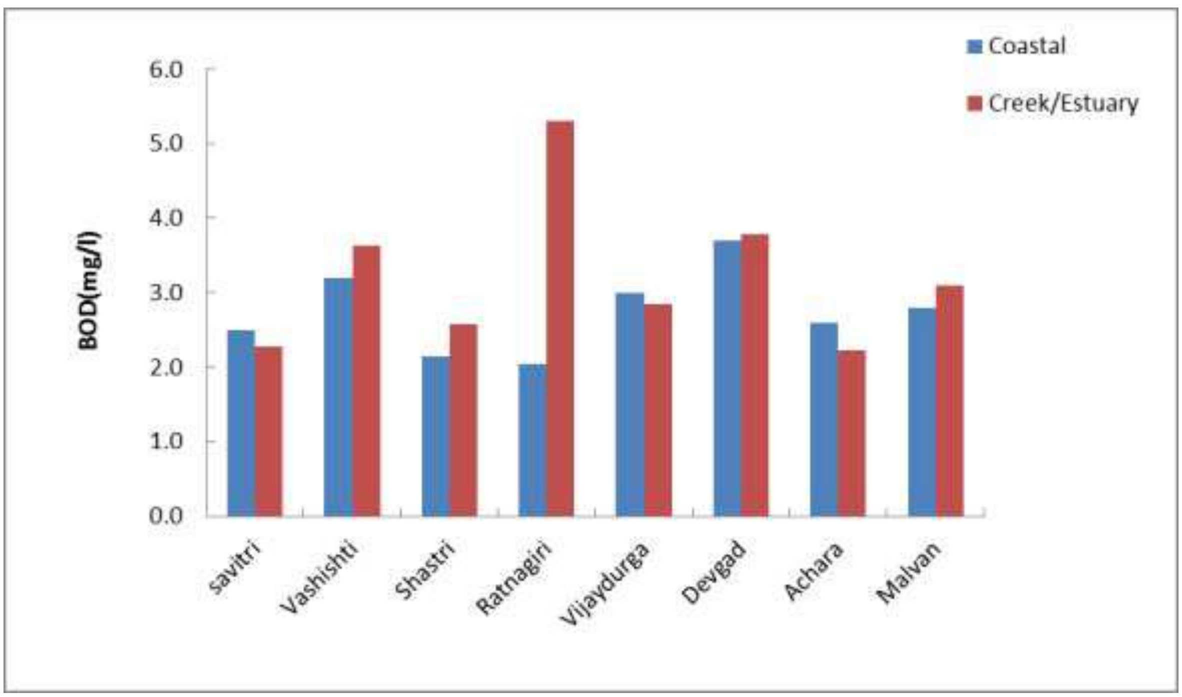


Figure 5.1.14: Biochemical Oxygen Demand along South Maharashtra coast.

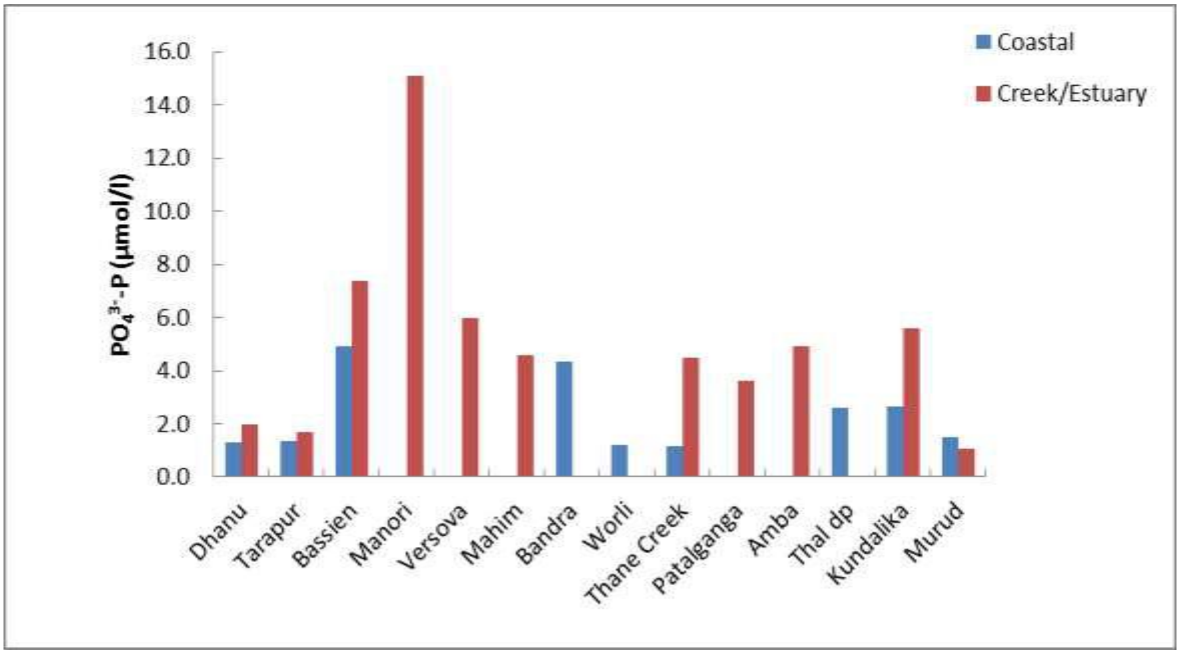


Figure 5.1.15: Phosphate phosphorus along North Maharashtra coast.

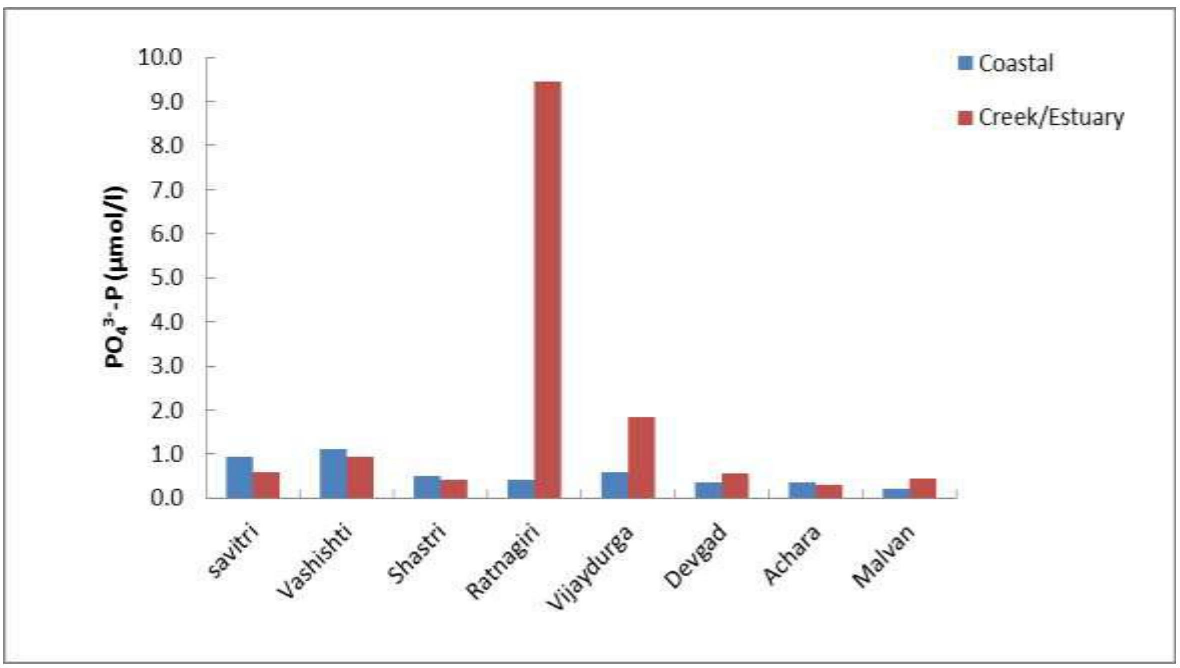


Figure 5.1.16: Phosphate phosphorus along South Maharashtra coast.

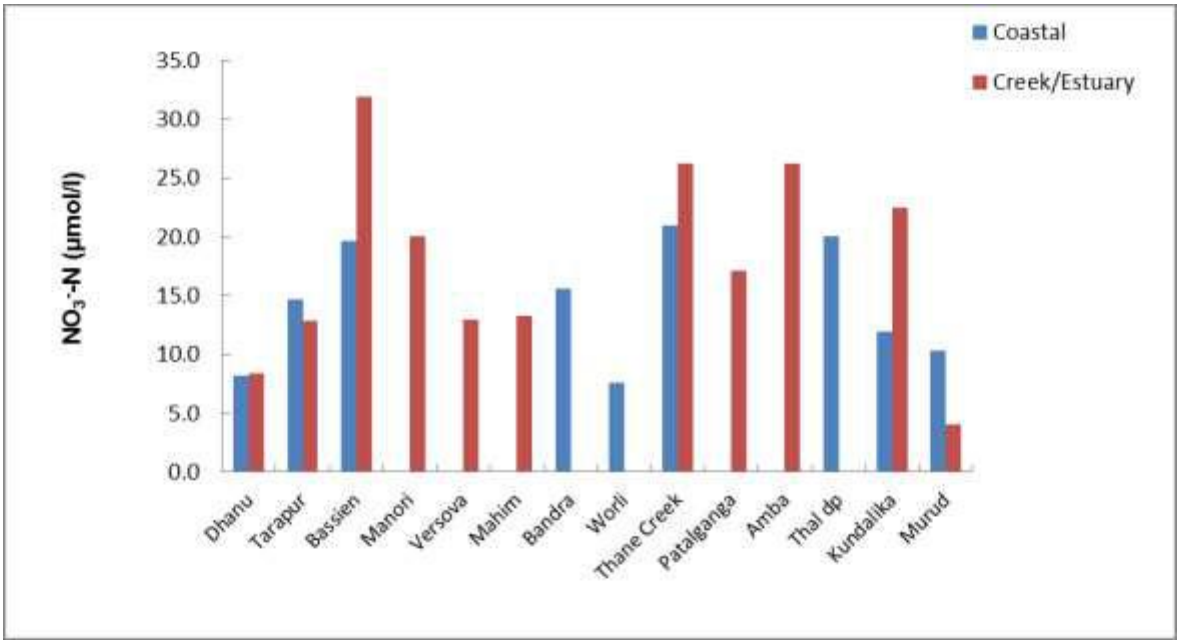


Figure 5.1.17: Nitrate Nitrogen along North Maharashtra coast.

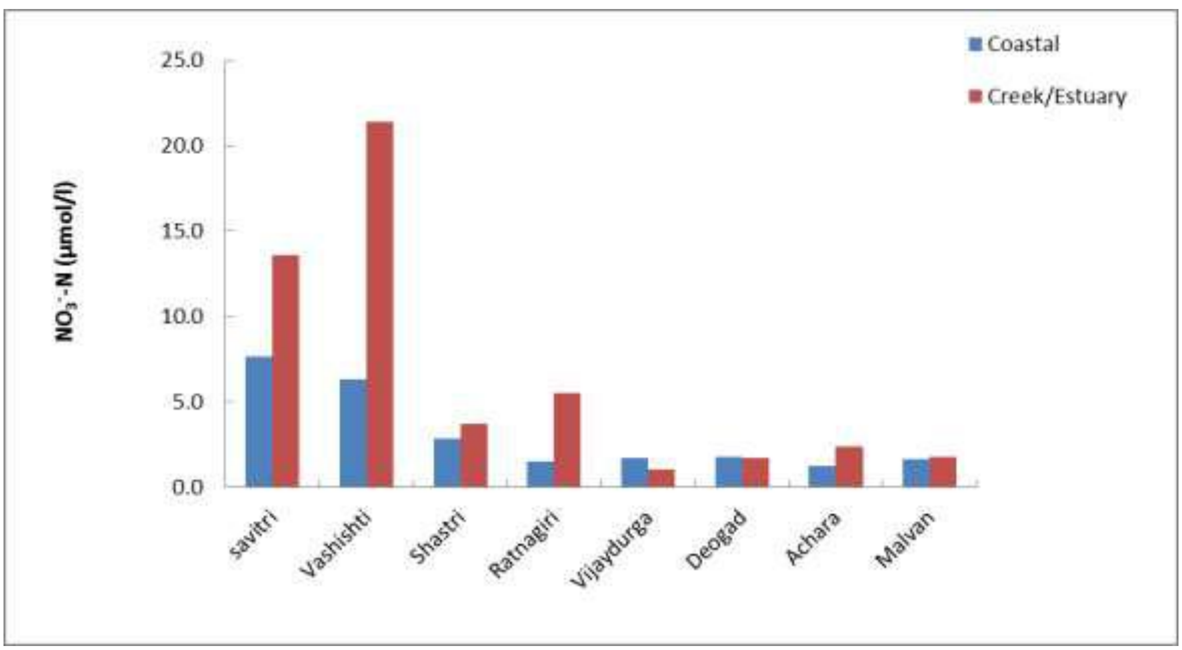


Figure 5.1.18: Nitrate Nitrogen along South Maharashtra coast.

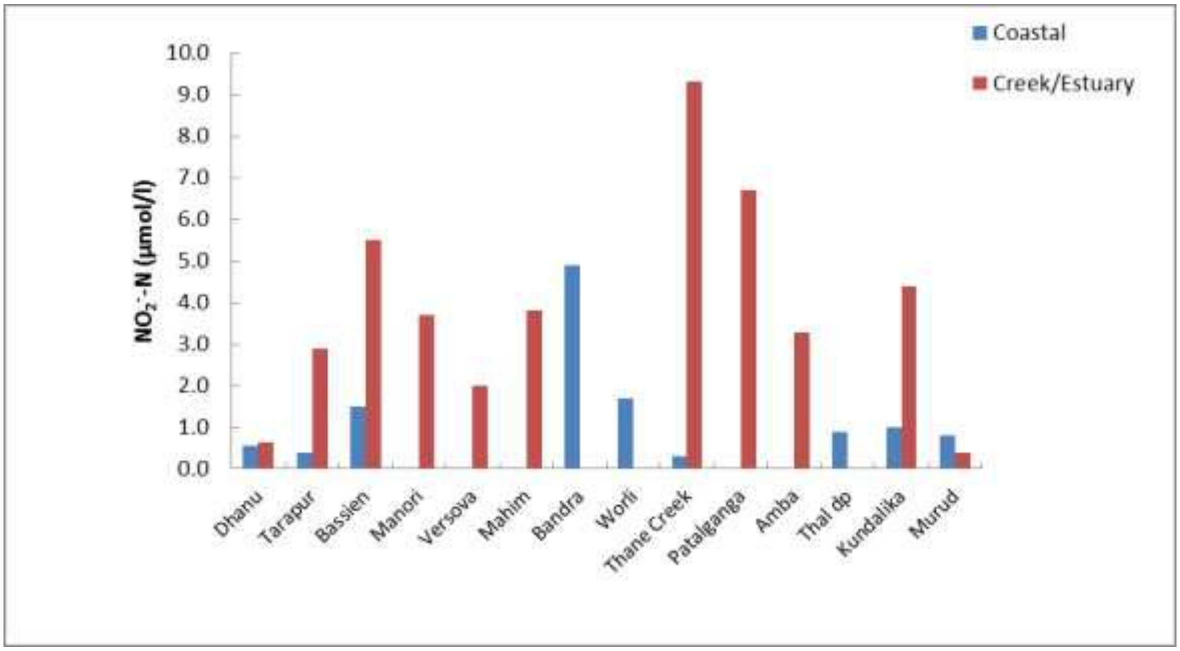


Figure 5.1.19: Nitrite Nitrogen along North Maharashtra coast.

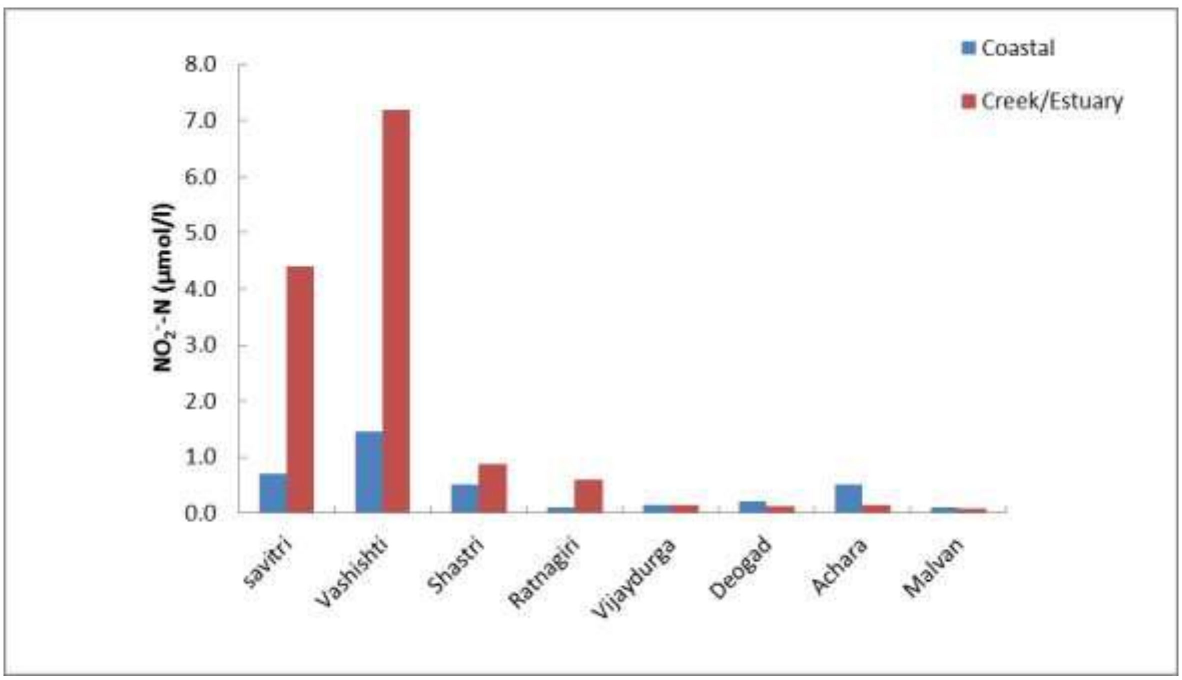


Figure 5.1.20: Nitrite Nitrogen along South Maharashtra coast.

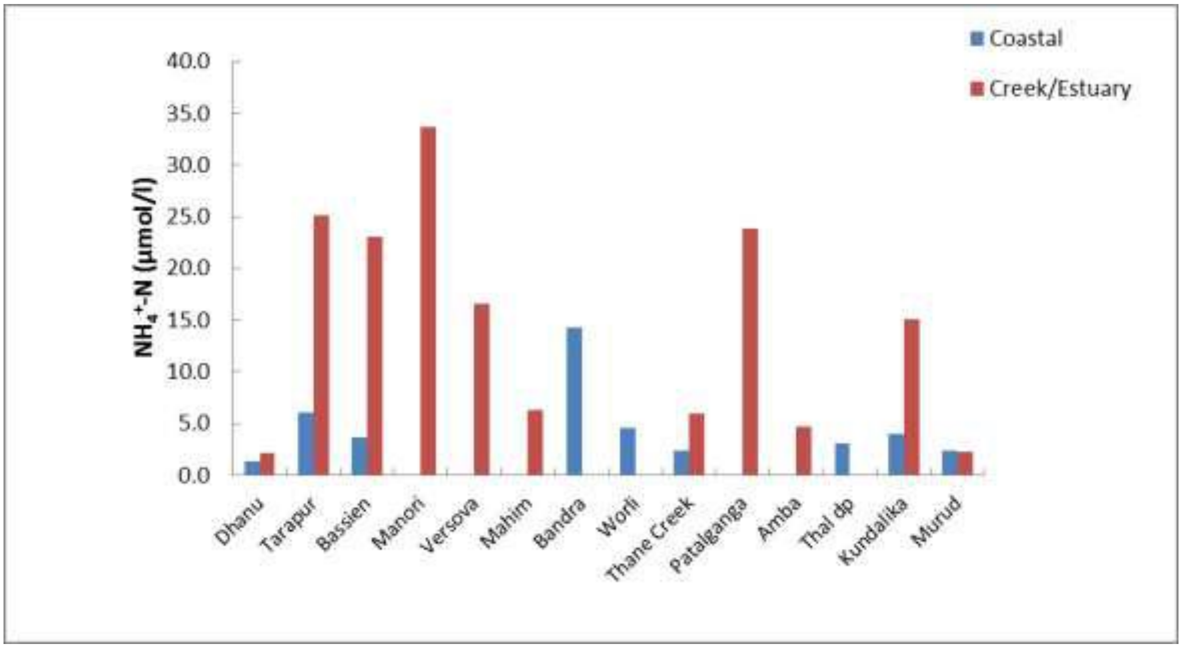


Figure 5.1.21: Ammonical Nitrogen along North Maharashtra coast.

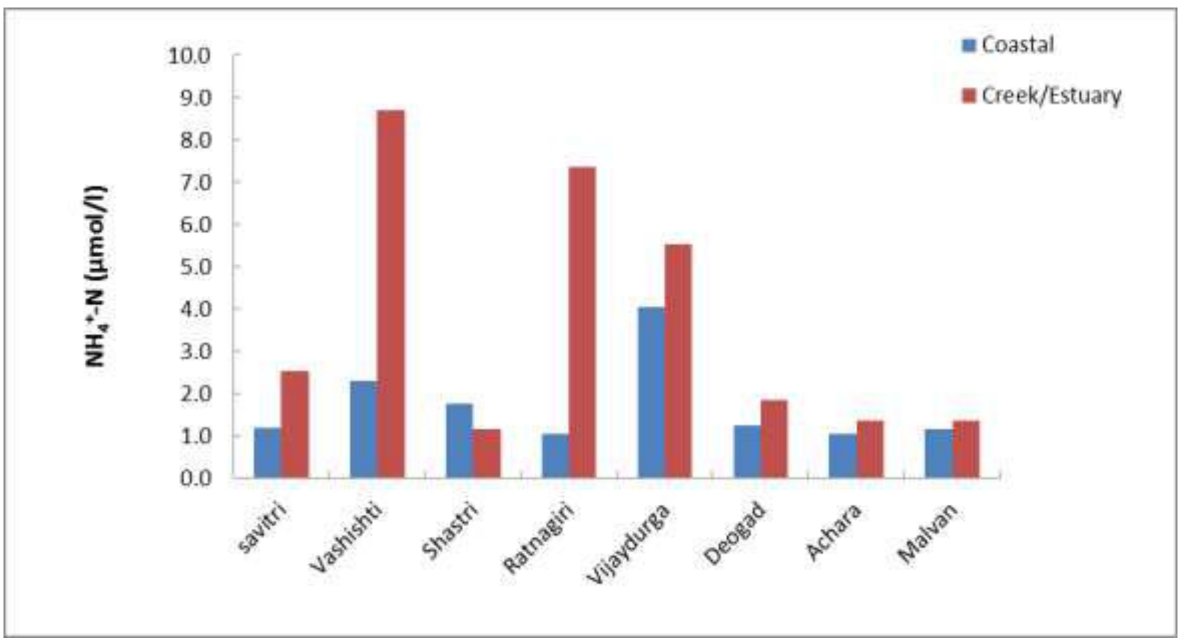


Figure 5.1.22: Ammonical Nitrogen along South Maharashtra coast.

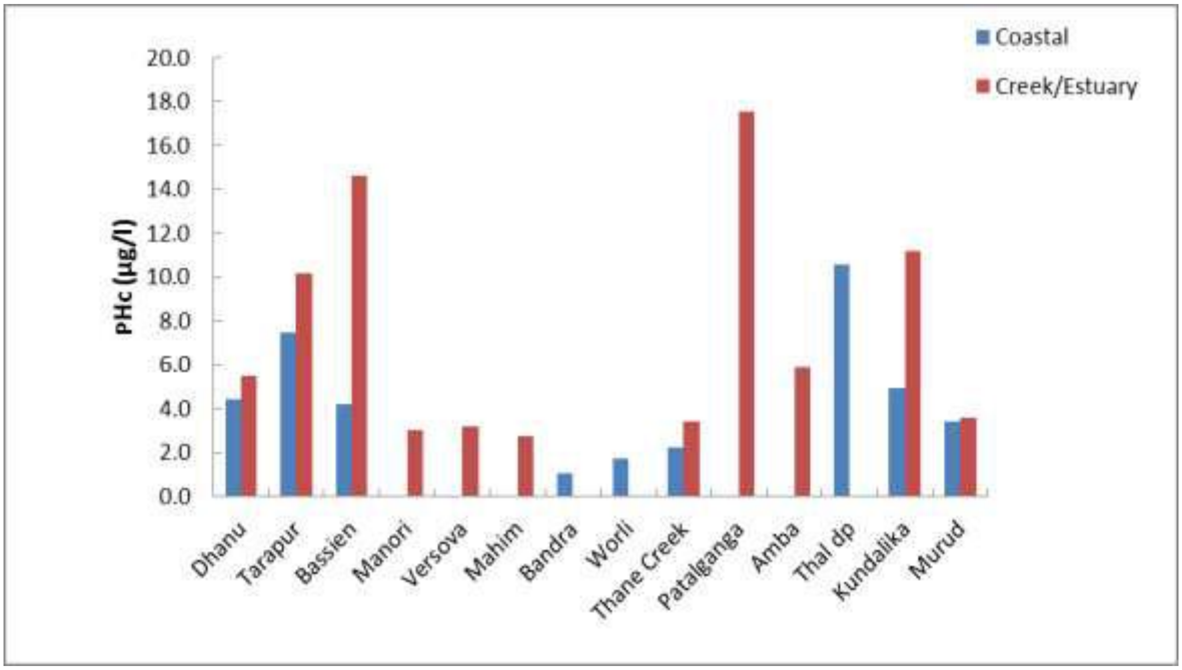


Figure 5.1.23: Petroleum hydrocarbon along North Maharashtra coast.

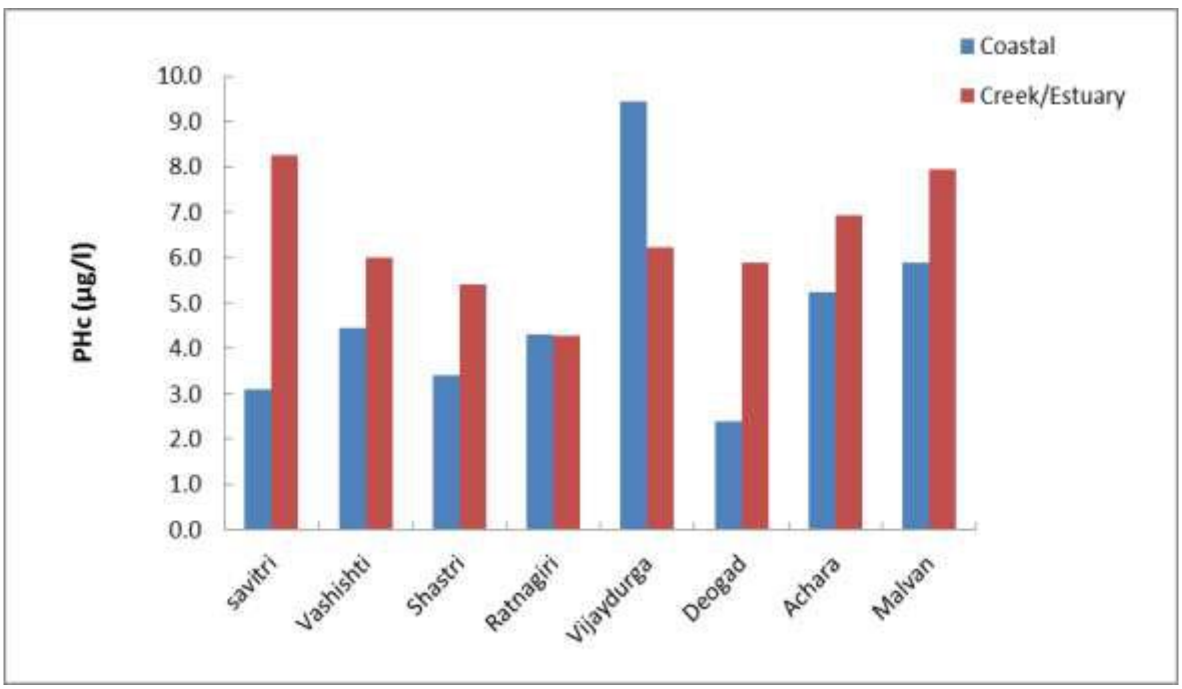


Figure 5.1.24: Petroleum hydrocarbon along South Maharashtra coast.

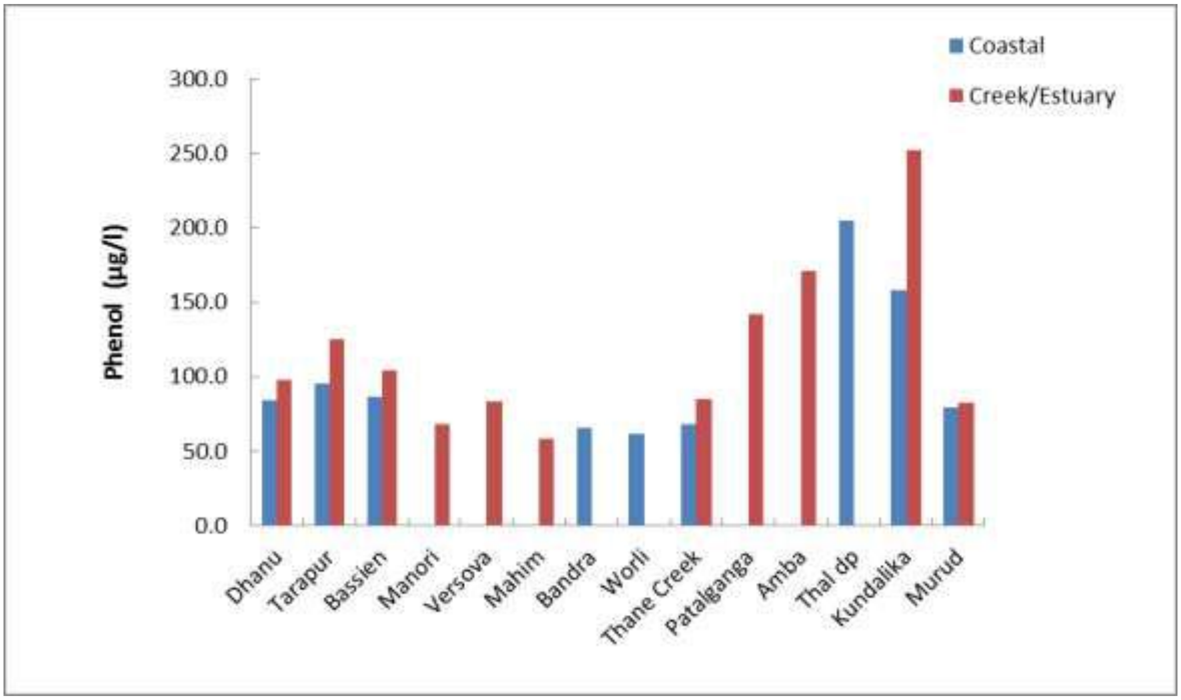


Figure 5.1.25: Phenol along North Maharashtra coast.

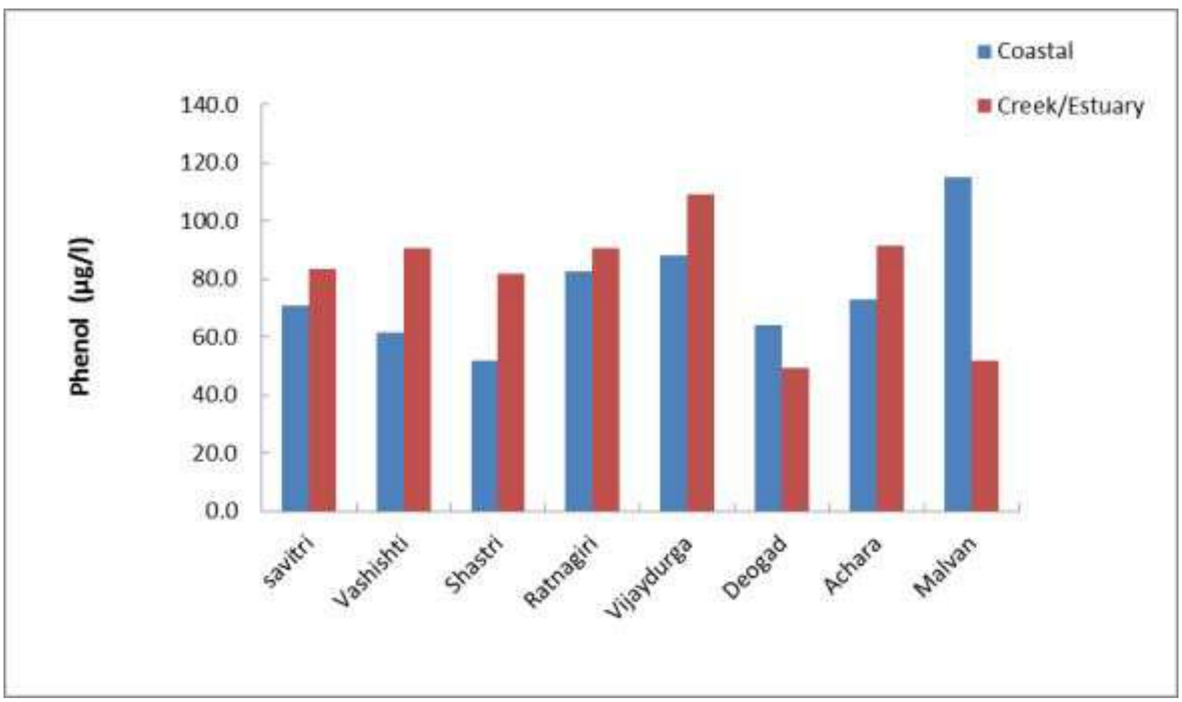


Figure 5.1.26: Phenol along Souh Maharashtra coast.

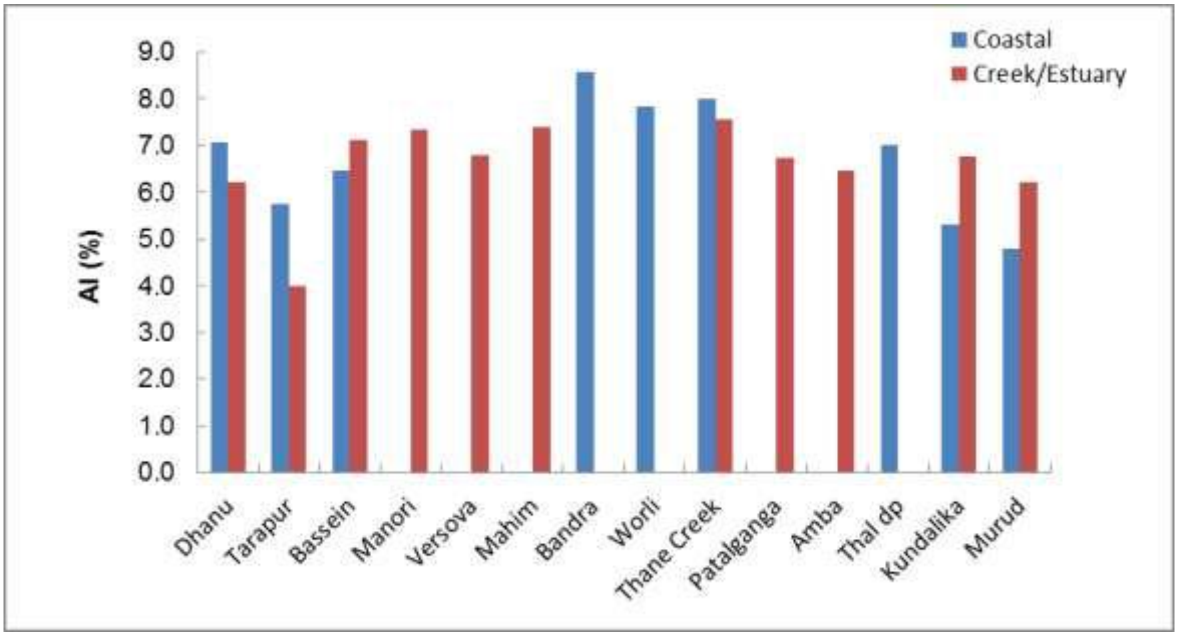


Figure 5.1.27: Aluminium in surface sediment along North Maharashtra Coast.

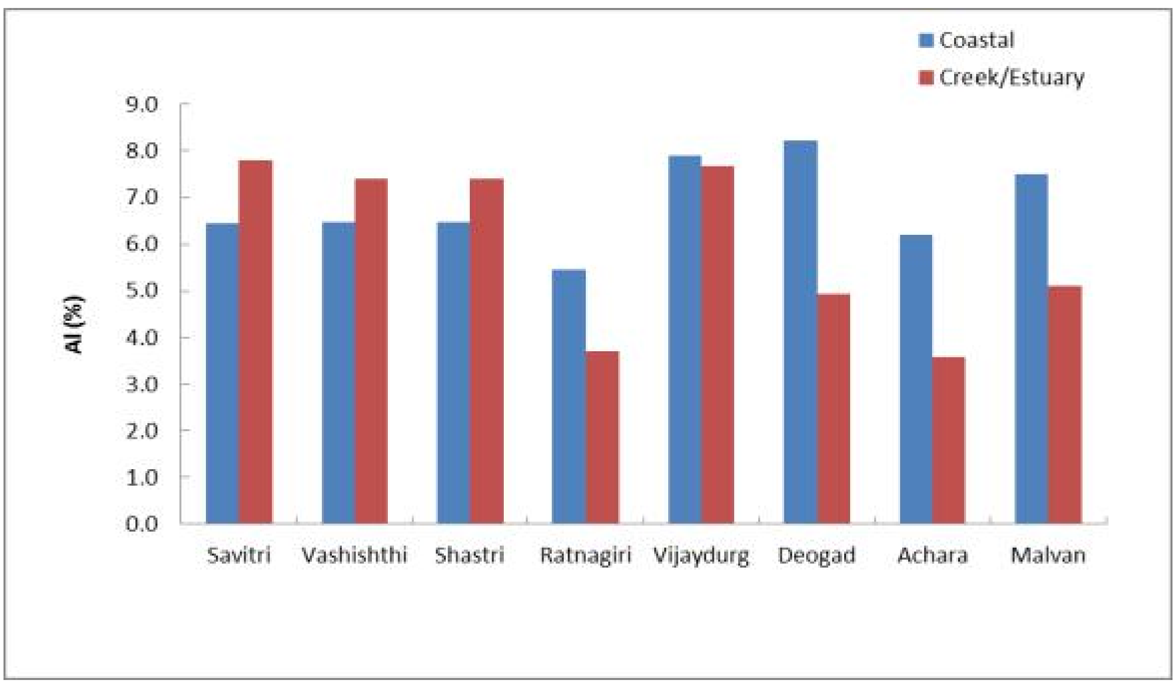


Figure 5.1.28: Aluminium in surface sediment along South Maharashtra Coast.

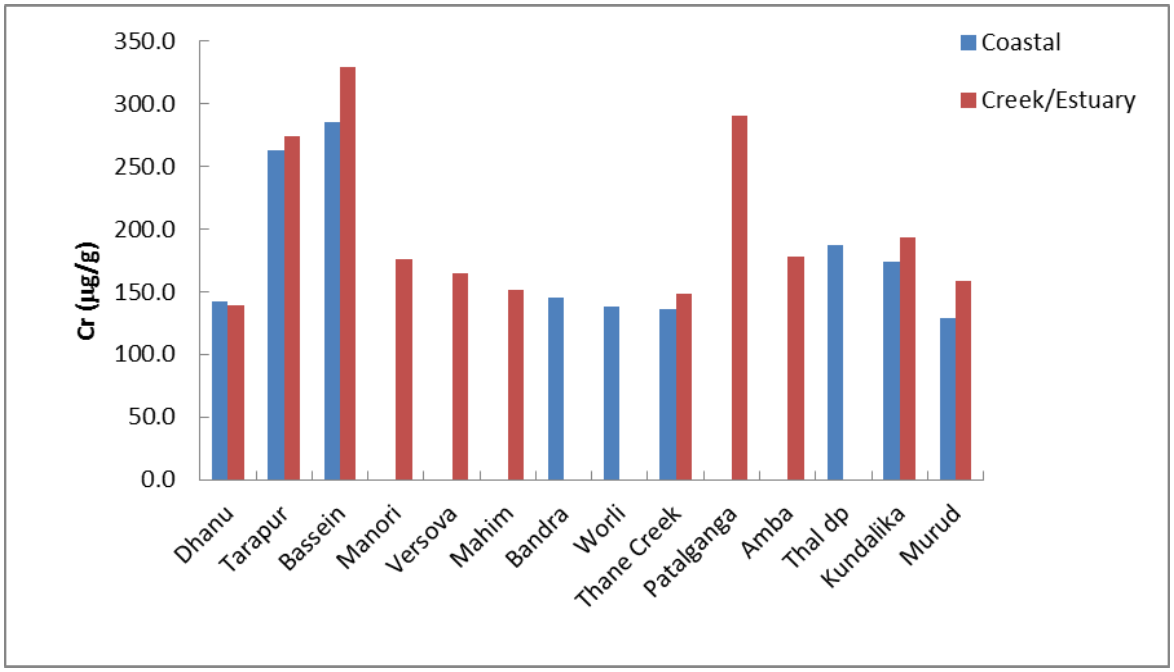


Figure 5.1.29: Chromium in surface sediment along North Maharashtra Coast.

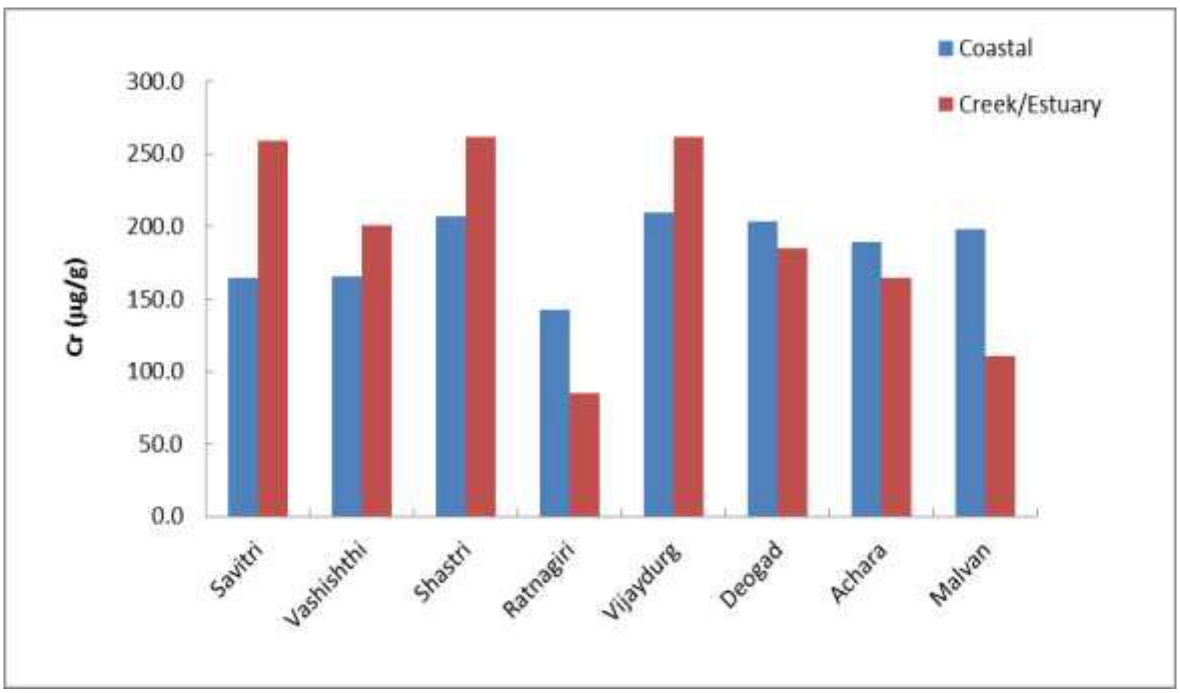


Figure 5.1.30: Chromium in surface sediment along South Maharashtra Coast.

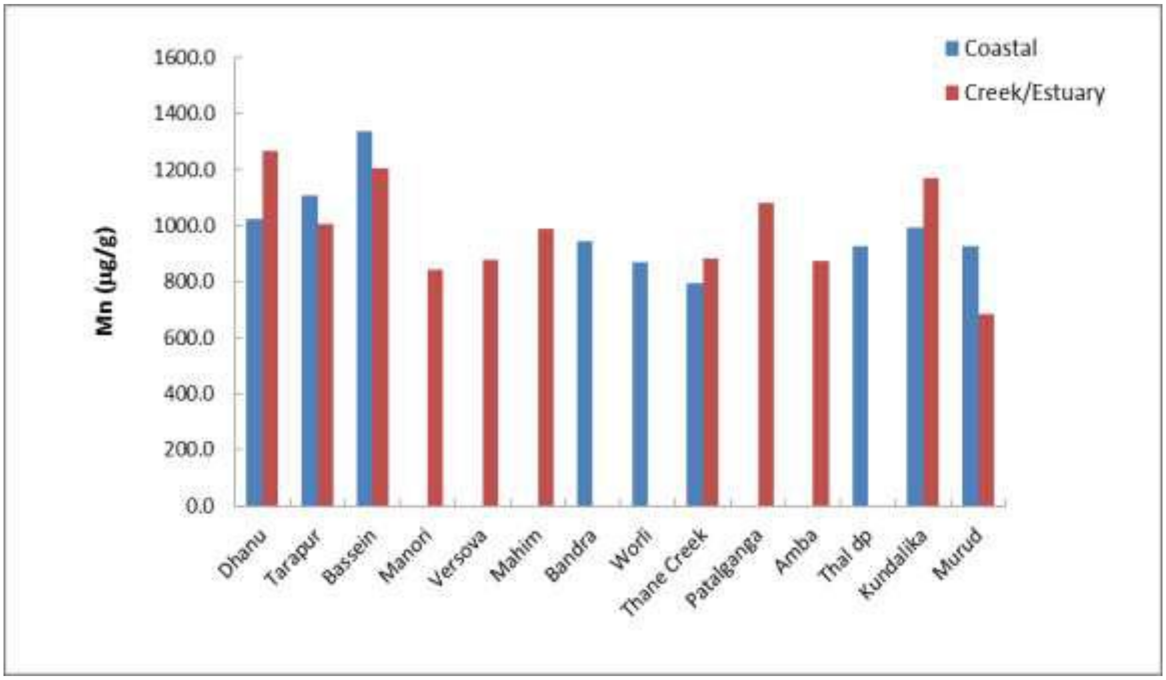


Figure 5.1.31: Manganese in surface sediment along North Maharashtra Coast.

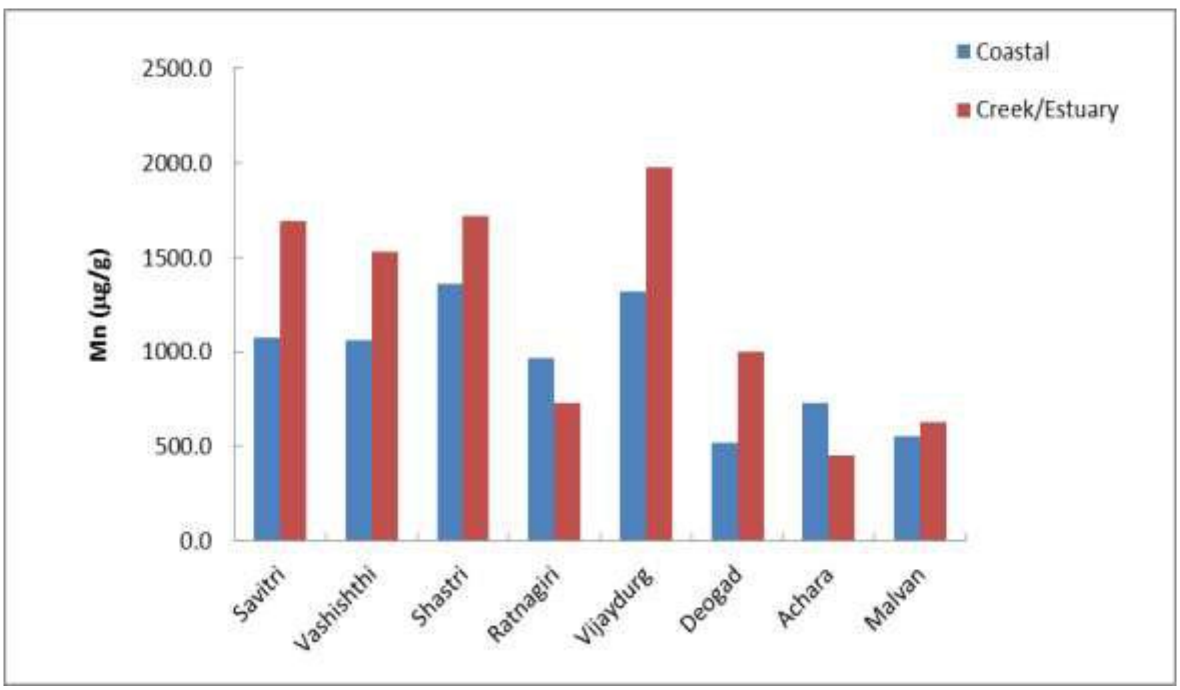


Figure 5.1.32: Manganese in surface sediment along South Maharashtra Coast.

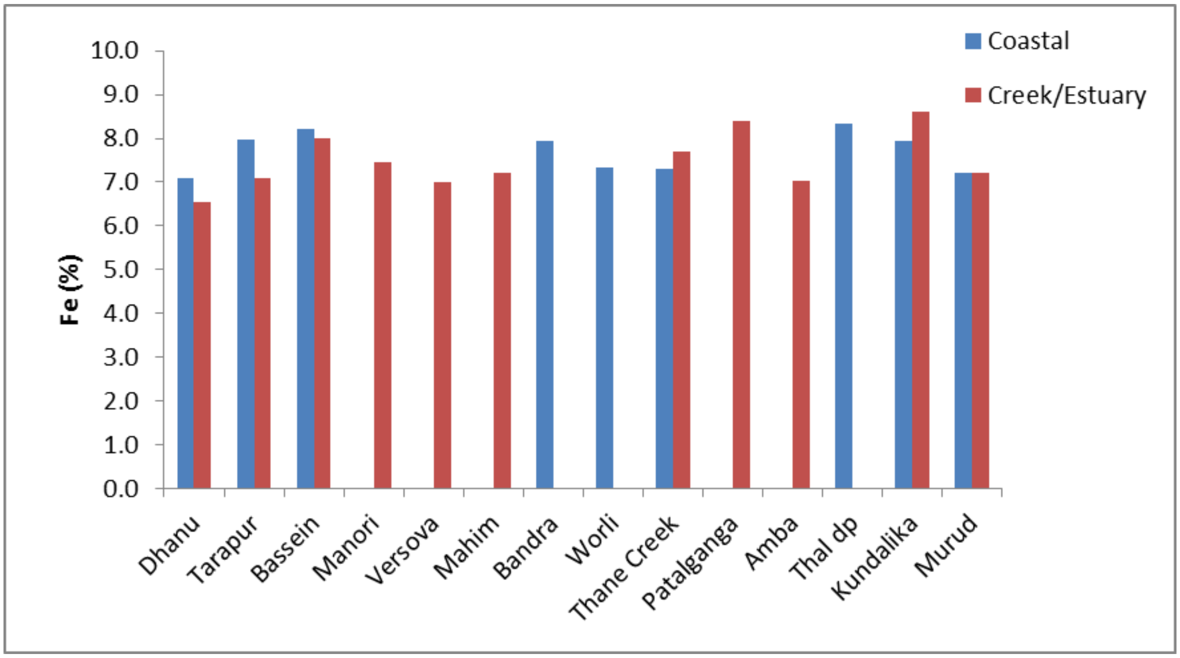


Figure 5.1.33: Iron in surface sediment along North Maharashtra Coast.

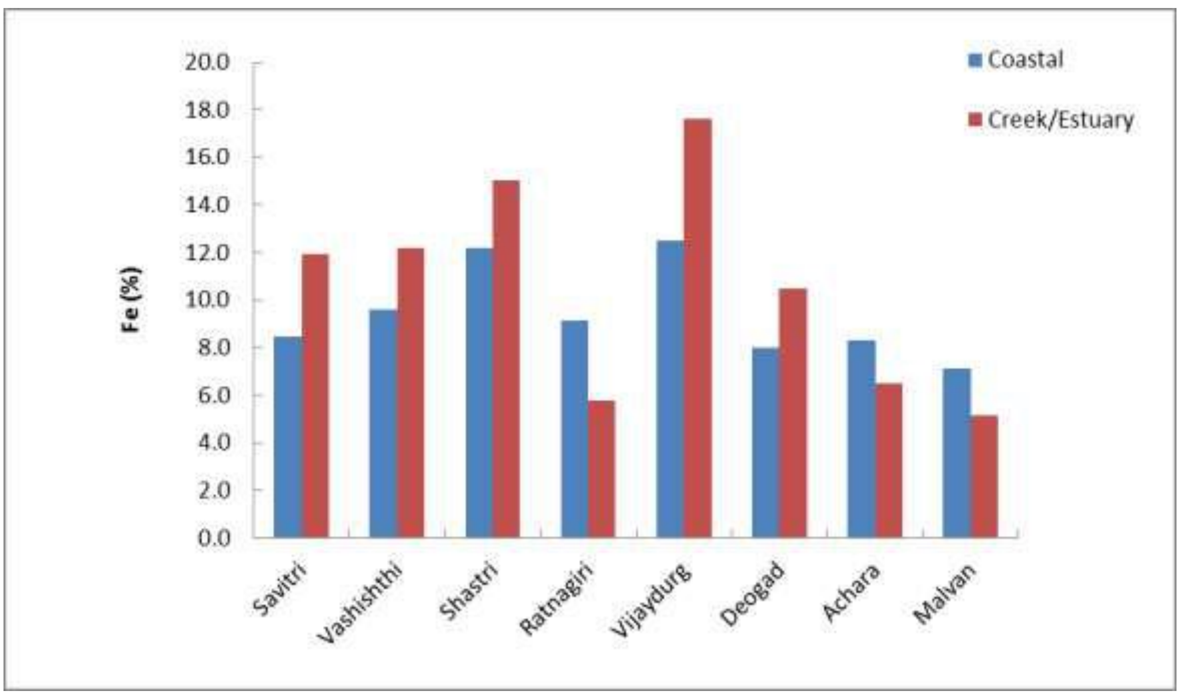


Figure 5.1.34: Iron in surface sediment along South Maharashtra Coast.

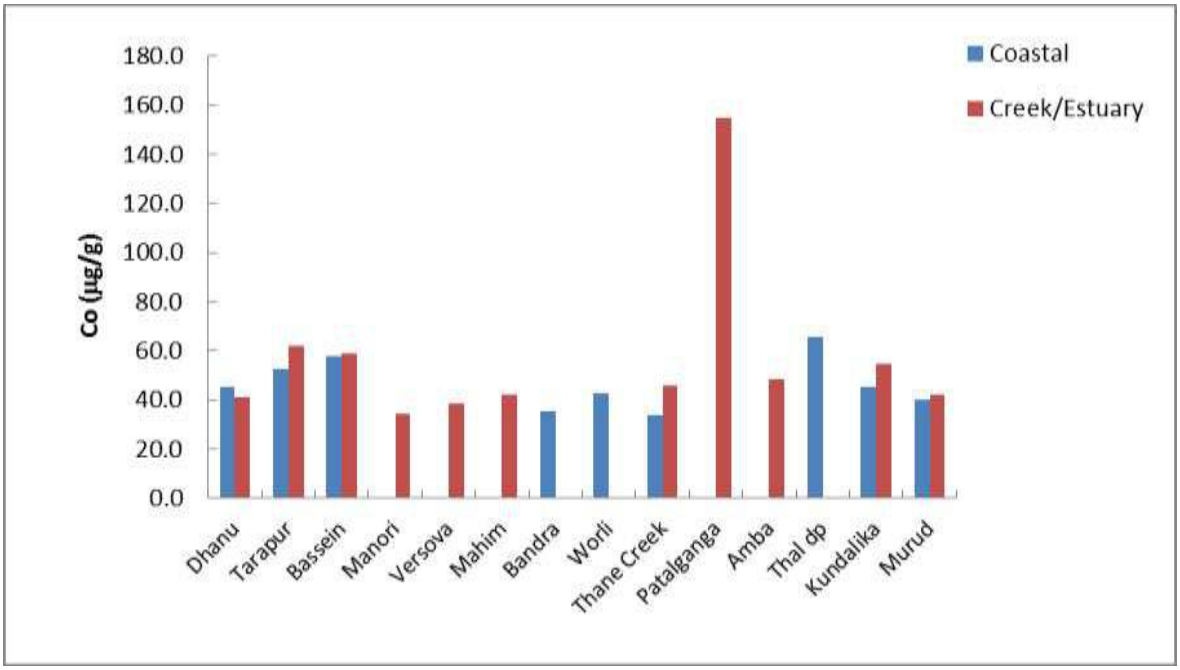


Figure 5.1.35: Cobalt in surface sediment along North Maharashtra Coast.

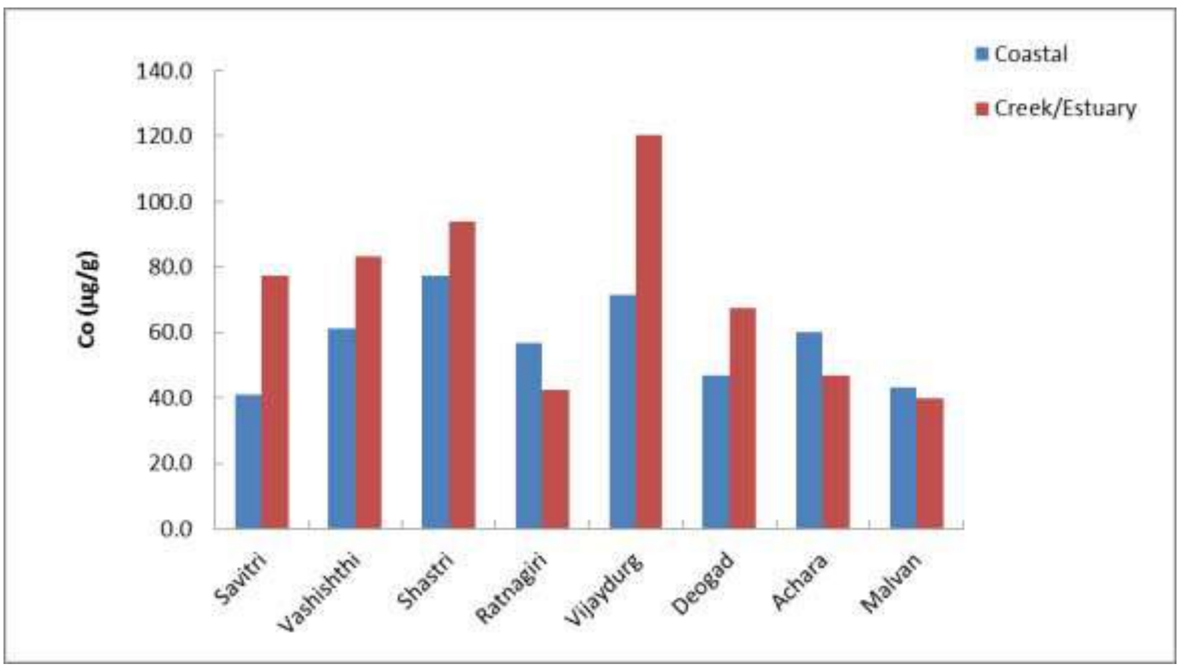


Figure 5.1.36: Cobalt in surface sediment along South Maharashtra Coast.

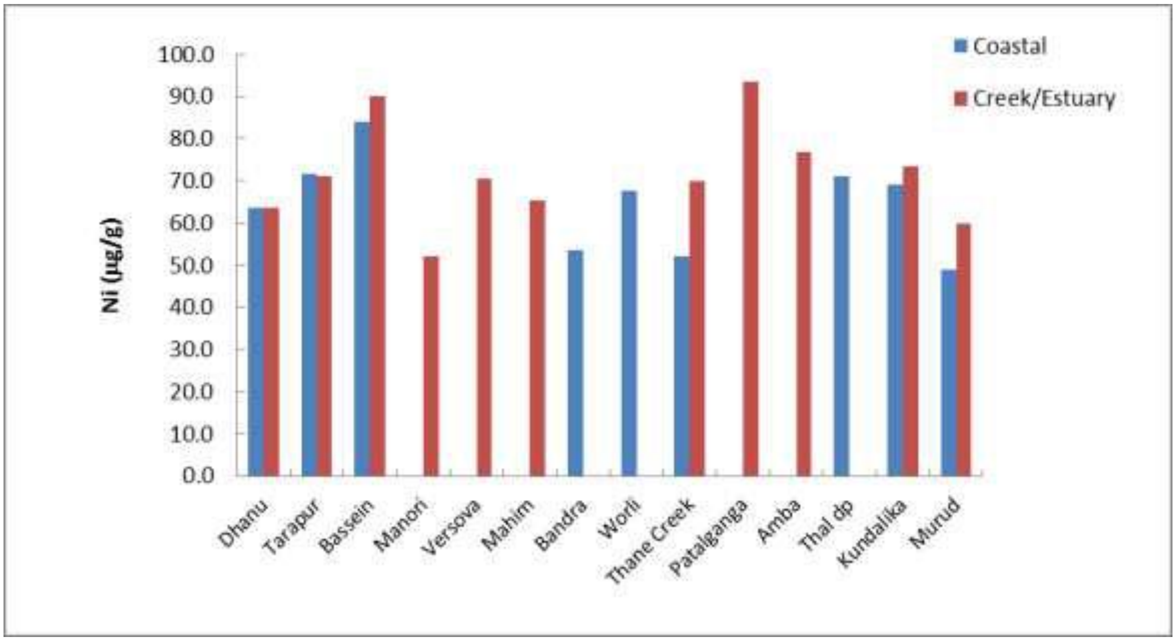


Figure 5.1.37: Nickel in surface sediment along North Maharashtra Coast.

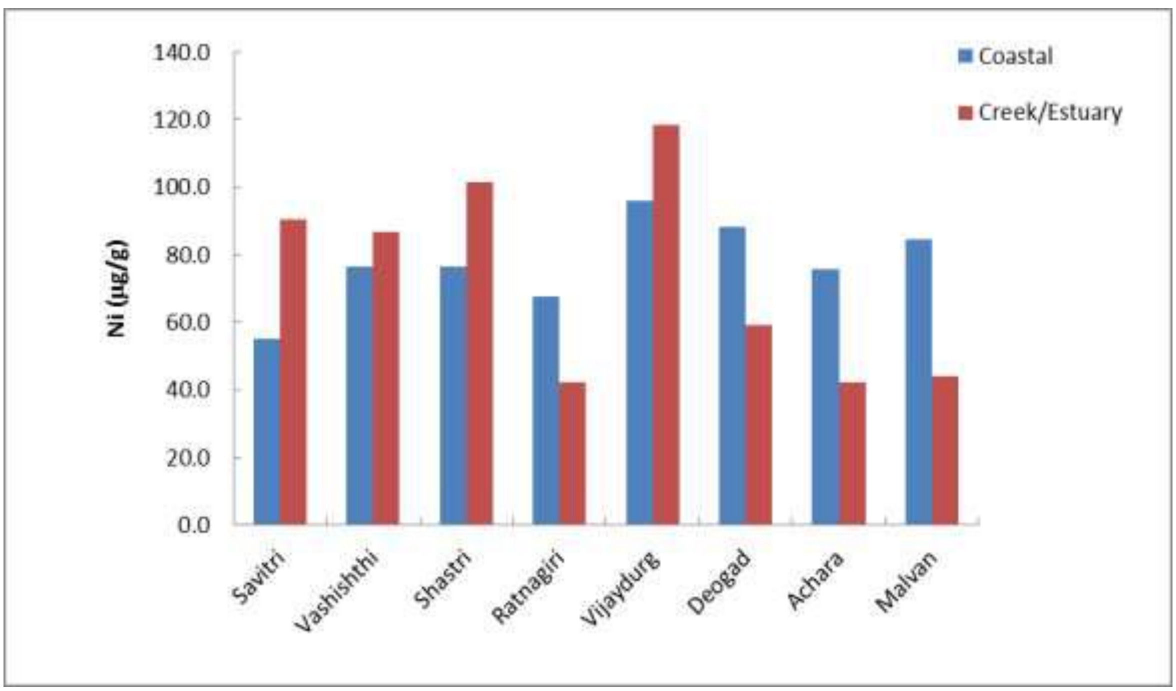


Figure 5.1.38: Nickel in surface sediment along South Maharashtra Coast.

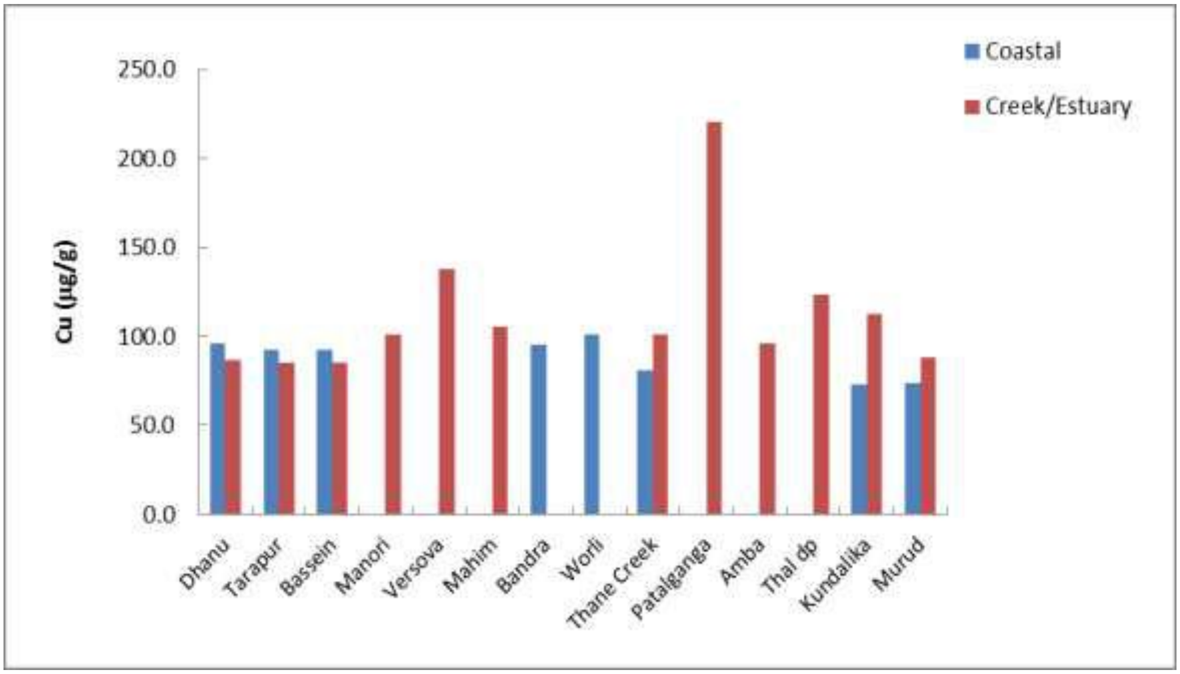


Figure 5.1.39: Copper in surface sediment along North Maharashtra Coast.

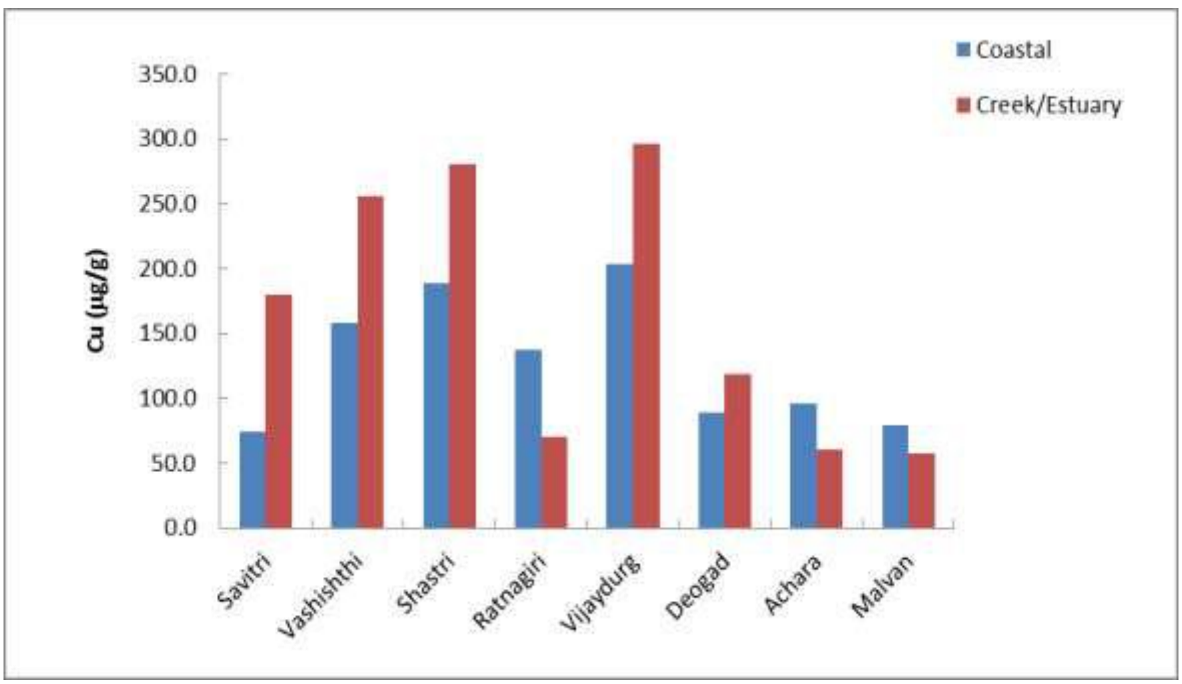


Figure 5.1.40: Copper in surface sediment along South Maharashtra Coast.

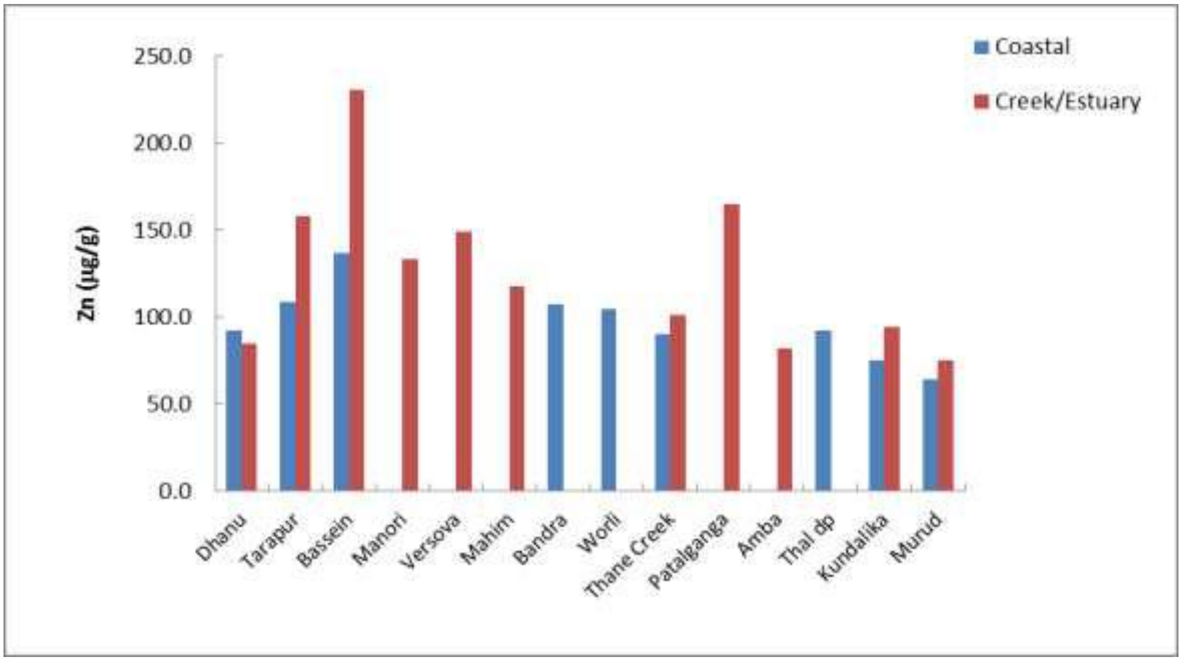


Figure 5.1.41: Zinc in surface sediment along North Maharashtra Coast.

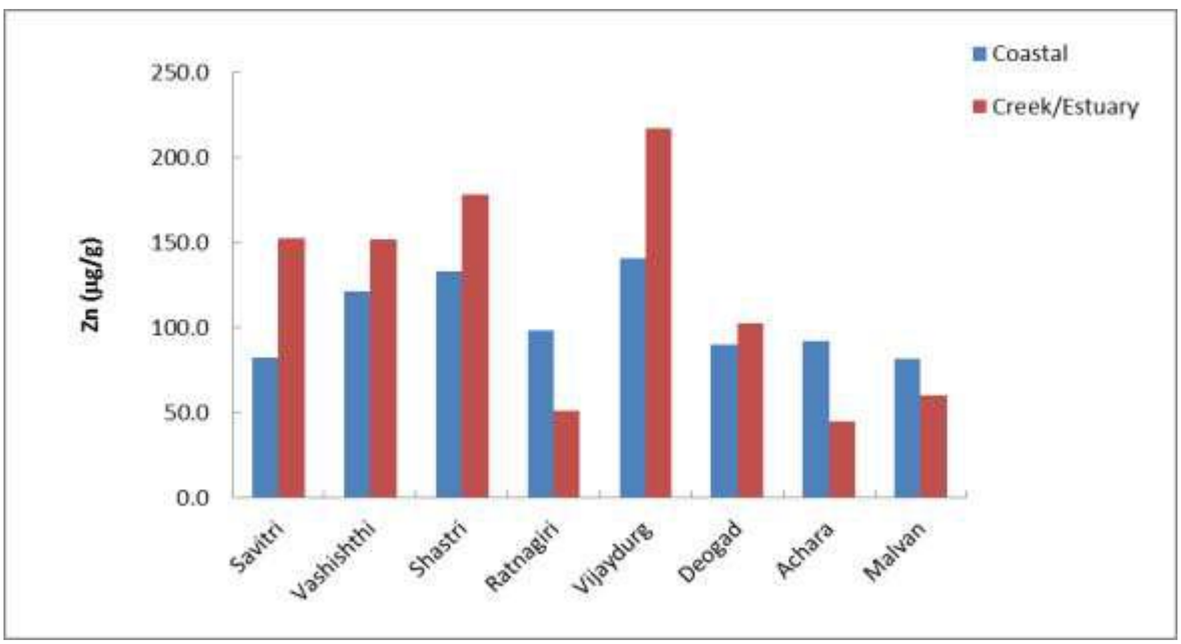


Figure 5.1.42: Zinc in surface sediment along South Maharashtra Coast.

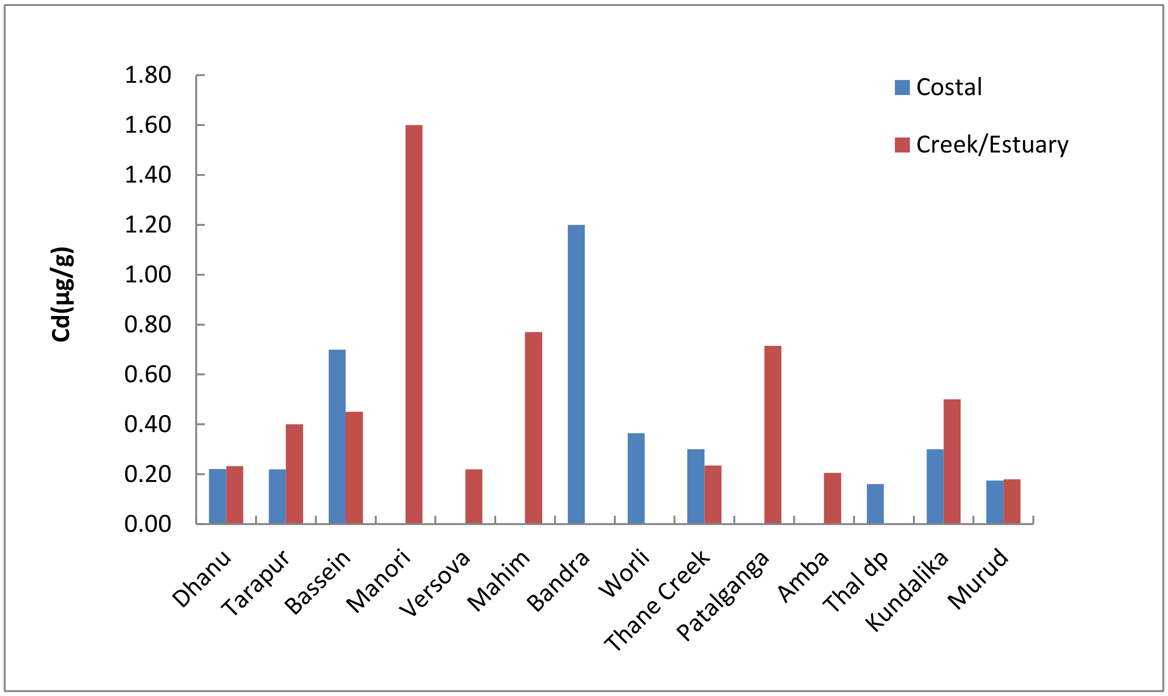


Figure 5.1.43: Cadmium in surface sediment along North Maharashtra Coast.

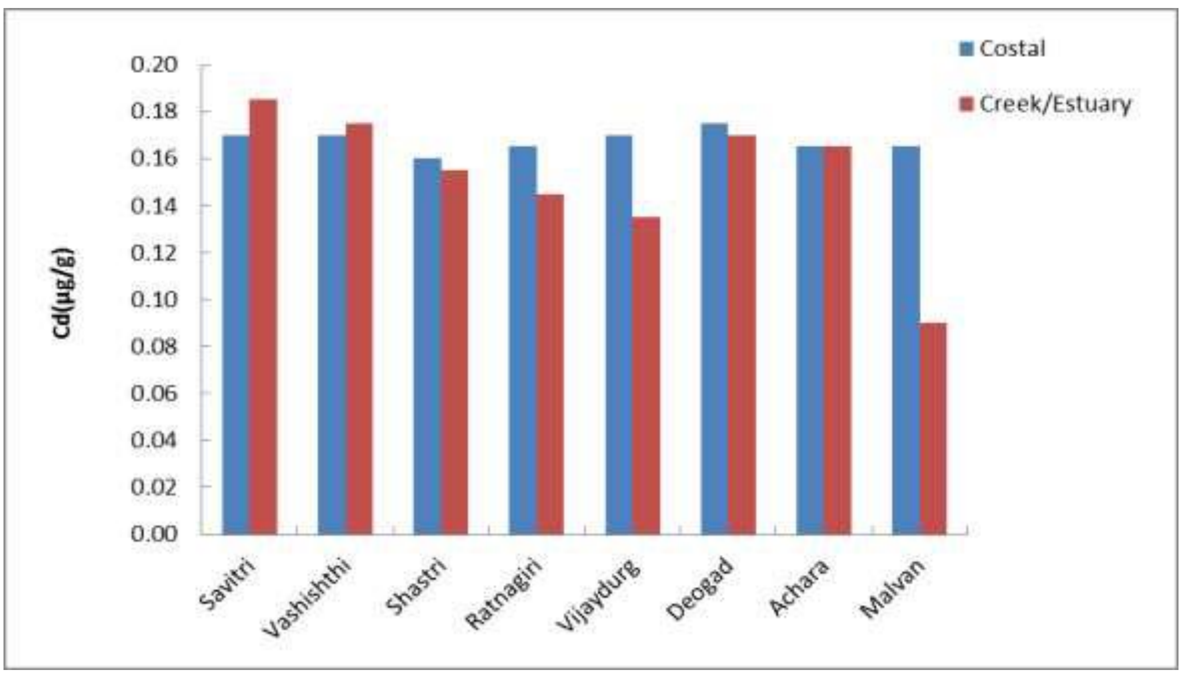


Figure 5.1.44: Cadmium in surface sediment along South Maharashtra Coast.

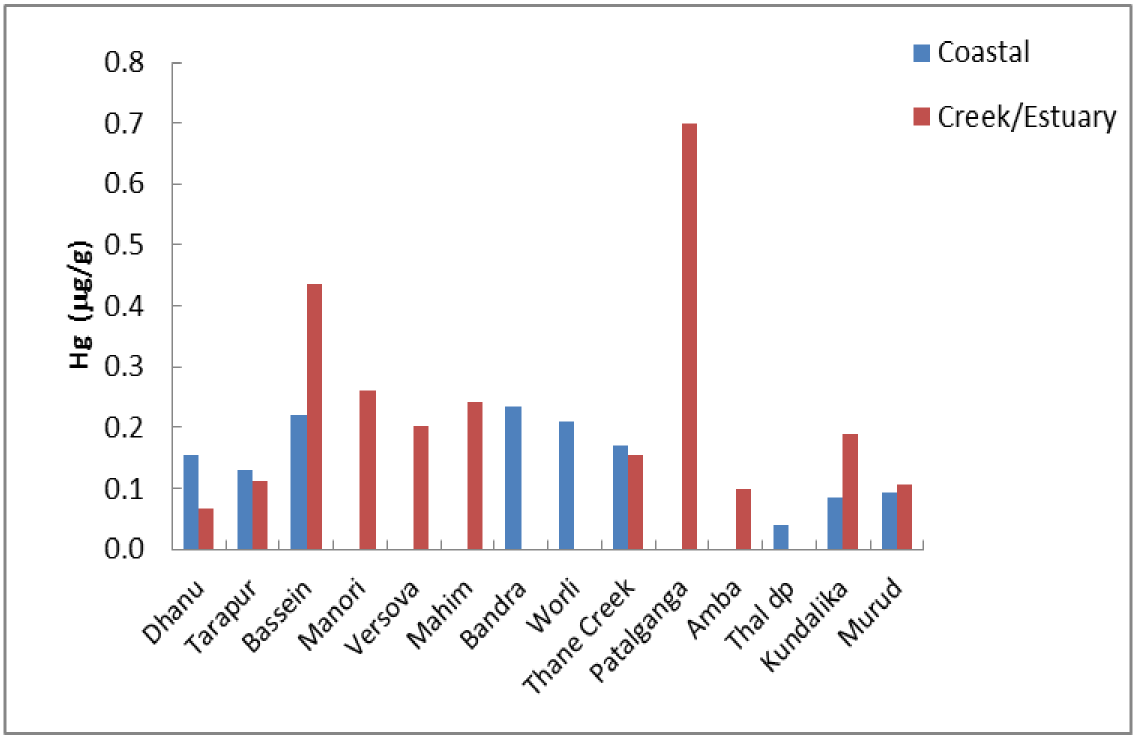


Figure 5.1.45: Mercury in surface sediment along North Maharashtra Coast.

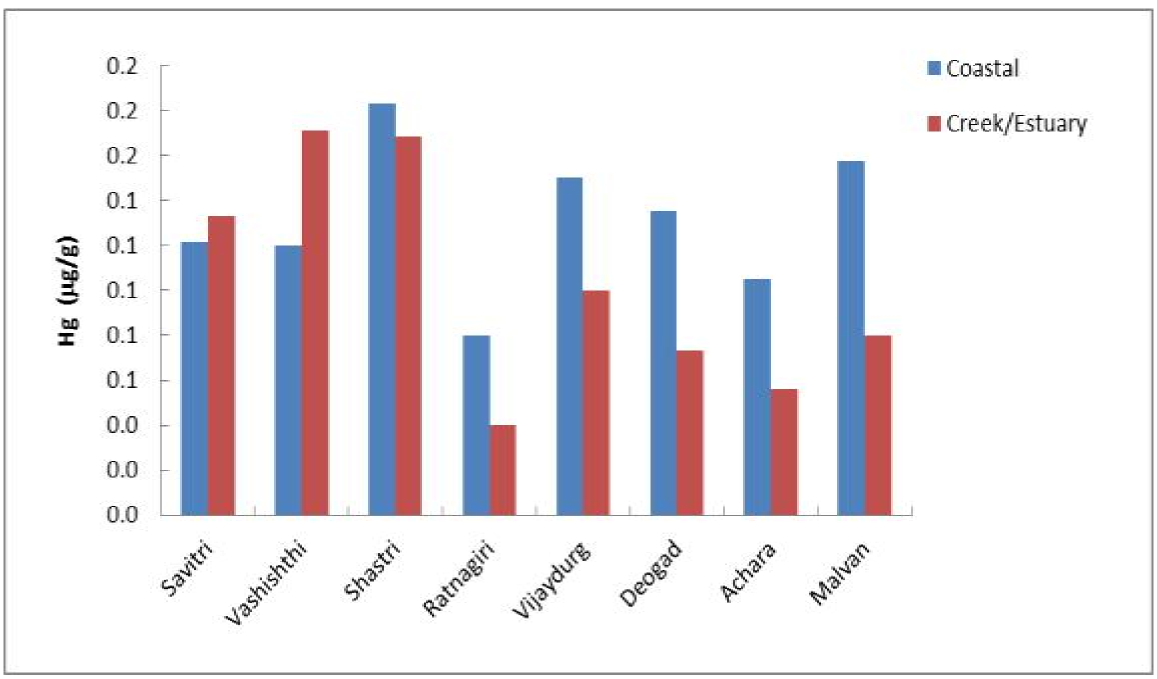


Figure 5.1.46: Mercury in surface sediment along South Maharashtra Coast.

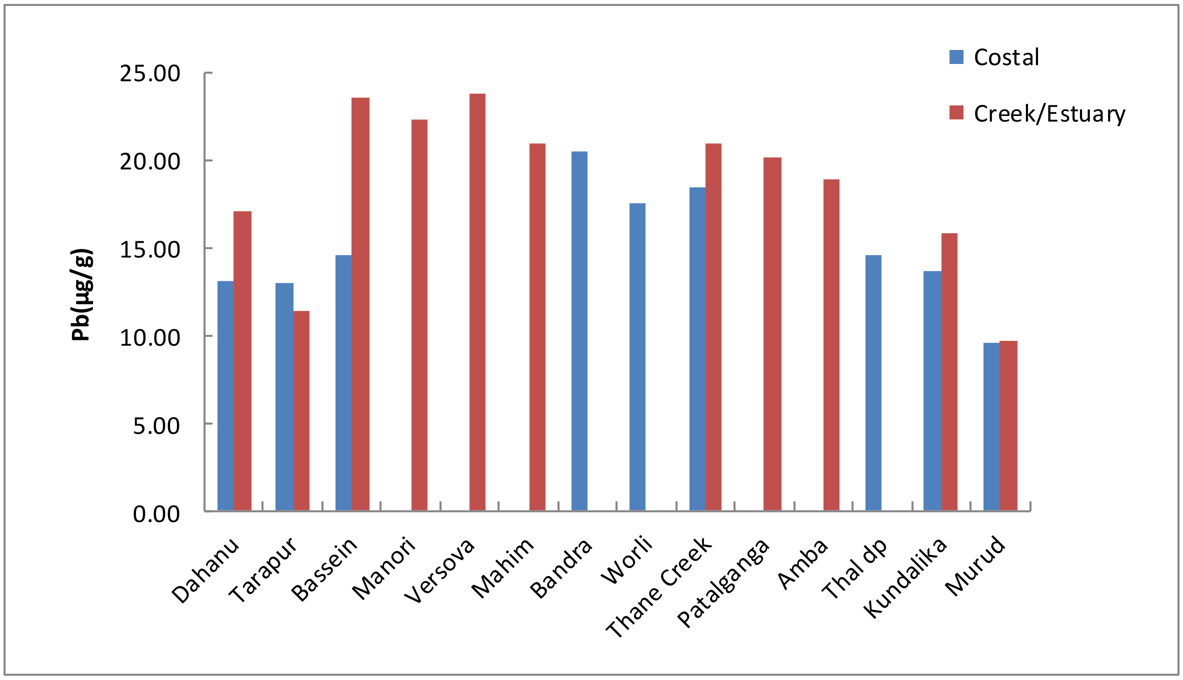


Figure 5.1.47: Lead in surface sediment along North Maharashtra Coast.

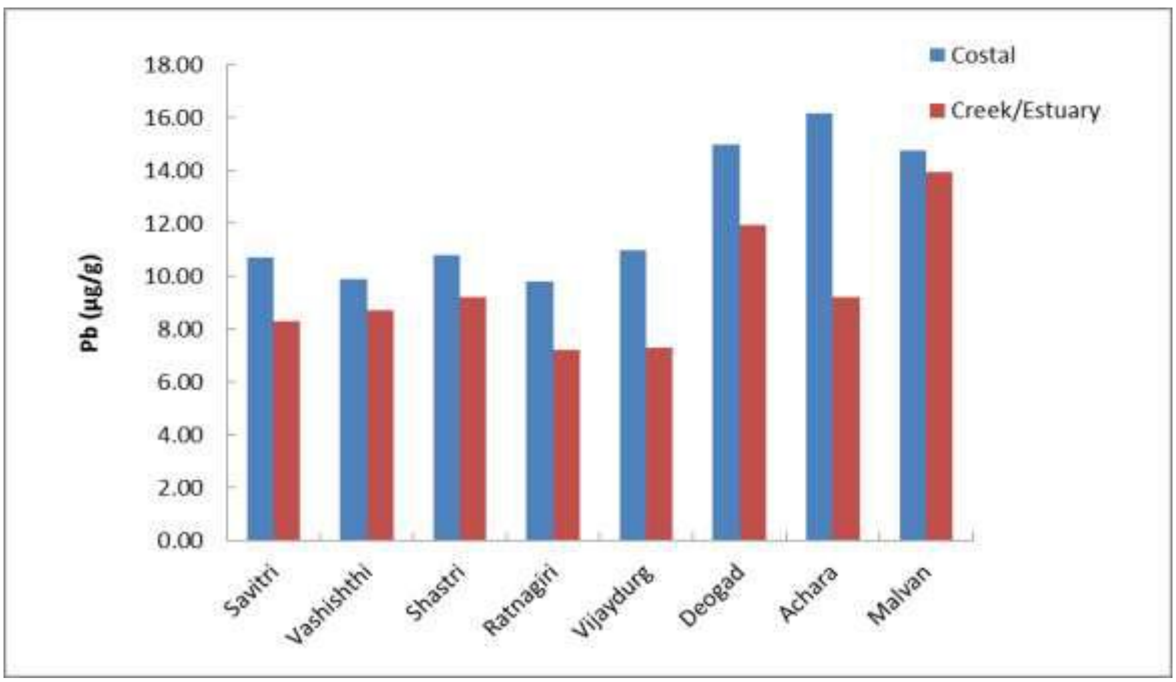


Figure 5.1.48: Lead in surface sediment along South Maharashtra Coast.

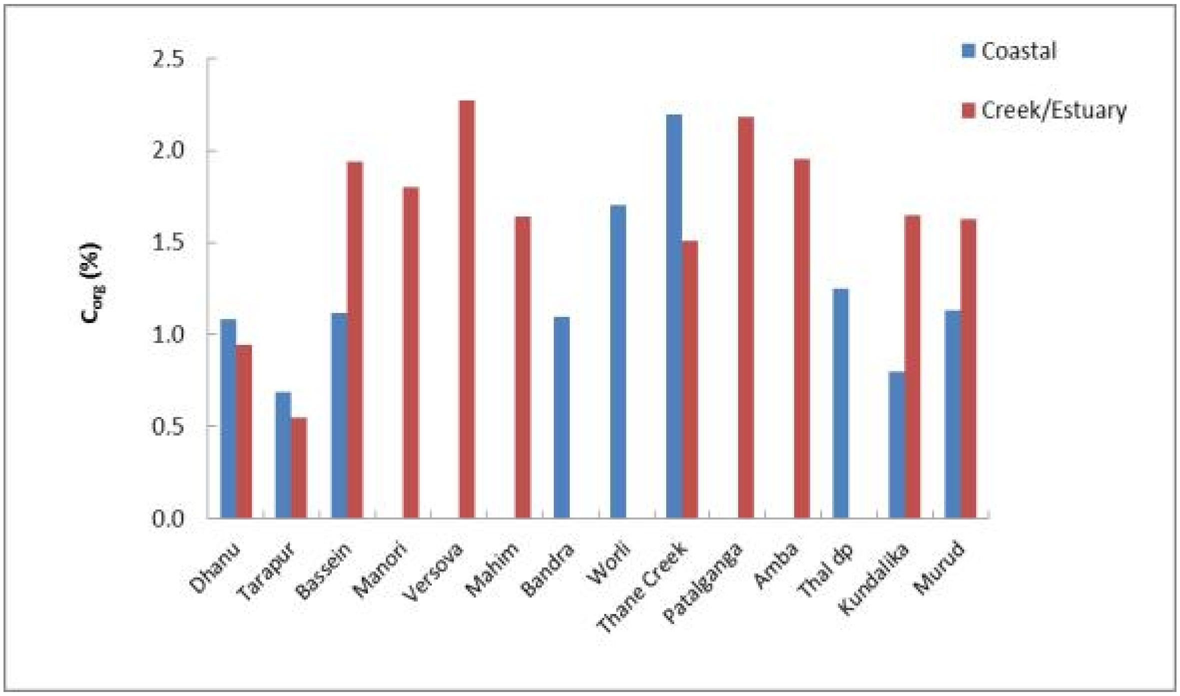


Figure 5.1.49: Organic Carbon in surface sediment along North Maharashtra Coast.

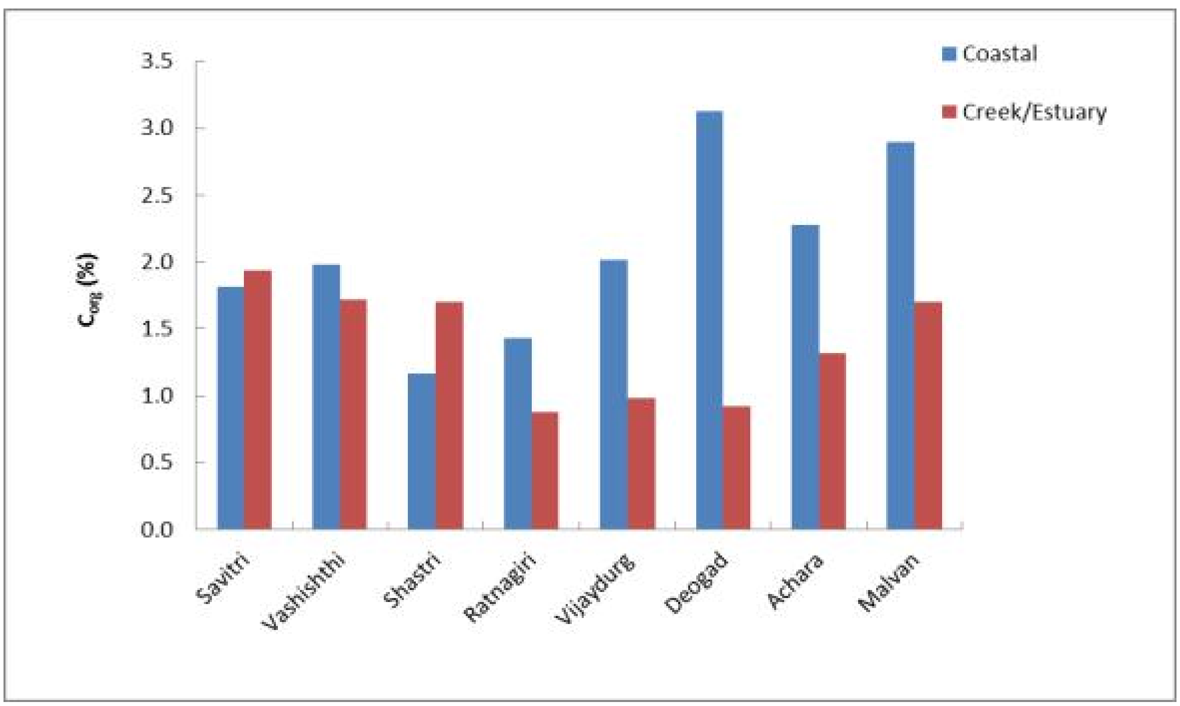


Figure 5.1.50: Organic Carbon in surface sediment along South Maharashtra Coast.

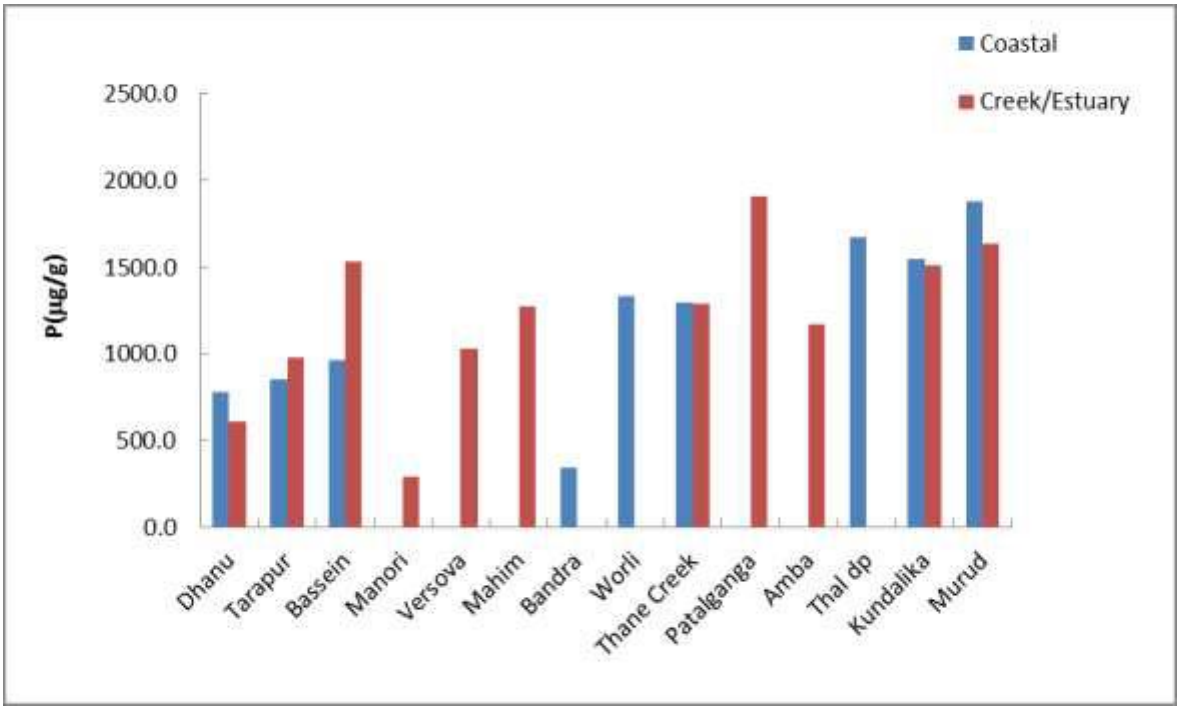


Figure 5.1.51: Phosphorus in surface sediment along North Maharashtra Coast.

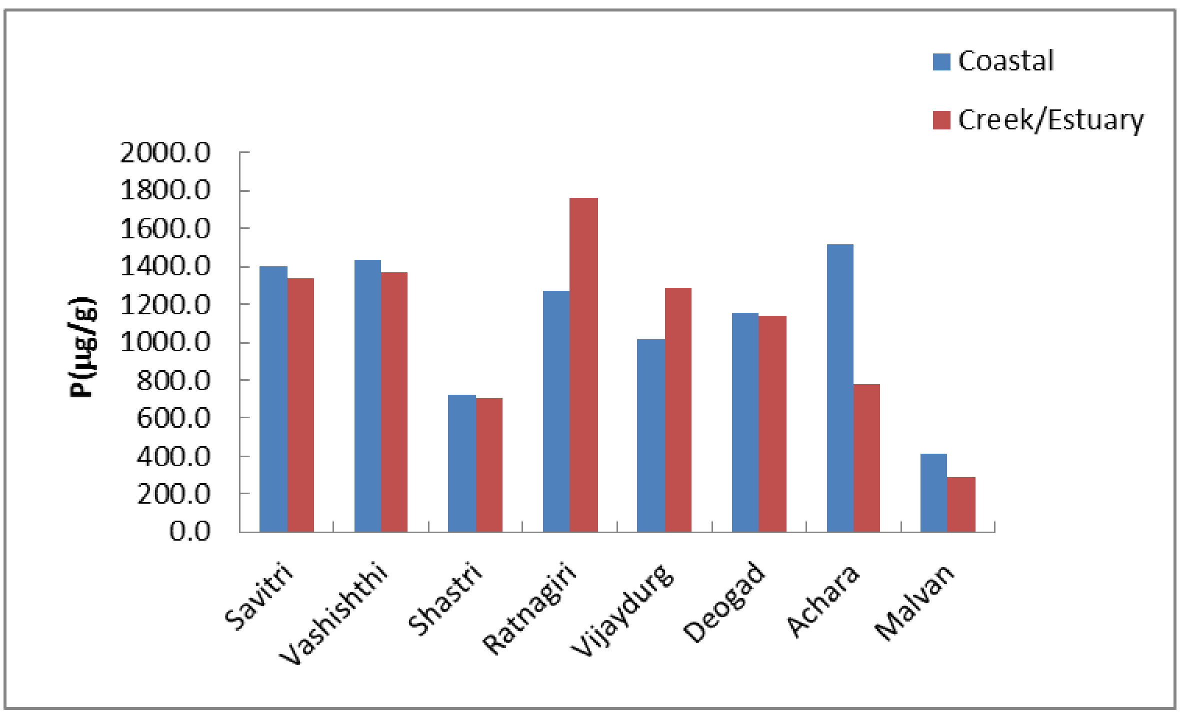


Figure 5.1.52: Phosphorus in surface sediment along South Maharashtra Coast.

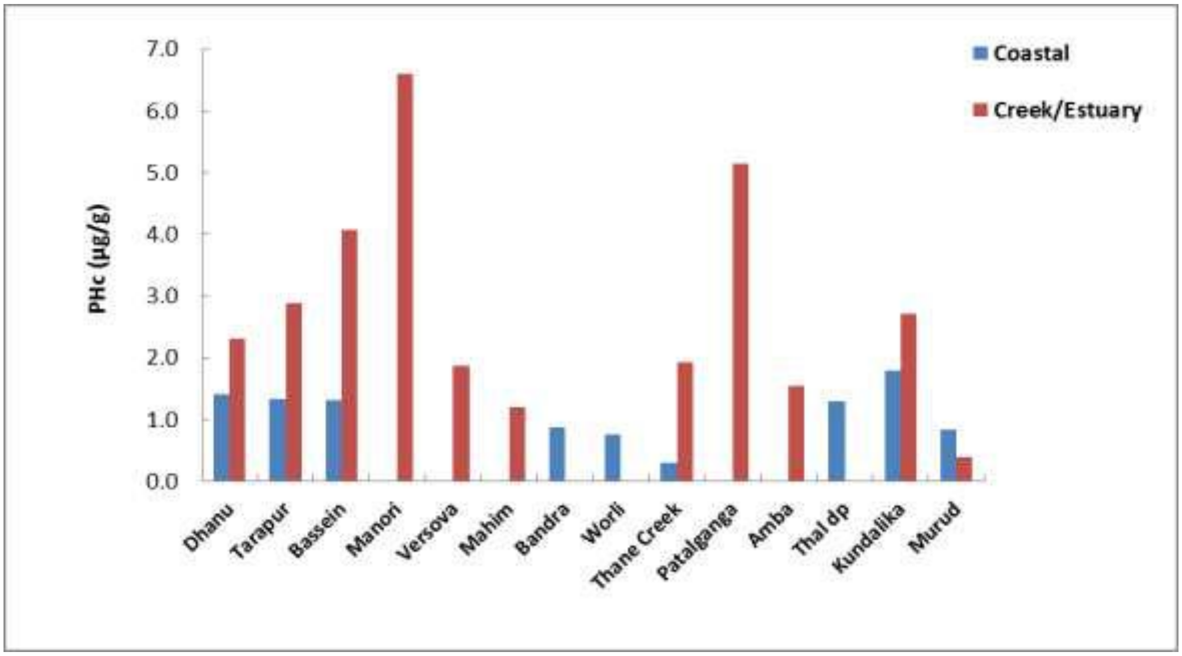


Figure 5.1.53: Petroleum Hydrocarbon in surface sediment along North Maharashtra Coast.

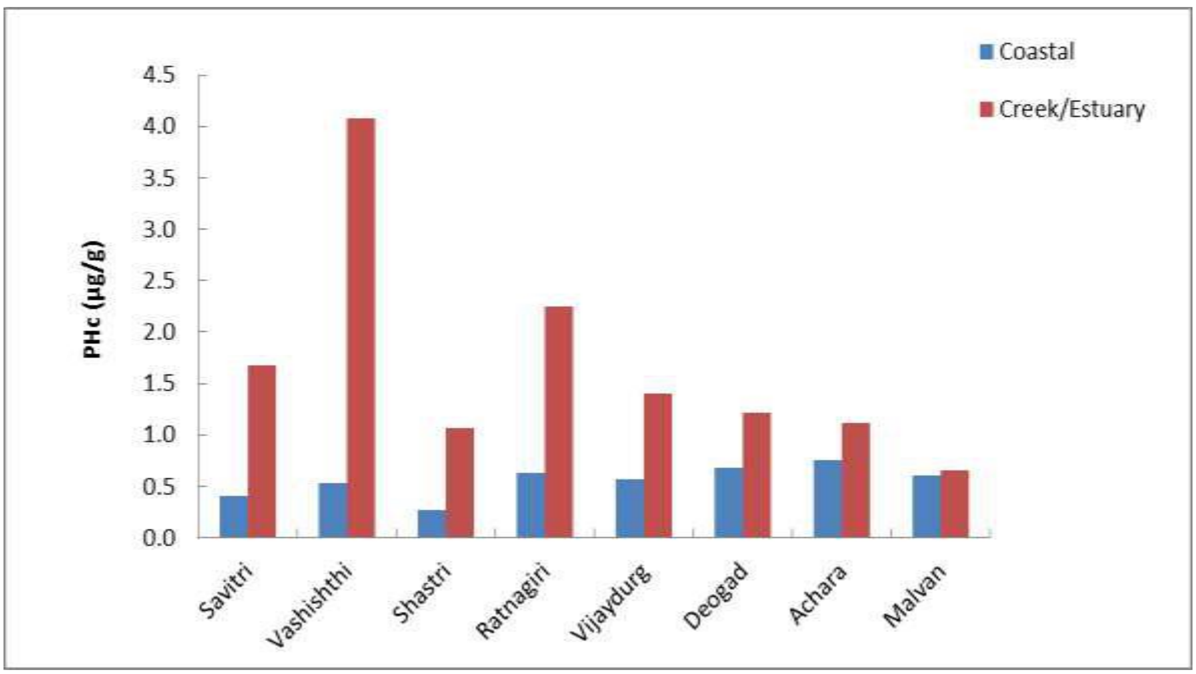


Figure 5.1.54: Petroleum Hydrocarbon in surface sediment along South Maharashtra Coast.

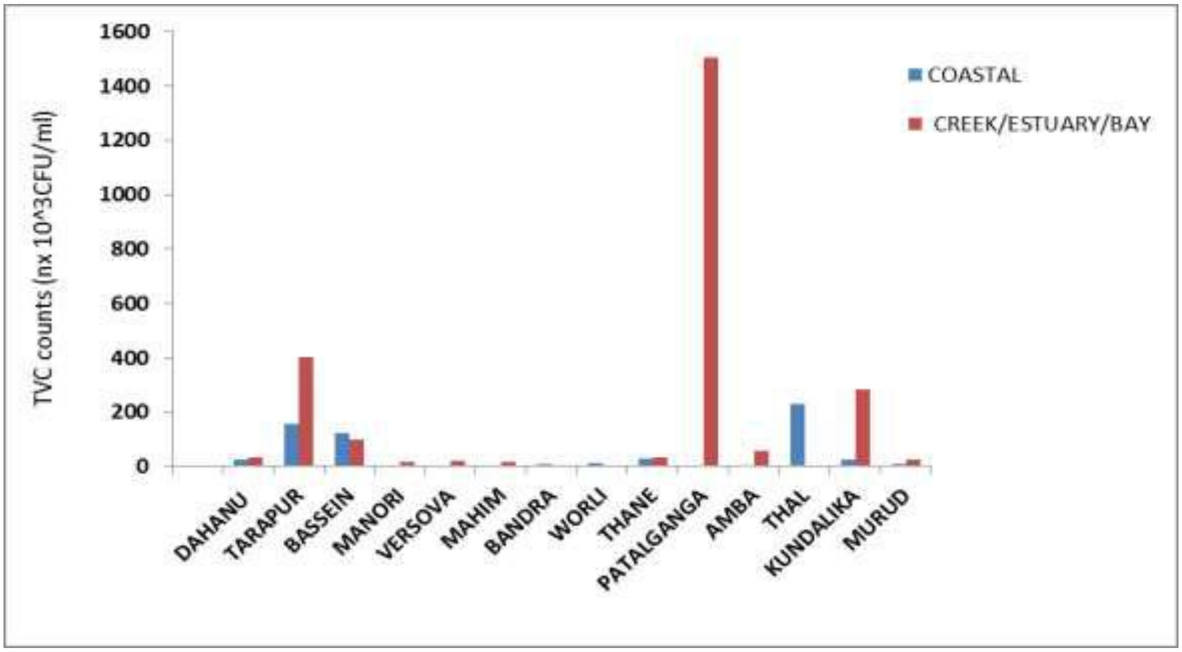


Figure 5.1.55: TVC Count in Water along North Maharashtra Coast.

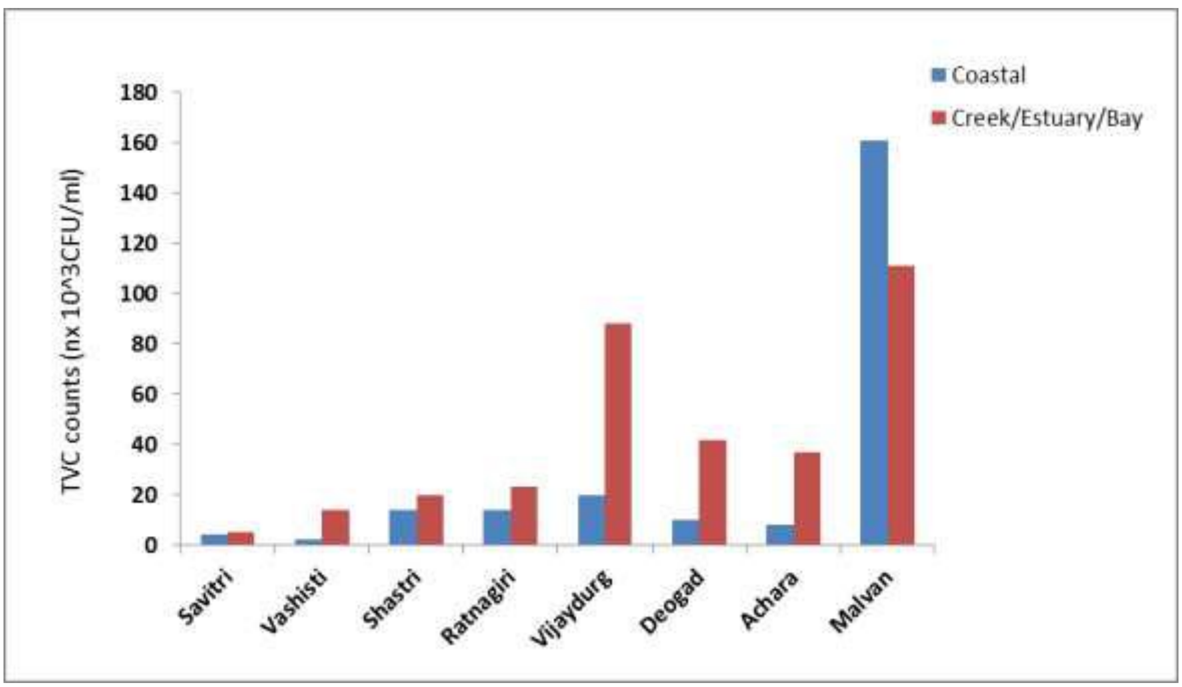


Figure 5.1.56: TVC Count in Water along South Maharashtra Coast.

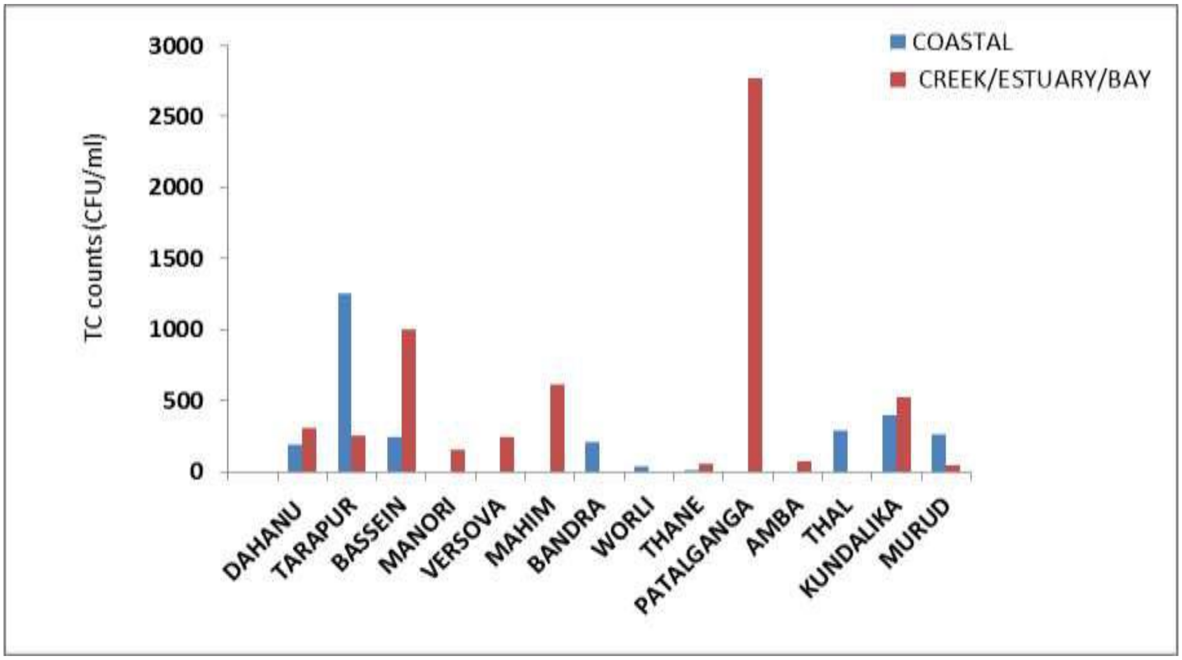


Figure 5.1.57: TC Count in Water along North Maharashtra Coast.

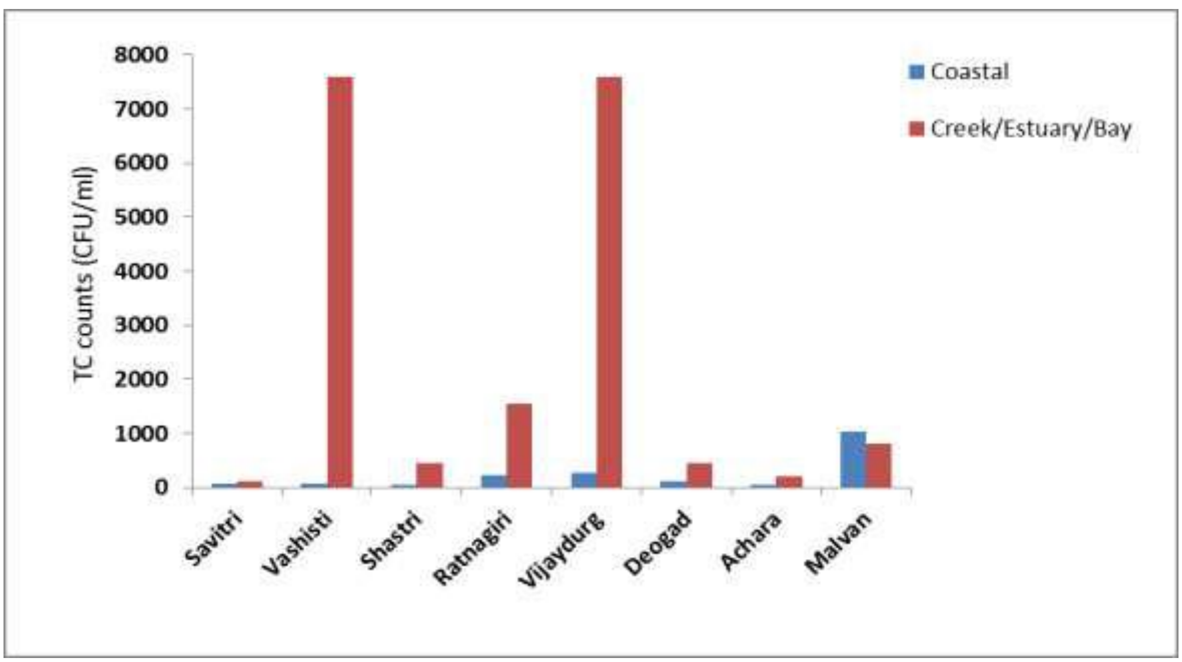


Figure 5.1.58: TC Count in Water along South Maharashtra Coast.

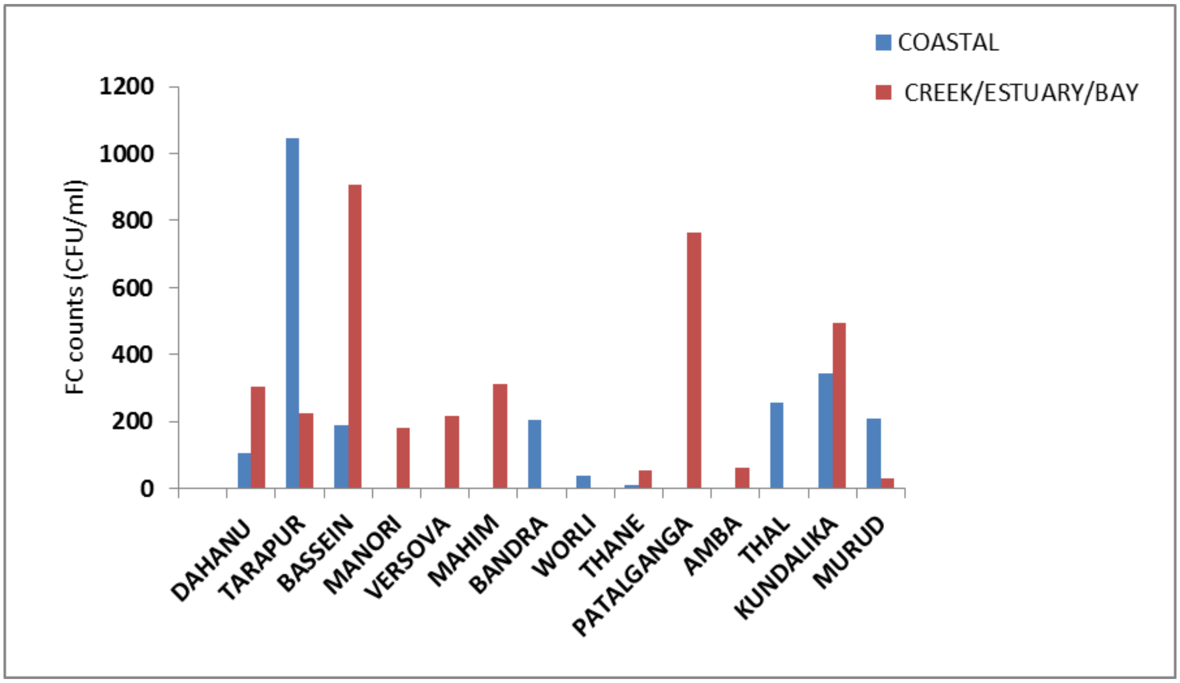


Figure 5.1.59: FC Count in Water along North Maharashtra Coast.

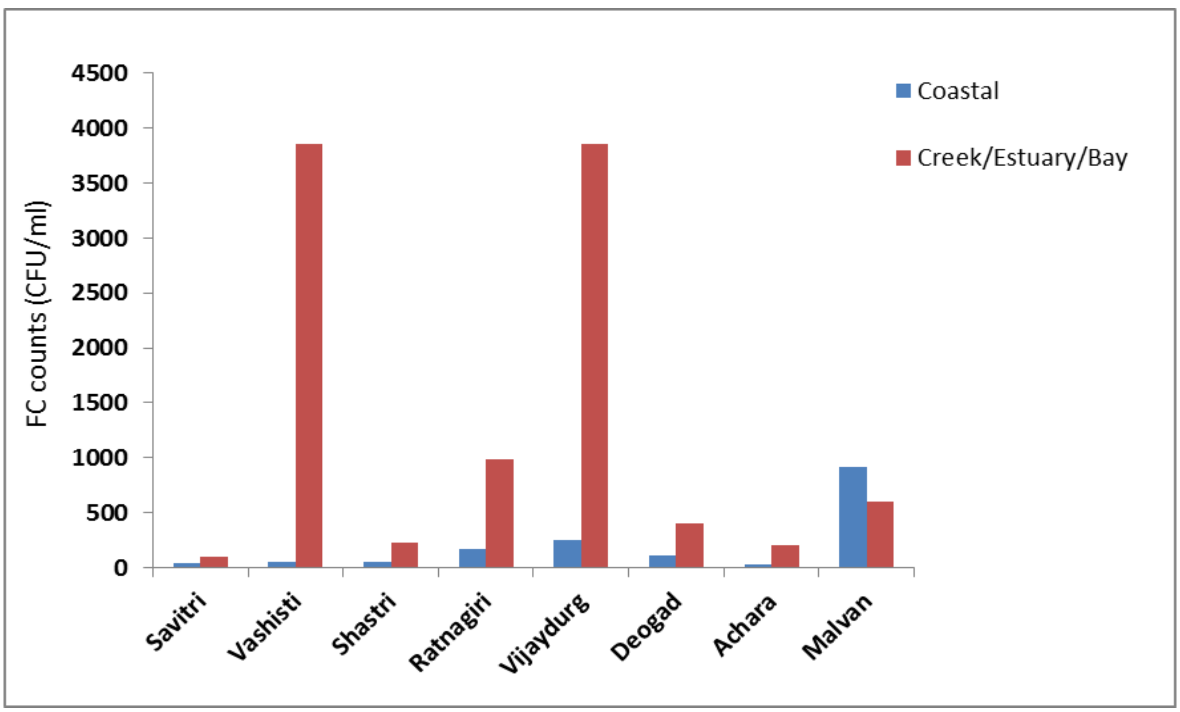


Figure 5.1.60: FC Count in Water along South Maharashtra Coast.

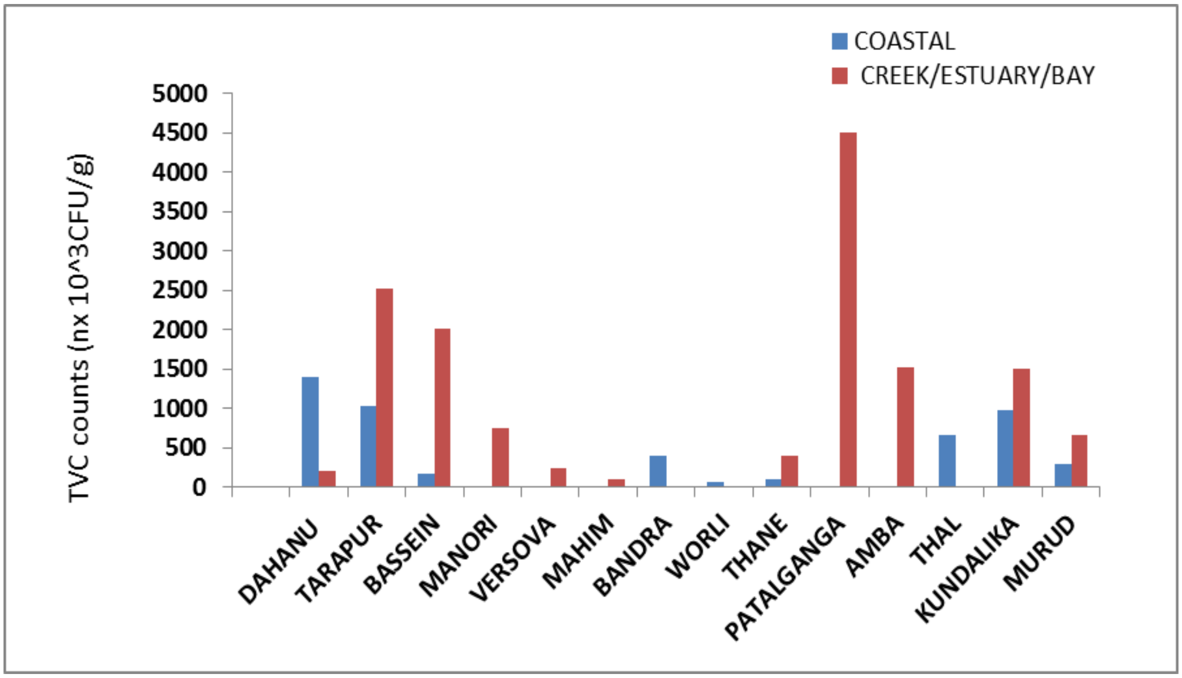


Figure 5.1.61: TVC Count in Sediment along North Maharashtra Coast.

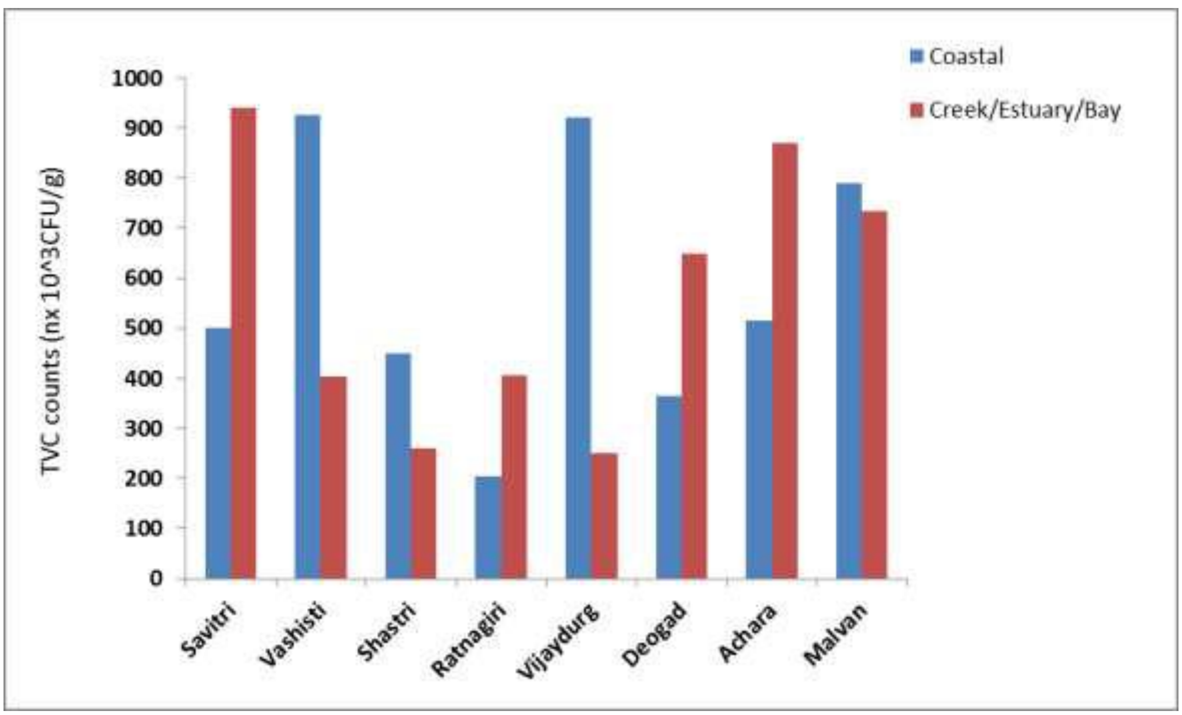


Figure 5.1.62: TVC Count in Sediment along South Maharashtra Coast.

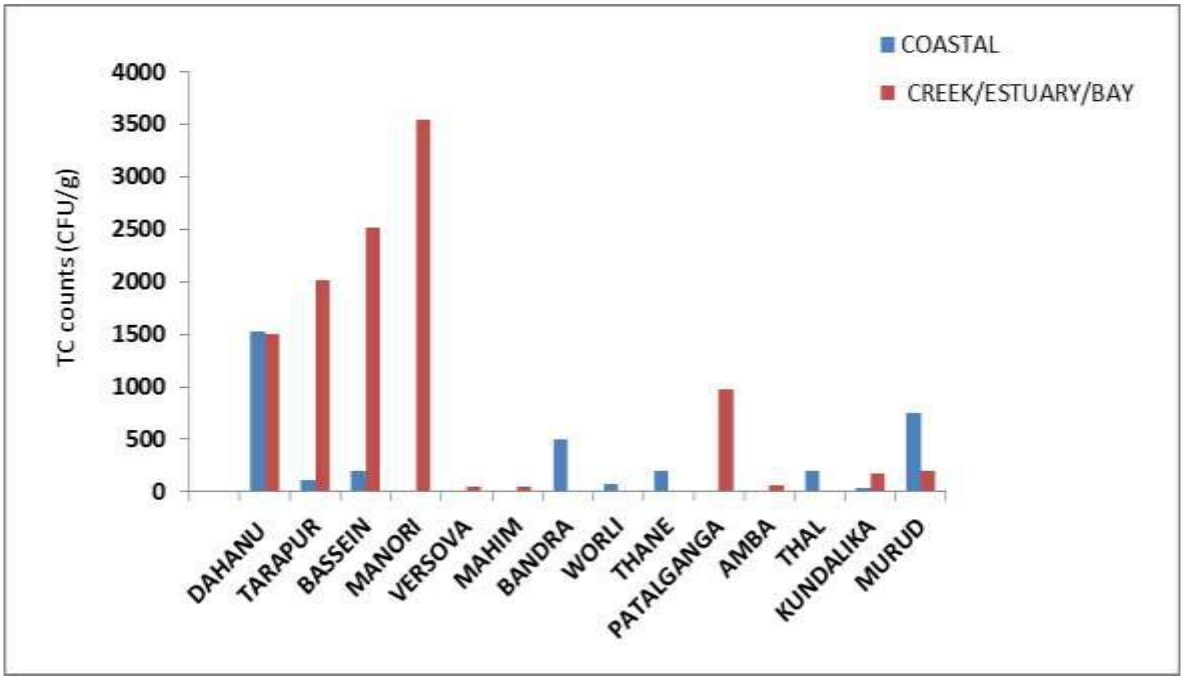


Figure 5.1.63: TC Count in Sediment along North Maharashtra Coast.

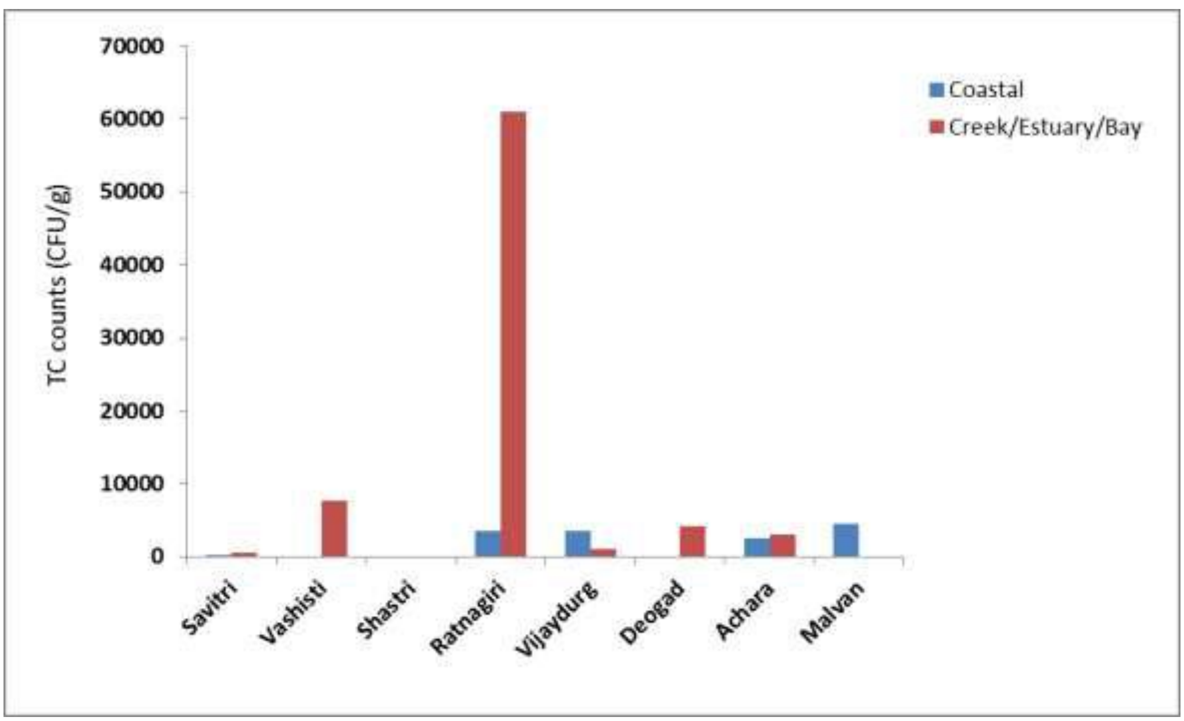


Figure 5.1.64: TC Count in Sediment along South Maharashtra Coast.

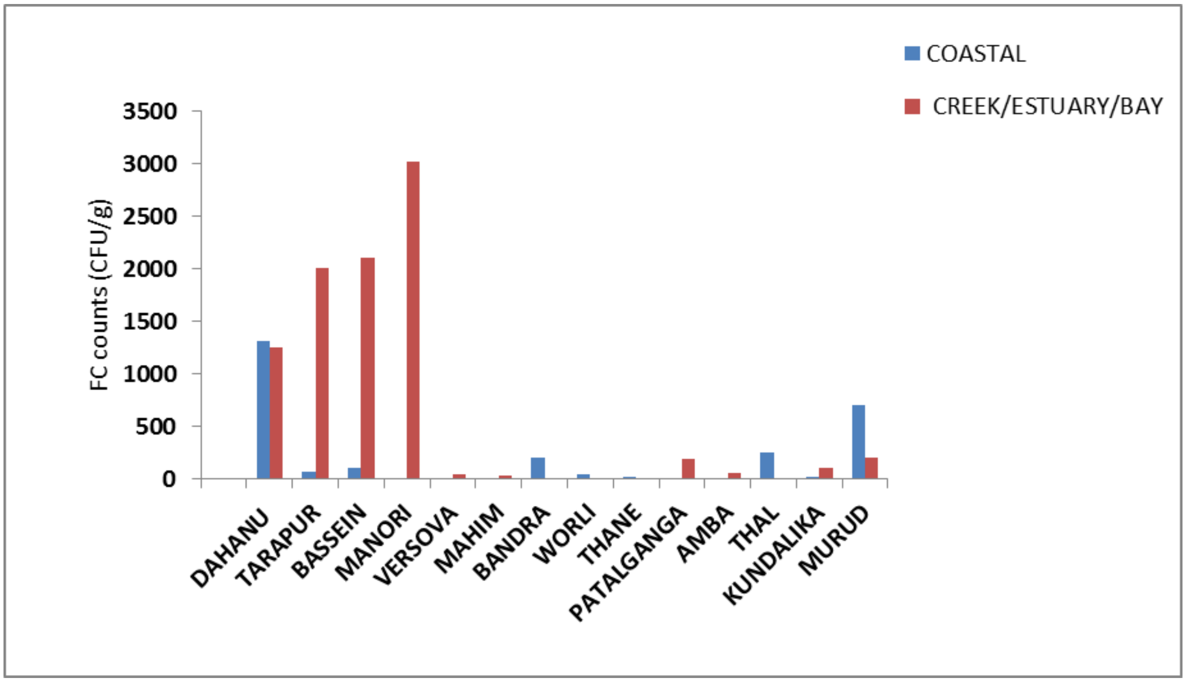


Figure 5.1.65: FC Count in Sediment along North Maharashtra Coast.

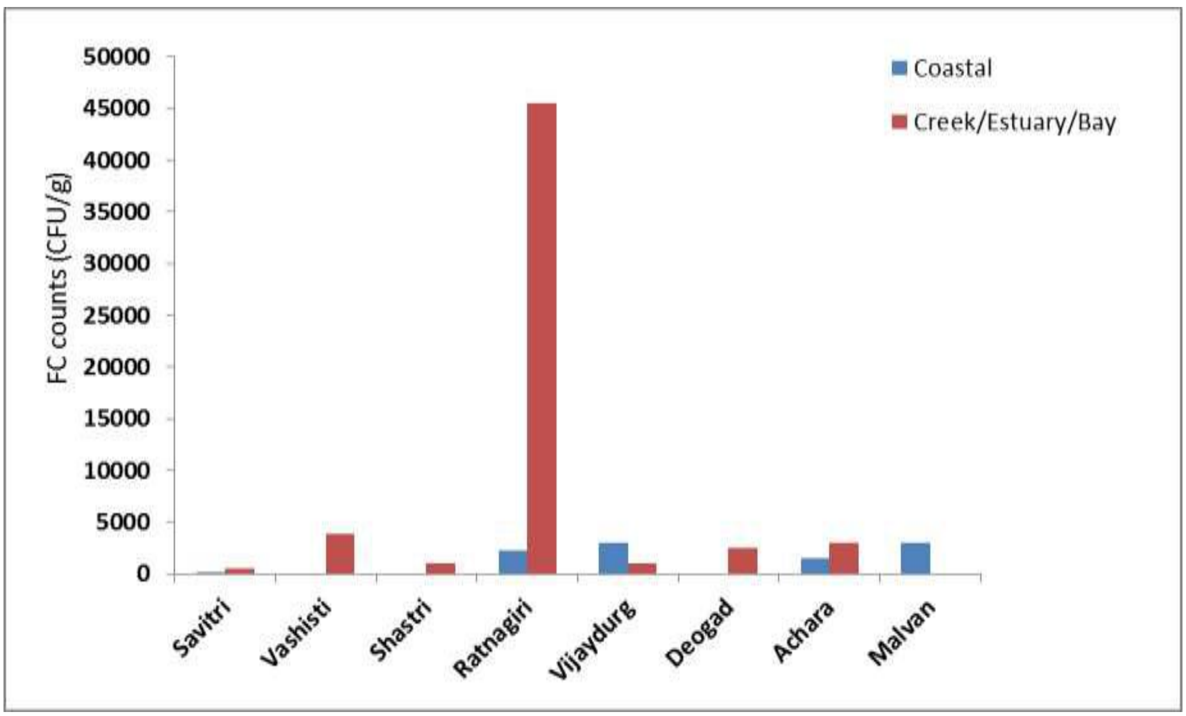


Figure 5.1.66: FC Count in Sediment along South Maharashtra Coast.

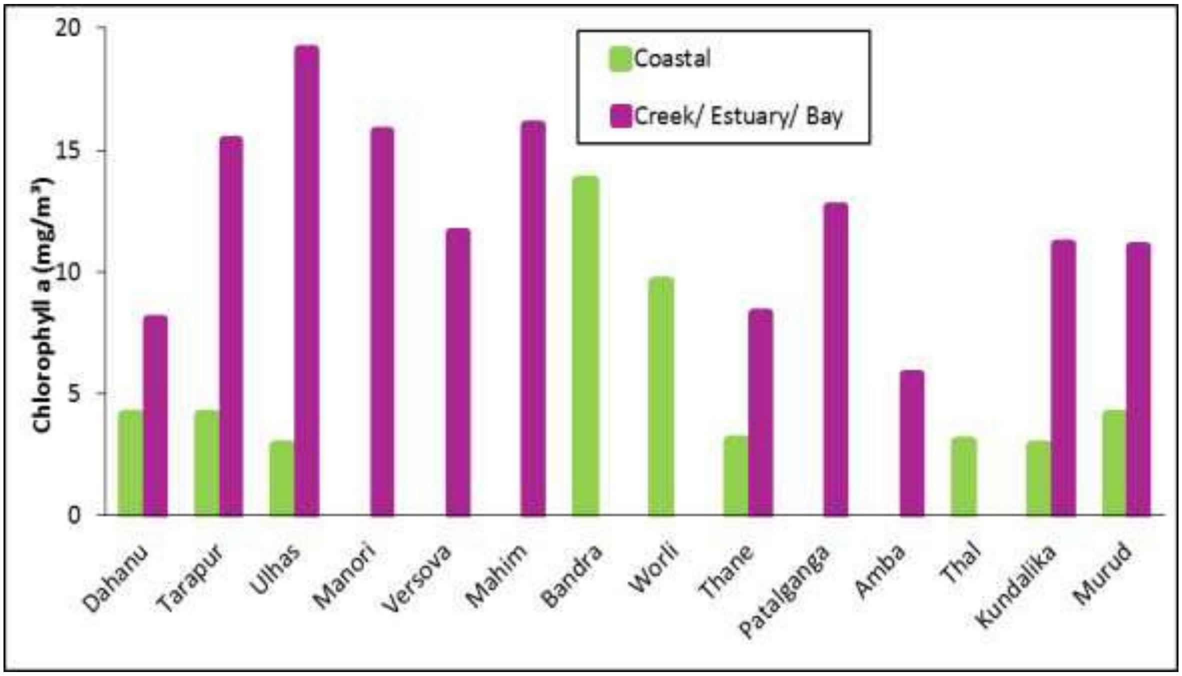


Figure 5.1.67: Average chlorophyll a concentration along North Maharashtra coast.

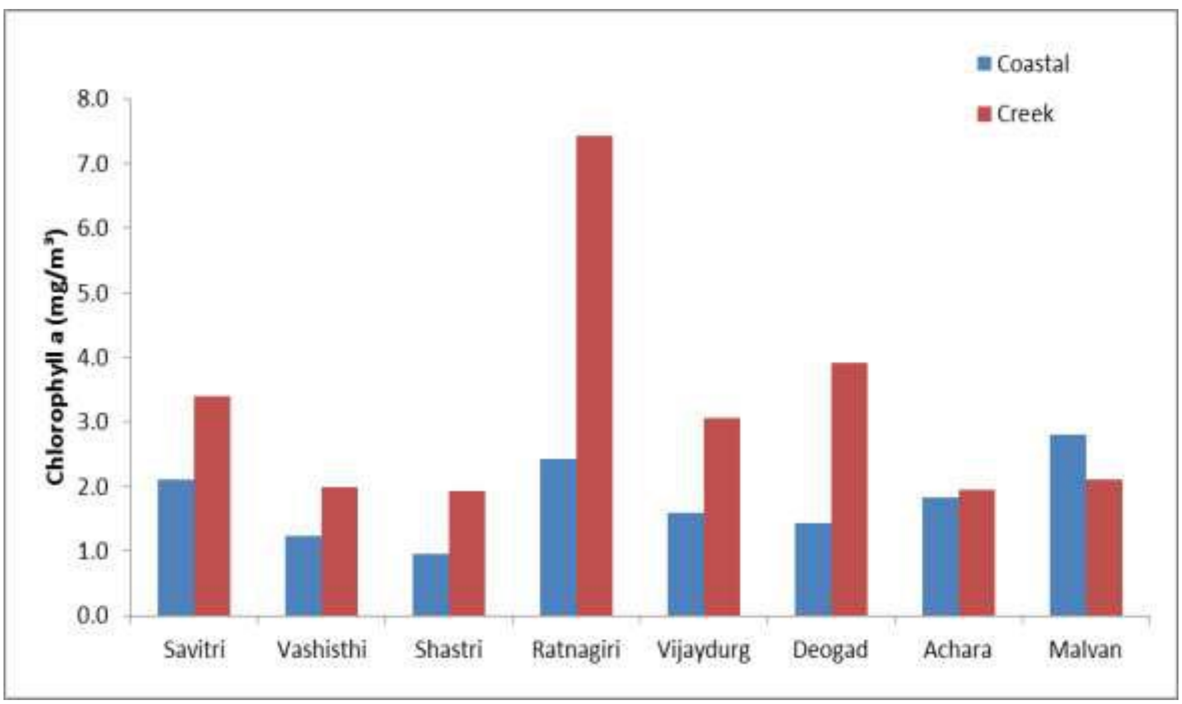


Figure 5.1.68: Average chlorophyll a concentration along south Maharashtra coast.

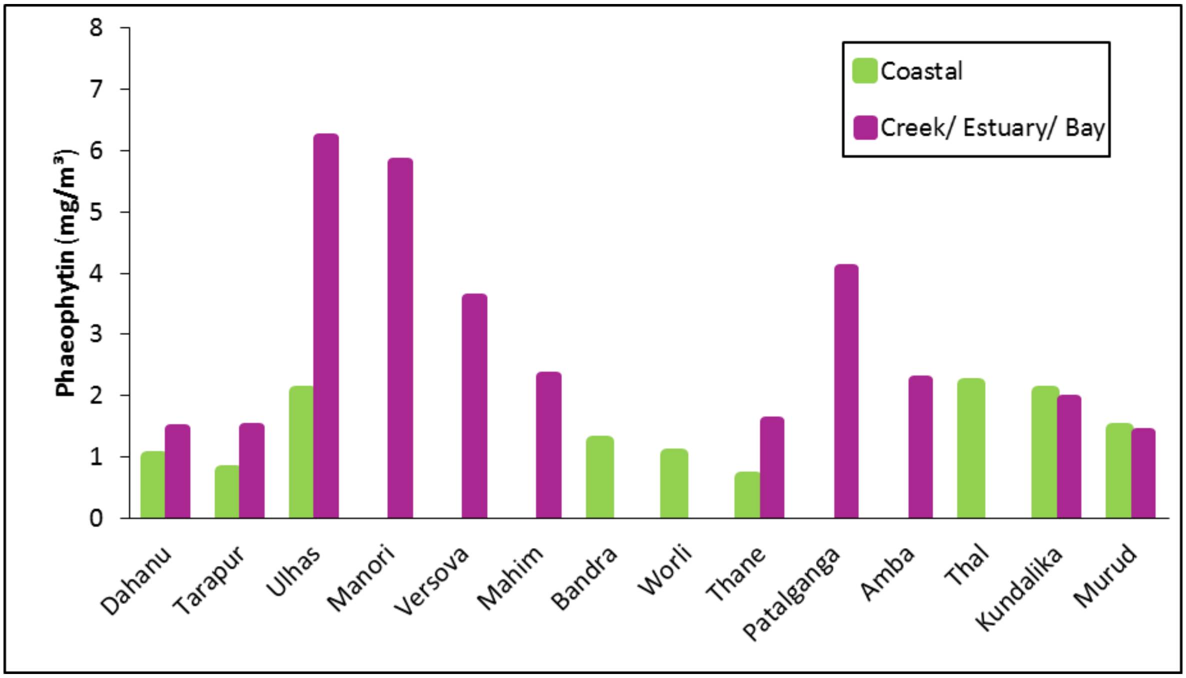


Figure 5.1.69: Average phaeophytin concentration along North Maharashtra coast.

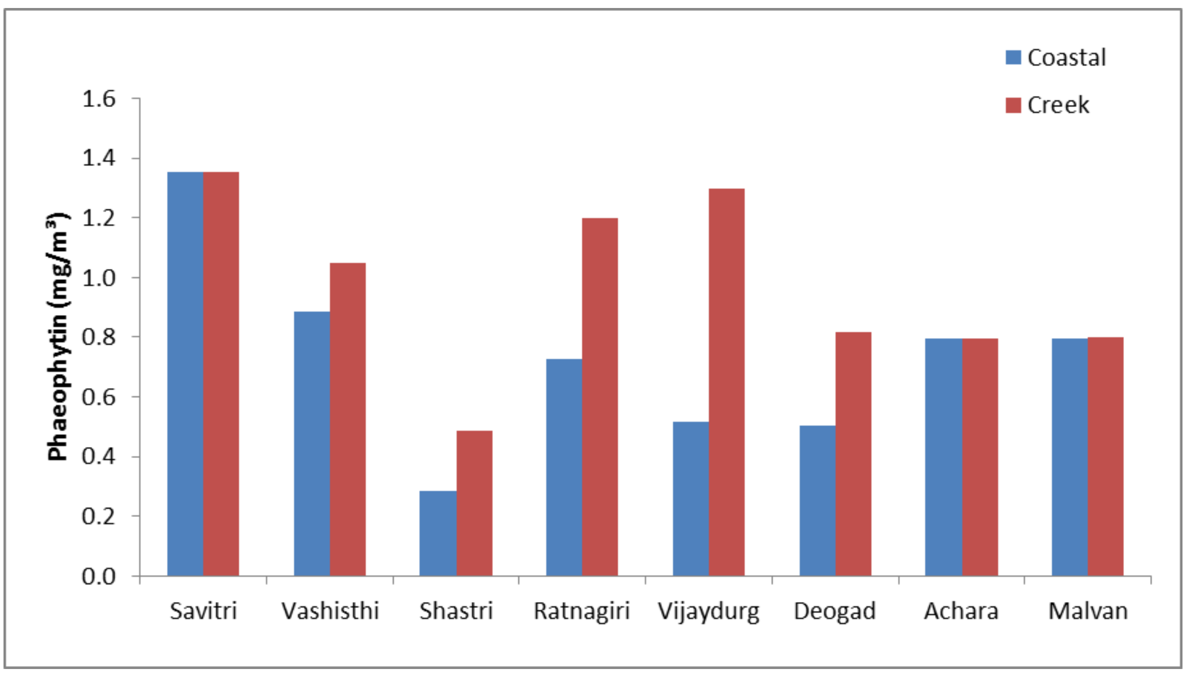


Figure 5.1.70: Average phaeophytin concentration along South Maharashtra coast.

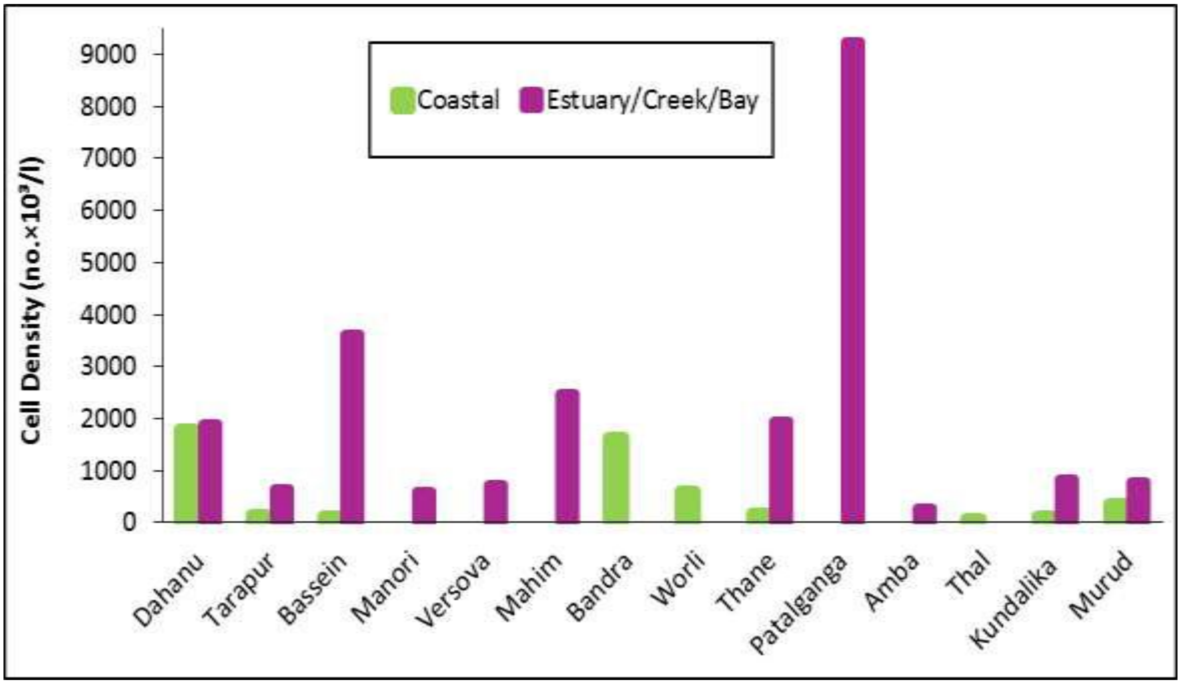


Figure 5.1.71: Average phytoplankton cell count along North Maharashtra coast.

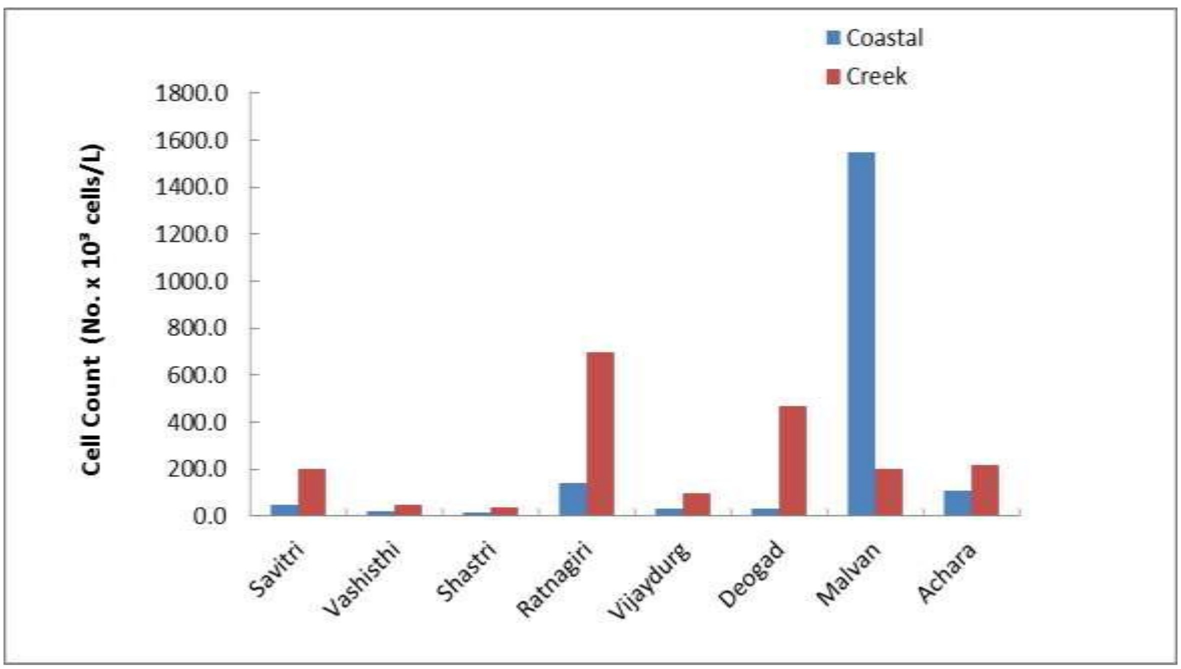


Figure 5.1.72: Average phytoplankton cell count along south Maharashtra coast.

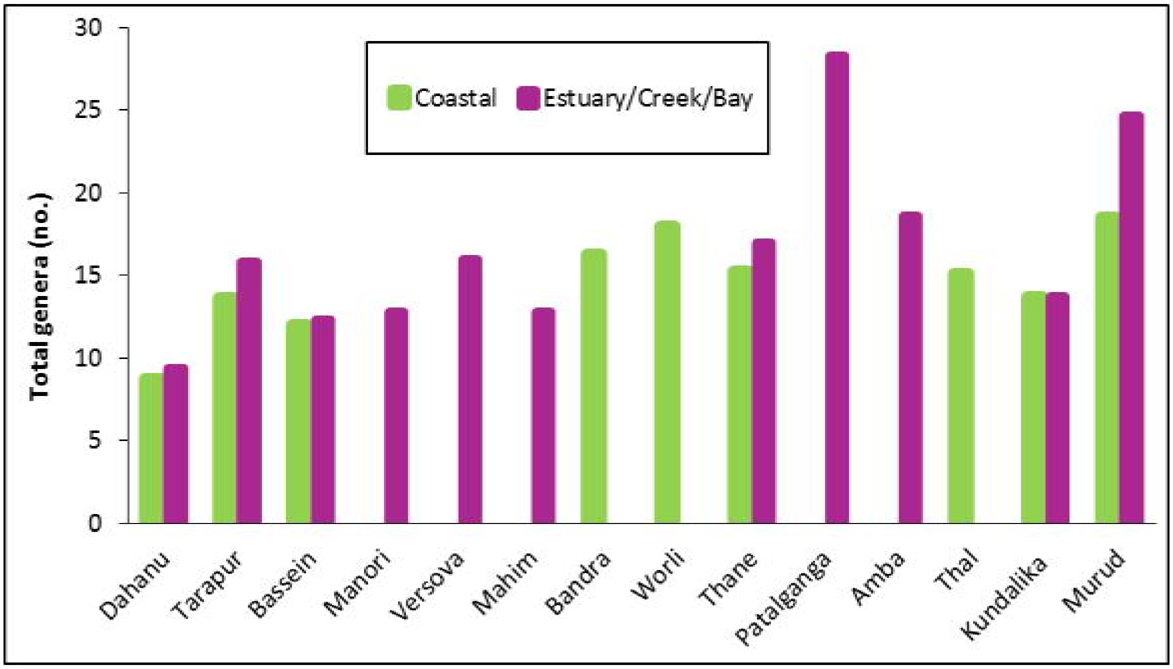


Figure 5.1.73: Average phytoplankton genera along North Maharashtra coast.

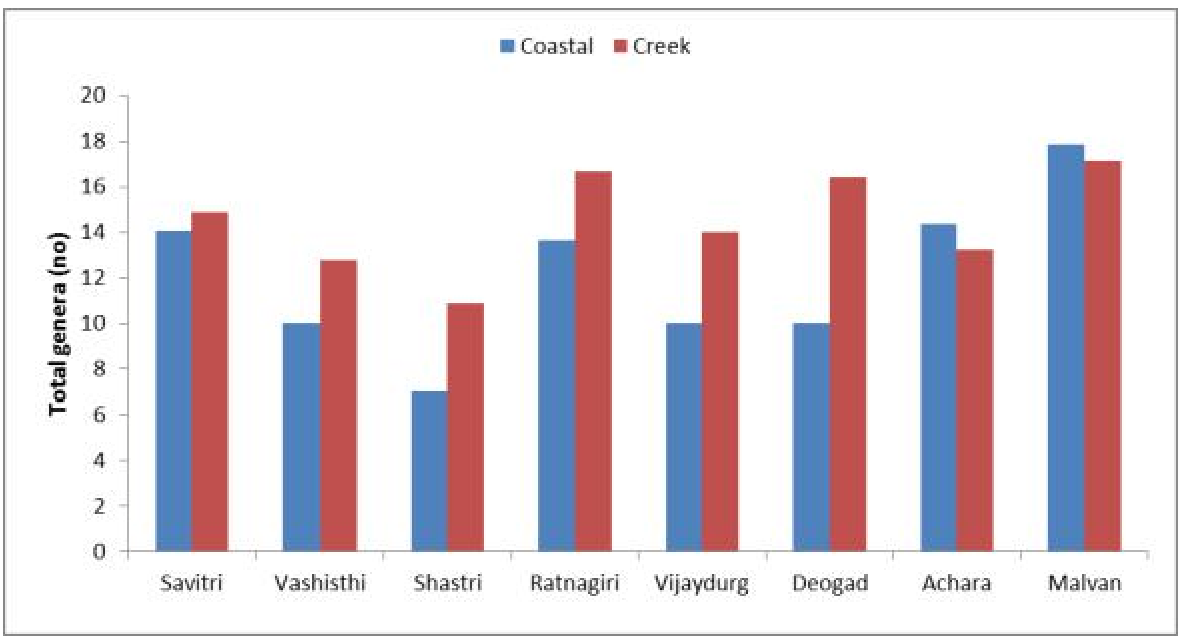


Figure 5.1.74: Average phytoplankton genera along South Maharashtra coast.

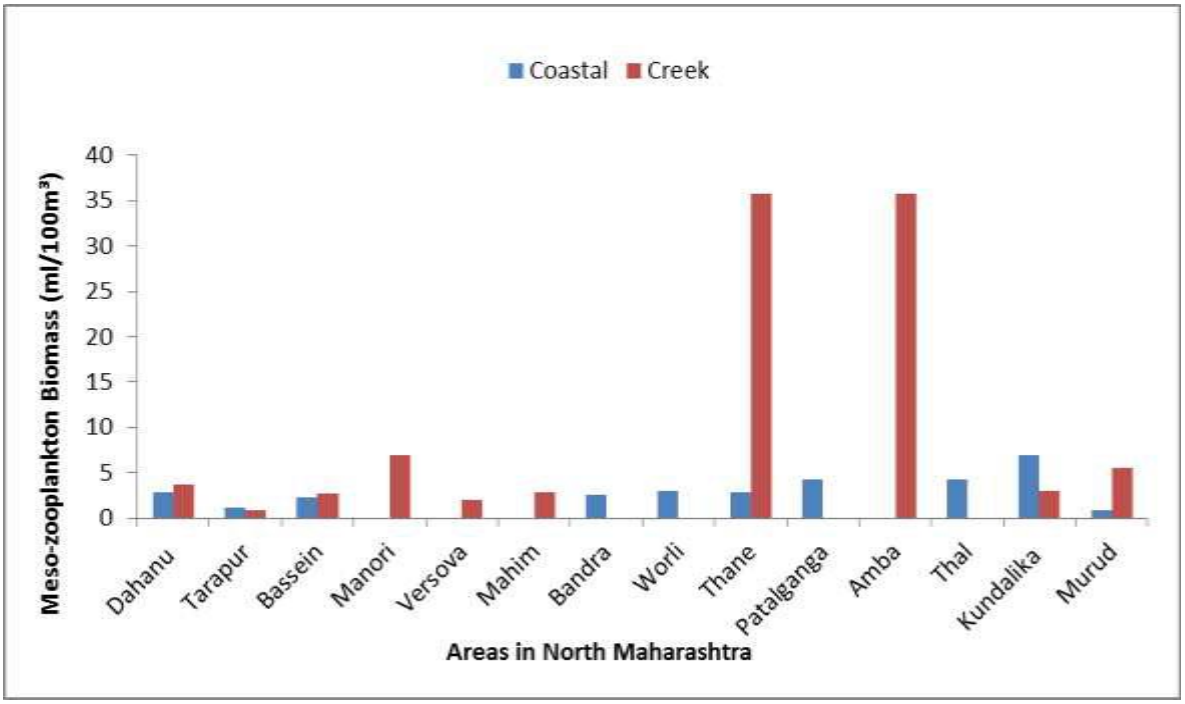


Figure 5.1.75: Average mesozooplankton biomass along North Maharashtra Coast.

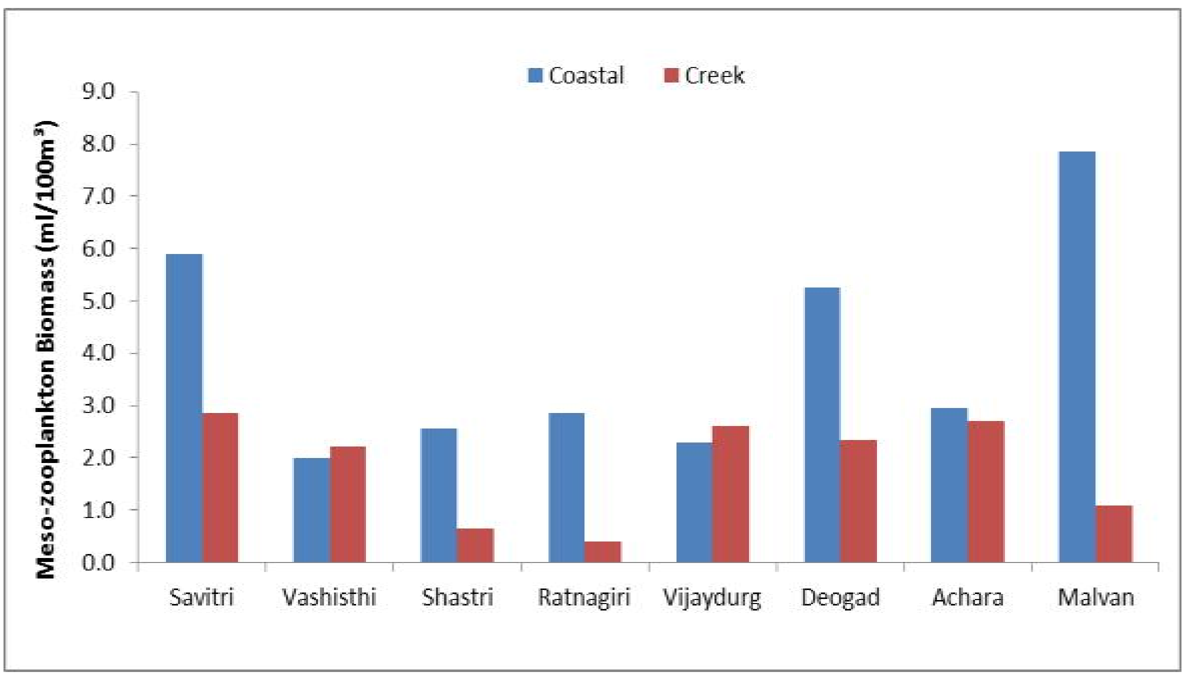


Figure 5.1.76: Average mesozooplankton biomass along South Maharashtra Coast.

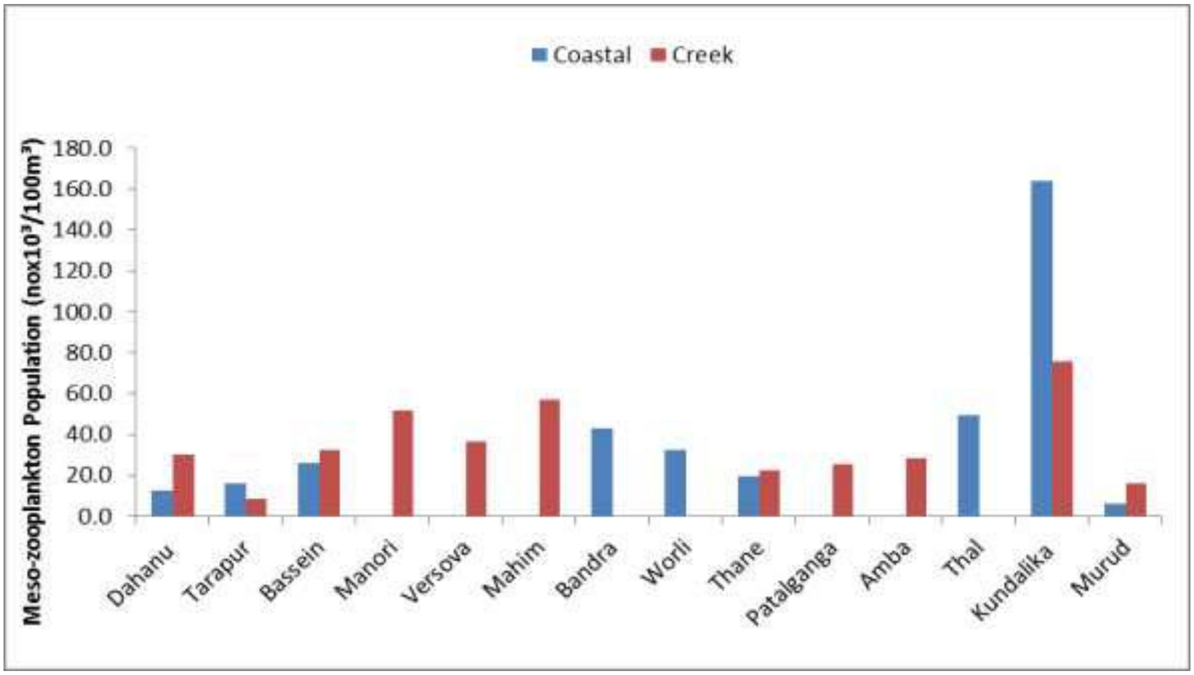


Figure 5.1.77: Average mesozooplankton population along North Maharashtra Coast.

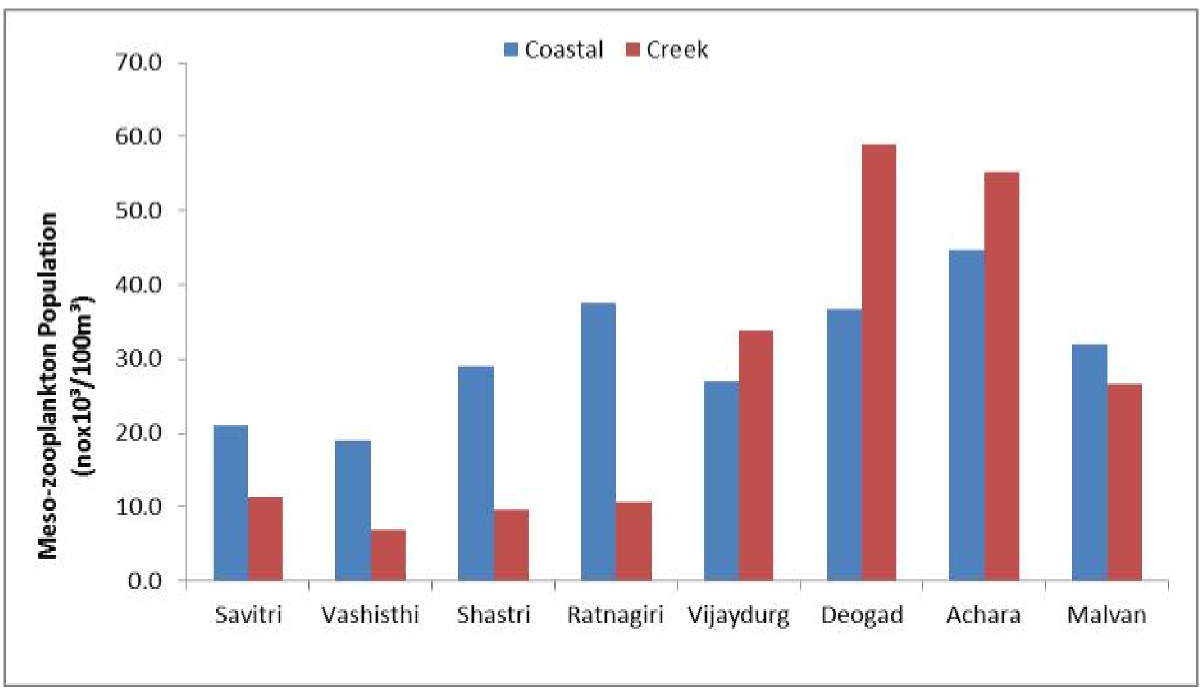


Figure 5.1.78: Average mesozooplankton population along South Maharashtra Coast.

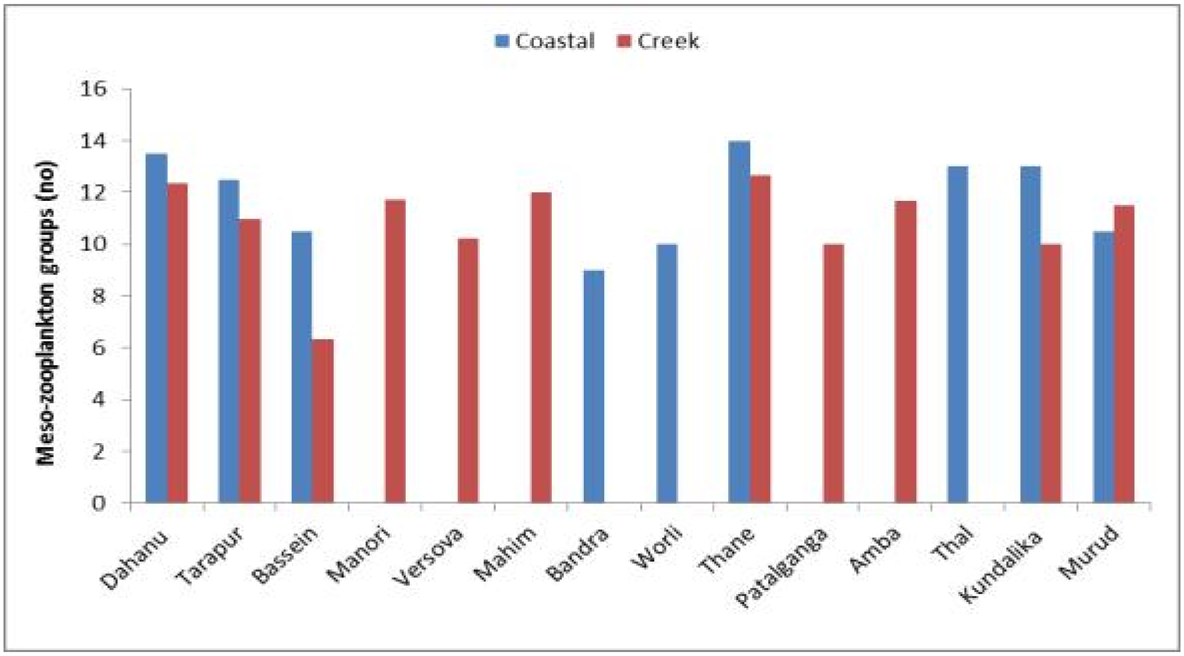


Figure 5.1.79: Average mesozooplankton groups along North Maharashtra Coast.

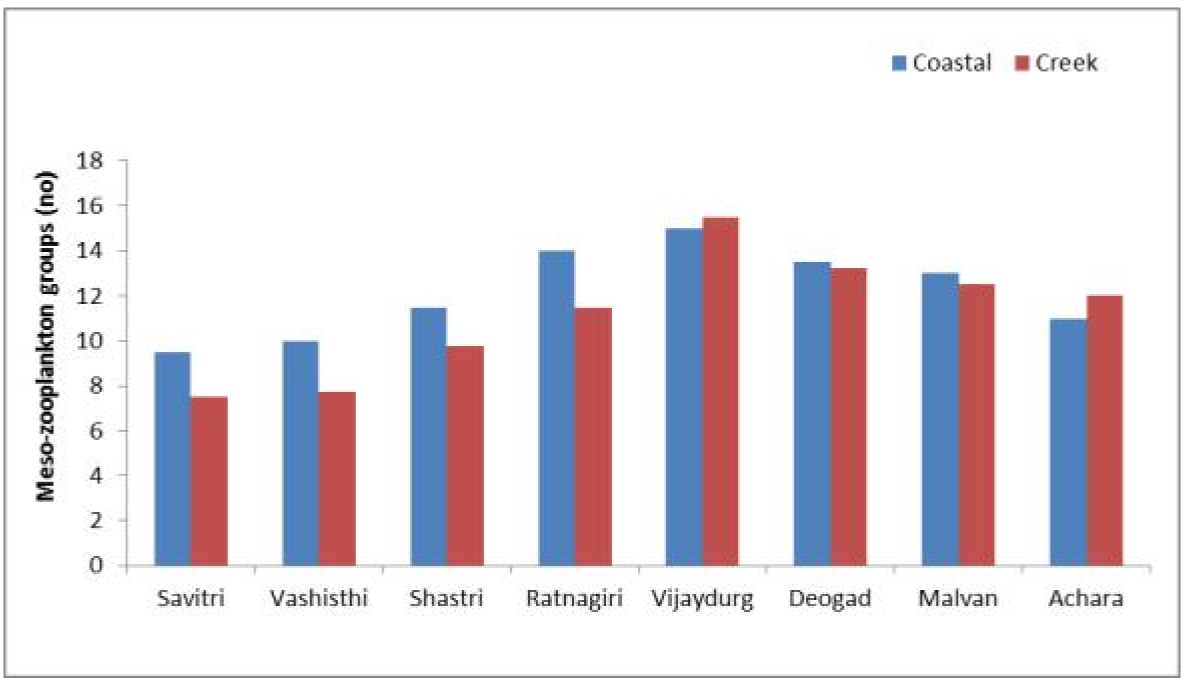


Figure 5.1.80: Average mesozooplankton groups along South Maharashtra Coast.

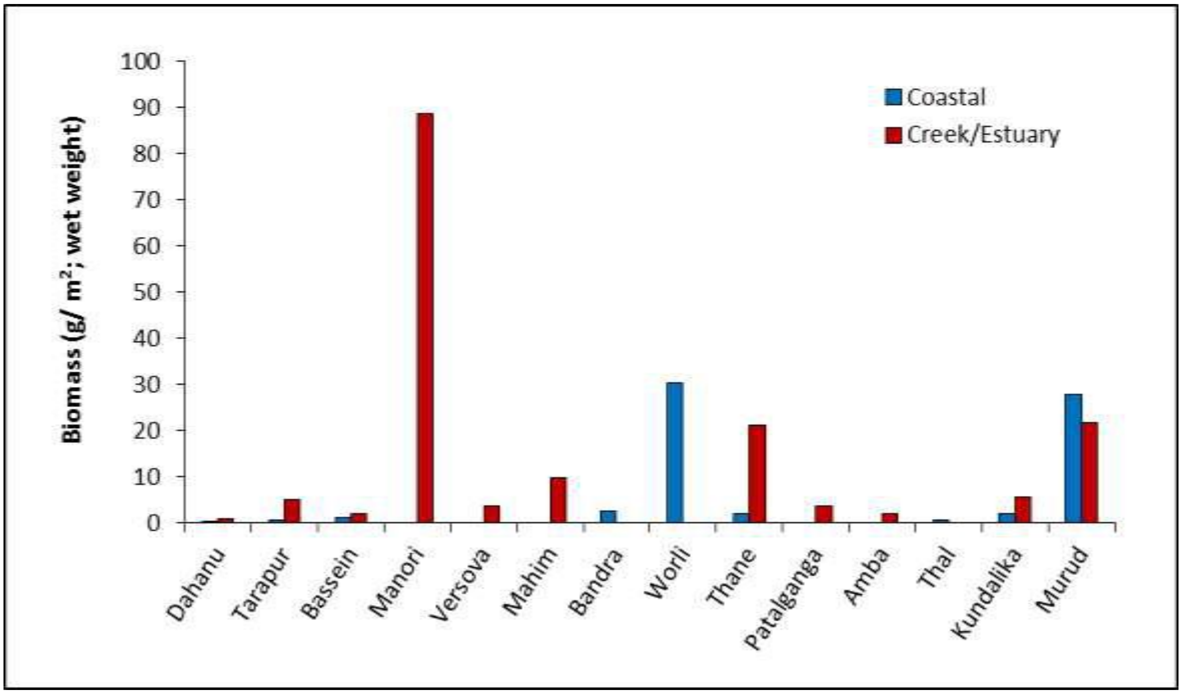


Figure 5.1.81: Average macrobenthic biomass along North Maharashtra coast.

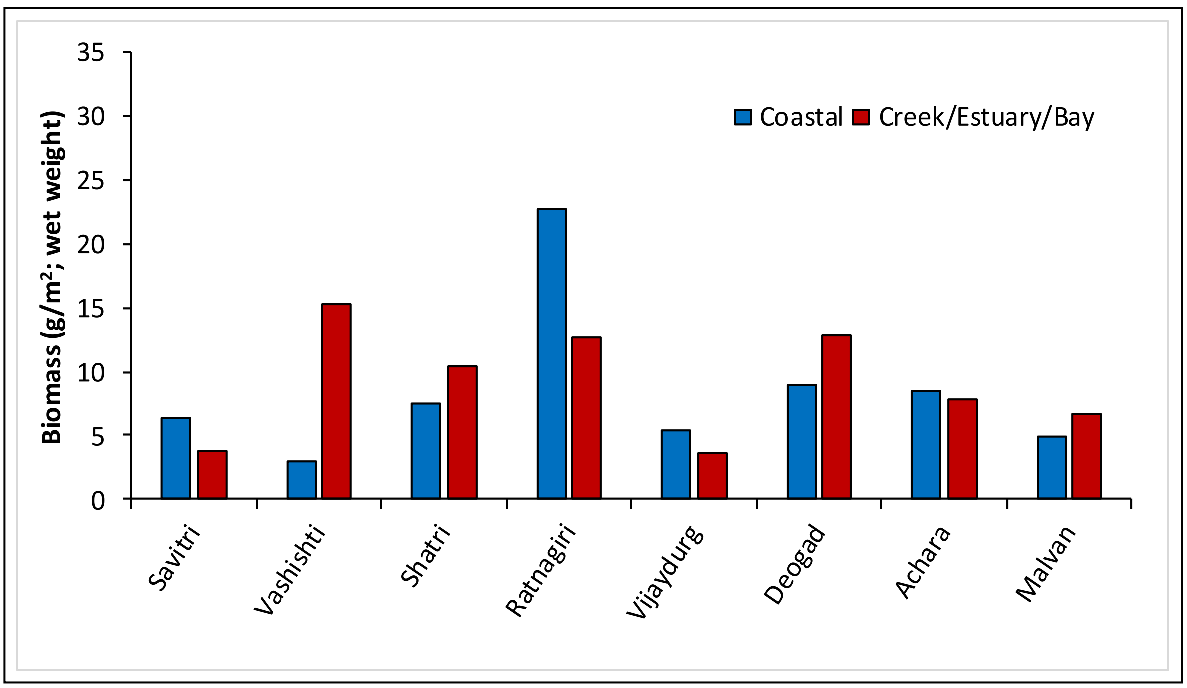


Figure 5.1.82: Average macrobenthic biomass along South Maharashtra coast.

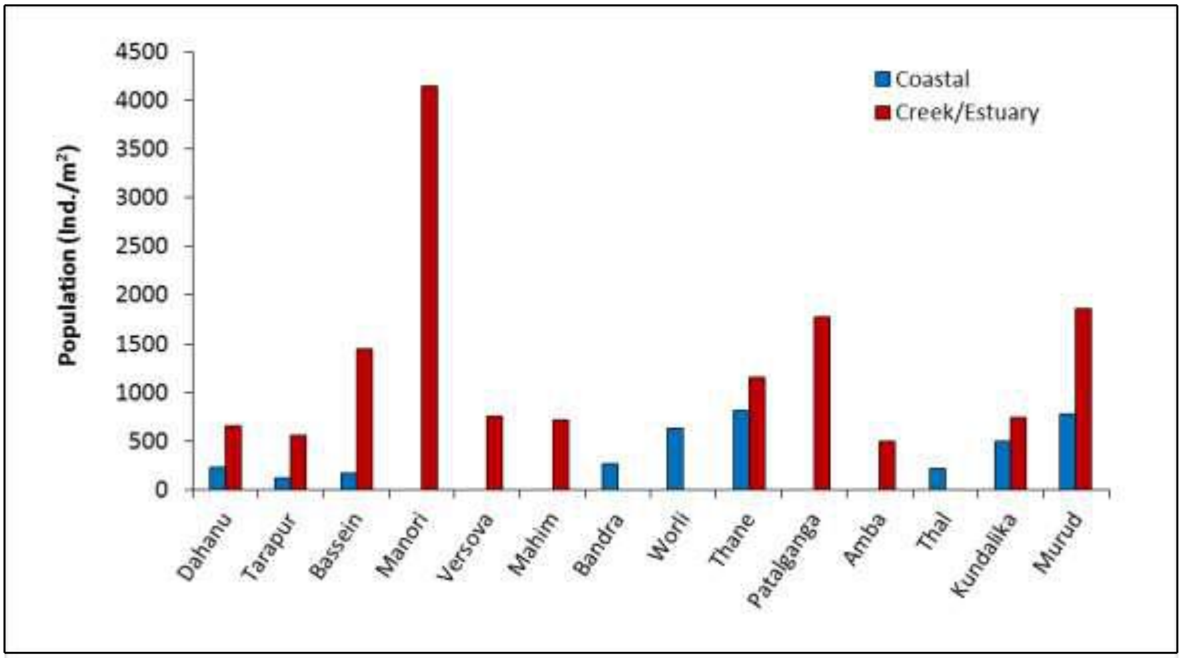


Figure 5.1.83: Average macrobenthic Population along North Maharashtra coast.

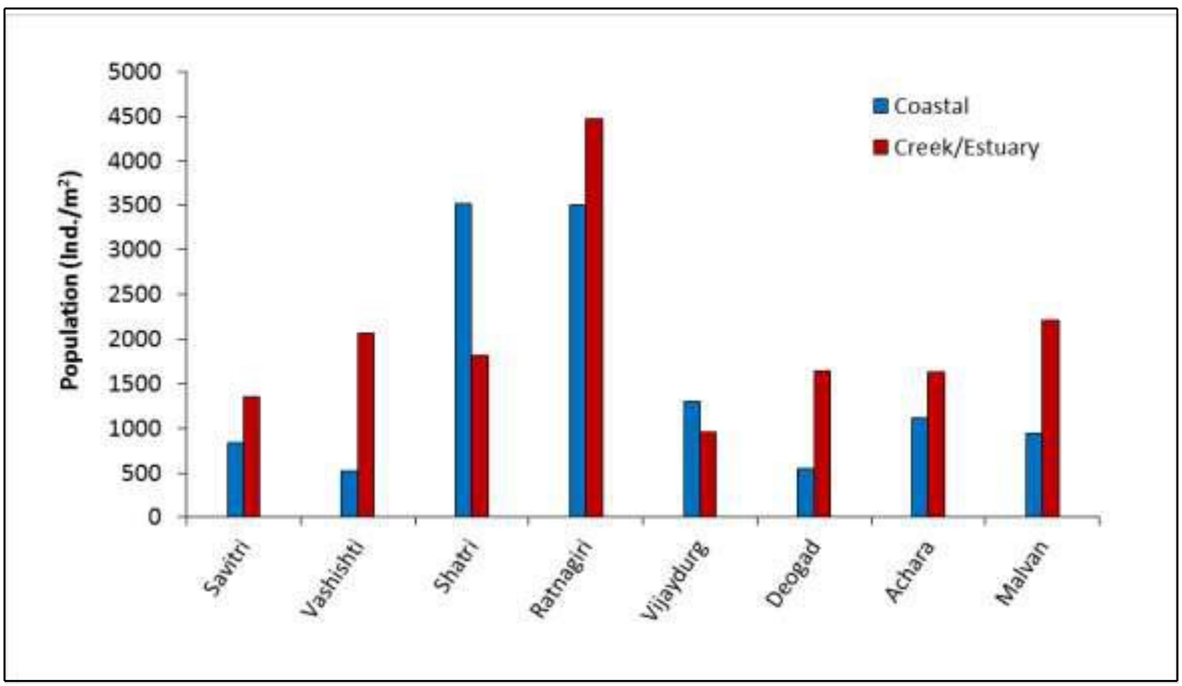


Figure 5.1.84: Average macrobenthic Population along South Maharashtra coast.

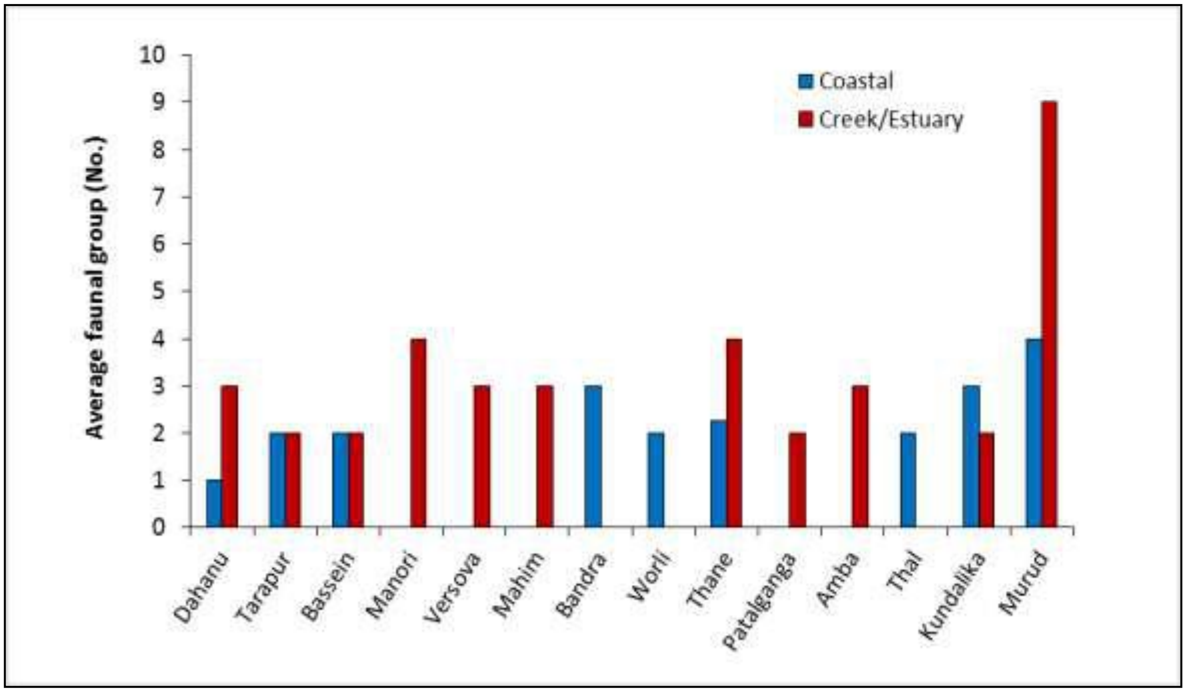


Figure 5.1.85: Average macrobenthic Faunal group along North Maharashtra coast.

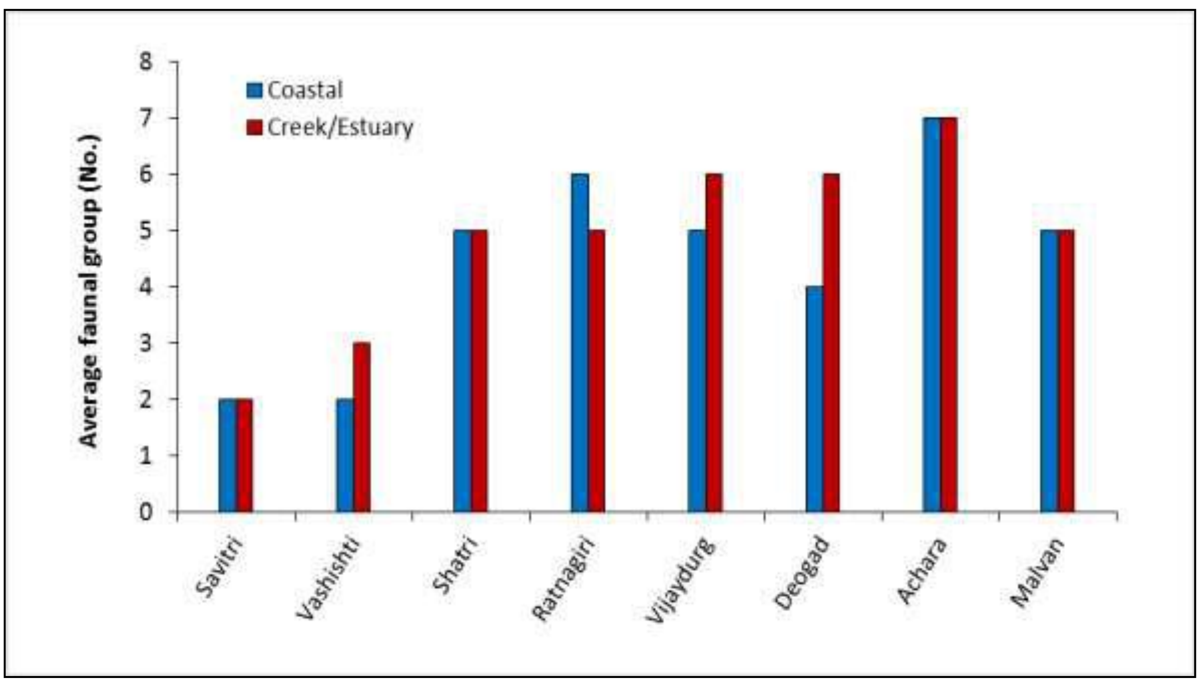


Figure 5.1.86: Average macrobenthic Faunal group along South Maharashtra coast.

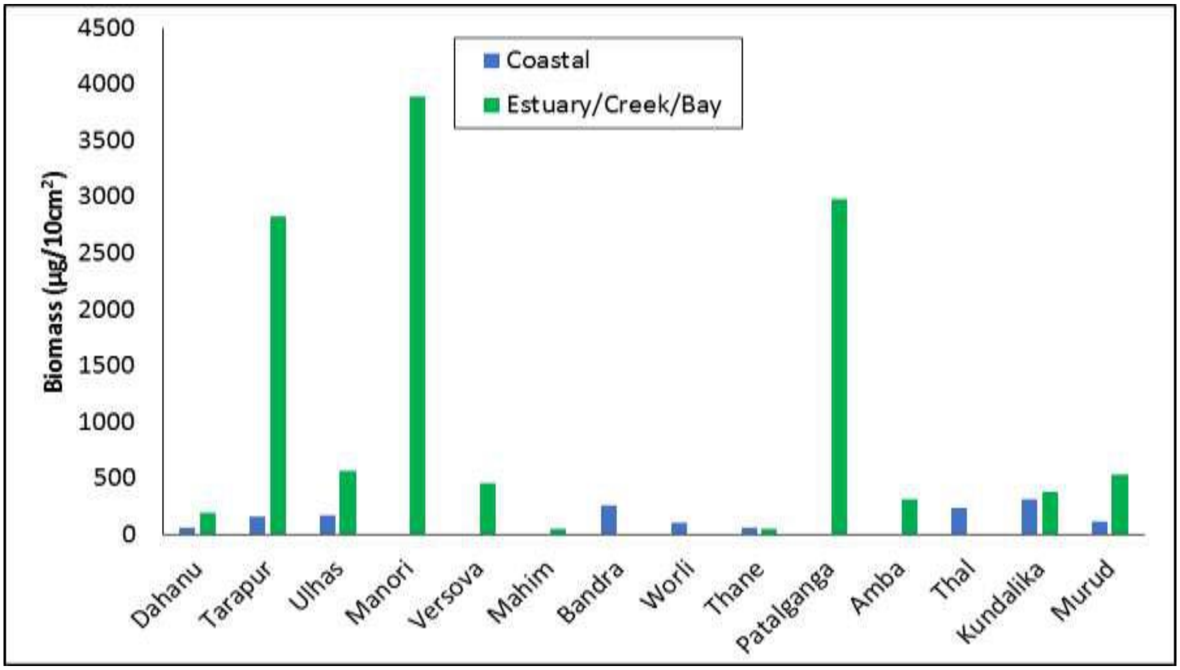


Figure 5.1.87: Average meiobenthic biomass along North Maharashtra coast.

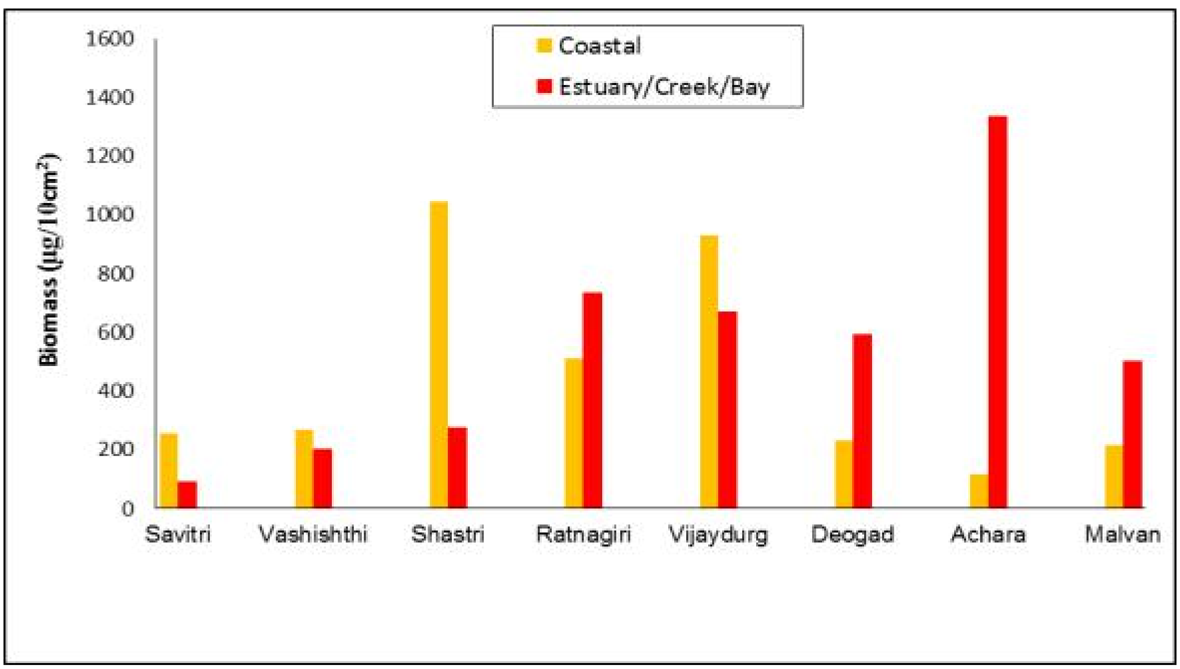


Figure 5.1.88: Average meiobenthic biomass along South Maharashtra coast.

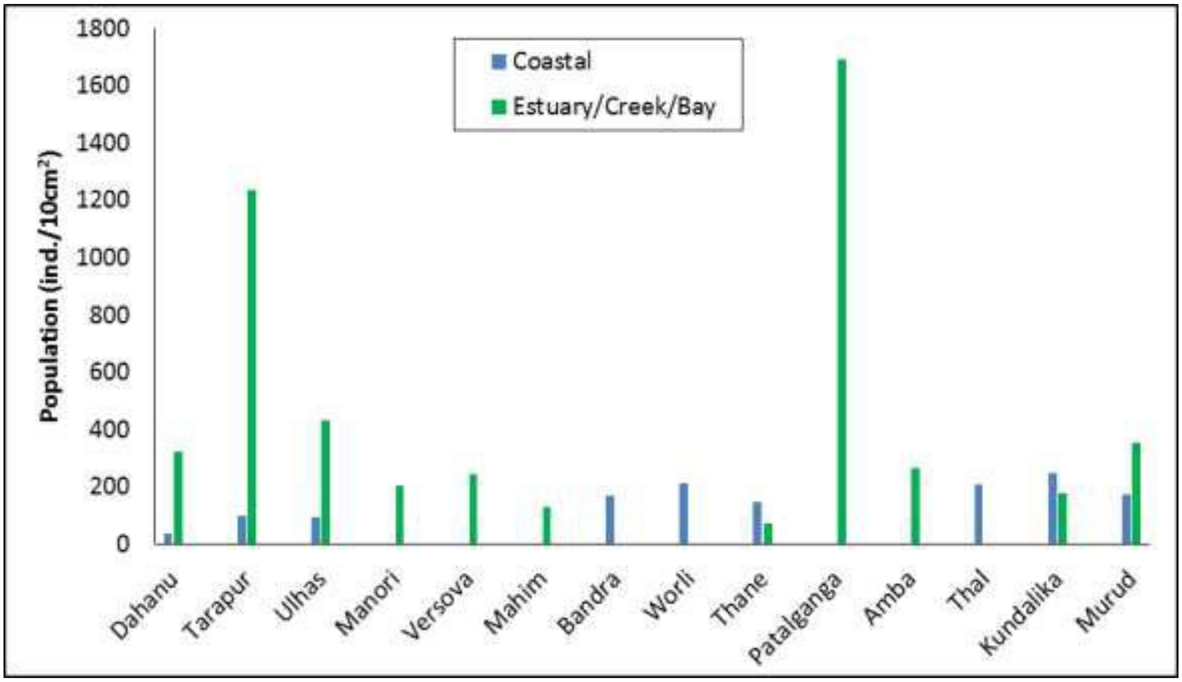


Figure 5.1.89: Average meiobenthic Population along North Maharashtra coast.

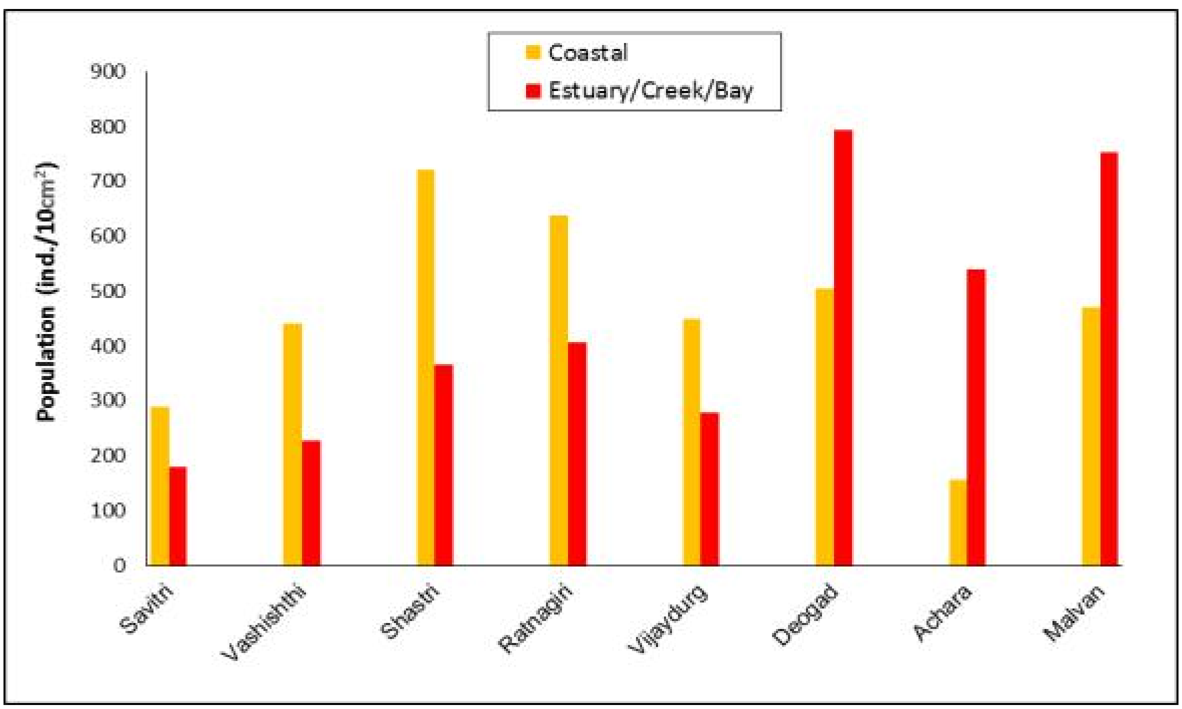


Figure 5.1.90: Average meiobenthic Population along North Maharashtra coast.

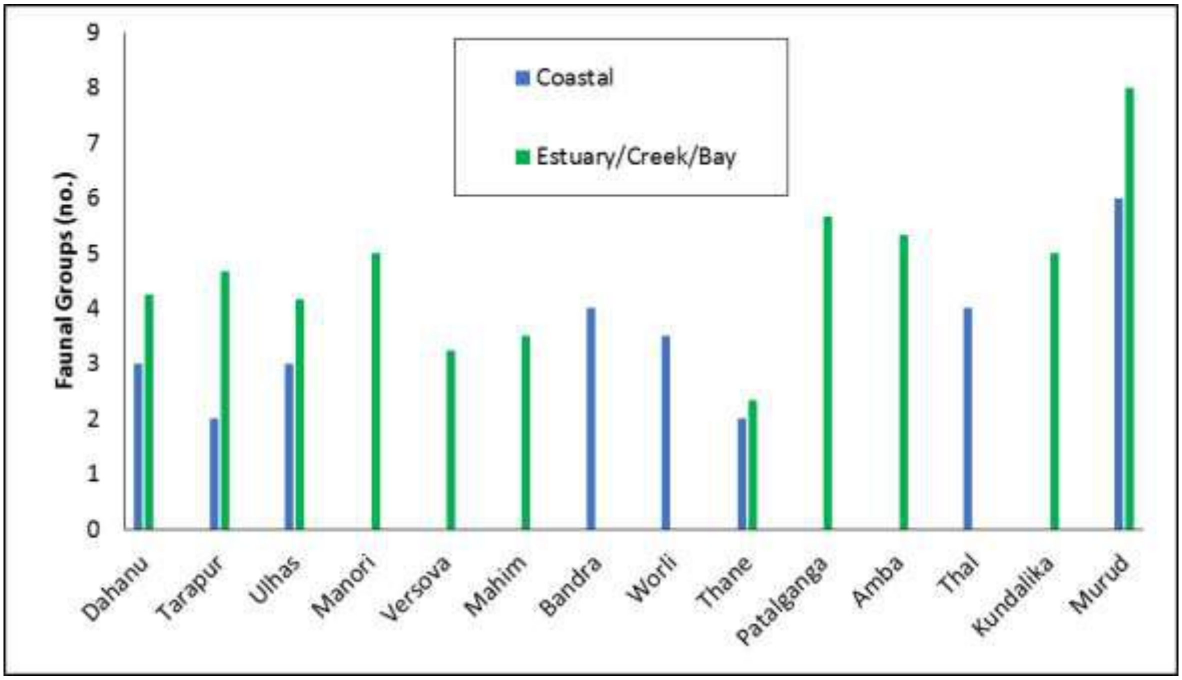


Figure 5.1.91: Average meiobenthic Faunal group along North Maharashtra coast.

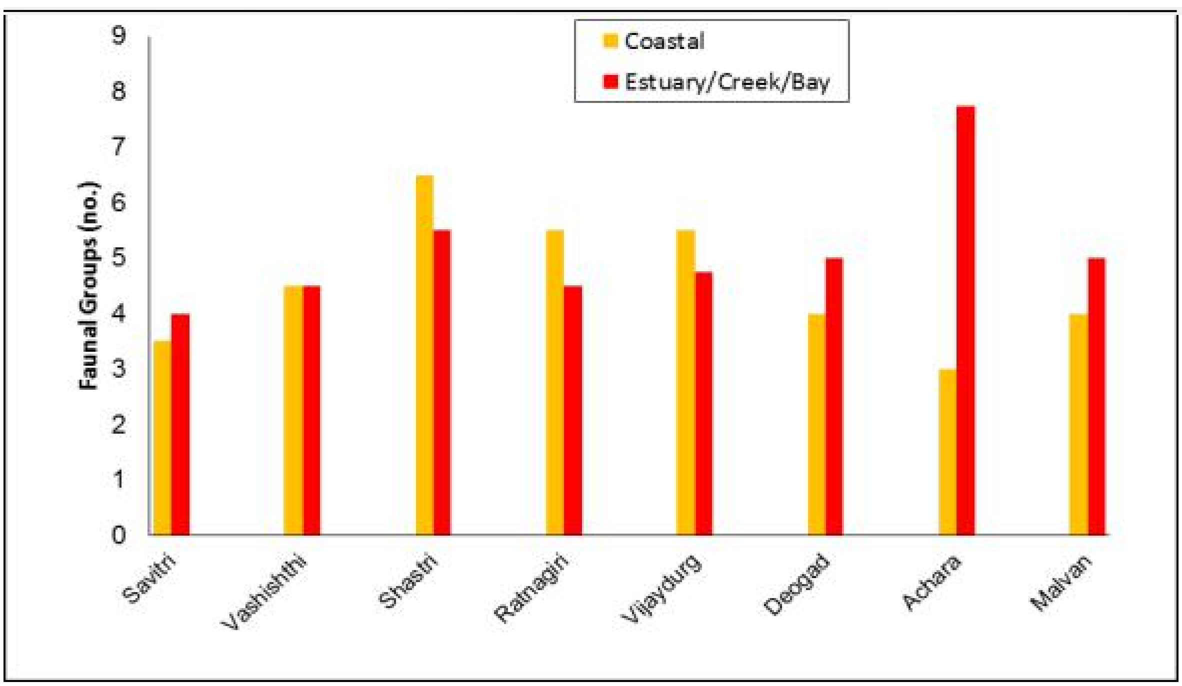


Figure 5.1.92: Average meiobenthic Faunal group along South Maharashtra coast.

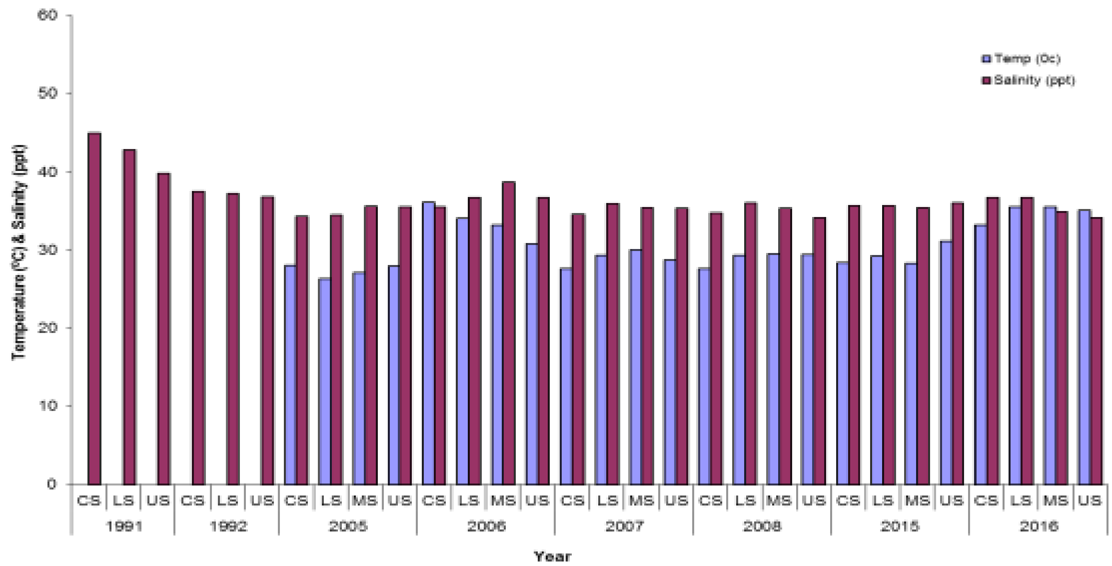


Figure 5.2.1: Temperature (°C) & Salinity (ppt) in Dhanu Creek (1991-2016).

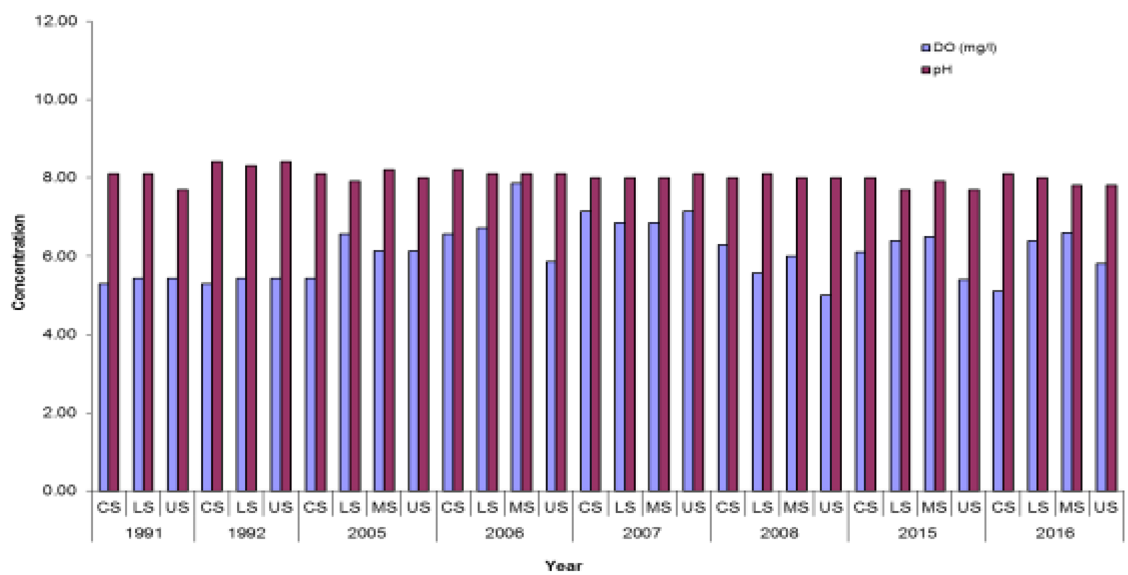


Figure 5.2.2: Concentration of DO (mg/l) & pH in Dahanu Creek (1991-2016).

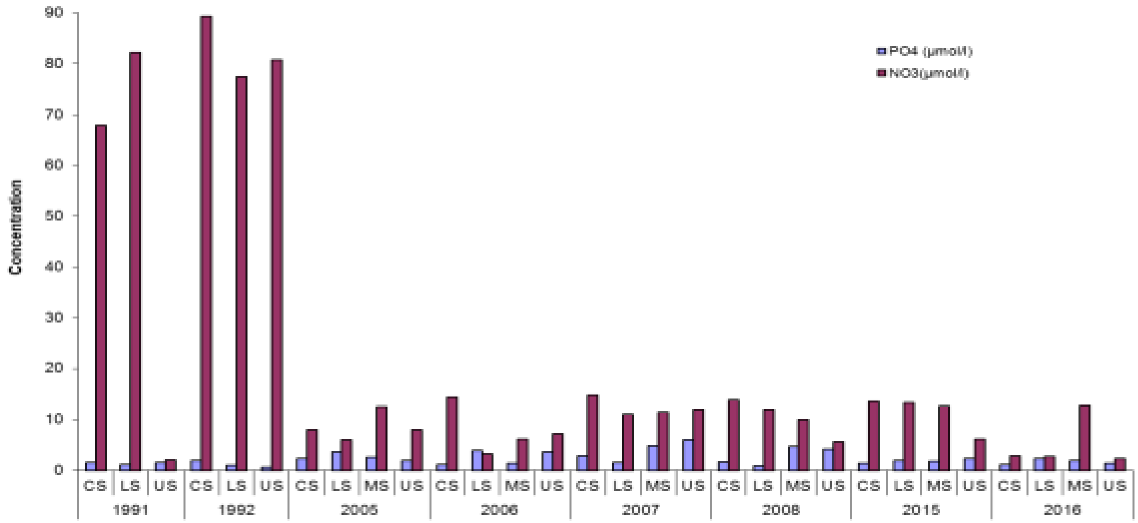


Figure 5.2.3: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Dhanu Creek (1991-2016).

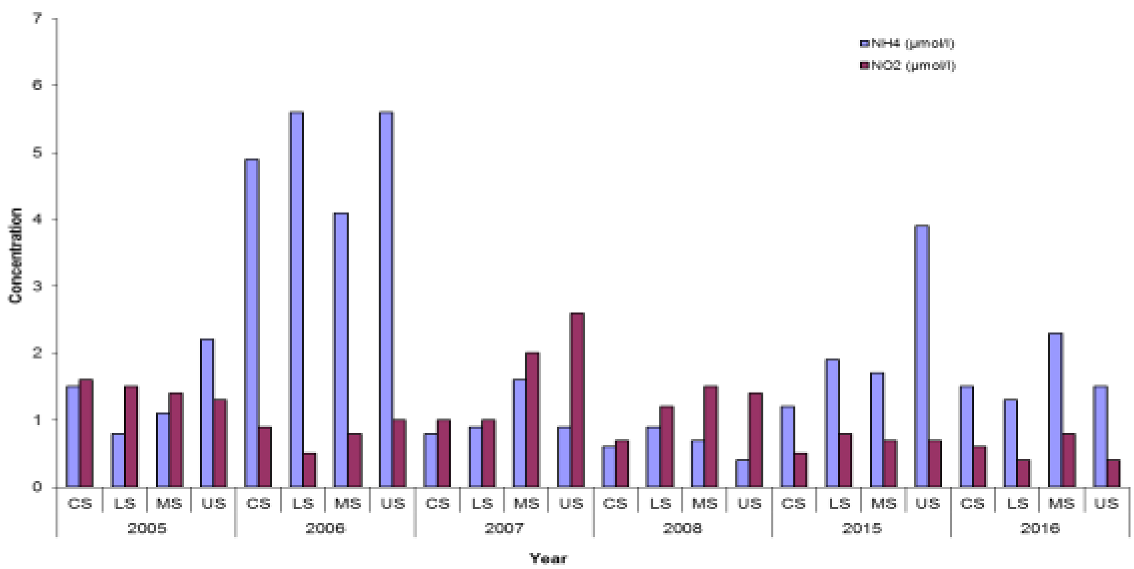


Figure 5.2.4: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Dhanu Creek (2005-2016).

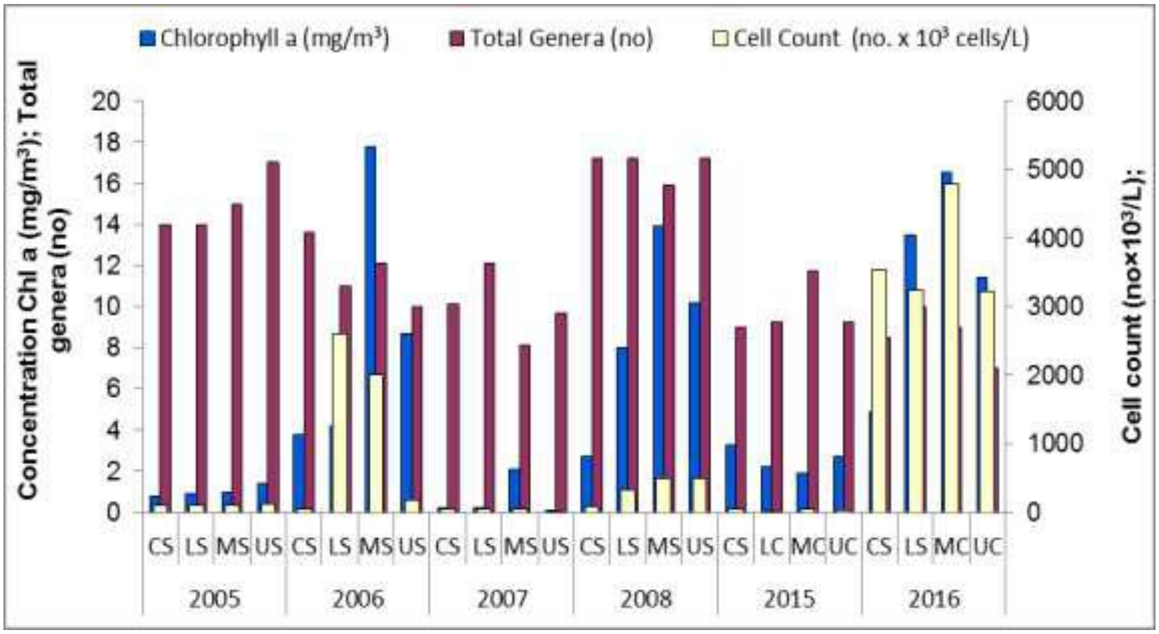


Figure 5.2.5: Comparative phytopigment and generic diversity of Dahanu Creek (2005-2016).

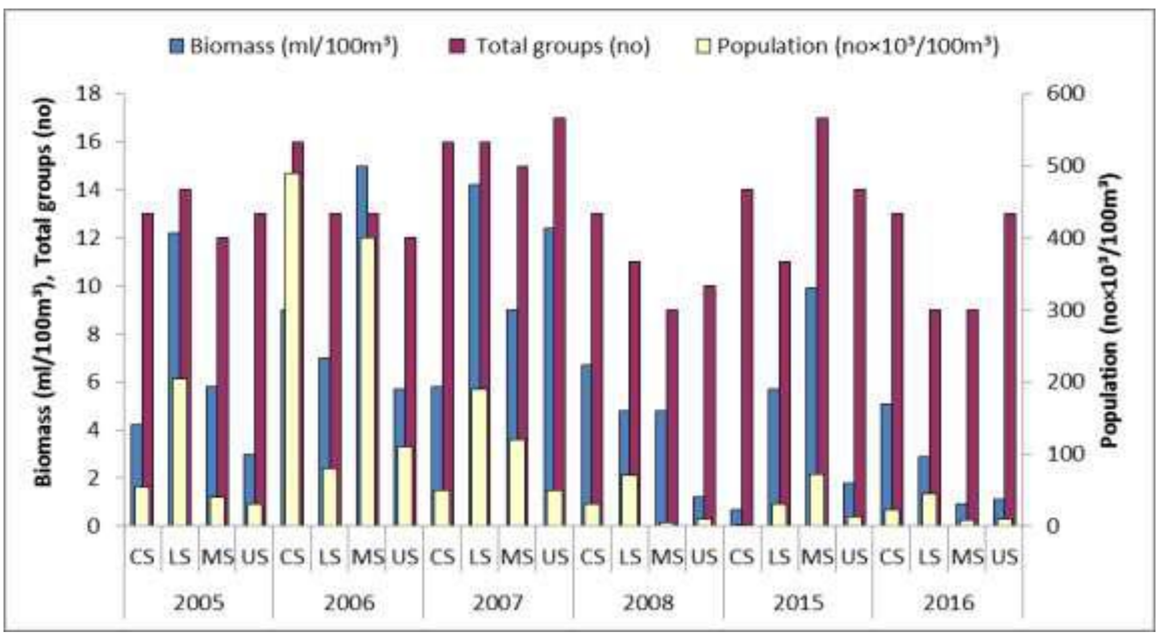


Figure 5.2.6: Comparative zooplankton biomass, population and group diversity of Dahanu Creek (2005-2016).

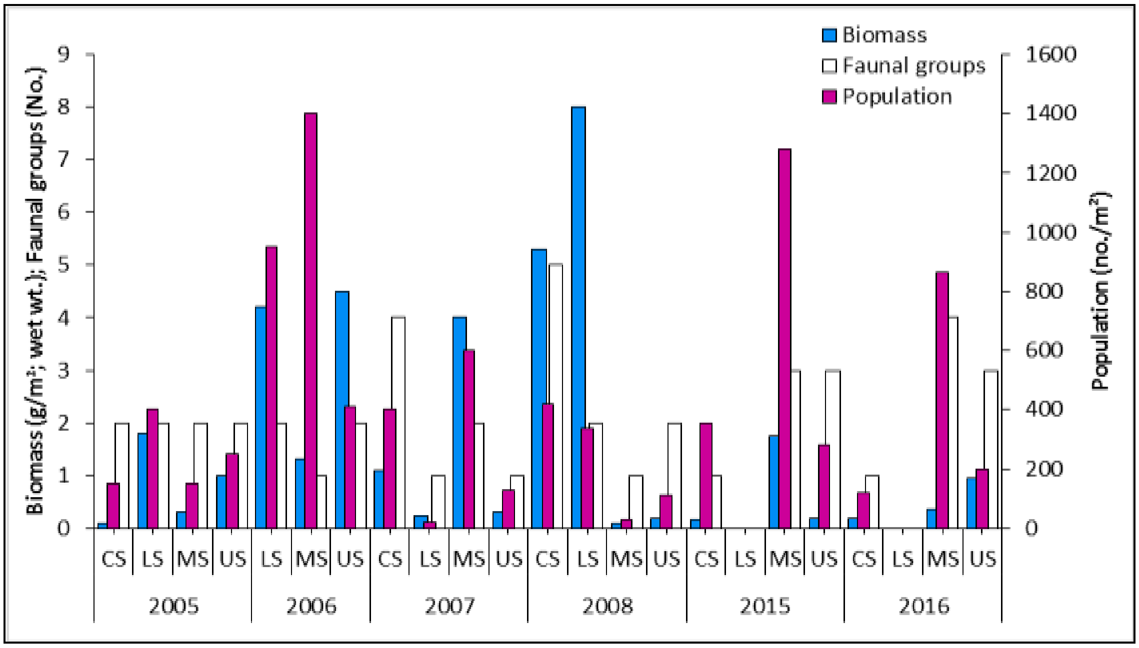


Figure 5.2.7: Comparative macrobenthos biomass, population and group diversity of Dahanu Creek (2005-2016).

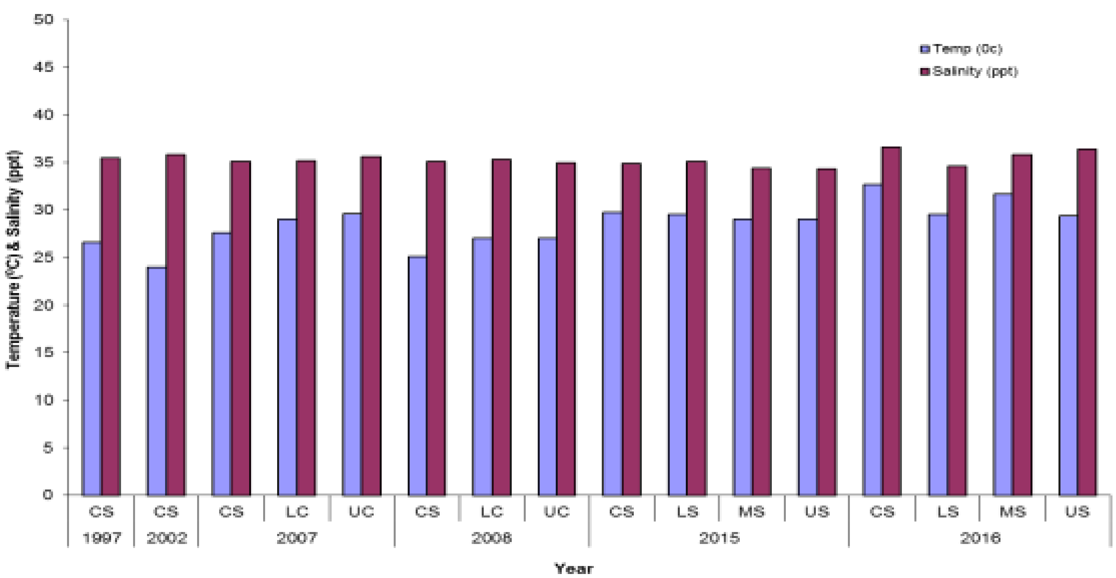


Figure 5.2.8: Temperature (°C) & Salinity (ppt) in Tarapur (1997-2016).

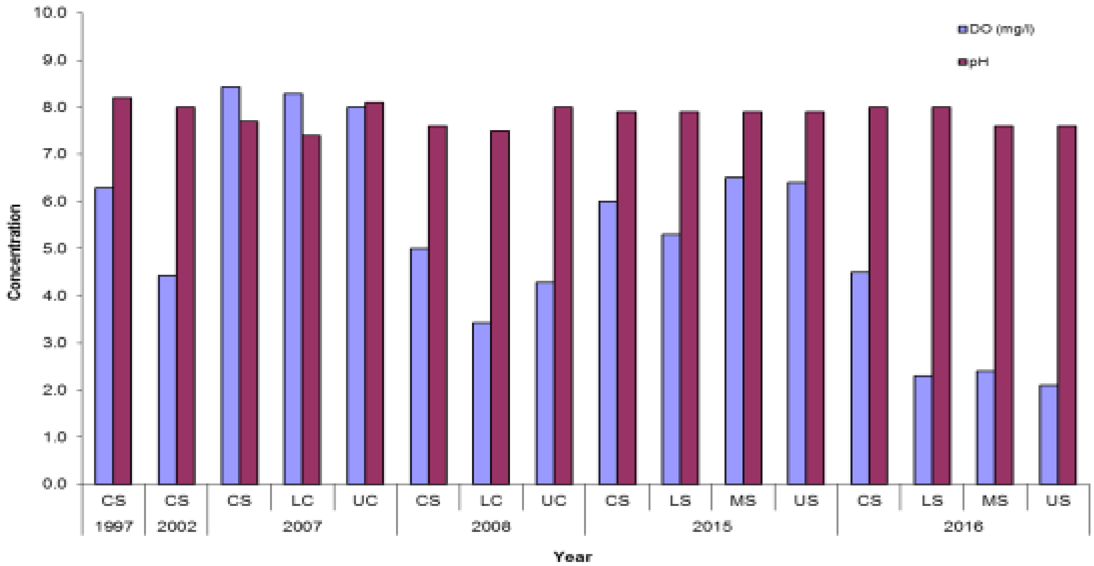


Figure 5.2.9: Concentration of DO (mg/l) & pH in Tarapur (1997-2016).

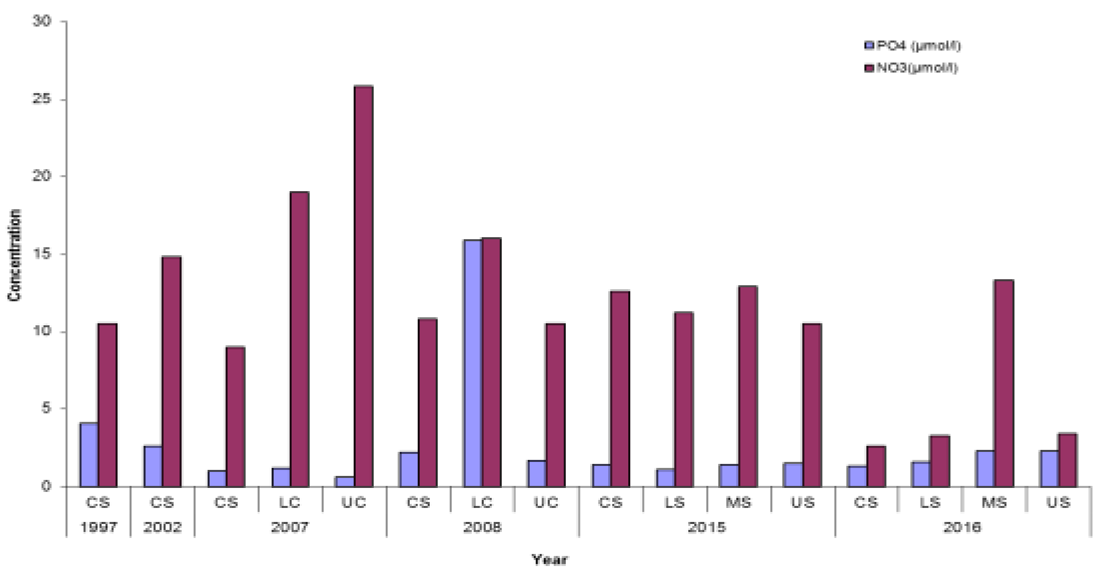


Figure 5.2.10: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Tarapur (1997-2016).

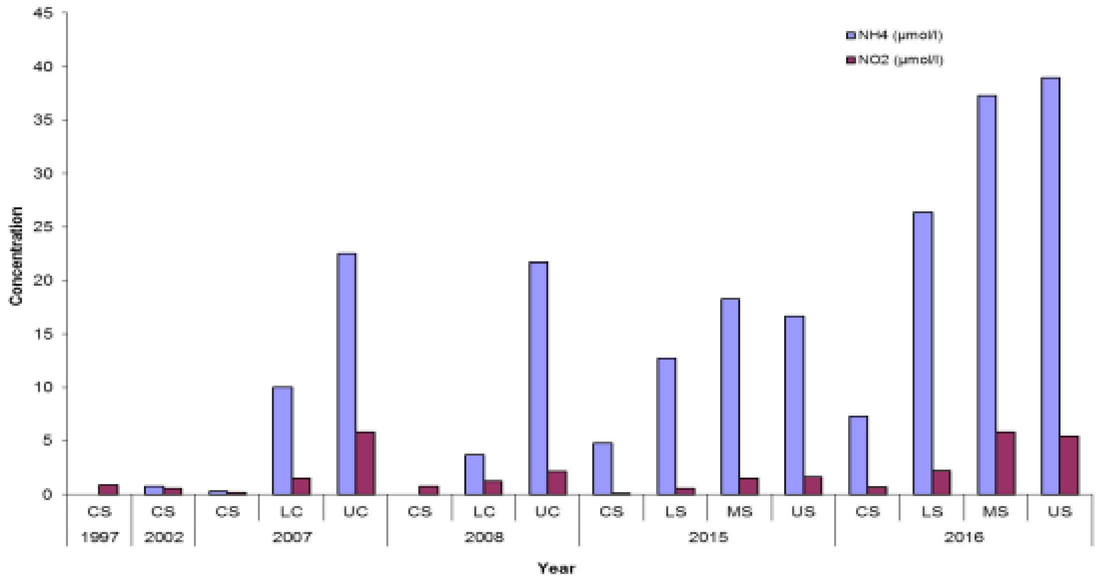


Figure 5.2.11: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Tarapur (1997-2016).

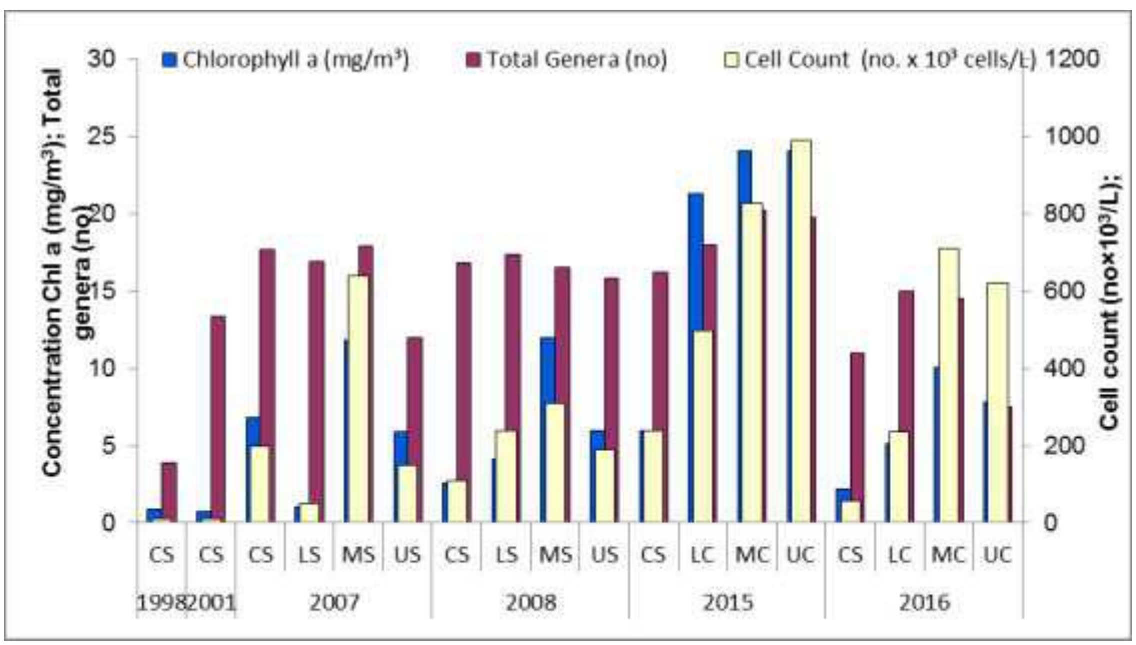


Figure 5.2.12: Comparative phytopigment and generic diversity of Tarapur (1998-2016).

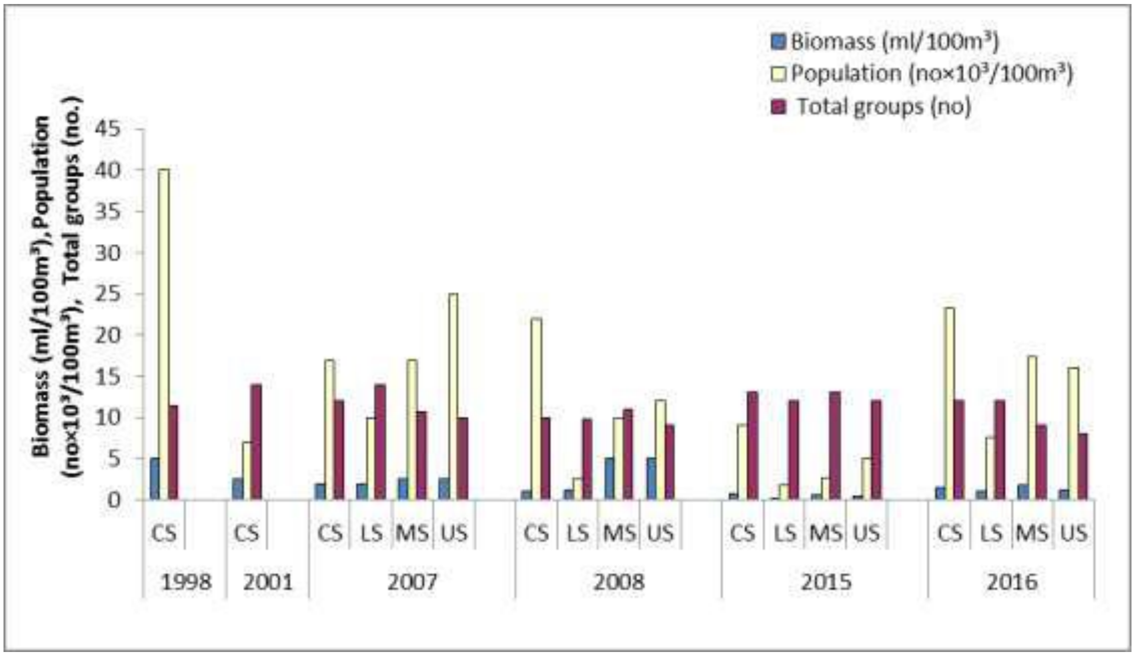


Figure 5.2.13: Comparative zooplanktonbiomass, population and group diversity of Tarapur (1998-2016).

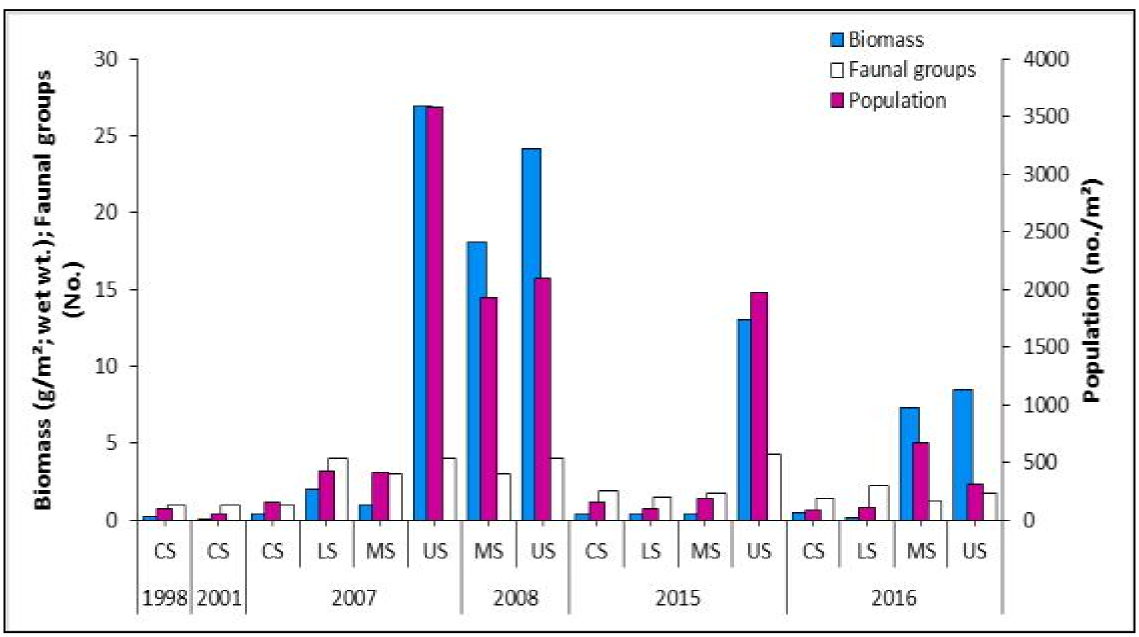


Figure 5.2.14: Comparative macrobenthos biomass, population and group diversity of Tarapur (1998-2016).

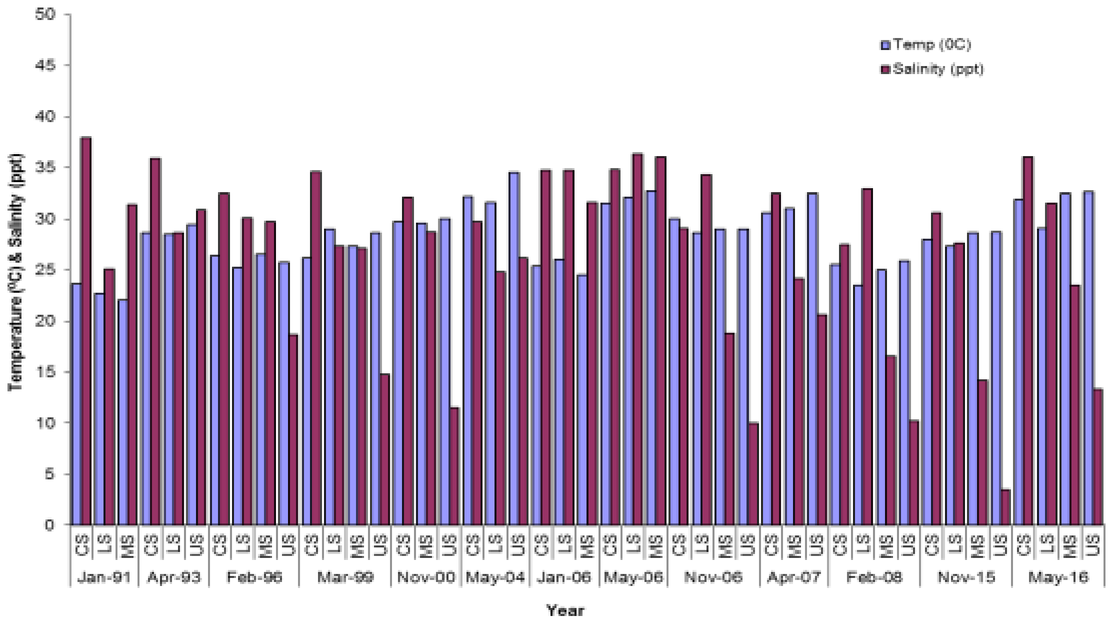


Figure 5.2.15: Temperature (°C) & Salinity (ppt) in Bassein/Ulhas Estuary (1991-2016).

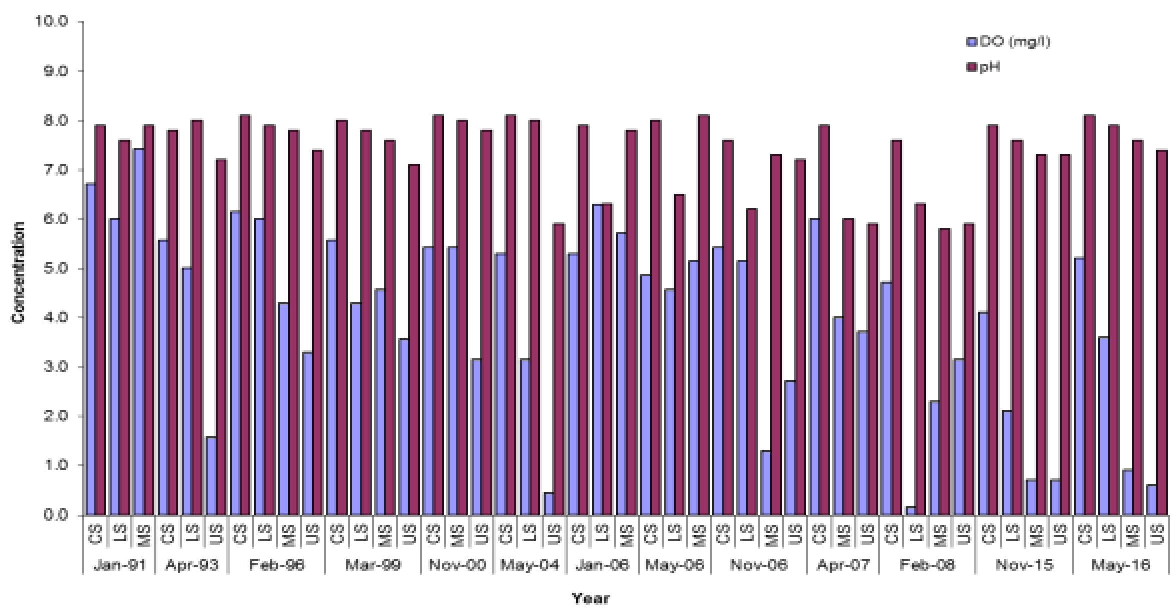


Figure 5.2.16: Concentration of DO (mg/l) & pH in Bassein/Ulhas Estuary (1991-2016).

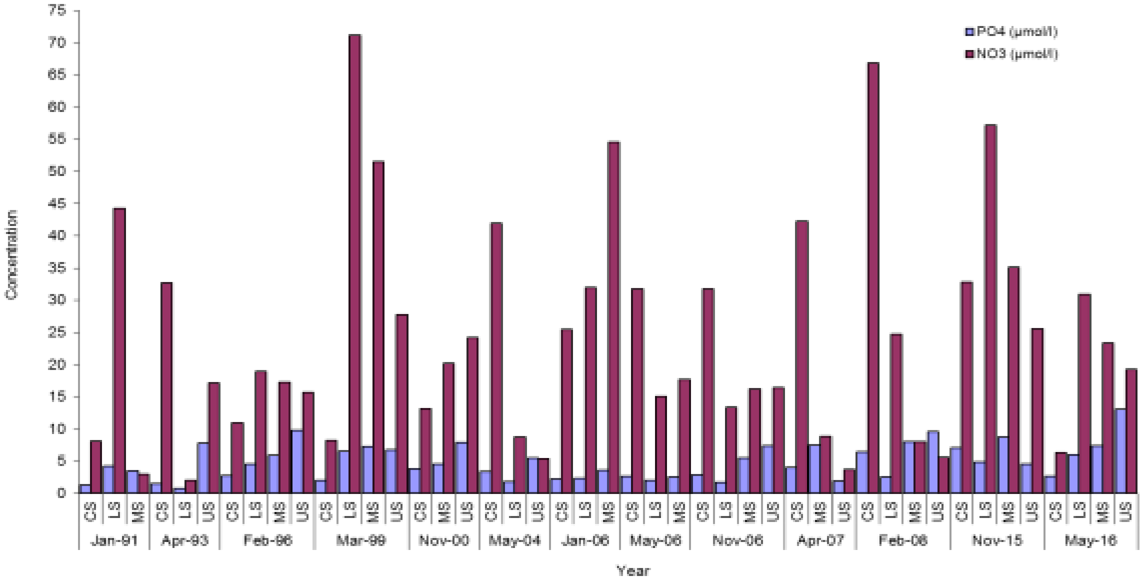


Figure 5.2.17: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Bassein/Ulhas Estuary (1991-2016).

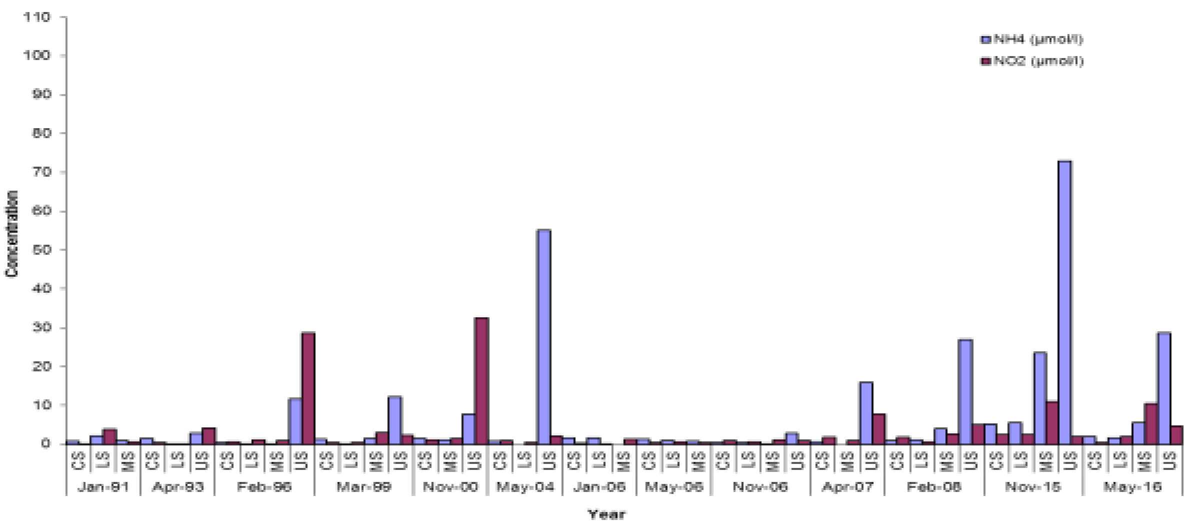


Figure 5.2.18: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Bassein/Ulhas Estuary (1991-2016).

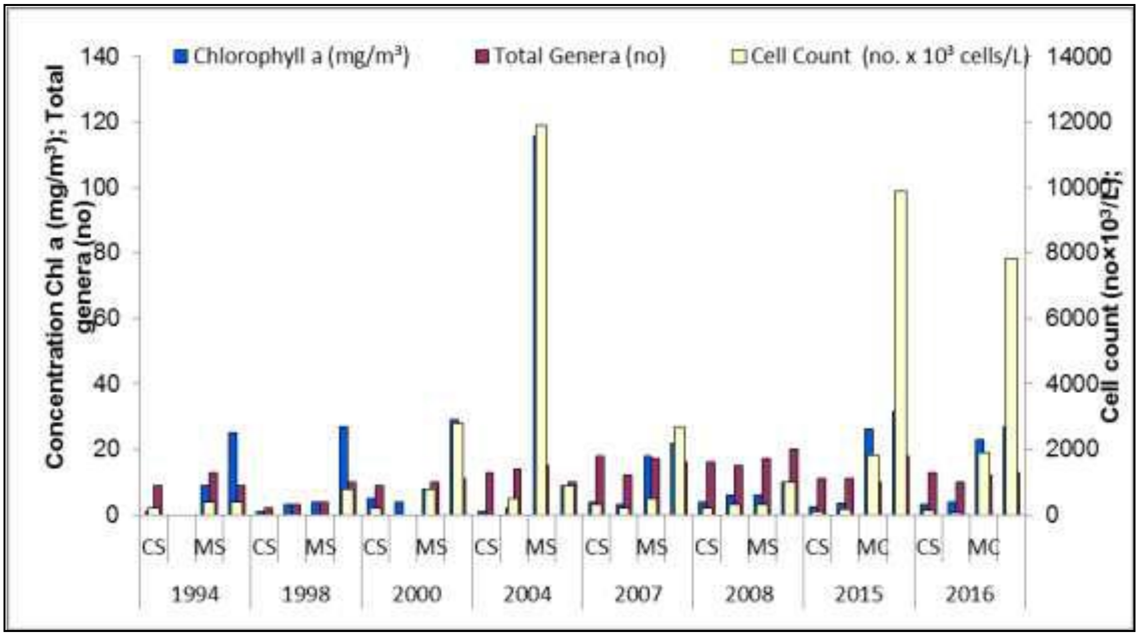


Figure 5.2.19: Comparative phytopigment and generic diversity of Bassein/Ulhas Estuary (1994-2016).

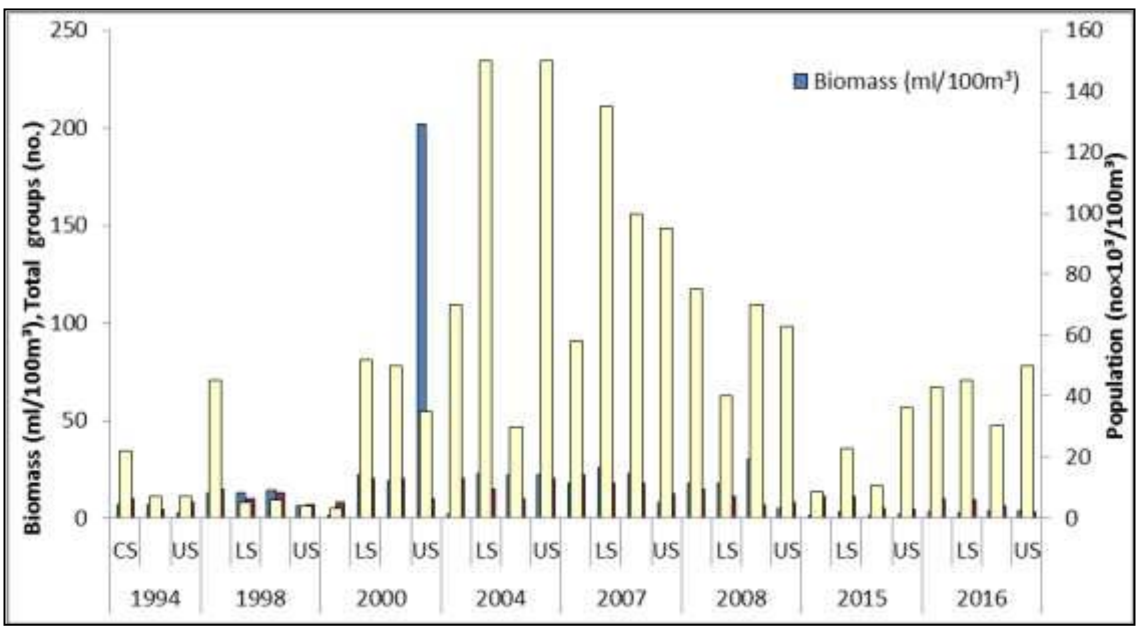


Figure 5.2.20: Comparative zooplankton biomass, population and group diversity of Bassein/Ulhas Estuary (1994-2016).

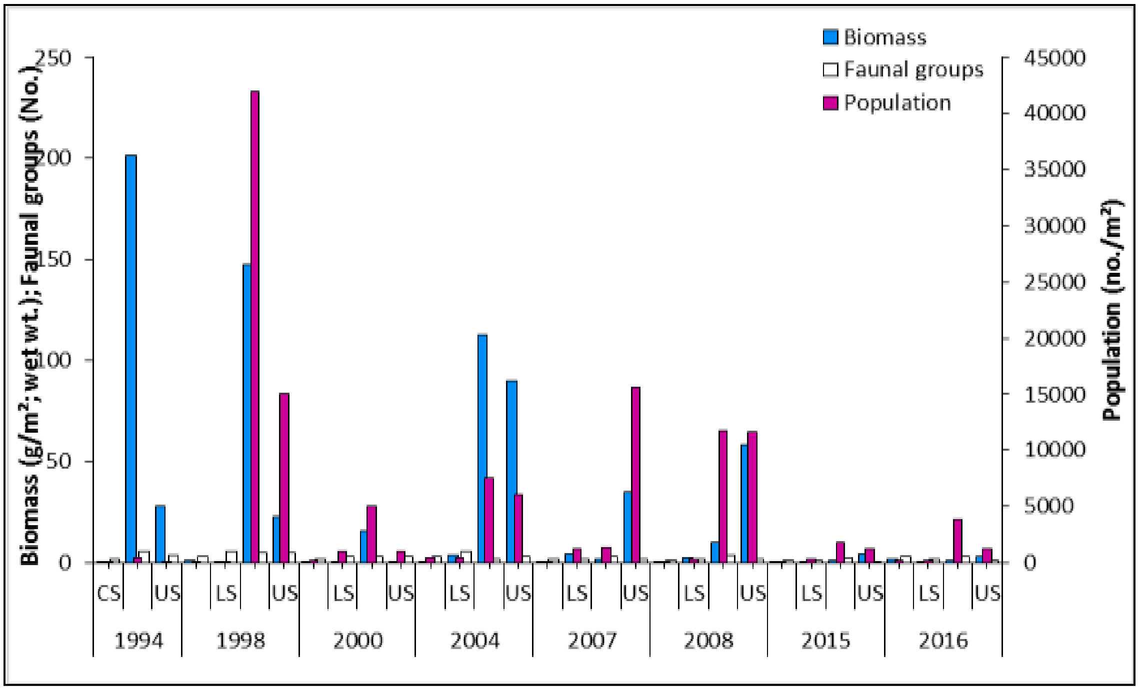


Figure 5.2.21: Comparative macrobenthos biomass, population and group diversity of Bassein/Ulhas Estuary (1994-2016).

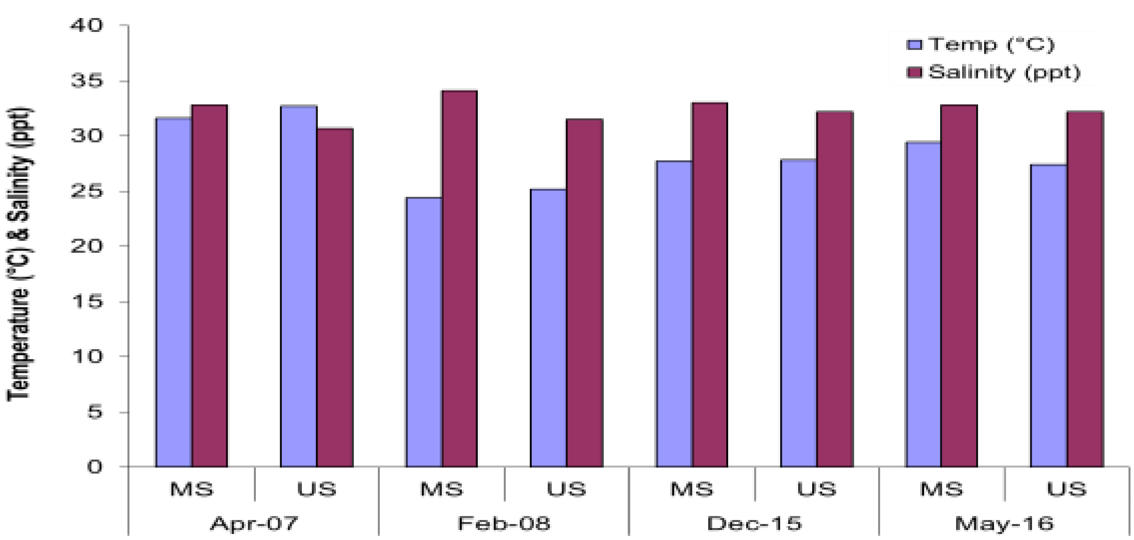


Figure 5.2.22: Temperature (°C) & Salinity (ppt) in Manori (2007-2016).

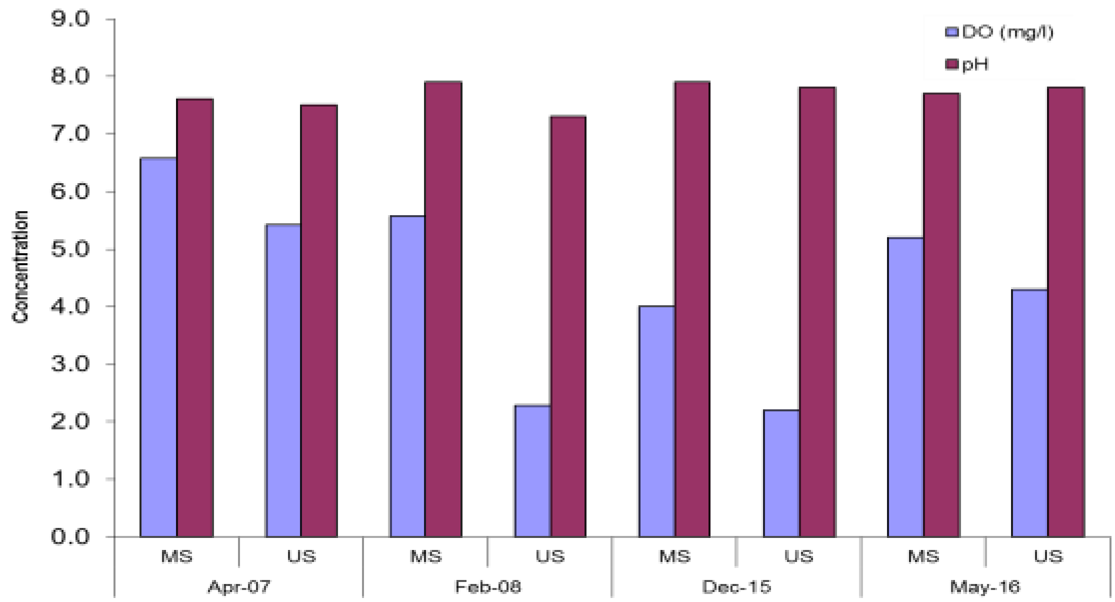


Figure 5.2.23: Concentration of DO (mg/l) & pH in Manori (2007-2016).

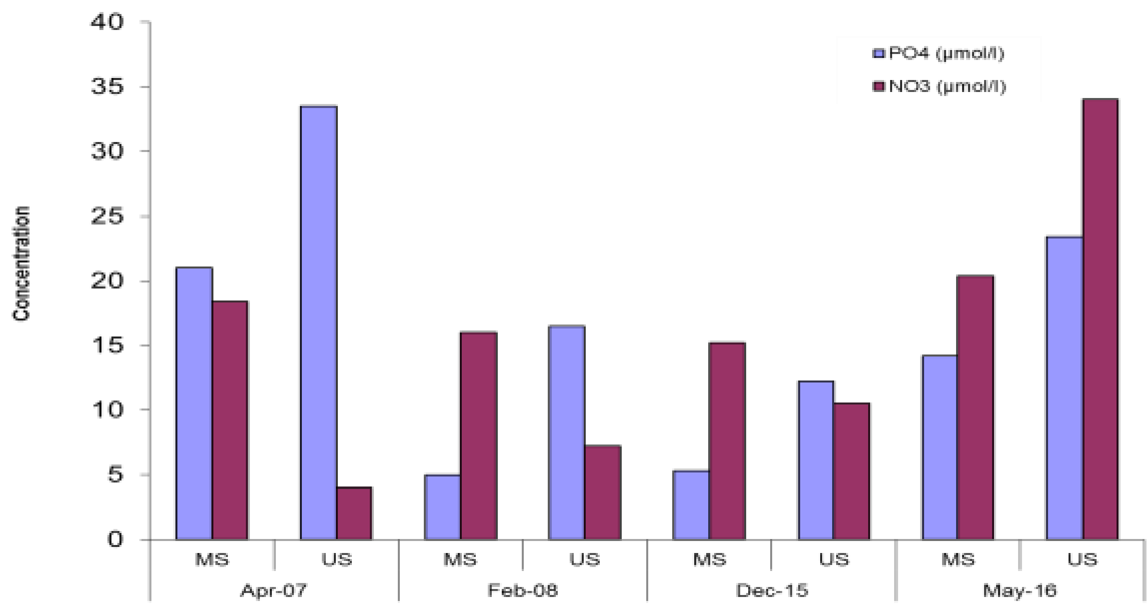


Figure 5.2.24: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Manori (2007-2016).

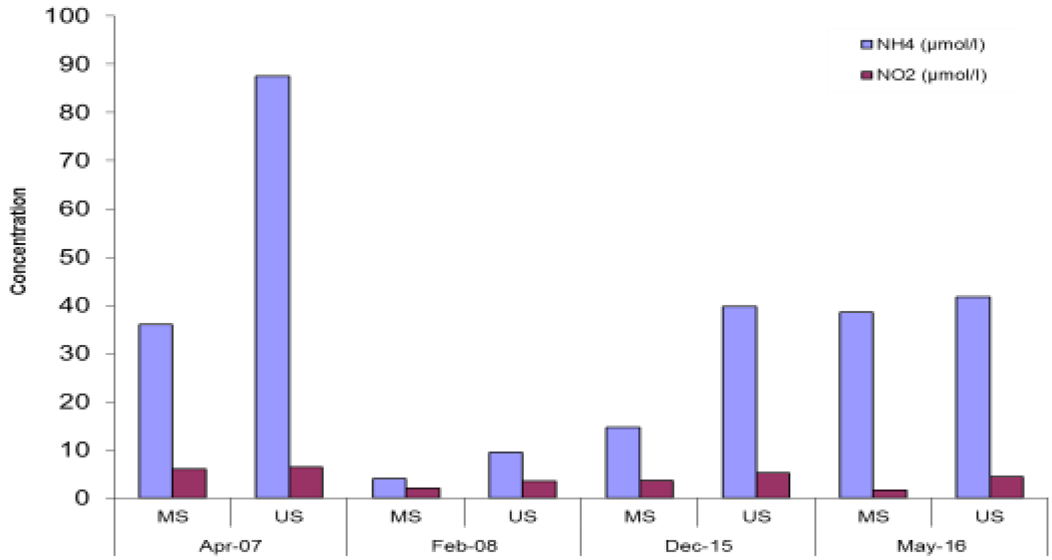


Figure 5.2.25: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Manori (2007-2016).

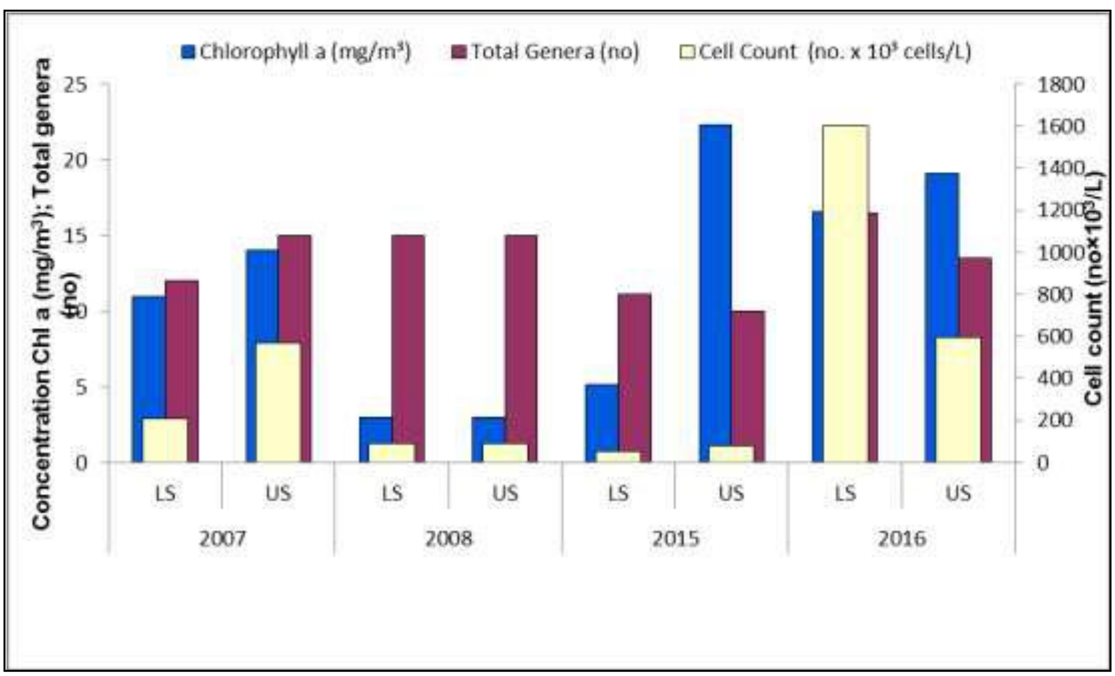


Figure 5.2.26: Comparative phytopigment and generic diversity of Manori (2007-2016).

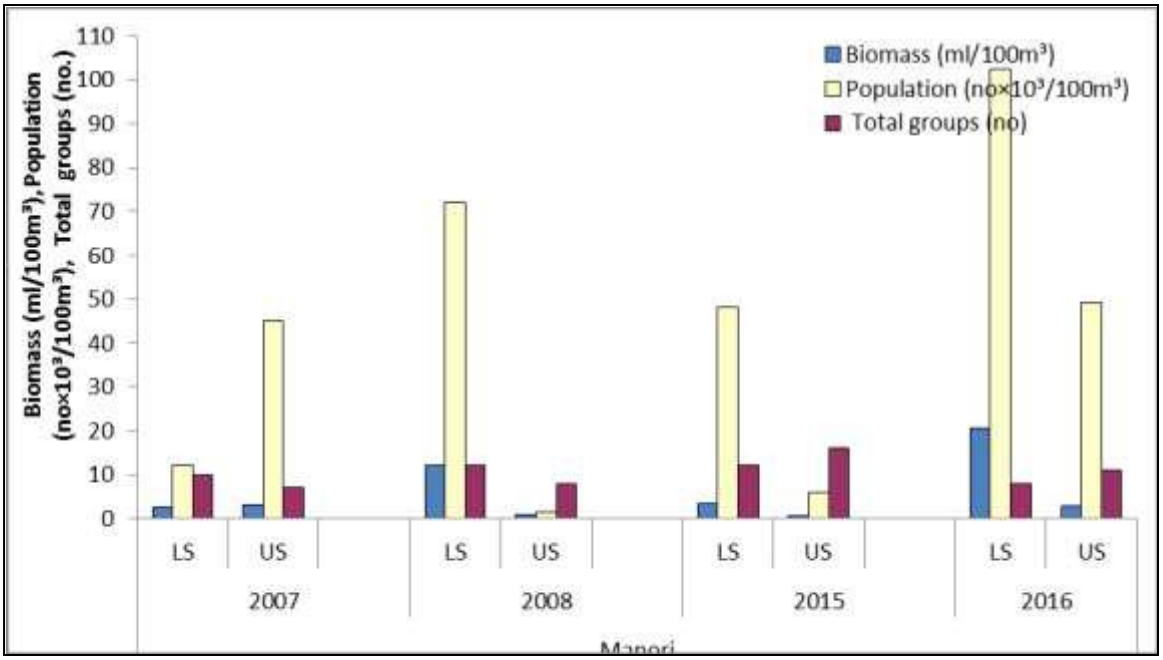


Figure 5.2.27: Comparative zooplankton biomass, population and group diversity of Manori (2007-2016).

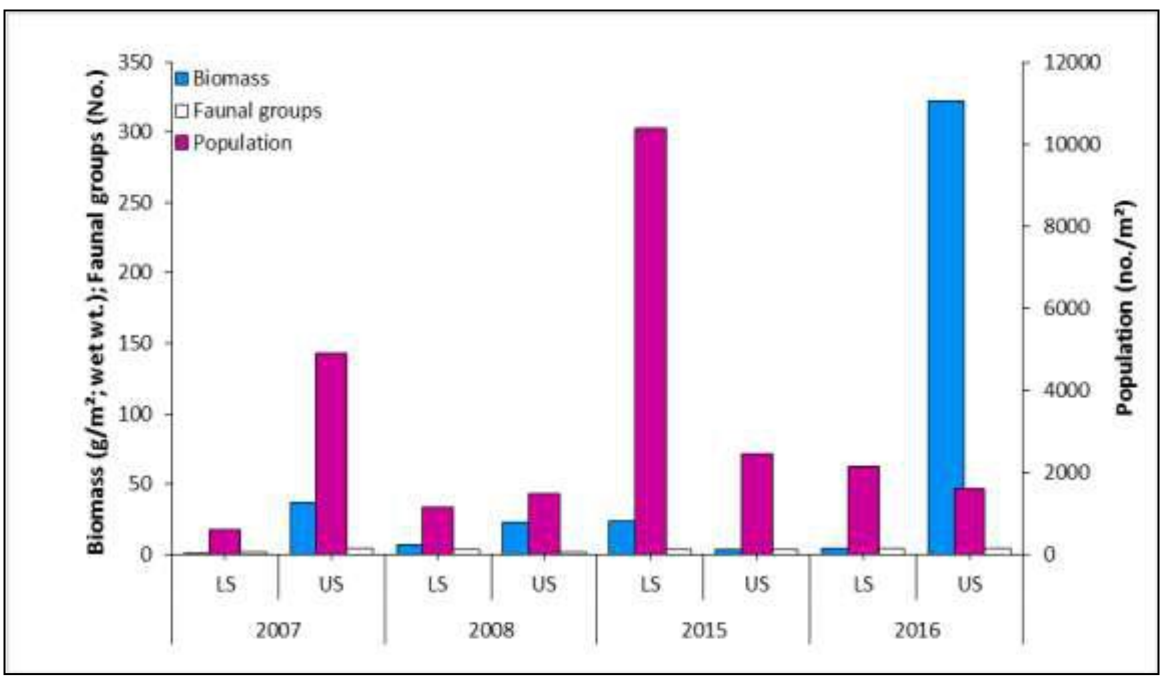


Figure 5.2.28: Comparative macrobenthos biomass, population and group diversity of Manori (2007-2016).

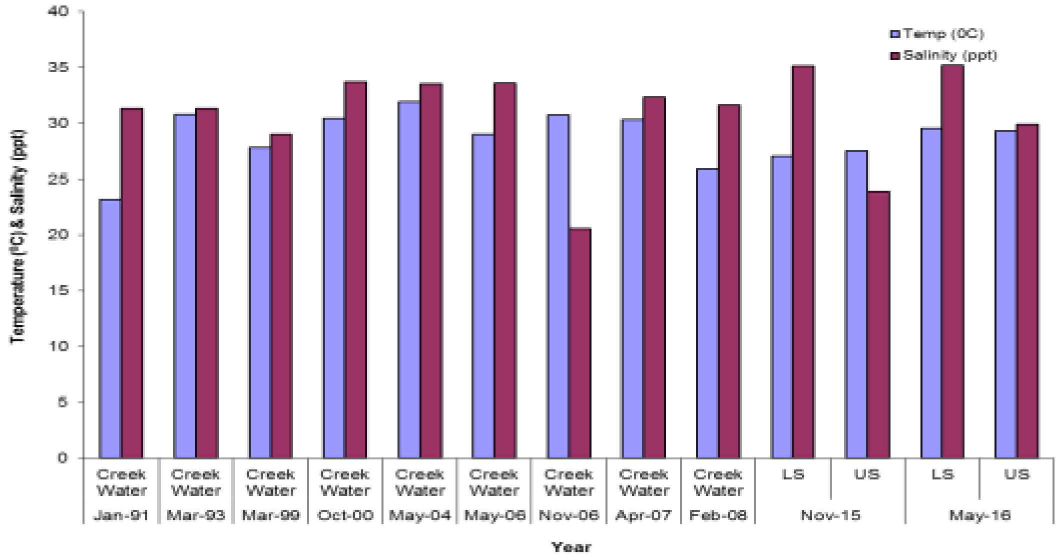


Figure 5.2.29: Temperature (°C) & Salinity (ppt) in Versova (1991-2016).

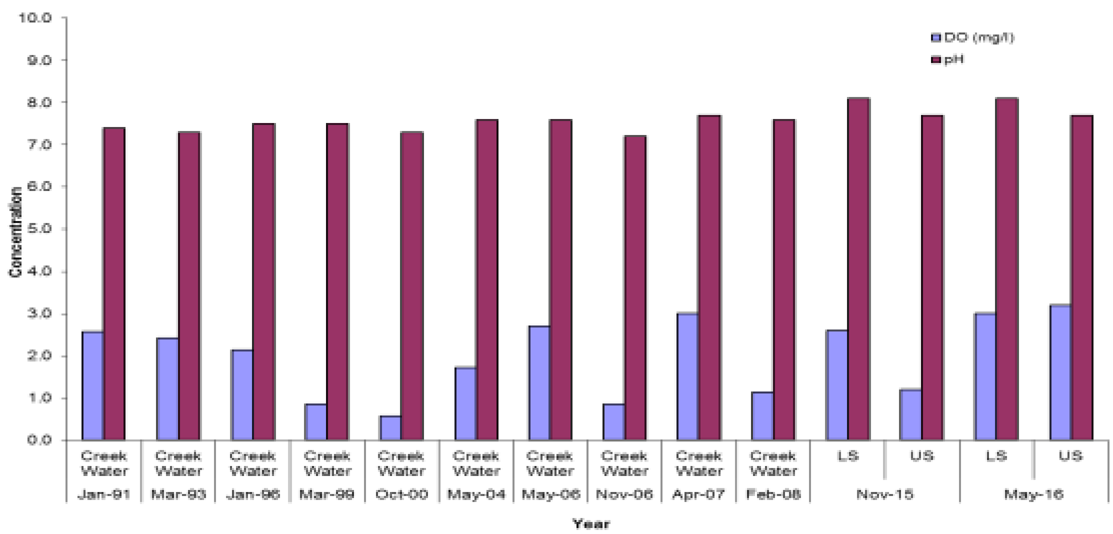


Figure 5.2.30: Concentration of DO (mg/l) & pH in Versova (1991-2016).

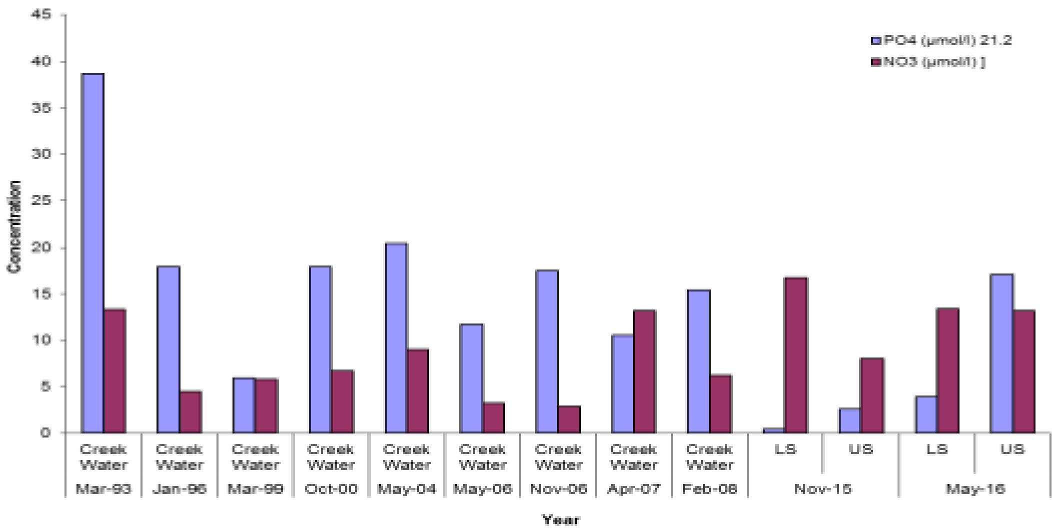


Figure 5.2.31: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Versova (1991-2016).

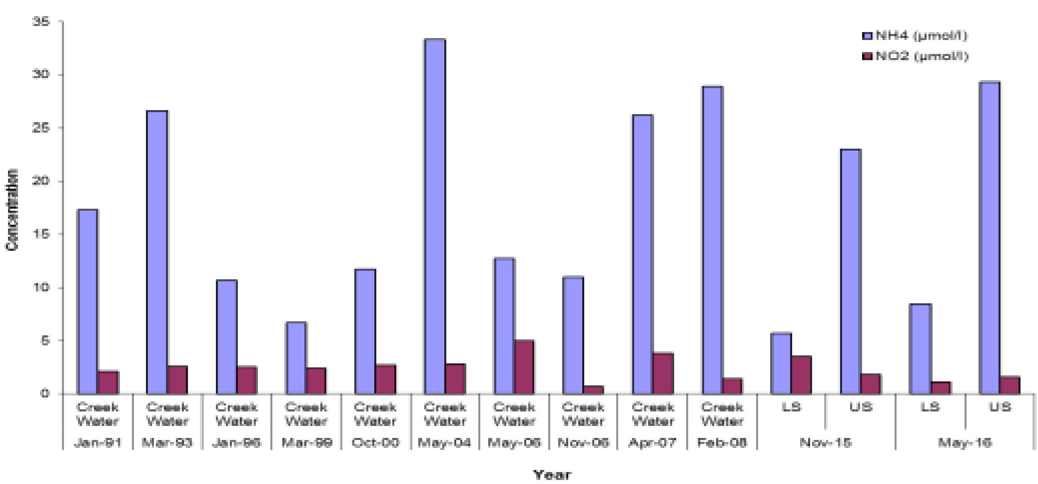


Figure 5.2.32: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in (1991-2016).

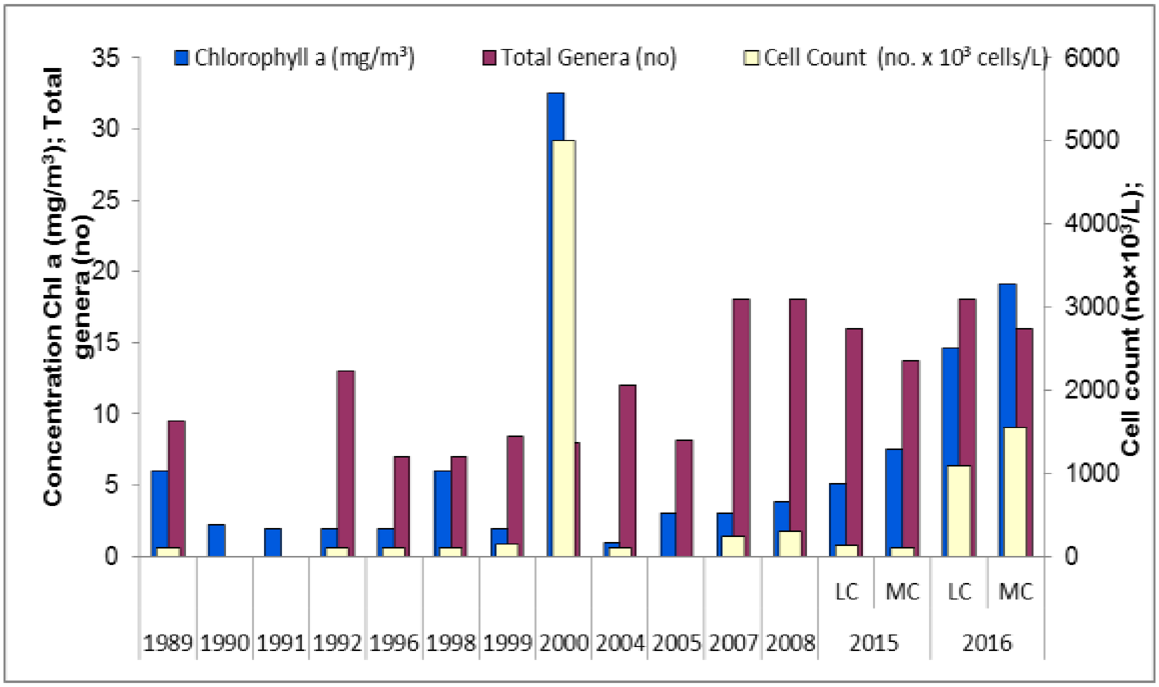


Figure 5.2.33: Comparative phytopigment and generic diversity of Versova (1989-2016).

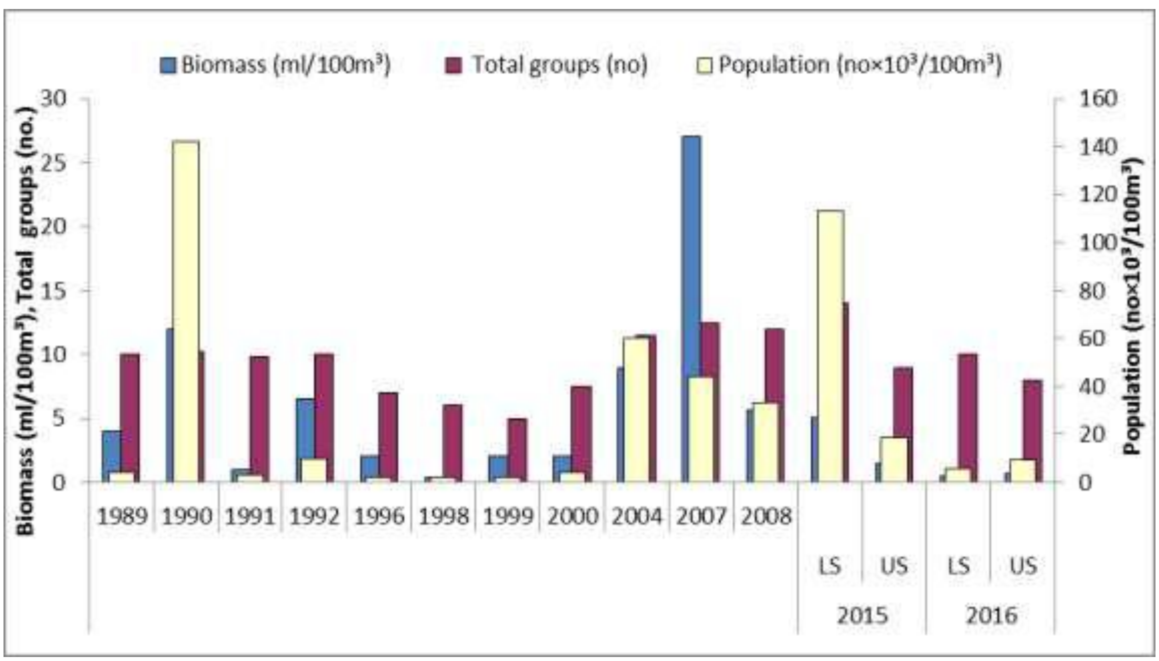


Figure 5.2.34: Comparative zooplankton biomass, population and group diversity of Versova (1989-2016).

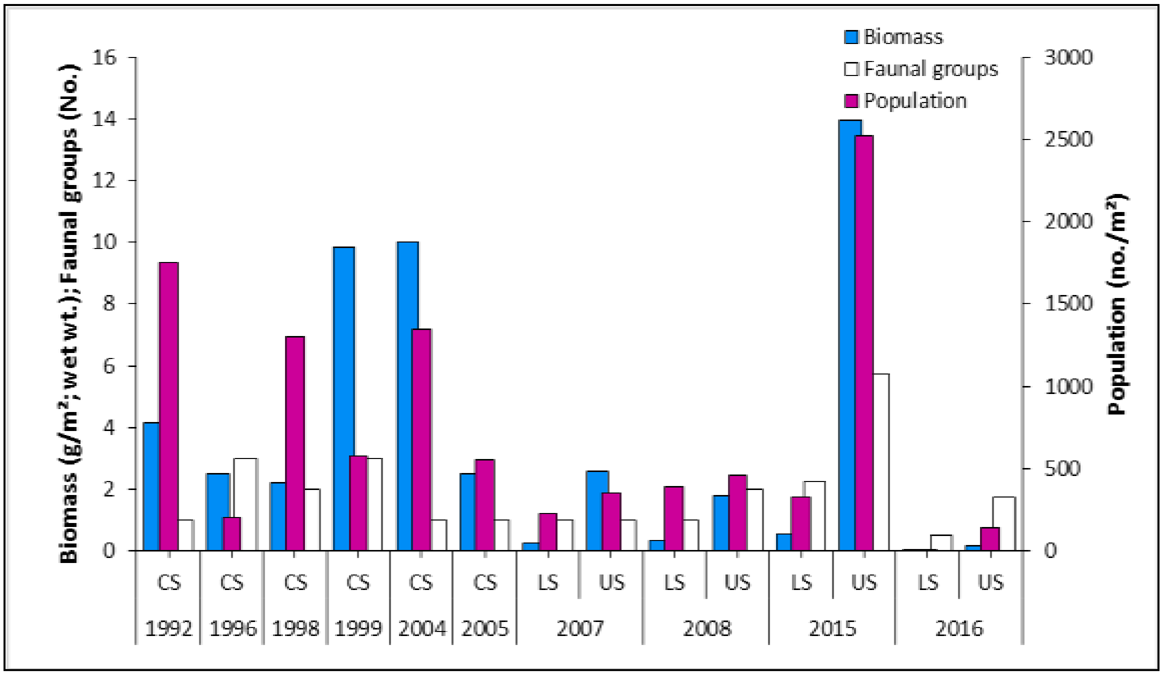


Figure 5.2.35: Comparative macrobenthos biomass, population and group diversity of Versova (1992-2016).

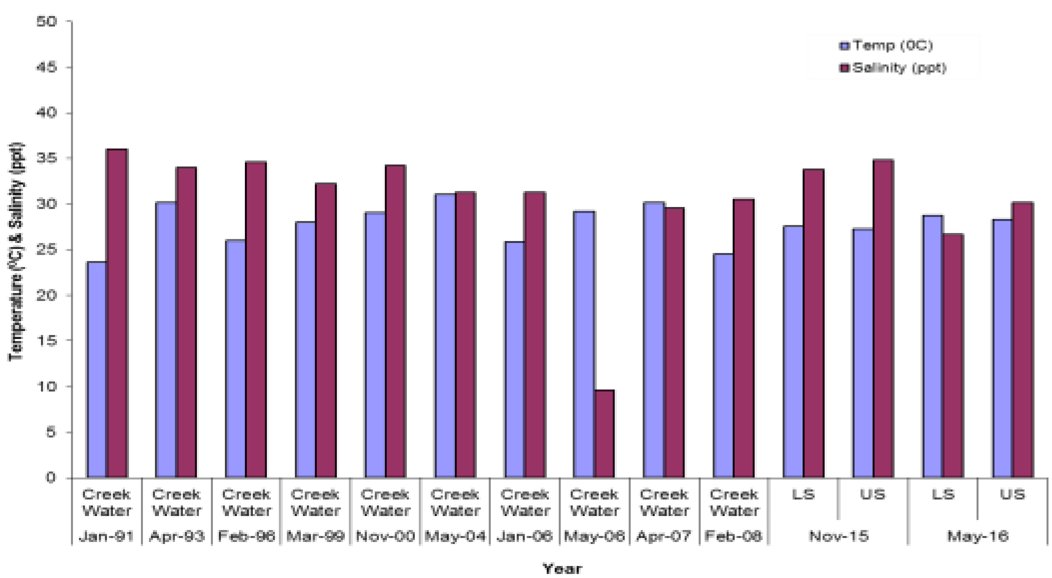


Figure 5.2.36: Temperature (°C) & Salinity (ppt) in Mahim (1991-2016).

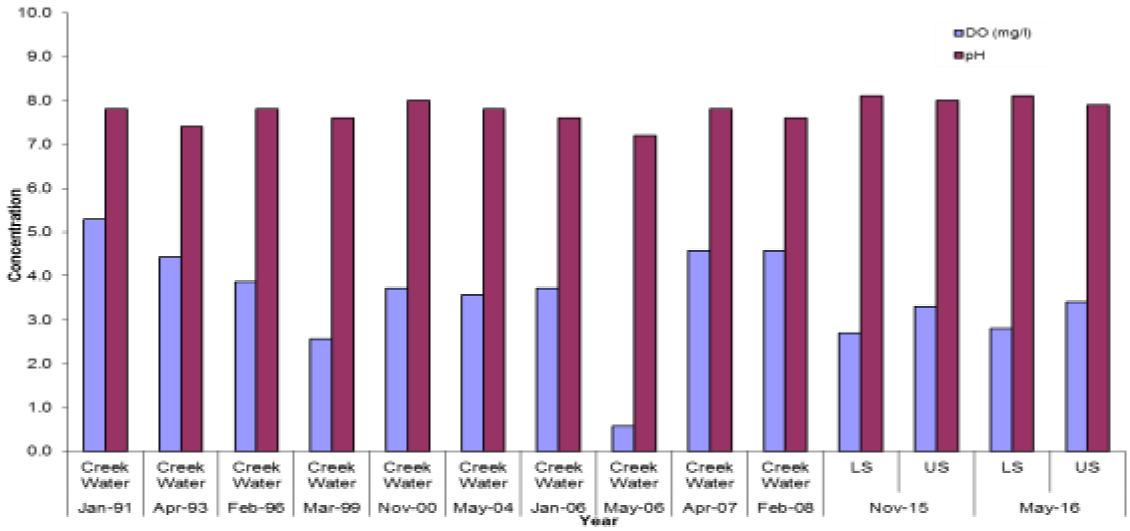


Figure 5.2.37: Concentration of DO (mg/l) & pH in Mahim (1991-2016).

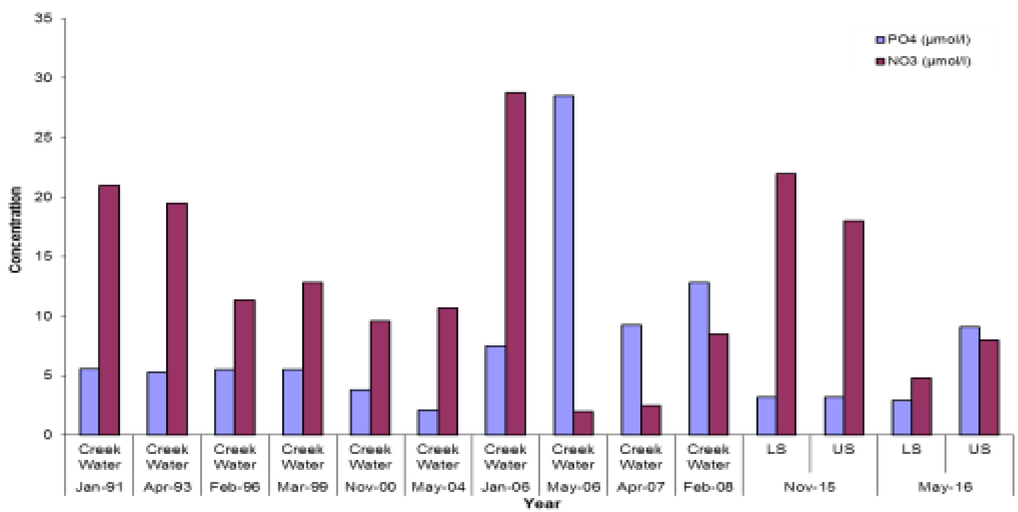


Figure 5.2.38: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Mahim (1991-2016).

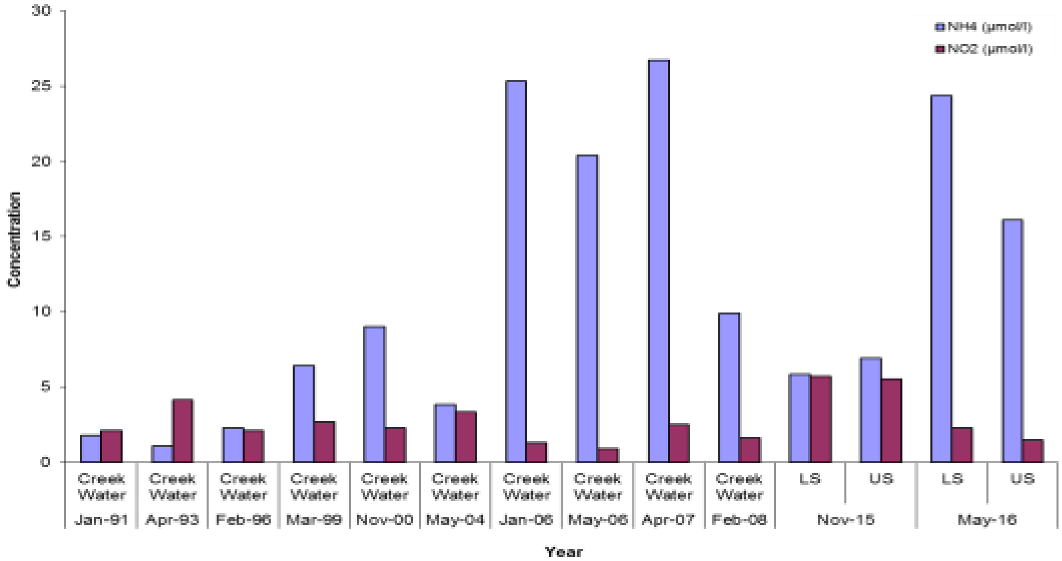


Figure 5.2.39: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Mahim (1991-2016).

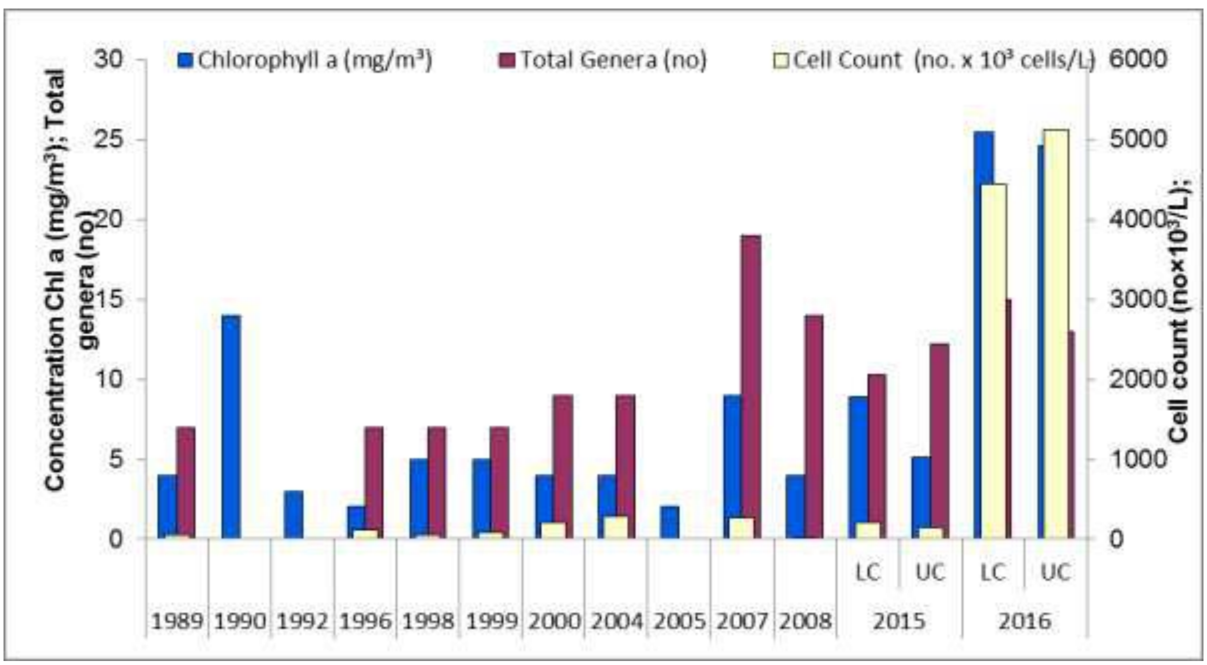


Figure 5.2.40: Comparative phytopigment and generic group diversity of Mahim (1989-2016).

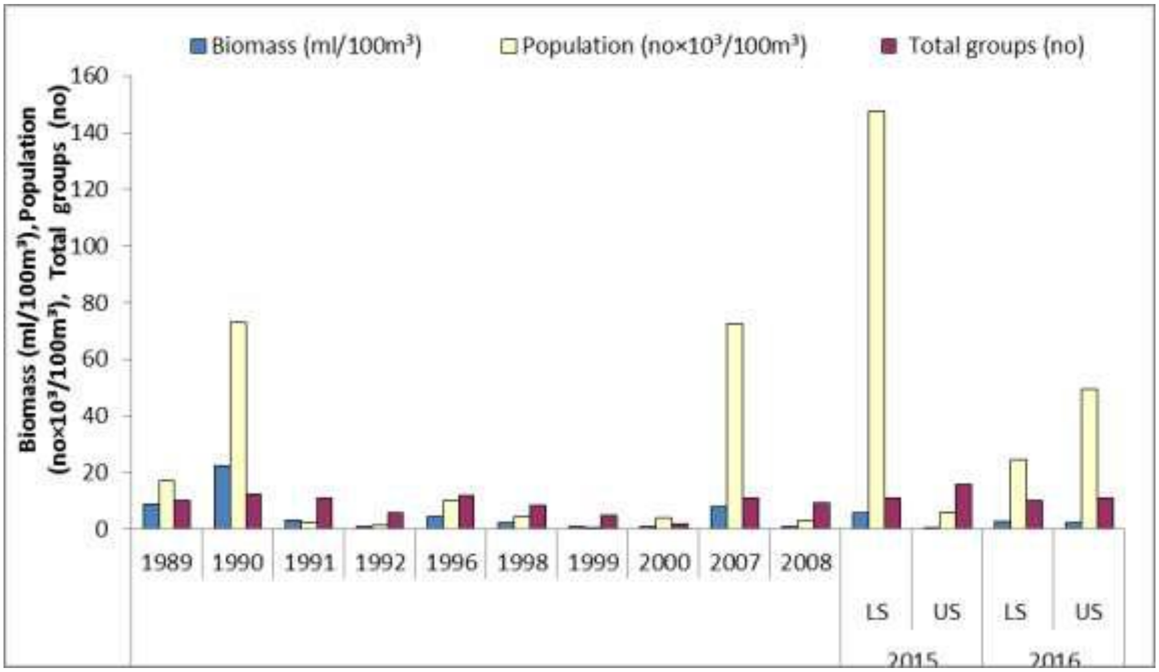


Figure 5.2.41: Comparative zooplankton biomass, population and group diversity of Mahim (1989-2016).

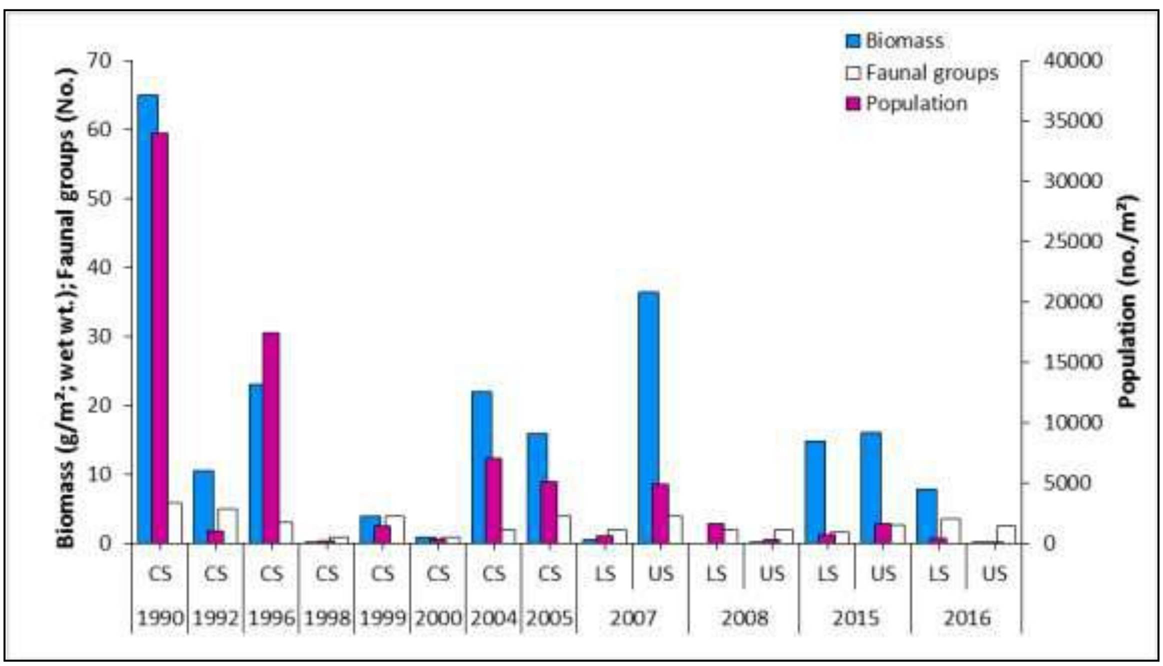


Figure 5.2.42: Comparative macrobenthos biomass, population and group diversity of Mahim (1990-2016).

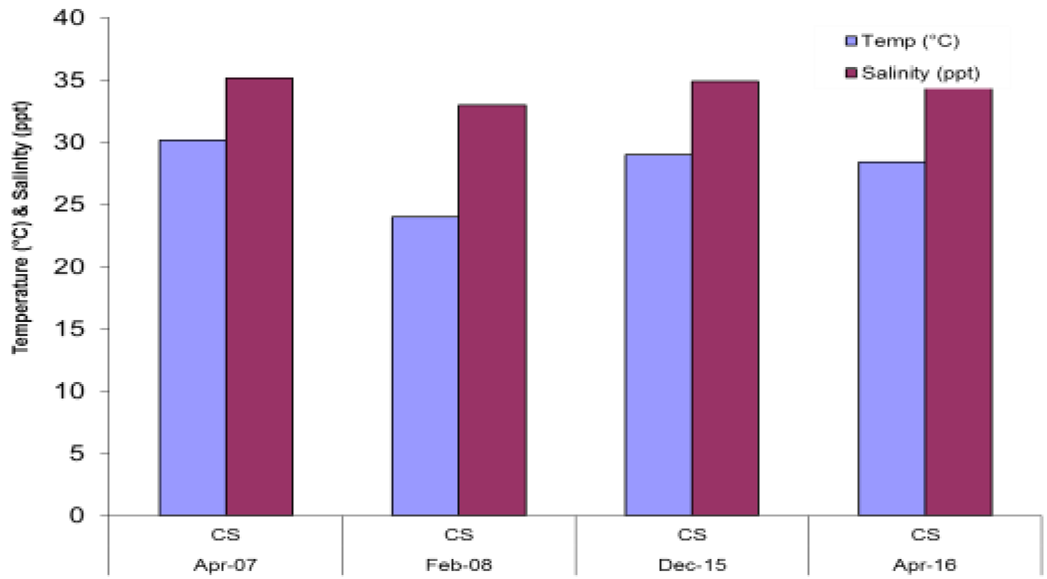


Figure 5.2.43: Temperature (°C) & Salinity (ppt) in Bandra (2007-2016).

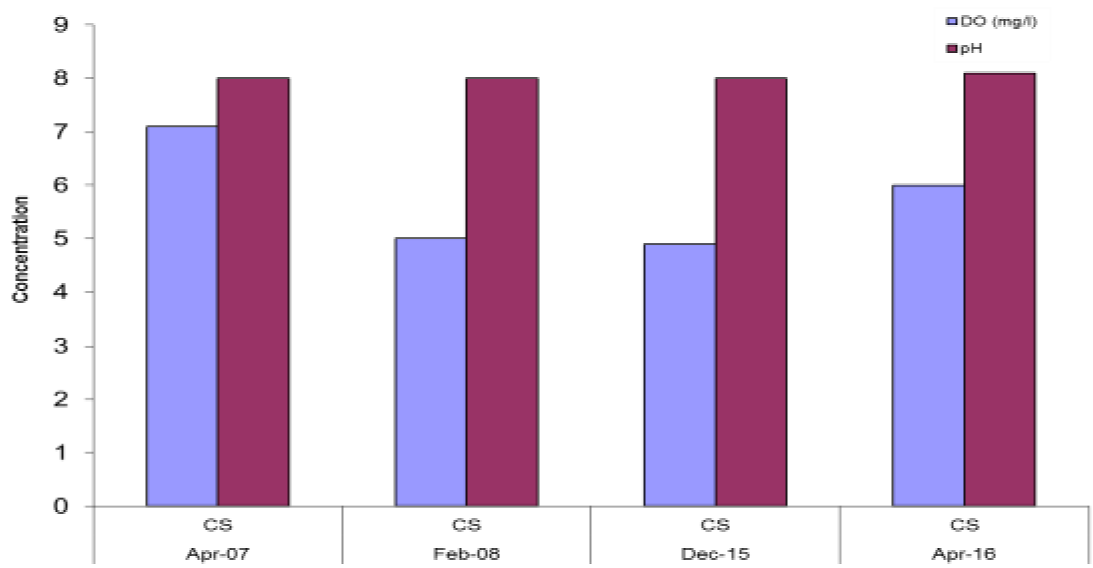


Figure 5.2.44: Concentration of DO (mg/l) & pH in Bandra (2007-2016).

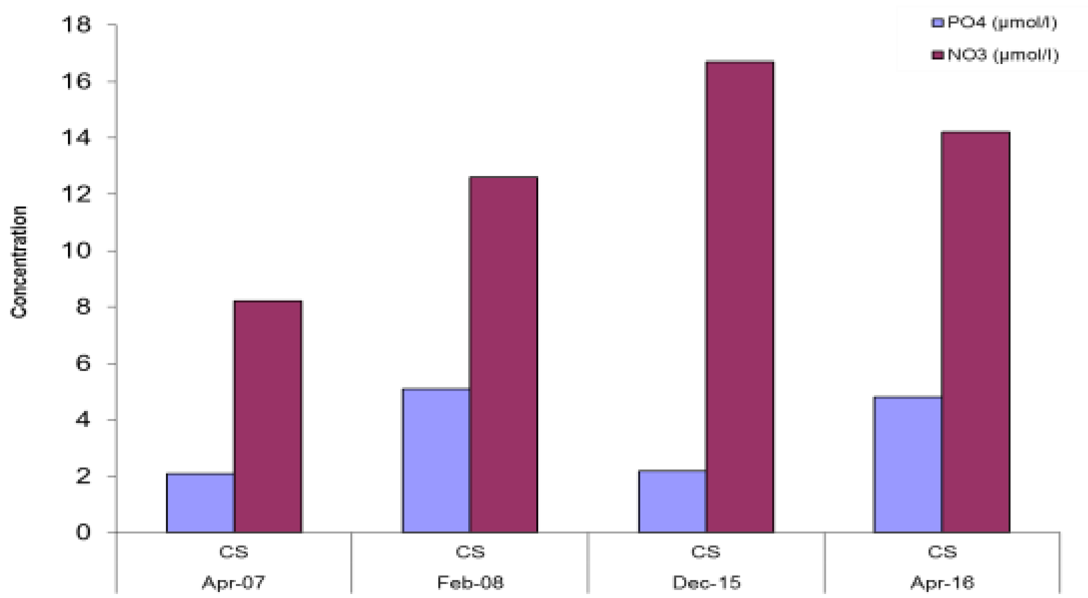


Figure 5.2.45: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Bandra (2007-2016).

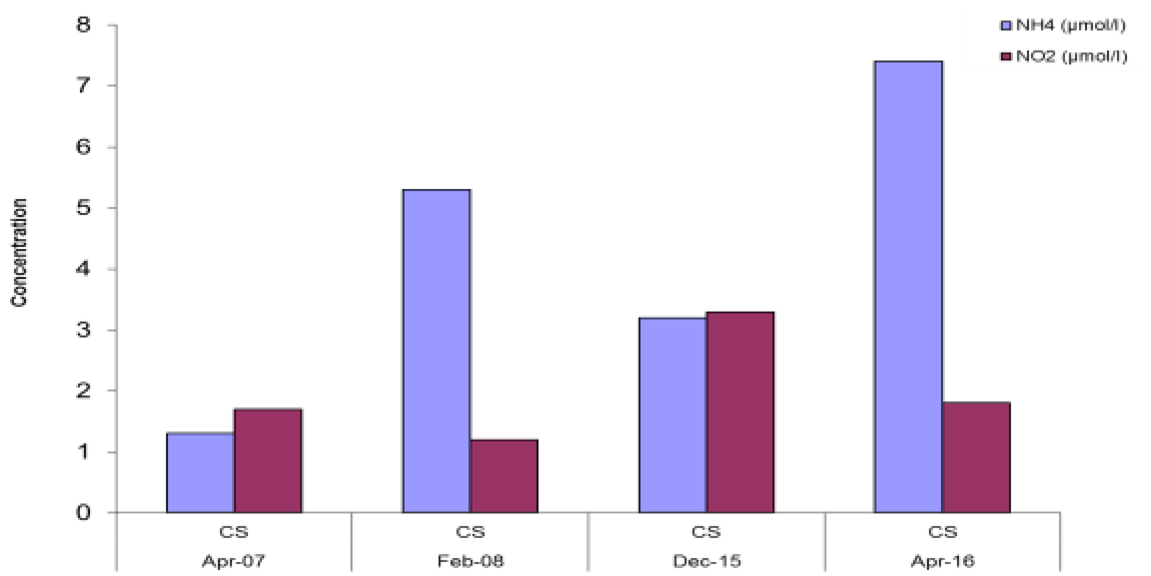


Figure 5.2.46: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Bandra (2007-2016).

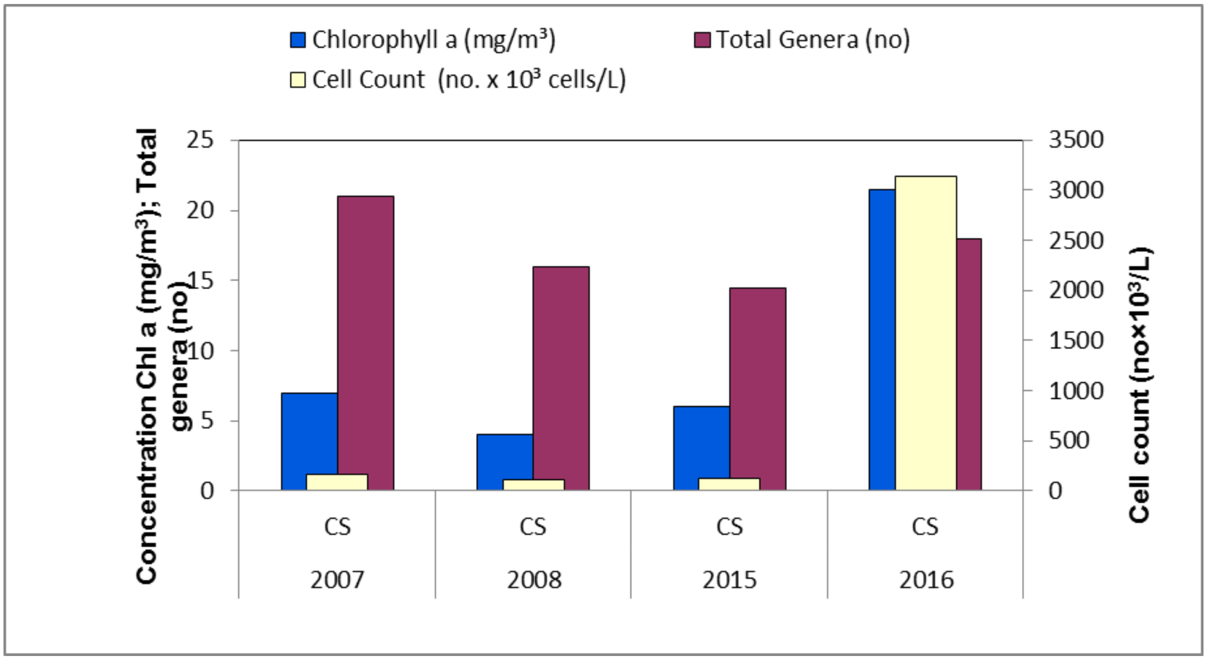


Figure 5.2.47: Comparative phytopigment and generic group diversity of Bandra (2007-2016).

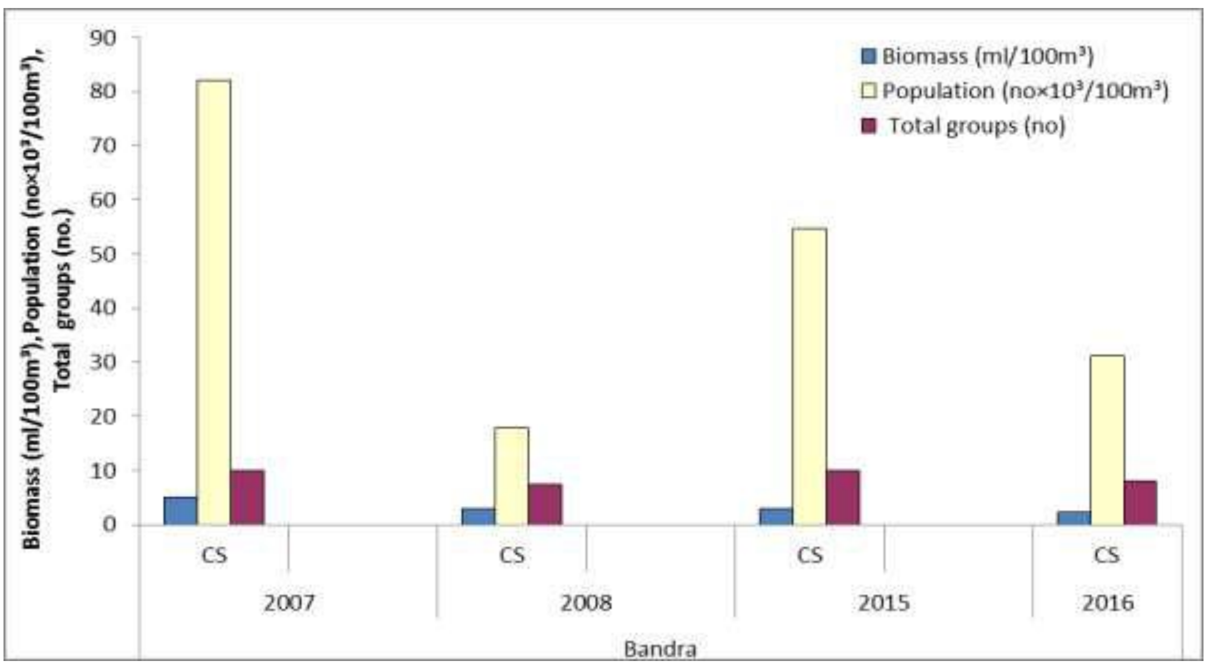


Figure 5.2.48: Comparative zooplankton biomass, population and group diversity of Bandra (2007-2016).

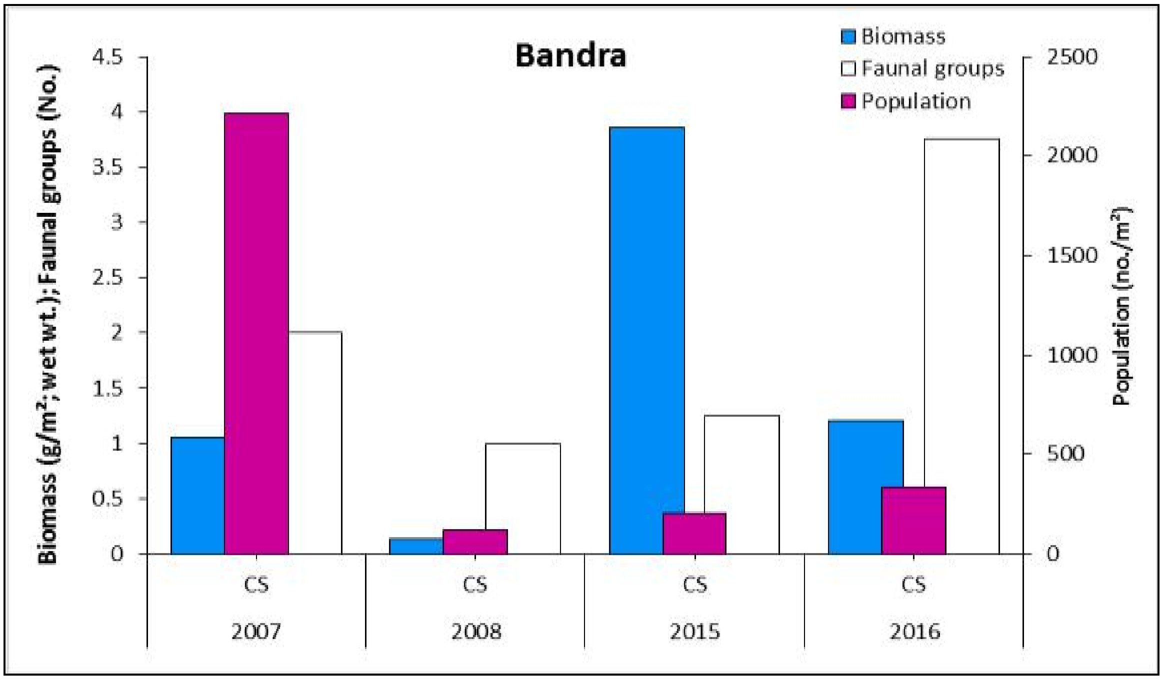


Figure 5.2.49: Comparative macrobenthos biomass, population and group diversity of Bandra (2007-2016).

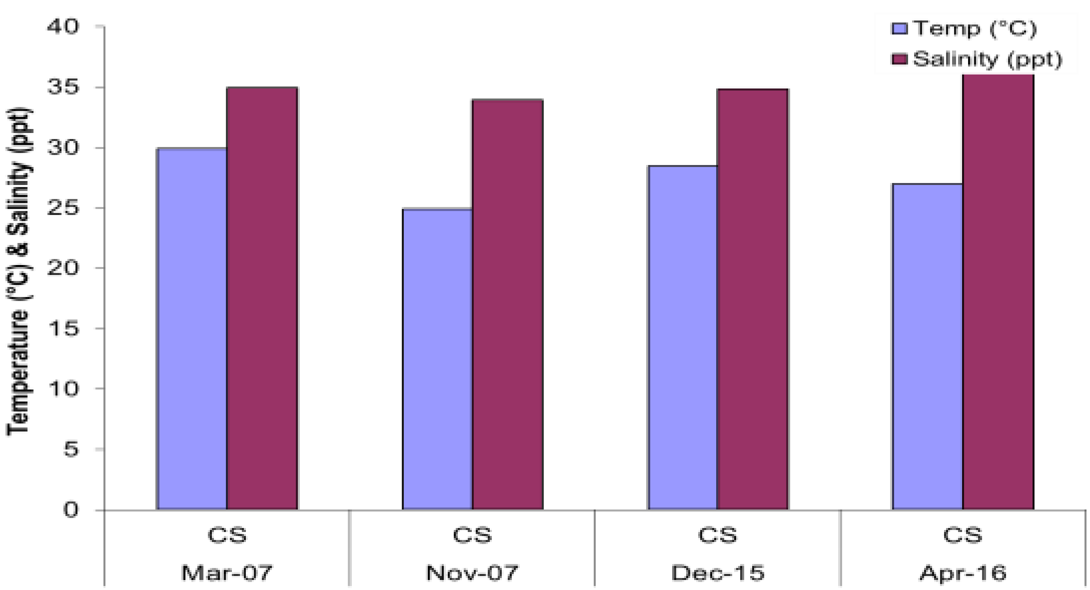


Figure 5.2.50: Temperature (°C) & Salinity (ppt) in Worli (2007-2016).

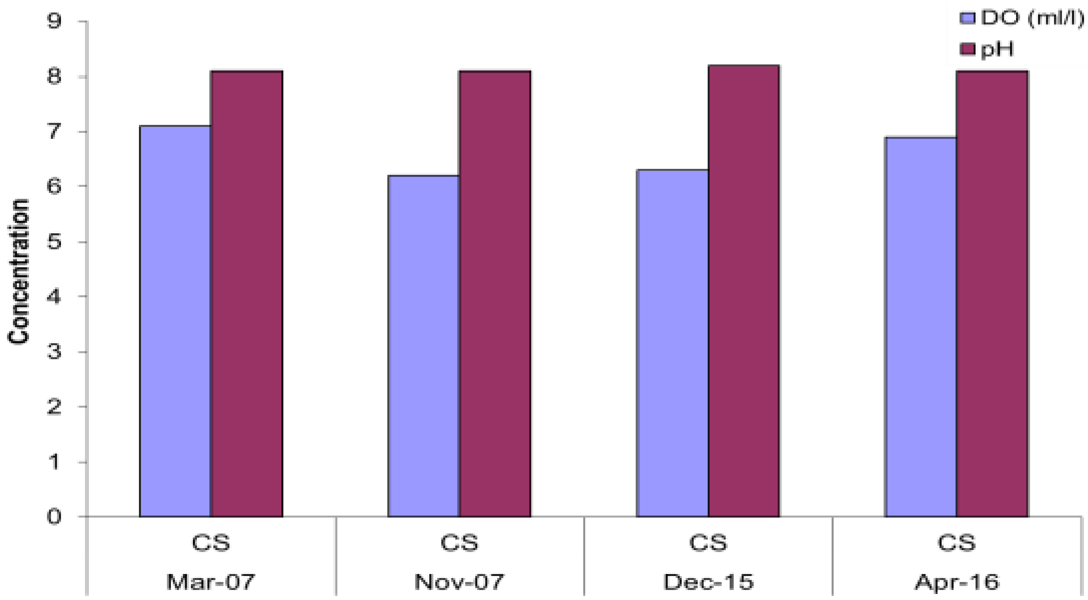


Figure 5.2.51: Concentration of DO (mg/l) & pH in Worli (2007-2016).

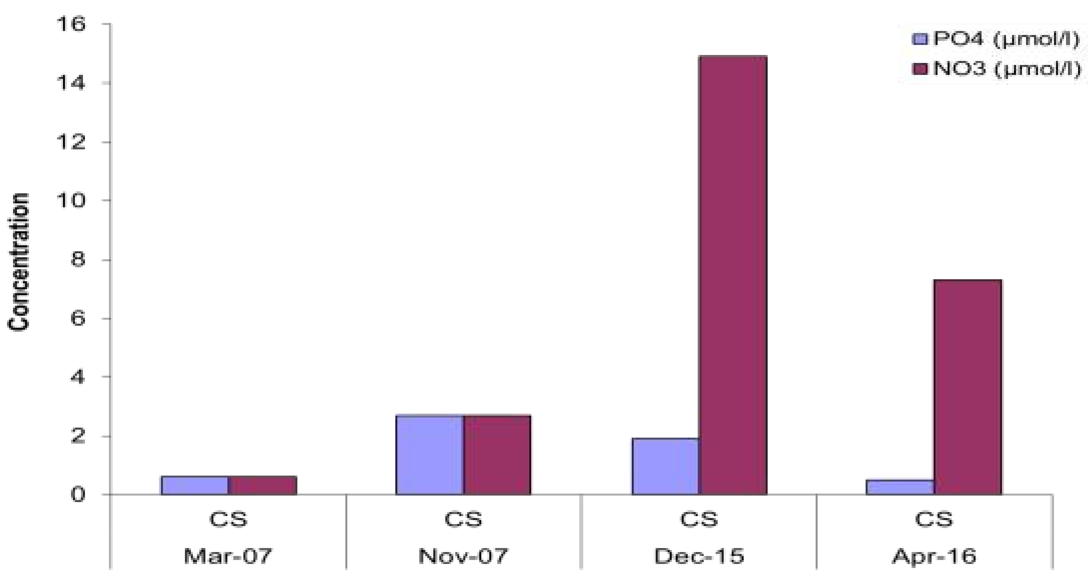


Figure 5.2.52: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Worli (2007-2016).

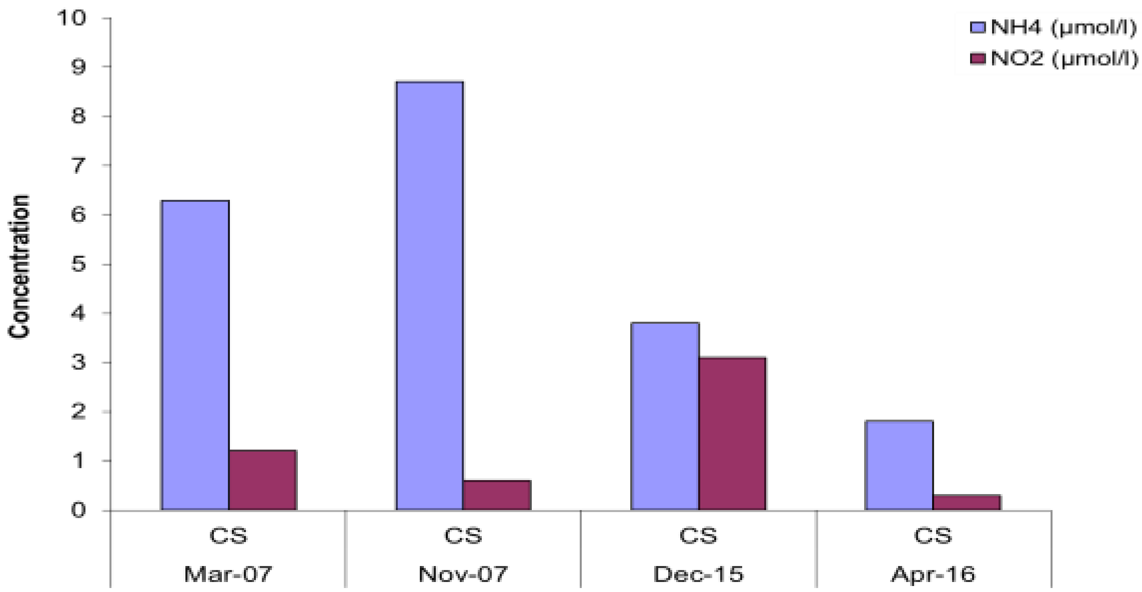


Figure 5.2.53: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Worli (2007-2016).

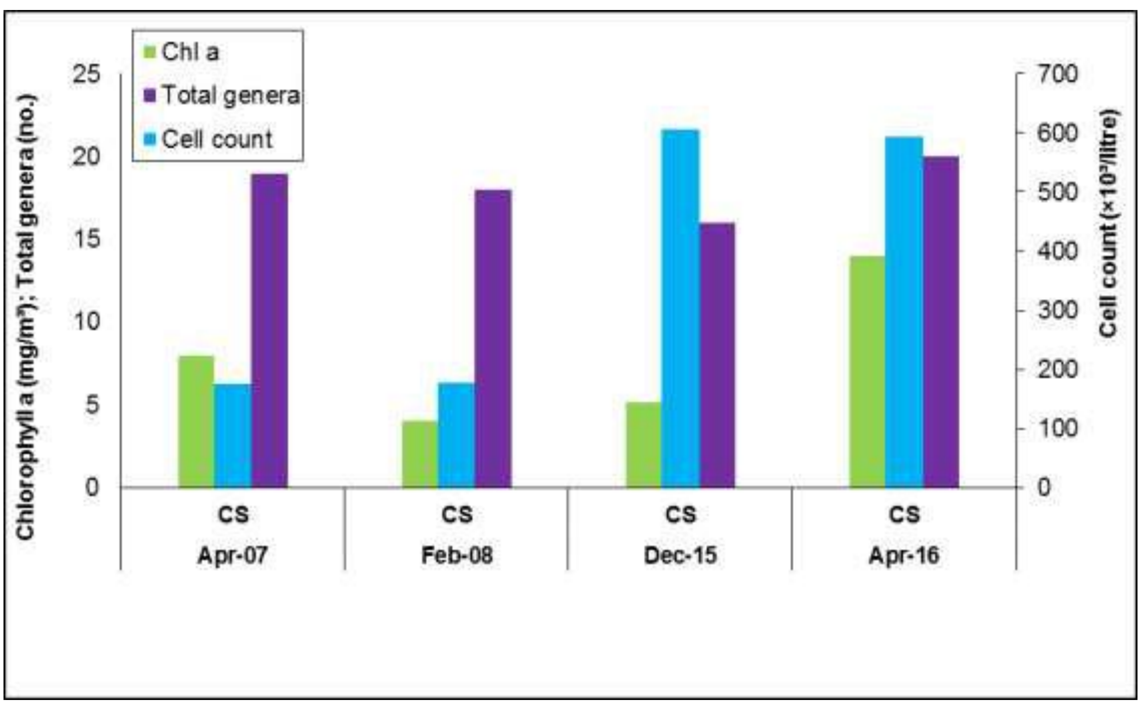


Figure 5.2.54: Comparative phytopigment and generic diversity of Worli (2007-2016).

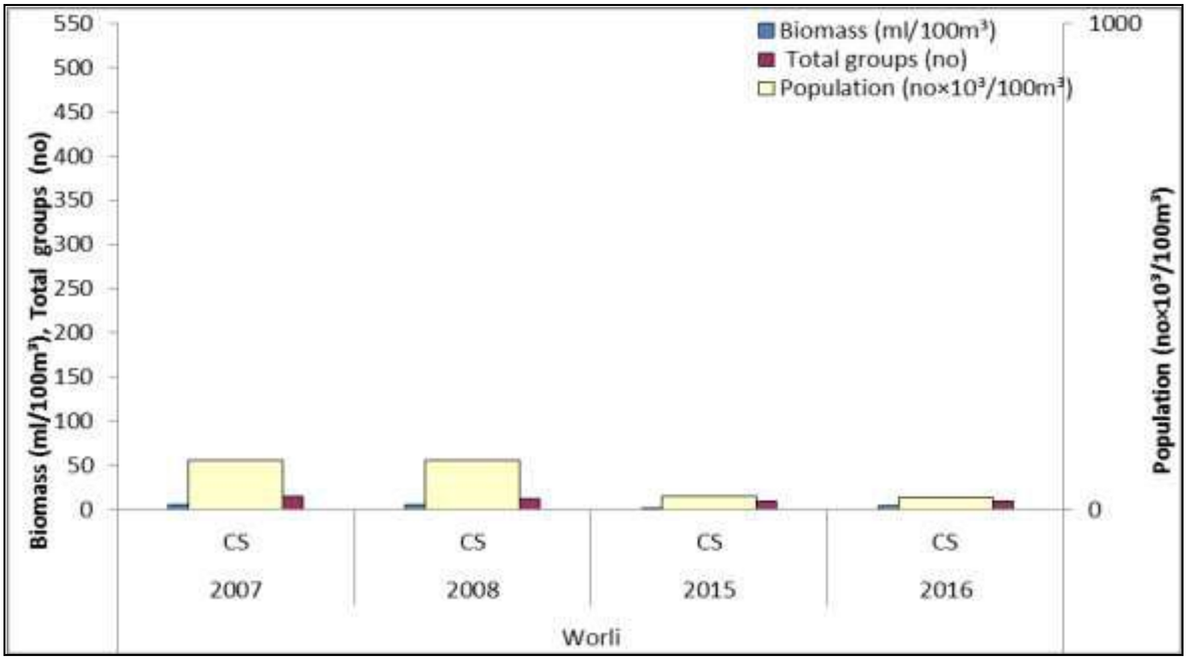


Figure 5.2.55: Comparative zooplankton biomass, population and group diversity of Worli (2007-2016).

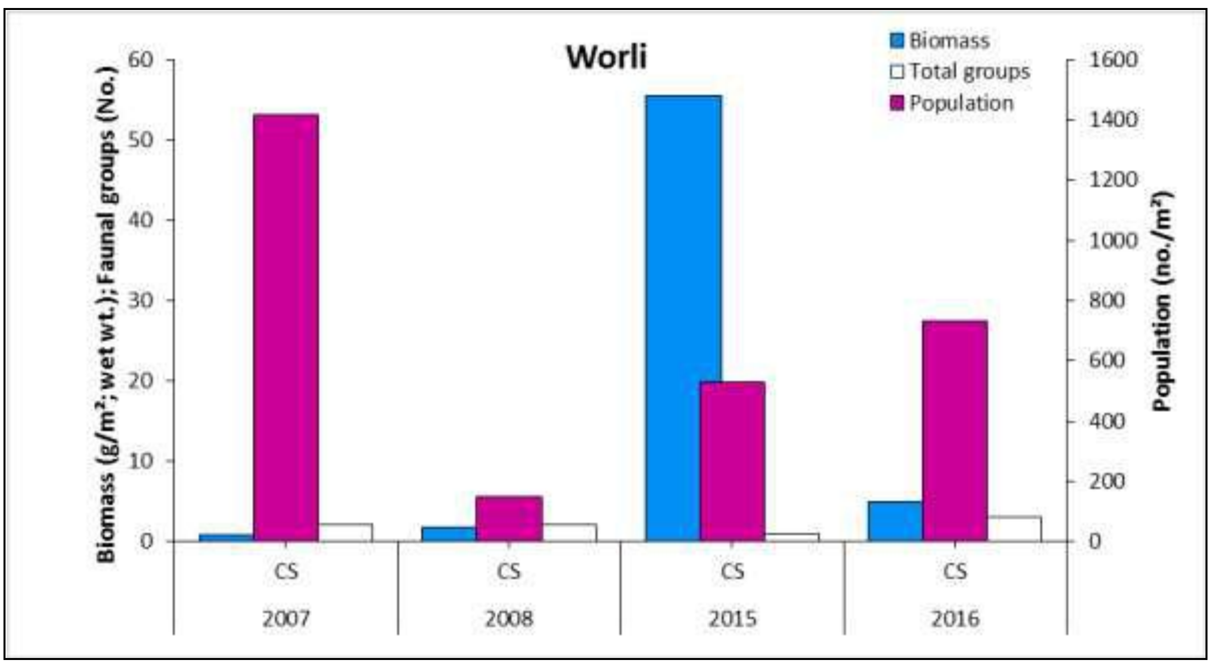


Figure 5.2.56: Comparative macrobenthos biomass, population and group diversity of Worli (2007-2016).

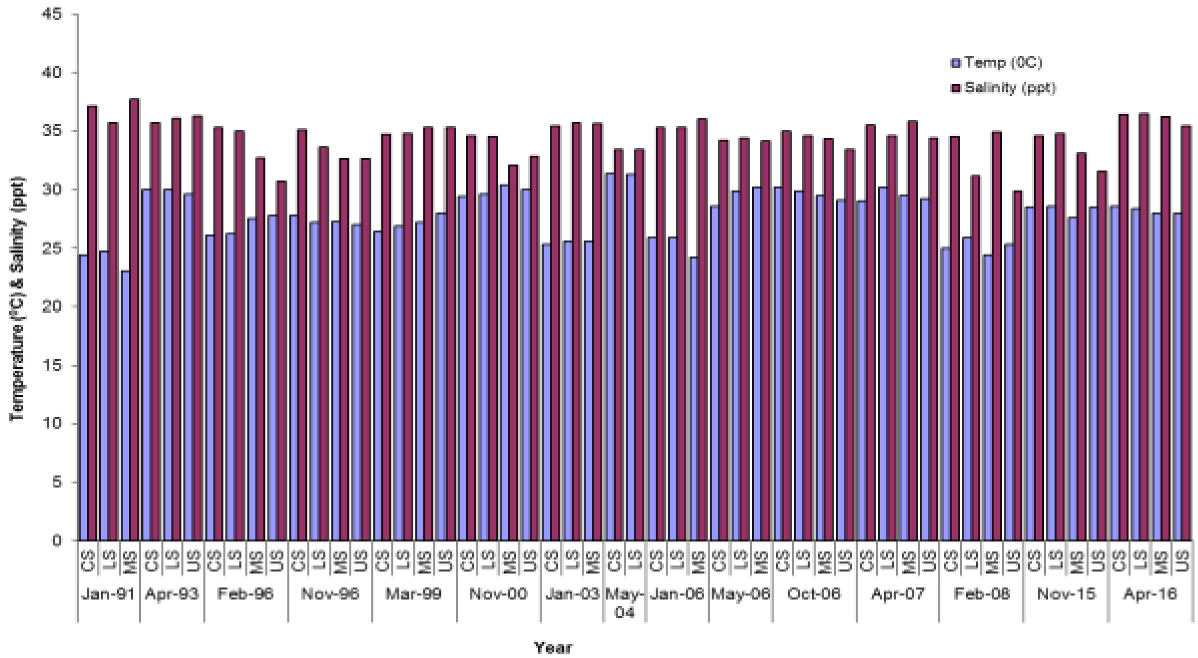


Figure 5.2.57: Temperature (°C) & Salinity (ppt) in Thane Creek (1991-2016).

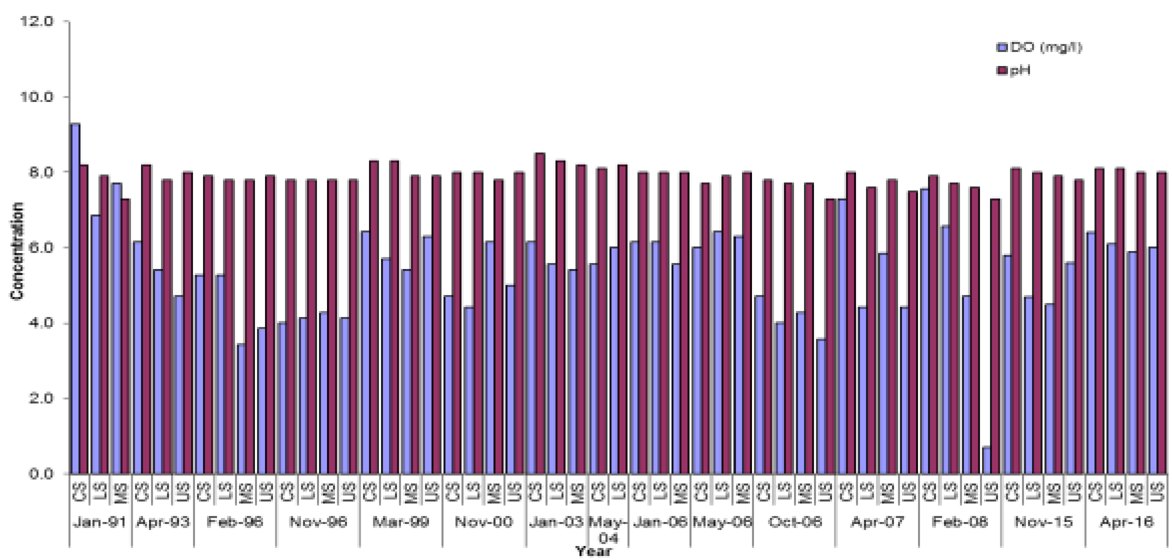


Figure 5.2.58: Concentration of DO (mg/l) & pH in Thane Creek (1991-2016).

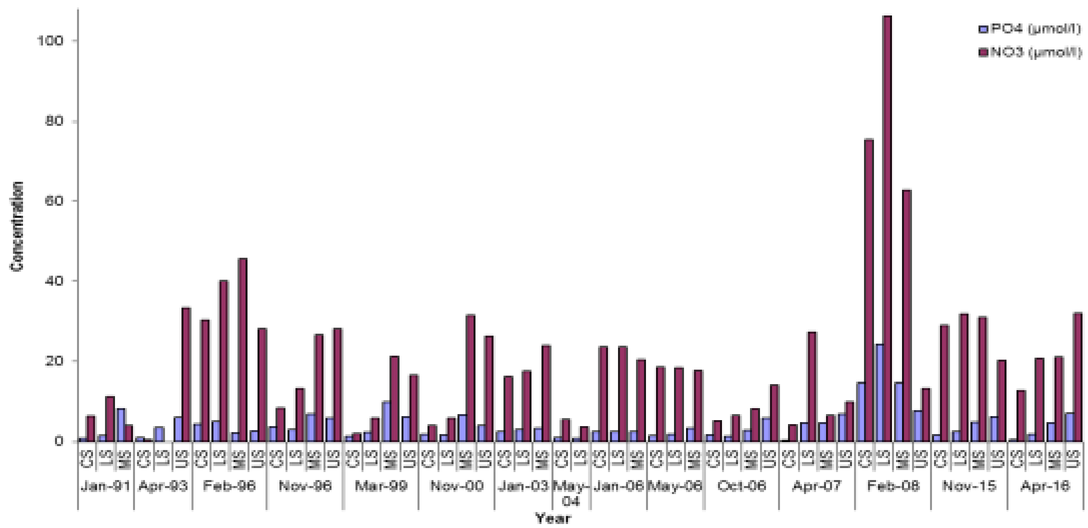


Figure 5.2.59: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Thane Creek (1991-2016).

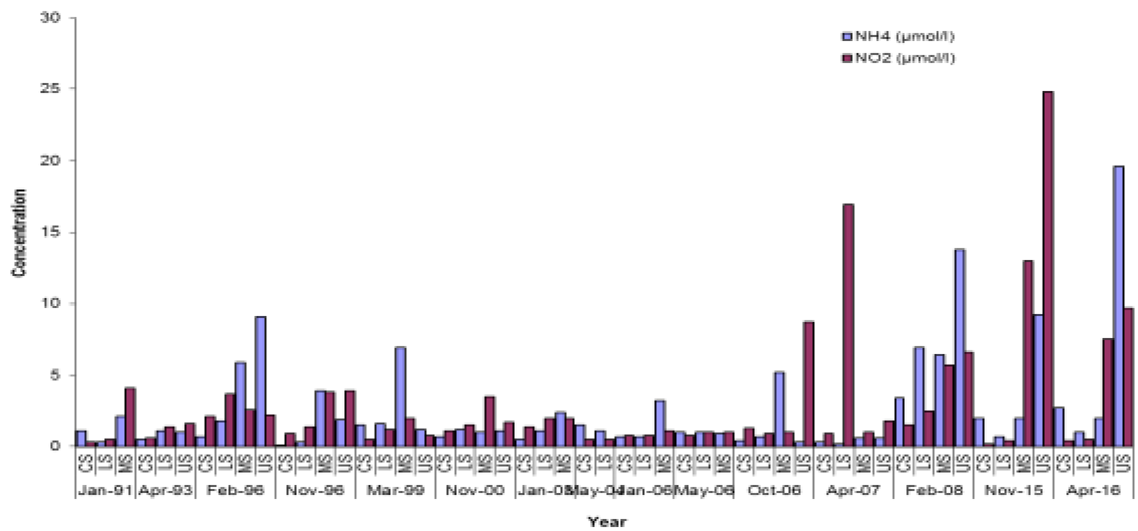


Figure 5.2.60: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Thane Creek (1991-2016).

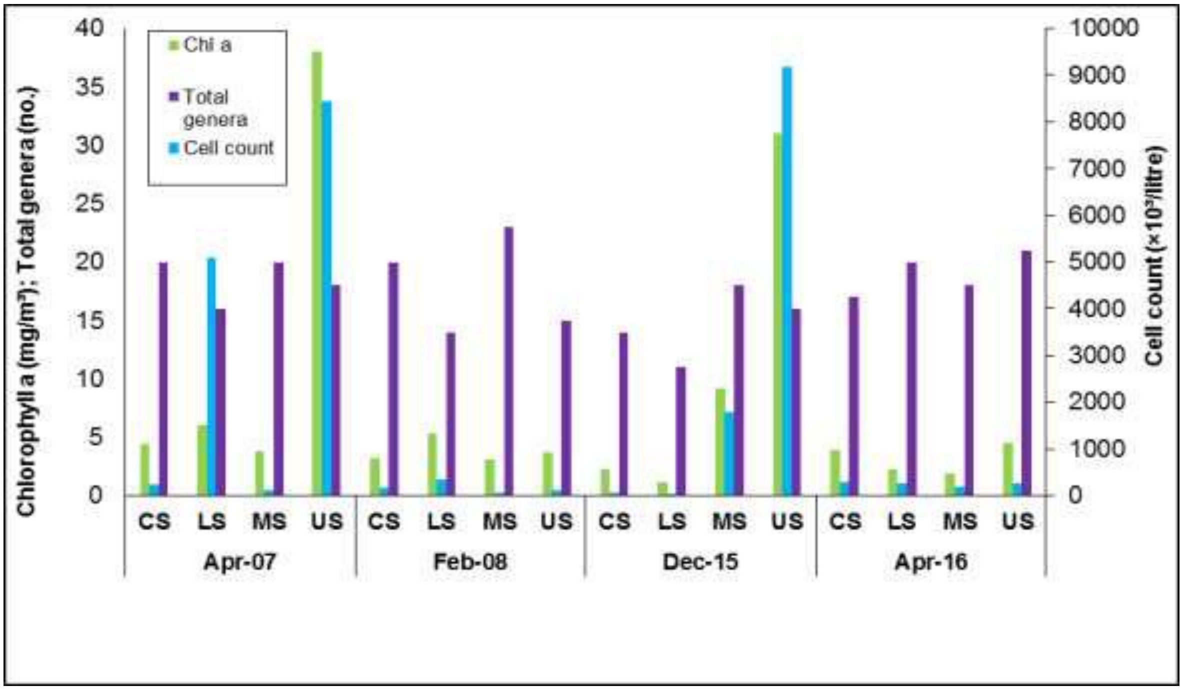


Figure 5.2.61: Comparative phytopigment and generic diversity of Thane Creek (2007-2016).

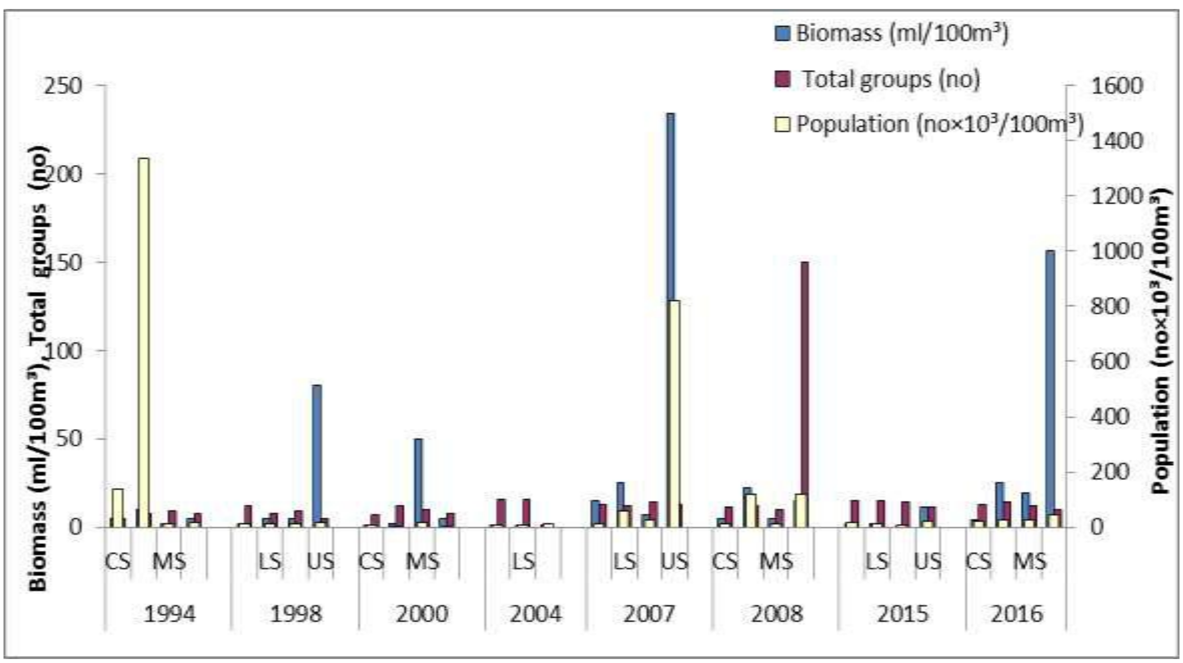


Figure 5.2.62: Comparative zooplankton biomass, population and group diversity of Thane Creek (1994-2016).

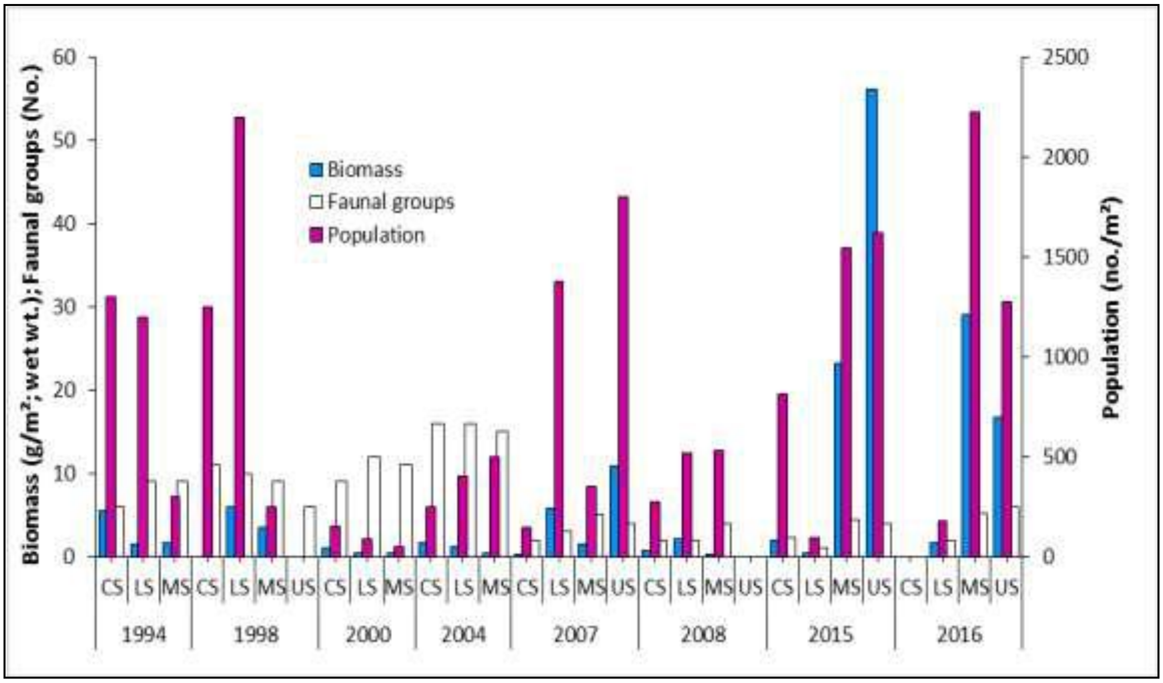


Figure 5.2.63: Comparative macrobenthos biomass, population and group diversity of Thane Creek (1994-2016).

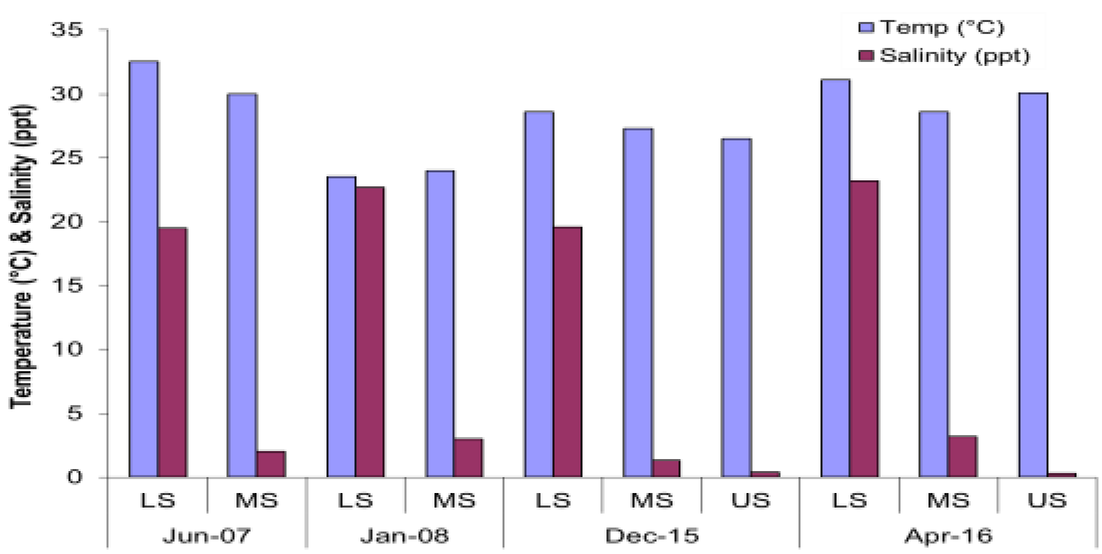


Figure 5.2.64: Temperature (°C) Salinity (ppt) in Patalganga (2007-2016).

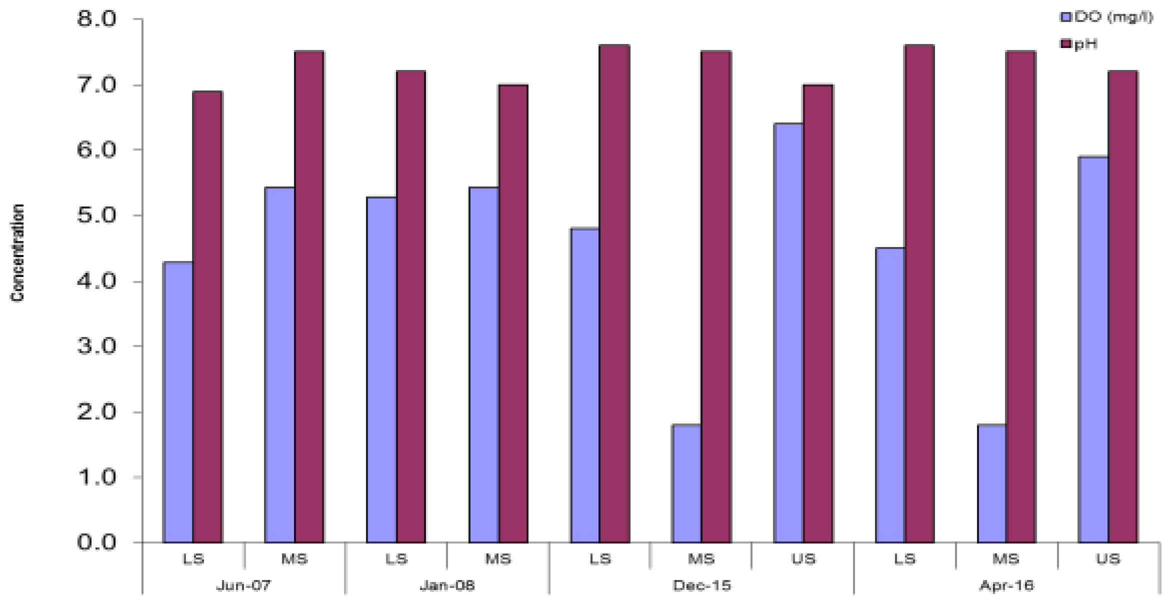


Figure 5.2.65: Concentration of DO (mg/l) & pH in Patalganga (2007-2016).

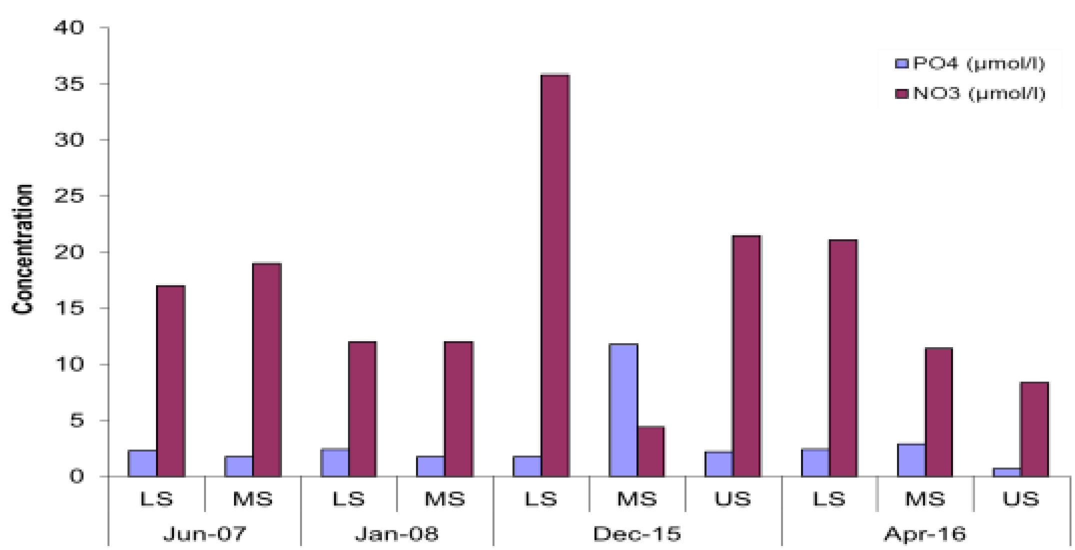


Figure 5.2.66: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Patalganga (2007-2016).

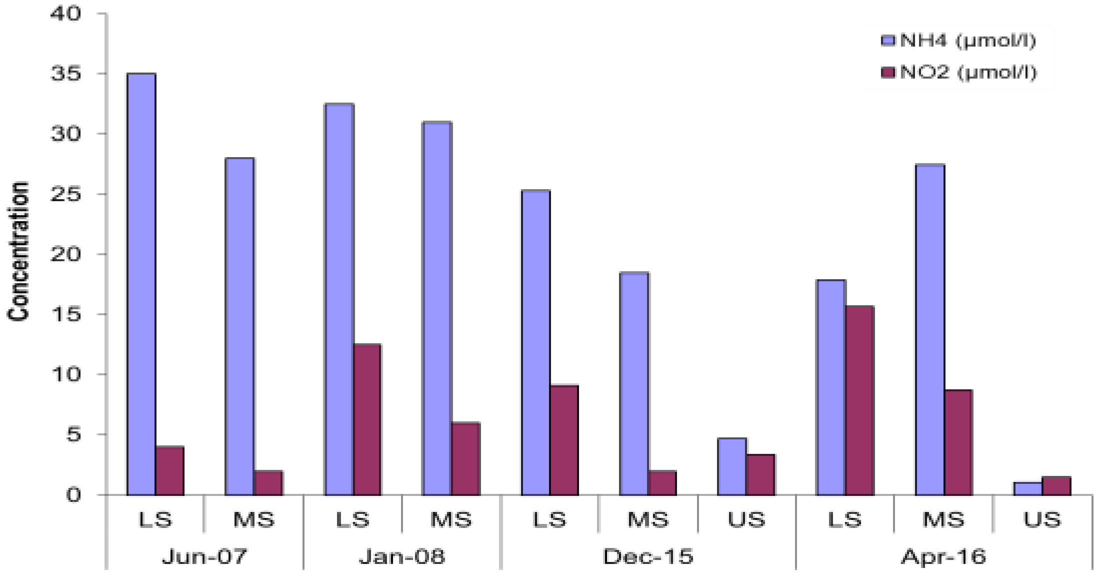


Figure 5.2.67: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Patalganga (2007-2016).

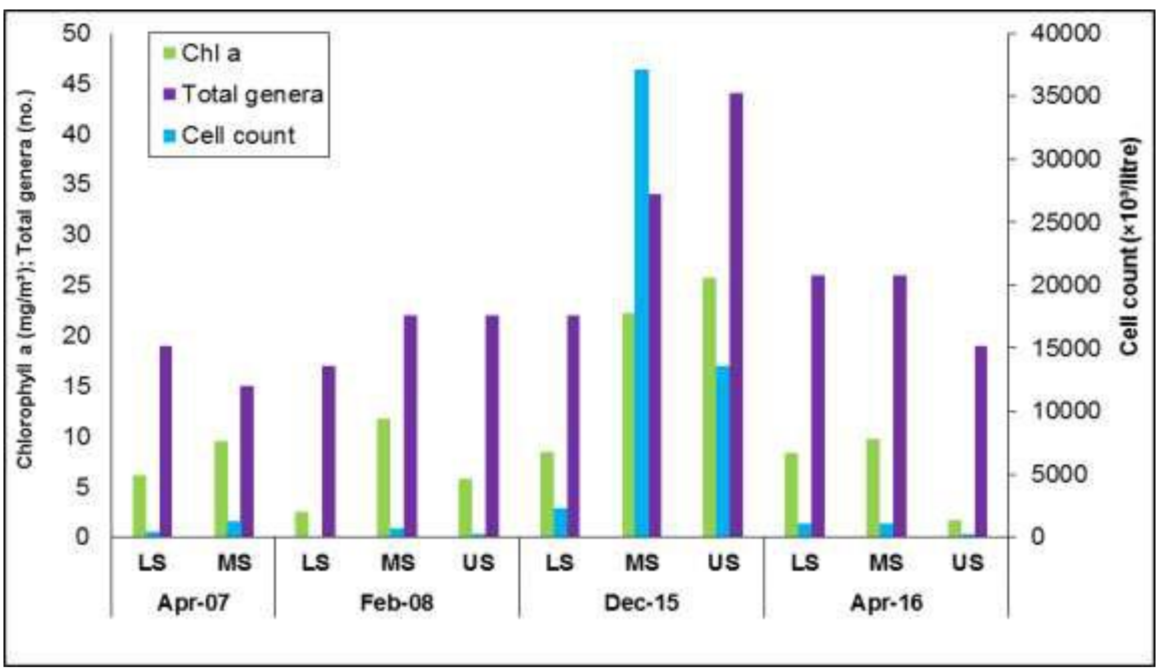


Figure 5.2.68: Comparative phytopigment and generic diversity of Patalganga (2007-2016).

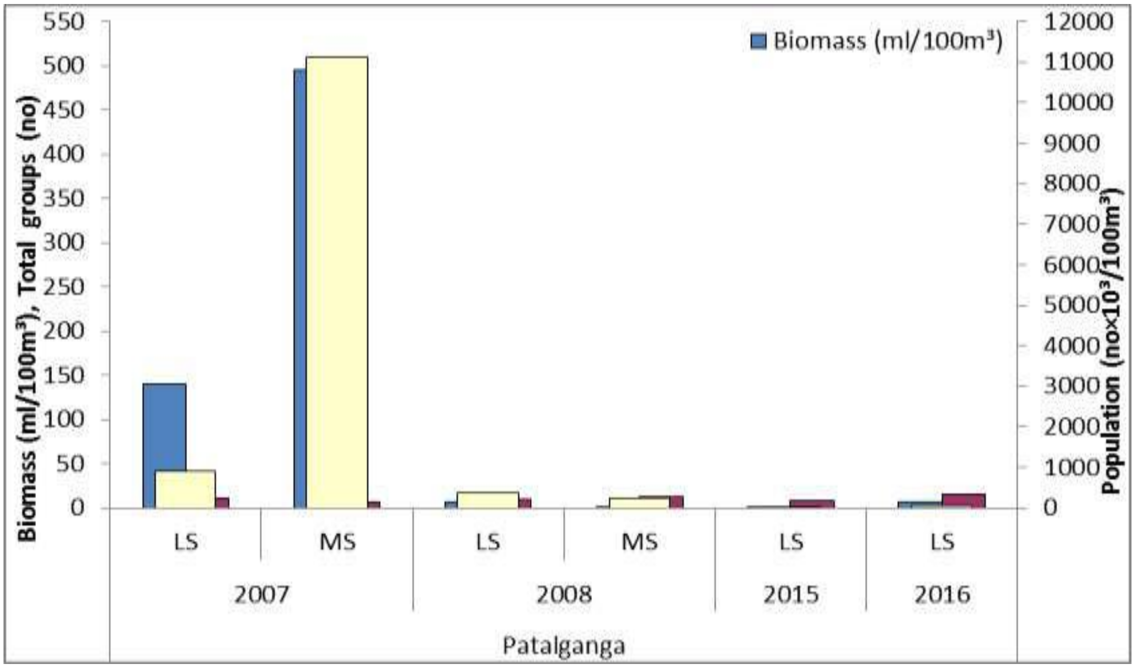


Figure 5.2.69: Comparative zooplankton biomass, population and group diversity of Patalganga (2007-2016).

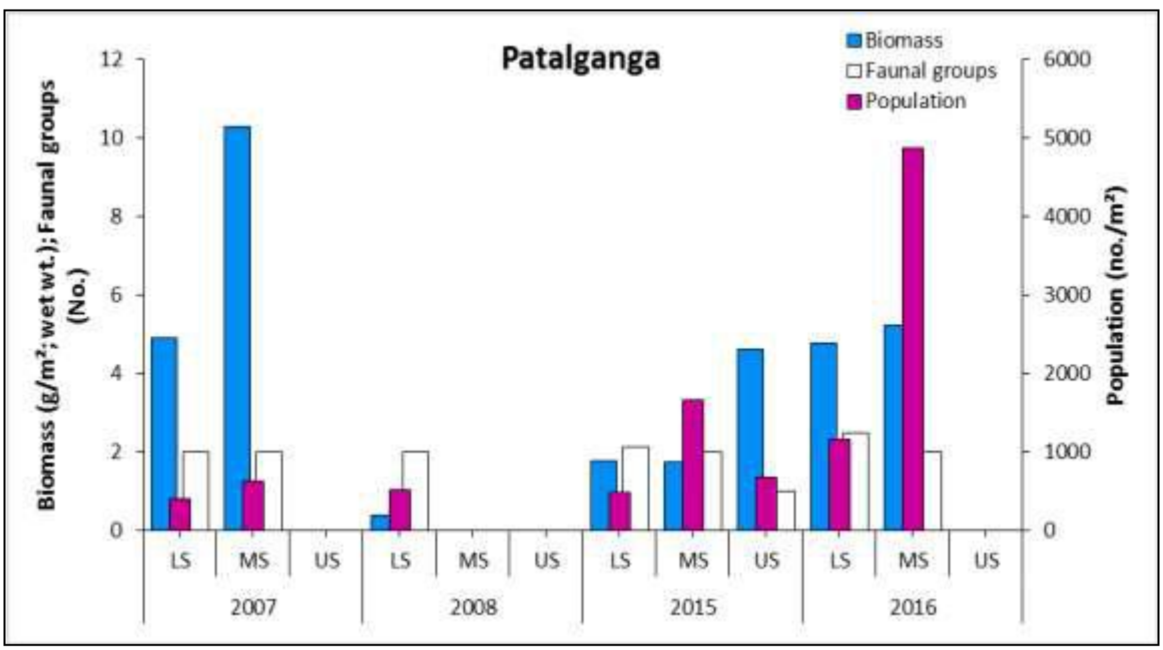


Figure 5.2.70: Comparative macrobenthos biomass, population and group diversity of Patalganga (2007-2016).

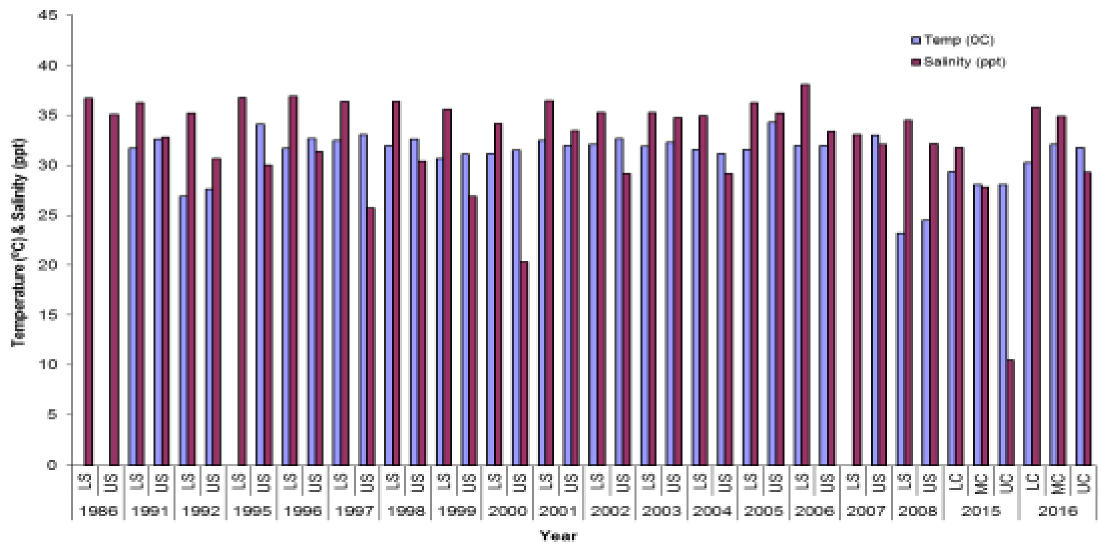


Figure 5.2.71: Temperature (°C) & Salinity (ppt) in Amba (1986-2016).

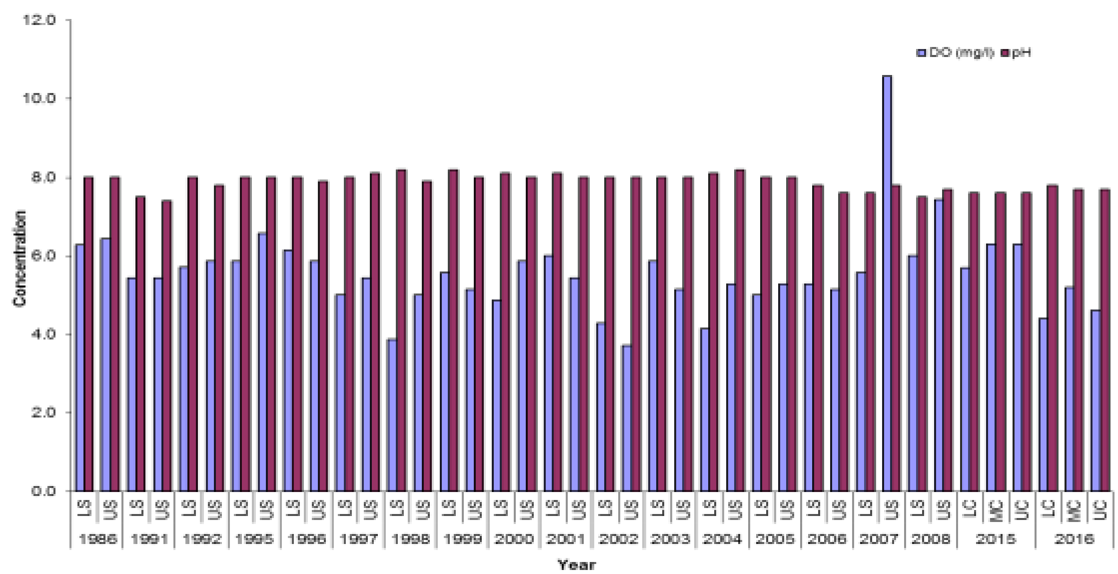


Figure 5.2.72: Concentration of DO (mg/l) & pH in Amba (1986-2016).

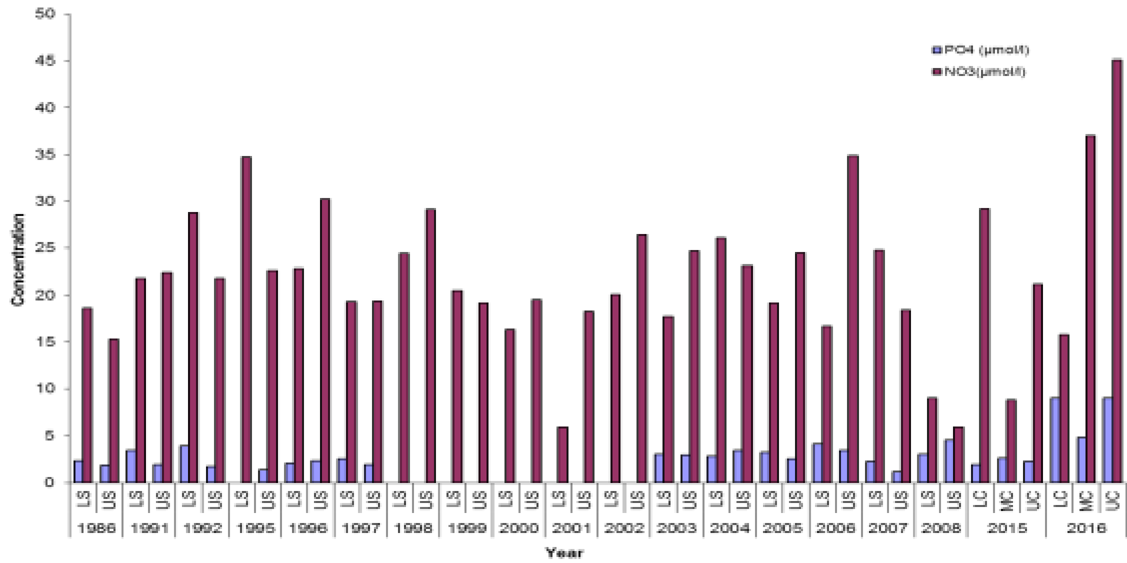


Figure 5.2.73: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Amba (1986-2016).

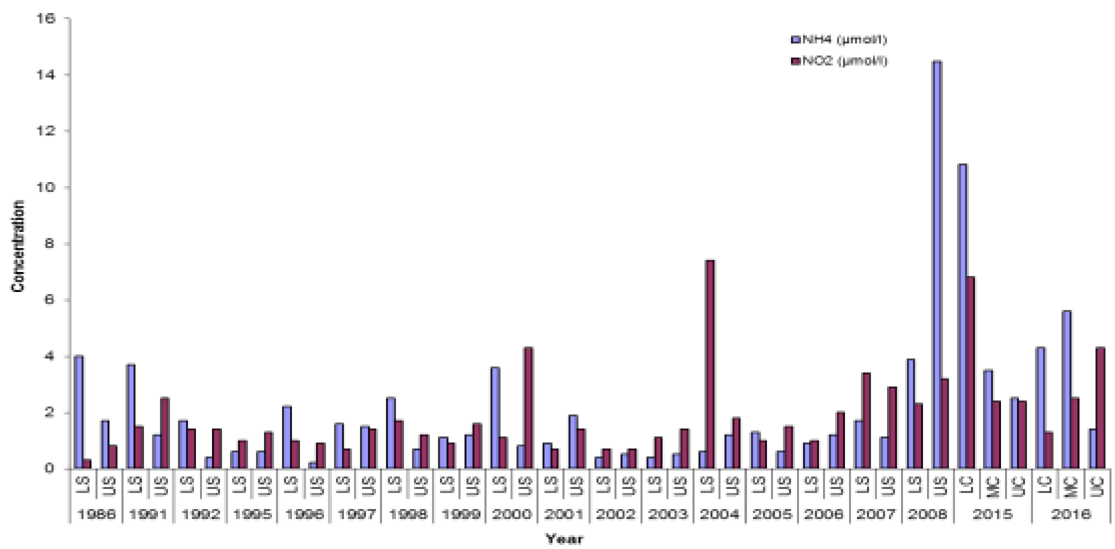


Figure 5.2.74: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Amba (1986-2016).

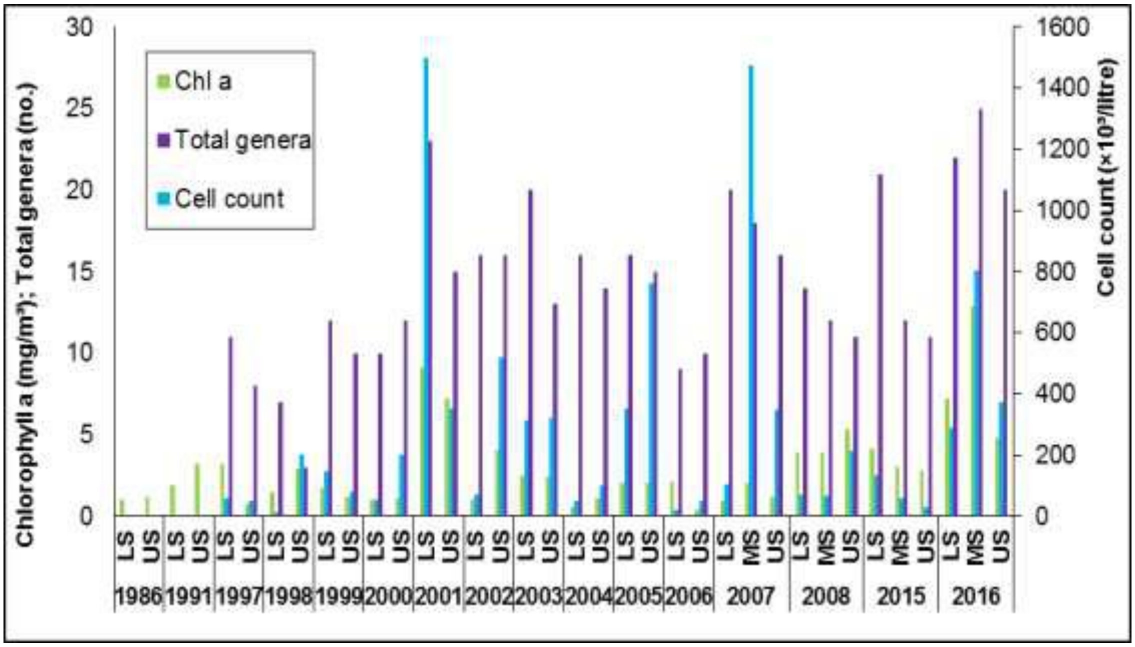


Figure 5.2.75: Comparative phytopigment and generic diversity of Amba (1986-2016).

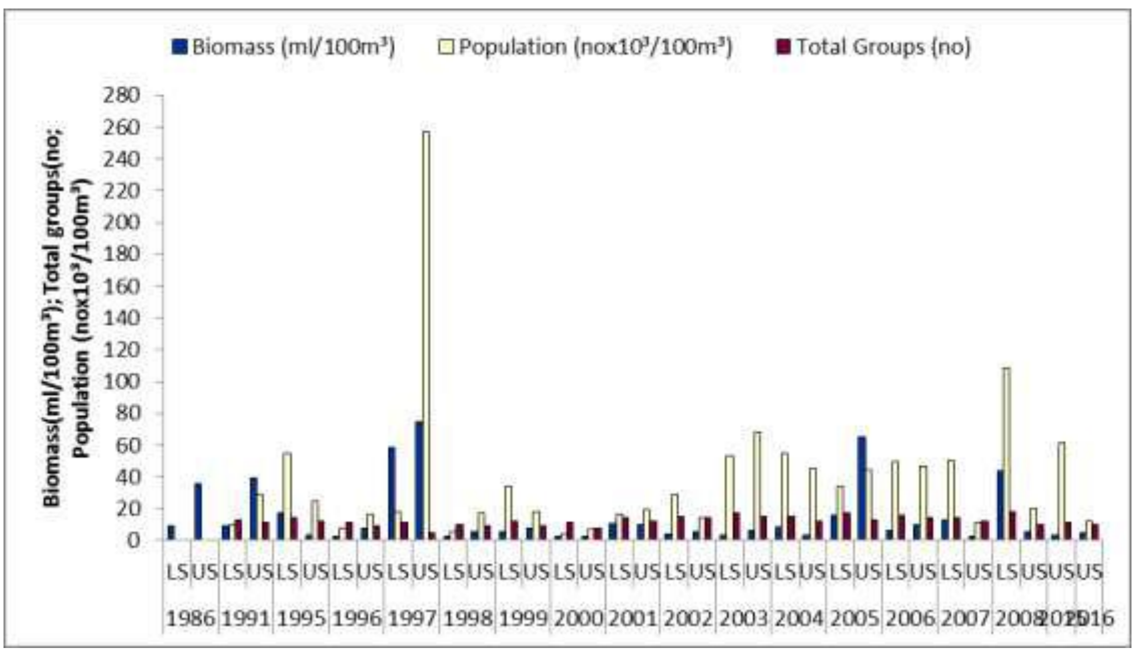


Figure 5.2.76: Comparative zooplankton biomass, population and group diversity of Amba (1986-2016).

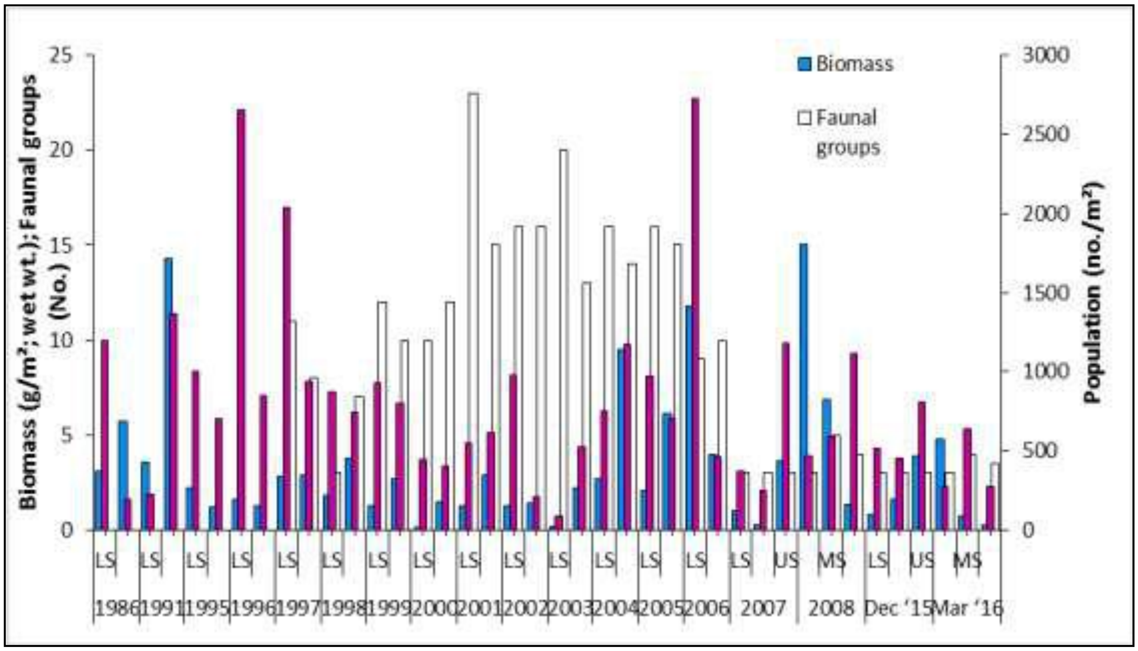


Figure 5.2.77: Comparative macrobenthos biomass, population and group diversity of Amba (1986-2016).

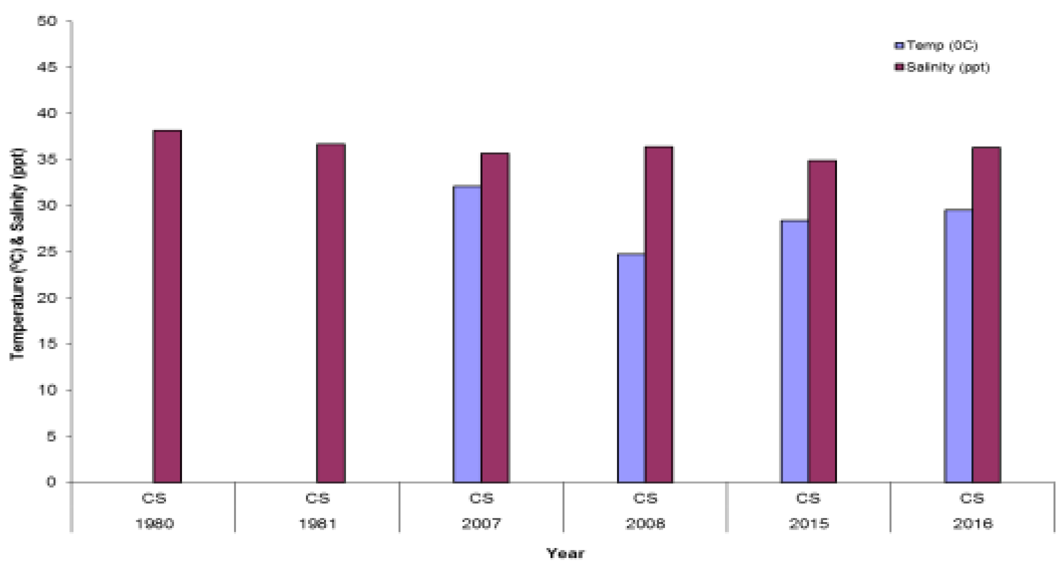


Figure 5.2.78: Temperature (°C) & Salinity (ppt) in Thal (1980-2016).

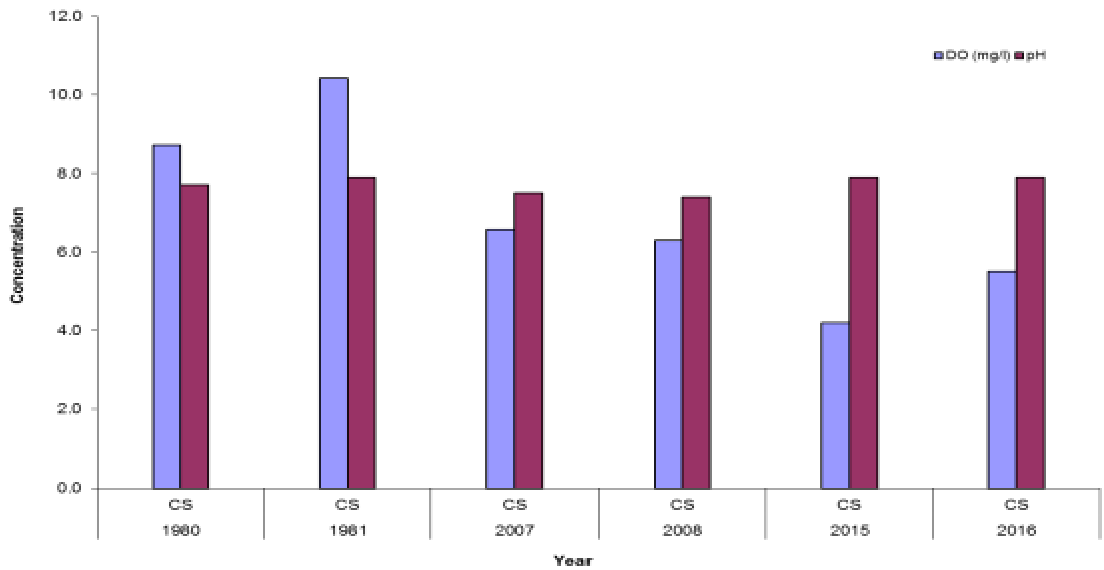


Figure 5.2.79: Concentration of DO (mg/l) & pH in Thal (1980-2016).

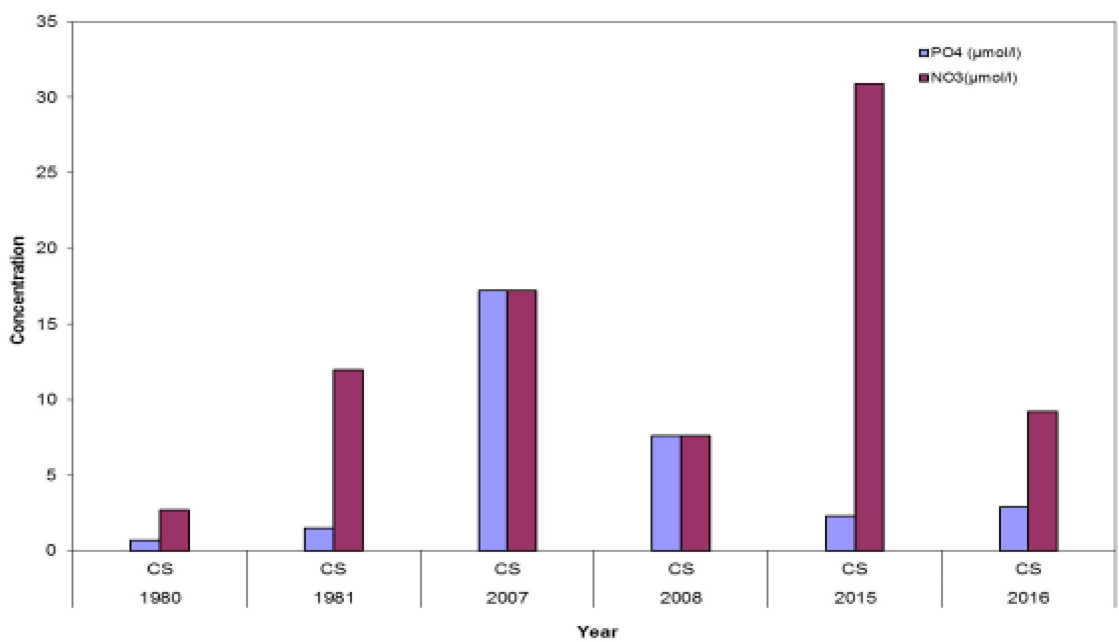


Figure 5.2.80: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Thal (1980-2016).

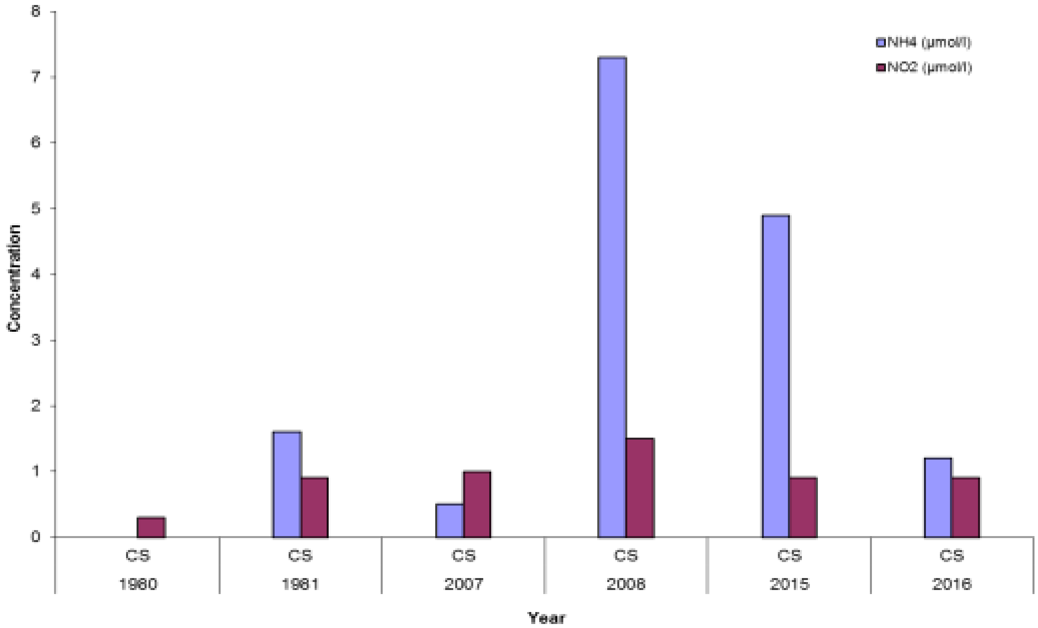


Figure 5.2.81: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Thal (1980-2016).

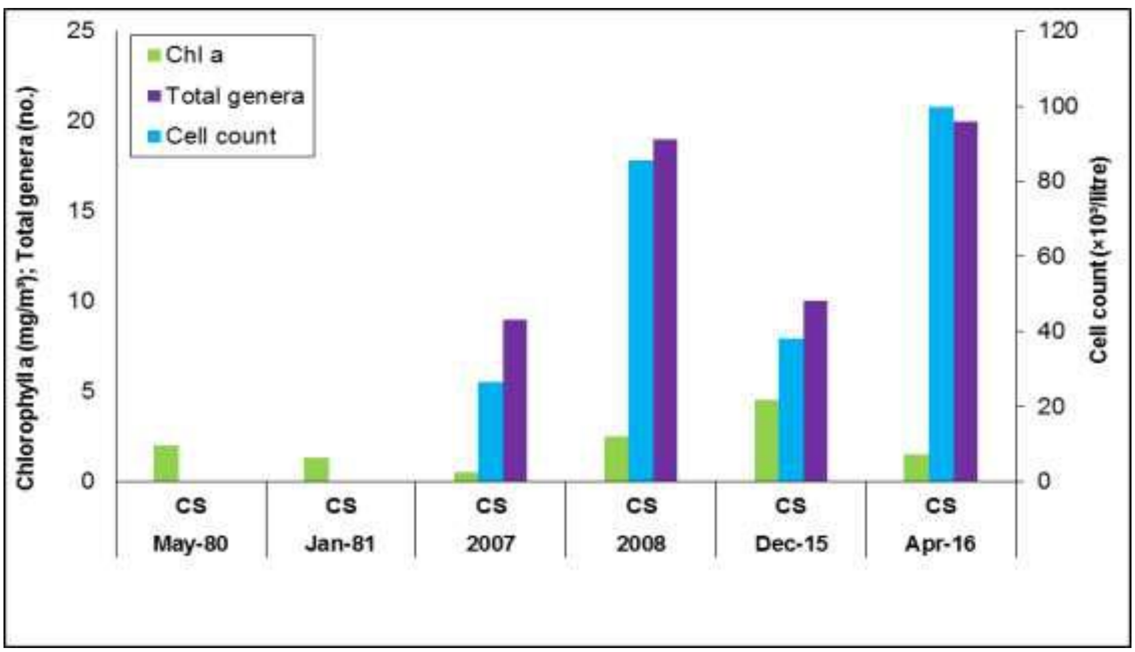


Figure 5.2.82: Comparative phytopigment and generic diversity of Thal (1980-2016).

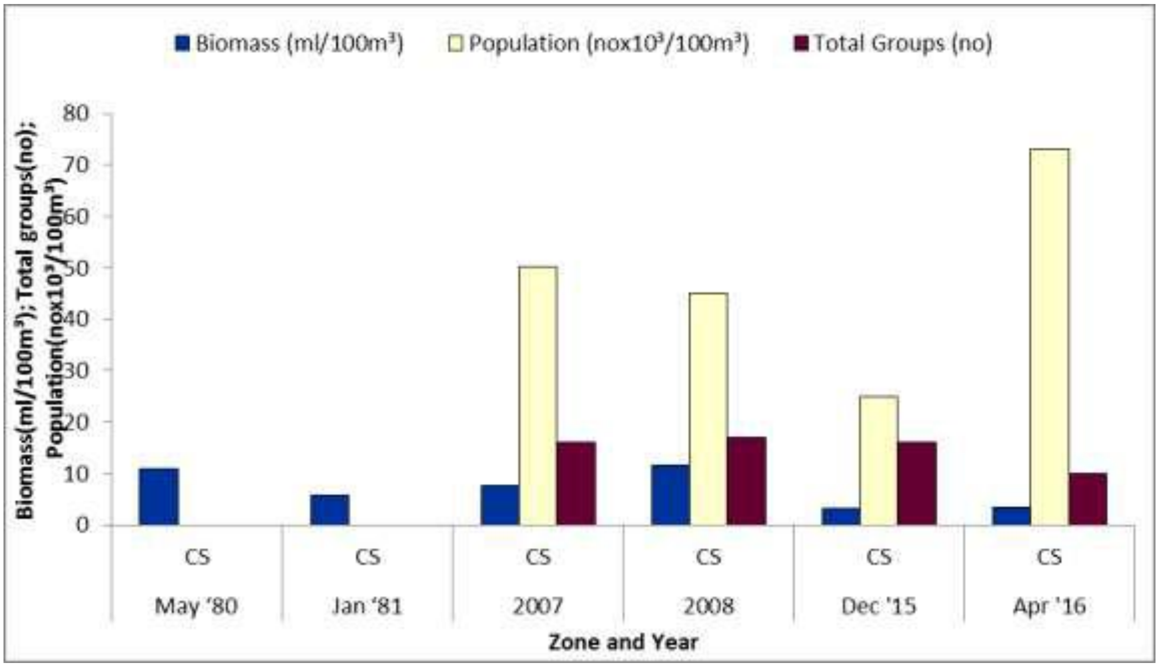


Figure 5.2.83: Comparative zooplankton biomass, population and group diversity of Thal (1980-2016).

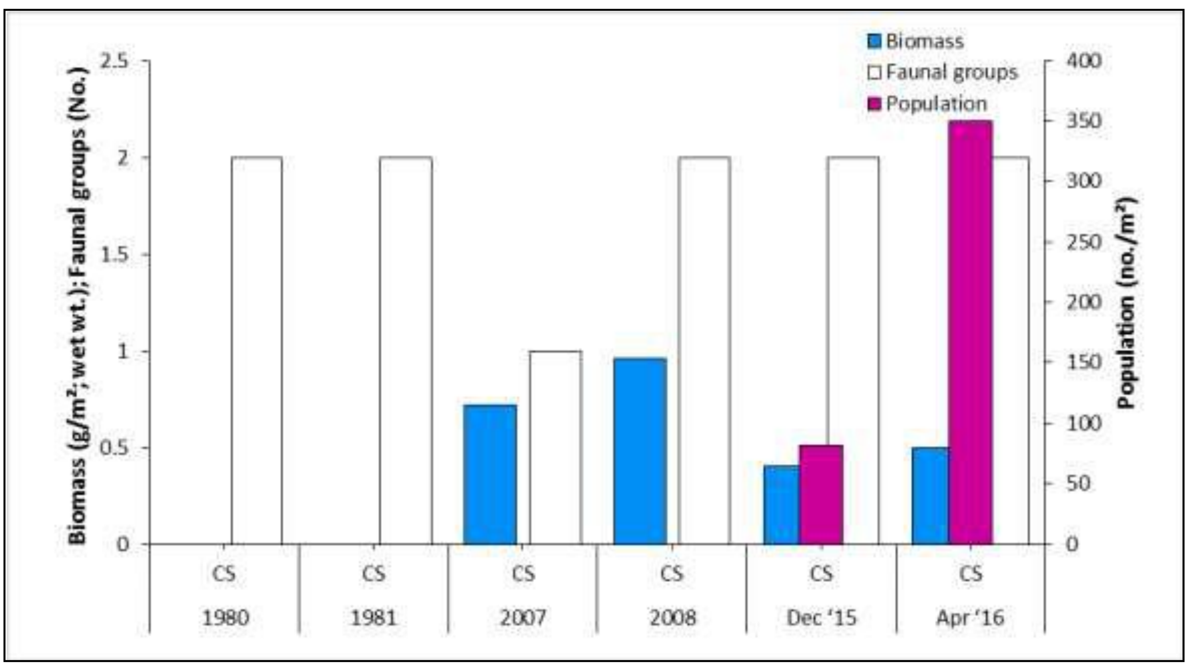


Figure 5.2.84: Comparative macrobenthos biomass, population and group diversity of Thal (1980-2016).

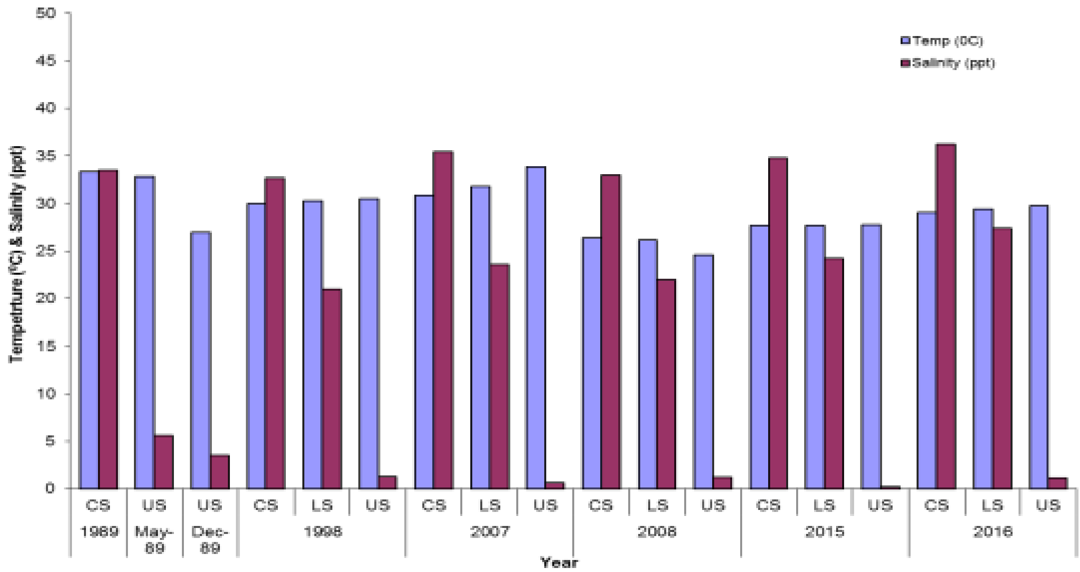


Figure 5.2.85: Temperature (°C) & Salinity (ppt) in Kundalika (1989-2016).

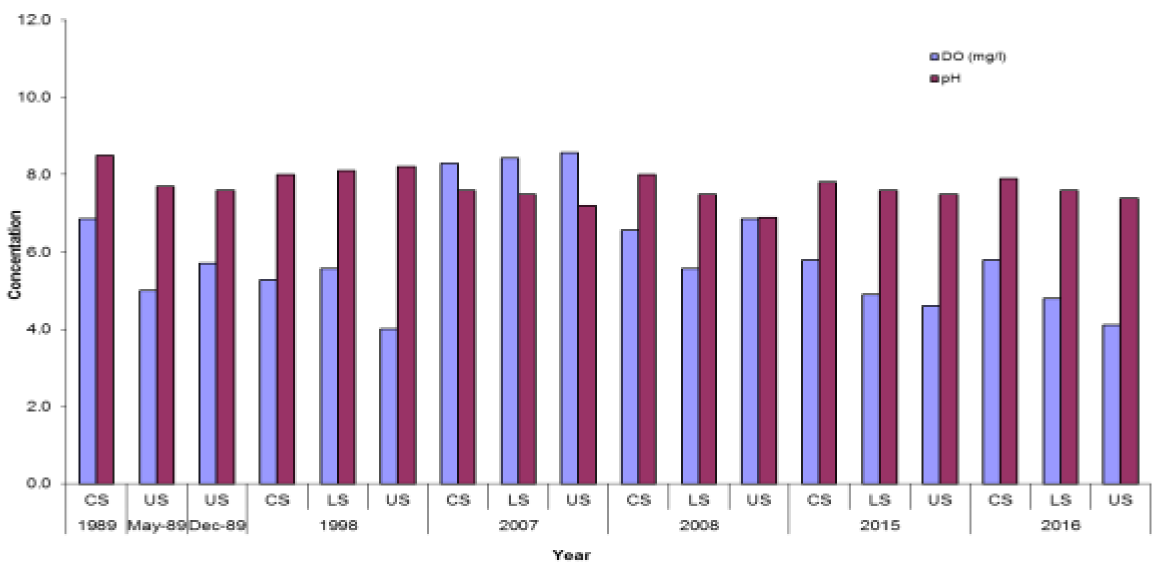


Figure 5.2.86: Concentration of DO (mg/l) & pH in Kundalika (1989-2016).

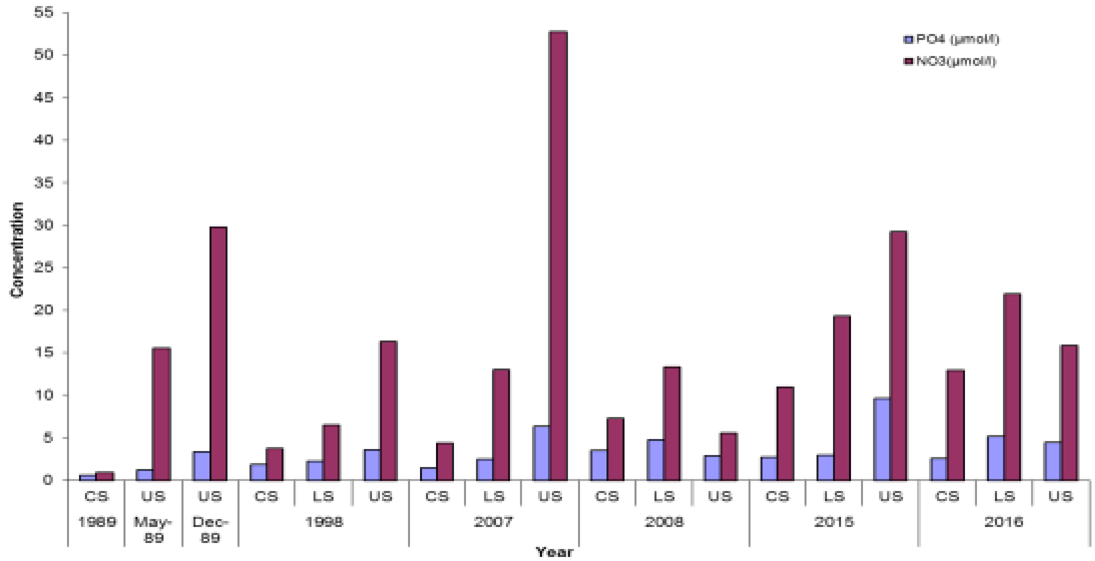


Figure 5.2.87: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Kundalika (1989-2016).

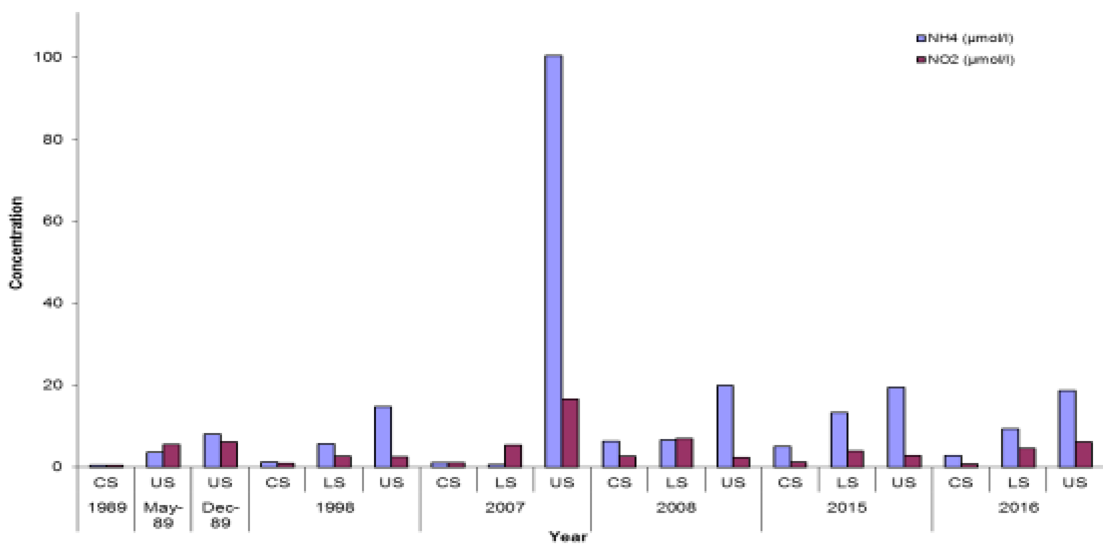


Figure 5.2.88: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Kundalika (1989-2016).

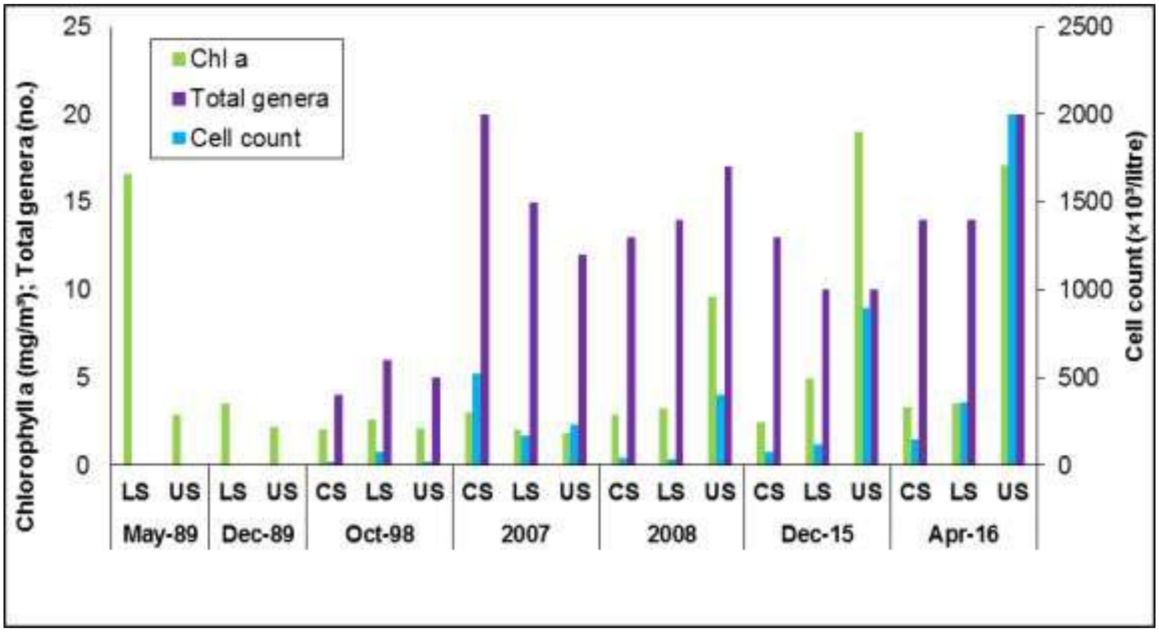


Figure 5.2.89: Comparative phytopigment and generic diversity of Kundalika (1989-2016).

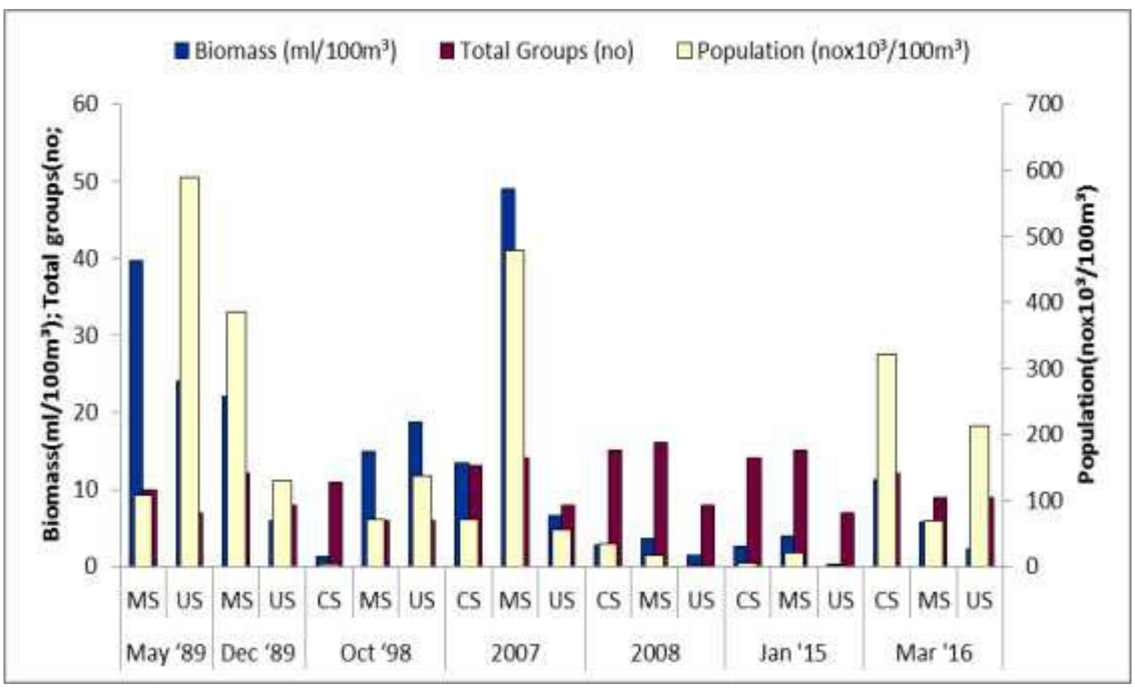


Figure 5.2.90: Comparative zooplankton biomass, population and group diversity of Kundalika (1989-2016).

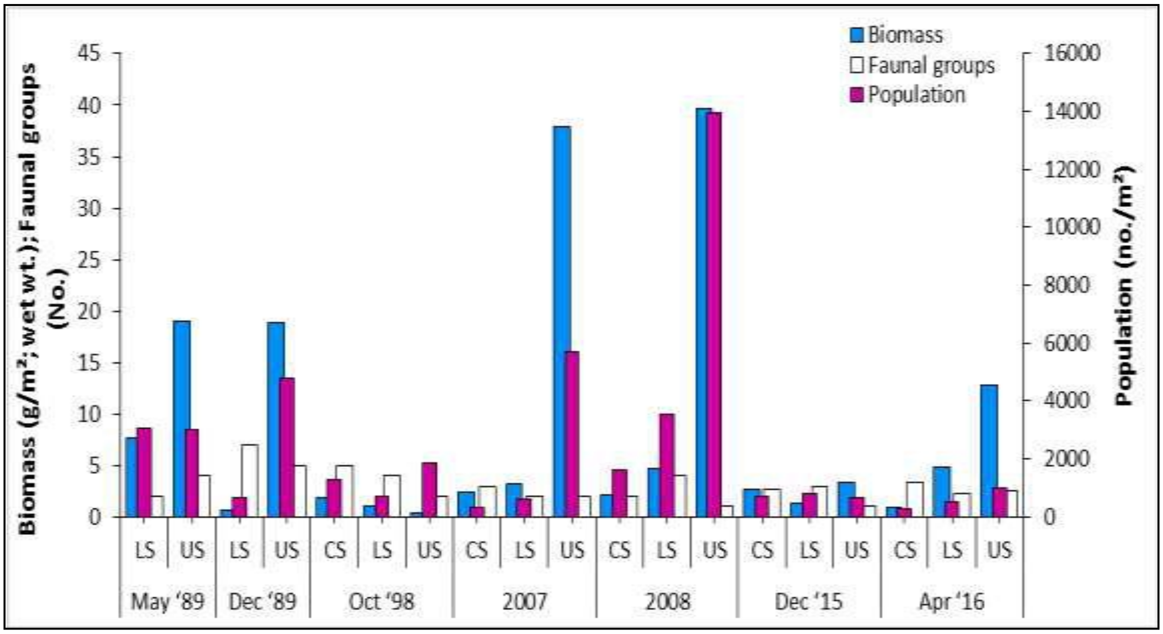


Figure 5.2.91: Comparative macrobenthos biomass, population and group diversity of Kundalika (1989-2016).

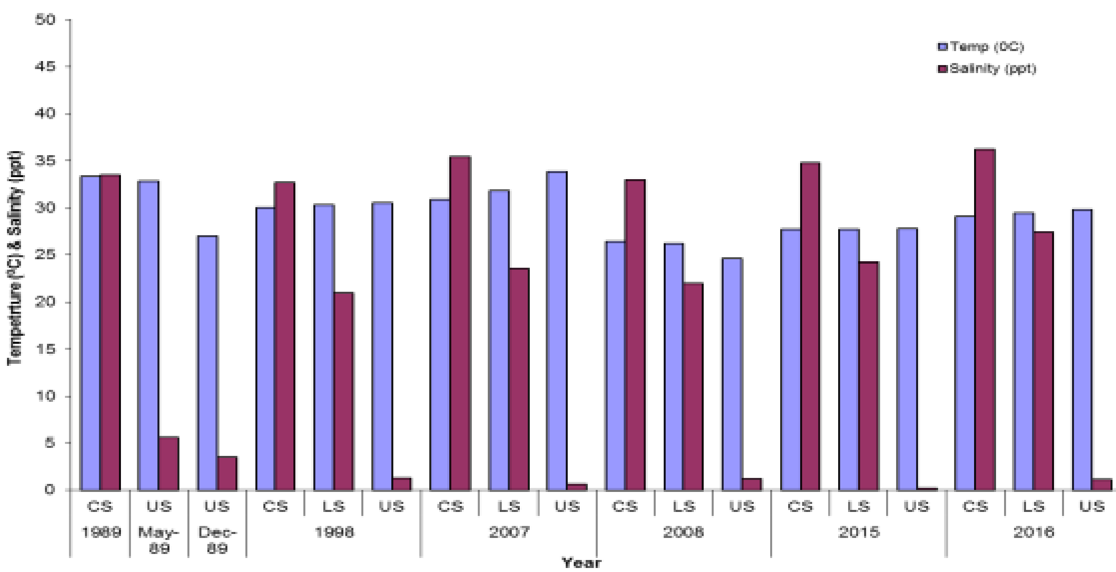


Figure 5.2.92: Temperature (°C) & Salinity (ppt) in Murud (1989-2016).

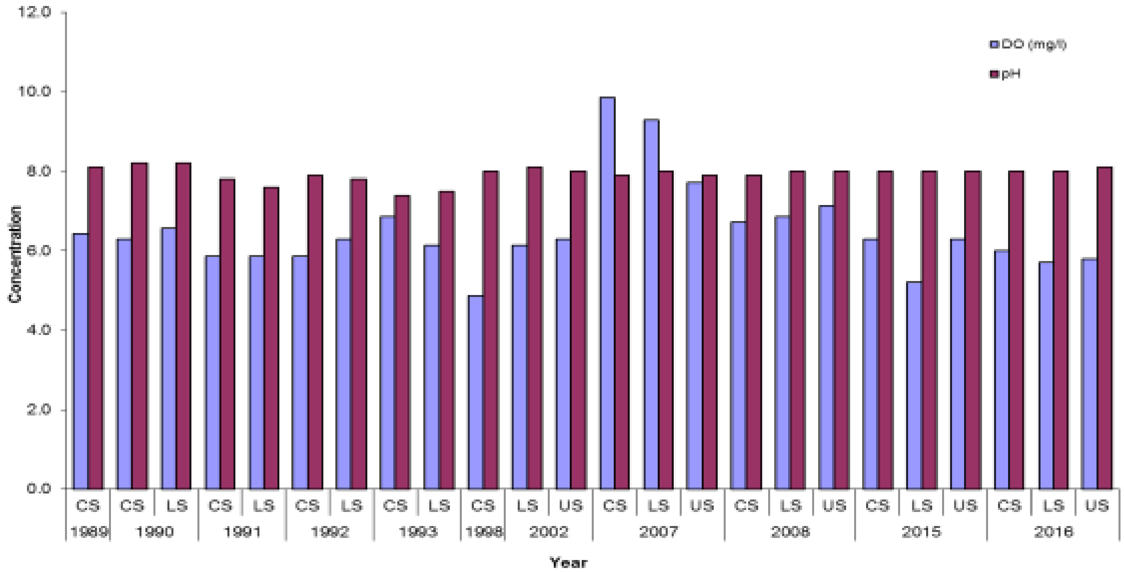


Figure 5.2.93: Concentration of DO (mg/l) & pH in Murud (1989-2016).

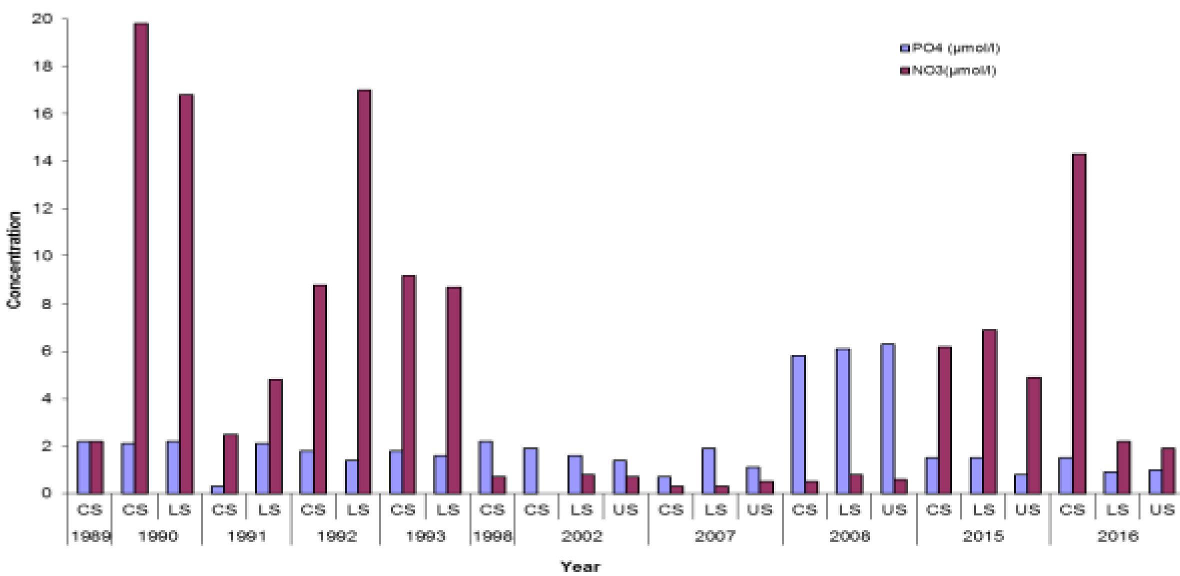


Figure 5.2.94: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Murud (1989-2016).

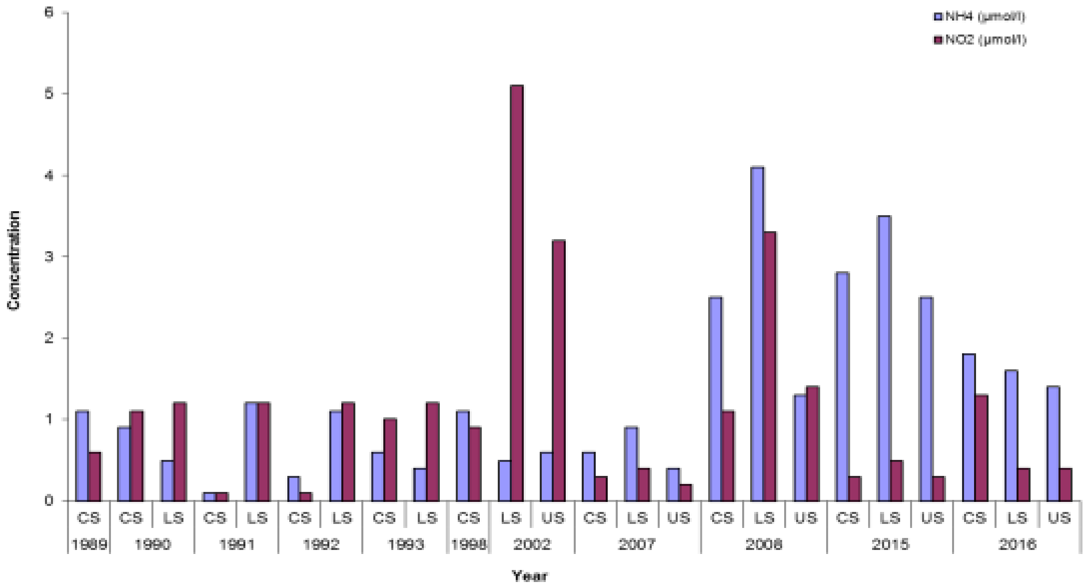


Figure 5.2.95: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Murud (1989-2016).

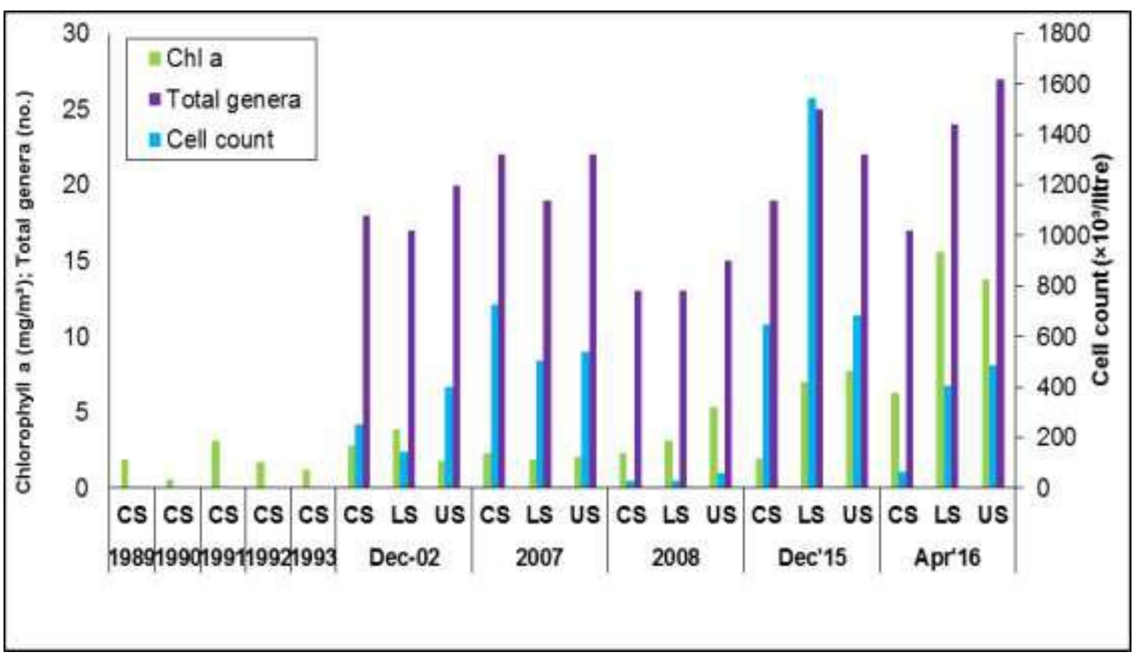


Figure 5.2.96: Comparative phytopigment and generic diversity of Murud (1989-2016).

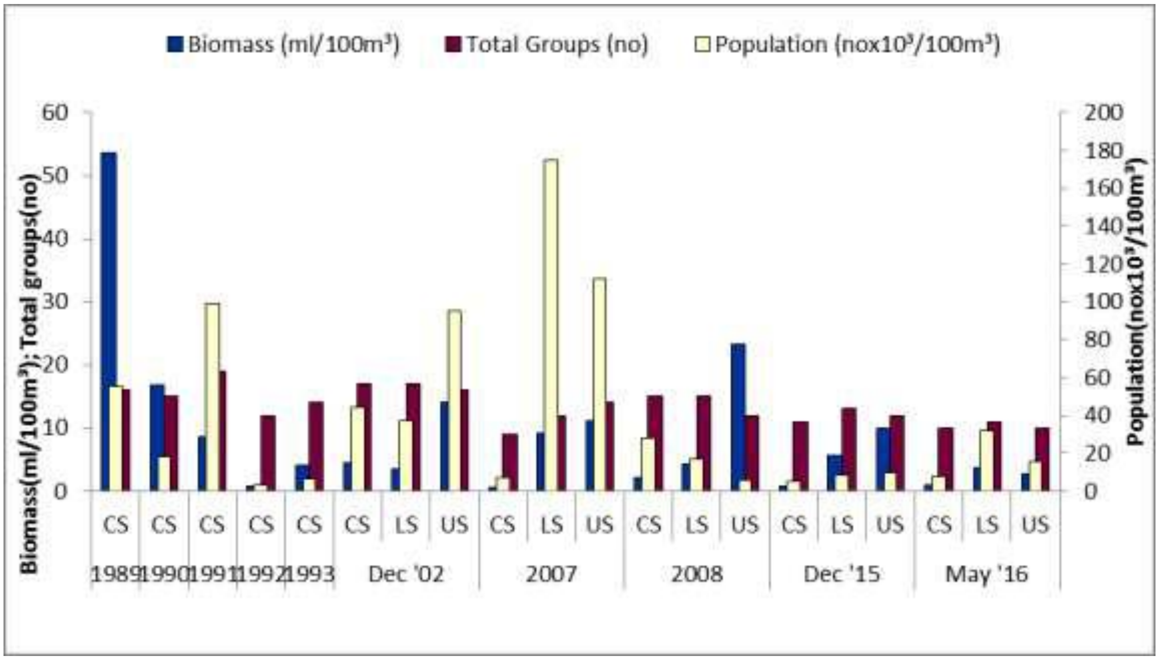


Figure 5.2.97: Comparative zooplankton biomass, population and group diversity of Murud (1989-2016).

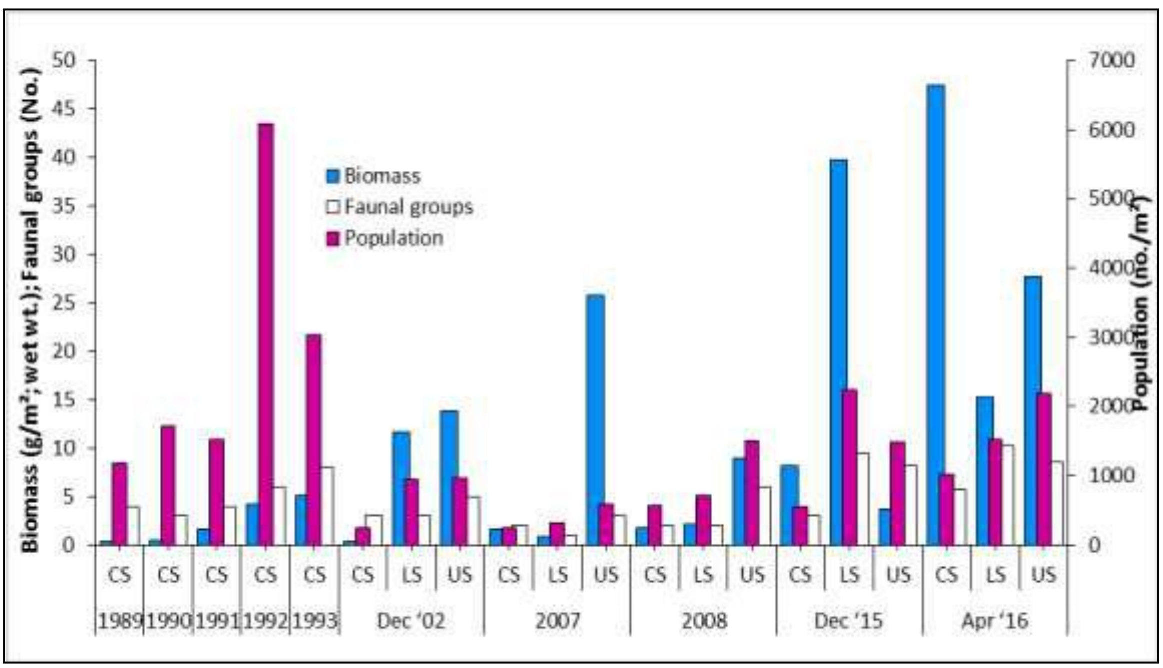


Figure 5.2.98: Comparative macrobenthos biomass, population and group diversityof Murud (1989-2016).

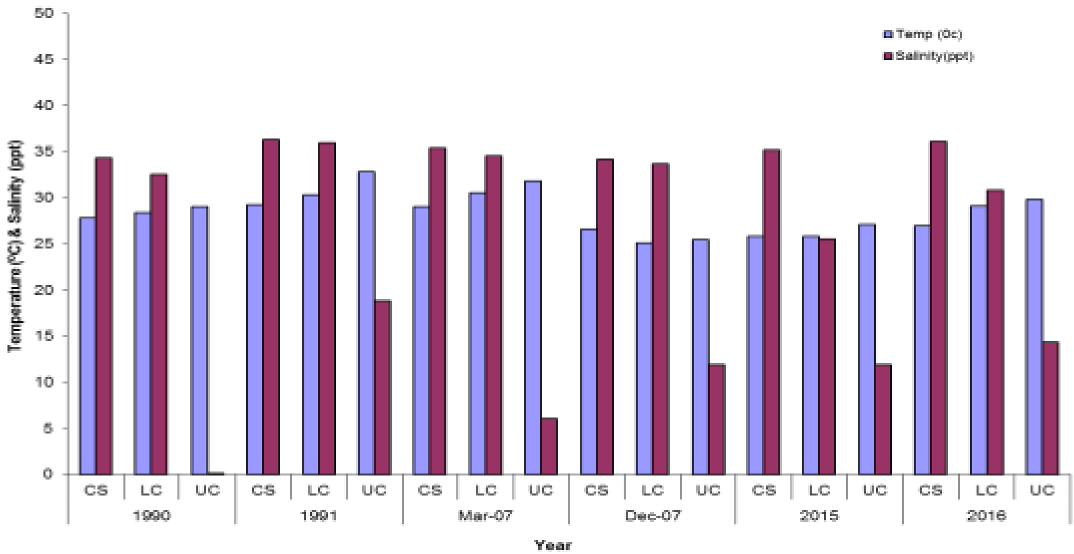


Figure 5.2.99: Temperature (°C) & Salinity (ppt) in Savitri from year 1990-2016

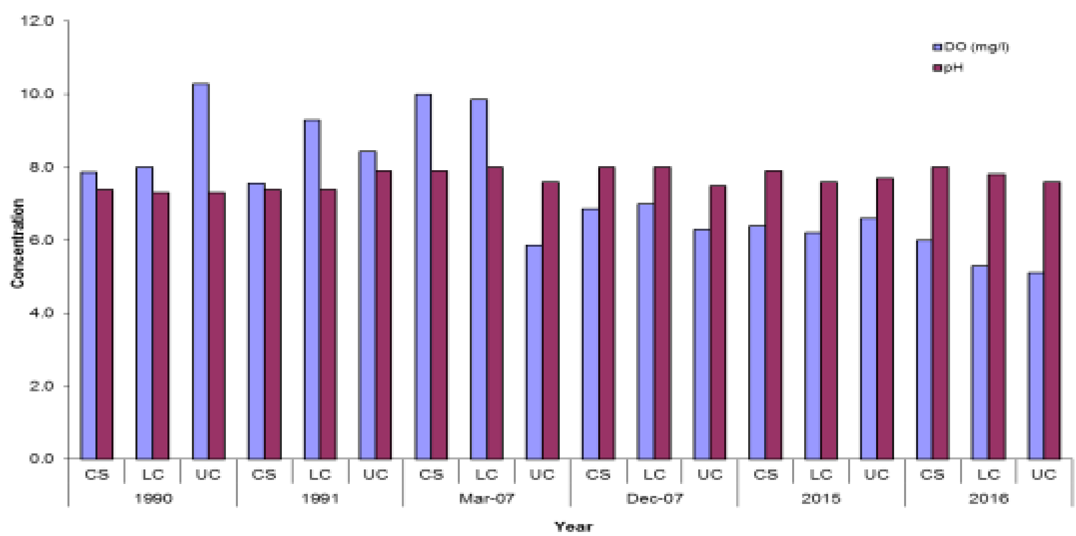


Figure 5.2.100: Concentration of DO (mg/l) & pH in Savitri from year 1990-2016

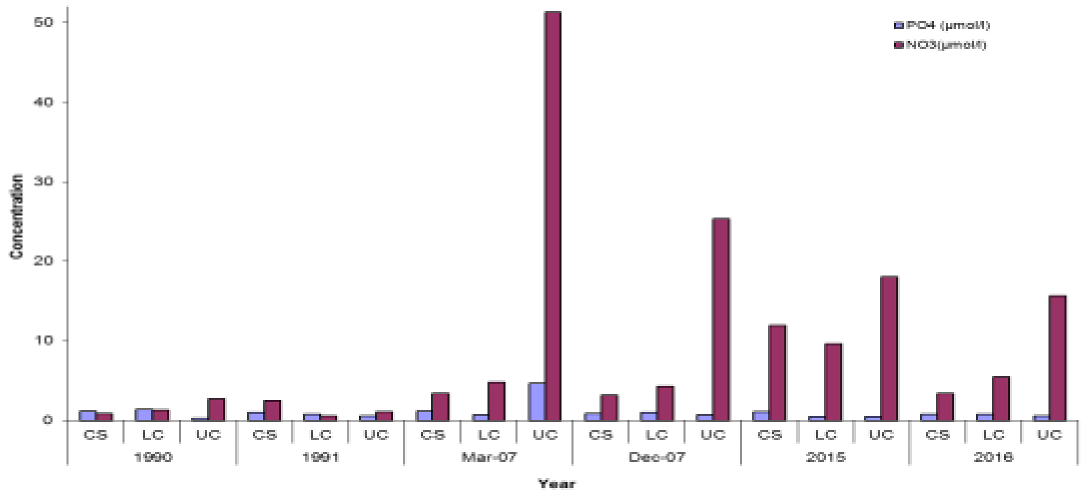


Figure 5.2.101: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Savitri (1990-2016).

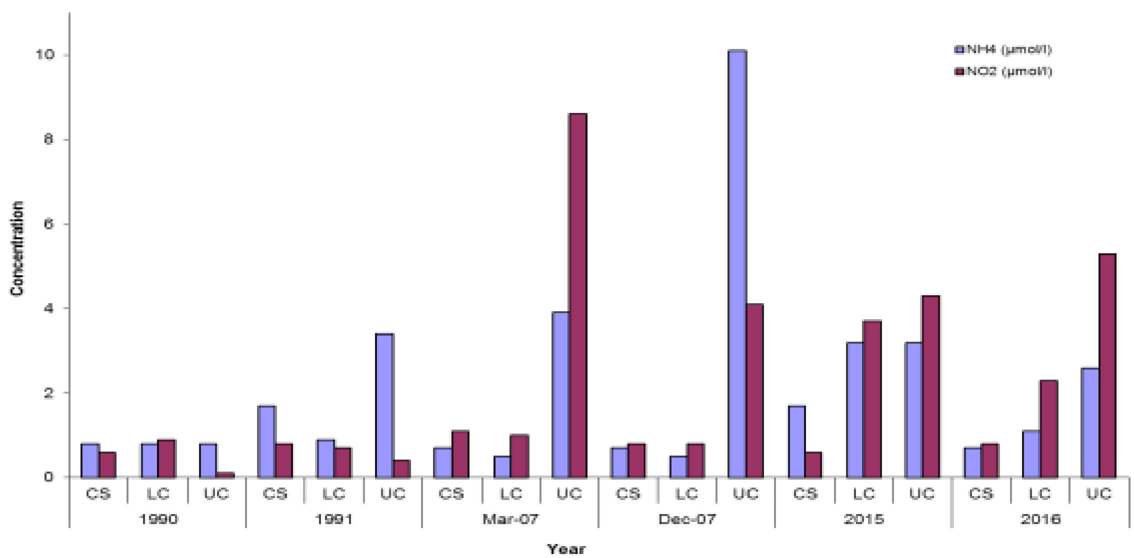


Figure 5.2.102: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Savitri (1990-2016).

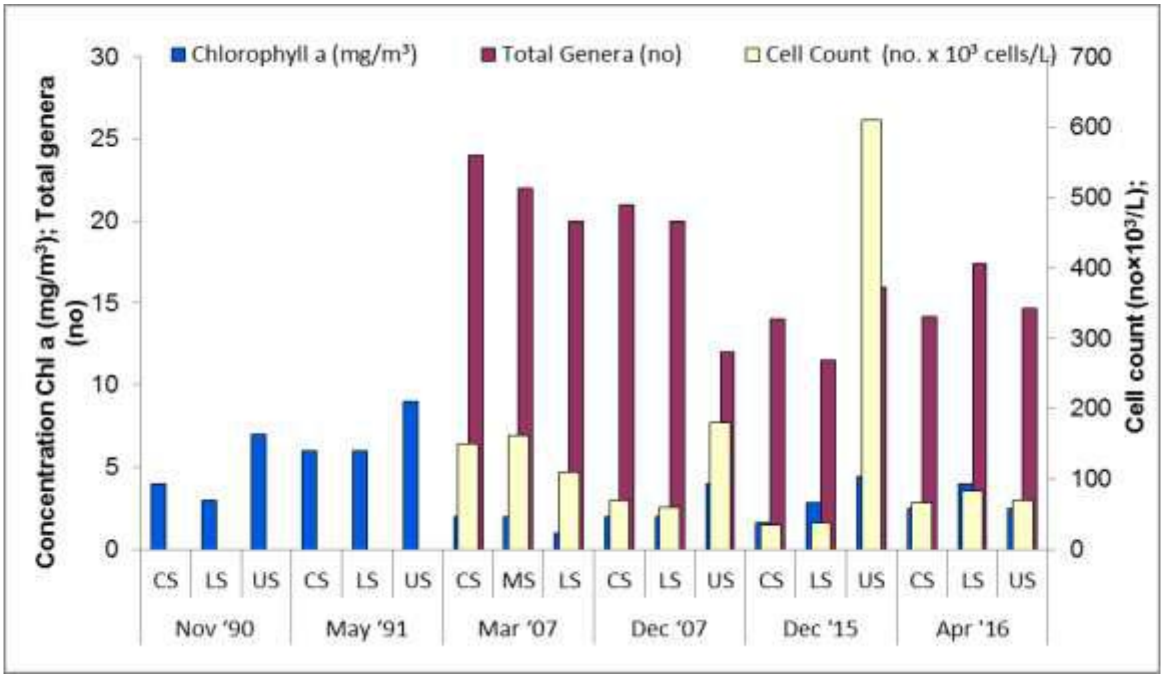


Figure 5.2.103: Comparative phytopigments and generic diversity of Savitri (1990-2016).

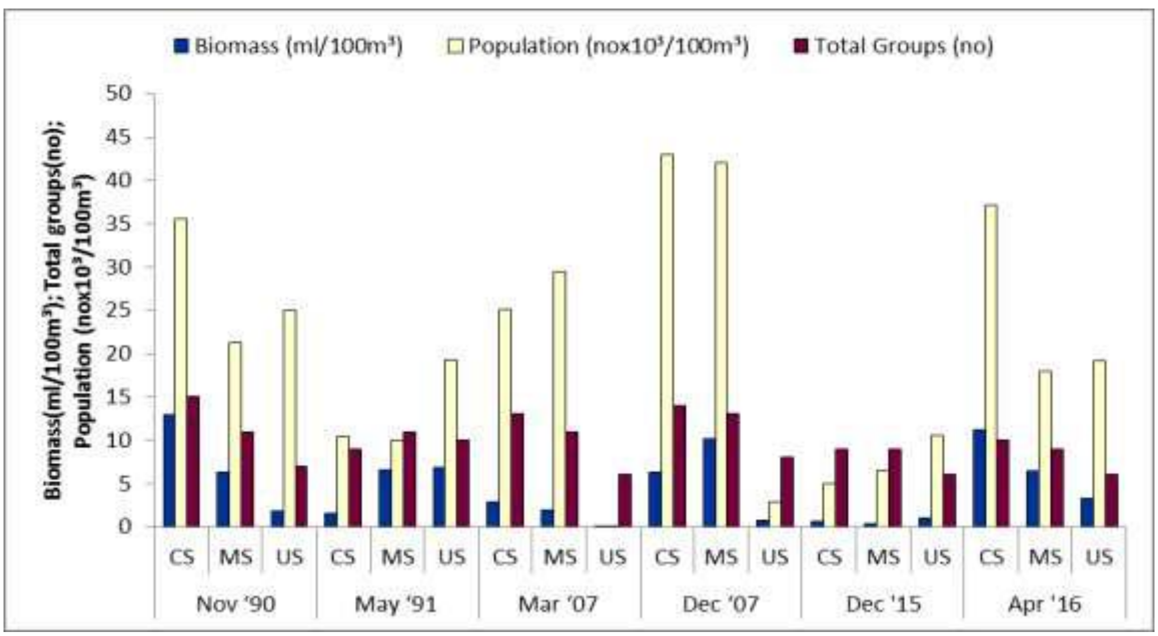


Figure 5.2.104: Comparative zooplankton biomass, population and group diversity of Savitri (1990-2016).

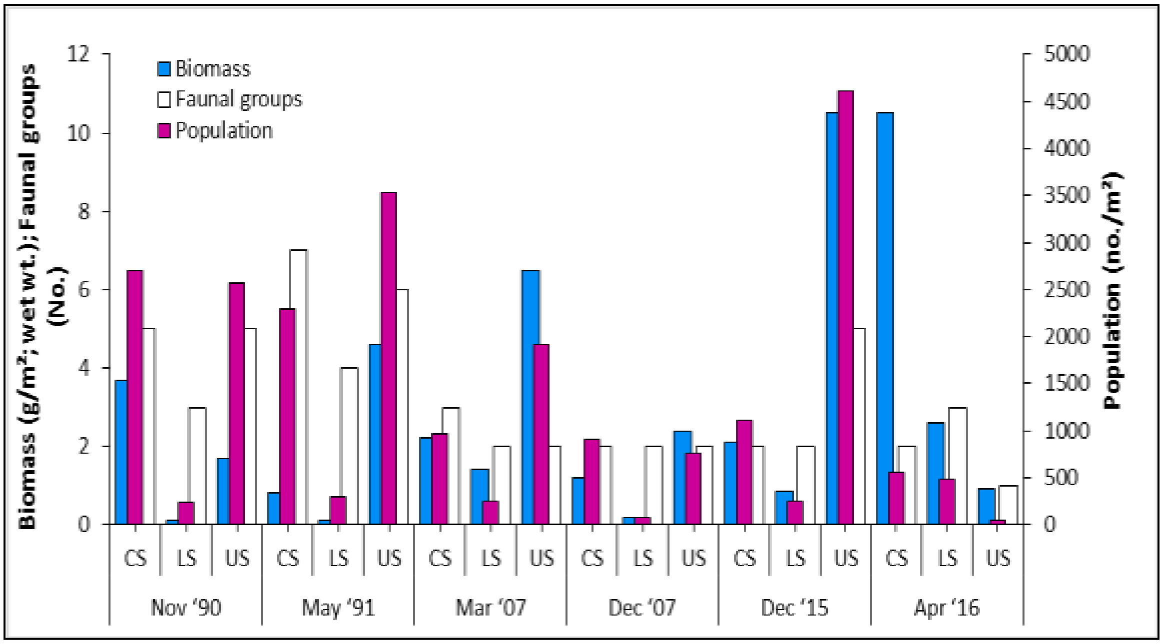


Figure 5.2.105: Comparative macrobenthos biomass, population and group diversity of Savitri (1990-2016).

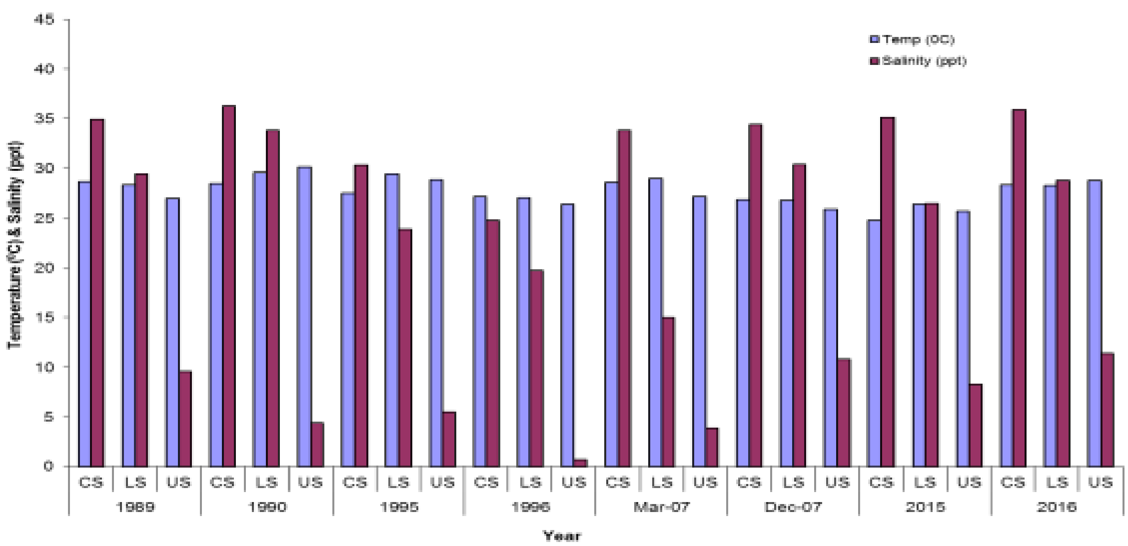


Figure 5.2.106: Temperature (°C) & Salinity (ppt) in Vashishti from year 1989-2016

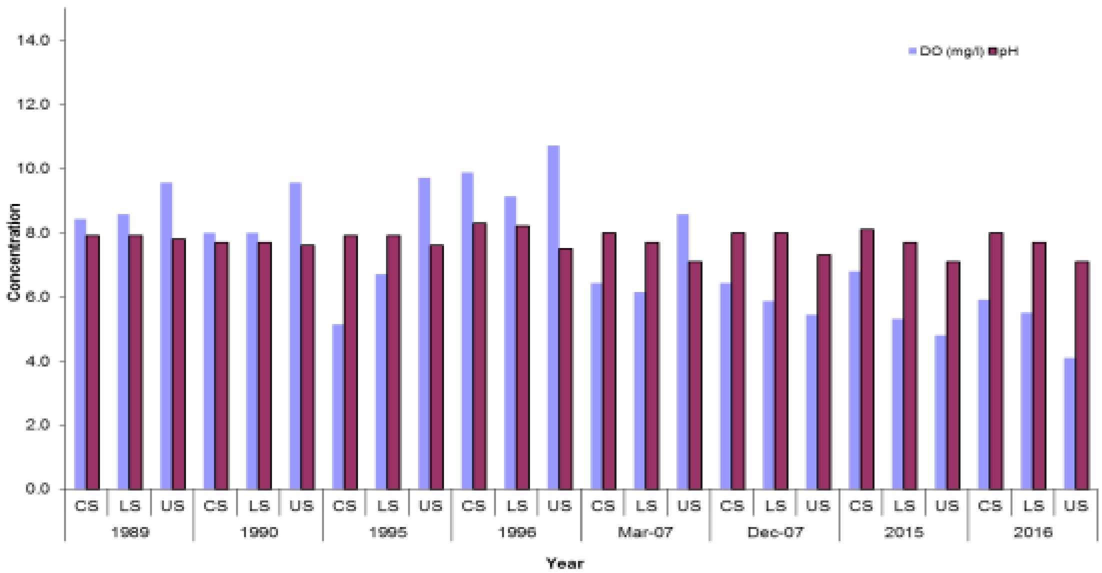


Figure 5.2.107: Concentration of DO (mg/l) & pH in Vashishti from year 1989-2016

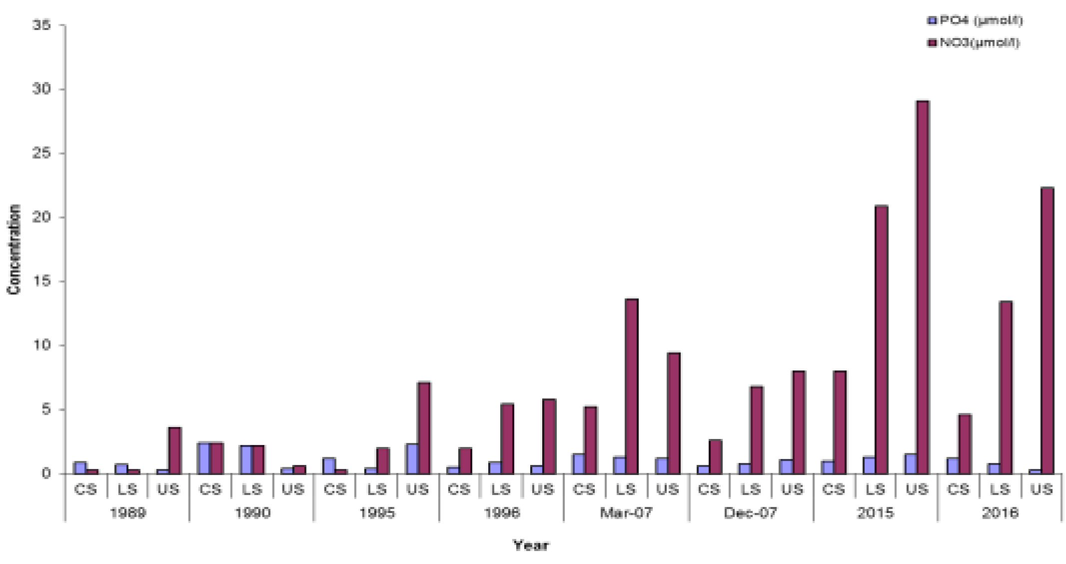


Figure 5.2.108: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Vashishti from Year1989-2016

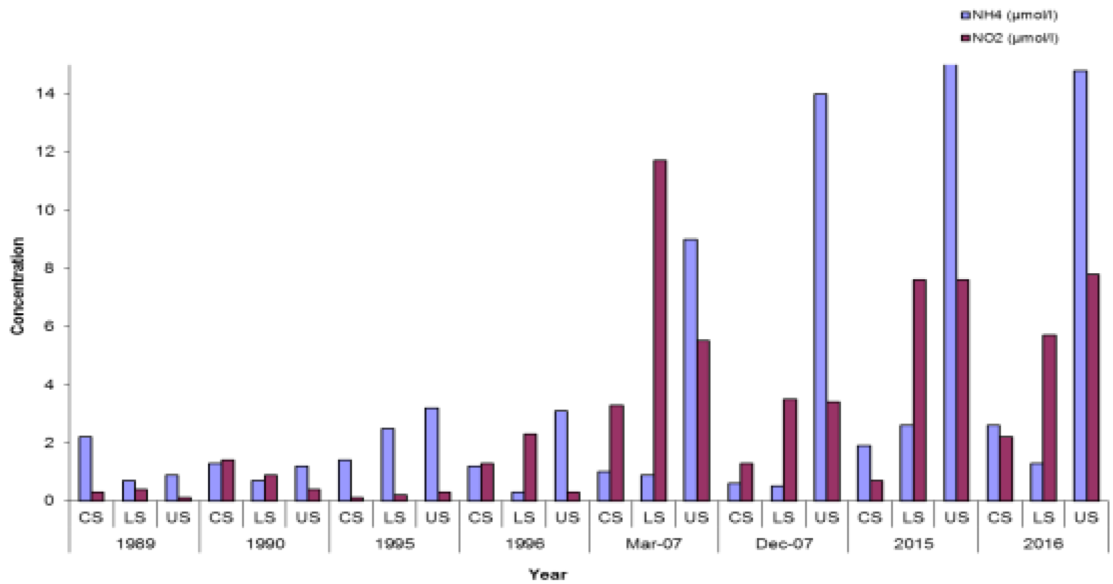


Figure 5.2.109: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Vashishti (1989-2016).

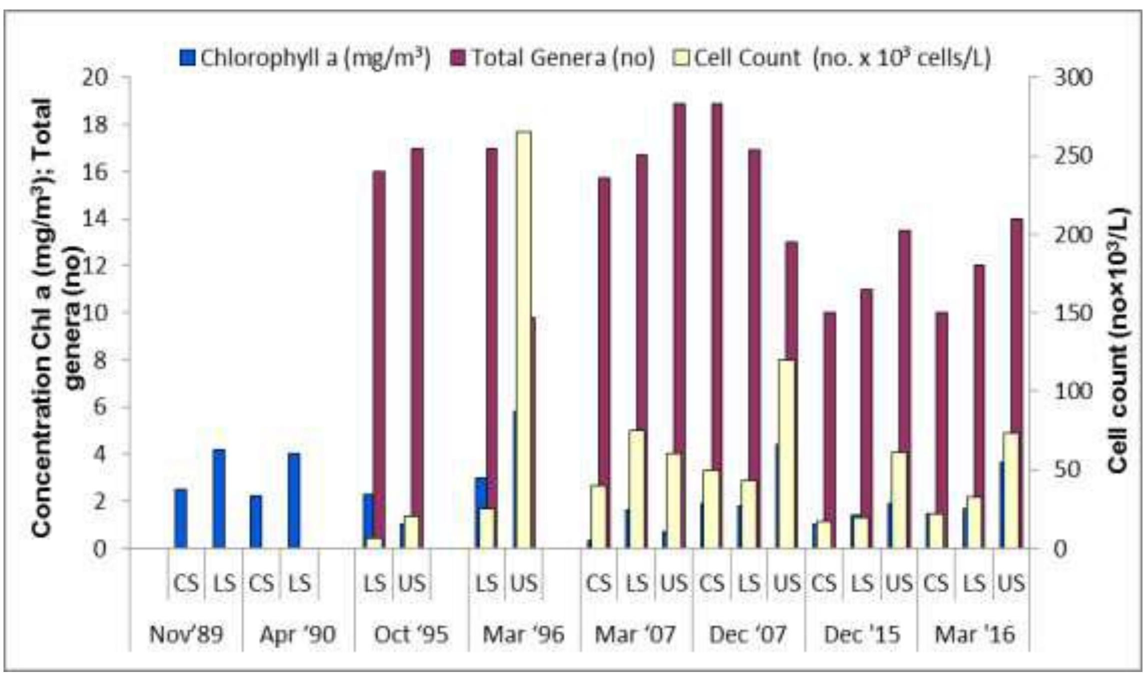


Figure 5.2.110: Comparative phytopigments and generic diversity of Vashishti (1989-2016).

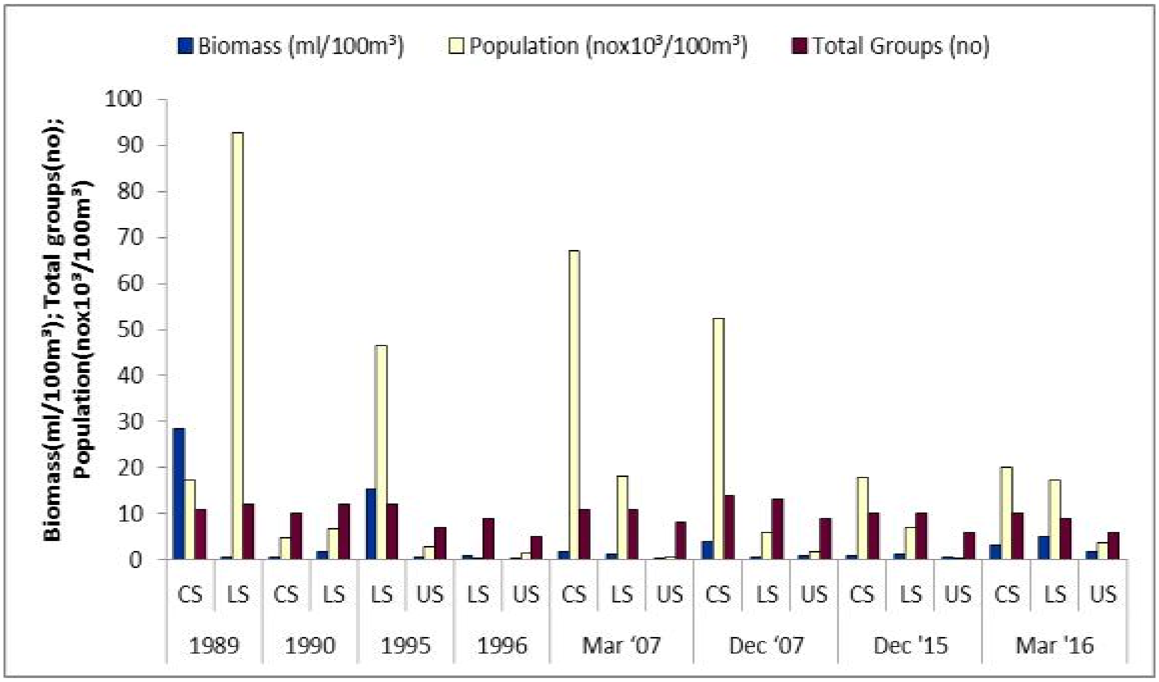


Figure 5.2.111: Comparative zooplankton biomass, population and group diversity of Vashishti (1989-2016).

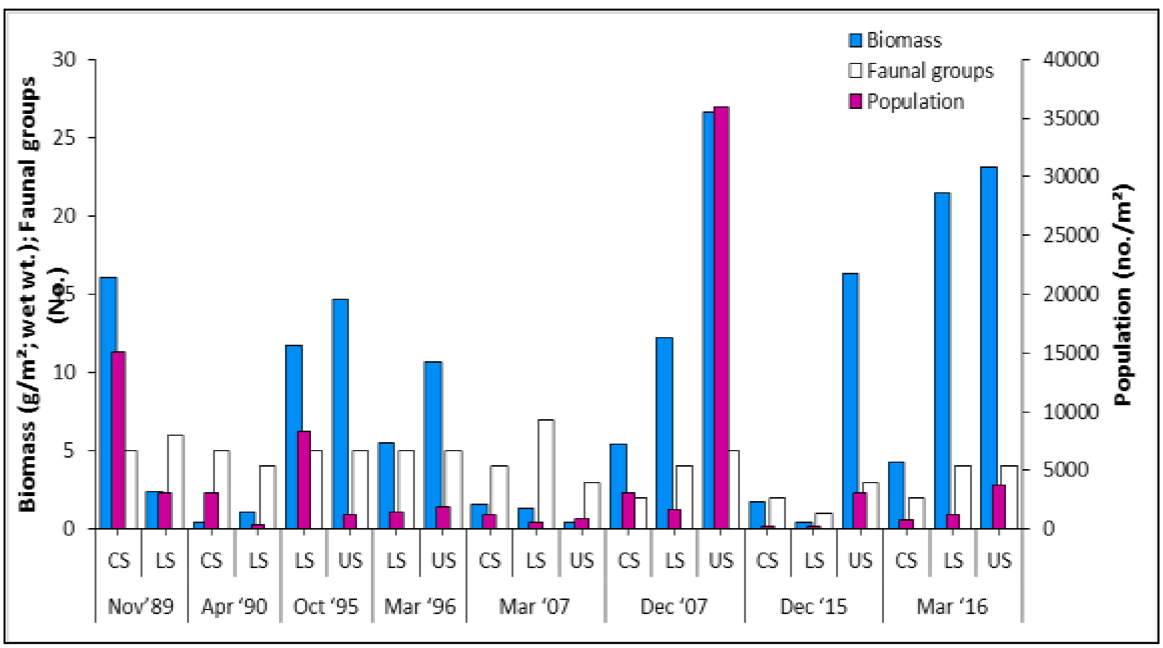


Figure 5.2.112: Comparative macrobenthos biomass, population and group diversity of Vashishti (1989-2016).

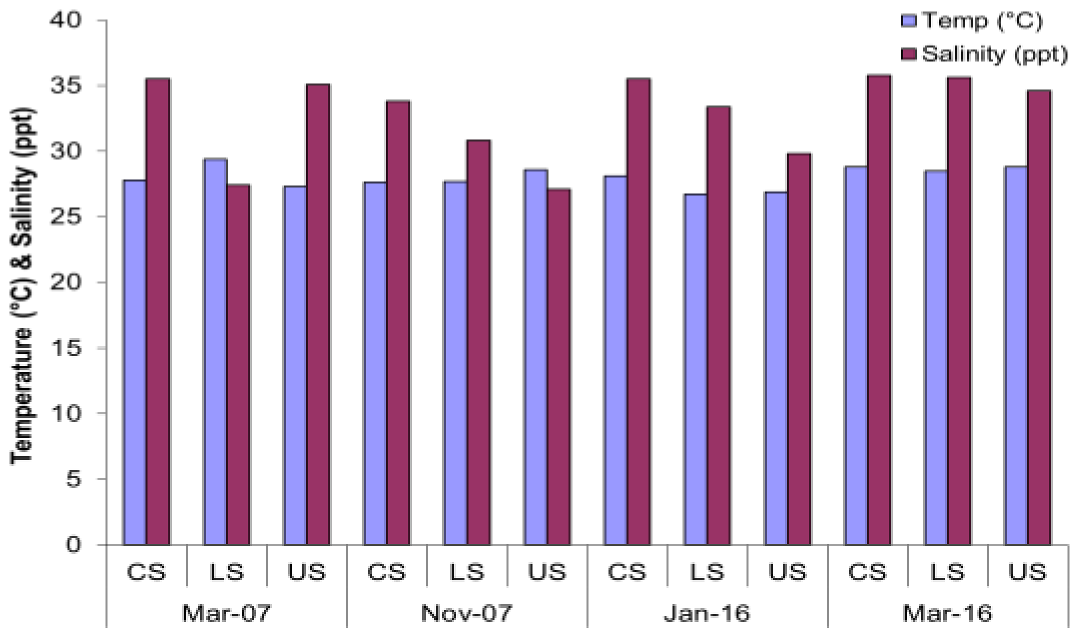


Figure 5.2.113: Temperature (°C) & Salinity (ppt) in Jaigad (2007-2016).

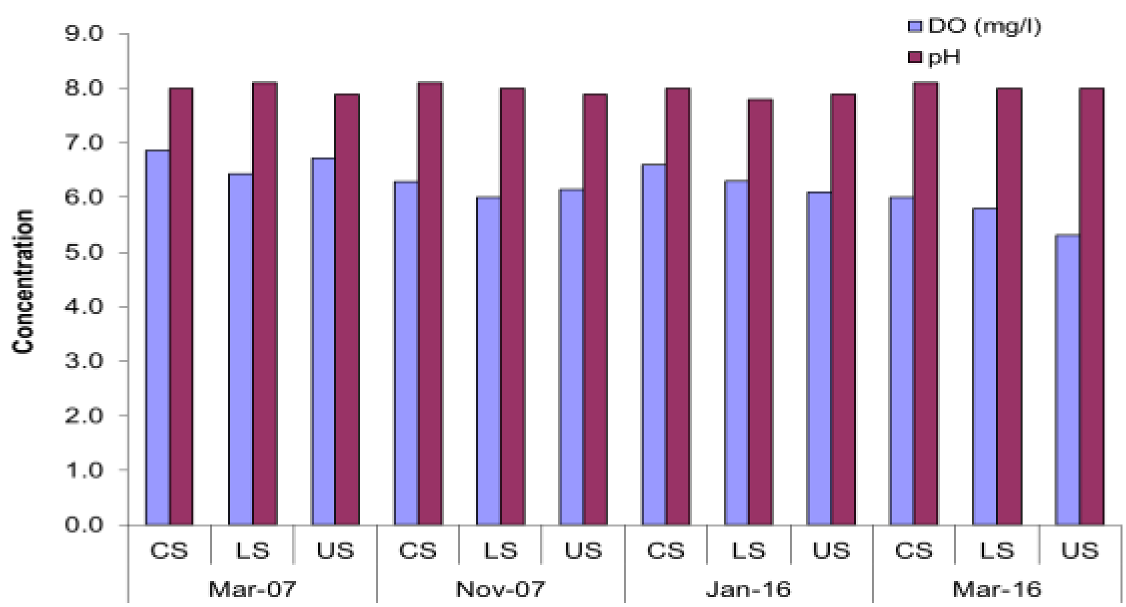


Figure 5.2.114: Concentration of DO (mg/l) & pH in Jaigad (2007-2016).

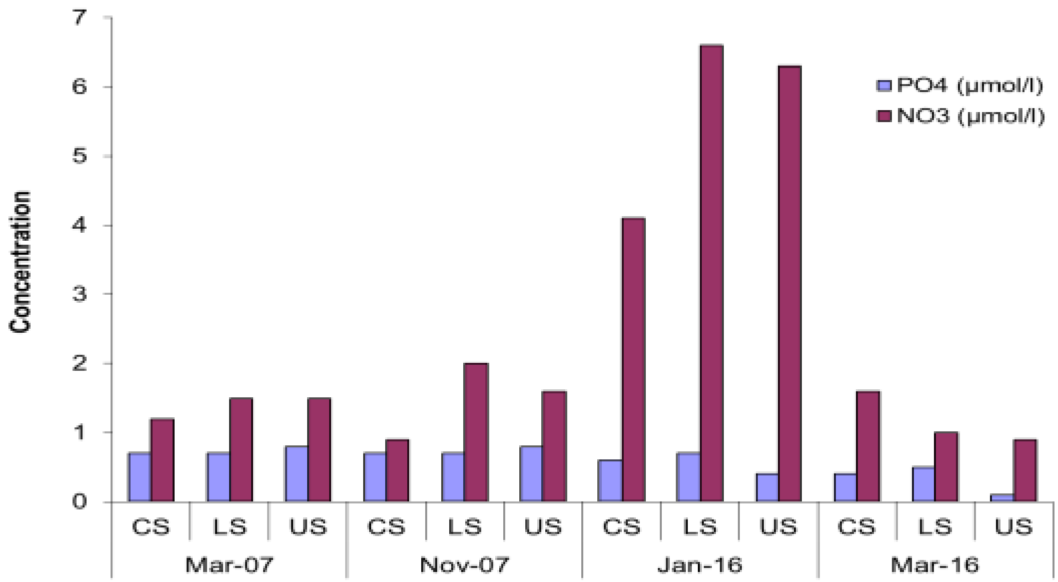


Figure 5.2.115: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Jaigad (2007-2016).

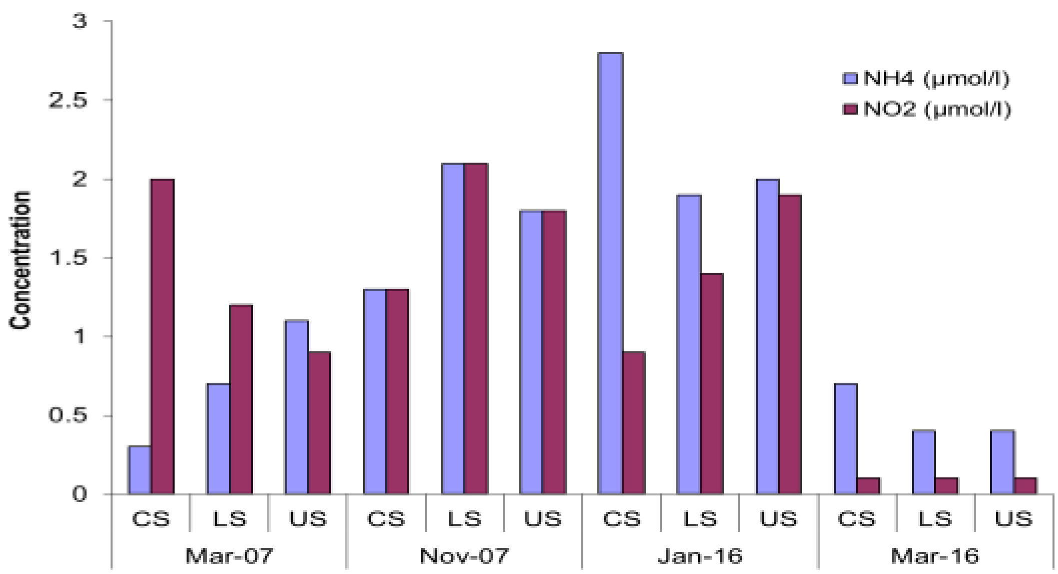


Figure 5.2.116: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Jaigad (2007-2016).

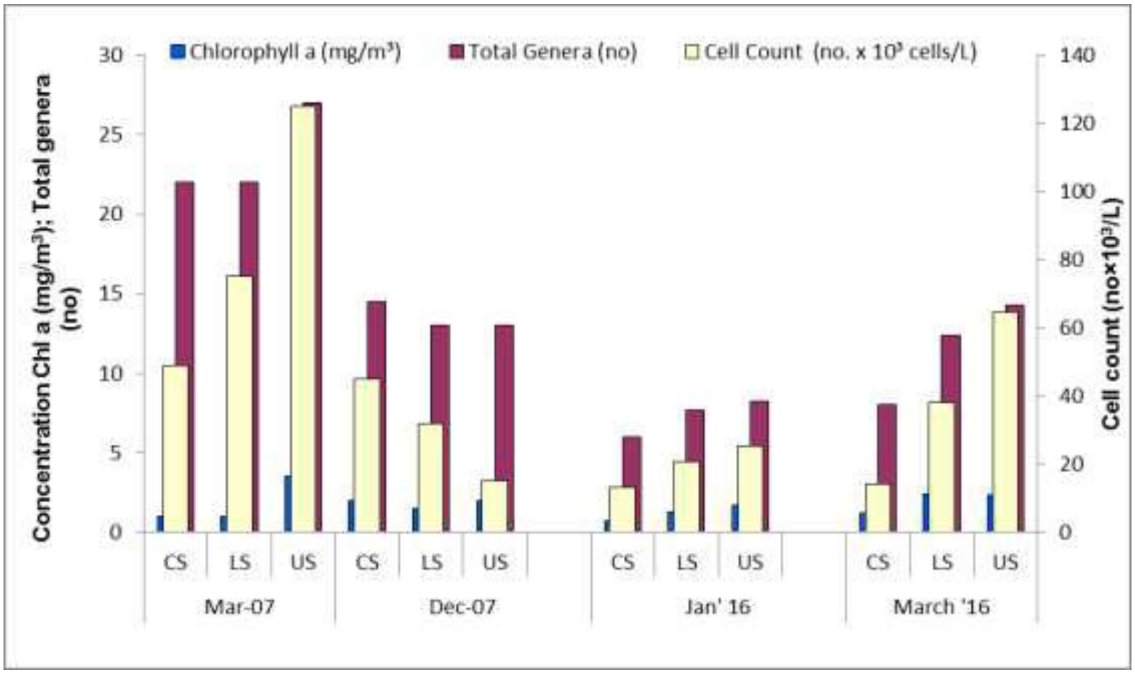


Figure 5.2.117: Comparative phytopigments and generic diversity of Jaigad (2007-2016).

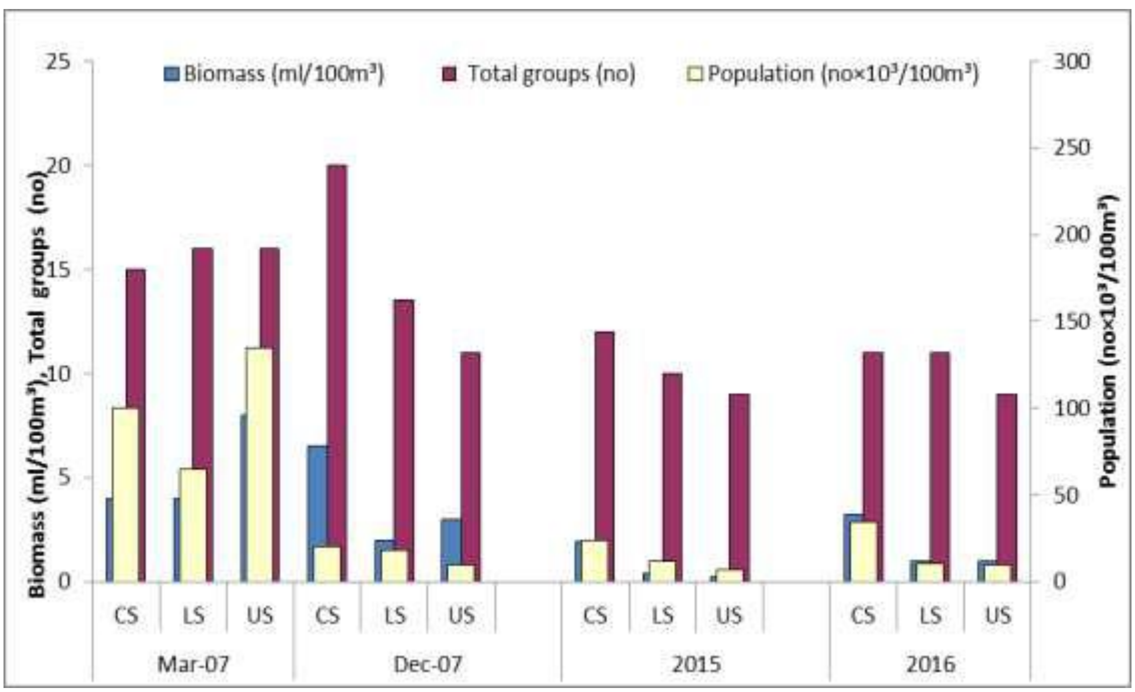


Figure 5.2.118: Comparative zooplankton biomass, population and group diversity of Jaigad (2007-2016).

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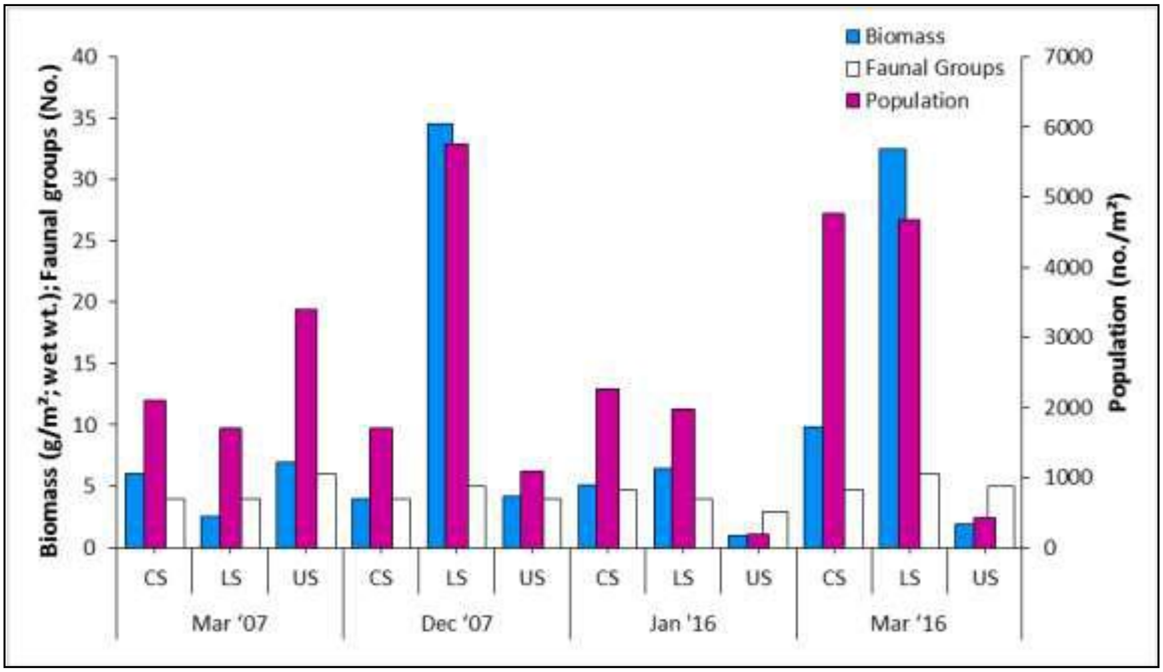


Figure 5.2.119: Comparative macrobenthos biomass, population and group diversity of Jaigad (2007-2016).

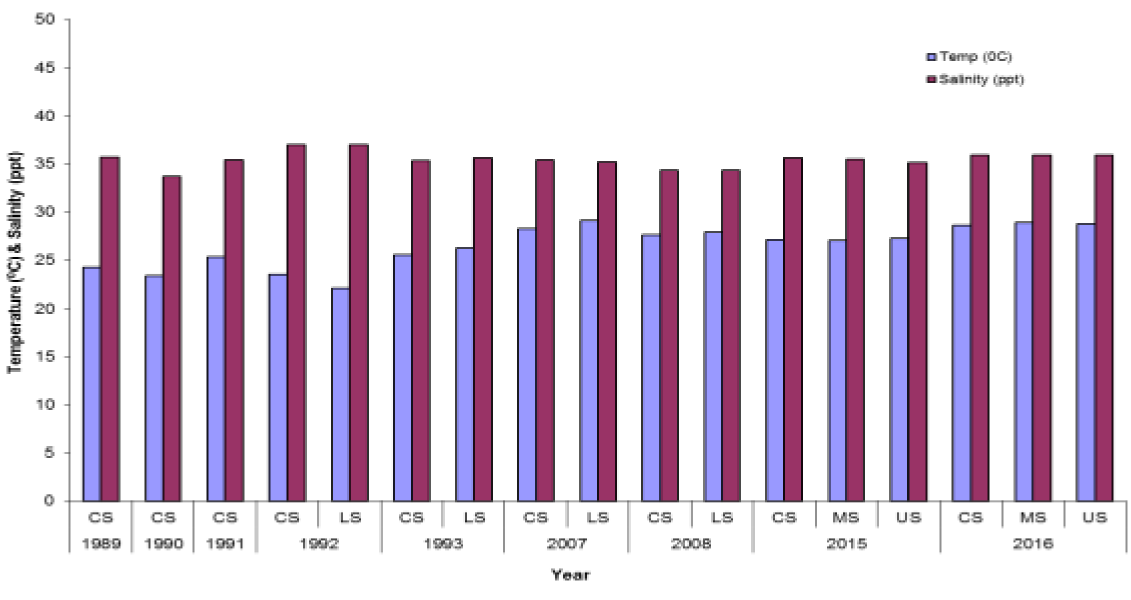


Figure 5.2.120: Temperature (°C) & Salinity (ppt) in Ratnagiri (1989-2016).

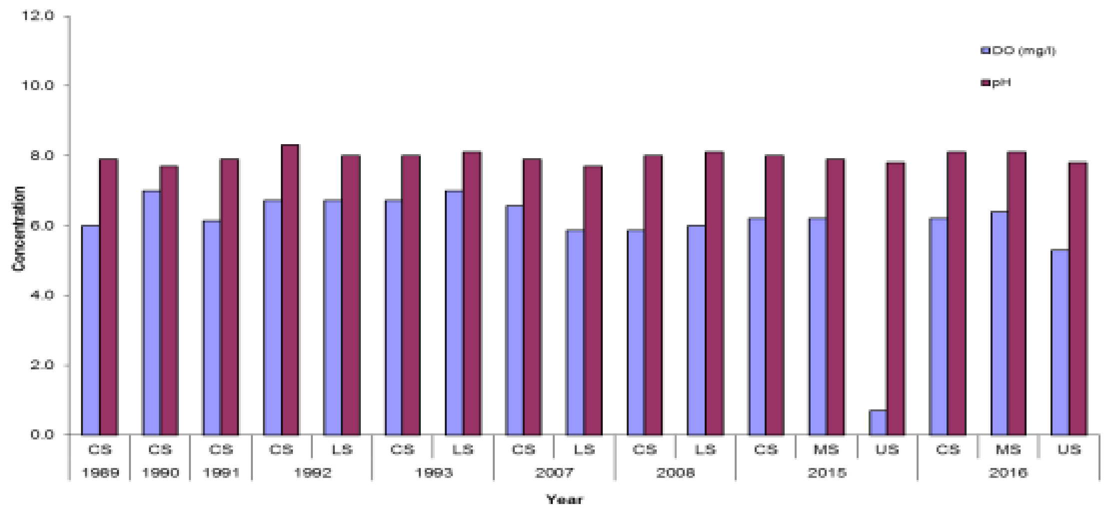


Figure 5.2.121: Concentration of DO (mg/l) & pH in Ratnagiri (1989-2016).

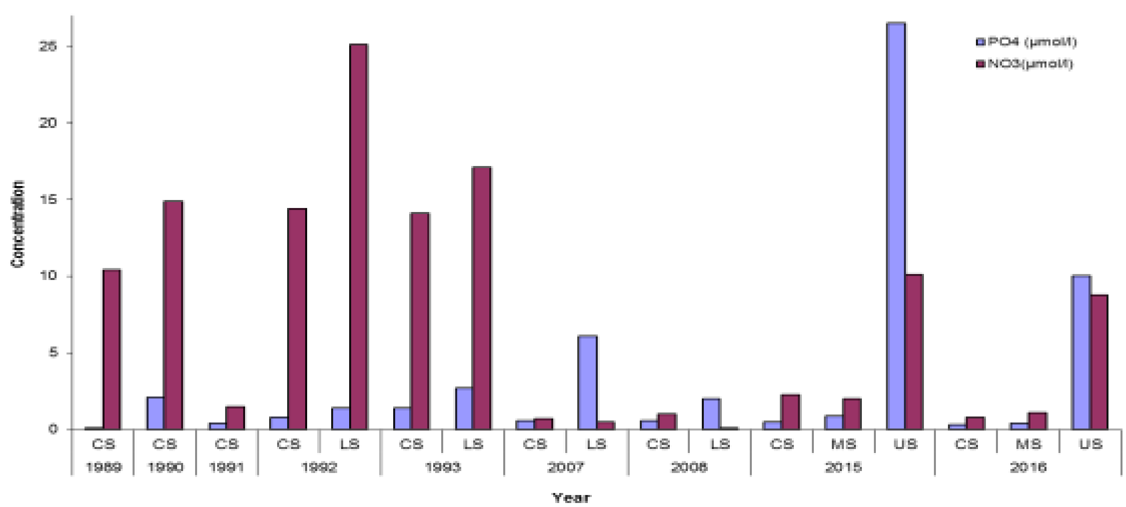


Figure 5.2.122: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Ratnagiri (1989-2016).

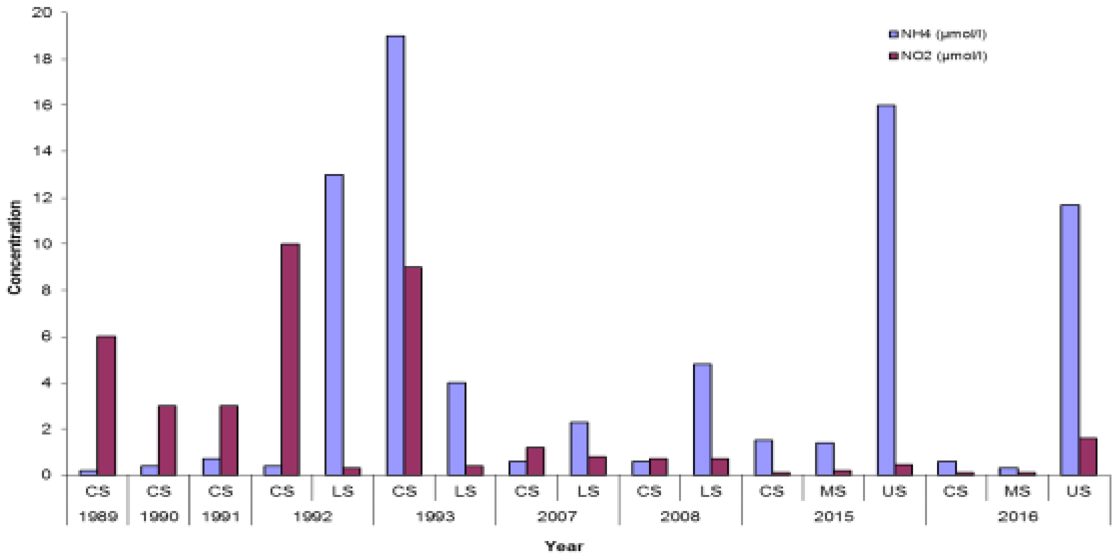


Figure 5.2.123: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Ratnagiri (1989-2016).

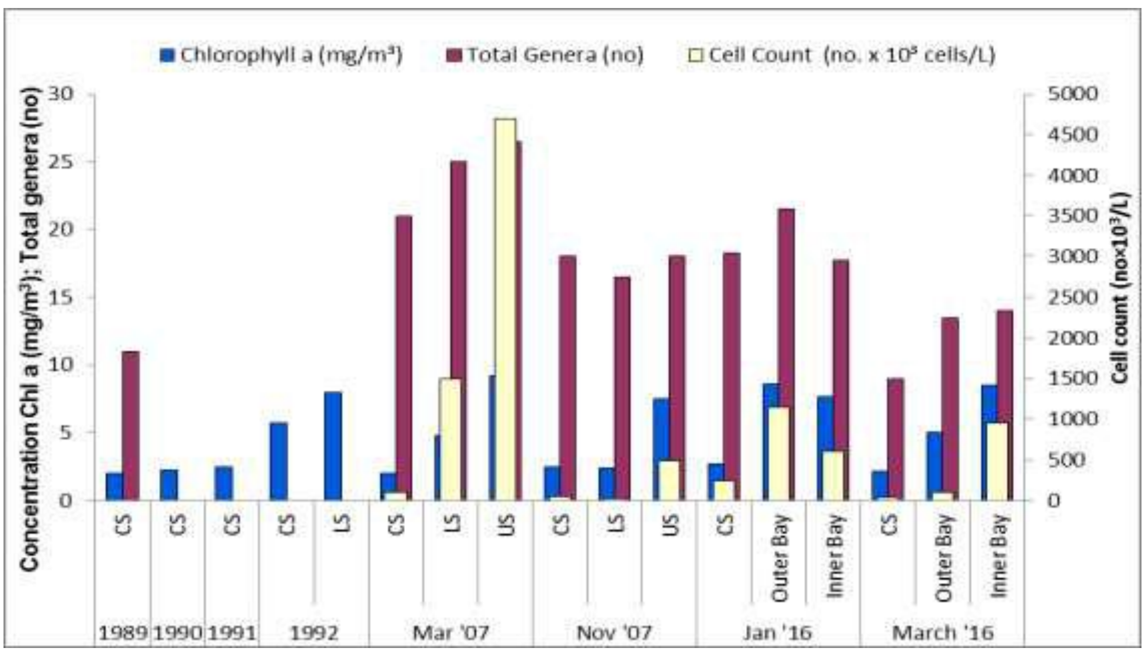


Figure 5.2.124: Comparative phytopigments and generic diversity of Ratnagiri (1989-2016).

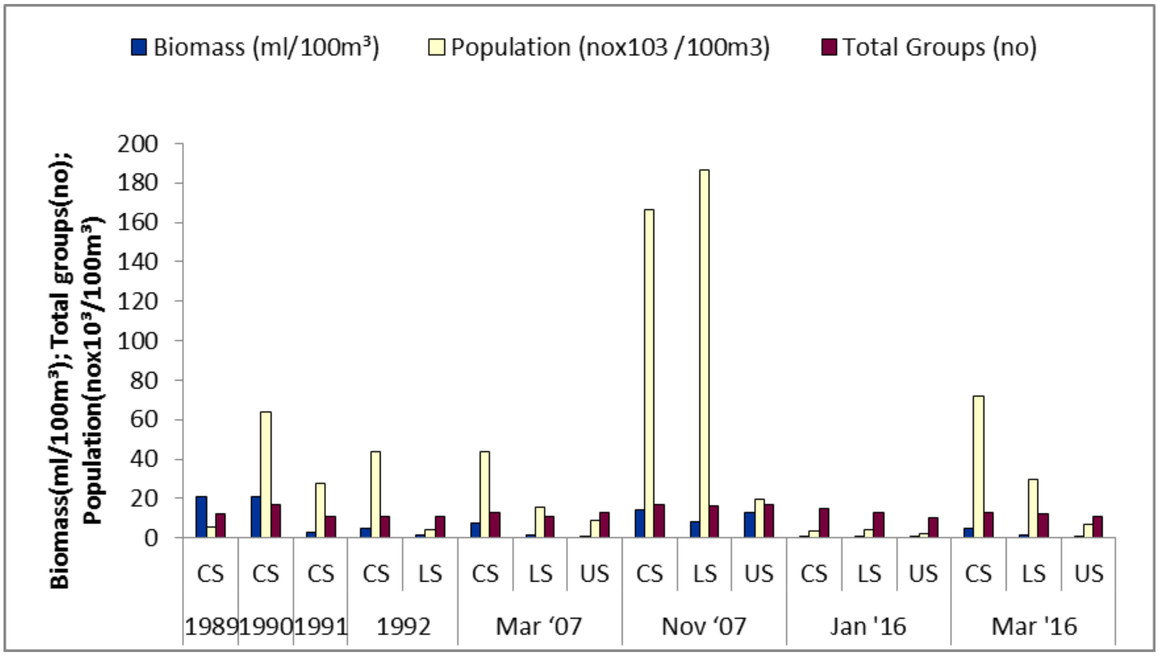


Figure 5.2.125: Comparative zooplankton biomass, population and group diversity of Ratnagiri (1989-2016).

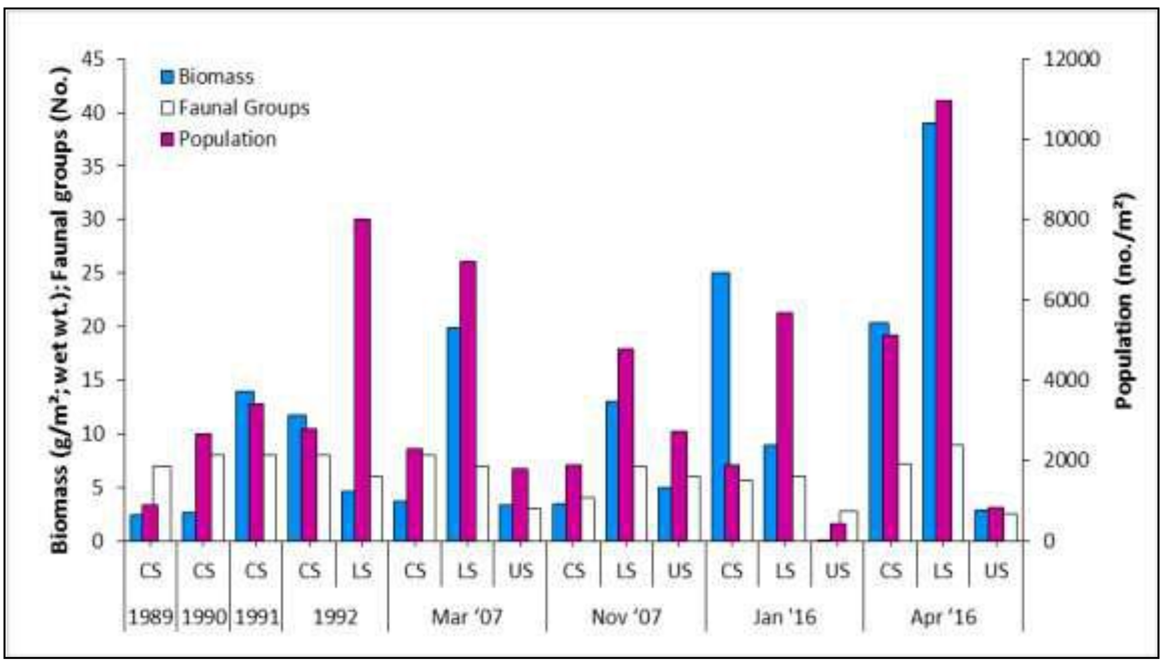


Figure 5.2.126: Comparative macrobenthos biomass, population and group diversity of Ratnagiri (1989-2016).

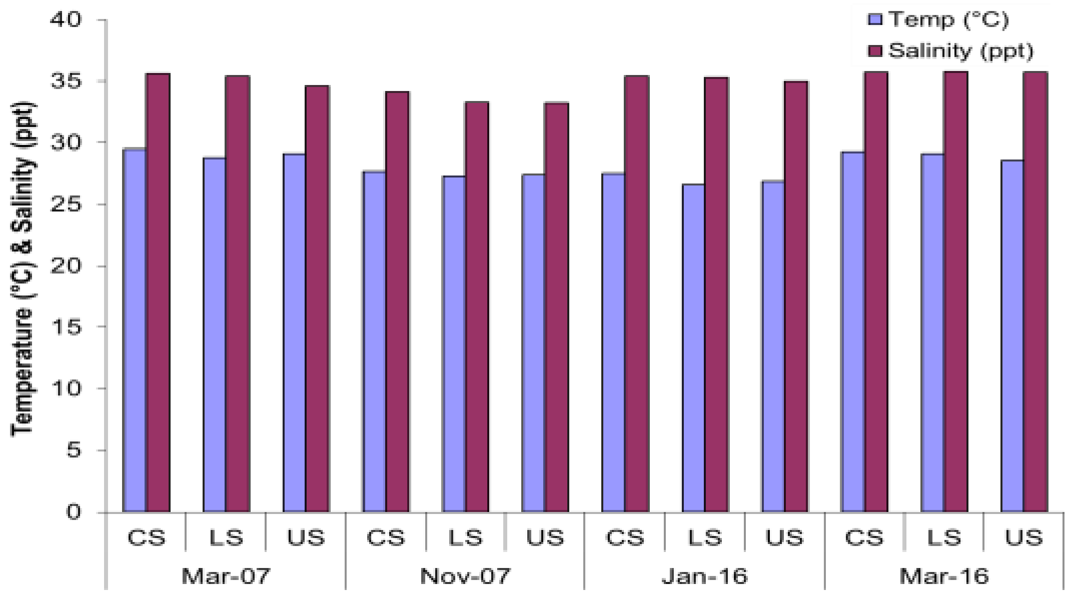


Figure 5.2.127: Temperature (°C) & Salinity (ppt) in Vijaydurg (2007-2016).

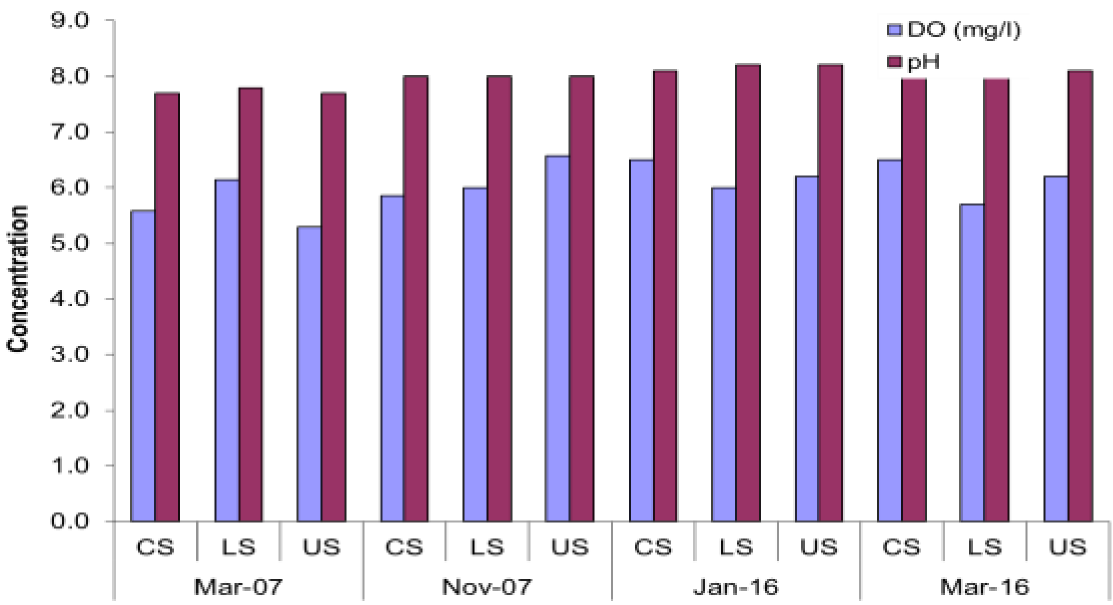


Figure 5.2.128: Concentration of DO (mg/l) & pH in Vijaydurg (2007-2016).

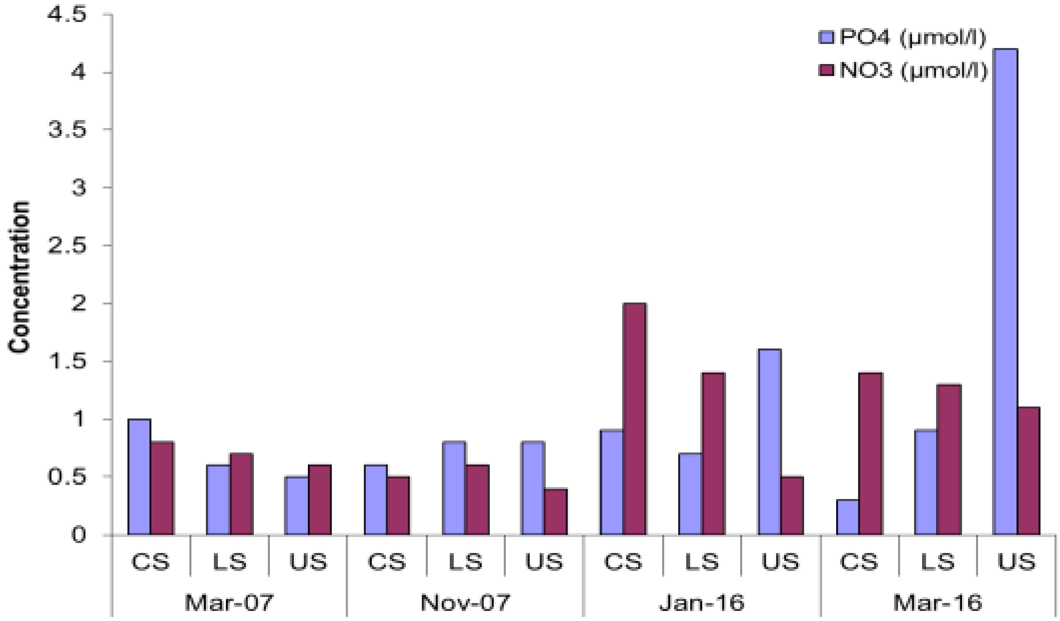


Figure 5.2.129: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Vijaydurg (2007-2016).

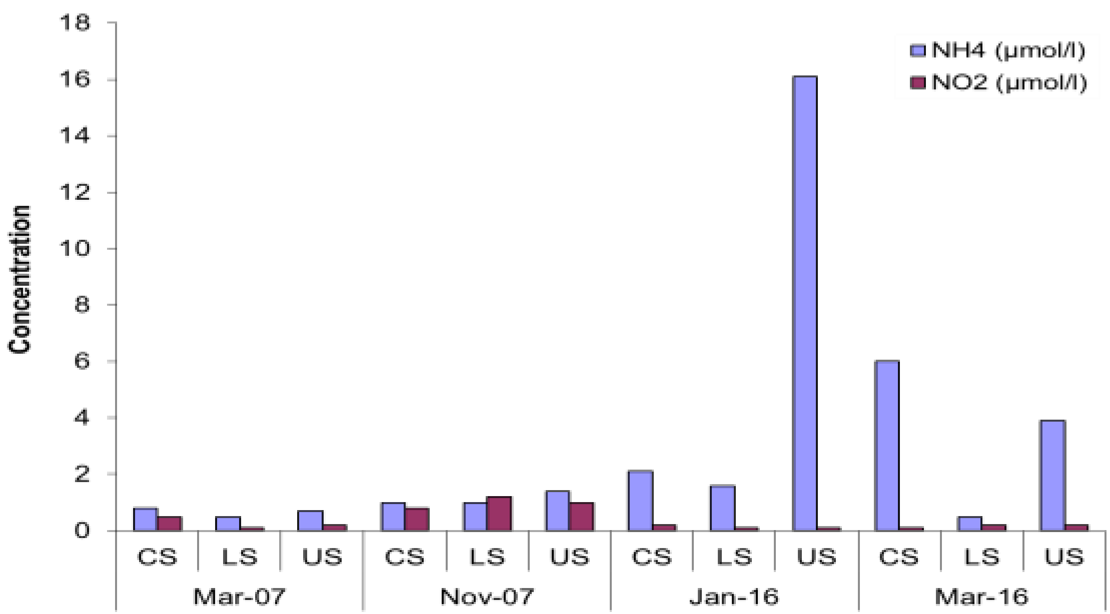


Figure 5.2.130: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in (2007-2016).

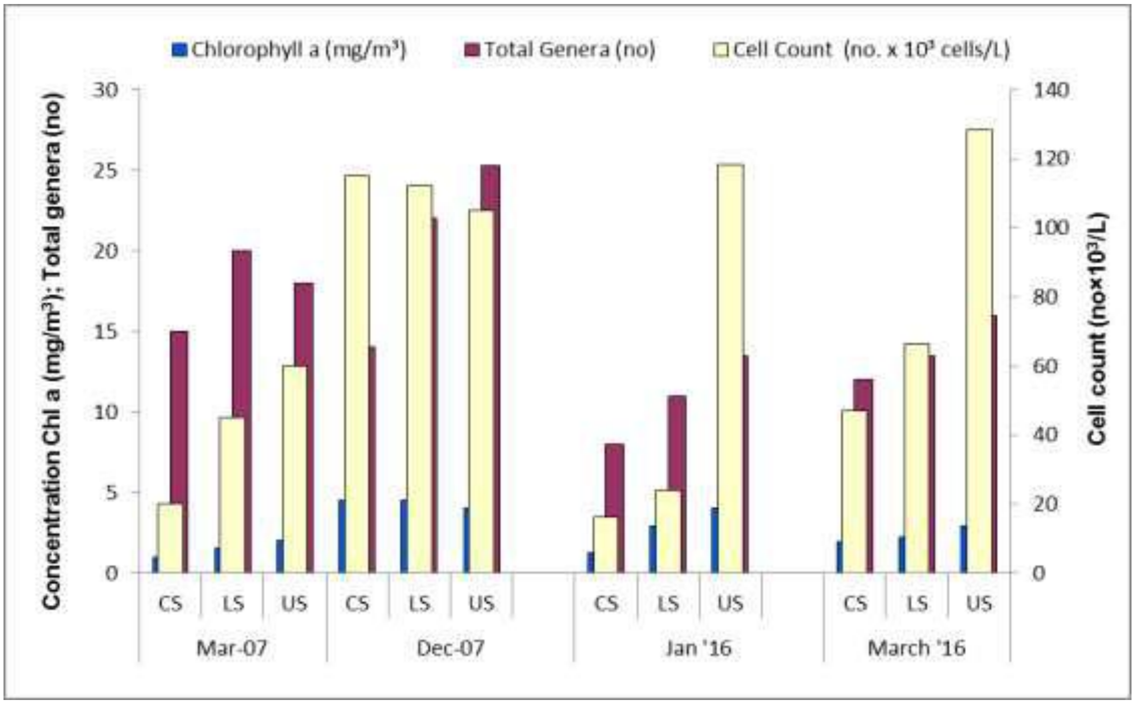


Figure 5.2.131: Comparative phytopigments and generic diversity of Vijaydurg (2007-2016).

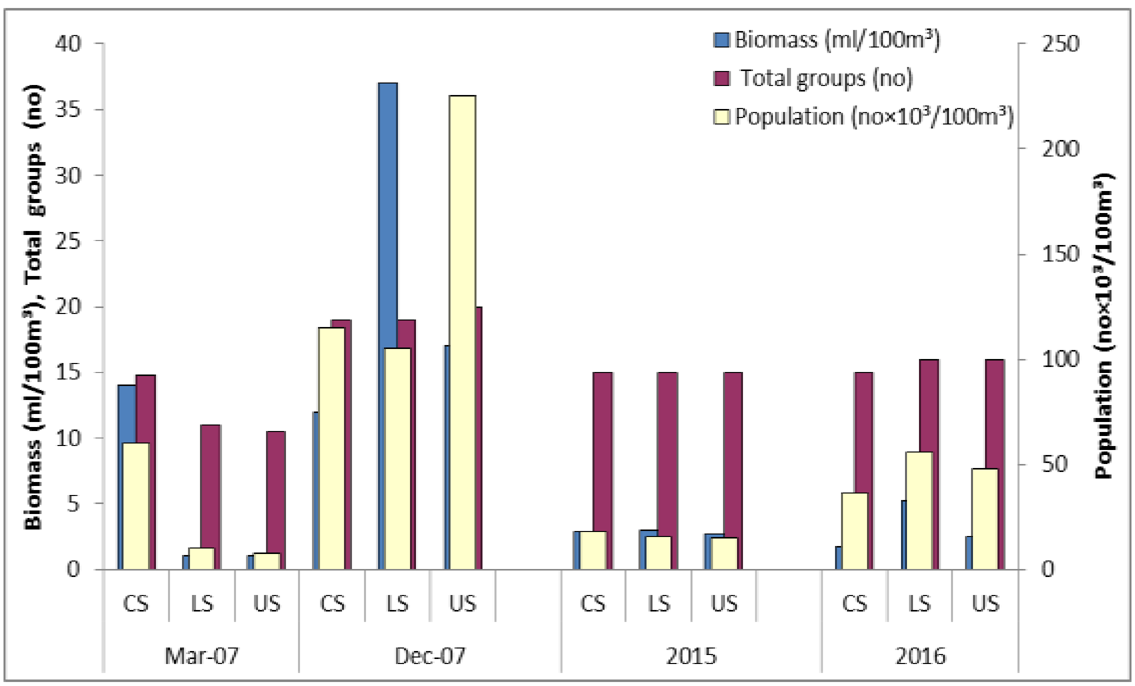


Figure 5.2.132: Comparative zooplankton biomass, population and group diversity of Vijaydurg (2007-2016).

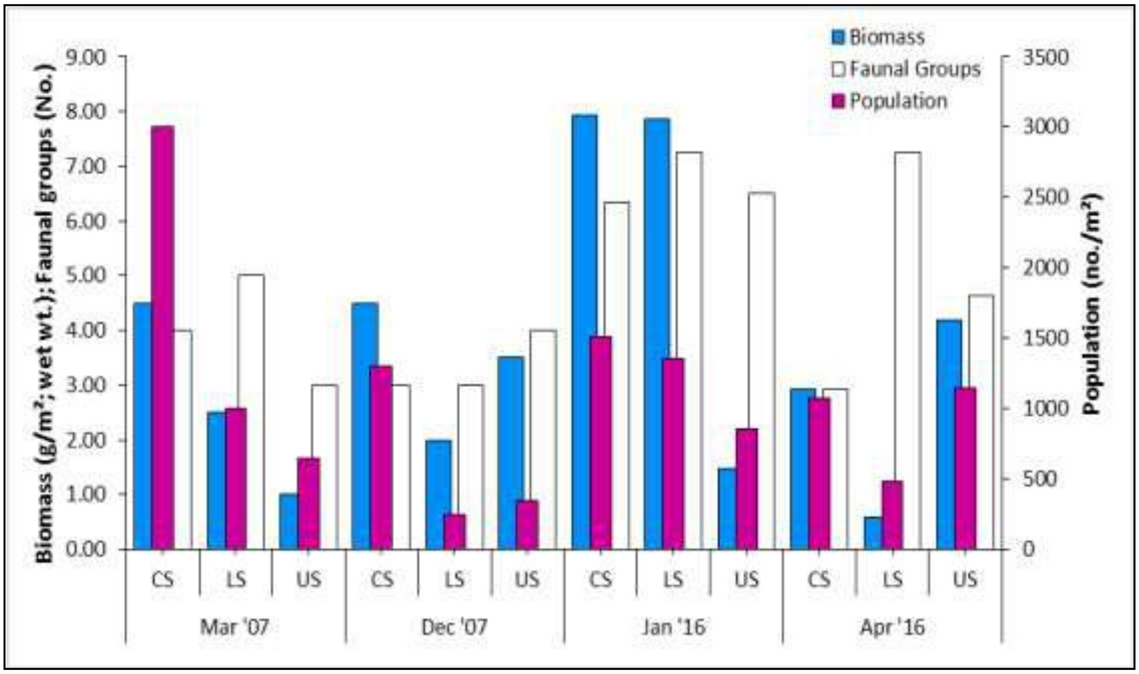


Figure 5.2.133: Comparative macrobenthos biomass, population and group diversity of Vijaydurg (2007-2016).

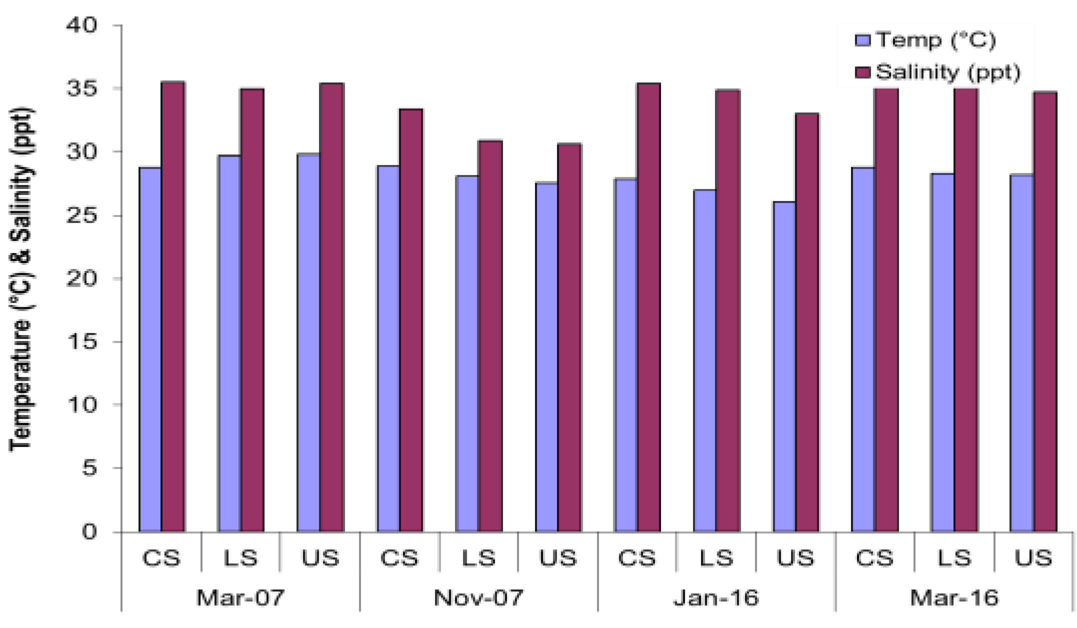


Figure 5.2.134: Temperature (°C) & Salinity (ppt) in Deogad (2007-2016).

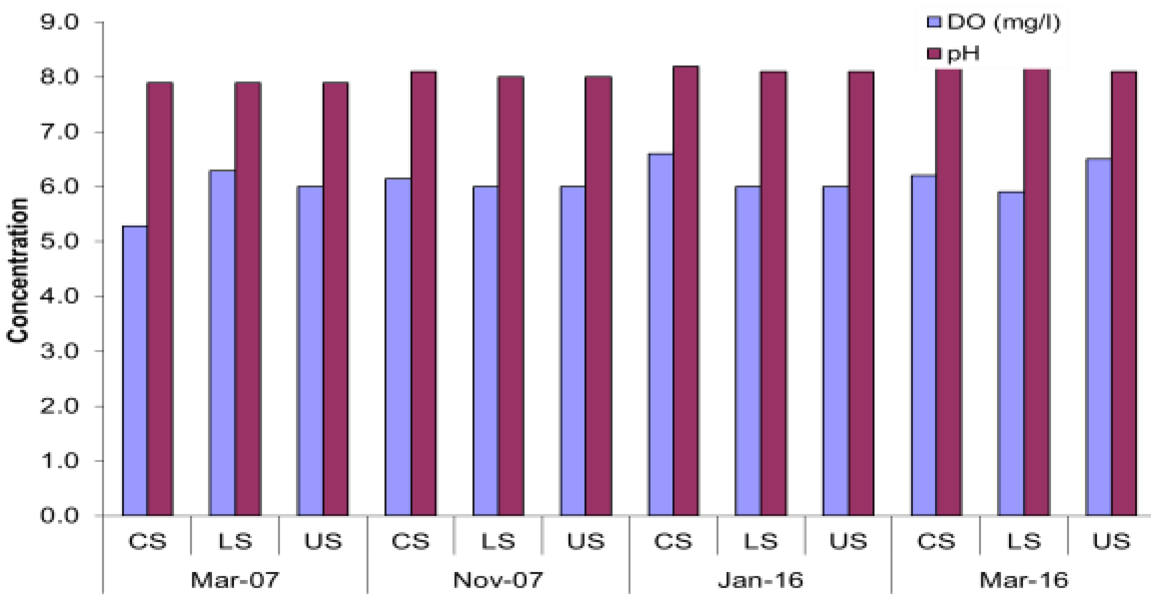


Figure 5.2.135: Concentration of DO (mg/l) & pH in Deogad (2007-2016).

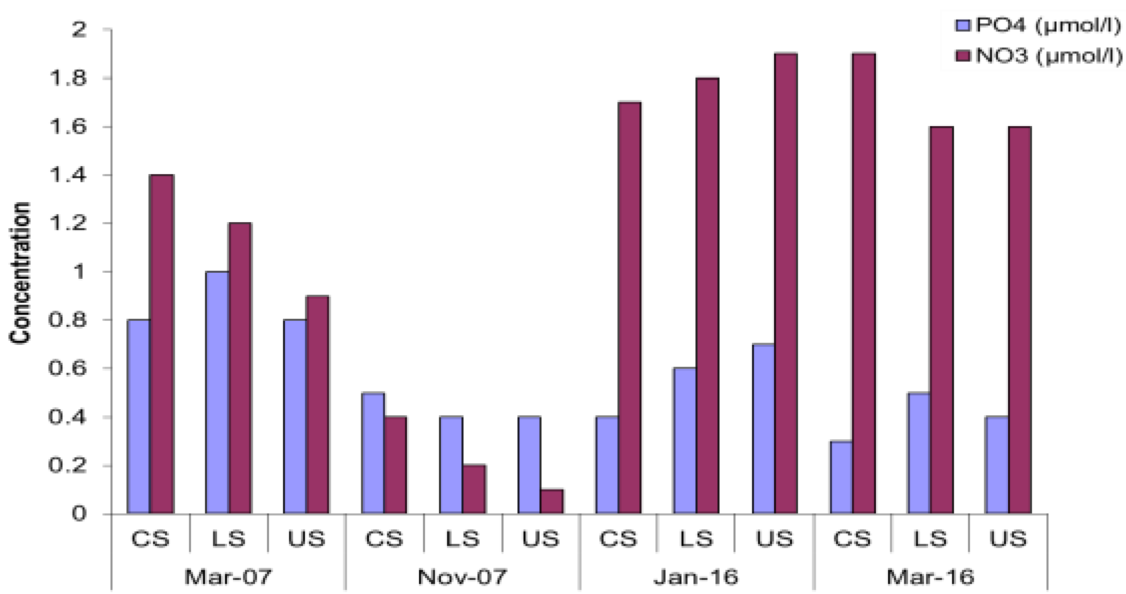


Figure 5.2.136: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Deogad (2007-2016).

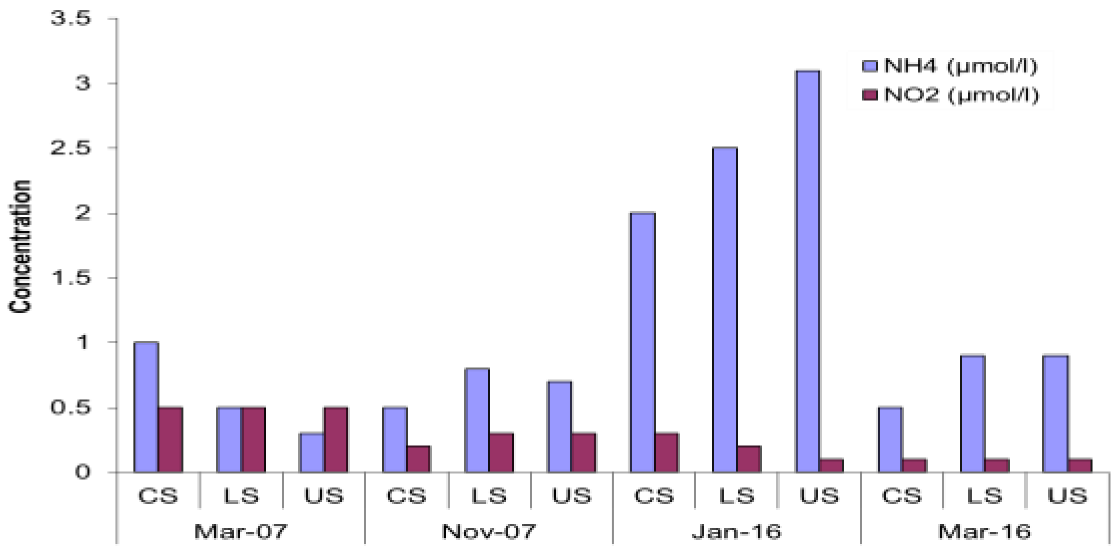


Figure 5.2.137: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Deogad (2007-2016).

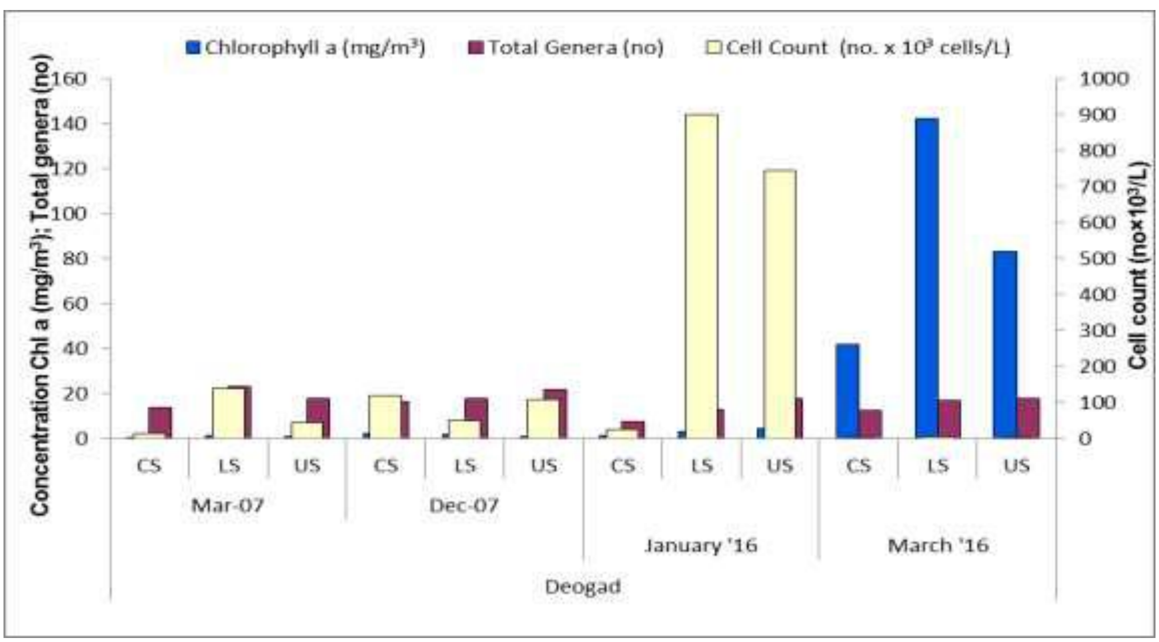


Figure 5.2.138: Comparative phytopigments and generic diversity of Deogad (2007-2016).

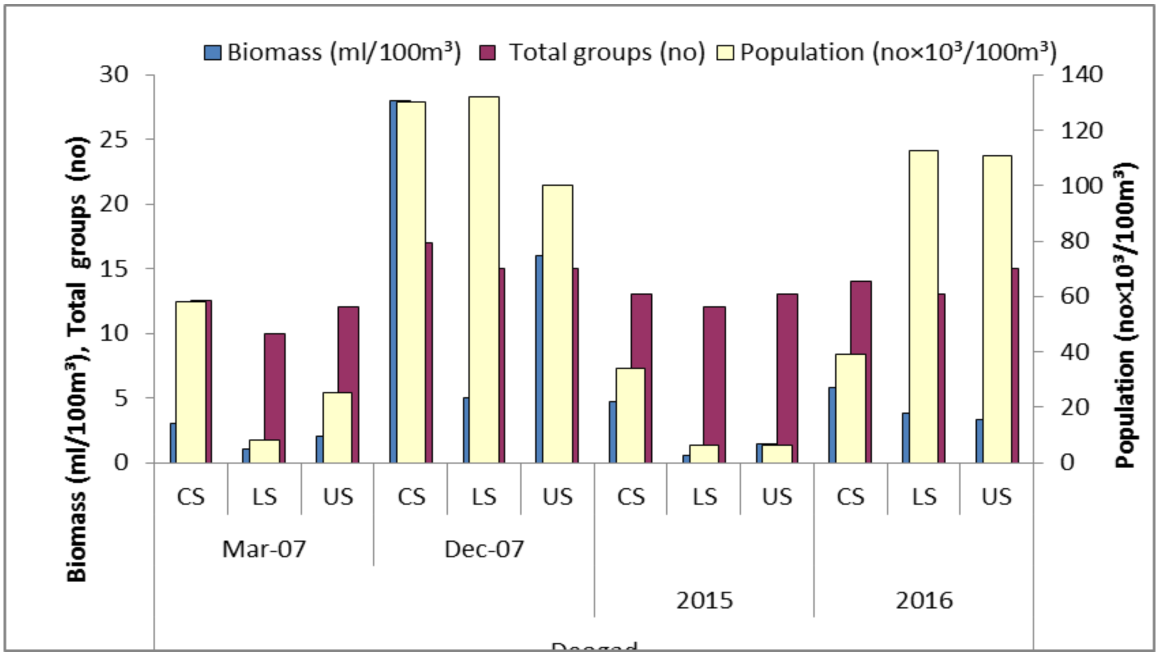


Figure 5.2.139: Comparative zooplankton biomass, population and group diversity of Deogad (2007-2016).

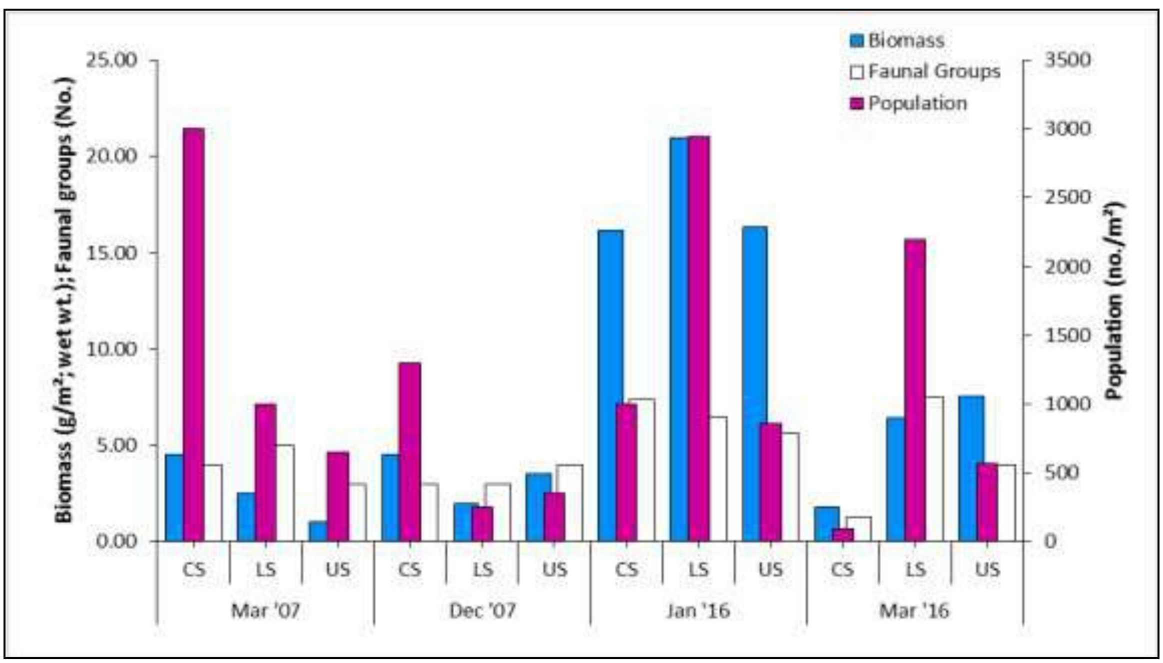


Figure 5.2.140: Comparative macrobenthos biomass, population and group diversity of Deogad (2007-2016).

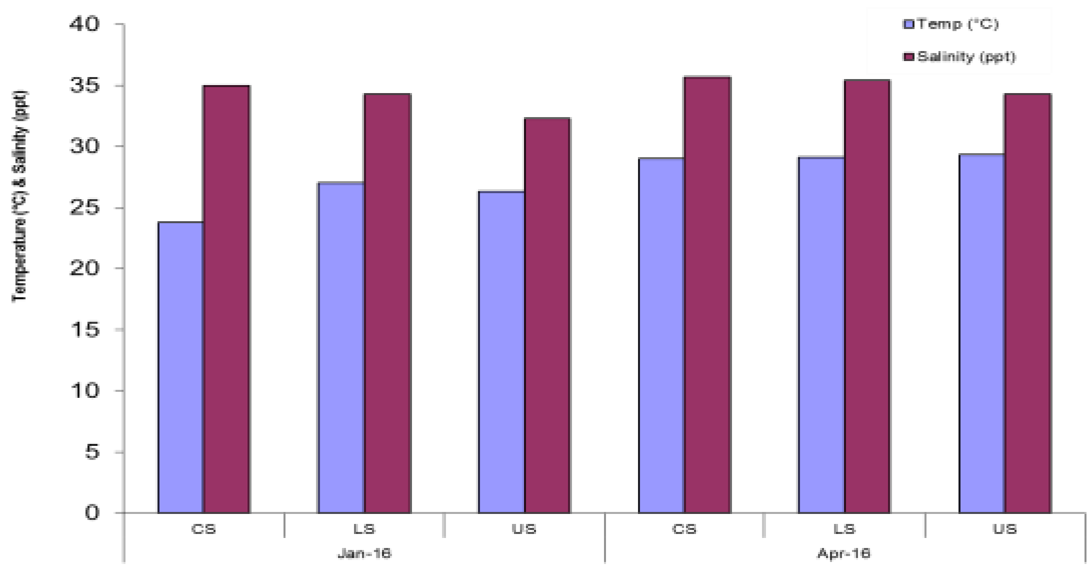


Figure 5.2.141: Temperature (°C) & Salinity (ppt) in Achara (2016).

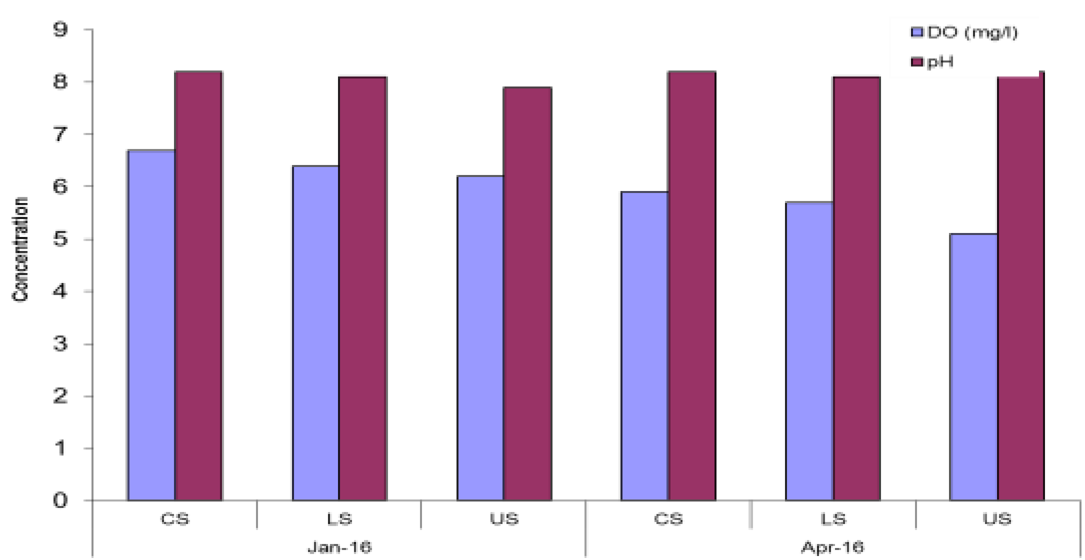


Figure 5.2.142: Concentration of DO (mg/l) & pH in Achara (2016).

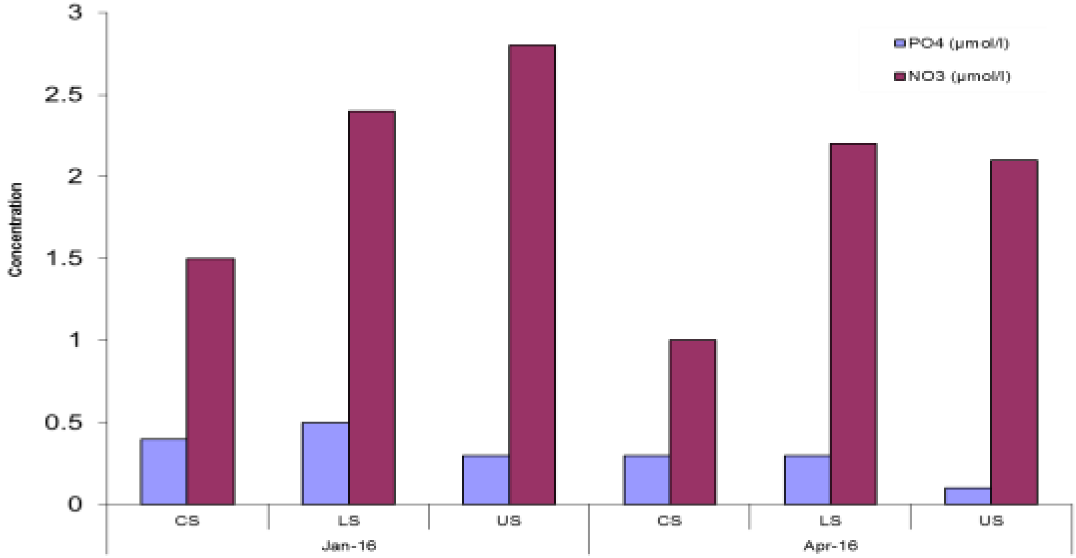


Figure 5.2.143: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Achara (2016).

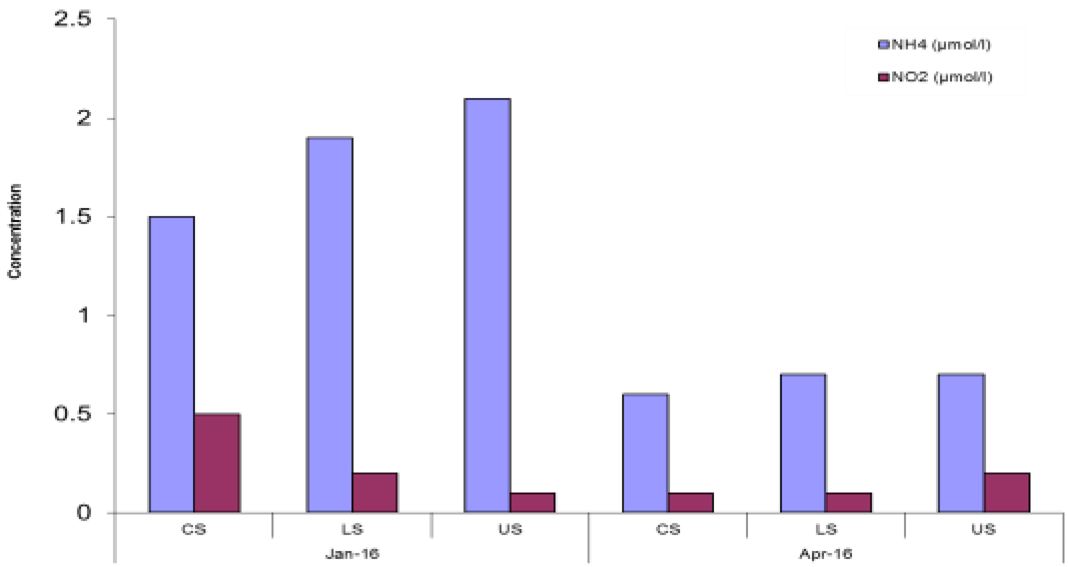


Figure 5.2.144: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Achara (2016).

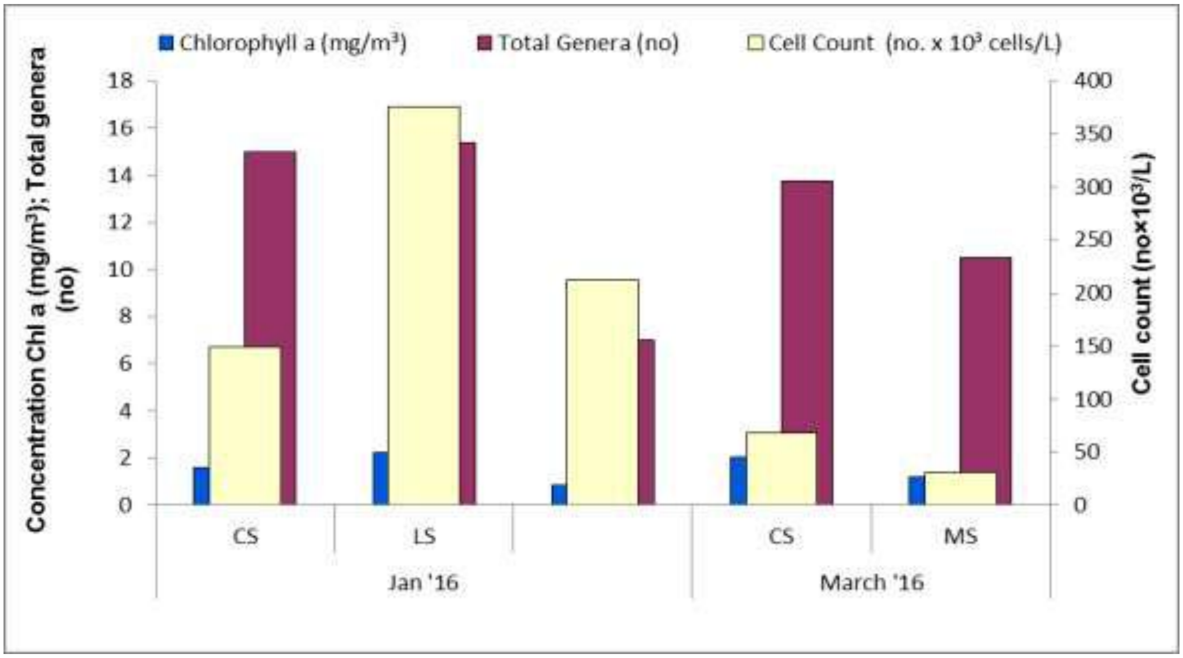


Figure 5.2.145: Comparative phytopigments and generic diversity of Achara (2016).

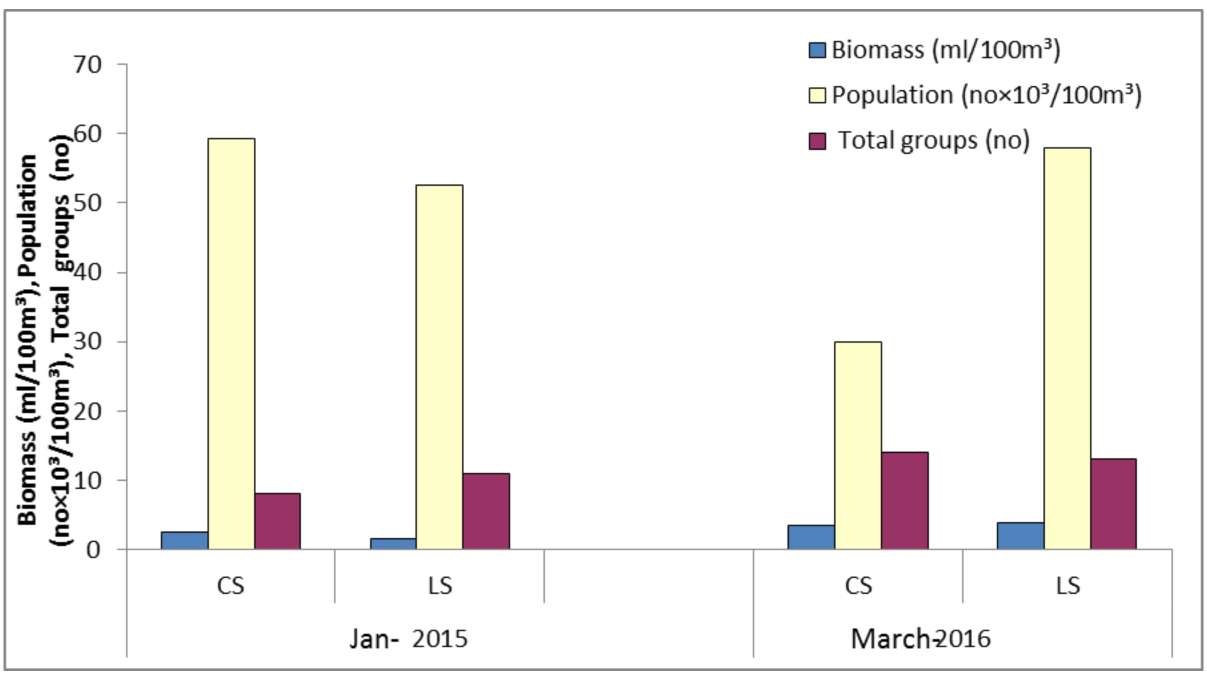


Figure 5.2.146: Comparative zooplankton biomass, population and group diversity of Achara (2016).

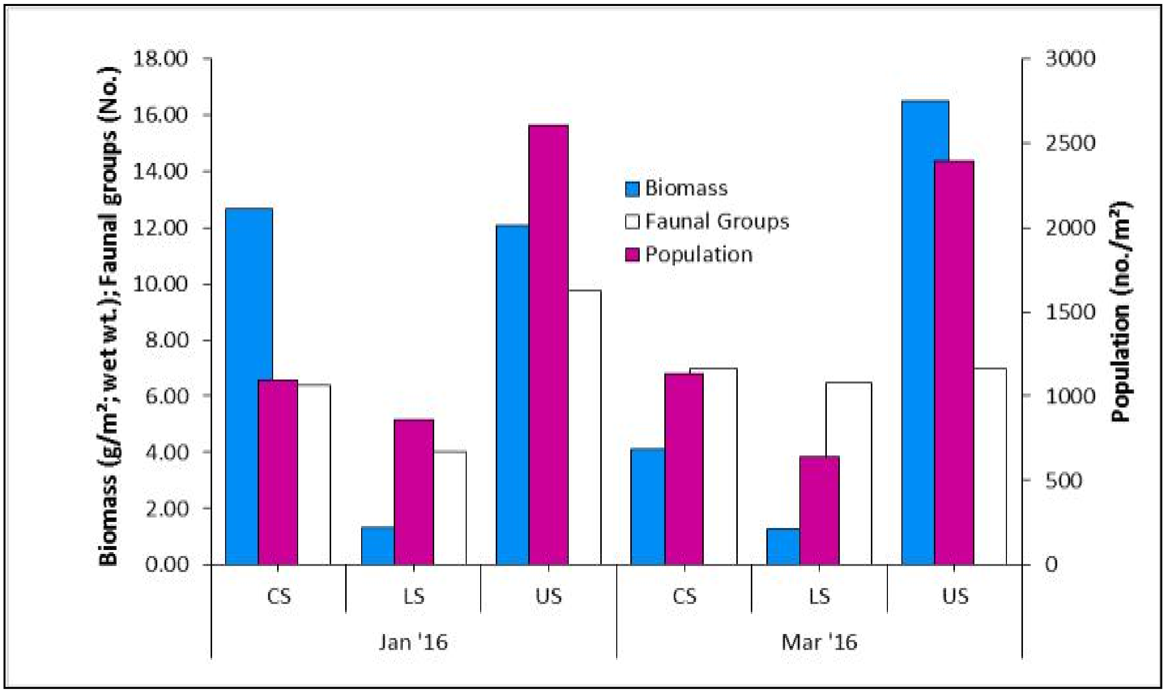


Figure 5.2.147: Comparative macrobenthos biomass, population and group diversity of Achara (2016).

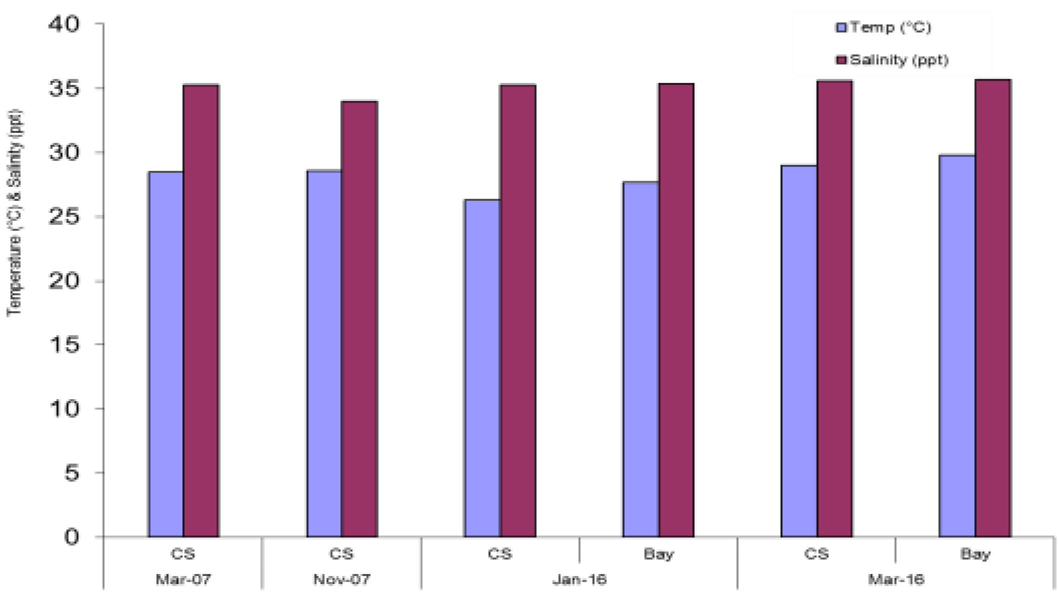


Figure 5.2.148: Temperature (°C) & Salinity (ppt) in Malvan (2007-2016).

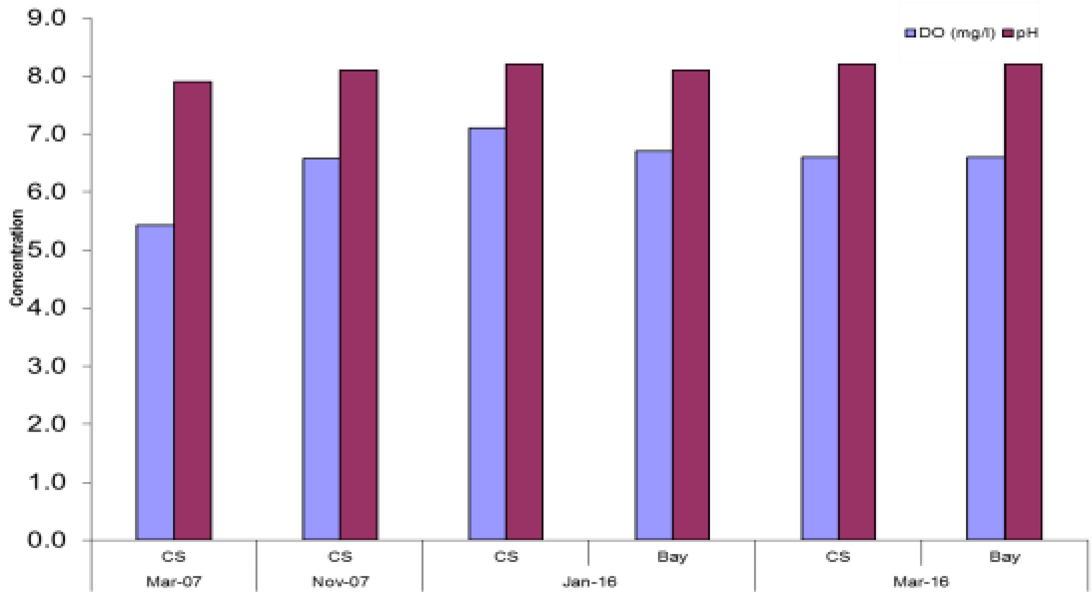


Figure 5.2.149: Concentration of DO (mg/l) & pH in Malvan (2007-2016).

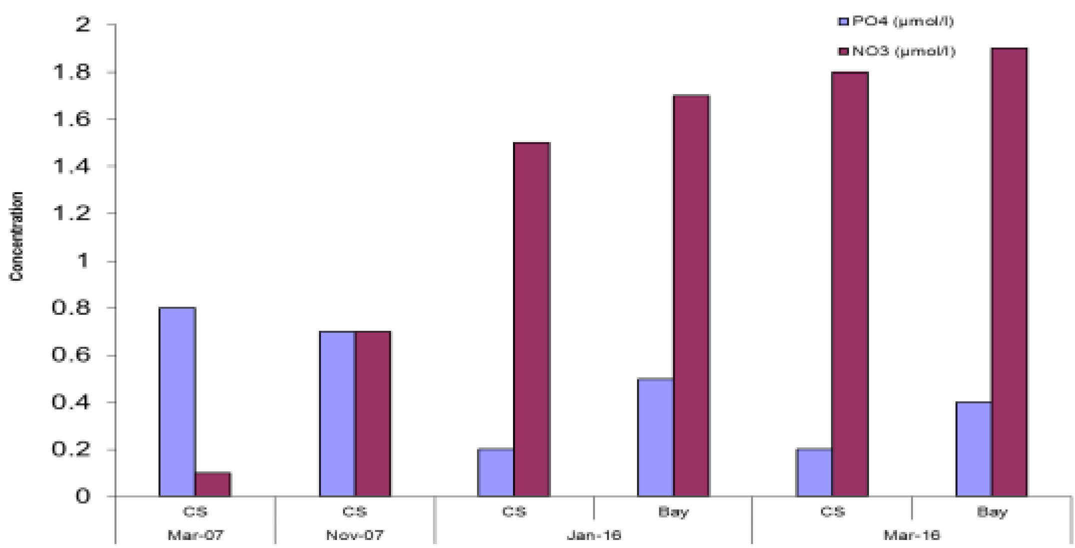


Figure 5.2.150: Concentration of PO_4 (µmol/l) & NO_3 (µmol/l) in Malvan (2007-2016).

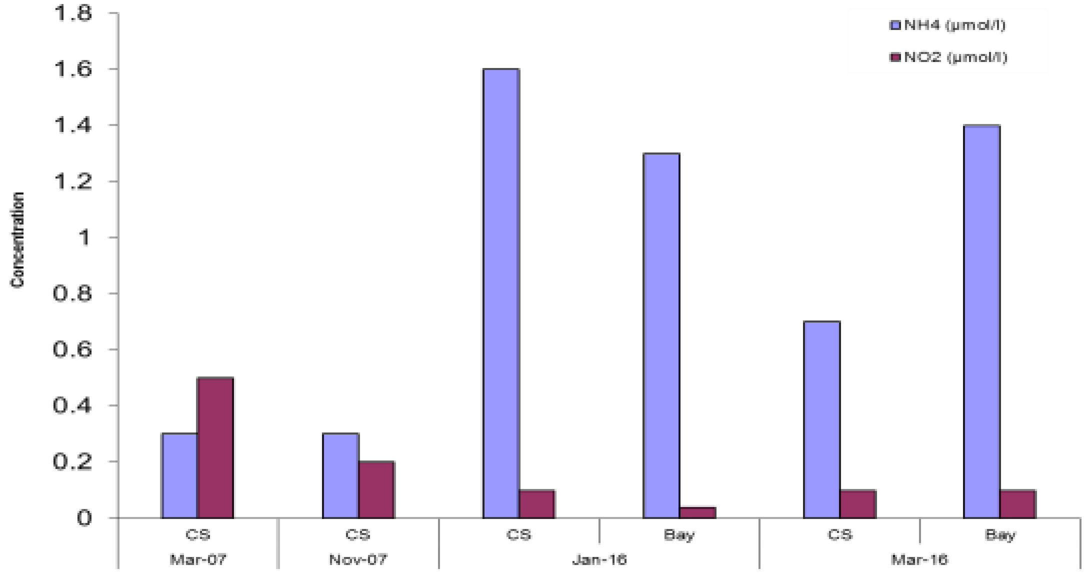


Figure 5.2.151: Concentration of NH_4 (µmol/l) & NO_2 (µmol/l) in Malvan (2007-2016).

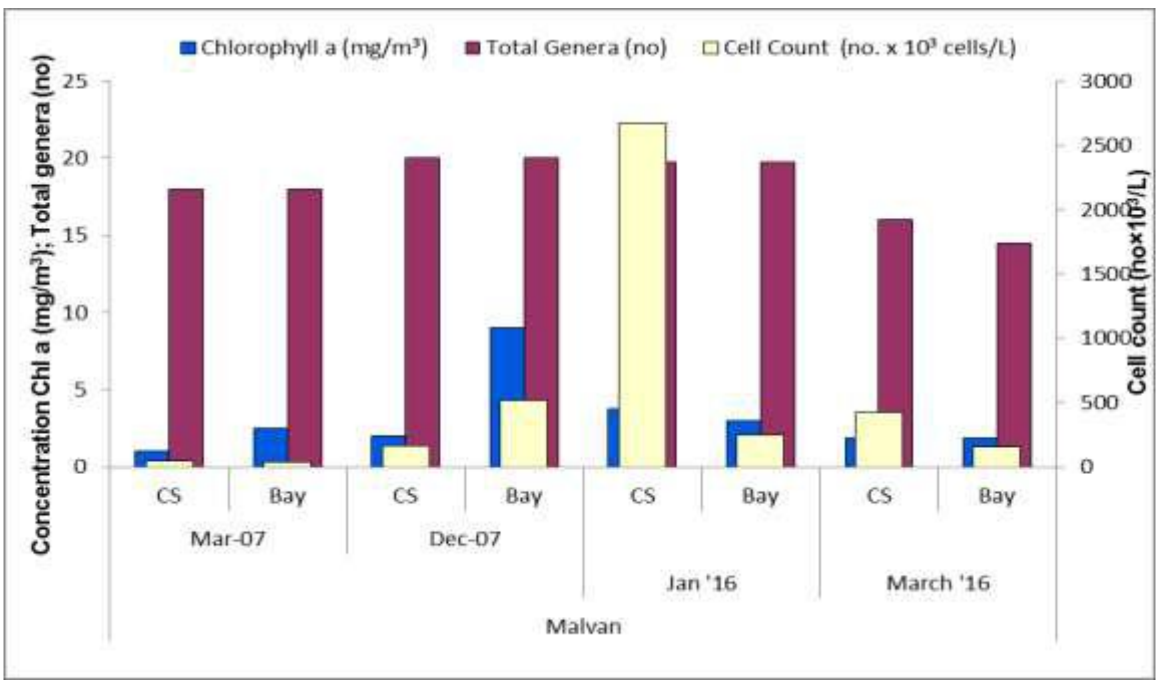


Figure 5.2.152: Comparative phytopigments and generic diversity of Malvan (2007-2016).

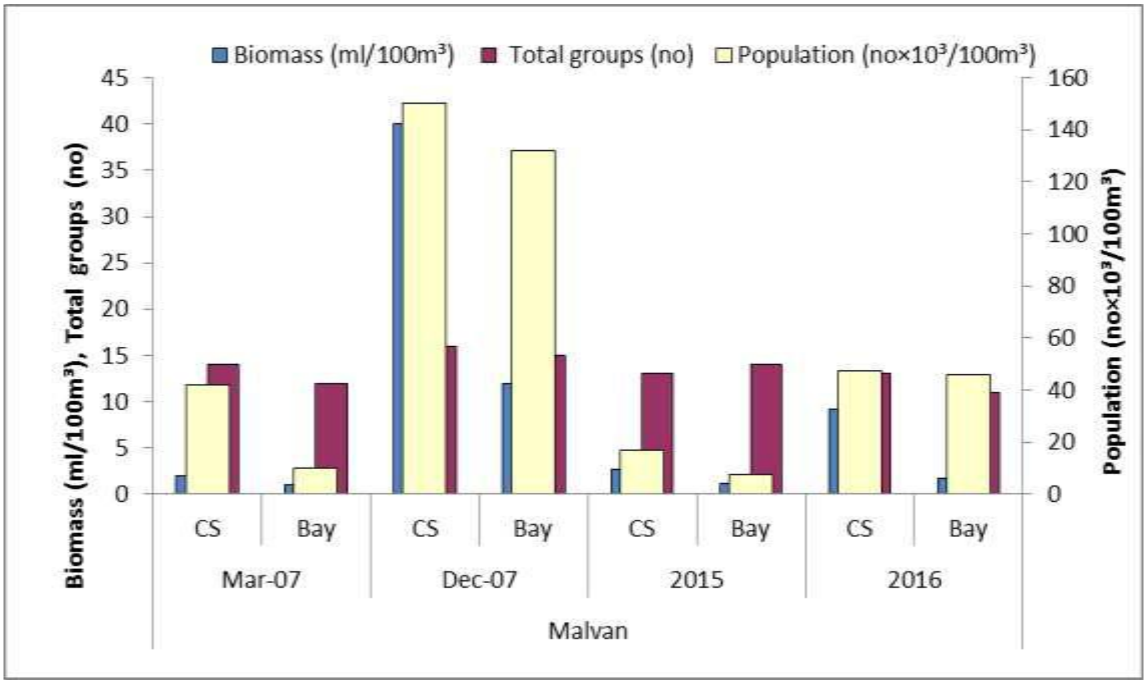


Figure 5.2.153: Comparative zooplankton biomass, population and group diversity of Malvan (2007-2016).

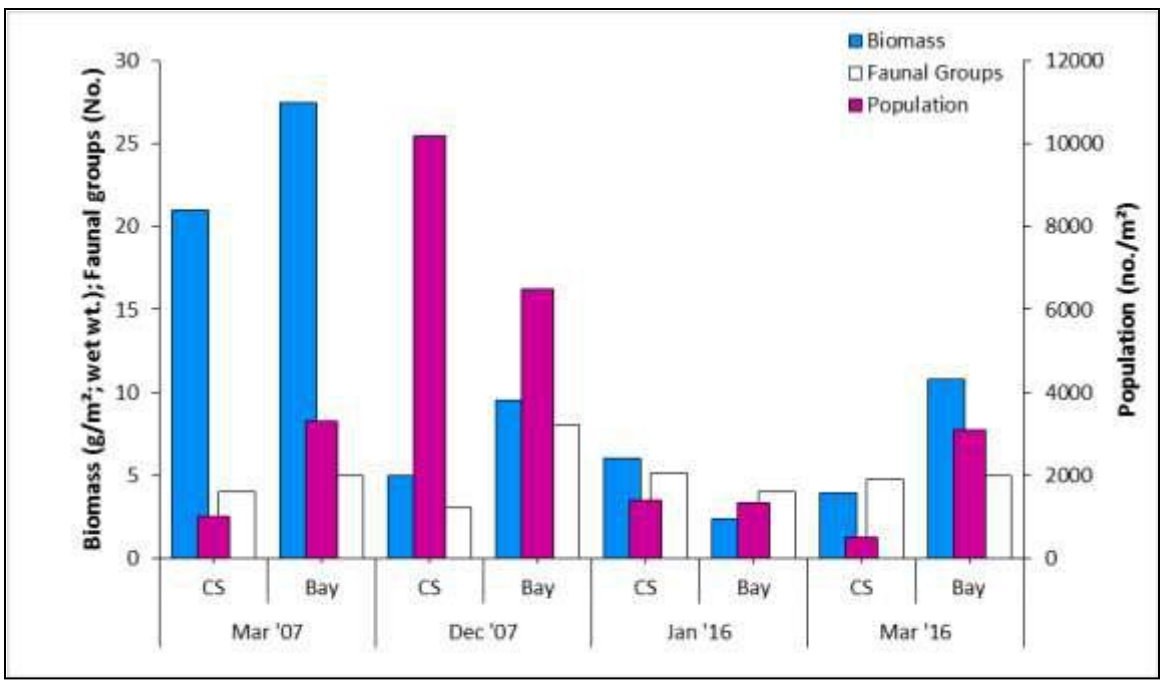


Figure 5.2.154: Comparative macrobenthos biomass, population and group diversity of Malvan (2007-2016).

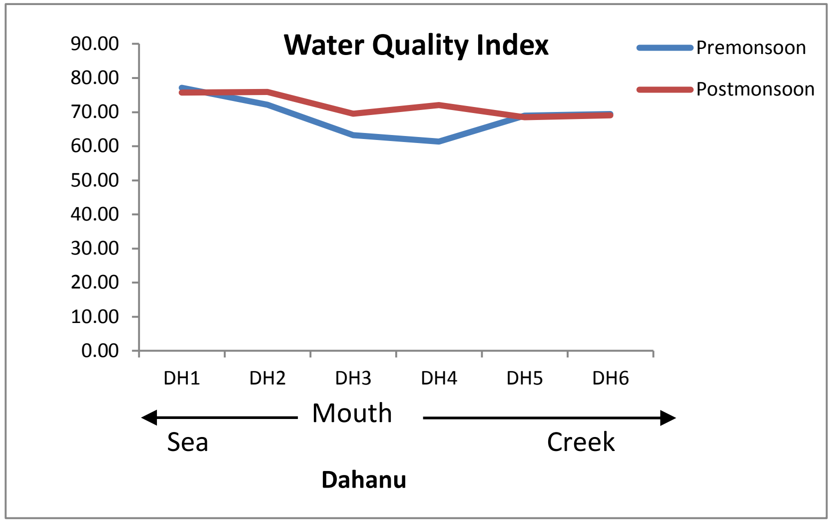


Figure 5.3.1: Spatial Variation of Water Quality Index in Dahanu Creek.

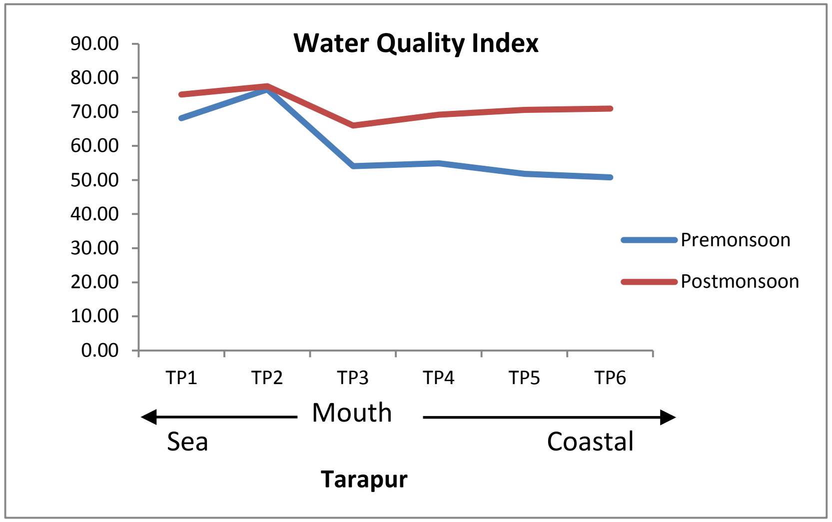


Figure 5.3.2: Spatial Variation of Water Quality Index in Tarapur Creek.

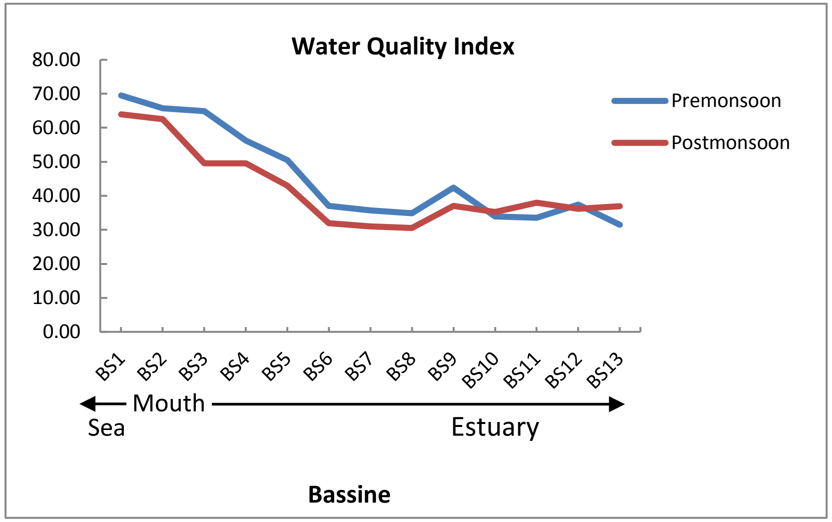


Figure 5.3.3: Spatial Variation of Water Quality Index in Bassein/Ulhas Estuary.

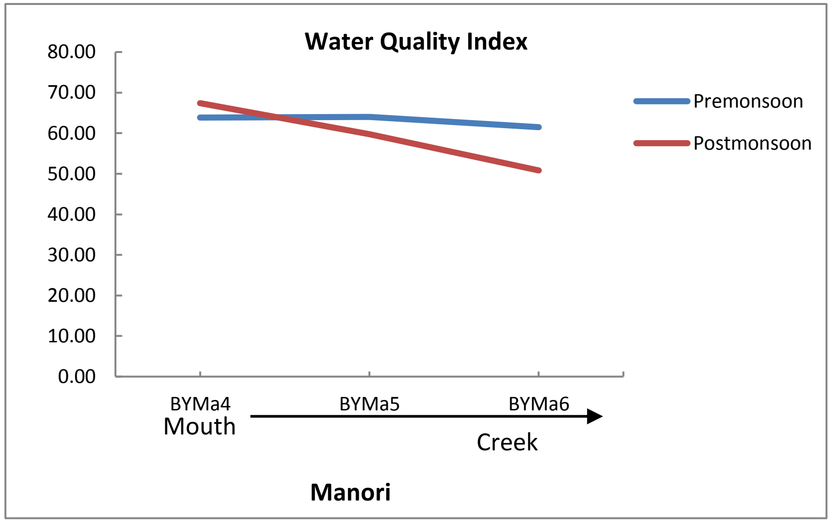


Figure 5.3.4: Spatial Variation of Water Quality Index in Manori Creek.

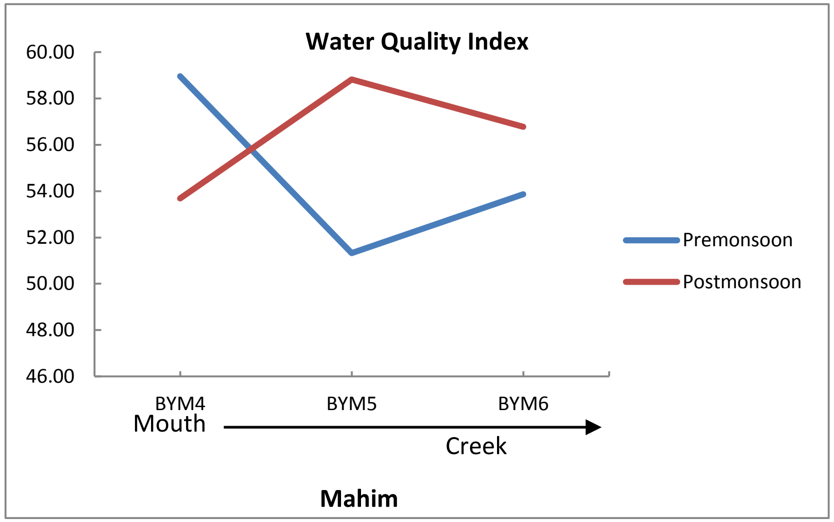


Figure 5.3.5: Spatial Variation of Water Quality Index in Mahim Creek.

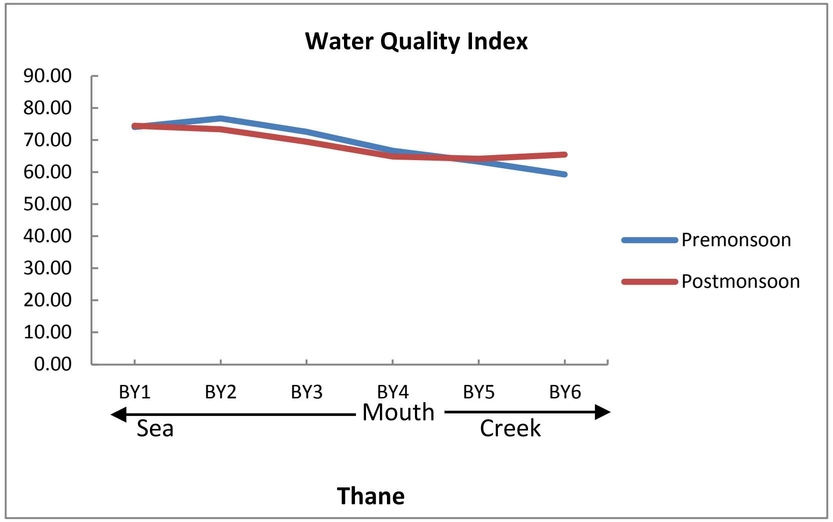


Figure 5.3.6: Spatial Variation of Water Quality Index in Thane Creek.

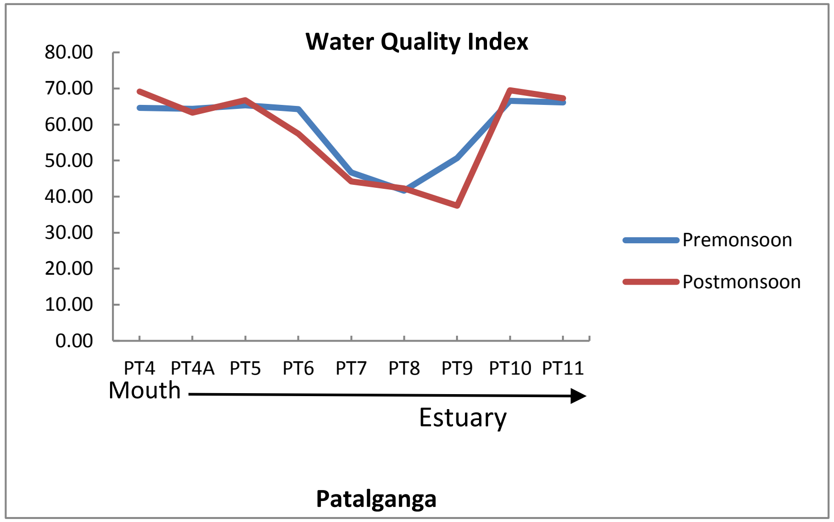


Figure 5.3.7: Spatial Variation of Water Quality Index in Patalganga Estuary.

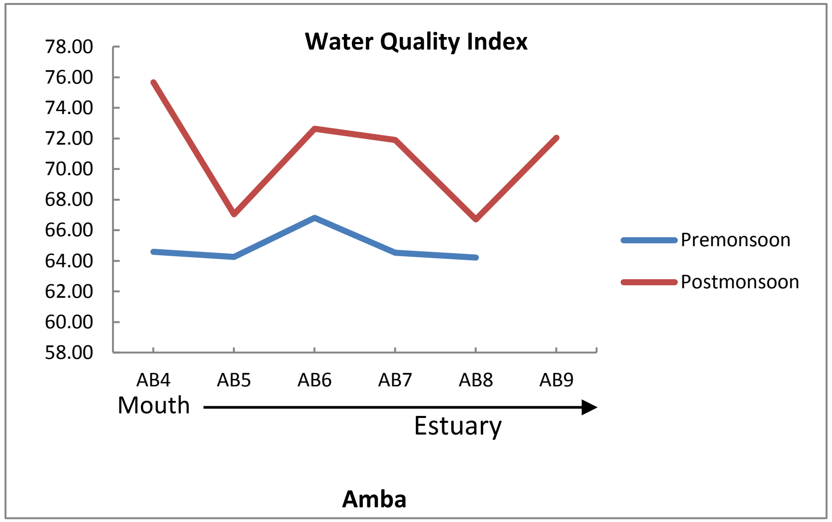
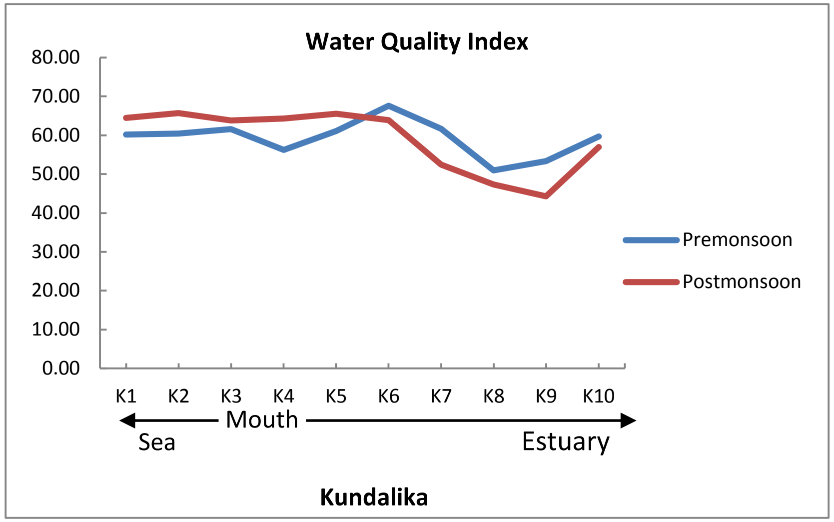


Figure 5.3.8: Spatial Variation of Water Quality Index in Amba Estuary.



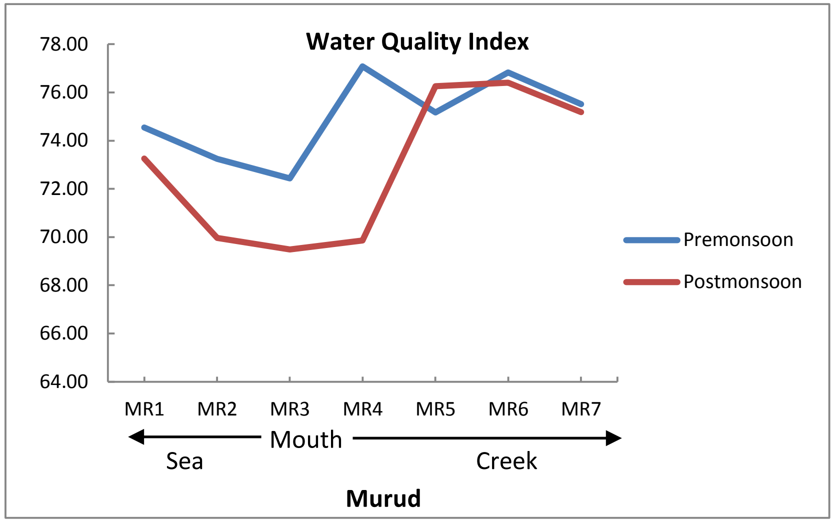


Figure 5.3.9: Spatial Variation of Water Quality Index in Kundalika Estuary.

Figure 5.3.10: Spatial Variation of Water Quality Index in Murud Creek.

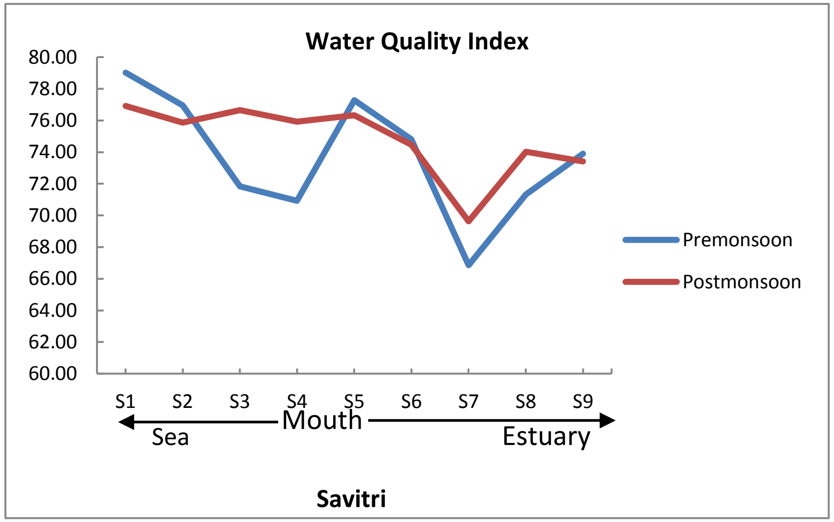


Figure 5.3.11: Spatial Variation of Water Quality Index in Savitri Estuary.

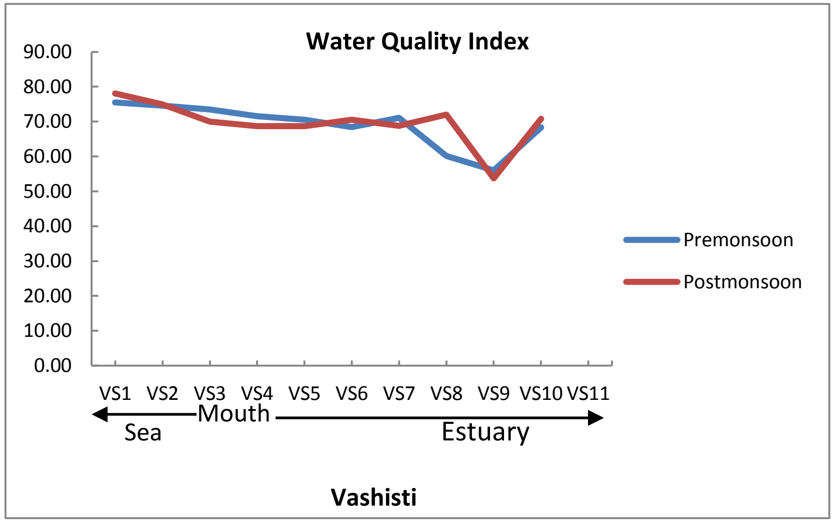


Figure 5.3.12: Spatial Variation of Water Quality Index in Vashishti Estuary.

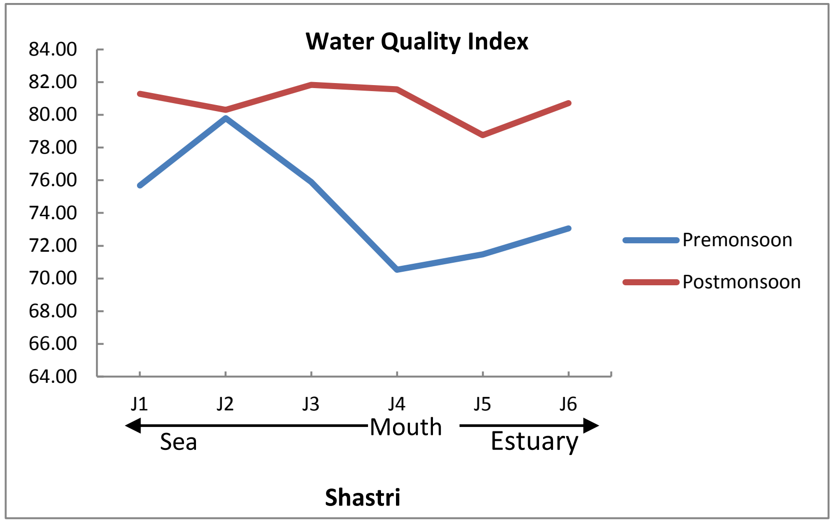


Figure 5.3.13: Spatial Variation of Water Quality Index in Jaigad Estuary.

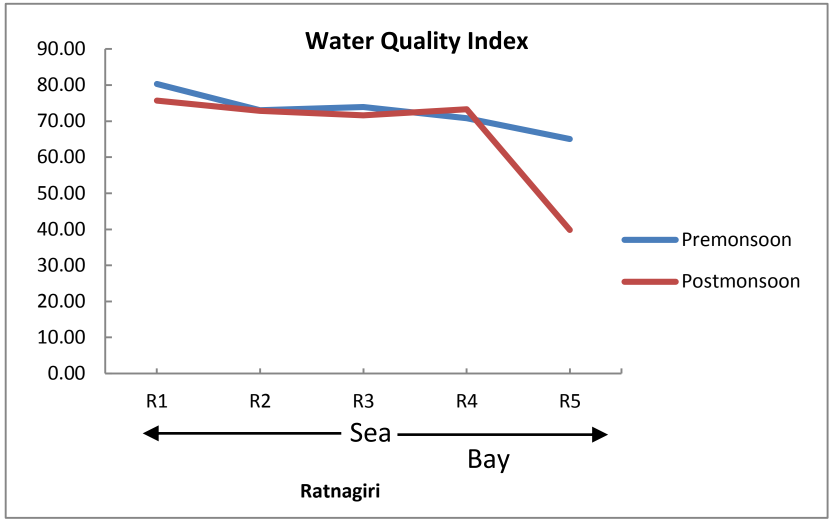


Figure 5.3.14: Spatial Variation of Water Quality Index in Ratnagiri.

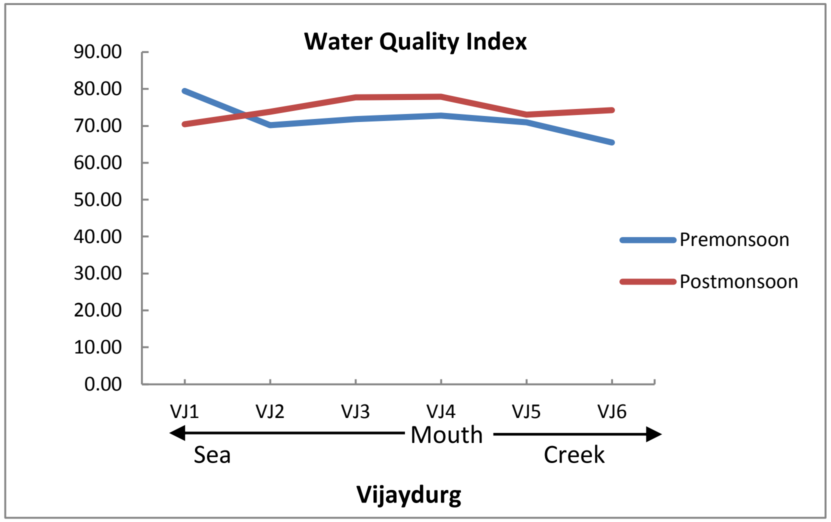


Figure 5.3.15: Spatial Variation of Water Quality Index in Vijaydiurg Creek.

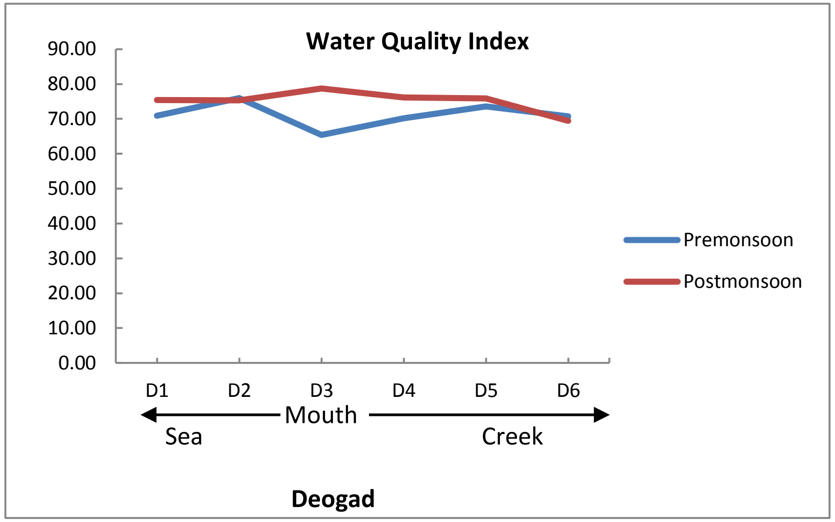


Figure 5.3.16: Spatial Variation of Water Quality Index in Deogad Creek.

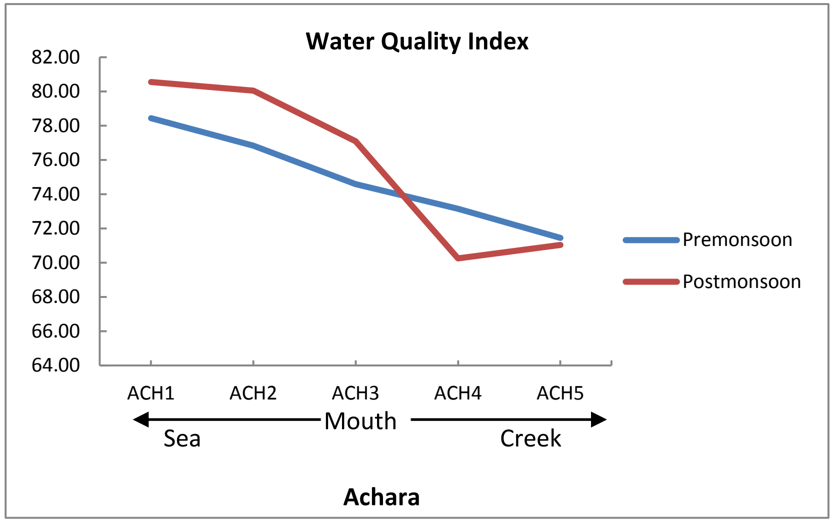


Figure 5.3.17: Spatial Variation of Water Quality Index in Achara Creek .

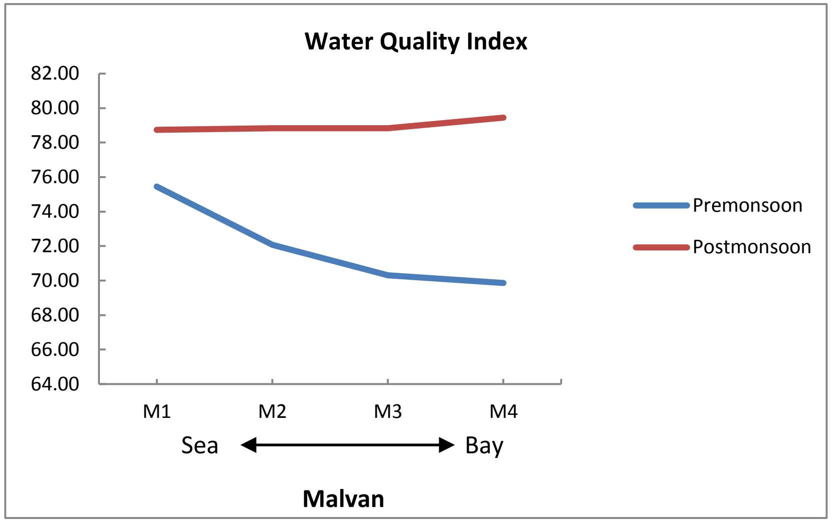


Figure 5.3.18: Spatial Variation of Water Quality Index in Malvan.

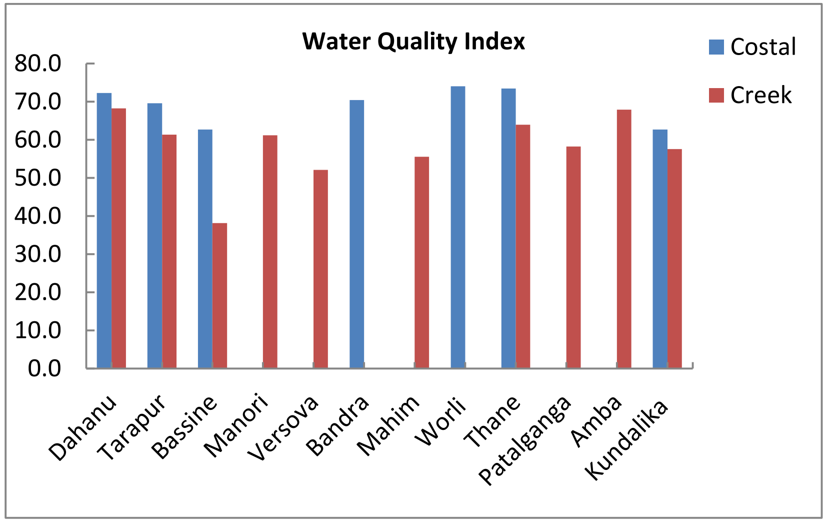


Figure 5.3.19: Water Quality Index along North Maharashtra Coast.

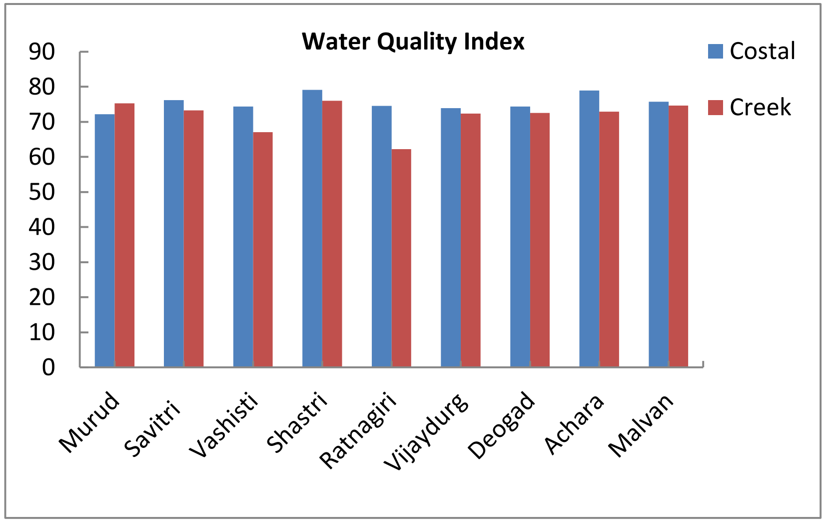


Figure 5.3.20: Water Quality Index along South Maharashtra Coast.

6 SUMMARY AND CONCLUSIONS

The Maharashtra coast that stretches between Bordi/Dahanu in the north and Redi/Terekhol in the south is about 720 km long - almost 10% of the total (about 7500 km long) coast line of the country, and 30-50 km wide. The shoreline is indented by numerous west flowing river mouths, creeks, bays, headlands, promontories and cliffs. There are about 18 prominent creeks/estuaries along the coast many of which harbor wetland and mangrove habitats. Like elsewhere in the world, the coastal region of the state is a place of hectic human activity, intense urbanization in pockets and enhanced industrialization, resulting in degradation, directly or indirectly, of marine environment through indiscriminate release of domestic and industrial effluents, reclamation, offshore constructions, movement of ships/fishing vessels and loading and unloading of a variety of cargo at ports etc.

Several coastal ecosystems along the west coast of India are now thus highly disturbed and threatened, encountering problem like pollution, siltation and erosion, flooding, saltwater intrusion, storm surges, human encroachment and other hazards. Hence, appropriate management strategies are needed to ensure the sustainable development and management of coastal areas and their resources.

Marine environmental management through proper assessment of water quality vis-a-vis the existing wastewater discharges, and reliable impact prediction on the coastal ecosystem due to ongoing activities are prerequisite for optimum utilization of marine areas without harming the ecosystem. A comprehensive programme for coastal area development in a sustainable manner, therefore, requires detailed information on levels of pollutants; quality and quantity of wastewater entering the system; physicochemical characteristics as well as biological productivity at different levels; flora and fauna inhabiting the area and their community structure; sediment nature; circulation; dispersion potential; tidal flushing etc. Evidently, environmental data requirements are extremely high and it is necessary to adopt a multidisciplinary approach for proper evaluation of ecosystems enabling corrective measures.

A pragmatic approach is therefore required to manage the vital marine zones while acknowledging the necessity to have coastal developments for the economic progress of the Konkan region. CSIR-National Institute of Oceanography (CSIR-NIO) carried out the preliminary monitoring during 2006-2007 and submitted the report entitled “Monitoring of Coastal Marine and Estuarine Ecology of Maharashtra” to the Maharashtra Pollution Control Board (MPCB) during December 2009. Maharashtra Pollution Control Board (MPCB) approached the CSIR-NIO, Mumbai to revisit the sites and find changes along the Maharashtra coast that might have occurred since 2007. The CSIR-NIO conducted these studies during November 2015-January 2016 (postmonsoon) and March-May 2016 (premonsoon) with the following objectives:

i) To conduct ecological monitoring of inshore and coastal areas to identify changes, if any, in water quality, sediment quality and biological characteristics and utilize the findings to suggest corrective measures.

ii) To monitor for indicator pollutants in areas identified to be contaminated with specific contaminant and assess recovery of the ecosystems or otherwise.

The findings based on the field investigations during postmonsoon and premonsoon of 2015-2016 at 22 transects in coastal and associated inshore waters of Maharashtra are presented in this report. Since, the pre-effluent release baseline for most of these transects was not available, database generated by NIO over the years through studies conducted from time to time in these areas was considered as the best approach to assess the impacts, if any. Also results of 2007-2008 were evaluated in comparision with the present study to find out the changes due to corrective measures taken thereafter. Major effluent releases to this coastal and inshore water through available source were also analysed to assess the anthropogenic loads of various pollutants on these water bodies. Fishes available in the locality of study regions were either caught by experimental trawling or obtained through local fishermen and analysed to find out the bioaccumulation of selected pollutants, if any.

The findings of the phase I studies are presented in two parts viz; Part A: Main Report and Part B: Data.

6.1 Study areas

Features of coastal and inshore areas depend on the characteristics of drainage of the respective water bodies which normally depends upon physiology, geology and climate of the region. The high tidal range also significantly influences the brackish water character of these water bodies. The tidal processes in the coastal Maharashtra have considerable influences on coastal and inshore areas which include creeks/estuaries like Dahanu, Tarapur, Ulhas, Manori, Versova, Mahim, Thane, Patalganga, Amba, Kundalika, Rajpuri, Savitri, Vashishti, Shastri, Ratnagiri Bay, Vijaydurg, Deogad, Achara Creek and Malvan Bay. However, its influence is less significant on the water bodies of the southern coastal region due to relatively lower tidal range and higher gradient of the inshore segments.

Tides which plays vital role in the coastal processes are predominantly semidiurnal with a diurnal inequality. The tidal ranges progressively increase from Redi in the south to Dahanu in the north. The tidal ranges also decrease progressively from mouth area of the creek/estuary to the head of the creek/river.

During the present study the sampling stations along the open coast were selected, as far as possible, to represent inshore (0 to 0.5 km), mid level (2 to 3 km) and offshore (4 to 5 km) region. Estuaries/creeks/bays were sampled to represent lower, middle and upper zones depending on the tidal ingress and the transect extended to the open sea. At least one station on each transect was operated over a tidal cycle of 12 h and the remaining stations were spot sampled during ebb and flood. Particular attention was given to sample marine and estuarine areas in the vicinity of significant urban, industrial or maritime establishments.

The details of transects and sampling stations are given below.

Sr. No.	Transect	Stations
1	Dahanu	DH1, DH2, DH3, DH4, DH5, DH6
2	Tarapur	TP1,TP2, TP3, TP4, TP5, TP6
3	Bassein	BS1, BS2, BS3, BS4, BS5, BS6, BS7, BS8, BS9, BS10, BS11, BS12 and BS13
4	Manori	BYMa4, BYMa5, BYMa6
5	Versova	BYV4, BYV5
6	Mahim	BYM4, BYM5, BYM6
7	Bandra	BYB1, BYB2
8	Worli	BYW1, BYW2
9	Thane Creek	BY1, BY2, BY3, BY4, BY5, BY6
10	Patalganga	PT4, PT4A, PT5, PT6, PT7, PT8, PT9, PT10, PT11
11	Amba Estuary	AB4, AB5, AB6, AB7, AB8, AB9
12	Thal DP	DP
13	Kundalika Estuary	K1, K2, K3, K4, K5, K6, K7, K8, K9, K10
14	Murud	MR1, MR2, MR3, MR4, MR5, MR6, MR7
15	Savitri Estuary	S1, S2, S3, S4, S5, S6, S7, S8, S9
16	Vashishti Estuary	VS1, VS2, VS3, VS4, VS5, VS6, VS7, VS8, VS9, VS10
17	Jaigad Creek	J1, J2, J3, J4, J5, J6
18	Ratnagiri	R1, R2, R3, R4, R5
19	Vijaydurg	VJ1, VJ2, VJ3, VJ4, VJ5, VJ6
20	Deogad	D1, D2, D3, D4, D5, D6
21	Achera	AC1, ACH2, ACH3, ACH4, ACH5
22	Malvan	M1,M2, M3, M4

The station locations were plotted on satellite imageries and presented in respective sections.

Data on 26 environmental parameters were collected at about 126 sampling locations with more than 1048 sampling events. All analyses were done following standard oceanographic procedures.

6.2 Wastewater influxes

The nature of wastewater received through point discharges at different transect was as follows.

1. Dahanu - Industrial and domestic wastes
2. Tarapur - Industrial and domestic wastes
3. Bassein - Industrial and domestic wastes
4. Manori - Industrial and domestic wastes
5. Versova - Industrial and domestic wastes
6. Mahim - Industrial and domestic wastes
7. Bandra - Domestic waste through marine outfall
8. Worli - Domestic waste through marine outfall
9. Thane Creek- Industrial, domestic and port based wastes
10. Patalganga- Industrial waste
11. Amba - Industrial and port based wastes
12. Thal - Industrial waste (RCF, DP)
13. Kundalika - Industrial and domestic (minor) wastes
14. Murud - Domestic (minor) waste
15. Savitri - Industrial and domestic (minor) wastes
16. Vashishti - Industrial and domestic (minor) wastes
17. Jaigad - Domestic (minor) and port based wastes
18. Ratnagiri - Industrial (minor), port based and domestic wastes
19. Vijaydurg - Domestic (minor) and port based wastes
20. Deogad - Domestic (minor) and fishery harbour wastes
21. Achara - Domestic (Minor) and fishery port based wastes
22. Malvan - Domestic (minor) and fishery harbour wastes

6.2.1 Dahanu

Dahanu transect is represented by the coastal and creek segments. It is a major commercial and industrial town in the Thane District. Though there is no domestic wastewater discharged by Thermal power plant, 528 MLD of warm return seawater is released to the Dahanu Creek which also received about 4 MLD of untreated domestic wastes from Dahanu Town.

6.2.2 Tarapur

Tarapur transect is represented by the coastal and interconnected Dandi Creek which carry effluents from Tarapur MIDC. The atomic power station also uses sea water as coolant for the reactors and lets out the thermal effluent to the coastal waters.

6.2.3 Bassein/Ulhas Estuary

Bassein also called Vasai is located at the lower segment of the Ulhas Estuary which in turn joins the Arabian Sea. Ulhas River is 135 km long and has many tributaries. Study area includes coastal water off Bassein and Ulhas Estuary. A variety of industries located in Ambernath-Kalyan-Dombivli-Mumbra industrial belt release their effluents in the inner estuary. Apart from industrial waste, the estuary also receives around 425 MLD of domestic sewage through several point discharges along its length. Discharge of all these effluents has resulted in severe deterioration of the Ulhas Estuary especially in the middle and upper segments.

6.2.4 Manori

Manori is a coastal fishing village of northern Mumbai and form a part of Manori-Gorai Creek. This creek is highly polluted and receives considerable volume of domestic and industrial wastewaters.

6.2.5 Versova Creek

Versova Creek which borders the coastal fishing suburb in Metropolitan Mumbai resembles a wastewater drain during low tide due to release of large volume of sewage from the sewage treatment plant at Versova. A few pharmaceutical and other small industries also use this creek for effluent disposal.

6.2.6 Mahim Creek

The Mahim Creek is the seaward end of the Mithi River. The untreated sewage from nearby pumping stations and effluents from small scale industries of Kurla-Dharavi are received in this creek.

6.2.7 Bandra

Bandra marine outfall is located about 3.7 km off the mouth of Mahim Bay in the Arabian Sea at a depth of 7 m CD. It receives around 1553 MLD of sewage, which is discharged through an underground tunnel.

6.2.8 Worli

Worli marine outfall is also located about 3.4 km off the Worli coast in the Arabian Sea at a depth of 7 m CD. Similar to Bandra outfall untreated sewage 757 MLD is released through this outfall.

6.2.9 Thane Creek

Thane Creek which comprises Thane Creek and Mumbai Harbour is about 27 km long with a width of 15 km at the mouth (off Colaba) narrowing to a few hundred meters at the head. Both Mumbai and JN ports are located in the mouth of the Mumbai Bay. The bay is V shaped semi-enclosed basin that opens to the Arabian Sea at its southwest approach and connected at its northern extremity to the Ulhas Estuary through a narrow channel. The tidal inlets of Dharamtar, Nava-Sheva and Panvel are the major tributaries to the creek discharging into its eastern shore.

Apart from spillages due to port operations, the creek/bay also receives around 1260 MLD of domestic and large quantity of industrial wastes from Mumbai, Thane, New Mumbai and surrounding regions.

6.2.10 Patalganga

The river Patalganga, a small river originating near Khopoli, flows to the west side and joins the Dharamtar Creek which in turn joins the Mumbai Harbour and receives industrial and domestic waste from Patalganga MIDC region.

6.2.11 Amba Estuary

Amba another small river joins Mumbai Bay/Harbour at Rewas. The lower reaches of the estuary often referred as Dharamtar Creek is a confluence zone of Karanja Creek, Patalganga and Amba estuaries. The estuary receives effluents from several industries mainly of petrochemical and metalurgical in nature. Outflow of Patalganga and Mumbai Harbour also influences the water quality of the Amba Estuary.

6.2.12 Thal

Thal transect represent single sampling station in the vicinity of the effluent disposal site of Rashtriya Chemicals and Fertilizer (RCF). The disposal point (D.P.) is located in coastal water off Thal at a distance of 3.5 km.

6.2.13 Kundalika Estuary

Kundalika is a shallow estuary with a fishing port and Ispat industrial unit at Revadanda. It receives wastes from the CETP of MIDC near Dhatav situated on the southern bank of the upper estuary. It was noticed during earlier field studies that green colour waste entered the estuary mainly through broken pipeline and spreadi in the receiving water depending on the tidal stage. However, during present study, the effluent was found to be released through diffuser around 30 km upstream from the mouth.

6.2.14 Murud

This transect represents the coastal water of Murud and the Rajpuri Creek/Bay. This transect is also being monitored since 1989 under COMAPS programme. The area is free from known point discharges except minor land base anthropogenic pollutants and discarded organic wastes resulting from fishery operation. Hence, the marine environment is expected to be largely uncontaminated and represent the baseline for the region.

6.2.15 Savitri Estuary

The Savitri River originates in the Sahyadri Hills and meets the Arabian Sea near Bankot. Savitri Estuary receives industrial effluents from Mahad MIDC which houses chemical and pharmaceuticals units. Treated effluent from the CETP of MIDC is discharged in the inner estuary (Station S8). It also receives untreated sewage from nearby area.

6.2.16 Vashishti Estuary

Vashishti is a fairly large estuary of south Maharashtra and experiences excellent flushing due to the large quantity of fresh water released upstream and considerable tidal influence. The upstream segment (Station VS9) of the estuary receives effluent from the industrial agglomeration at Lote Parsuram.

6.2.17 Jaigad Creek

This transect represents the coastal waters of Jaigad and inshore water of Shastri Estuary. The estuary does not receive any effluent from point sources. The fishing port is an active centre at this transect, hence fishery related wastes enter into the creek.

6.2.18 Ratnagiri

Ratnagiri fishery harbour is located inside the Mirya Bay. There is no river opening in the bay. Apart from domestic wastewater from the Ratnagiri Town the bay is influenced by the fishery and Bhagawati Port operations.

6.2.19 Vijaydurg Creek

Vijaydurg Creek which intern connects to Vaghotan River does not receive any effluent directly; however handling of molasses and fishery operation releasing unknown quantity of wastes at the port have the potential to influence environmental quality of this coastal system.

6.2.20 Deogad Creek

The study area includes coastal waters and inshore waters of Deogad Bay/Creek. Deogad Bay is connected with Deogad Creek which in turn joins the Deogad River at the upstream end and the study area does not receive much freshwater. Except for small volume of untreated sewage from Deogad Town and wastes from Anandwadi Fishery Harbour the region is free from gross anthropogenic influences.

6.2.21 Achara Creek

Achara Creek is a remote end of the Devgad Tahsil. It is a well-known and rich habitat for typical creek biodiversity including dense mangroves in Sindhudurg district of South Konkan. There is no known effluent discharge in the Achara Creek.

6.2.22 Malvan

Malvan Bay adjoining the Malwan Town does not have any known source of industrial waste; however a few non-point discharges of domestic waste water enter the bay. The port and fishery activities can also degrade the environmental quality of the semi enclosed bay.

6.3 Prevailing Environment /Ecological Status of Coastal Maharashtra

Results of the present monitoring are discussed transect-wise in Section 4 entitled “Prevailing environment” under the sub-heads of water quality, sediment quality and flora and fauna. To facilitate discussion the data have been grouped under different segments of the study area like coastal water, lower segment, middle segment and upper segment. Stations 1 to 3 were part of the open coastal area. The stations operated in the bay/creek/river/estuary were grouped appropriately depending on the length of the respective water body. Comparison of the two season data i.e. postmonsoon and premonsoon for a given transect is included in the Section 4. The results of temporal variations which would reveal tidal variability of selected parameters were plotted graphically for each parameter and included in Section 4.

The parameter wise ecological assessment for the study area was done for coastal and creek/estuarine waters separately for two major regions viz; (i) North Maharashtra-Dahanu to Murud and (ii) South Maharashtra-Savitri to Malvan.

Segment wise ecological assessment of all transects in combination with the historical data was also made and plotted as bar charts. Therefore, this section under “Ecological assessment” the overall status of prevailing marine environment along the coastal Maharashtra viz; north and south as well as transect wise ecological status in reference to pollution stress are reported and discussed to the extent possible.

6.3.1 Coastal water

The Maharashtra coast which is popularly known as the Konkan coast is a narrow strip of land between the Arabian Sea and the hilly terrain of Sahyadris which run parallel to the sea. The main drainage in the coastal area tends in a general east-west direction and flows to the Arabian Sea in the west. It comprises the coastal districts of Thane, Greater Mumbai, Raigad, Ratnagiri and Sindhudurg.

The general climate of the region is typical of that of the west coast of India, with plentiful rain during southwest monsoon, oppressive weather in the summer months, mild winter and high humidities throughout the year.

Tides which play a vital role in the coastal processes including dispersion of contaminants are predominantly semidiurnal with a diurnal inequality.

Maharashtra is the most industrialized state in India with many industrial clusters established in the coastal belt, and a considerable fraction of effluents generated in the coastal region is transported to the nearshore water via estuaries/creeks/bays or directly depending on the location of the settlement/industry.

During monsoon the high freshwater flow results in efficient flushing out of contaminants entering the creek/riverine/estuarine zones. The coastal inshore system of Maharashtra experienced poor flushing during the dry season, since majority of rivers have dams and barrages constructed on them to impound freshwater and regulate the flow in many cases thereby starving the estuaries of freshwater to enhance seaward transport of pollutants. The data on water quality as evaluated from various physico-chemical and biological parameters indicated that the coastal waters (upto 5 km) between Dahanu and Malvan are healthy except for a few areas near highly industrialized centres of Tarapur and Mumbai along the north Maharashtra coast.

Water quality

Overall, results most of environmental parameters indicated healthy marine environment along the south Maharashtra coast compared to the north Maharashtra with noticeable deviations.

As expected for shallow areas, the water temperature varied in accordance with the air temperature. The average water temperature was higher by 3-6^{o}C during premonsoon period than in postmonsoon. In general, the various coastal segments of north Maharashtra revealed marginally higher temperature (av 2.5-4^{o}C) than that of south Maharashtra. This could be due to difference in time of sampling apart from influence of large land drainage associated with urbanization and industrialization along north Maharashtra.

Salinity was generally lower in creek/estuaries and increased towards open coastal waters. Also, surface waters had lower salinity which increased with the depth, thus indicating some influence of river discharge on coastal salinity. Salinity of the open coast, creek/estuary of north and south Maharashtra was closely comparable suggesting absence of significant freshwater influx to the coastal area during dry season.

The pH of coastal segments of Maharashtra was in the range of seawater pH. However, pH of creeks and estuaries varied significantly depending upon the organic load input to the system. The uniform pH values observed vertically as well as laterally on a given segment during the study period indicated that waters were well mixed.

Suspended solids were in a range of 7-505 mg/l in the coastal waters of Maharashtra. The levels varied widely with the bottom water invariably sustaining relatively higher loads indicating that the SS in coastal regions largely results from the dispersion of the fine particles of bed materials in waters by currents. The north coast revealed higher SS as compared to south coast.Turbidity varied in accordance with suspended solid and ranged between 0.5 to 236.7 NTU in coastal water and 0.3 to 232.7 NTU in creeks/estuaries.

During present study the depleted DO concentration was recorded in the coastal water off Tarapur and Bassein in north Maharashtra. In the coastal waters of Maharashtra DO was >3.5 mg/l suggesting good oxidizing potential inspite of organic pollutants reaching the coastal system from urbanized and industrial areas. Such observations reveal that coastal water of Maharashtra carry good assimilative capacity. The signature of organic load extended in coastal water off Bassein and Tarapur affecting assimilative capacity of the region. Many creek/estuarine segments, however revealed (DO <2 mg/l) deterioration along the coastal Maharashtra. Surface to bottom variations were minor as expected for vertically well-mixed waters. The coastal waters of Maharashtra sustained BOD generally <5.4 mg/l. Elevated concentration (28.5 mg/l) of BOD recorded in the coastal water off Tarapur revealed the extent of spread of organic load in the region. Similarly the creeks/estuaries of coastal Maharashtra showed varying degree of BOD values (0.3-226.0 mg/l) depending upon the volume of organic load discharged to the region.

The nutrients like PO_4^{3-}-P, NO_3^--N, NO_2^--N and NH_4^+-N indicated higher values in creeks and some estuarine segments with considerable reduction towards the sea. The higher levels of NO_2^--N and NH_4^+-N in the inshore waters along the north Maharashtra as compared to the south segment suggested high organic input to the northern coast through anthropogenic activities leading to severe environmental deterioration in many instances. The concentration of PO_4^{3-}-P, NO_2^--N, NO_3^--N, and NH_4^+-N varied respectively in the range of ND-49.4 µmol/l, ND-31.4 µmol/l, 0.1-71.6 µmol/l and ND-97.1.6 µmol/l during the study period in the coastal system of Maharashtra. In general, these nutrients were relatively low in the open coastal waters than in creeks/estuaries.

PHc (0.8 to 112.8 µg/l) and phenols (2.6 to 922.3 µg/l) indicated relatively higher petroleum contamination in the creeks/estuaries of northern than that of southern Maharashtra due to high industrial and port activities along northern shore. The open coastal waters indicated low (0.2-25.3 µg/l) contamination of PHc during study period. These results indicated a variable trend in the coastal waters. The variable concentrations of PHc often occur in areas of shipping lanes because the petroleum being insoluble in water, its distribution is often patchy when it enters the aquatic environment through an anthropogenic source such as releases through boat traffic.

The average concentration of phenols in water widely varied with no discernible trends. High variations in phenols (20.6-414.7 µg/l) in the open coastal segment of Maharashtra were also noticed. The Kundalika Estuary showed the highest value (922.3µg/l) of phenols for the coastal Maharashtra.

In summary, severe deterioration in water quality was noticed at transect like Tarapur, Bassein/Ulhas Estuary, Manori, Versova, Mahim, Thane, Patalganga, Kundalika, Savitri, Vashishti and Ratnagiri Bay. The inner segments of above transects indicated deterioriation in the water quality as compared to the 2007-08 results.

Sediment quality

Bed sediments were by and large free from anthropogenic trace metals except for Hg in some instances around Mumbai. However, majority of creek and estuaries along north indicated elevated levels of metals, C_{org}, P and PHc in sediments as compared to south where a few places showed high values. Elevation in Cr levels in the northern area and Cu in the south, and occasional high values of Co, Zn, Cd and Pb at transects like Tarapur, Bassein, Manori, Versova, Mahim, Bandra, Worli, Thane, Patalganga and Kundalika indicated some anthropogenic contamination. Higher levels of trace metals in Savitri, Jaigad and Vijaydurg appeared to be lithogenic origin. Further detailed studies including analysis of sediment from the catchment-soils, rocks and bottom cores are necessary to resolve this issue. Low to moderate level of PHc contamination in the sediment of selected coastal segments along Maharashtra was noticed. However, the C_{org} and P indicated mixed trend with high values associated with both anthropogenic activities and high biological production respectively as indicated along north and south coastal Maharashtra.

Flora and fauna

The coastal and creek/estuary along coastal Maharashtra revealed high variations in bacterial counts viz; TVC, TC and FC in surface water. In general, bacterial counts were abnormally high along northern shore than that of southern coast. The counts of TVC, TC and FC both in water and sediment were significantly high at transect like Tarapur, Bassein, Manori, Versova, Bandra, Mahim, Thane, Patalganga and Kundalika of the northern shore suggesting high sewage input to these coastal areas. Along the southern shore water bodies like Vashishti, Ratnagiri, Vijaydurg and Malvan showed abnormal counts of TVC, TC and FC. Compared to the 2007-08 results, counts of TVC, TC and FC during present study showed increase in most of the coastal/estuarine/creek regions.

The biological productivity interms of phytopigments and cell counts indicated higher primary production potential for the northern coastal segment as compared to the southern areas of Maharashtra. Such trend in high primary production along north shore was probably associated with the nutrient input through anthropogenic fluxes such as sewage. The concentration of chlorophyll *a* (0.1-47.0 mg/m^3) in the coastal system of Maharashtra varied widely suggesting high patchiness in the distribution of phytopigment. Abnormally high values of chlorophyll *a* at Dahanu, Tarapur, Bassein, Manori, Versova, Mahim, Bandra, Worli, Thane, Patalganga, Kundalika, Savitri, Vashishti, Ratnagiri Bay, Vijaydurg and Deogad could be due to regional differences, environmental conditions like organic input to the coastal system and grazing pressure by secondary producers. Similar to chlorophyll *a* the phaeophytin values also varied widely and ranged between 0 to 23.3 mg/m^3 with maximum at Bassein.

The phytopopulation also revealed wide variations in accordance with the distribution of phytopigments along coastal Maharashtra. All the openshore coastal transect of north recorded high cell counts with abnormally high values (>200 x 10^3/l) at all transects except Vaishisti and Jaigad. The generic composition of phytoplankton at different coastal segments varied widely in accordance with trends in phytopigments and population. Overall, the generic diversity of phytoplankton was comparable at coastal Maharashtra where the dominance of opportunistic species under more stress conditions was noticed. The composition of phytoplankton genera widely varied from 3 to 52 no at individual stations. In general, the dominant genera of phytoplankton between northern and southern coastal Maharashtra were comparable. The most dominant genera along northern segment were *Navicula*, *Skeletonema*, *Guinardia*, *Nitzschia*, *Peridinium*, *Cyclotella*, *Bacteriastrum*, *Oscillatoria*, *Chaetoceros*, *Pleurosigma, Biddulphia* and *Thalassionema*. Similarly, the southern segments were represented by the generic dominance in the order of *Bacteriastrum*, *Biddulphia*, *Thalassiosira*, *Thalassionema*, *Navicula*, *Nitzschia*, *Amphiprora, Chaetoceros, Aulocoseira*, *Coscinodiscus*, *Peridinium*, *Cyclotella*, *Ceratium* and *Dictyocha*.

The zooplankton standing stock in terms of biomass and population ranged widely from 0.1 to 571 ml/100m^3 and 0.02 to 693 x 10^6 nos./100m^3 respectively suggesting patchiness in their distribution associated with spatial, temporal and seasonal variability. The faunal diversity varied between 1 and 19 (no) groups with the maxima at Thane and minima at Bassein. The faunal groups like copepods, decapods, chaetognaths, foraminiferans, gastropods, lamellibranchs, medusae and fish eggs were dominant along the northern coast. Whereas, copepods, decapods, siphonophores, cladocerans, *Lucifer* sp., gastropods, lamellibranchs, chaetognaths, appendicularians and fish eggs and fish larvae were dominant along the southern coast. The results indicated clear cut difference in group dominance between the north and south coastal systems of Maharashtra. The faunal diversity was maximum at Vijayadurg and minima at Bassein.

The macrobenthic standing stock in terms of population and biomass range varied from 0 to 23950 Ind./m^2 and 0 to 513.06 g/m^2; wet wt respectively with the highest population and biomass at Manori.The open coastal waters indicated wider range of benthic biomass in the north than south Maharashtra. The coastal waters off Dahanu, Tarapur, Bassein, Bandra, Thane, Thal, Kundalika, and Vashishti sustained low biomass; out of which all transects, except Vashishthi, are from north Maharashtra. In general, the open shore coastal system of south Maharashtra revealed better benthic production than north Maharashtra. The creek/estuaries of coastal Maharashtra showed good benthic potential. The benthic biomass in the creeks and estuaries have also revealed the same results as in case of coastal waters i.e. northern segments showed wide range of spatial variation in biomass as compared to southern coast of Maharashtra. The overall results revealed wide spatial variations in the subtidal macrobenthic standing stock with 0-15 faunal groups. The macrobenthic population generally depended on the sediment quality and texture. However, selected tolerant species like polychaetes and amphipods were more dominant in organic polluted areas along coastal Maharashtra.

The meiobenthic biomass varied widely in the coastal system of Maharashtra.The subtidal meiobenthic standing stock interms of population varied from 0 (Bassein) to 7691 Ind./10cm^2 (Patalganga). The meiofaunal biomass ranged from 0 (Bassein) to 47374 µg/10cm^2 (Manori).The open coastal waters indicated higher variations in the south whereas in north Maharashtra the biomass was comparable and low. The coastal waters off Dahanu, Tarapur, Bassein (Ulhas), Worli, Thane creek and Murud showed lower biomass values than other transects of North Maharashtra. In general, the open shore coastal system of south Maharashtra revealed normal to high values suggesting better benthic production for south than north Maharashtra, except Achara where coastal meiofaunal biomass was low.Among the creeks and estuaries of north Maharshtra most regions recorded normal meiofaunal counts, except Mahim which showed low meiofaunal density, and Tarapur, Manori and Patalganga where counts were very high as a result of nematode dominance in the region. Of the south Maharashtra transects except Savitri, all other showed normal population of meiofauna in inshore waters. Savitri, Vashishthi, Shastri, Ratnagiri and Vijaydurg showed higher meiofaunal counts in the coastal waters than in the inshore region.

6.3.2 Segment-wise environmental/ecological status

General features of transects (coastal/creek/estuaries) and their water quality, sediment quality as well as biological characteristics are briefly discussed in the preceding sections. The environmental/ecological status of the 22 monitoring transects of the Maharashtra coast is discussed in this subsection.

i) Dahanu

The creek being located at the north of Maharashtra coast experiences strong tidal influence in the mouth zone that decreases considerably with the distance from the mouth. The creek receives coolant water discharge from a power plant.

Water quality: The water temperature (26.0 to 38.0^oC) varied in accordance with the air temperature in the vicinity of the warm discharge of power station. The creek segments sustained higher temperature of the order of 4^oC than that of coastal waters. The pH (7.5 to 8.2) varied in narrow range. Salinity (26.0 to 37.2 ppt), SS (20 to 210 mg/l), turbidity (3.1-76.7 NTU) and DO (3.5-7.4 mg/l) varied widely. The DO level was fairly good with low BOD. There was evidence of enhancement of nutrients in the creek. The observed PHc content though high does not indicate gross contamination by petroleum.

The comparison of earlier data indicated that the parameters like temperature, pH and DO were comparable over the years along this transect. However, nutrients revealed high variations with a noticeable reduction in NO_3^--N and PO_4^{3-}-P and increase in NH_4^+-N over the years especially in the creek system suggesting increase in the input of organic wastes to the creek system.

Sediment quality: The surface sediment was made up of sand, silt and clay and the concentrations of heavy metals namely Cr, Co, Ni, Cu and Zn varied considerably and appeared to be lithogenic. The concentrations of P, C_{org} and PHc were low indicating uncontaminated status of the coastal sediments.

Flora and fauna: Dahanu Creek sustained higher count of TVC, TC, FC and VLO as compared to coastal segment which suggested contamination of the region by sewage in the inner creek. Phytopigments viz; chlorophyll *a* (0.5-30.6 mg/m^3) and phaeophytin (0.1-9.8 mg/m^3) varied widely as commonly observed for coastal areas along Maharashtra. The creek sustained high concentration of chlorophyll *a*, cell counts and normal community structure of phytoplankton especially during premonsoon as compared to the coastal waters. Zooplankton standing stock also exhibited temporal and spatial variability with lower generic diversity during premonsoon. The coastal segment supported poor macrobenthic potential for the study area. Postmonsoon sustained better standing stock and diversity than the premonsoon values. Meiobenthic standing stock was low in the creek except for the upper creek region in premonsoon, associated with increased phytoplankton which is a food source for benthic detritivores

Overall, organic pollution induced primary production without adequate support of secondary producers was noticed. Macrobenthic organisms did not reveal measurable adverse impact of release of warm effluent on their community. In contrast the present study showed better standing stock and group diversity in the creek region than the coastal segment.

ii) Tarapur

Tarapur Creek is a minor creek with poor tidal flushing. The creek transporting effluents to the coastal waters was highly degraded and resembled a sewer during low tide. The creek receives coolant water from the nuclear power plant as well as sewage from Tarapur town. In the past the creek also received effluents from MIDC, however, in recent years MIDC is conveying the treated effluent to coastal area through a pipeline. But due to inadequate effluent release scheme, the effluent spreads in the nearshore area and along the beach and enters in the creek with tidal movements.

Water quality: The water temperature (28.0 to 34.5^oC) varied on a narrow range with spatial trends. The salinity varied between 32.1 and 36.8 ppt in the absence of significant freshwater input during the dry season. The pH (7.4 to 8.1) was in the range of coastal seawater. The DO (0.6 to 9.0 mg/l) indicated low values especially in the creek during premonsoon with high BOD (1.6-28.5 mg/l) indicated organic pollution in the creek. In general, the nutrients especially NO_2^--N and NH_4^+-N had increased over the years suggesting an increasing trend of the waste disposals. PHc (8-25.3 µg/l), and phenols (82.8-206.9 µg/l) indicated occasional high values.

Sediment quality: The concentrations of many heavy metals in the surficial sediment varied in wide ranges. The concentrations of Zn (97-253 µg/g) and Cr (125-522 µg/g) were relatively high as compared to uncontaminated coastal sediment of Maharashtra. The concentrations of other metals, P and C_{org} were however in the expected ranges. Elevated concentration of PHc in some instances indicated its release from fishing boats and industrial wastes which partly settled on the bed sediment.

Flora and fauna: The bacterial counts in water were in the normal range excepting TVC which was high in the creek than that of open coastal segments. Tarapur Creek sediment sustained high count of TVC, TC, FC, VLO and PKLO than coastal stations. The phytopigments i.e. chlorophyll *a* (0.8-43.6 mg/m^3) and phaeophytin (0.1-12.7 mg/m^3) varied widely with creek water sustaining relatively higher concentration. The population and generic diversity indicated comparable trend as that of chlorophyll *a*. The standing stock of zooplankton interms of biomass (0.1-4.2 ml/100m^3), population (0.3-74.9x10^3/100m^3) and faunal diversity (8-16 no) varied in narrow range and broadly comparable between two season as well as between coastal and creek segments. The Macrobenthic standing stock was relatively high at the inner creek along with better group diversity. However, overall the faunal group diversity was low and dominated by polychaetes and gastropods. Meiobenthic standing stock was highest in the upper creek region in both seasons. Meiofaunal density and biomass showed an abrupt increase in the upper creek in postmonsoon season, due to increase in nematode density. Overall, the coastal/creek system revealed minor environmental stress due to anthropogenic fluxes.

iii) Bassein Creek (Ulhas Estuary)

Bassein Creek/Ulhas Estuary transports a variety of anthropogenic contaminants to the coastal waters.

Water quality: The water temperature (25.0 to 35.0°C) varied on a wide range and spatial variations were marginal. The pH (7.2 to 8.2) varied considerably with invariably low pH in the creek/estuarine segment. The SS (69 to 620 mg/l) varied widely with higher values at the lower creek and coastal waters due to greater tidal influence and silty substratum. High turbidity (34-236.7 NTU) varied in accordance with SS. Salinity (0.4 to 36.8 ppt) was as expected for a typical estuarine system with freshwater inflow. DO (<0.2-7.0 mg/l) showed a decreasing trend towards the upper estuary due to high organic load discharged in the middle and upper estuarine zone. PO_4^{3-}-P

(0.2-25.6 µmol/l), NO_3^--N (0.7-19.3 µmol/l), NO_2^--N (0.1-15.0 µmol/l) and NH_4^--N (0.8-97.1 µmol/l) indicated higher levels in the estuary than associated coastal waters. Though the water quality parameters varied temporally due to the changing volume of the estuary with the incursion of seawater, there was distinct improvement in the levels of DO and NO_3^--N and decrease in NH_4^+-N at the mouth suggesting good flushing of the estuarine system and efficient oxidization of organic matter. However, the increasing trend in NO_2^--N and NH_4^+-N of the estuary over the years was evident which could be due to the increasing input of organic load – particularly sewage, to the estuarine system.

Sediment quality: The sediment texture widely varied from clayey-silty-sand (coastal) to clayey-sandy-silt (estuary) in the coastal system of Bassein. The metal content in sediment varied widely with elevated level of Cr (691 µg/g), Co (96 µg/g), Ni (128 µg/g), Zn (777 µg/g), Hg (0.91 µg/g) and Pb (76.5 µg/g). However, the sediment appeared to be free from anthropogenic Cd except for a few stray values. The concentration of Hg in upper estuary was considerably high compare to the values reported during 2007-08 because the sampling in the inner most part of estuary was missed during 2007-08. After decommissioning of the mercury-based chlor-alkali plant which released the effluent to the estuary, concentration of Hg has decreased drastically as compare to 1996-97 values. The values of C_{org}, P and PHc were relatively high in the estuarine region as compared to the coastal waters.

Flora and fauna: Bassein Creek sustained higher count of TVC, TC, FC SLO, PKLO PALO and SFLO compared to coastal areas in both water and sediment due to contamination of the estuary by sewage.Phytopigments (chlorophyll *a* 0.8-42.4 mg/m^3) distribution revealed an increasing trend from the coast (av 2.9 mg/m^3) to the upper estuary (av 19.5 mg/m^3) with higher values in the upper estuary. Similar trends were also observed in phaeophytin. The cell counts (19 to 45996 x 10^3/l) and total genera (3 to 24 no) varied widely without significant trends. Zooplankton standing stock indicated no significant variations from coastal to the middle and the upper estuary. However, the high zooplankton standing stock noticed at the upper estuary as compared to the rest could be related to their tolerance to high environmental stress. Hence, organic pollution induced high primary production was supported by secondary producers like zooplankton especially at the upper estuary. The macrobenthic standing stock of costal and lower segment has remained similar since the year 1998, whereas middle and upper zones showed decreasing trend. Overall health of the estuary had depleted with low macrobenthic faunal group diversity over the years.

In general, the estuary indicated deterioration in water and sediment quality as well as induced biological productivity at different tropic levels associated with high organic input through anthropogenic fluxes. Meiobenthic faunal count was poor throughout the Ulhas estuary, except for lower estuary in premonsoon. The anomalous count at lower estuary was due to very high nematode density (99.6%), and absence of other meiofaunal groups (except copepods, 0.4%).

iv) Manori

The creek though minor with limited tidal flushing, receives anthropogenic wastes mainly from domestic sectors.

Water quality: The variations in water temperature were within 26.0-32.0°C ranges and waters were thermally well mixed. The pH varied from 7.6 to 8.1 with some values lower than expected for seawater and could be due to the impact of sewage release. The DO was under saturated and low values were recorded in many instances at the inner estuary. The average DO (5.3 mg/l) at the coastal waters was indicative of fairly good oxidizing condition with a few exceptions. Marked enrichment in the levels of PO_4^{3-}-P (2.5-36.9 µmol/l) was evident. Abnormal high concentrations of PO_4^{3-}-P (36.9 µmol/l), NO_3^--N (37.5 µmol/l), NO_2^--N (5.6 µmol/l) and NH_4^--N (51.0 µmol/l) often recorded in the region were typical of estuarine areas under environmental stress. PHc (1.8-5.5 µg/l) values were low. However, some values of phenols (111.6) indicated minor elevation. During present study avrage concentration of DO was lower than that of the 2007-08 results. Similarly concentration of phenols have increased in recent years. However, other parameters were in the same ramge as recorded during 2007-08.

Sediment quality: The sediment texture was mostly silty. There was no accumulation of C_{org} and phosphorous in sediments of the creek. The levels of PHc were low. The levels of metals in sediment did not indicate any serious contamination and comparable between the two periods, indicating absence of significant enrichment excepting minor elevation in Hg and Pb. concentration of Cd and Hg was higher than the values recored during 2007-08, indicating there anthropogenic inputs.

Flora and fauna: High counts of TVC, TC and FC in water and sediment clearly indicated the influence of sewage released in the creek. The counts of VLO were also high in water. Phytoplankton standing stock interms of chlorophyll *a* (av 16.7 mg/m^3) and cell counts (av 584 x 10^{3}no/l) indicated enhanced primary production probably due to enrichment of nutrients associated with organic pollution. The creek sustained variable zooplankton biomass (0.4 to 94.1 ml/100m^3), population (1.0 to 504.9 x 10^3 no/100m^3) and faunal diversity (6 to 16 no). Marked variation with high values was also noticed in macrobenthic biomass (0.01 to 513.06 g/m^2; wet wt.), population (25 to 23950 no/m^2) and total genera (0 to 8 no). The selected macrofaunal communities like polychaetes and amphipods which are tolerant to organic pollution were found proliferated in such a creek ecosystem. Meiobenthos of Manori Creek varied widely with very high biomass (av. 6508.62 µg/10cm^2) in premonsoon. Upper creek region sustained better meiobenthic potential than the lower creek in postmonsoon, whereas the reverse trend occurred in premonsoon season. Such variability is due to changes in physico-chemical parameters in the creek system - spatially as well as temporally.

Overall, the creek showed severe environmental stress due to indiscriminate waste disposals through anthropogenic activities.

v) Versova

This minor creek dries during low tide except for a narrow channel extending 5-6 km inland with poor flushing and resembles a effluent drain due to the release of large quantum of anthropogenic (sewage as well as industrial) wastes.

Water quality: The salinity (10.7-36.7 ppt) varied widely depending upon tide and season. The pH (7.3-8.2) was occasionally low, while SS (38-139 mg/l) and turbidity (13.2-31.5 NTU) were high with normal range (26.0-31.0^{o}C) of temperature. The DO (<0.2-6.7 mg/l) varied with the tide and BOD level was high (0.6-30.6 mg/l). The high nutrients like PO_4^{3-}-P (0.1-35.0 µmol/l), NO_3^--N (0.5-22.0 µmol/l), NO_2^--N (ND-4.5 µmol/l) and NH_4^+-N (2.1-62.8 µmol/l) were variable. DO falling to near zero at low tides in some instances clearly indicated the severity of degradation of the creek. However, PHc concentration (0.8-4.7 µg/l) was low with elevated concentration (29.3-185.8) of phenols. There was no improvement in the water quality as compared to 2007-08 results, but increased values of BOD was recorded in the present study.

Sediment quality: The sediment was mainly composed of silty-clay. The metals content varied in the expected ranges except for minor elevation in Cr, Cu, Zn, Hg and Pb on some occasion. The concentration of P, C_{org} and PHc were also in the expected ranges. No much variation in the sediment quality was discernible in present study and almost all the paremeters were recored in similar range as during 2007-08.

Flora and fauna: Bacterial populations were very high both in water and sediment suggesting pathogenic contamination associated with sewage disposals. The phytoplankton standing stock interms of chlorophyll *a* (av 11.6 mg/m^3) and cell counts (av 717 x 10^3 no/l) as well as generic diversity (av 16 no) was in the higher range. The zooplankton population was low in the area while the costal segment exibited relatively high standing stock. Middle segment of the creek also sustained good standing stock and diversity of zooplankton when comparing with the rest. This could be due to swarming of selected zooplankton faunal groups like carnivores in the creek system.

The macrobenthic faunal standing stock revealed a decrease over the years except post monsoon of the present study.The fauna was mostly constituted by polychaetes Versova creek sustained low meiofaunal standing stock except in the upper creek region in premonsoon where meiofaunal density and biomass were multiple times higher than its counterparts. This could be due to organic load in the upper segments of the creek.

Overall, the creek revealed deteriorated water quality, low contamination of anthropogenic waste in sediment and high bacterial counts, nutrients induced primary production with normal zooplankton and low benthic standing stock associated with organic pollution.

vi) Mahim

Mahim Creek/Bay interconnected with Mithi River continued to exhibit highly deteriorated environment due to poor flushing and high input of anthropogenic wastes.

Water quality: The salinity (17.4-36.1ppt) was largely influenced by wastewater discharges during the dry season. The pH (7.5-8.4) was in normal range with occasional decrease. Reduction in DO (av <2 mg/l) was associated with organic load. High PO_4^{3-}-P (0.1-8.3-39.5 µmol/l), NO_3^--N (1.2-29.4 µmol/l), NO_2^--N (0.1-6.6 µmol/l), and NH_4^+-N (2.5-17.0 µmol/l)) were observed at creek station. Overall, the impact of wastewater on the water quality of Mahim Creek was clearly evident.

Sediment quality: The texture of sediment varied from silty to clay. The distribution of trace metals was patchy with enhanced levels of Hg (0.30 µg/g), Cd (1.43 µg/g), Pb (27 µg/g), Cr (162 µg/g) and Zn (131 µg/g). The PHc and C_{org} contents did not indicate any enrichment. There was a decrease in Cr, Zn and PHc concentration in present study as compared to 2007-08 result. P revealed minor increase.

Flora and fauna: Mahim Creek sustained high count of bacteria in water and sediment. The chlorophyll *a* (1.3-32.4 mg/m^3) and cell counts (39-8719 x10^3 no/l) revealed enhanced values indicating induced primary production associated with organic load. The average generic diversity varied between 9 and 21 no. and the spatial and seasonal trends in community structure were comparable. Zooplankton standing stock was low (av 2.9 ml/100m^3) with variable faunal diversity. Macrobenthic standing stock was normal (av 56.5 g/m^2; wet wt) with faunal diversity (av 1-7 no). In Mahim creek meiofuna was generally low, although it was slightly higher in premonsoon than postmonsoon.

In general, the creek revealed deteriorated water quality, high bacterial contamination, enrichment of metals in sediment and organic pollution induced primary productivity.

vii) Bandra

Bandra area receives sewage through a massive submarine outfall and diffuser system at a depth of 7 m CD.

Water quality: The pH (7.8-8.4) and salinity (29.0-35.7 ppt) varied as expected for the normal coastal area. SS (46-168 mg/l) and turbidity 1.9-16.8 NTU) was high Elevation in PO_4^{3-}-P (0.2-13.8 µmol/l), NO_3^--N (4.7-31.3 µmol/l), NO_2^--N (0.1-6.3 µmol/l), NH_4^+-N (0.2-41.6 µmol/l), phenols (31-136 µg/l) and occasional drop in DO (3.5-7.0 mg/l) were recorded in recent years probably due to the influence of sewage reaching to the coastal area.

Sediment quality: Sediment was mainly silty in nature. Selected metals like Cr (152 µg/g), Cd (1.6 µg/g), Hg (0.27 µg/g) and Pb (24.8 µg/g) indicated elevated level. Organic carbon, phosphorus and PHc contents were in the expected ranges. A marginal increase in Cr, Cd, Hg and Pb in sediment value as compare to 2007-08 may be due to the build up of these elements through sewage and fluxes from Mahim Bay, which receives effluents from several small scale industries.

Flora and fauna: Bacterial counts were low both in water and sediment. Chlorophyll *a* (av 11.9 mg/m^3), cell counts (av 1629 x 10^3 no/l), zooplankton biomass (av 2.6 ml/100m^3) and population (av 42.9 x 10^3no/100m^3) were normal with occasional high values and variable with normal generic/faunal diversity. However, benthic biomass (av 2.5 g/m^2; wet wt.) and population (av 269 no/m^2) were low with poor faunal diversity. Overall average meiofaunal standing stock was low.

The coastal system, in general indicated minor environmental stress due to waste disposals.

viii) Worli

The coastal area of Worli also receives domestic sewage through a large marine outfall.

Water quality: The water quality in the vicinity of the outfall was good with high DO (3.8-9.6 mg/l), low BOD (4.8 mg/l), normal nutrients (PO_4^{3-}-P: 0.1-3.3 µmol/l. Though the concentration of SS, NO_2^--N and NH_4^+-N were higher as compare to coastal water away from the anthropogenic inputs, the values were lower than that recorded during 2007-08. Low PHc (1.2-2.4 µg/l) and phenols (46.1-72.5 µg/l) were recorded.

Sediment quality: The sediment was generally clayey-silt and metal contents did not indicate any serious contamination except for Hg (0.24 µg/g), representing lithogenic concentrations. However, the value was lower than the 2007-08 values. The levels of C_{org} and PHc were in normal ranges.

Flora and fauna: Bacterial population was low in water and sediment as compared to the adjacent coastal systems like Bandra. Phytoplankton productivity both interms of chlorophyll *a*, cell counts and generic diversity was high and comparable with adjacent coastal area. The standing stock of zooplankton was mainly dominated with copepods, appendicularians and lamellibranchs. A similar trend was noticed for macrobenthos with normal standing stock and poor diversity. The Polychaeta was the most dominant group found in water off worli. Worli showed low to moderate meiofaunal standing stock. Nematodes were the most dominant group. Cnidarians were observed only during postmonsoon.

This segment indicated a normal coastal system with low environmental stress.

ix) Thane Creek

Thane Creek/Mumbai Harbour is a dynamic water body with impressive tidal influences that generates swift water movements. This good tidal flushing rendered this creek in a relatively better health than other creeks though it receives voluminous domestic sewage and industrial effluents. However, the flushing was poor at the head of the creek.

Water quality: The wastewater entering the marine environment had deteriorated the water quality in some segments. The temperature (27.0 - 30.0^oC), and pH (7.5-8.2) varied on a normal range. The SS (22-389 mg/l) and turbidity (16.3-106.9 NTU) were high in the region. The salinity (28.9-36.9 ppt) varied considerably due to wastewater discharges and influx from Ulhas Estuary. The tide dependent DO (2.6-9.6 mg/l) levels often fell to <3 mg/l especially during low tide in the creek. However the coastal water revealed stable salinity (34.4-36.5 ppt) and DO (5.1-6.1 mg/l) than the creek segments. DO and BOD distribution pattern indicated that the organic load entering every day ($8.7x10^4$ kg/d of BOD) was being effectively dispersed by the tidal currents and assimilated in the coastal water itself and their transport offshore was low. The nutrients like PO_4^{3-}-P (0.4-49.4 µmol/l), NO_3^--N (4.6-60.3 µmol/l), NO_2^--N (0.1-31.4 µmol/l) and NH_4^+-N (0.9-36.1 µmol/l) were all high along the transect especially the creek segments. The PHc (1.2-7.4 µg/l) was in normal range suggesting absence of any severe PHc contamination. However, concentration of phenols (22.3-333.8 µg/l) varied widely and showed contamination in the region. The concentrations of PO_4^{3-}-P, NO_3^--N were lower than the 2007-08 results, however, elevated concentrations of NO_2^--N and NH_4^+-N, especially in upper creek region were recorded during the present study as compared to earlier data.

Sediment quality: The sediment texture varied from silty to clayey-sandy silt. Heavy metal contents indicated wide spatial and temporal variability. During the present study substantial reduction in the concentration of heavy metals was recorded compared to the earlier results, which may be attributed to the enforcement of regulations to treat the effluents prior to their disposal. C_{org}, and phosphorus contents were mostly low, however PHc showed enhancement suggesting minor PHc contamination in sediment.

Flora and fauna: The counts of TVC, TC and FC were abnormally high both in water and sediment of Thane Creek system, which may may due to anthropogenic inputs from Thane Creek and creeks opening to the Mumbai harbor. The primary production interms of chlorophyll *a* (0.7-47.0 mg/m^3) and cell counts (31.2-13343.4 x 10^3 no/l) revealed wide spatial and temporal variability with an increase from coastal to the upper creek segment. Due to near euthrophic conditions of temporary nature especially at the inner creek during postmonsoon, the phytoplankton bloom was noticed with very high chlorophyll a (av 8.3 mg/m^3) and cell counts (av 1.95 x 10^6 no/l) which was mostly dominated by *Skeletonema* (84.7%). The zooplankton standing stock both interms of biomass (0.2-570.8 ml/100m^3) and population (0.6-147.6 no x 10^3/100m^3) were high and varied widely in the regions, as commonly observed for coastal areas under high tidal influences. The zooplankton population was predominantly composed of carnivores. Macrobenthic standing stock was normal and exhibited wide spatial and temporal variations in biomass (0.1-217.8 g/m^2; wet wt) and population (50-4550 no/m^2). The faunal composition was comparable with variable (1-9 no) faunal diversity. The overall meiobenthic standing stock ranged from low to moderate. Postmonsoon recorded slight increase in meiofaunal density

Overall, the creek revealed deterioration in water quality, sediment quality and organic pollution induced biological production which may not represent a diverse ecosystem.

x) Patalganga

Patalganga River meets Amba Estuary near Rewas. The lower estuarine part indicates marine influence with moderate flushing whereas middle segment has weak flushing. The estuary receives effluents from MIDC at the upper middle segment (Station PT9). Apart from MIDC, several no-MIDC industries also release their effluent mostly in the freshwater zone.

Water quality: The water quality results varied at different segments depending on the prevailing tidal regime. Low salinity (0.1-32.5 ppt) and low pH (7.0-8.0) were noticed especially at the inner estuary associated with freshwater and effluent releases. SS varied between 9-183 mg/l and turbidity was in 4.7- 42.8 NTU range. DO was highly variable (0.3-7.0 mg/l) with low values at the middle estuary indicating excess loading of organic matter that lead to high BOD (6.5-35.6 mg/l) in the middle estuary. The nutrients like phosphate (0.6-27.0 µmol/l), nitrate (0.5-59.3 µmol/l), nitrite (ND-31.2 µmol/l) and ammonia (0.6-73.8 µmol/l) varied on a wide range with higher values in the entire estuary. . The NH_4^+-N had high concentration at the middle estuary as compared with the past data. PHc (1.0-112.8 µg/l) and phenols (41.3-346.8 µg/l) were more than normal indicating significant deterioration due to effluent release.

Sediment quality: The sediment texture was mostly a mixed type representing clayey-silty-sand. The heavy metals distribution varied widely with elevated levels of Cr (525 µg/g), Co (940 µg/g), Ni (218 µg/g), Cu (488 µg/g), Zn (592 µg/g), Cd (2.1 µg/g), Hg (3.64 µg/g) and Pb (33.6 µg/g) and indicated possible metal enrichment in the sediment of Patalganga Estuary. C_{org}, P and PHc also varied with relatively higher content in the segment of middle estuary. The values recored for Cr, Co, Cd, Hg and Pb during present study were higher than the 2007-08 results in the upper segment, indicating discharge of these metals through industrial wastes.

Flora and fauna: The Patalganga estuary was highly contaminated by faecal indicator bacteria like TVC, TC, FC, ECLO and pathogenic microbes like, SHLO, PKLO, VPLO and VCLO. The chlorophyll *a* (0.98-30.7 mg/m^3) and phytopopulation (103.8-96607 x 10^3 no/l) varied widely, temporally and spatially with normal generic diversity. The standing stock of zooplankton both interms of biomass (0.3-27 ml/100m^3), population (0.3-283.3 x 10^3 no/100m^3) and faunal diversity (4-18 no) varied both spatially and seasonally. The estuary sustained low standing stock of macrobenthos during postmonsoon and it was relatively better during premonsoon. The faunal diversity of benthos was low during the study period. A wide fluctuation in meiofaunal community was apparent in Patalganga during both the seasons, and no trend was observed in the distribution of meiofauna. Overall, the estuary indicated considerable deterioration in water and sediment quality and organic pollution induced biological productivity.

xi) Amba Estuary

The tidal excursion is very high in the estuary and its influence can be seen upto Nagothane village where the ingress is stopped by a weir constructed to store freshwater. The estuary receives petrochemical wastes through an outfall located in the lower estuary (Station AB6)

Water quality: The Amba Estuary was characterized by water quality expected for mildly contaminated environments. The salinity (0.3-36.5 ppt) and SS (23-117- mg/l) varied widely, whereas pH (7.4-8.0) was low in the range of estuarine water. DO (2.9-7.9 mg/l) was in the normal range with low BOD suggesting good oxidation potential for the estuary. PO_4^{3-}-P (1.3-14.7 µmol/l), NO_2^--N (0.1-9.5 µmol/l), NH_4^+-N (ND-32.4 µmol/l) and NO_3^--N (5.2-71.6 µmol/l) showed their build up in the estuary. PHc (3.1-8.7 µg/l) was normal suggesting absence of noticeable PHc contamination inspite of release of petrochemical wastes. However, higher concentration of phenols (2.6-592.1 µg/l) with maximum concentration during postmonsoon season suggesting land based contamonation. An increase in the concentration of nutrients (PO_4^{3-}-P, NO_3^--N, NO_2^- -N, and NH_4^+-N) as compared to the 2007-08 results, which may be due to the increase in the swage discharge.

Sediment quality: The sediment texture was mostly clayey-silt in nature. The content of trace metals, C_{org}, P and PHc revealed considerable scatter but there was no evidence for their accumulation in the estuarine sediments. There was not much elevation in the concentration of the metals and values were almost similar to that reported during 2007-08.

Flora and fauna: Amba estuary sustained higher count of TVC, TC, FC and VLO during ebb period than that of flood. The chlorophyll *a* (2.0-24.5 mg/m^3), phytopopulation (21--2866.4 x 10^3no/l), generic diversity (8-32 no) indicated considerable seasonal and spatial trends in different segments of the estuary. The standing stock of zooplankton was higher during premonsoon than postmonsoon. However, standing stock of macrobenthos varied widely and no appreciable seasonal and spatial variability was evident. Amba estuary recorded low to moderate meiofaunal biomass and density. The middle and lower estuary sustained highest meiofaunal standing stock in postmonsoon and premonsoon respectively. Overall, the distribution of phytoplankton, zooplankton and macrobenthos were highly variable with normal generic/faunal diversity.

In general, the estuary did not reveal severe environmental stress except high nutrients which could be due to the release of industrial effluents and tidal waters high in nutrients entering from Patalganga Estuary and Mumbai Harbour to the Amba Estuary.

xii) Thal (RCF, DP)

Thal represent single sampling location in the vicinity of the effluent disposal site of RCF. The effluent release site being being in the open coastal waters it is subject to high dispersion potential due to high tidal influence.

Water quality: The most of the water quality parameter indicated normal range as compared with open coastal waters along Mumbai. However, elevated levels of SS (104-363 mg/l), turbidity (23.5-78.0 NTU)NO_3^--N (5.9-47.5 µmol/l) and NH_4^+-N (3.6-35.5 µmol/l) than normal clearly showed the possible impact of waste disposals as well as the influence of water draining from from the Mumbai Harbour to the Thal coastal system, during ebb tide. Overall, though this site received industrial wastewater, the water quality was relatively good with normal seasonal and temporal variations. The comparison of present results with earlier data shows that the temperature, pH, and salinity were stable and comparable over the years. However, fluctuation in DO associated with varying values of essential nutrients over the years was noticed.

Sediment quality: The sediment texture was silty. The trace metals were in the expected ranges expected for the normal coastal system of Maharashtra and were comparable with earlier results. The values indicated lithogenic source and no gross anthropogenic contamination. C_{org}, P and PHc content in sediment were low suggesting absence of their enrichment.

Flora and fauna: In general, Thal coastal system revealed lower counts of TVC, TC and FC both in water and sediment as compared to the openshore segments of Mumbai. The chlorophyll *a* (1.1-18.8 mg/m^3) was high and phytopopulation (24.8-150.4 x10^3 no/l) and generic diversity (9-22 no) were in the normal range. The zooplankton standing stock and diversity were in normal range though temporal variations were high as expected for areas with tide dependant circulation. Macrobenthic standing stock was low with poor diversity suggesting unstable substrate conditions. Faunal groups like polychaetes (76-96%) were dominant in the area. Meiofaunal density was higher in postmonsoon whereas, biomass was higher in premonsoon.

In general, the Thal coastal system revealed low level environmental stress.

xiii) Kundalika Estuary:

The estuary receives industrial as well as domestic wastes. The study area of Kundalika Estuary represents four segments, of which the coastal and lower estuarine segments are marine dominant and the upper segment is freshwater zone. The middle or inner estuarine segments experience moderate tidal ingress with poor flushing.

Water quality: Water quality of Kundalika Estuary varied widely but indicated considerable degradation of upper and middle segments due to poor flushing. However, coastal water revealed good and comparable water quality in both seasons. Water quality parameters like salinity (0.1-36.7 ppt), temperature (26.0-30.5^{o}C), pH (7.2-8.0), SS (56-327 mg/l), turbidity (25.4-149.0 NTU), DO (1.6-7.0 mg/l) and BOD (0.9-19.4 mg/l) varied widely but indicated considerable degradation of upper and middle segments. However, the coastal waters revealed normal water quality that was comparable with adjacent coastal sites excepting occasional increase in the values of PO_4^{3-}-P, NO_2^--N, $NH4^+$-N, and phenols suggesting the impact of organic and industrial pollution loads transferred through the estuary. Estuarine segments sustained low and variable pH and salinity, frequently low DO and often high BOD with high nutrients, PHc and phenols associated with release of industrial effluents and sewage in the upper estuary. The deviations in the water quality in respect of high nitrate, nitrite, ammonia, PHc and phenols are clearly evident at the disposal site. An increase in the concentration of NO_3^- -N and phenols as compare to the 2007-08 results is attributed to the waste discharge to the estuary.

Sediment quality: The sediment texture was highly varied in the study area and composed of silt, silty sand and clayey-silt. The trace metal contents were variable with relative high values of Cr (275 µg/g), Cd (1.8 µg/g), Hg (0.50 µg/g) and Pb (32.0 µg/g) at the upper estuary indicating contamination due to ongoing waste disposal. C_{org}, and PHc were low, comparable between coastal and estuarine segment and did not indicate their accumulation. However, elevated concentration of P was recorded in coastal as well as estuarine regions. Increase in the Hg concentration in the estuarine region, as compared to the 2007-08 values indicated its discharge through the industrial wastes.

Flora and fauna: The Kundalika estuary revealed higher counts of TVC, TC and FC both in water and sediment in the estuarine segments as compared to the openshore areas under the influence of sewage. The chlorophyll *a* (1.1-25.4 mg/m^3), phytopopulation (58-2941.8x10^3 no/l) and generic diversity (9-22 no) varied widely, spatially, temporally and seasonally. The high standing stock of phytoplankton strongly suggested primary production induced by a severe organic pollution in the coastal system of Kundalika. The zooplankton standing stock also indicated wide variation with normal faunal group diversity. The macrobenthic standing stock was high with wide spatial and temporal variation, low in coastal water and increased in the mid and upper estuary. In both the seasons, average meiofauna density in Kundalika was lowest in the lower estuary, and comparable between the coastal and upper segments.

Overall, the estuary indicated high environmental stress due to industrial and sewage waste disposals as evident from quality of water and sediment as well as biological productivity.

xiv) Murud

Murud/Rajpuri Bay is a dynamic ecosystem with strong flushing and is free from known point discharges. Hence, the marine environment is expected to be largely uncontaminated and represent the baseline for the region.

Water quality: The coastal water of Murud was relatively free from anthropogenic pollutants and the prevailing water quality represented natural background levels. Variations in salinity (34.1-37.7 ppt), pH (7.9-8.2), SS (9--274 mg/l), turbidity (1.4-29.3 NTU), DO (4.4-7.0 mg/l) and BOD (0.3-4.9 mg/l) were not marked as the tide progressed from coastal area to the estuary. Though the concentration of PO_4^{3-}-P (0.4-3.3 µmol/l), NO_3^--N (0.3-16.9 µmol/l), NO_2^--N (0.1-1.7 µmol/l) and NH_4^+-N (0.8-6.5 µmol/l), PHc (0.6-8.2 µg/l) and phenols (23.0-117.6 µg/l) were low, they indicate input of some organic matter through the coastal wetland. In the absence of any known anthropogenic source, the litters from the lush mangrove vegetations of the region may be the source of organic load in the area increasing the ammonia concentration.

Sediment quality: The sediment was mainly sandy-silt with low percentage of clay content, comparable between coastal and creek segments. The selective metals except Mn and Fe revealed comparatively lesser scatter of values. The levels of other metals possibly represented the lithogenic concentrations. Relative high P suggested enrichment through mangrove ecosystem. C_{org} and PHc were low in sediment. The results of sediment quality were comparable with that of the 2007-08 results.

Flora and fauna: Bacterial populations in water were low with narrow spatial and temporal variations as compared with sediments. The chlorophyll *a* (1.0-18.8 mg/m^3), phytopopulation (17.4-2382.0x10^3 no/l) and total genera (10-33 no) were higher than normal but revealed spatial, temporal and seasonal variations in the coastal/estuarine system of Murud. The zooplankton standing stock varied widely with spatial and temporal fluctuations. The creek sustained better standing stock than that of coastal waters. Macrobenthic biomass (0-279.6 g/m^2; wet wt) and population (0-4700 no/m^2) varied widely suggesting seasonal and spatial variability in benthic standing stock and were low in coastal and relatively high in creek system. Similar to the macrobenthos, the Murud creek sustained better meiobenthic stock than the open coastal region, during the study period with moderate meiofaunal density with good diversity (22 groups).

Overall, the coastal system was free from anthropogenic stress and indicated high bio-potential of natural origin.

xv) Savitri Estuary

The tidal influence in the Savitri Estuary was observed upto upper segment (St S9) which is around 70-80 km upstream from the estuary mouth. The effluent disposal site of the Mahad Industrial Estateis located in the weak tidal zone (Station S8).

Water quality: The status of water quality in the inner estuary is distinctly different from that of the lower estuary. Water quality parameters like salinity (10.0-36.2 ppt), temperature (24.0-31.5^{o}C), SS (16-228 mg/l), turbidity (0.5-74.5 NTU), DO (3.8-7.1 ml/l) and BOD (1.0-4.1 mg/l) exhibit seasonal, spatial and temporal variability. The coastal waters though revealed low nutrient concentrations, the estuary indicated higher contents of NO_3^--N (1.7-21.6 µmol/l), NO_2^--N (0.3-10.8 µmol/l) and NH_4^+-N (0.5-4.8 µmol/l). The concentration of NO_2^--N was higher than NH_4^+-N, indicating its build up prior to the oxidation to NO_3^--N in the savitri Estuary.

The comparison of present results with earlier data showed that the parameters like temperature, pH and salinity though varied were broadly comparable over the years. However, the DO revealed a noticeable reduction in the upper estuary over the years. The nutrients like PO_4^{3-}-P varied on a lower range and broadly comparable over the years. However, present results of NO_3^--N, NO_2^--N and NH_4^+-N indicated their enhancement towards the lower estuarine region suggesting spread of the organic load towards downstream of the estuary.

Sediment quality: The sediment texture varied from clayey-silt to silty-sand. P, C_{org} and PHc were marginaly high in estuarine segments as compared to the coastal sediment. Metals in sediment varied widely without any discernible trends. It appeared that precipitation of materials had possibly taken place in the coastal nearshore and mouth of the estuary due to change in matrix. Hence, some deterioration in sediment quality had been evident at the upper estuary near the effluent disposal point of MIDC. The present results were in line with earlier results. These high concentrations were invariably associated with the high levels of iron and / or manganese probably indicating their lithogenic source.

Flora and fauna: The counts of TVC, TC and FC both in water and sediment were much higher in the estuarine segments as compared to the open coastal waters. Average standing stocks of phytoplankton, zooplankton and benthic were low with wide spatial, temporal and seasonal variability. The chlorophyll *a* (0.2-9.5 mg/m^3), phytopopulation (10.2-1614.4 $x10^3$ no/l) revealed temporal and spatial variation with high generic diversity. The zooplankton standing stock varied widely and no regular trend was discernible. Phytoplankton production induced zooplankton standing stock was noticed in the estuary. Macrobenthic distribution also indicated wide fluctuations. The estuarine segment sustained high benthic standing stock with low diversity indicating adverse effect of effluent on estuarine ecology. Polychaeta, Tanaidacea and Amphipoda were the most common groups in the study area. Meiobenthic standing stock was also higher in postmonsoon than premonsoon. Group diversity was low.

Overall, the estuary revealed deterioration in water quality and sustained organic pollution induced biological productivity. However, the sediment quality indicated increased metal concentration associated with lithogenic characteristics.

xvi) Vashishti Estuary

Vashishti is a fairly large estuary with excellent flushing due to the large quantity of freshwater released at upstream and considerable tidal influence. The estuary receives effluents from MIDC Chiplun and port related wastes from DabholPort.

Water quality: The water quality which was normal in the coastal water had not changed appreciably over the years and comparable with clean coastal water off Maharashtra. The salinity varied between 0.6 to 36.2 ppt representing a typical estuarine system. However, the estuary revealed low pH (6.8-8.3), with occasional decrease in DO (1.6-7.0 mg/l) coupled with high BOD (1.0-15.4 mg/l), NO_2^--N (0.0.6-17.8 µmol/l), NO_3^--N (0.7-39.0 µmol/l) and NH_4^+-N (0.6-30.2 µmol/l) mainly associated with effluent disposal in the upper estuary. The low salinity indicated adequate freshwater influx to the estuary even during dry period. The entire estuary indicated higher deterioration due to tidal oscillations as compared to the open coastal waters which had very good assimilative capacity. The values of PO_4^{3-}-P were low, varied and comparable over the years. The nutrients like NO_3^--N, NO_2^--N and NH_4^+-N had noticeably increased especially in the estuarine segments over the years.

Sediment quality: The sediment texture was predominantly silty-sand type with low percentage of clay, but seasonally variable.C_{org} (0.2-4.1%) however, high concentration of PHc (0.2-8.2 µg/g) indicated moderate petroleum contamination. Metal contents were relatively high in the mouth of the estuary. It appeared that sediment at mouth acted as the sink to metals due to change of matrix and more so because of sand bar at the mouth; which restricted transportation of sediment associated materials to the open sea. The contents of heavy metals like Cr, Mn, Co, Ni, Cu and Zn were higher at the upper segments. An increase in the Hg and Pb concentration was recorded in present study as compared to the 2007-08 results.However, analysis of effluent from MIDC Lote does not reveal gross input of these metals.

Flora and fauna: The bacterial counts in water were relatively high in the coastal area than that of estuarine segments. Whereas a reverse trend was noticed in sediment with higher values confined to the estuarine segments. Biological productivity indicated spatial, temporal and seasonal variability. Phytopigments (0.5-12.5 mg/m^3; av 1.6 mg/m^3) were normal and variable with occasional high values. Phytopopulation (12.8-152.4 $x10^3$ no/l) was also normal and comparable to that of phytopigments with normal generic diversity. The zooplankton standing stock varied widely and indicated an overall low secondary production in the estuary with spatial and temporal variability. The inner segment sustained higher macrobenthic standing stock during the study period with dominance of polychaetes, amphipoda and pelecypods. Meiofaunal distribution showed wide variations in Vashishthi, and no clear trend was observed. Group diversity ranged from 2 (low) to 10 (moderate).

Overall, the estuary revealed moderate environmental stress as indicated by the water and sediment quality.

xvii) Jaigad/Shastri Estuary

Jaigad Creek/Shastri Estuary and associated coastal segment experienced limited tidal impact and tidal ingress is expected to be weak in the middle and upper segment. The organic input through fishing port activities and vast mangrove forest is expected to the nearshore zone.

Water quality: The Jaigad coastal and estuarine water is free from any anthropogenic input and sustained clean water quality. Salinity varied widely in estuary (27.2-36.5 ppt) than that of coastal (35.3-35.8 ppt). The pH (7.7-8.1) was constant and in the expected range. SS were below 40 mg/l, hence turbidity was also low (0.3-2.3 NTU). The average DO content was above 4.8 mg/l and consequently BOD was low. Phosphate (ND-1.9 µmol/l), nitrate (0.2-11.1 µmol/l) and nitrite (ND-2.2 µmol/l) were uniformly low and in the normal range and seasonal as well as spatial variations were absent. However, somewhat elevated concentration of NH_4^+-N (0.3-5.8 µmol/l) in creek water may be due to mainly mangrove and fishing based organic load. PHc and phenols concentrations were also in the normal range. The results were comparable to the 2007-08 results.

Sediment quality: The sediment was mainly silty-sand with variable percentage of clay and sustained higher content of C_{org} and low PHc. The heavy metals show considerable spread of the concentrations without any spatial variation. The higher level of Al, Cr, Fe, Mn, Co, Cu, Zn and Hg were evident in the estuary. These levels can be of lithogenic origin associated with the basalts of the catchments. It is necessary to study the Shastri Estuary in detail to understand the fate of selected metals and C_{org}.The results were similar to the 2007-08 resultas.

Flora and fauna: Pathogens like ECLO, VLO, VCLO, SHLO, SLO and PKLO in noticeable counts showed pathogenic contamination of the estuarine and coastal system of Jaigad. The chlorophyll *a* (av 0.2-3.1 mg/m^3), phytopopulation (6.6-96.4 x10^3/l) and generic diversity (5-16 no) were patchy and varied widely spatially as well as temporally. Zooplankton distribution revealed normal range with seasonal and spatial variation. Macrobenthic standing stock varied and no clear seasonal trend in their distribution was discernible. In both seasons, coastal segment sustained highest meiofaunal standing stock. Highest nematode biomass was also observed in the coastal segment during the study period. The benthos revealed normal faunal diversity with a less seasonal trend.

In general, the estuary indicated low level of environmental stress associated with fish landing activities.

xviii) Ratnagiri

The inner part of the Mirya Bay has very poor flushing and port breakwater also obstructs efficient exchange of marine waters, resulting in increasing accumulation of organic matter released through town sewage and organic discards associated with hectic fish landing activities.

Water quality: The coastal water off Ratnagiri was relatively free from anthropogenic fluxes of pollutants and the water quality represented the natural background. However, inner part of Mirya Bay was severely affected by organic pollution due to very poor flushing and was characterized by low DO (0.6-7.0 mg/l, av 3.3 mg/l), high phosphate (3.1-27.6 µmol/l), ammonia (2.4-28.0 µmol/l) and phenols (64.3-117.6 µgl/l). The stagnation and built-up of organic pollutants at the inner bay especially during premonsoon were evident. An increase in PO_4^{3-}-P ,NO_3^--N and NH_4^+-N as compared to 2007-08 was evident in the in the inner bay of Ratnagiri.

Sediment quality: Sediment was silty-sand with low content of clay. P, C_{org} and PHc were generally low. The metals (Mn, Cr, Fe, Cu and Hg) were highly variable which could be attributed to changes in sediment texture as well as Al and Fe content apart from anthropogenic fluxes. The present results were comparable to that of 2007-08 results.

Flora and fauna: The open coastal waters of Ratnagiri sustained the lowest counts of TVC and FC for the coastal Maharashtra suggesting clean coastal system. However, Ratnagiri Bay sustained much higher counts of TVC, TC and FC in water and sediment as compared to the openshore areas. Biological standing stock interms of phytoplankton, zooplankton and macrobenthos were in the normal range and exhibited spatial, temporal and seasonal changes. Chlorophyll *a* (av 4.9 mg/m^3) and phytopopulation (4.20 x 10^{5}no/l) were high suggesting organic pollution induced primary production in the deteriorated bay. Zooplankton distribution along with group diversity showed reduction from coastal waters to the inner bay. Macrobenthic standing stock varied spatially and temporally. The standing stock was low in the inner bay during the entire study period.The outer bay was the richest in meiobenthic standing stock in Ratnagiri, in terms of both density and biomass, whereas inner bay was the poorest.

In general, the RatnagiriBay revealed severe organic pollution due to sewage disposals and organic discards from fishing activities whereas the coastal waters were clean and healthy.

xix) Vijaydurg Creek

The tidal excursion in the inner segment of creek is expected to be low with poor flushing. The handlings of molasses and fish landings are likely to influence the marine environment.

Water quality: In the absence of known anthropogenic fluxes the water quality of Vijaydurg Creek may be considered to represent unpolluted marine environment. However, relatively low DO (3.5 mg/l) was recorded occasionally in the nearshore waters. Elevated concentration of PO_4^{3-}-P (0.3-6.4 µmol/l), NH_4^+-N (0.2-19.4 µmol/l) and phenols (80.9-144.0 µg/l) in the upper creek segmens and low concentration of NO_3^--N (0.1-2.4 µmol/l) indicated some inputs of the organic load to the system probably associated with port activities. Ecxept phenols the other parameters were comparable with the 2007-08 results.

Sediment quality: The sediment texture varied from clayey-silt to silty-sand with low percentage of clay. The organic carbon and PHc were low. The concentration of Cr, Fe, Mn, Co, Ni, Cu and Zn were relatively high and appeared to be natural and lithogenic. Like water quality, the results of sediment quality were also comparable with that of the 2007-08 results.

Flora and fauna: Counts of faecal indicator bacteria TVC, TC, FC were low in water compare to counts in sediment. SHLO, SLO, and SFLO were mostly absent during premonsoon. Biological characteristics indicated normal distribution of phytoplankton, zooplankton and macrobenthos with variable generic/faunal diversity. The distribution of phytoplankton, zooplankton and macrobenthic faunal distribution indicated wide spatial and seasonal variations. In Vijaydurg, meiofaunal standing stock was normal to high throughout the creek (except premonsoon lower creek), The creek system sustained better phytoplankton and zooplankton than coastal water, whereas coastal waters encountered better macrobenthic standing stock.

Overall, the coastal waters were clean and healthy but the creek system revealed low level of organic pollution due to fishing activities at the port.

xx) Deogad Creek

The study area represents coastal, bay and creek segments, where the upper creek is expected to be poorly flushed. This coastal system is free from any significant effluent release but hectic fishing activities can influence the marine environment.

Water quality: As the creek did not receive any effluent the water quality represented a least polluted marine environment off Maharashtra. The openshore and creek waters were characterized mostly by normal range of water quality which includes salinity (25.2-35.7 ppt), temperature (23.5-35.0^{o}C), pH (8.2-8.2), SS (14-26 mg/l) and DO (5.1-7.7 mg/l) suggesting clean waters. The selective nutrients (phosphate, nitrate, nitrite and ammonia) were uniformly low without any spatial and seasonal variations. PHc and phenols were low. Elevated concentration of phenol as compared to 2007-08 results may be attributed to the non point discharge of sewage.

Sediment quality: Sediment texture was highly variable and was mainly composed of sandy-silt to silty-sand with low but variable percentage of clay. Phosphorous, and C_{org} build-up in sediment appeared to be of natural origin and the elevated levels of PHc could be due to operational discharge of fishery harbor. Similarly elevated concentrations of heavy metals indicate lithogenic origin. Concentration of Cr continues to be high in coastal as well as creek area in the line with other area of south Maharashtra, indicating lithogenic characteristics.

Flora and fauna: The bacterial counts were variable but high in the bay and creek mouth suggesting human influences through port and fishery activities. Segment wise distribution of phytoplankton indicated higher production in the inner estuary. Overall the generic diversity was normal with the absence of spatial or seasonal trends.The zooplankton biomass was better in the coastal sgment while population was comparable between the different segments. High macrobenthic standing stock was indicative of good benthic productivity with spatial and seasonal variations. In postmonsoon, Deogad recorded high overall meiofaunal standing stock, whereas in premonsoon it was significantly low. In short, biological characteristics also exhibited normal standing stock with variable generic/faunal diversity.

The coastal system in general, the creek especially showed minor organic pollution stress.

xxi) Achara

The Achara Creek is surrounded by lush healthy mangroves. Sand deposition at the mouth of the creek makes navigation difficult especially during ebb. There is no known anthropgenic discharge in the creek. However, due to attaractive natural beach, some disturbance due to tourism may be expected, apart from activities of Achara village and a small fishing port.

Water quality

Coastal water of Achara revealed the natural background for SS, turbidity, pH, salinity, DO, BOD, phosphate, nitrate, nitrite and PHc. The creek water indicated high concentration of ammonia and phenols indicating minor organic load to the in the creek, which may be due to detritus from mangroves and fishing activities. Temporal variation of salinity near the mouth of Achara Creek revealed substantial dercease in salinity during ebb tide, indicating influx of freshwater even during dry season.

Sediment quality

Texture of the sediment of the Achara region was sandy-silt. Concentration of C_{org} and PHc was low in coastal and creek region. Concentration of all the metals was low. However, the elevated concentration of Fe and Cr may be associated with lithogenic matrix as in the other part of south Maharashtra.

Flora and fauna

Achara Creek sustained relatively high count of TVC, TC, FC and VLO during premonsoon which suggested sewage contamination. The standing stock of phytoplankton and diversity were comparable between different segments suggesting strong marine influence in the creek system. Zooplankton standing stock both interms of biomass and population were normal with occasionally high secondary production and wide temporal and spatial fluctuations. The faunal diversity of macrobenthos was normal with less variation between the the segments. The groups like Polychaeta and

Pelecypoda were common and dominant in the area during both the seasons. In Achara, postmonsoon showed higher meiofaunal standing stock. Upper creek sustained the highest meiofaunal density and biomass.

The Achara Creek represents clean marine environment indicating absence of significant anthropogenic input in the region.

xxii) Malvan

The tidal flushing in the semi enclosed bay may not be efficient and is in the influence of port and fishing activities apart from low quantity of sewage disposals.

Water quality: In the absence of any known and major anthropogenic source of effluent, Malvan coast represented an unpolluted marine environment. Some influence of fishery generated waste aided by inefficient flushing in the bay was however a possibility. The water quality was good with minor spatial and temporal variations. The pH (8.0-8.2), salinity (35.3-35.8 ppt), water temperature (25.0-31.0^{o}C) and SS (7-34 mg/l) were in the normal range and indicated a typical marine area with low freshwater inflow. The water was well-oxygenated (DO, 5.4-7.7 mg/l) and the BOD (1.0-4.1 mg/l) was low. Selective nutrients namely phosphate, nitrate, nitrite and ammonia were uniformly low with normal ranges. PHc and phenols showed moderate petroleum contamination, which may be attributed to fishing and port based activities. The present data was comparable with the past study of 2007-08.

Sediment quality: Bed at most of the inner stations was rocky. The texture of sediment in the coastal waters was mostly silty with low percentage of clay, whereas the outer bay was mostly sandy. Metal contents in the bay were low compared to the coastal areas and there was no evidence of enrichments of any particular trace metal in sediment. C_{org}, P and PHc as compared to 2007-08 results, but occasionally elevated.

Flora and fauna: High bacterial populations in the Malvan bay indicated influence of human influence through port and fishery activities as well as diffused sewage releases. Phytoplankton, zooplankton and macrobenthic standing stock were high with good generic/faunal diversity as well as spatial and seasonal variability. Phytoplankton was high in bay, whereas zooplankton standing stock was more in coastal segment than bay. The faunal diversity was normal with more or less similar values in the bay and the coastal system.The bay region sustained highest meiobenthic standing stock in both seasons.

Overall, the coastal system of Malvan represents clean area and healthy marine ecosystem with good assimilative capacity for minor organic pollutants.

The creek/estuarine system which showed critical environmental stress during 2007-2008 monitoring revealed comparable results during the present study; in fact some of them had been deteriorated even further.

6.4 Water quality Index (WQI)

WQI is one of the most effective tools to provide feedback on the quality of water to the policy makers and environmentalists. It provides a single number expressing overall water quality status of a certain time and location. It is actually the categorization counting the combined influence of different important water quality parameters; as it is calculated based on the concentration of several important attributes. In the present study spatial variation of water quality index was calculated taking average measured values of 8 parameters.

The result of WQI indicated that most of the coastal (beyond 5 km from the coast) waters are in medium to good category. However, the WQI of the creeks/estuaries and bays varied spatially, temporally and seasonally. Thus the Bassein/Ulhas estuary was in the bad category followed by Tarapur Creek in premonsoon and Patalgang in both season in bad to medium range. Upper Thane Creek was in medium range. Similarly Mahim Creek was close to bad range during premonsoon. Kundalika Estuary was in bad range in the vicinity of effluent disposal and the medium range in the open coast of Kundalika estuary. In south Maharashtra estuaries, WQI was lower in the vicinity of effluent release. Surprisingly the WQI of Shastri Estuary was low in the upper estuary during premonsoon season. Though there is no known anthropogenic discharge in the region, such low WQI may be due to natural variability. Similar WQI was also recorded in Achara Creek and Malvan Bay.

6.5 Effluent analysis

During monitoring period effluents were collected in the presence of MPCB officials from different CETPs, discharging effluent to nearshore water bodies of the Maharashtra coast. From the results, it is evident that only CETP of Mahad MIDC (20.2 mg/l of BOD) and CETP at Ambernath (Chemical) (44.8 mg/l of BOD) met BOD criteria specified by MPCB, during postmonsoon season. This is because the inlet BOD of effluent at CETP of Ambernath (96.0 mg/l) and CETP Mahad (60.2 mg/l) itself was lower. However, BOD of other CETPs was above 120 mg/l and some of them exceeded 800 mg/l in the final effluent. Similarly, COD values of final effluents were multifold above the specified criteria of MPCB for CETPs and some are discharging effluent containing COD value above 31000 mg/l, the concentration of metals and PHc were within the prescribed limits of MPCB/CPCB for the CETPs. Hoever, total load calculated based on the effluent quantity, the estuaries and coast receive substantial amount of metals. Apart from point sources, the creeks/estuaries and coastal water receive effluents from several non-point sources of industrial and domestic wastes, which put organic load several times higher than the known industrial wastes.

6.6 Metals and PHc in biota

The bioaccumulation of selected metals like Cr, Co, Ni, Cu, Zn, Hg and Pb and PHc were analysed in fish obtained during experimental trawling as well as through local fishermen in areas between Dahanu and Vijaydurg.

Overall, the results indicated that the fishes/prawns collected from different part of Maharashtra coast were free from contamination by toxic metals and PHc and levels were below the permissible limit for human consumption.

7 RECOMMENDATIONS

The recommendations made in this report are based on the two sets of monitoring with respect to water quality, sediment quality and biological characteristics conducted at 22 transects along the Maharashtra coast during 2015-16 and 2007-2008, information made available by MPCB, data-base at CSIR-NIO and available published literature. Thus the recommendations in this report would emerge from ecological status of the inshore and coastal environments of Maharashtra vis-s-vis the anthropogenic contaminants entering the coastal systems through domestic and industrial effluents. Consequences due to other serious issues such as reclamation, habitat destruction, damming of rivers and climate change which by no means less important are not considered being outside the scope of this report.

The coastal sea off Maharashtra is shallow due to gently sloping shelf. Hence, the volume of water available off the coast has a defined capacity to dilute and disperse contaminants released directly or indirectly via the innumerous creeks, estuaries and bays. The present results indicate that the coastal sea off Maharashtra is by and large unpolluted except for a pocket off Mumbai and Tarapur wherein some degradation limited to a few kilometers off the shoreline is a possibility.

The inshore water bodies comprising of estuaries, creeks and bays though vary considerably in morphology and environmental setting, they have certain common features. Typically, these water bodies are shallow with wide mouth and tidal ingress is good in the outer segment but decreases considerably inland from the mouth. The catchment-derived fresh water discharge into these water bodies that is high during July-September decreases considerably over the dry season and becomes insignificant after December leading to near stagnation in the inner zones. Presence of prominent sand bars in the mouth zone of several estuaries hinders the out flow of water particularly during spring low tides. These characteristics of the water bodies have considerable bearing on their flushing behaviour. It is paradoxical that many of these estuaries and creeks receive effluents predominantly in their inner zones.

Based on the above preamble which briefly describes the features of the Maharashtra coast and the results of the monitoring conducted along the coast, the following recommendations are made:

7.1 General

a) The creek/estuarine system which showed critical environmental stress during 2007-2008 monitoring revealed comparable results during the present study; in fact some of them had been deteriorated even further.

b) The critical areas of high environmental stress identified based on the present study are the creek systems like Tarapur, Manori, Versova and Thane and estuaries like Ulhas, Patalganga, Kundalika, Savitri, Vashishti and Ratnagiri Bay.
c) Reliable model studies to understand the coastal hydrodynamics, flushing characteristics and pollutant transport at the above critical areas should be initiated in order to formulate suitable remedial measures to reduce the environmental stress.
d) Release of effluents meeting CPCB/MPCB norms in the estuarine segment where tidal flushing is highand salinity is > 5.0 ppt during driest season (as per CRZ notification 2011), should be permitted only after proper studies. Wherever feasible, new industries should be persuaded to convey the treated effluent to the open sea at a properly identified site.
e) Domestic wastewater being the major contributor to degradation in the ecology of bays/creeks and estuaries receiving these wastes, it is vital to free these inshore areas from such unplanned release and sewage should be released in the Arabian Sea through properly sited and designed marine outfalls like those off Bandra and Worli after meeting the CPCB/MPCB norms. This should be carried out on priority basis for selected critical areas identified around Mumbai.
f) Apart from point sources, non-point sources contribute substantial amount of effluent having potential to degrade the aquatic system. All the non-point discharges should be channelized to the effluent collection systems.
g) Ecological conditions in the Versova Creek have not improved even with treatment to sewage in aerated lagoons prior to release. Considering the large volume of sewage released, and the assimilative capacity of the creek, its quality is unlikely to improve. This sewage should be released to the sea through properly sited and designed marine outfall. Similar strategy is recommended for the Manori Creek and Thane Creek.
h) Domestic/industrial effluent releases to the inner bay/creek/estuarine zones must be stopped. Existing discharges should be shifted downstream to a site selected after proper hydrographic, ecological and numerical modeling studies. This should be carried out on priority for the critical areas likeTarapur, Ulhas, Patalganga, Kundalika, Savitri, Vashishti and Ratnagiri Bay.
i) Bacterial and pathogenic contaminations both in water and sediment are alarming in selected coastal segments, therefore, suitable measures to reduce them as well as to avoid pathogenic contamination of marine food should be considered.
j) Incremental increase in the volume of sewage released in the Arabian Sea through marine outfalls has potential to endanger the recreational areas such as beaches, swimming zones etc due to enhancement in pathogens that have known to have caused cholera and hepatitis epidemics

elsewhere. These sites should, therefore, be regularly monitored for selected pathogens.

k) The baseline for water quality, sediment quality and biological characteristics in order to make reliable future comparison of the coastal Maharashtra, should be established.

l) The coastal area of Maharashtra seems to be grossly free from contamination by heavy metals except for Hg in some instances. However, in the absence of dependable baseline it is difficult to interpret distinct high values of metals such as Cr, Zn and Cu recorded in some sites. Baseline for heavy metals for different coastal segments should, therefore, be evolved by analyzing a series of soil and rock samples from the associated catchment and a few sediment cores from marine zones, the bottom sections of which would represent the baseline.

m) Considering the toxicity of Hg and its transfer to humans through the marine food chain, Hg in sediments of areas identified to have been contaminated by this metal must be regularly monitored. Edible marine resources of such areas such as clams, oysters, prawns and fishes also should be periodically monitored for their Hg levels.

n) Environmental awareness programme for the fishermen in order to discourage them for throwing trash fishes and boat generated oily wastes into the inshore waters should be evolved. They should be provided suitable collection system onshore to dispose above such wastes.

o) Study should be initiated to establish the carbon and nutrient fluxes to the coastal system through natural viz; coastal wetland and biological productivity and anthropogenic activities, so that the exact impact of anthropogenic interventions on selected coastal system can be precisely evaluated. Such studies are possible through isotopic analysis.

p) A clean and healthy creek/estuarine ecology should be maintained along coastal Maharashtra in order to conserve and protect the fragile and highly bio-diversified coastal wetland and nearshore ecosystem of Maharashtra.

7.2 Site specific

Dahanu: Periodic monitoring of the creek segment especially water quality with reference to temperature should be considered.

Tarapur: The coastal system reveals substantial deterioration. Hence, the creek segment needs corrective measures treat the effluent efficiently and dispose at suitable location and should be monitored for water quality in reference to temperature and organic pollutants as well as metals like Cr and Zn in sediments.

Bassein: The estuary reveals severe deterioration. Hence needs corrective measures to treat industrial as well domestic wastes to meet the MPCB/CPCB standards and disposal at suitable location and the estuary should be monitored for the bacteria, water (DO, BOD and nutrients) and sediment quality (bacteria, Cr, Zn, Cd and Hg). The organic pollution induced high primary productivity should also be monitored.

Manori: The creek shows severe deterioration. Hence needs corrective measures to restrict the waste disposal and the creek should be monitored for the water quality (bacteria, DO, BOD and nutrients), sediment quality (bacteria, Cr, Hg and Pb) and high primary productivity induced by organic pollutants.

Versova: The creek indicates severe deterioration. Hence needs corrective measures to reduce the BOD values by treating the effluents efficiently and the creek should be monitored for the water quality and sediment quality (bacteria, Cr, Cu, Zn, Hg and Pb) as well as organic enrichment induced high primary production.

Mahim: The creek reveals severe deterioration. Hence, the creek should be monitored for the water quality (bacteria, DO, BOD and nutrients), sediment quality (bacteria, Cr, Zn, Cd, Hg and Pb) and organic enrichment induced primary production.

Bandra: The coastal system represents low environmental stress with relatively sustaining better marine ecosystem as compared to the creeks around Mumbai. However, the water quality (bacteria, DO, BOD and nutrients) and sediment quality (bacteria, Cr, Cd, Hg and Pb) need to be monitored.

Worli: The coastal ecosystem is comparable to Bandra and indicated low level deterioration. Hence, the water quality (bacteria, DO, BOD and nutrients) and sediment quality (bacteria, Hg) should be monitored.

Thane Creek/Mumbai Harbour: The coastal and creek system experience environmental stress due to waste disposals. Therefore, it needs corrective measures to treat domestic waste efficiently, so as to meet the MPCB/CPCB standards and disposal at suitable location and the water quality (bacteria, DO, BOD and nutrients), sediment quality (bacteria, Cr, Hg and Pb) and abnormally high primary production in the inner creek should be monitored.

Patalganga Estuary: The estuary indicates severe deterioration. Hence, it needs corrective measures to treat industrial waste and dispose at suitable location and restrict the disposal of untreated domestic wastes to the estuary and the water quality (pH, DO, BOD, nutrients, PHc and phenols), sediment quality (Cr, Co, Ni, Cu, Zn, Hg and Pb) and organic pollution induced high primary productivity should be monitored.

Amba Estuary: The estuary reveals low environmental deterioration due to anthropogenic fluxes. Hence, the water quality (pH, SS, DO, BOD and nutrients), sediment quality and organic pollution induced high primary production should be monitored.

Thal: The coastal system represents minor environmental stress due to industrial waste disposals. Hence, water quality (pH, SS, DO, BOD and nutrients) should be monitored as sediment is free from metal contamination.

Kundalika Estuary: The estuary shows severe deterioration. Though the disposal of effluent is through diffusers, it seems that the treatment is not proper to meet the MPCB/CPCB standards. Hence, it needs corrective measures to treat the effluent as per MPCB/CPCB standards and the water quality (pH, SS, DO, BOD, nutrients and phenols) the sediment quality (Cr, Cu, Hg and Pb) and nutrients enriched primary production should be monitored.

Murud: The coastal waters of Murud represent good water quality, sediment quality and biological productivity hence this segment can represent the baseline for the coastal segments of north Maharashtra. Therefore, it should be monitored for making reliable comparison.

Savitri Estuary: The estuary indicates deterioration. Though the treated industrial effluent going to the estuary meets MPCB/CPCB standards, hence shifting of effluent disposal point is required. Effluents and the water quality (bacteria, DO, BOD and nutrients), the sediment quality (bacteria, Cr, Ni, Cu, and Hg) and organic pollution induced high primary production of the estuary should be monitored.

Vashishti Estuary: The estuary reveals minor ecological deterioration due to waste disposals. The industrial effluent from Lote-Parshuram industrial area is discharged at the junction of Jabudi and Vashisti estuaries through diffuser system, however, enhanced effluent treatment of the effluent to meet the MPCB/CPCB standards and shifting of disposal point is required. Hence, it needs corrective measures and the water quality (pH, DO, BOD nutrients and bacteria) and the sediment quality (Cr, Ni, Cu, Zn, Hg and bacteria) should be monitored as the biological productivity appeared to be normal.

Jaigad/Shastri Estuary: The coastal waters and estuary reveal normal water quality with good biological production. However, high bacterial counts both in water and sediment indicate organic enrichment possibly through the coastal wetland and such trend need to be studied in detail. The possible metal enrichment in sediment (Cr, Cu, Zn and Hg) also needs to be investigated.

Ratnagiri: The coastal waters are clean and healthy. However, the inner bay which is polluted due to weak flushing needed corrective measures to stop the effluent disposal to the bay and should be monitored for water quality (DO, BOD, nutrients, phenols and bacteria), sediment quality (Cr, Cu, Hg and bacteria) and nutrient induced high primary production.

Vijaydurg: The coastal and creek segments reveal normal marine ecosystem. However, the elevated levels of metals in sediment (Cr, Co, Ni, Cu, Zn and Cd) need to be investigated.

Deogad: The coastal system of Deogad indicates normal marine ecosystem comparable with Vijaydurg. However, the elevated levels of metals in sediment (Cu and Zn) should be studied in details in order to understand their lithogenic nature.

Achara: Coastal water of Achara revealed the natural background. However, elevated level of Cr and Fe in sediment needs to be studied for their natural background.

Malvan: The coastal waters off Malvan reveal clean and healthy conditions. However, the inner bay shows minor deterioration due to sewage disposals and organic wastes from fishing boats at the port. Hence, the water quality (DO, BOD, nutrients and bacteria) and sediment quality (Cr and Hg) of the inner bay should be monitored.

8 ADDENDUM

Background

The CSIR-National Institute of Oceanography (CSIR-NIO), Mumbai conducted exhaustive monitoring of coastal (upto 5 km from the shoreline) and inshore (creek, estuary and bay) waters of Maharashtra along predefined transects during pre- and post-monsoon seasons as follows:

- February 2007
- March 2008
- November 2015
- May 2016

The objectives of monitoring conducted with a multidisciplinary approach encompassed the following:

- Ecological monitoring of inshore and coastal areas to identify changes, if any, in water quality, sediment quality and biological characteristics and utilize the findings to suggest corrective measures.
- Monitor for indicator pollutants in areas identified to be contaminated with specific pollutants and assess recovery of the ecosystems or otherwise.

Same transects were monitored in all above-listed campaigns between Dahanu in the north and Malvan in the south.

Draft Report based on the monitoring conducted during 2015-16 was submitted to MPCB vide letter NIO-2017/MPCB/344 dated 11 August 2017. Subsequently, the findings emerging from these studies were presented to the Chairman, MPCB, in a meeting held on 03.08.2018. MPCB vide their letter MPCB/JD(WPC)/B-3466 dated 14 September 2018 has desired to include the following information in the Report:

- Details of study area.
- Comparison and graphical presentation of results of monitoring conducted in 2007-08 and 2015-16 to identify areas where deterioration of ecological quality had occurred.
- Recommend measures required to be taken by MPCB and other departments not only to arrest further degradation but improve the ecological status of flagged areas. Status of marine ecology along coastal towns and urban settlements.

Accordingly, the following information is added in the Final Report.

8.1 Study Area

The Maharashtra coast was monitored between Dahanu in the north and Malvan in the south at predefined transects as given in Table 1.4.1. The study area is illustrated in Figure 1.4.1 while transect at each along which the monitoring was undertaken are presented in Figures 2.2.1-2.2.18

8.2 Comparison between 2007-08 and 2015-16 Results

Results of water quality and sediment quality at each transect monitored during the two periods are discussed in this Section.

8.2.1 Dahanu

The comparison between 2007-08, and the present data indicate that the parameters like pH and DO were comparable over the years along this transect. However, nutrients revealed high variations with a noticeable reduction in NO_3^--N and PO_4^{3-}-P and increase in NH_4^+-N (Figure 8.2.1) over the years especially in the creek system suggesting increase in the input of organic wastes to the creek. Increase temperature in the creek could be due to the discharge of warm return water from thermal power plant.

The sediment continues to be free from gross contamination with anthropogenic trace metals (Figure 8.2.2), PHc and organic matter and there is no much variation in the sediment quality as compared to the 2007-08 result.

There is an increasing trend in microbial populations from 2007 to 2016 with TVC, TC, FC counts high during 2015-16 suggesting increase in the volume of sewage in the system.

Overall, except for increase in temperature in the segment of effluent release, the creek ecology was largely free from gross impact due to release of effluents. However, organic pollution induced primary production without adequate support of secondary producers especially during dry periods, was evident.

8.2.2 Tarapur Creek

Environmental condition off Tarapur continued to be deteriorated compare to that of the 2007-08 results. Buildup of organic load was evident in the entire creek and mouth region in 2016 compared to 2007-08 results probably due to enhancement in anthropogenic organic loading through effluents. During oxidation of the organic matter, the DO is consumed creating anoxic condition in the creek and increasing BOD values particularly during ebb. Also increased concentration of ammonia-nitrogen and nitrite-nitrogen with decreased DO particularly in the creek was suggestive of considerable ecological stress and there is no improvement in quality with respect to 2007-08 results (Figure 8.2.3). TVC, TC, and FC counts were high in Tarapur region during 2015-16 as compared to 2007-08 results, indicating increased domestic and industrial wastes in the region.

The sediment burden of chromium in the creek exceeded 300 µg/g in the Upper Creek in 2007, increased to over 400 µg/g in 2008 but subsequently decreased to around 270 µg/g in 2016 (Figure 8.2.4). Otherwise, the sediment is free from anthropogenic contamination by other trace metals studied, PHc, organic carbon and phosphorous during all sampling events.

Spread of effluent was also observed upto Nandgaon Beach. Overall the environmental condition of the creek and effluent release area is in deteriorated condition.

8.2.3 Bassein Estuary

Water of Bassien Creek/Ulhas Estuary has deteriorated as compared to the 2007 results**.** In the Middle and Upper Creek segments the DO which was 2.6 mg/l in 2007 had depleted to below 1 mg/l with dramatic increase in BOD from less than 3 mg/l (2007) to in excess of 40 mg/l (Figure 8.2.5). The nutrients had also enhanced over the period. These trends suggest increase in the loading of organic matter through sewage / industrial effluents. If the trend continues, there is likelihood of inner estuary going completely anoxic over the dry season with the generation of hydrogen sulphide causing mortalities of organisms including fish. Microbial such as TVC and SFLO were high during 2015-16, whereas the TC, FC and ECLO were high during 2007-08.Overall appearance of high microbial counts in the upper segment indicates contamination of sewage, which is discharged in high quantity in the region.

The concentration of Hg and Pb in upper estuary was marginally high compare to the values reported during 2007-08 (Figure 8.2.6). Because the sampling in the inner most part of estuary was missed during 2007-08. After decommissioning of the mercury-based chlor-alkali plant which released the effluent to the estuary, concentration of Hg has decreased drastically as compare to 1996-97 values. Other trace metals did not indicate any definite trend.

8.2.4 Manori Creek

High concentrations of nutrients viz; PO_4^{3-}-P, NO_3^--N, NO_2^--N and NH_4^+-N continue to persist in the creek over the years (2007-2016) and are associated with the disposal of domestic wastewater in the creek. Low and fluctuating DO with elevated levels of NO_2^--N and NH_4^+-N clearly indicated the impact of organic pollution in the creek system (Figure 8.2.7). In case of microbial counts, TC and FC counts decreased during present study as compared to the 2007-08 results.

Concentrations of trace metals in sediment indicate a fluctuating trend with no evidence for their built-up in the bottom deposits (Figure 8.2.8)

8.2.5 Versova Creek

The comparison of present values with earlier data revealed that the parameters like temperature, pH, salinity, SS, phenols and PHc varied but broadly comparable over the years. The DO in the Upper Creek had improved considerably in 2016 compared to the previous results. However, this could be a chance occurrence and further monitoring is necessary to establish the trend. Moreover the BOD in the creek has increased multi-fold from 2007 suggesting an increase in organic loading on the creek. The nutrients like PO_4^{3-}-P, NO_3^--N, NO_2^--N showed high variability without any clear trend. However, the abnormally high concentrations of PO_4^{3-}-P and NH_4^+-N particularly in the Upper Creek (Figure 8.2.9) are associated with the release of sewage in the creek severely deteriorating the ecological quality of the creek.

No much variation in the sediment quality was discernible in present study and almost all the parameters were in the similar range as during 2007-08, but an increase in the concentration of Cr was noticed during present study (Figure 8.2.10).The creek showed the highest average bacterial counts both in water and sediment compared to the coastal area. High nutrient concentrations result increase in chlorophyll *a* and phaeophytin, and only organic tolerant species of phytoplankton were recorded in the creek. The results indicate that the creek has further deteriorated compare to 2007-08 results.

8.2.6 Mahim Bay

Compared to 2007-08 results, the Upper Creek seems to have improved in water quality with respect to DO, PO_4^{3-}-P and NH_4^+-N (Figure 8.2.11), though further monitoring is necessary to confirm the perceived improvement. The presence of pathogens like ECLO, VCLO and VPLO in high numbers showed contamination of the creek system by sewage. But as compared to results of 2007-08, FC and TC counts are found to be decreased in creek regions.

Concentration of Zn in sediment of the Upper Creek that exceeded 200 μg/g during 2007-08 had decreased markedly in 2016 though other trace metals varied randomly and indicated lithogenic levels (Figure 8.2.12).

8.2.7 Bandra and Worli outfalls

The water quality in the vicinity of these outfalls indicated efficient dilution of effluent with most parameters except NH_4^+-N are comparable to natural coastal waters of central Maharashtra coast. NH_4^+-N was sometimes marginally high due to its association with sewage but unlikely to be of serious consequence in view of high DO and its uptake in primary production. BOD was low at both the locations (Figures 8.2.13 and 8.2.14). The microbial counts like TVC, TC, FC and VLO in high numbers showed contamination due to higher influence of adjacent creeks like Versova and Mahim on the nearshore water mass. But as compared to results of 2007-08, FC and TC counts are found to be decreased in both Bandra and worli.

Sediment at the both outfalls sustained expected natural levels of trace metals (Figures 8.2.15 and 8.2.16), phosphorus, organic carbon and PHc.

8.2.8 Thane Creek

With respect to the 2007-08 results DO was markedly improved in the Upper Creek while, the BOD marginally increased towards upstream. The distribution of PO_4^{3-}-P remained patchy but Upper Creek invariably sustained high levels than expected for clean coastal waters. Occasional occurrence of relative high levels of NH_4^+-N and NO_2^--N in the system (Figure 8.2.17) is suggestive of influence of sewage releases in the creek. As expected availability of abundant nutrients triggered high primary production in the inner creek. TC and FC were high during 2007-08 as compared to the 2015-16.

The creek sediment continues to be free from contamination by anthropogenic (Figure 8.2.18).

8.2.9 Patalganga Estuary

With respect to 2007-08, the water quality of the Middle Estuary seems to have deteriorated with depletion of DO and increase in BOD (Figure 8.2.19). The estuary continues to sustain high levels of NH_4^+-N and occasional high NO_2^--N, PHc and phenols**.** Abnormal counts of TVC were found to be present in Patalganga water and sediment samples as compared to results obtained in 2007-08. However, TC and FC counts were high during 2007-08 study.

The sediment of the Middle Estuary invariably had elevated concentrations of Co, Zn, Cu and Hg (Figure 8.2.20) which appear to be due to anthropogenic addition over the natural background.

8.2.10 Amba Estuary

With respect to the 2007-08 baseline, the water quality of the Amba estuary has remained relatively unchanged in 2016 except for PO_4^{3-}-P which revealed relatively high levels in 2016 (Figure 8.2.21).

Concentrations of trace metals, organic carbon, P, and PHC in sediments have remained comparable between the two sets of measurements (Figure 8.2.22).On comparing with 2007-08 report, Amba Estuary was found to sustain low counts of TC and FC both in water and sediment.

8.2.11 Thal DP

The comparison of 2016 results with those of 2007-08 showed that the water quality and sediment quality in the vicinity of the DP had not changed within the natural variability inherent to coastal waters (Figures 8.2.23 and 8.2.24). In general, Thal coastal system revealed lower bacterial counts viz; TVC, TC and FC both in sediment and water as compared to the openshore segments of Mumbai.

8.2.12 Kundalika Estuary

During 2007-08 monitoring, it was observed that the industrial effluent was being discharged as open drain due to broken pipeline. However, during 2015-16, it was observed that the industrial discharge was through diffuser. However, there is no substantial change in the water quality of Kundalika Estuary and an increase in the BOD level in upper estuary (Figure 8.2.25) indicates discharge of organic load beyond its assimilation capacity. Also increase in the TVC was recorded during 2015-16 compared to 2007-08 results. Almost similar trend of metal concentration in sediment was recorded during 2015-16 as in 2007-08 monitoring, with elevated concentration of Cr in upper segment during both attempts (Figure 8.2.26).

8.2.13 Murud

In the absence of any known anthropogenic source, the litters from the lush mangrove vegetation of the region may be the source of organic load in the area increasing the ammonia concentration. BOD values were lower during 2015-16 as compared to the 2007-08 results. The results of other parameters recorded during 2015-16 monitoring were comparable to that of 2007-08 results with random variation (Figure 8.2.27). Murud showed high TVC counts in 2015-16 compared to 2007- 08. However, TC, FC and ECLO counts were moderately same as the previous study. Overall, the coastal system was free from anthropogenic stress and indicated high bio-potential of natural origin. Elements like Co, Ni, Cu and Zn varied according to the Al content, indicating lithogenic characteristic (Figure 8.2.28).

8.2.14 Savitri Estuary

The comparison of present results with 2007-08 data showed that almost all the parameters were broadly comparable over the years. Elevated levels of NO_2^--N and NH_4^+-N recorded during both the sampling events particularly in upper segments (Figure 8.2.29) of the estuary indicated discharge of organic load in the upper estuary. Concentration of phenols was high during 2015-16 as compared to the 2007-08 values. Effluent quality of MIDC, Mahad analysed during sampling period (2015-16) meets the MPCB criteria (Section 5.4). It indicates that sewage of Mahad town is major contributor of the load.The present results of sediment quality were in line with 2007-08 results (Figure 8.2.30). Savitri Estuary sustained high TVC counts in the year 2015-16 compared to 2007- 08. Except TVC counts, TC, FC and ECLO counts were high during 2007-08.

8.2.15 Vashishti Estuary

The values of PO_4^{3-}-P were low, varied and comparable over the years. The nutrients like NO_3^--N, NO_2^--N and NH_4^+-N had noticeably increased especially in the estuarine segments over the years (Figure 8.2.31). Concentration of trace metals were comparable to the 2007-08 results (Figure 8.2.32). However, elevated concentration of PHc were observed during 2015-16 as compared to 2007-08 results in the middle and upper segment of the estuary. Like Savitri Estuary, Vasishthi Estuary also sustained high TVC counts in 2015-16 compared to 2007- 08.

8.2.16 Jaigad/Shastri Estuary

Jaigad Creek/Shastri Estuary and associated coastal segment experienced limited tidal impact and tidal ingress is expected to be weak in the middle and upper segment. The organic input through fishing port activities and vast mangrove forest is expected to the nearshore zone. Elevated concentration of NH_4^+-N (0.3-5.8 µmol/l) in creek water (Figure 8.2.33) may be due to mainly mangrove and fishing based organic load. Results of present monitoring of water and sediment quality were comparable with the 2007-08 results. Higher concentration of Cu and Zn is in line with Al and Fe values (Figure 8.2.34), indicating natural variations. Shashtri estuary is showing high TVC counts in 2015-16 compared to 2007- 08. Except TVC counts ECLO counts were high during 2015-16.

8.2.17 Ratnagiri

The coastal water off Ratnagiri was relatively free from anthropogenic fluxes of pollutants and the water quality represented the natural variability. The inner part of the Mirya Bay has very poor flushing and port breakwater also obstructs efficient exchange of marine waters, resulting in increasing accumulation of organic matter released through town sewage and organic discards associated with hectic fish landing activities. An increase in PO_4^{3-}-P, NO_3^--N and NH_4^+-N as compared to 2007-08 was evident in the inner bay of Ratnagiri (Figure 8.2.35).The present results of sediment quality were comparable to that of 2007-08 results (Figure 8.2.36), indicating no enhancement of trace metals for the years.The open coastal waters of

Ratnagiri sustained the lowest counts of TVC and FC for the coastal Maharashtra suggesting clean coastal system. Abnormally higher counts of TC and FC were found to be present in sediment of bay regions as compared to 2007-08. Overall, Ratnagiri showed high microbial counts in 2015-16 compared to 2007- 08 as it receives sewage from nearby town and wastes from Ratnagiri port.

8.2.18 Vijaydurg Creek

High concentration of NH_4^+-N and phenols were recorded during 2015-16 monitoring as compared to the 2007-08 results (Figure 8.2.37), indicating domestic waste based contamination in the region. Other parameters were comparable in both the periods. Like water quality, the results of sediment quality were also comparable with that of the 2007-08 results (Figure 8.2.38). Elevated concentration of Ni and Cu were associated with high concentrations of Al and Fe. Overall, Vijaydurg showing high microbial counts in 2015-16 compared to 2007- 08.

8.2.19 Deogad Creek

The study area represents coastal, bay and creek segments, where the upper creek is expected to be poorly flushed. This coastal system is free from any significant effluent release but hectic fishing activities can influence the marine environment. As the creek did not receive any effluent the water quality represented a least polluted marine environment of Maharashtra. Minor increase in the values of BOD and NH_4^+-N was noticed during 2016 as compared to the 2007-08 results (Figure 8.2.39). Sediment of Deogad region did not show any elevation in the trace metal concentration and were comparable with 2007-08 results (8.2.40).

Deogad Creek is showing high microbial counts in 2015-16 compared to 2007- 08. TC, FC and ECLO counts were also high during 2015-16 compared to 2007-08.

8.2.20 Achara

The Achara Creek is surrounded by lush healthy mangroves. Sand deposition at the mouth of the creek makes navigation difficult especially during ebb. There is no known anthropgenic discharge in the creek. However, due to attractive natural beach, some disturbance due to tourism may be expected, apart from activities of Achara village and a small fishing port. Coastal water of Achara revealed the natural background for SS, turbidity, pH, salinity, DO, BOD, phosphate, nitrate, nitrite and PHc. The creek water indicated high concentration of ammonia (Figure 8.2.41) indicating minor organic load to the creek, which needs to be checked before further enhancement of the organic load takes place.The sediment of the region was free from the trace metals (Figure 8.2.42).

8.2.21 Malvan

The tidal flushing in the semi enclosed bay may not be efficient and is in the influence of port and fishing activities apart from low quantity of sewage disposals.The present data showed minor increase of BOD, NO_3^--N, and NH_4^+-N during 2016 as compared to the past study of 2007-08 (Figure 8.2.43). Sediment was free from any contamination (Figure 8.2.44). An increase in the microbial count was noticed during 2016 study.

8.3 Status of marine environment along coastal towns and urban settlements

In this section the findings in the vicinity of towns/cities situated in the coastal region are presented in terms of water and sediment quality and discussed below.

The concentration of heavy metals in sediment depends on the size of particles. The trace metals are therefore often associated with clays. Hence, the variation of concentration of heavy metals can not be compared directly. To overcome this difficulty the results are normalized with Al content of the sediment, which is considered to represent the clay fraction. Also, because of high natural concentration of Al in clays, its level in sediment is unlikely to be grossly influenced by anthropogenic inputs of the metal. Thus the metal enrichment factor (EF) can be calculated as follows:

EF = ([Mx/Alx])/([Ms/Als])

Where Mx = concentration of the metal in the sample

Alx = percentage of aluminium in the sample

Ms = concentration of metal in the uncontaminated sediment

Als = concentration of aluminium in the uncontaminated sediment

Average concentration of metals in bottom sections of cores collected around 25 km away from the shoreline off Mumbai and Ratnagiri representing more than 200 years were considered as background values (uncontaminated sediment), as these sediments represent pre-industrialized years. Hence, the variation of metals is discussed in terms of EF in this section.

EF<2	Deficiency to minimal enrichment
EF=2-5	Moderate enrichment
EF=5-20	Significant enrichment
EF=20-40	Very high enrichment
EF>40	Extremely high enrichment

Table 8.3.1: Table showing five contamination categories recognized on the basis of the enrichment factor

8.3.1 Dandi and Navapur

Dandi and Navapur are situated on opposite side to each other near the mouth of Tarapur Creek. As discussed in Chapter 3 Tarapur Creek receives around 2.0 MLD domestic and around 80.0 MLD of industrial effluent in the nearby coastal water. These discharges have exceeded the assimilation capacity of the creek, deteriorating the aquatic environment as given in Figure 8.3.1 below:

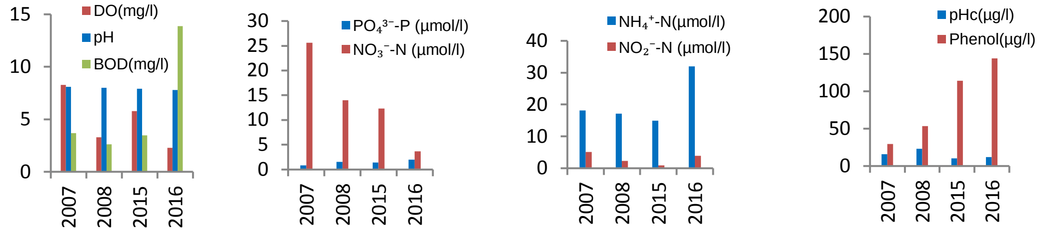


Figure 8.3.1: Status of Water quality of Tarapur Creek near Dandi & Navapur town.

From above figure, it is evident that the water quality near towns is severely deteriorated with low DO, NO_3^--N and increased BOD, PO_4^{3-}-P, NH_4^+-N and phenols.

Sediment quality in terms of EF are graphically presented in the Figure 8.3.2 below:

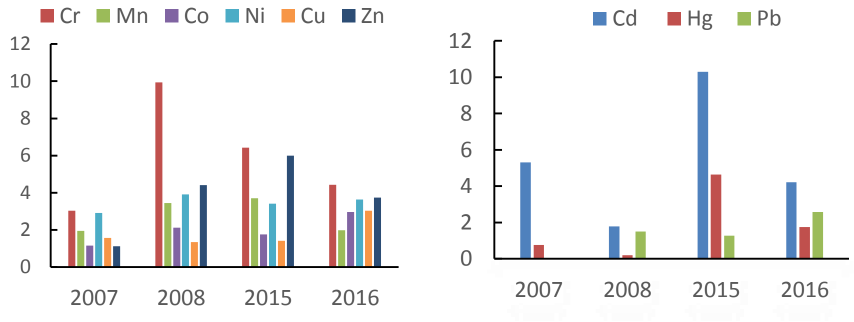


Figure 8.3.2: Enrichment factor of selected metals in sediment of Tarapur Creek near Dandi and Navapur town.

From the above figure, it is evident that the sediment near Dandi and Navapur is enriched significantly with respect to Cr and Cd, which may be associated to the effluent discharged in the region.

8.3.2 Ambivali-Ulhas Nagar town

Ambivali and Ulhas Nagar are established on upper segment of the Ulhas Estuary. Valdhuni nallah, which flows through Ulhas Nagar, receives untreated effluent from small scale industries, around 150 MLD domestic and 11.5MLD industrial waste from Badlapur-Ambernath industrial sectors and meets Ulhas Estuary near the confluence of Ulhas River at Ambivali area. The water quality recorded in this area is presented in the Figure 8.3.3 below:

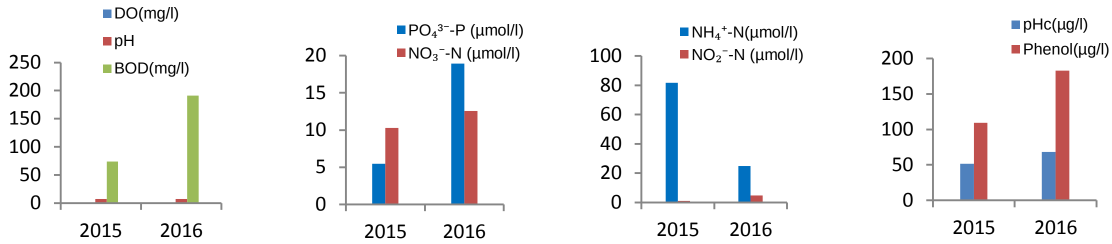


Figure 8.3.3: Status of Water quality of Bassein/Ulhas Estuary near Ambivili town.

Multi fold increase of BOD, PO_4^{3-}-P, NH_4^+-N has taken place in the vicinity of Ambivali town, indicating discharge of organic load is far beyond the assimilative capacity of the water body. Enrichment factor of trace metals recorded in the region are given in the Figure 8.3.4 below:

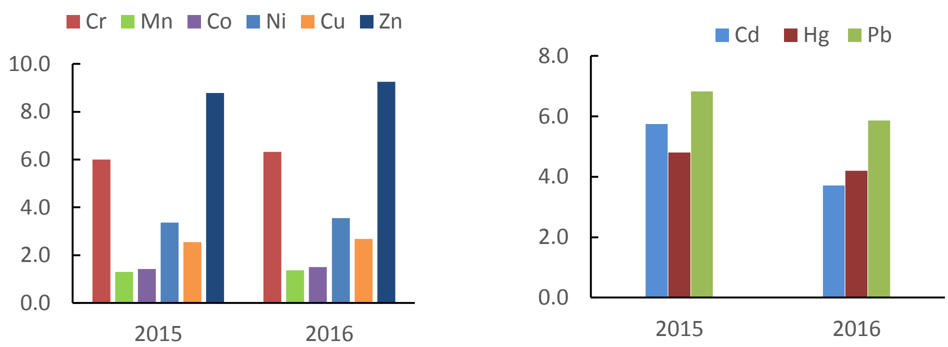


Figure 8.3.4: Enrichment factor of selected metals in sediment of Bassein/Ulhas Estuary near Ambivili town.

Thus the significant enrichment of Cr, Zn, Cd, Hg and Pb is indicative from the above figure.

8.3.3 Kalyan-Dombivali town

Around 350 MLD of domestic waste generated from the urban settlement and 16.5 MLD of industrial waste from Dombivali industrial belts goes to the Ulhas Estuary Ulhas Estuary. Such huge wastes are not assimilated in the area and deterioration of water quality takes place in the region. Water quality recorded in the region is presented in the Figure 8.3.5 below:

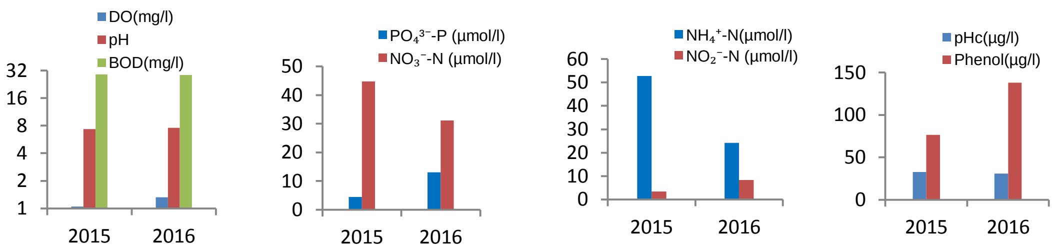


Figure 8.3.5: Status of Water quality of Bassein/Ulhas Estuary near Kalyan- Dombivili town.

As it is evident from the above figure discharge of high organic load has resulted in high BOD and nutrients, thus depleting the DO in the region. The water quality of the region is highly deteriorated. Enrichment factor calculated for selected trace metals is given in Figure 8.3.6 is presented below:

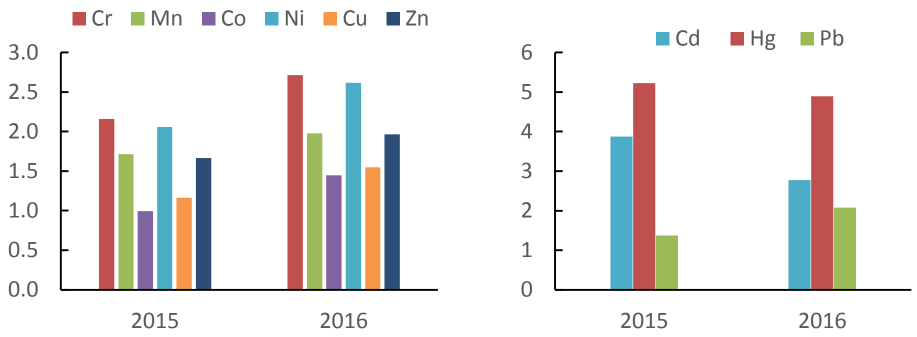


Figure 8.3.6: Enrichment of trace metals in Bassein/Ulhas Estuary near Kalyan- Dombivili town.

Thus moderate enrichment of Hg was recorded in the region. Enrichment factor of other elements was <4.0**.** After closer of Hg-based chlor-alkali industries, concentration of Hg has decreased drastically, but still above background level (0.10 µg/g; dry wt).

8.3.4 Towns along Manori Creek

Manori Creek also known as Gorai/Marve Creek receives domestic as well as industrial wastes from the towns along its bank such as Sanjay Gandhi National Park, Dahisar Gorai, Manori and an amusement park known as Essel World. Hence, it has become a waste water drain. Water quality of Manori Creek collected during present is presented in the Figure 8.3.7 below:

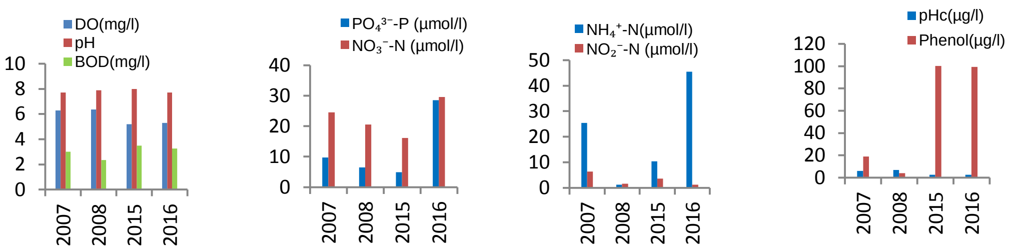


Figure 8.3.7: Status of Water quality of Manori Creek near Koliwada.

It is evident from above figure that the level of nutrients as well as phenols have increased in recent years due to increase in the waste discharge from nearby towns. Sediment quality of the area in terms of enrichment factor is presented in the Figure 8.3.8 below:

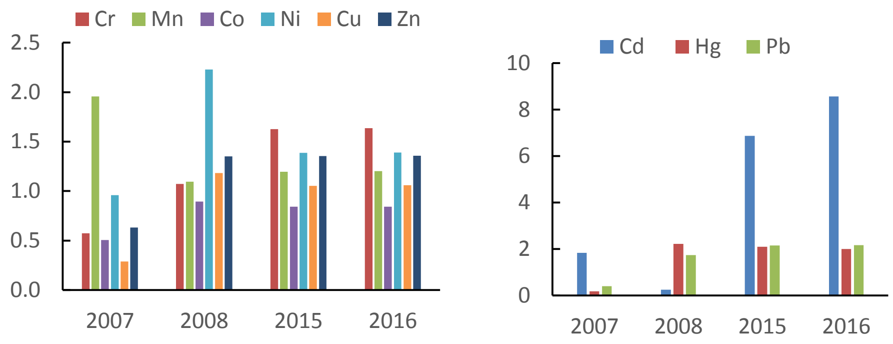


Figure 8.3.8: Enrichment factor of selected metals in sediment of Manori Creek near Koliwada

The above figures indicate that except Cd, there is no significant enrichment of other element in the sediment of study area.

8.3.5 Versova fishing village

Versova fishing village is established on the mouth of Versvo/Malad Creek. It receives about 440 MLD sewage from Malad and Versova pumping stations. It also receives industrial waste of Goregaon industrial estates through Oshiwara River. Results of water quality studied during 2007-2016 is presented in the Figure 8.3.9 below:

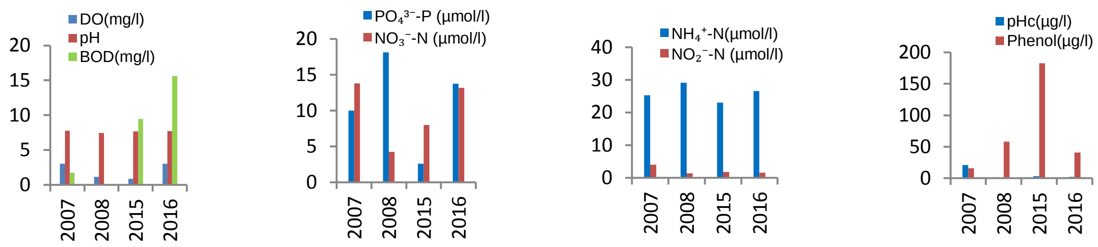


Figure 8.3.9: Status of Water quality of Versova Creek near Versova village.

Discharge of huge quantity of sewage and industrial wastes has deteriorated the water quality of Versova Creek with increase of BOD, phosphate and ammonia and DO often falling zero, especially during low tide. Enrichment factor of trace metals calculated for Verso creek sediment near Versova village is given in the Figure 8.3.10 below:

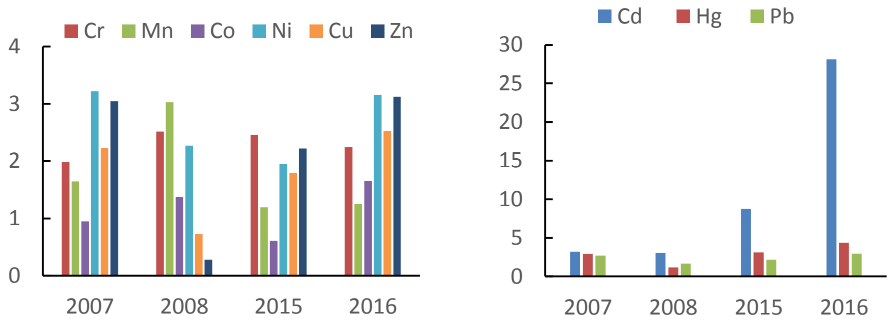


Figure 8.3.10: Enrichment factor of selected metals in sediment of Versova Creek Versova Village.

Like Manori, sediment of Versova Creek is also enriched with Cd from significant to very high level, indicating similar source of Cd in both the creek, which may be from small scale industries situated on the bank of these creeks. Moderate enrichment of Cr, Mn, Cu and Zn was observed in some instances.

8.3.6 Mahim and Bandra

Mahim Bay receives wastes through Mithi River from several small scale industries and urban settlements. Around 1553 MLD of sewage, which is discharged off the Bandra coast through an underground tunnel, except for removal of grit, no treatment is given to the sewage before its disposal off Bandra. Water quality recorded off Bandra and Mahim Bay is presented in Figures 8.3.11 and 8.3.12 below:

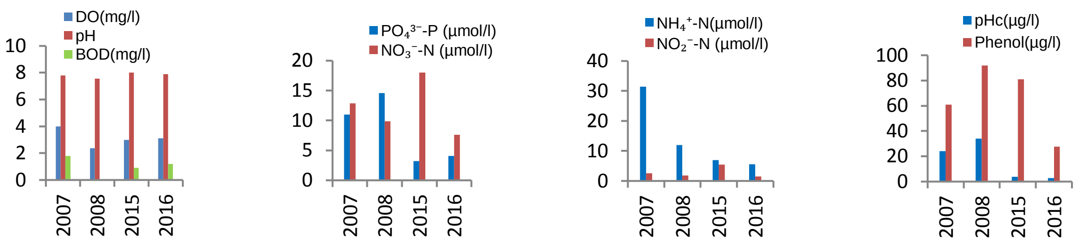


Figure 8.3.11: Status of Water quality of Mahim Creek.

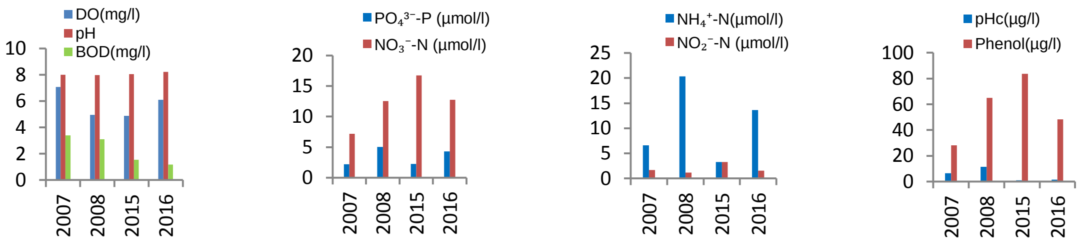


Figure 8.3.12: Status of Water quality off Bandra outfall.

As it is evident from the above figures, improvement in the water quality has taken place in Mahim creek in recent years in terms of lower BOD and ammonia, but low DO persists, due to high organic load. In the vicinity of Bandra outfall, there is no DO depletion, though high ammonia is recorded before its oxidation to nitrate. Enrichment factors calculated for trace metals in the region are given in the Figures 8.3.13 and 8.3.14 below:

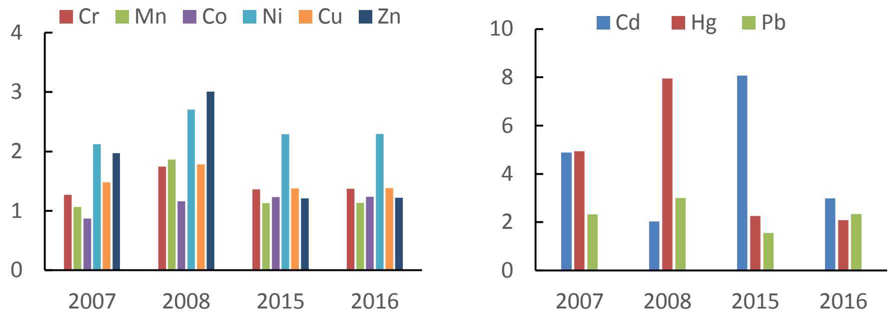


Figure 8.3.13: Enrichment factor of selected metals in sediment of Mahim Creek.

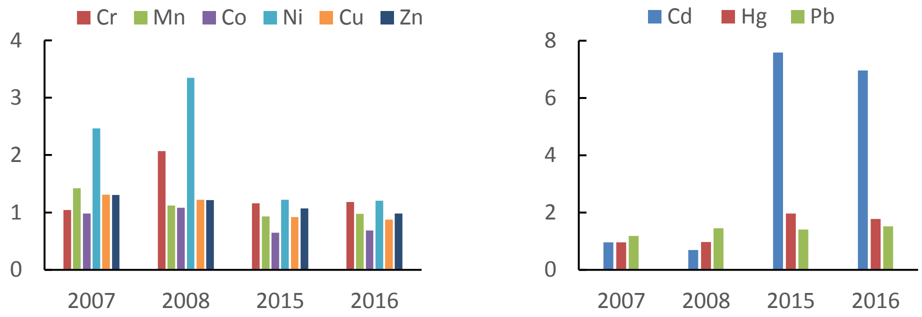


Figure 8.3.14. Enrichment factor of selected metals in sediment of Bandra outfall.

As it is evident from the above figures, except Cd none of the trace metal is significantly enriched in the sediment of both the places.

8.3.7 Worli

Love-Grove sewage pumping station situated at Worli discharges around 757 MLD of sewage to the Arabian Sea through a marine outfall after degretting and preliminary treatment. To check the environmental status around outfall, monitoring was done during 2015-16 and results of water quality are given in Figure 8.3.15.

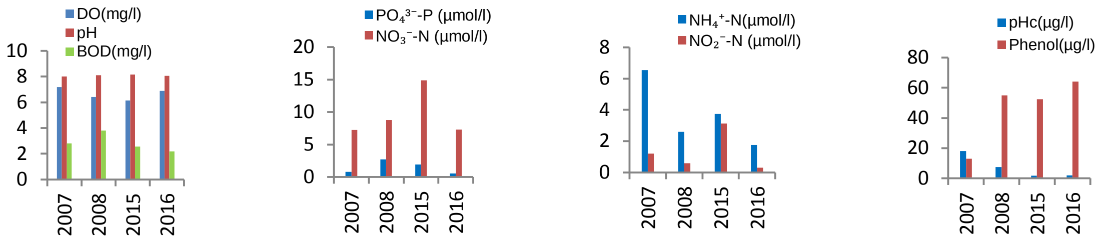


Figure 8.3.15: Status of Water quality near Worli outfall.

As evident from above figure, there is no indication of deterioration of water quality in the vicinity of Worli outfall. To see the build-up of trace metals, if any, enrichment factor calculated for trace metals is presented in the Figure 8.3.16.

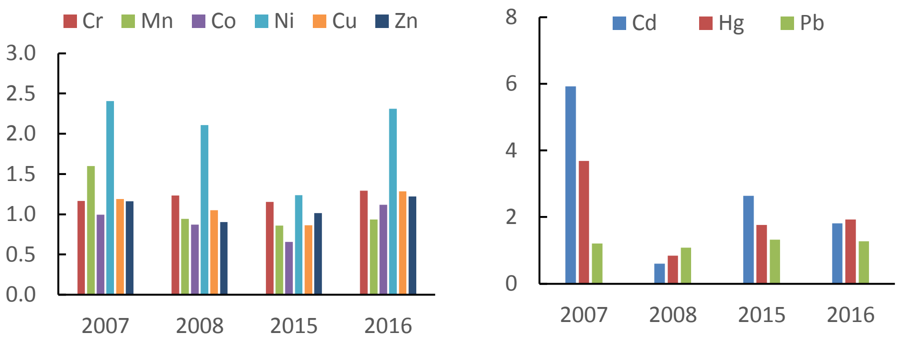


Figure 8.3.16: Enrichment factor of selected metals in sediment near Worli outfall.

Thus there is no significant enrichment of metals in the Worli outfall area during recent years.

8.3.8 Thane

Altogether the Thane Creek receives around 1260 MLD of sewage, often untreated or partially treated from towns Tank Bandar, Wadala, Ghatkopar, Bhandup and Thane on the western part of the creek, whereas the eastern part of the creek receives sewage from Koparkhairane, Nerul, Belapur, Vashi and Airoli. Apart from sewage, the creek also receives treated industrial effluents from surrounding areas (Table 3.4). Water quality monitored in the upper creek region is presented in Figure 8.3.17 below:

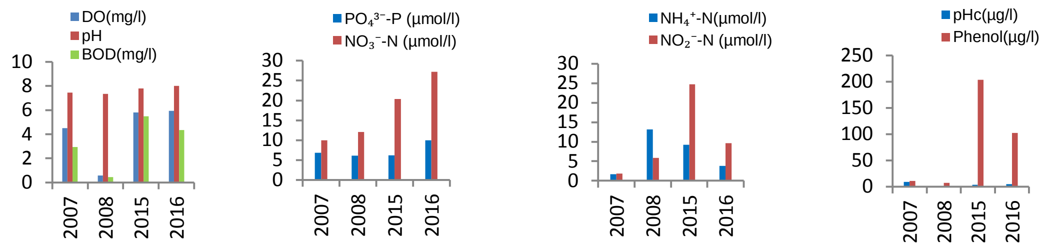


Figure 8.3.17: Status of Water quality of upper Thane Creek.

Although concentration of DO has improved in recent years, high concentration of phosphate, nitrite, ammonia and phenols indicate the impact of sewage discharged to the creek. Values of trace metals in terms of enrichment factor are presented in the Figure 8.3.18 below:

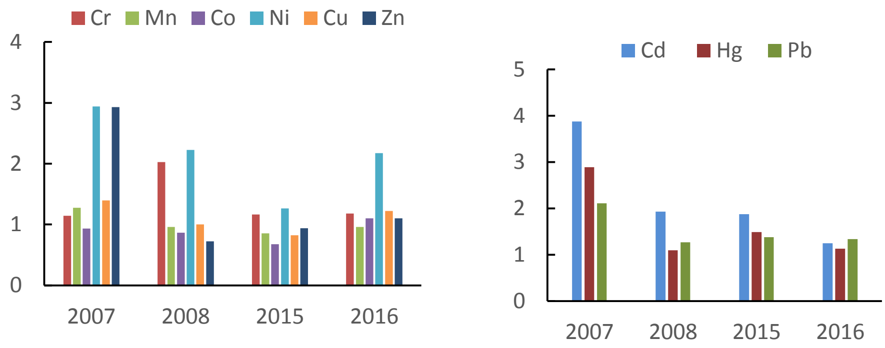


Figure 8.3.18: Enrichment factor of selected metals in sediment of upper Thane Creek.

Thus there is no significant enrichment of trace metals in the region. It is clear from the above figure that enrichment of Hg is decreasing with time. Such changes are due to scrapping of Hg-Cell based caustic soda producing industries, thus restricting the Hg laden effluent discharge to the creek.

8.3.9 Roha

Roha area is an industrial belt of MIDC. The effluents from these industries amounting to 14000 m^3/d after minimal treatment is collected in storage sumps and subsequently pumped into the Kundalika Estuary through a point discharge about 7 km downstream of the industrial estate. Apart from industrial waste, the estuary receives around 1.4 MLD of domestic wastes. Water quality recorded in Kundalika Estuary near Roha town is presented in figure 8.3.19 below:

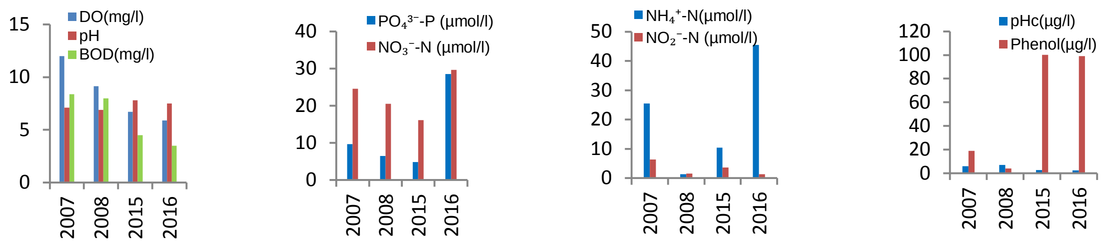


Figure 8.3.19: Status of Water quality of Kundalika Estuary near Roha town.

Although BOD values have decreased in recent years with normal DO values, high concentration of phosphate ammonia and phenols indicate the contamination of the area with respect to organic wastes. Enrichment factor calculated for selected trace metals in the sediment of the area is presented in the Figure 8.3.20 below.

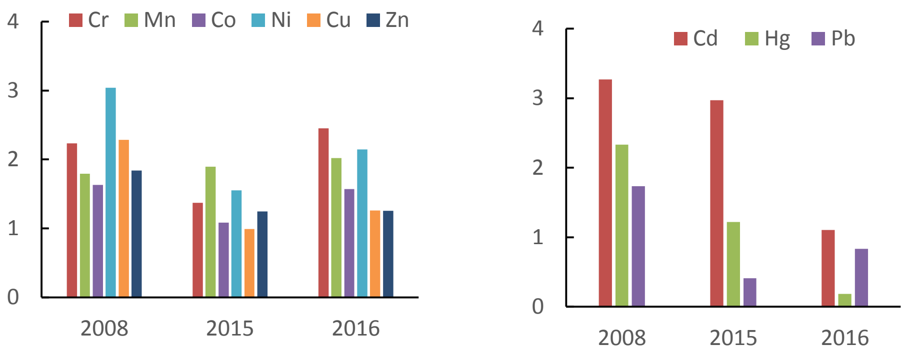


Figure 8.3.20: Enrichment factor of selected metals in sediment of Kundalika Estuary near Roha.

Moderate enrichment Zn and Cd was observed in earlier time, but no significant enrichment was observed during recent years. However, increased enrichment of Cr during 2016 needs to be checked with repeated monitoring.

8.3.10 Mahad

The wastewater generated by the MIDC area was estimated to be under 6.0MLD, which are treated by individual industry and collected into the collection system provided by MIDC. The combined effluent is released in the Savitri River upstream of Ambet. Apart from the industrial effluent, the river receives 7.5 MLD of domestic sewage. The water quality of the region is presented in the Figure 8.3.21 below:

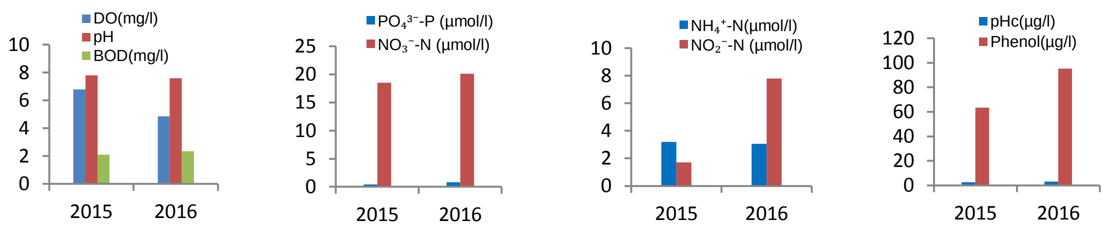


Figure 8.3.21: Status of Water quality of Savitri Estuary near Mahad.

Increased concentration of nitrite, ammonia and phenol indicate the contamination of the area with sewage. Sediment quality in terms of enrichment factor is presented in the Figure 8.3.22 below:

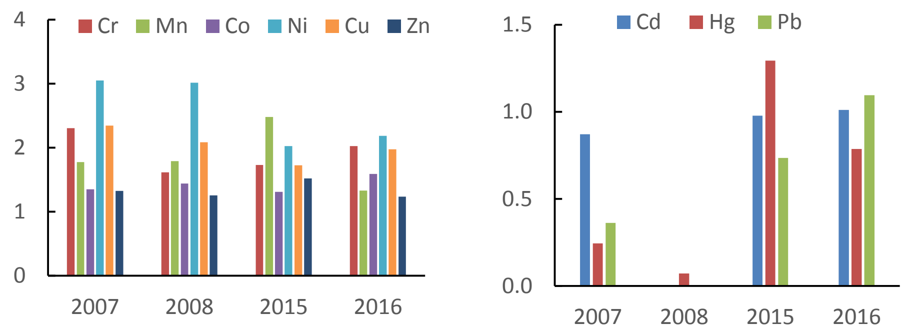


Figure 8.3.22: Enrichment factor of selected metals in sediment of Savitri Estuary near Mahad.

Moderate enrichment of Ni, which was seen in 2007-08 results was lower during 2015-16. There was no significant enrichment of other elements, indicating the lithogenic characteristic of the trace metals.

8.3.11 Ratnagiri

Ratnagiri Port and fishery harbour is located inside the Mirya Bay. Though, any industrial effluents are not received at this coastal system, untreated sewage from the Ratnagiri town enters the bay. The quantam of waste released to this system is not known. The water quality of the bay is presented in the Figure 8.3.23 below:

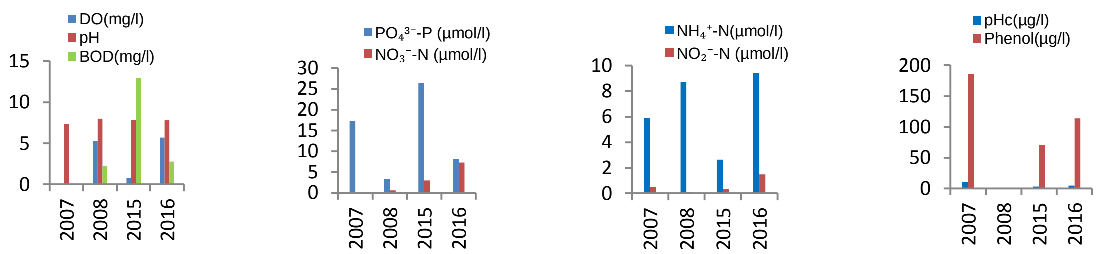


Figure 8.3.23: Status of Water quality of Mirya Bay near Ratnagiri town.

As it is evident from the above figure, an increase in the phosphate, nitrate and ammonia indicates organic load in the bay. Sediment enrichment is presented in the Figure 8.3.24 below:

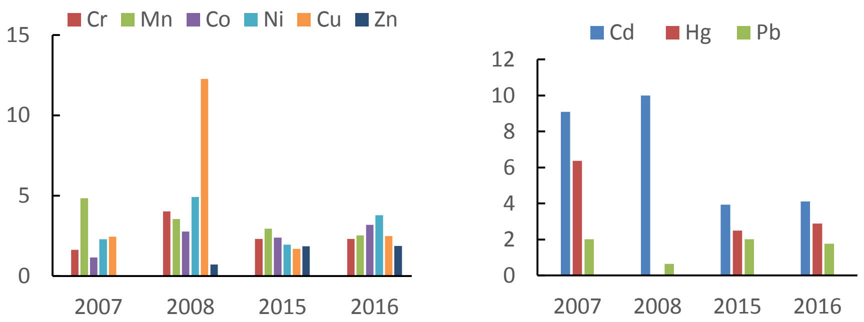


Figure 8.3.24: Enrichment factor of selected metals in sediment of Mirya Bay Ratnagiri town.

Thus the enrichment of Cu, Cd and Hg, which was significant during 2007-08 has decrease in recent year indicating that the burden of these element has decreased in recent years.

8.3.12 Malvan

No known industrial or domestic point release exists in the coastal waters of Malvan though few non-point discharges of domestic waste waters (about 1 MLD) enter the bay. The port operates as the fish landing centre and a passenger jetty for the tourists. The water quality recorded in the Malvan Bay/Port area is presented in the Figure 8.3.25.

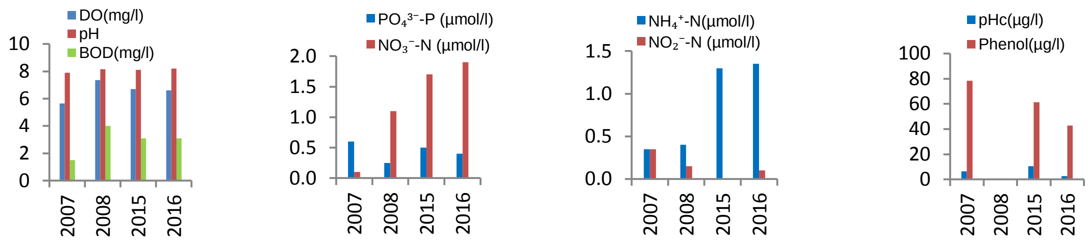


Figure 8.3.25. Status of Water quality in Malvan Port area.

Thus the water of Malvan Port area represents healthy water quality, but increase of nitrate and ammonia in recent years indicate enhancement of nutrient due to increase in organic load. Enrichment of some of the trace elements is presented in the Figure 8.2.26 below:

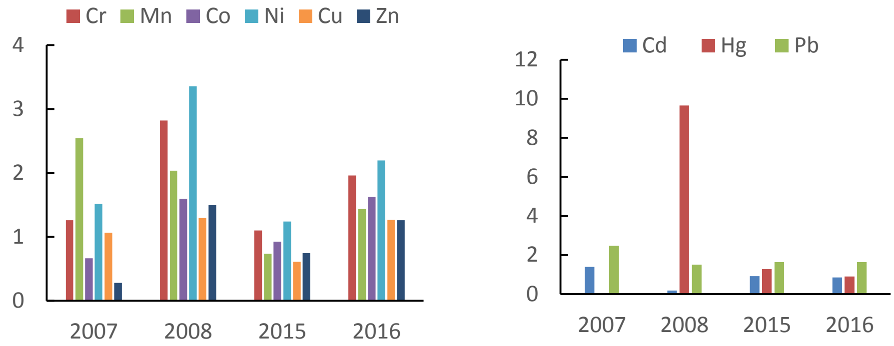


Figure 8.3.26: Enrichment factor of selected metals in sediment of Malvan Port area.

Above figure indicates that there is no significant enrichment of metals in the sediment of Malvan Bay.

8.4 Deteriorated areas and measures to be taken by MPCB and other departments

A thorough analysis of the results of monitoring conducted during November 2015 to May 2016 and their comparison with the past monitoring results at the same transects the pollution hot-spots have been identified and corrective actions aimed at improving the prevailing ecology of the affected marine zone are recommended. These are discussed below:

Dahanu: Increase in NH_4^+-N over the years especially in the creek system suggests enhancement in the input of organic wastes. Increase in temperature in the creek was also evident which can be due to the discharge of warm return water from the thermal power plant.

The organic waste released to the creek needs to be quantified and treated to the required norms. Periodic monitoring of the creek segment especially water quality with particular reference to the temperature of the effluent from the thermal power plant is necessary and follow-up action taken accordingly.

Tarapur: Environmental condition off Tarapur continued to be deteriorated probably due to enhancement in anthropogenic organic loading through effluents leading to anoxic condition in the creek particularly during ebb.

It appears that the waste assimilation capacity of the creek has been exceed. It may be therefore necessary to undertake numerical modeling of the coastal area and convey the treated effluent through a submarine pipeline and released at a suitable site in the open shore waters.

Bassein: Water of Bassien Creek/Ulhas Estuary has deteriorated as compared to the 2007-08 results particularly in the Middle and Upper Creek segments and monitoring trends suggest increase in the loading of organic matter through sewage / industrial effluents. If the trend continues, there is likelihood of inner estuary going anoxic over the dry season causing mortalities of organisms.

Hence, there is urgent need to reverse the trend through urgent measures taken by municipalities and MIDC by strict compliance to MPCB norms for wastewater and release it through subsurface pipelines at locations identified after detailed studies of the assimilation capacity of the estuary.

Manori: The 2007-16 monitoring results point to considerable deterioration in the ecological quality of the Manori Creek due to the release of domestic wastewater. Evidently, urgent measures to ensure the effluents comply with the MPCB norms before release are required. It will be also necessary to assess the waste assimilative capacity of the creek and findings used to release the treated wastewater at scientifically identified outfall either within the creek or the open-shore area.

Versova: Considering the volume of seawater available in the creek even during high tide and the quantity of sewage released, it is unlikely that the creek water quality would improve even if the effluents released in the creek meet MPCB norms. It may therefore be inevitable to release these effluents through a submarine pipeline to the coastal water at scientifically identified outfall.

Mahim: High concentrations of nutrients continue to persist in the creek and are associated with the disposal of effluents in the creek. Mithi River flowing through industrial and urban zones receives sewage and untreated effluent mainly from non-point sources transporting these loads to the creek and the bay.

To improve the environmental quality, all sources of effluents may be identified and adequate treatment provided before its disposal. It may even be necessary to convey the treated effluents through a pipeline and release it at a scientifically identified site off the mouth of Mahim creek / bay after detailed investigations aimed at assessing the waste assimilation capacity of the system.

Bandra and Worli: The coastal system represents low environmental stress sustaining better marine ecosystem as compared to the creeks around Mumbai. However, the water quality (bacteria, DO, BOD and nutrients) and sediment quality (bacteria, Cr, Cd, Hg and Pb) needs to be monitored.

Thane Creek/Mumbai Harbour: Though several measures have been taken in past to curtail the load of pollutants entering in the Thane Creek, the water quality of the creek has not improved sufficiently. The major contributor is sewage. Hence, proper action is required to collect, treat and dispose the sewage to the aquatic system after proper study of assimilation capacity of the receiving water body.

Patalganga Estuary: To improve the water quality, apart from treatment to the effluent to meet desired norms, it is necessary to assess the assimilative capacity of the estuary and limit the organic load within the assimilative capacity. The effluent release location needs also to be identified after proper studies and adequate treatment to effluents needs to be ascertained.

Amba Estuary: The ecological quality of the estuary did not reveal deterioration over the years within the natural variability inherent to coastal waters. However, in view of several developments planned along the banks including port facilities, regular monitoring of the estuary needs to be undertaken, to enable corrective measures if necessary.

Thal: The water quality and sediment quality in the vicinity of the DP had not changed over the years (off Thal). However, periodic monitoring off Thal needs to be undertaken to identify changes in ecological quality if any to enable corrective action**.**

Kundalika Estuary: Monitoring results indicate that though the industrial discharge was through a diffuser, there is no substantial change in the water quality of the estuary.

It is therefore necessary to ascertain proper treatment to the industrial effluent prior to release and other sewage releases in the inner estuary are quantified and treated adequately.

Savitri Estuary: Effluent collected and analyzed from Mahad CETP meets the MPCB/CPCB criteria. However, the quality of the Savitri Estuary has not improved adequately. It is possible that there are non-point discharges of sewage and industrial effluents. These need to be identified and treated before release. Other possibility is that the load entering the estuary from the CEPT is in excess of the assimilative capacity of the upper estuary. This can be resolved through proper numerical modeling of the estuary with respect to load being released.

Vashishti Estuary: The industrial effluent from MIDC Lote-Parshuram discharged at the confluence of the Jagbudi and Vaishisti rivers continue to cause stress on ecology of the upper estuary. The effluent from the CETP did not meet MPCB/CPCB norms. This needs immediate corrective measures. It is also suggested that the assimilative capacity of the estuary is studied through proper numerical modeling and suitability of the present effluent release location or otherwise is ascertained.

Jaigad/Shastri Estuary: The estuary sustains good ecological environment though some minor influence of the fishing activities and fringing mangroves was evident. However, estuary may be periodically monitored due to increasing human activities along the estuary.

Ratnagiri: The inner zone of the Mirya Bay has very poor flushing leading to accumulation of organic matter released through town sewage and organic discards generated in fish landing activities.

In order to improve the ecological environment of the bay discharge of sewage and other waste needs to be stopped. The treated sewage may be released through a sub-surface pipeline at a scientifically identified location that permits sufficient dilution of effluents. Discarding of unwanted fishes in the harbor/bay needs to be stopped by providing waste collection bins at the landing centre and the collected waste is appropriately disposed.

Deogad and Achara: These coastal systems indicate natural coastal ecosystem of south Maharashta coast. However, minor influence of sewage releases is possible.

These areas may be periodically monitored for their ecological status to ascertain their healthy environment.

Malvan: The coastal waters off Malvan reveal clean and healthy conditions. However, the inner bay shows minor deterioration due to sewage disposal and release of organic wastes from fishing boats at the port.

To prevent further deterioration of the bay, the sewage releases may be identified and treated in septic tank – soak pit. Discarding of unwanted fish in the bay needs to be stopped by providing waste collection bins at the landing centre and the collected waste is appropriately disposed.

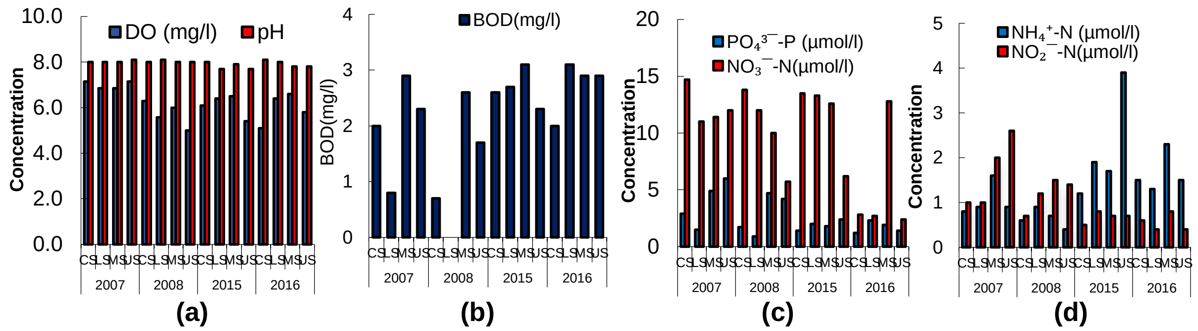


Figure 8.2.1: Comparison of water quality of Dahanu Creek measured during 2007-08 and 2015-16.

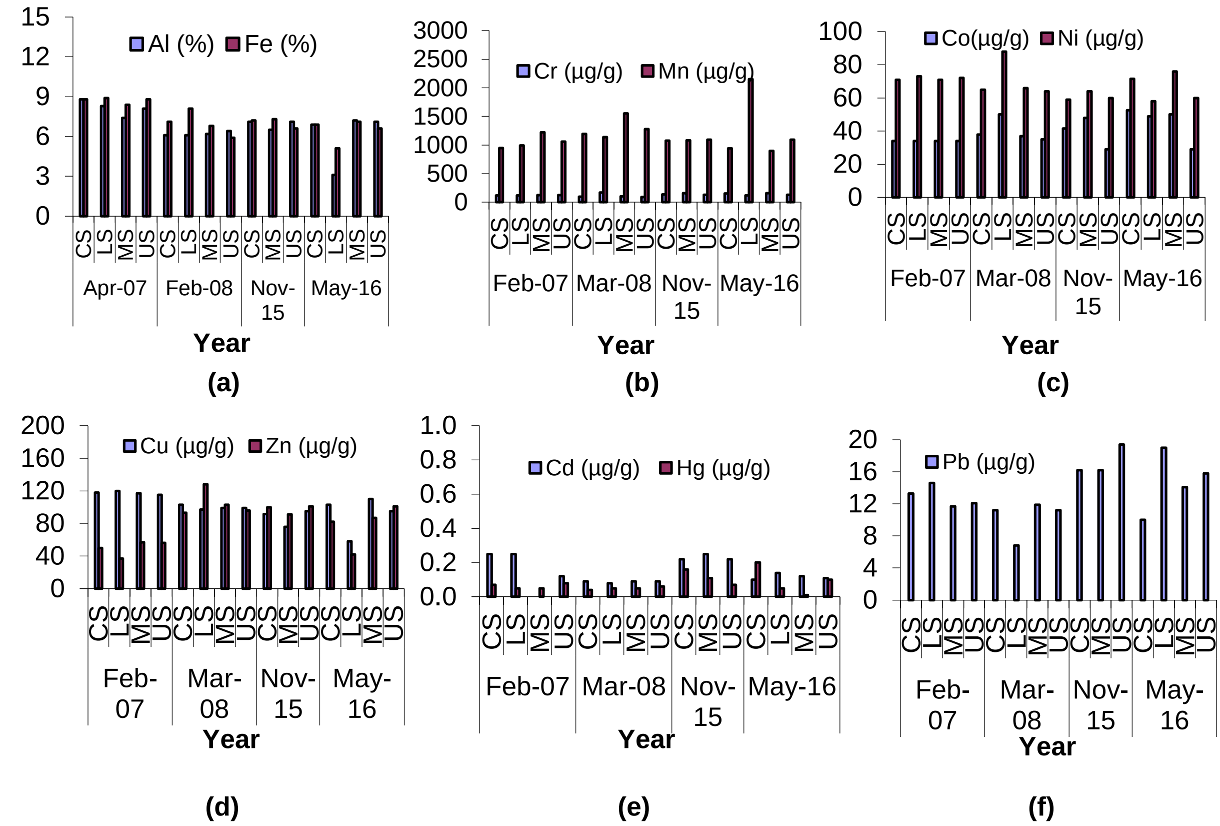


Figure 8.2.2: Comparison of sediment quality quality of Dahanu Creek measured during 2007-08 and 2015-16.

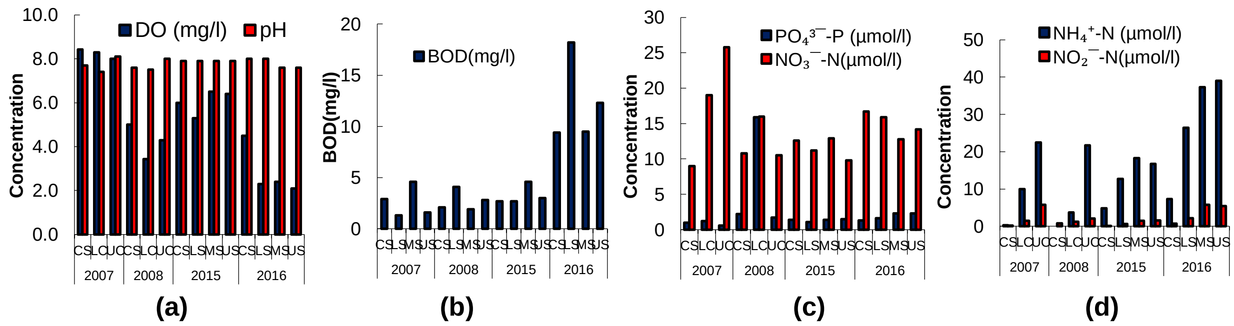


Figure 8.2.3: Comparison of water quality of Tarapur Creek measured during 2007-08 and 2015-16.

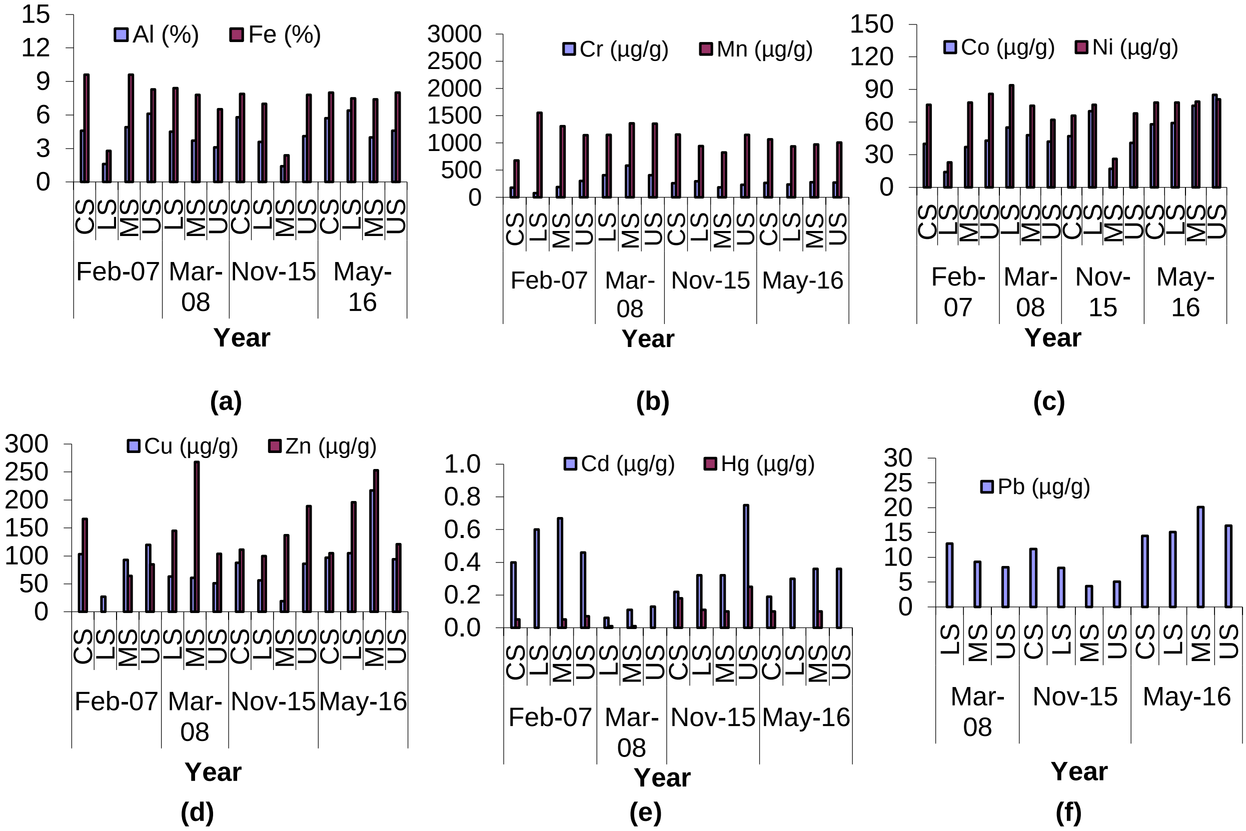


Figure 8.2.4: Comparison of sediment quality of Tarapur Creek measured during 2007-08 and 2015-16.

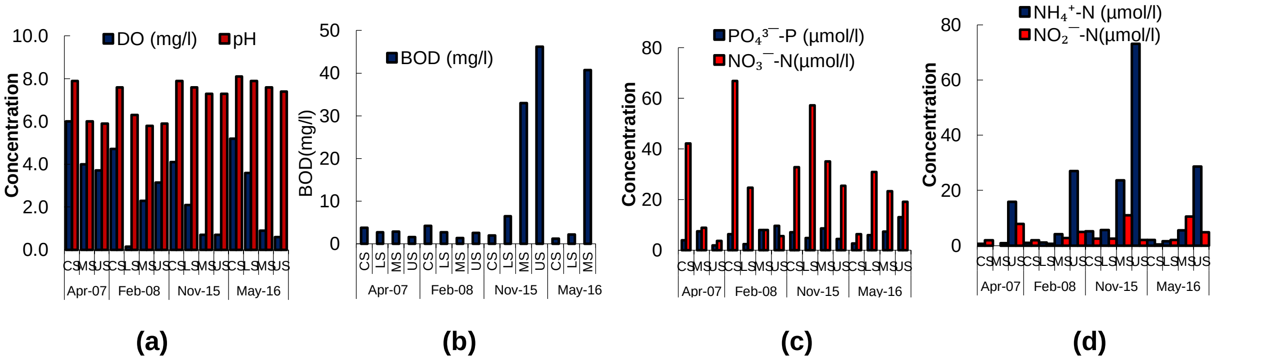
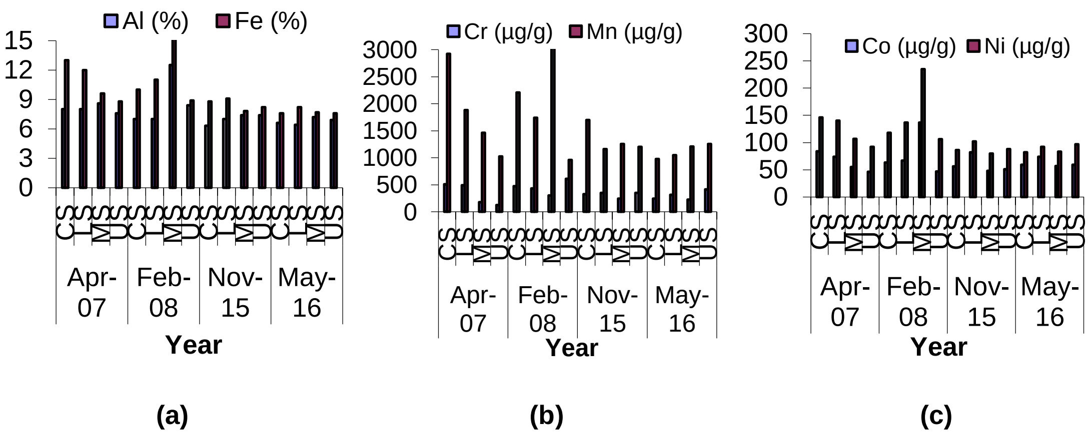


Figure 8.2.5: Comparison of water quality of Bassein/Ulhas Estuary measured during 2007-08 and 2015-16.



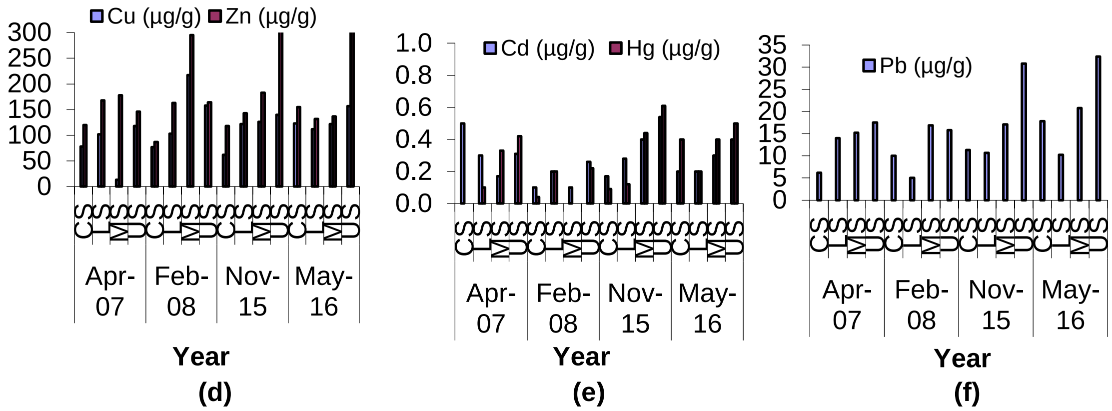


Figure 8.2.6: Comparison of sediment quality of Bassein/Ulhas Estuary measured during 2007-08 and 2015-16.

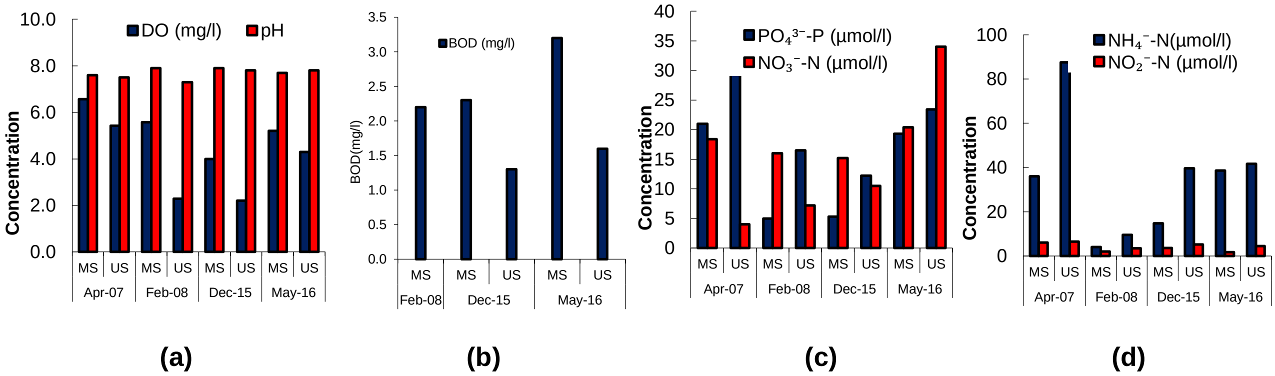


Figure 8.2.7: Comparison of water quality of Manori Creek measured during 2007-08 and 2015-16.

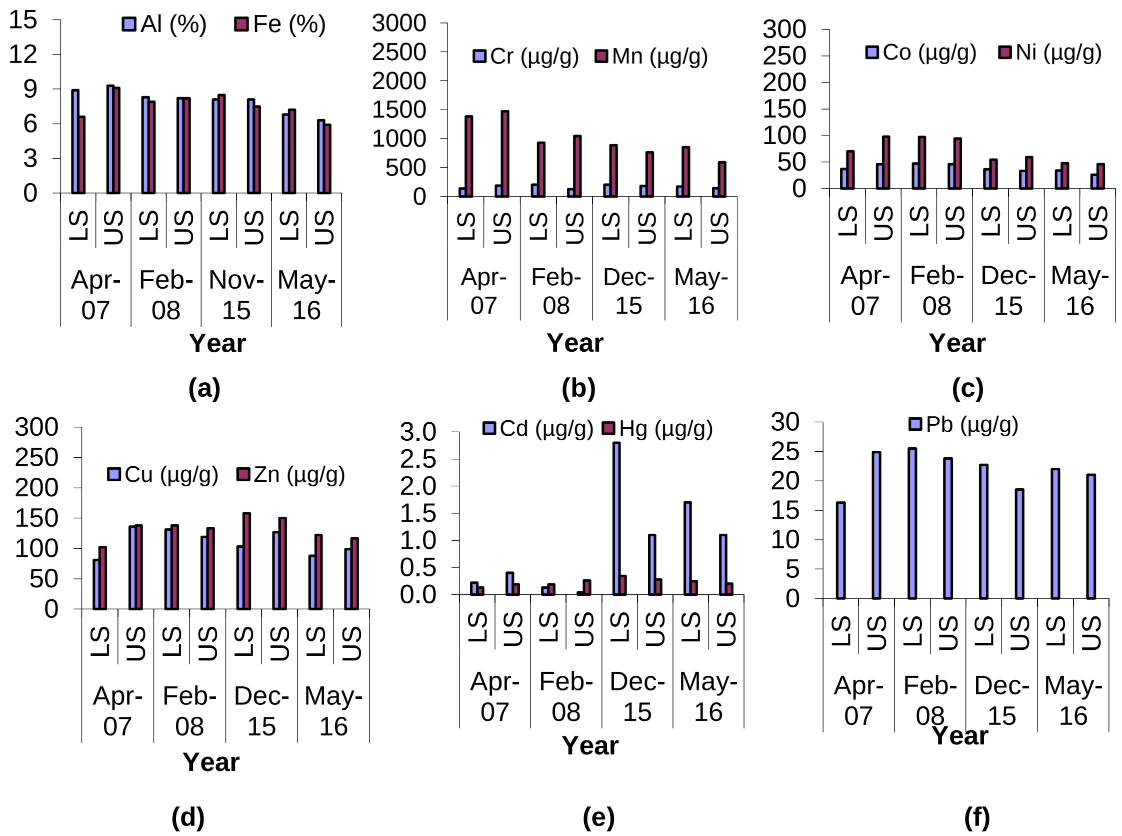
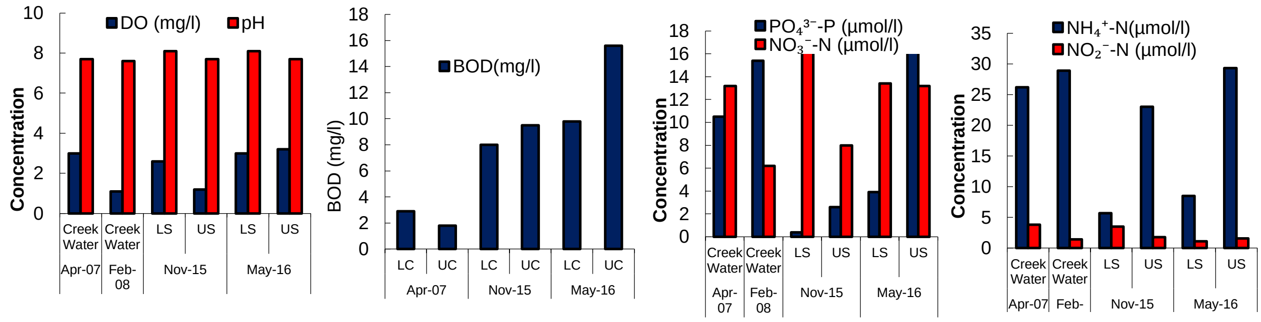
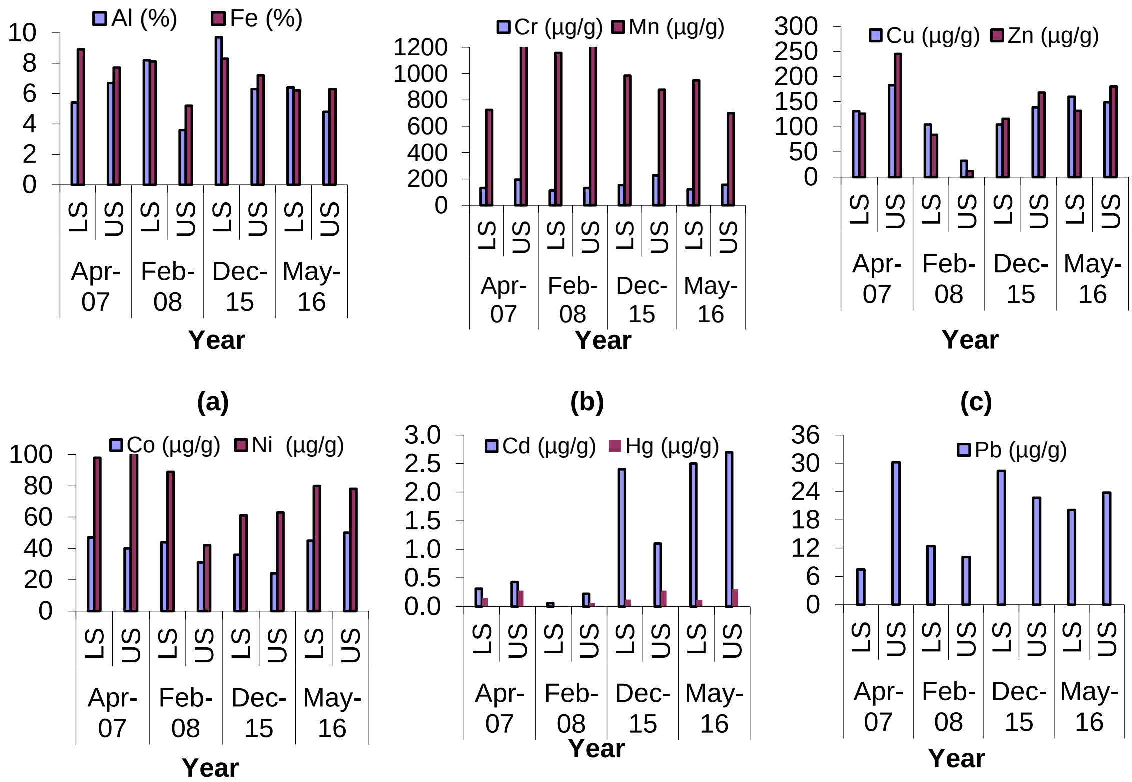


Figure 8.2.8: Comparison of sediment quality of Manori Creek measured during 2007-08 and 2015-16.



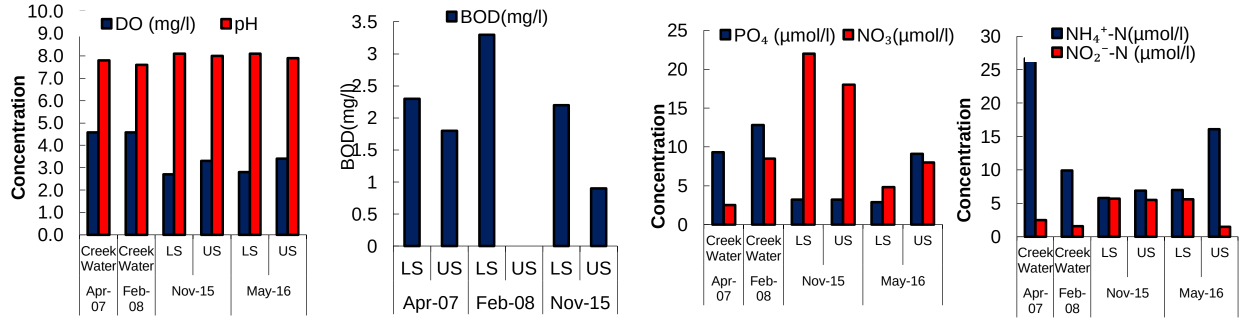
(a) (b) (c) (d)

Figure 8.2.9: Comparison of water quality of Versova Creek measured during 2007-08 and 2015-16.



(d) (e) (f)

Figure 8.2.10: Comparison of sediment quality of Versova Creek measured during 2007-08 and 2015-16.



(a) (b) (c) (d)

Figure 8.2.11: Comparison of water quality of Mahim Creek measured during 2007-08 and 2015-16.

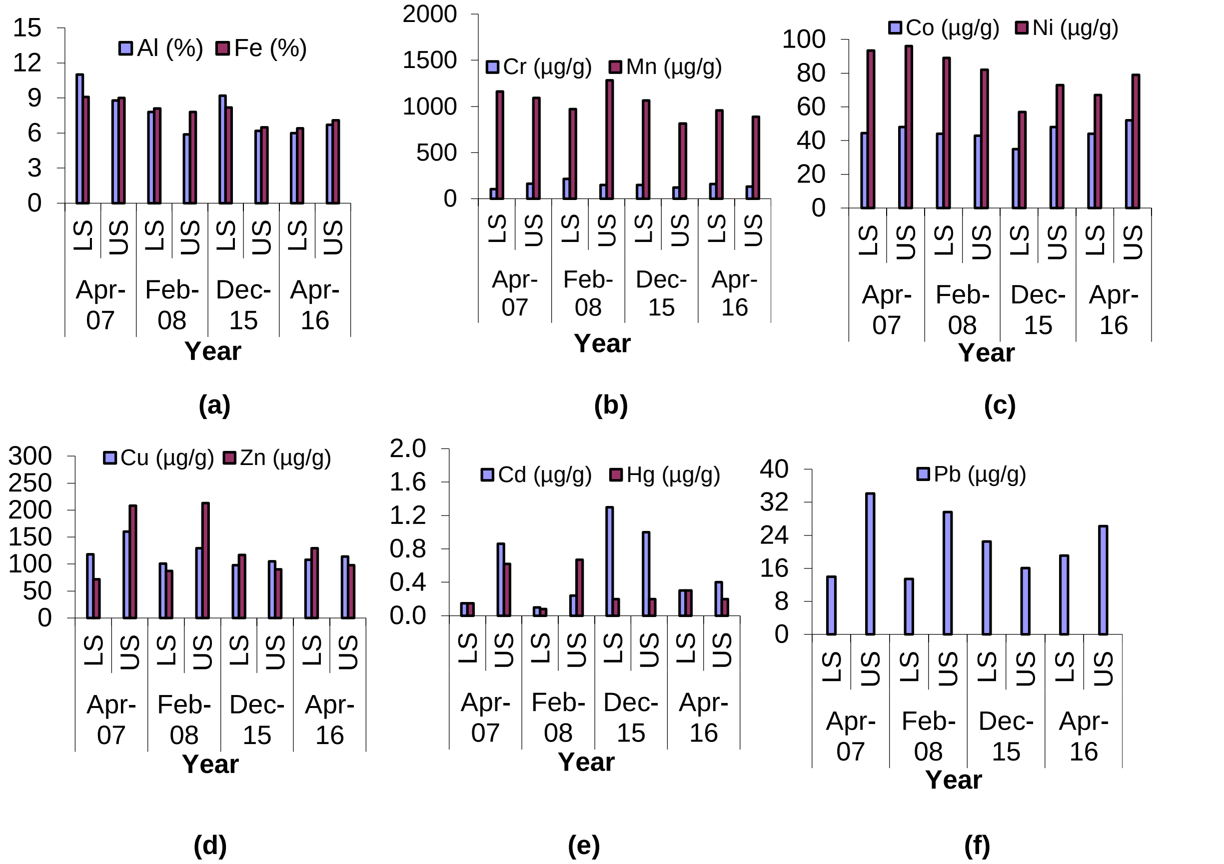


Figure 8.2.12: Comparison of sediment quality of Mahim Creek measured during 2007-08 and 2015-16.

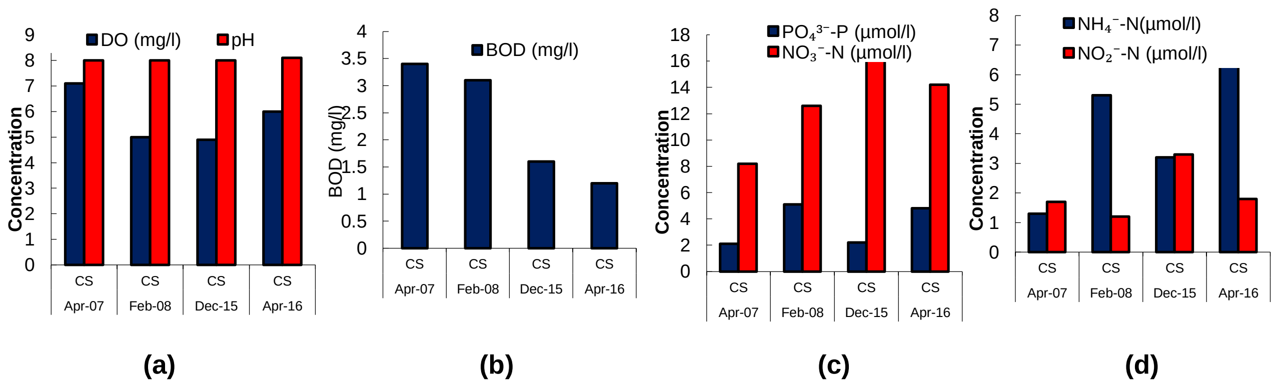


Figure 8.2.13: Comparison of water quality of Bandra measured during 2007-08 and 2015-16.

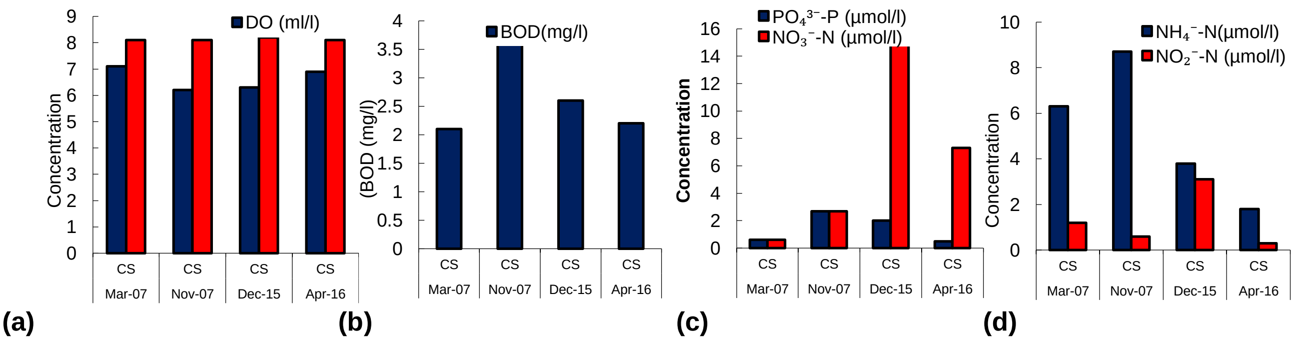


Figure 8.2.14: Comparison of water quality of Worli measured during 2007-08 to 2015-16.

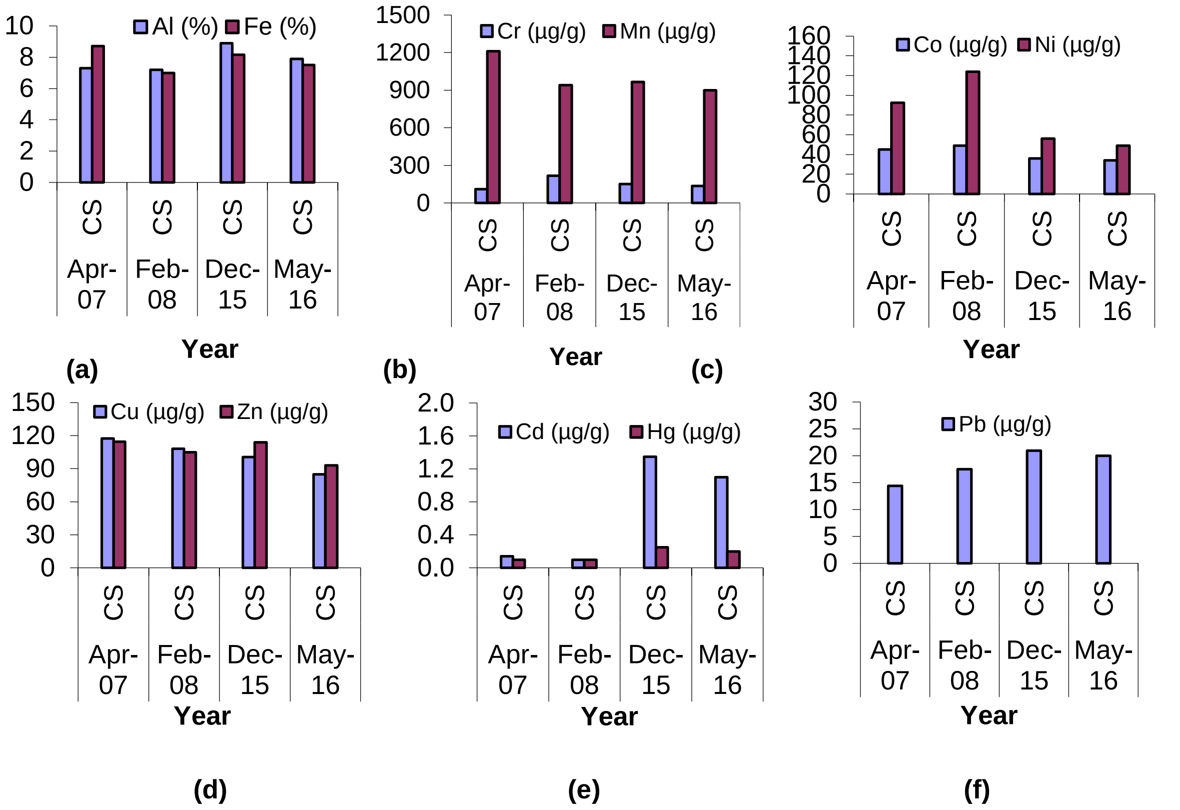


Figure 8.2.15: Comparison of sediment quality of Bandra measured during 2007-08 and 2015-16.

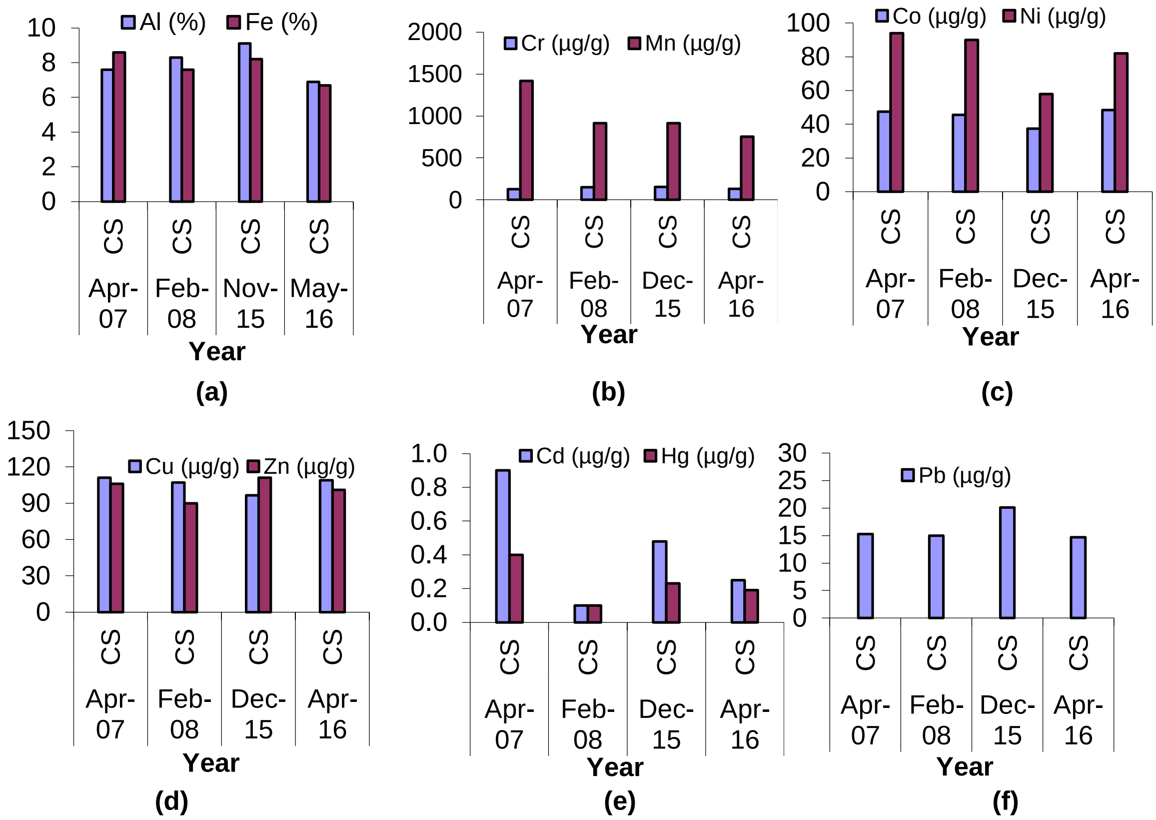


Figure 8.2.16: Comparison of sediment quality of Worli measured during 2007-08 and 2015-16.

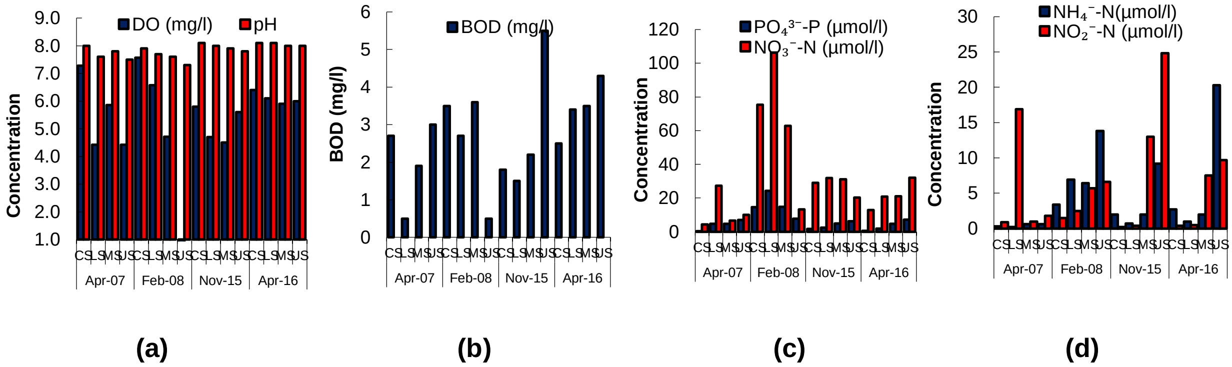


Figure 8.2.17: Comparison of water quality of Thane creek measured during 2007-08 and 2015-16.

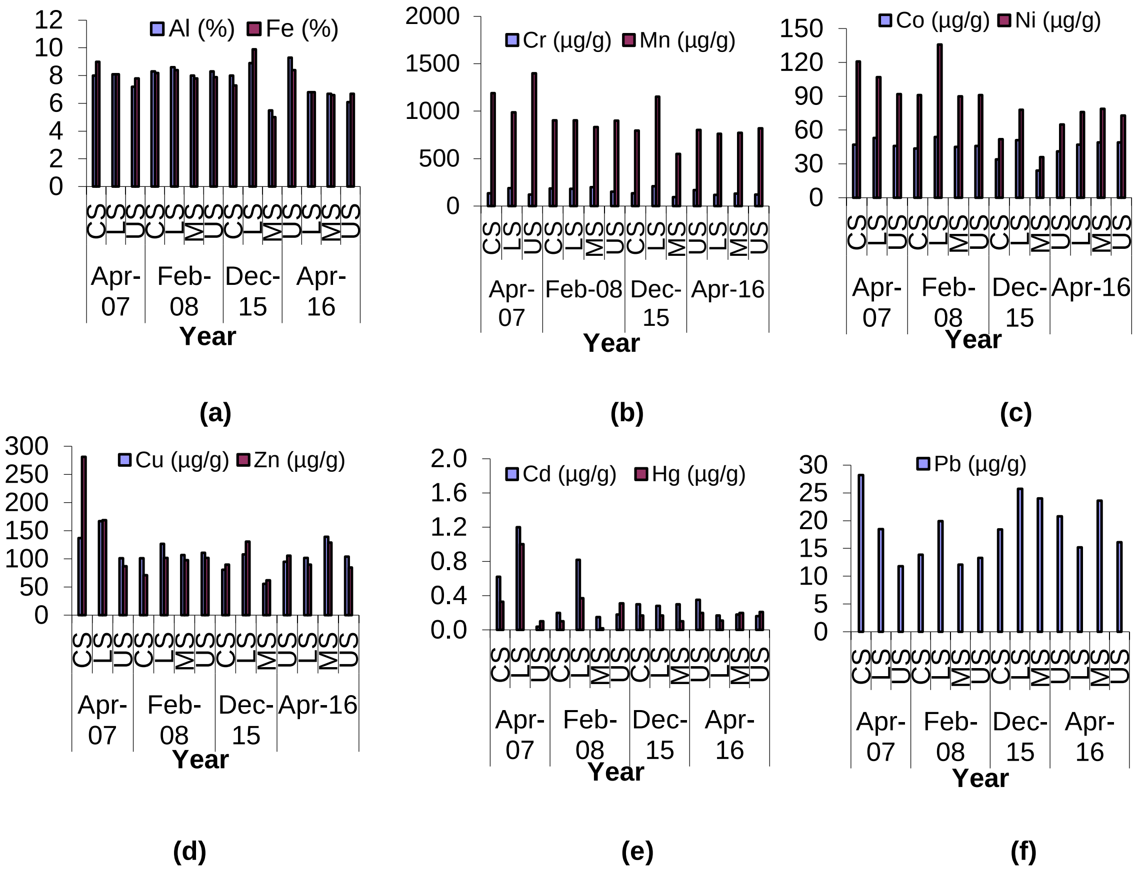


Figure 8.2.18: Comparison of sediment quality of Thane creek measured during 2007-08 and 2015-16.

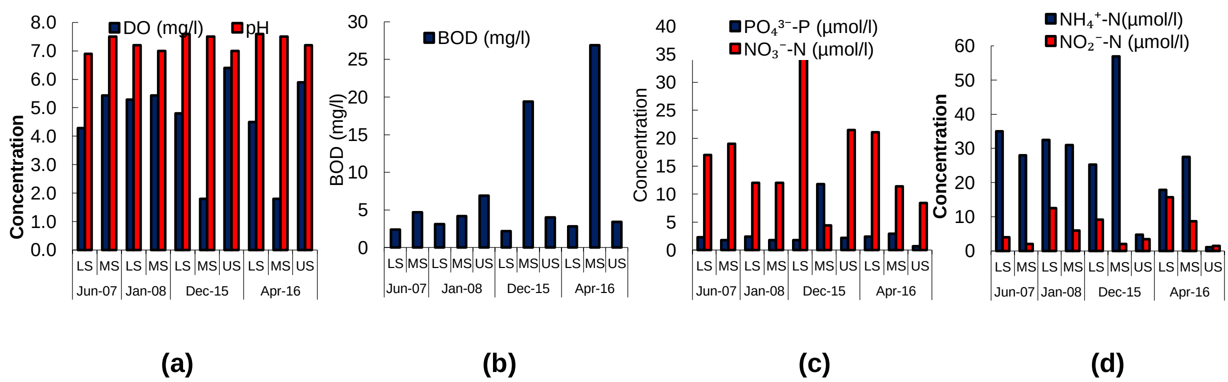


Figure 8.2.19: Comparison of water quality of Patalganga Estuary measured during 2007-08 and 2015-16.

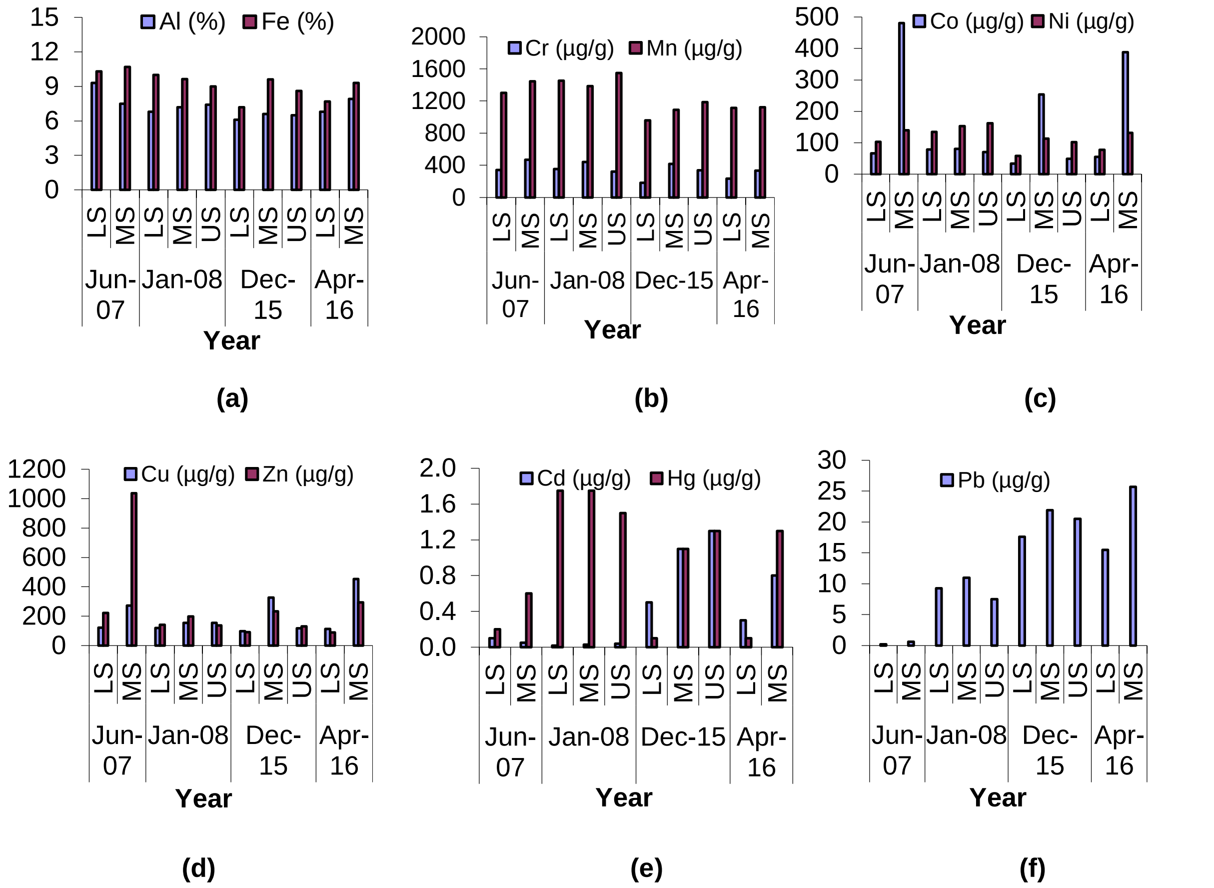


Figure 8.2.20: Comparison of sediment quality of Patalganga Estuary measured during 2007-08 and 2015-16.

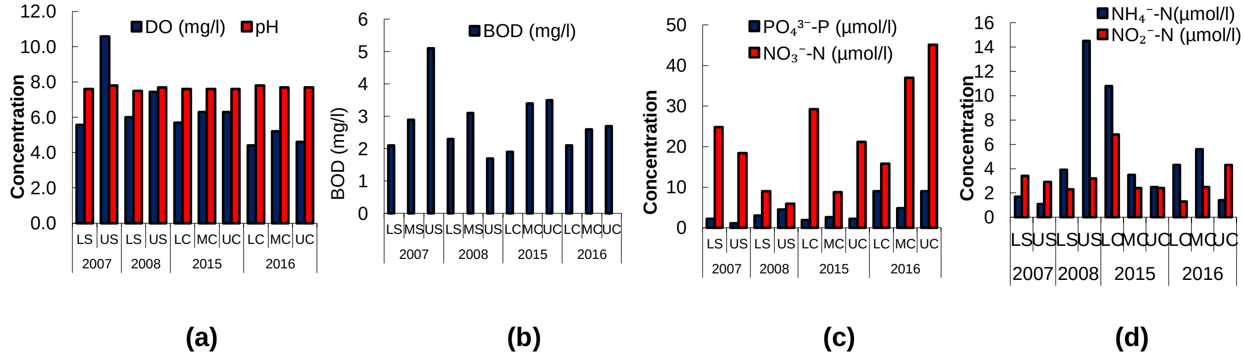
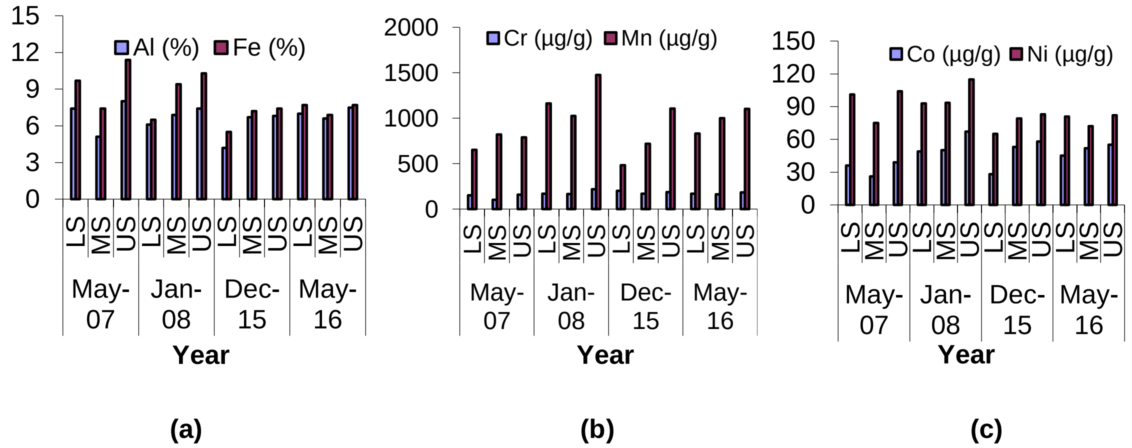


Figure 8.2.21: Comparison of water quality of Amba Estuary measured during 2007-08 and 2015-16.



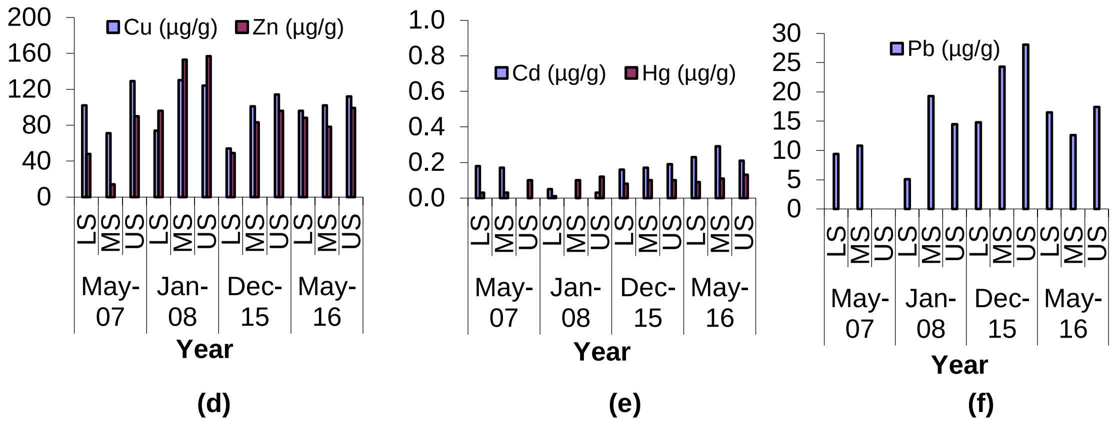


Figure 8.2.22: Comparison of sediment quality of Amba Estuary measured during 2007-08 and 2015-16.

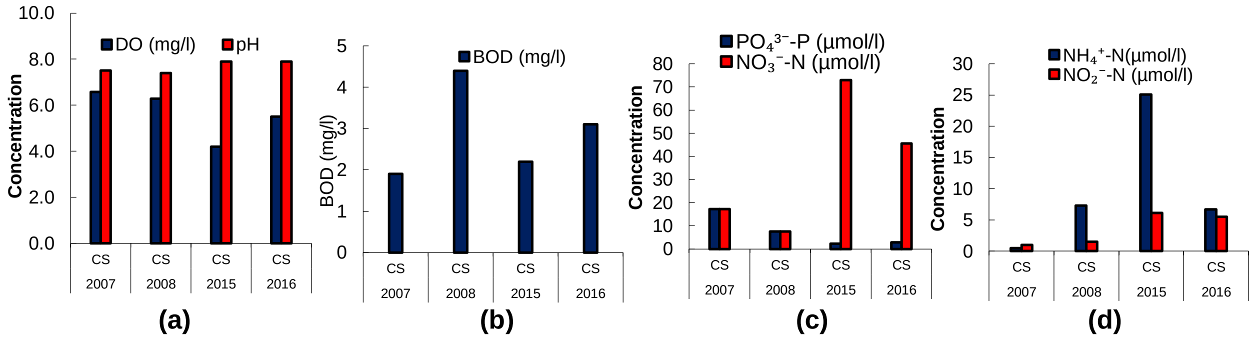


Figure 8.2.23: Comparison of water quality of Thal DP measured during 2007-08 and 2015-16 .

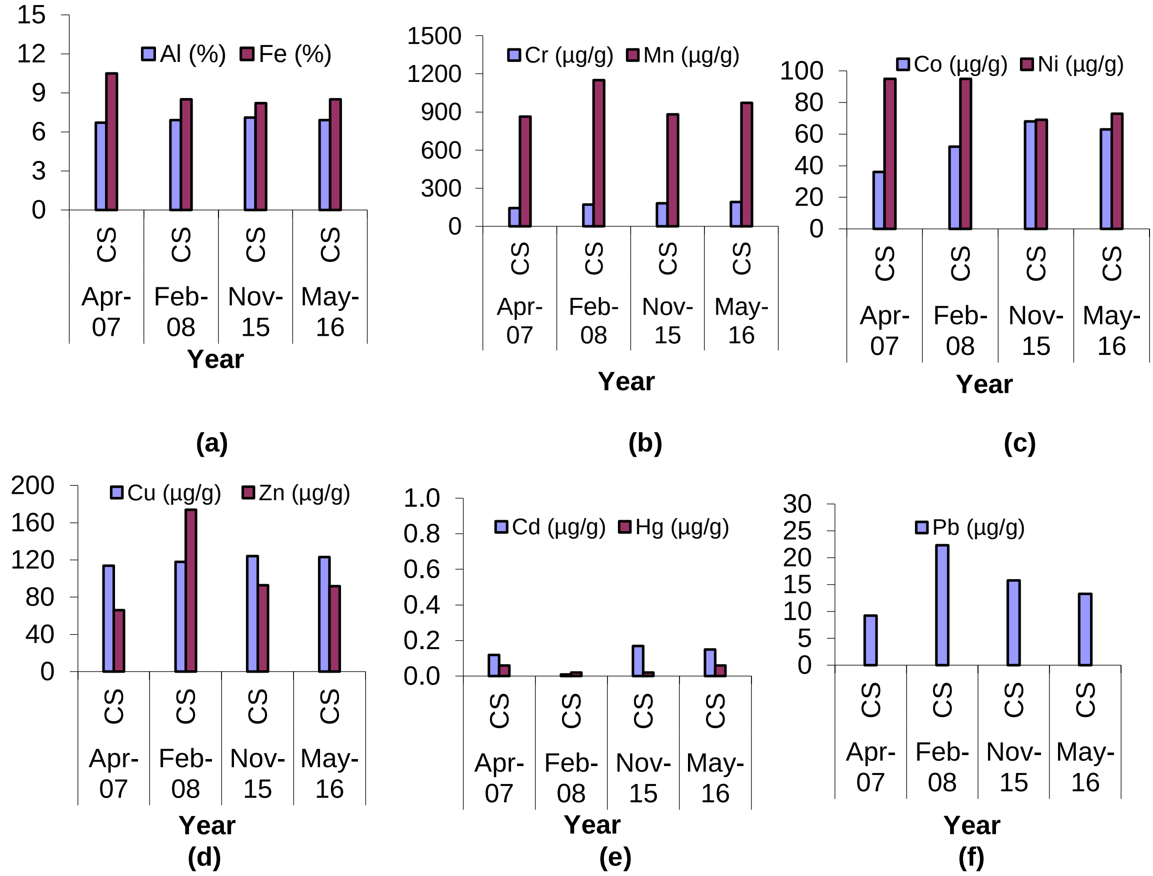
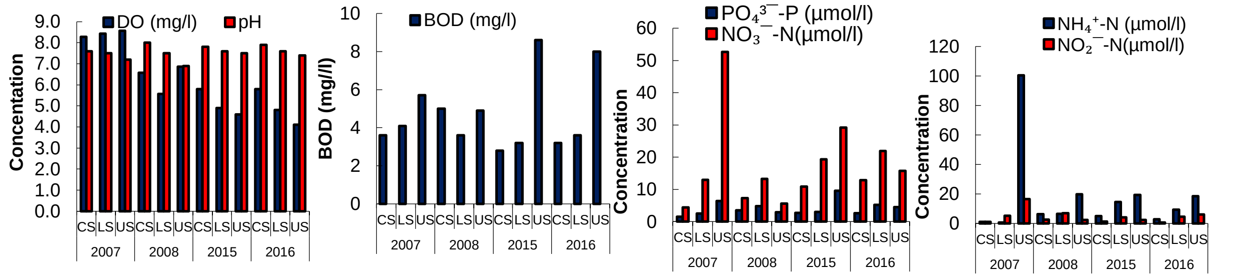


Figure 8.2.24: Comparison of sediment quality of Thal DP measured during 2007-08 and 2015-16.



(a) (b) (c) (d)

Figure 8.2.25: Comparison of water quality of Kundalika Estuary measured during 2007-08 and 2015-16.

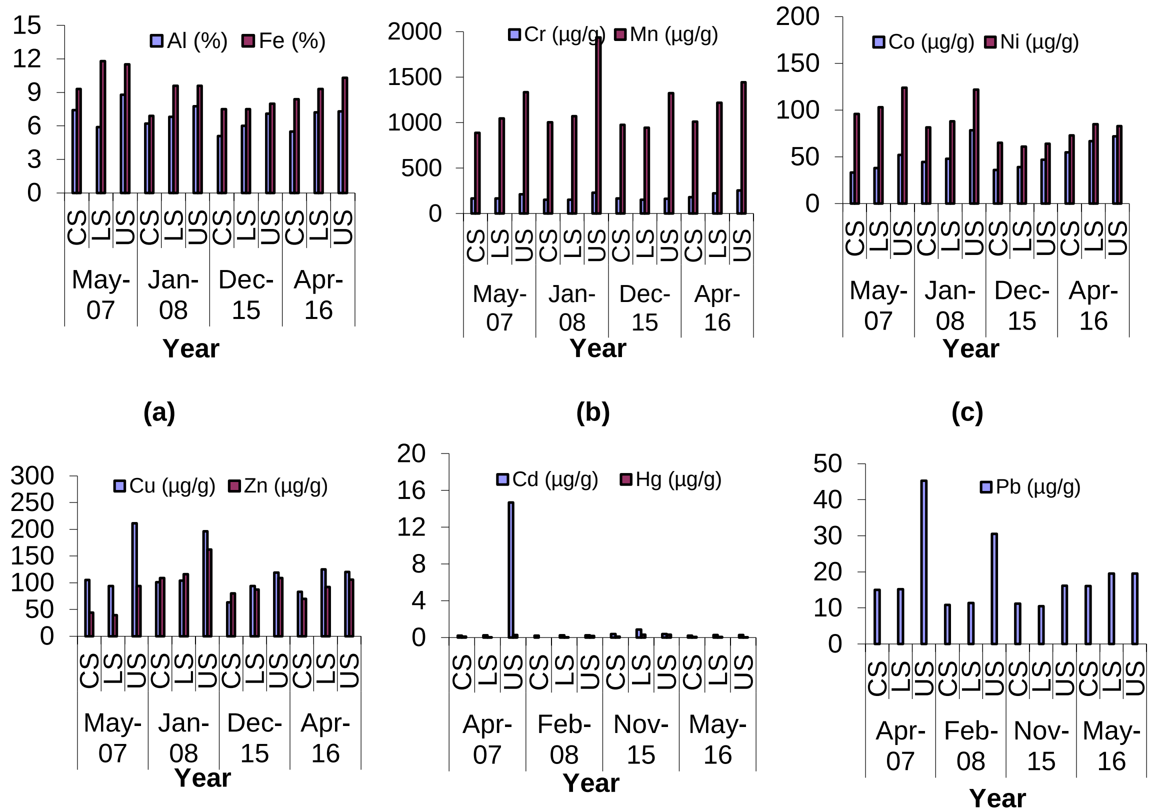
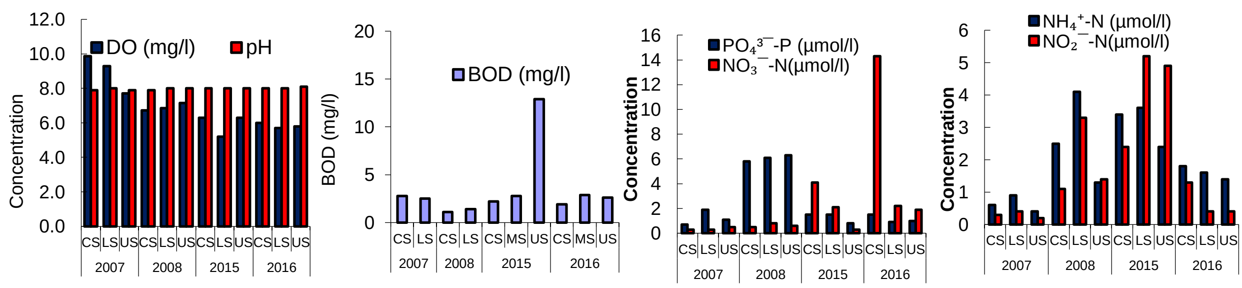
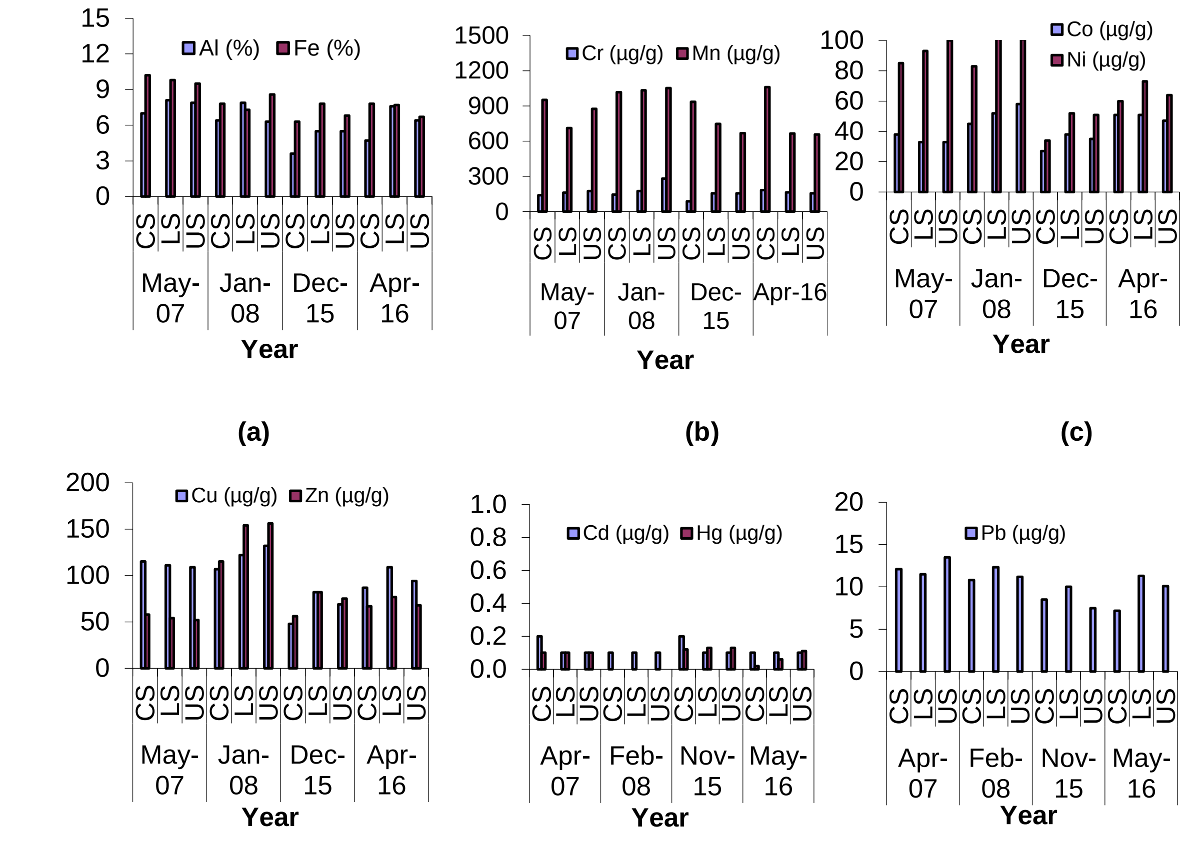


Figure 8.2.26: Comparison of sediment quality of Kundalika Estuary measured during 2007-08 and 2015-16.



(a) (b) (c) (d)

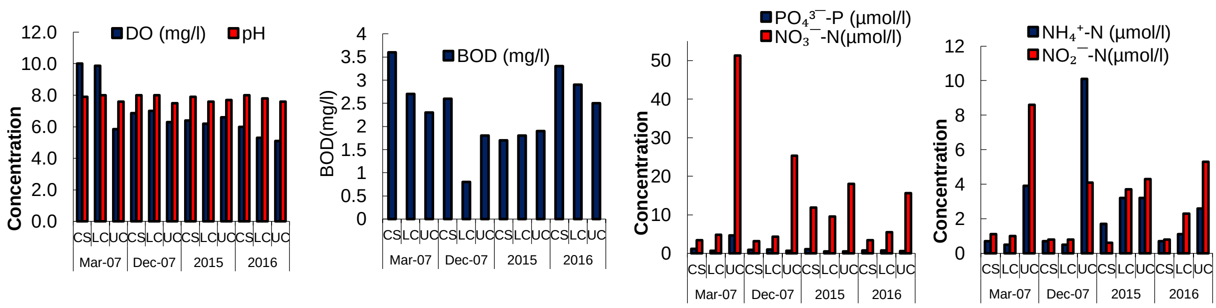
Figure 8.2.27: Comparison of water quality of Murud Creek measured during 2007-08 and 2015-16.



(a) (b) (c)

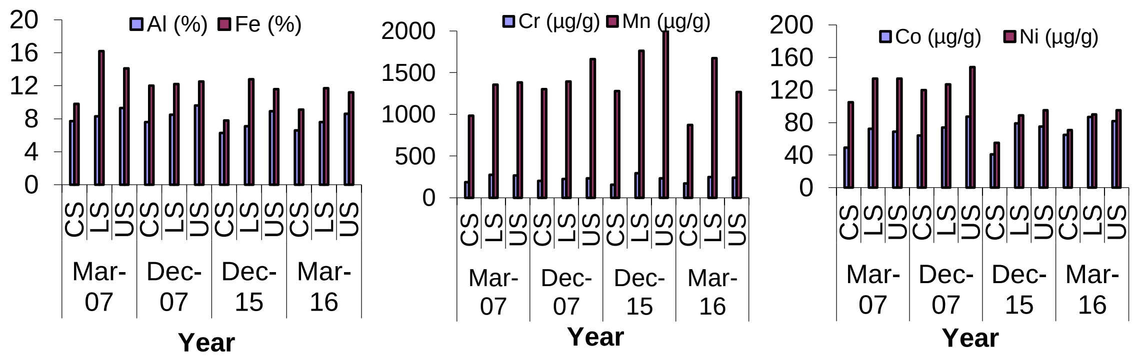
(d) (e) (f)

Figure 8.2.28: Comparison of sediment quality of Murud Creek measured during 2007-08 and 2015-16.



(a) (b) (c) (d)

Figure 8.2.29: Comparison of water quality of Savitri Estuary measured during 2007-08 and 2015-16.



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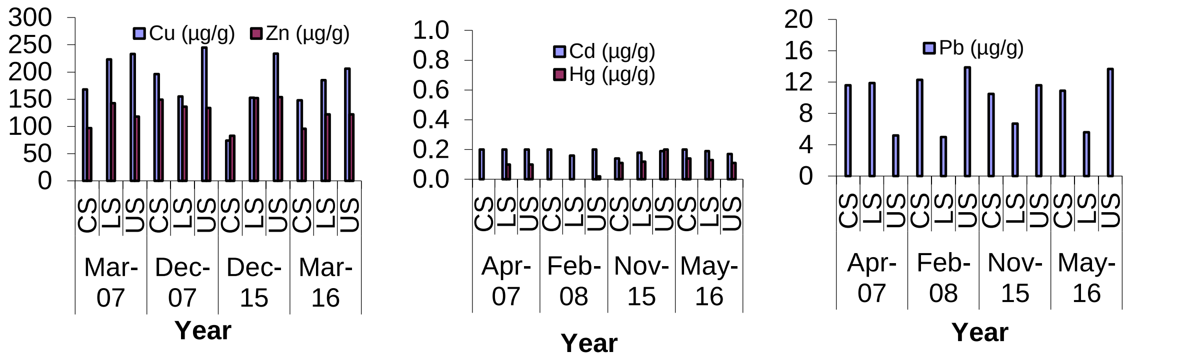
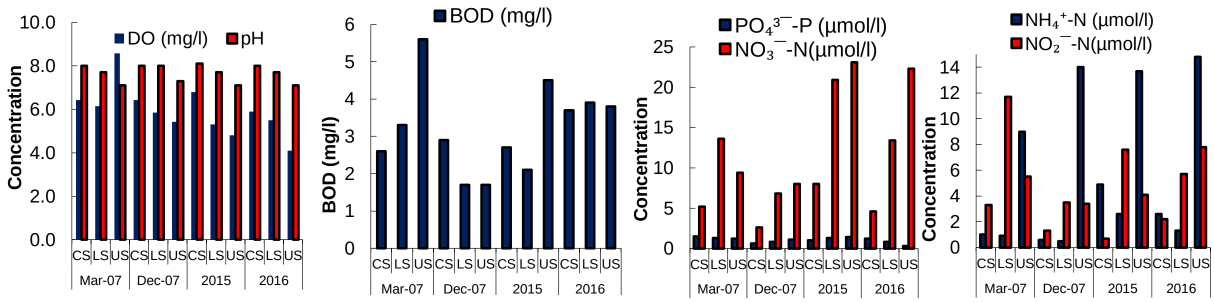


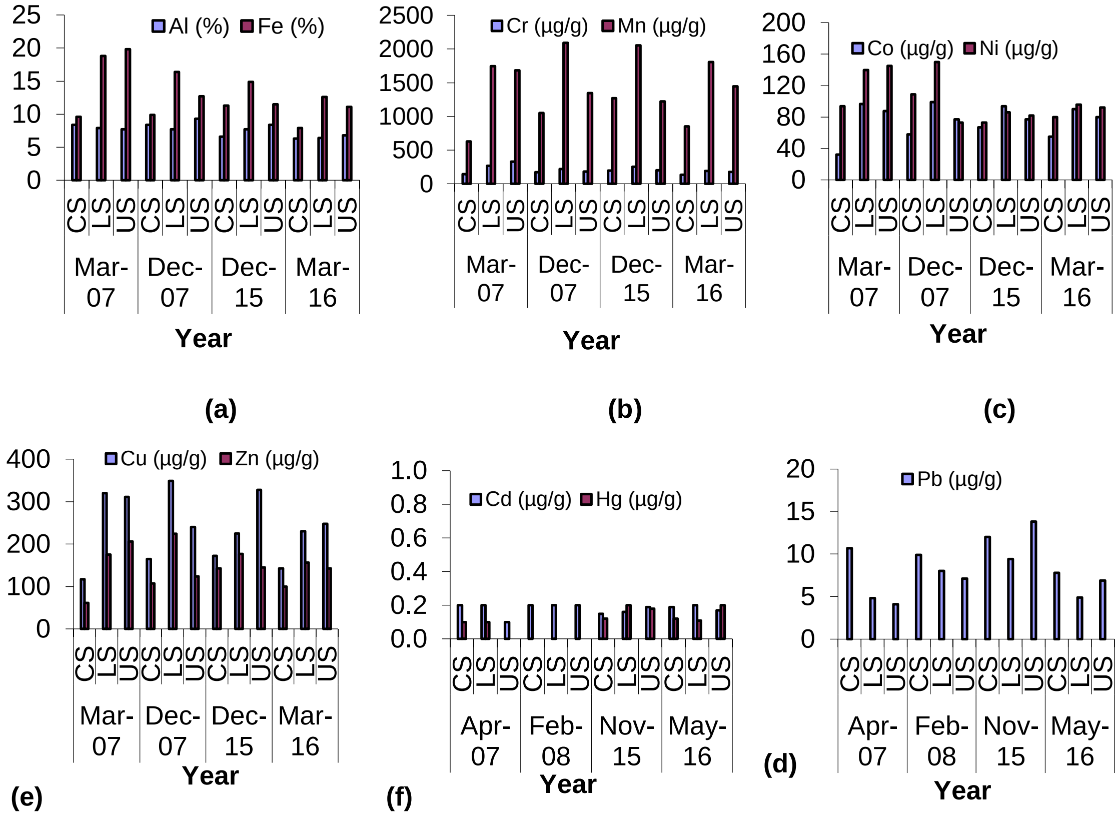
(d) (e) (f)

Figure 8.2.30: Comparison of sediment quality of Savitri Estuary measured during 2007-08 and 2015-16.



(a) (b) (c) (d)

Figure 8.2.31: Comparison of water quality of Vashishti Estuary measured during 2007-08 and 2015-16.



(a) (b) (c)

(e) (f) (d)

Figure 8.2.32: Comparison of sediment quality of Vashishti Estuary measured during 2007- 08 and 2015-16.

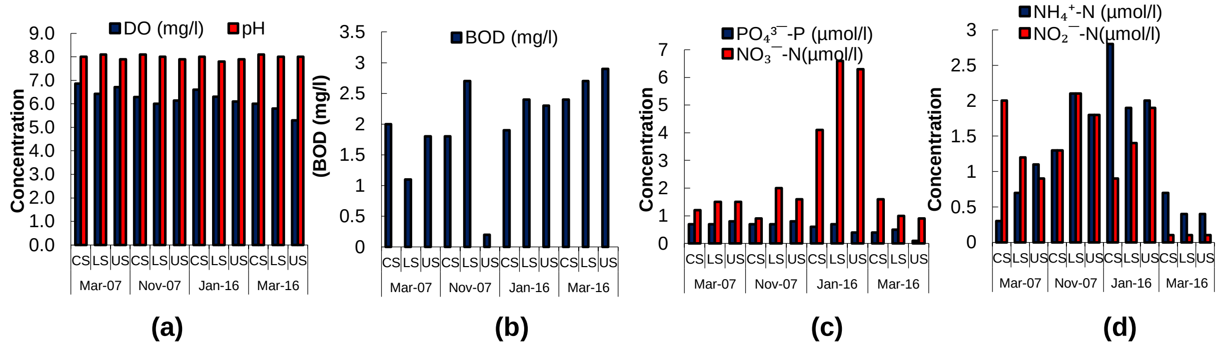


Figure 8.2.33: Comparison of water quality of Jaigad/Shastri Estuary measured during 2007-08 and 2015-16.

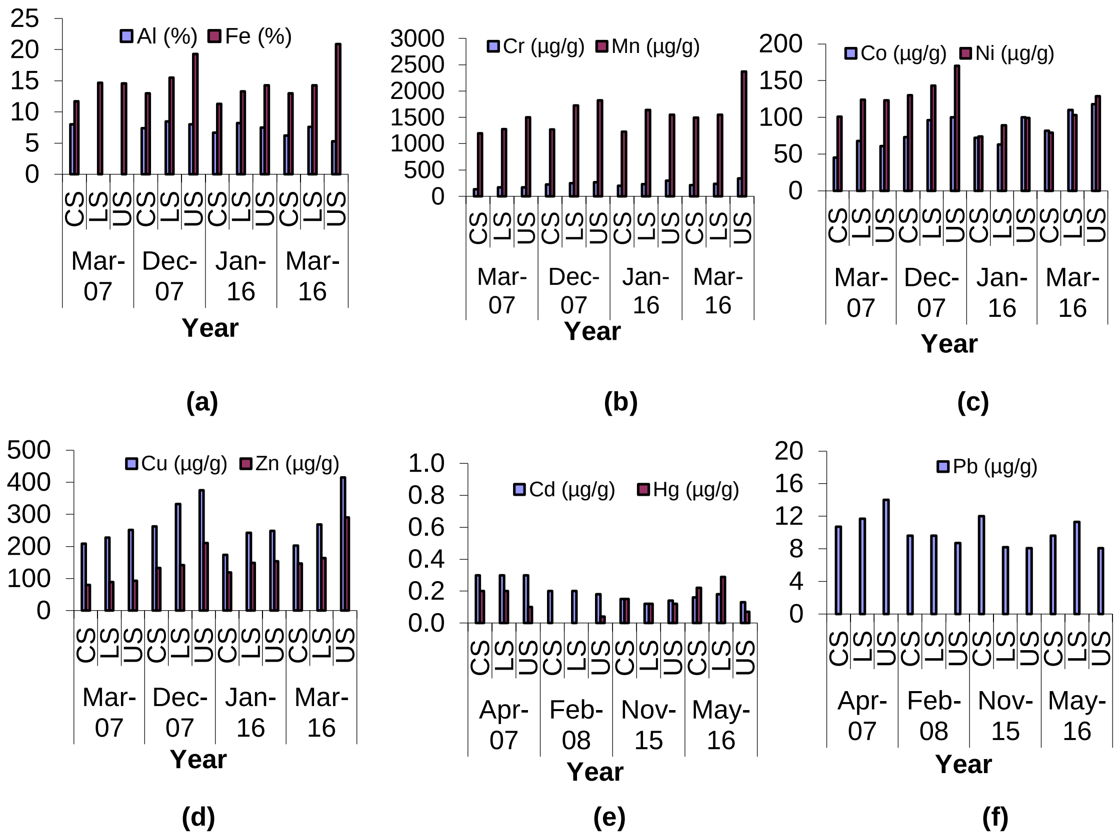


Figure 8.2.34: Comparison of sediment quality of Jaigad/Shastri Estuary measured during 2007- 08 and 2015-16

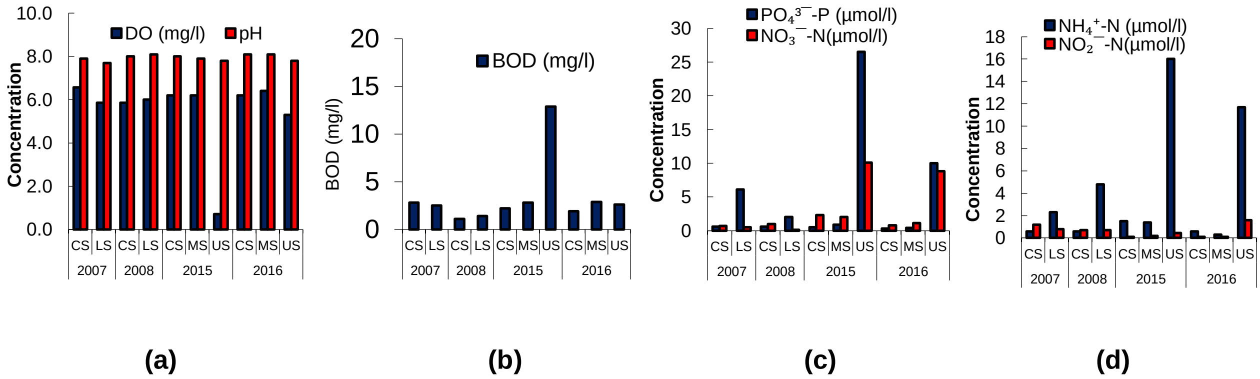


Figure 8.2.35: Comparison of water quality of Ratnagiri measured during 2007-08 and 2015-16.

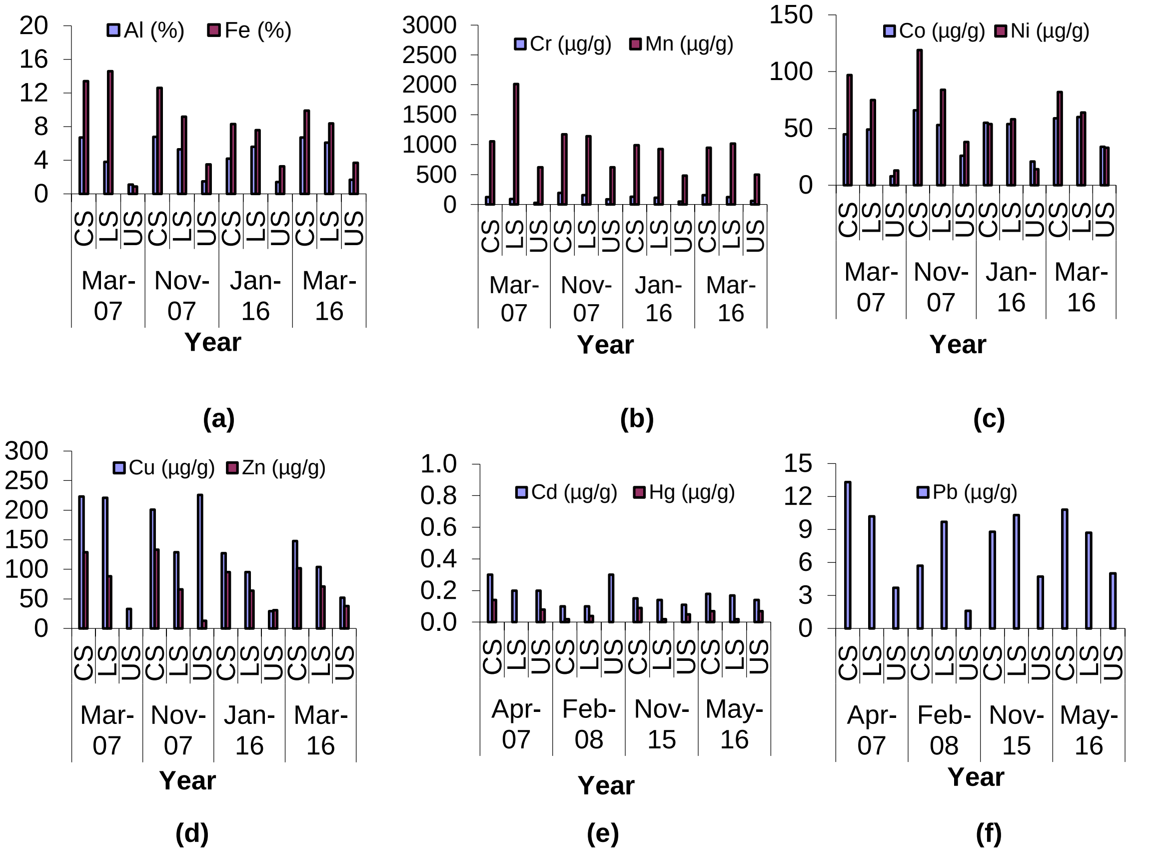


Figure 8.2.36: Comparison of sediment quality of Ratnagiri measured during 2007- 08 and 2015-16

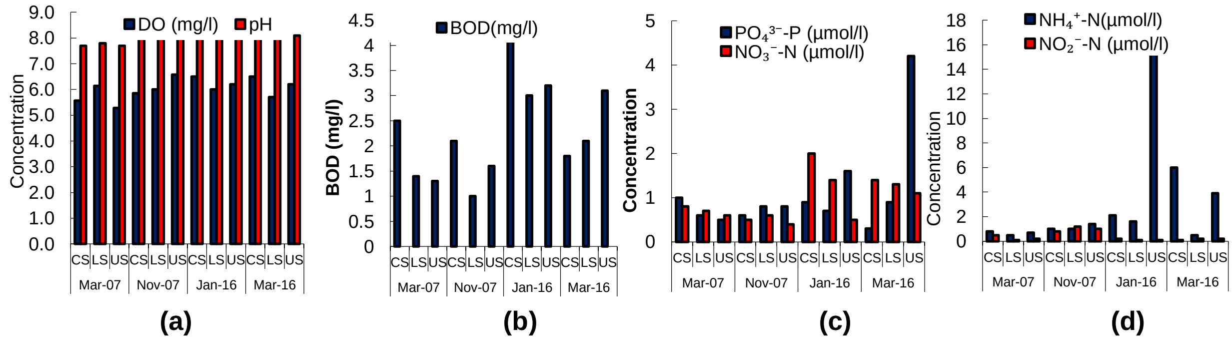
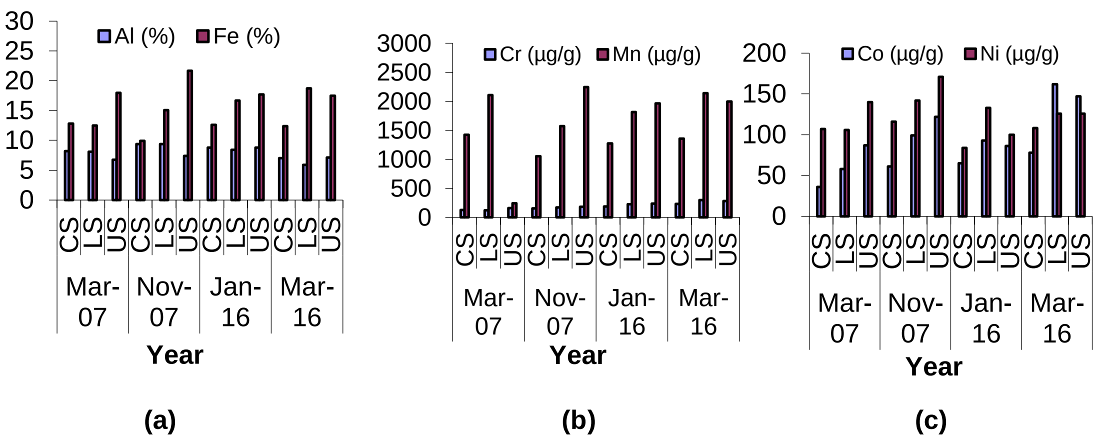


Figure 8.2.37: Comparison of water quality of Vijaydurg Creek measured during 2007-08 and 2015-16.



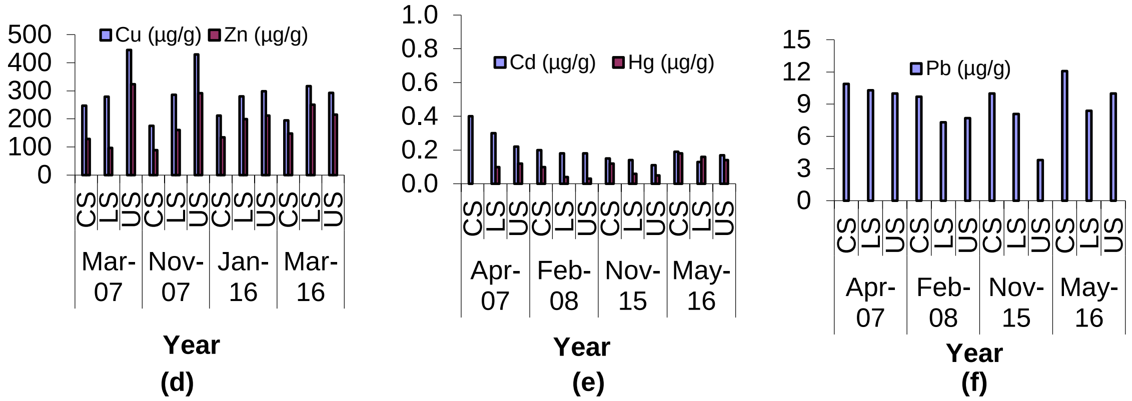


Figure 8.2.38: Comparison of sediment quality of Vijaydurg Creek measured during 2007- 08 and 2015-16

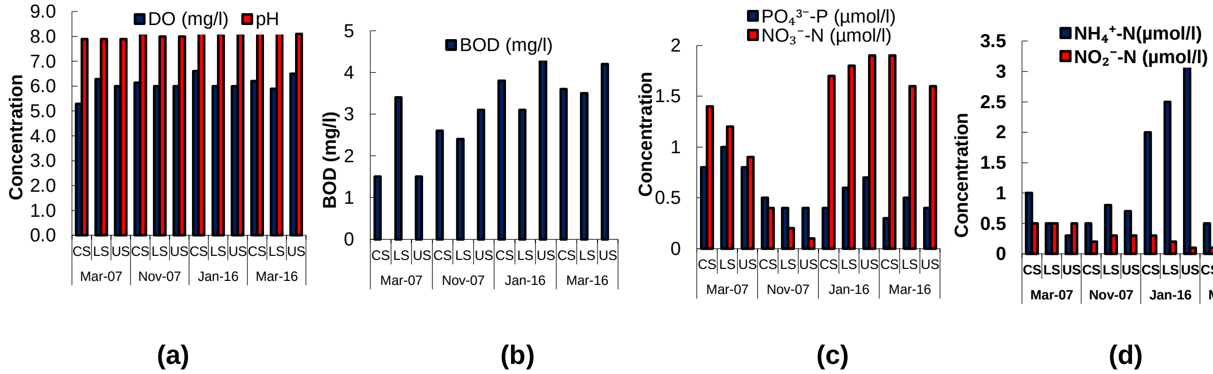


Figure 8.2.39: Comparison of water quality of Deogad Creek measured during 2007-08 and 2015-16.

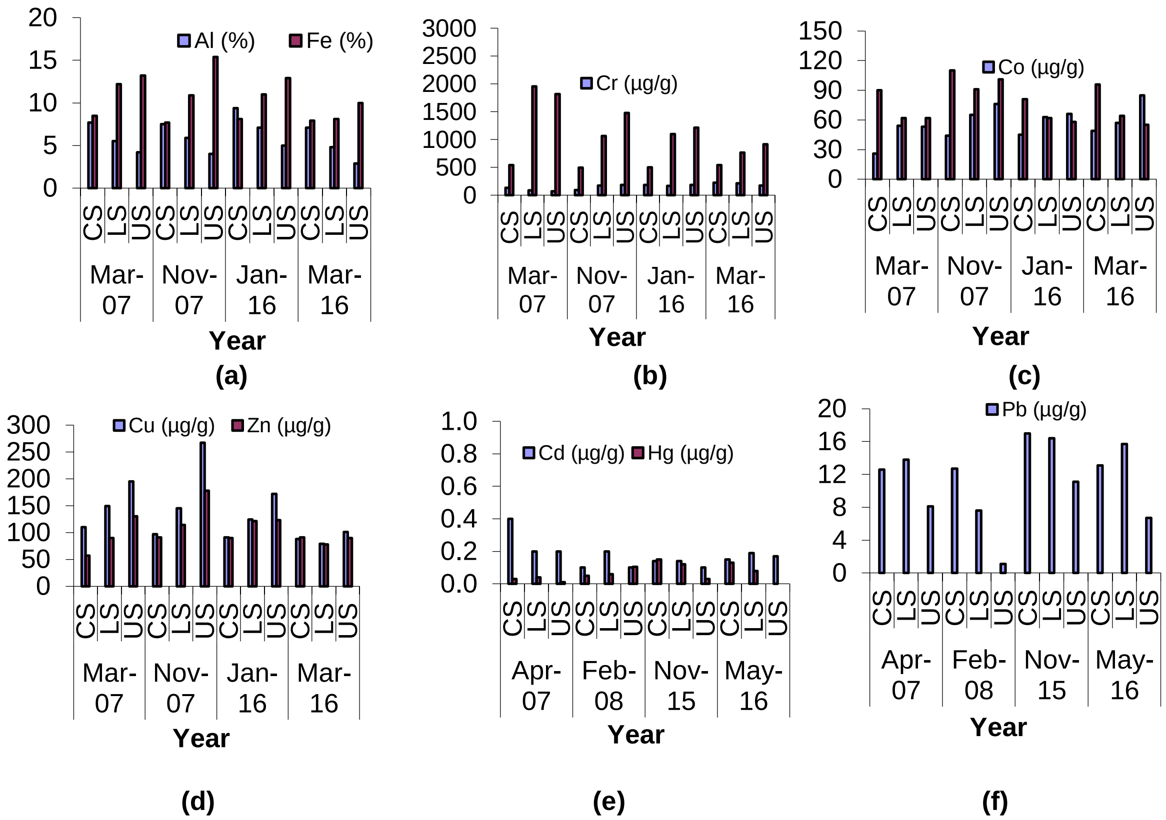


Figure 8.2.40: Comparison of sediment quality of Deogad Creek measured during 2007- 08 and 2015-16

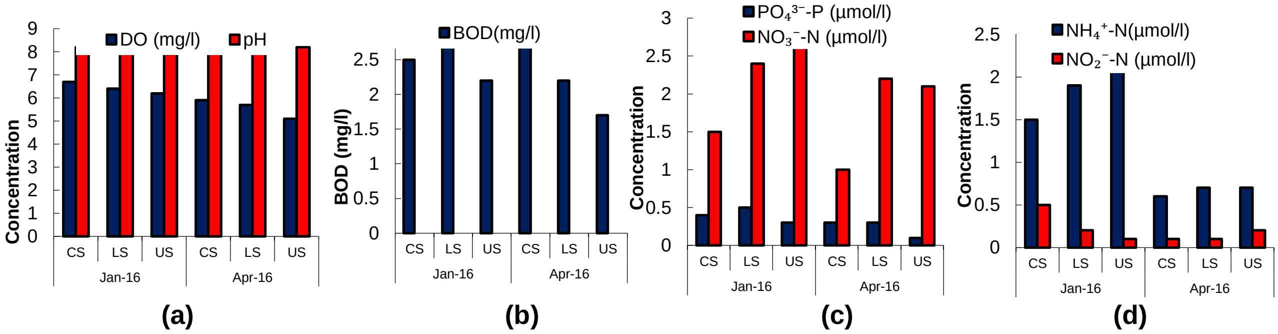


Figure 8.2.41: Comparison of water quality of Achara Creek measured during 2007-08 and 2015-16.

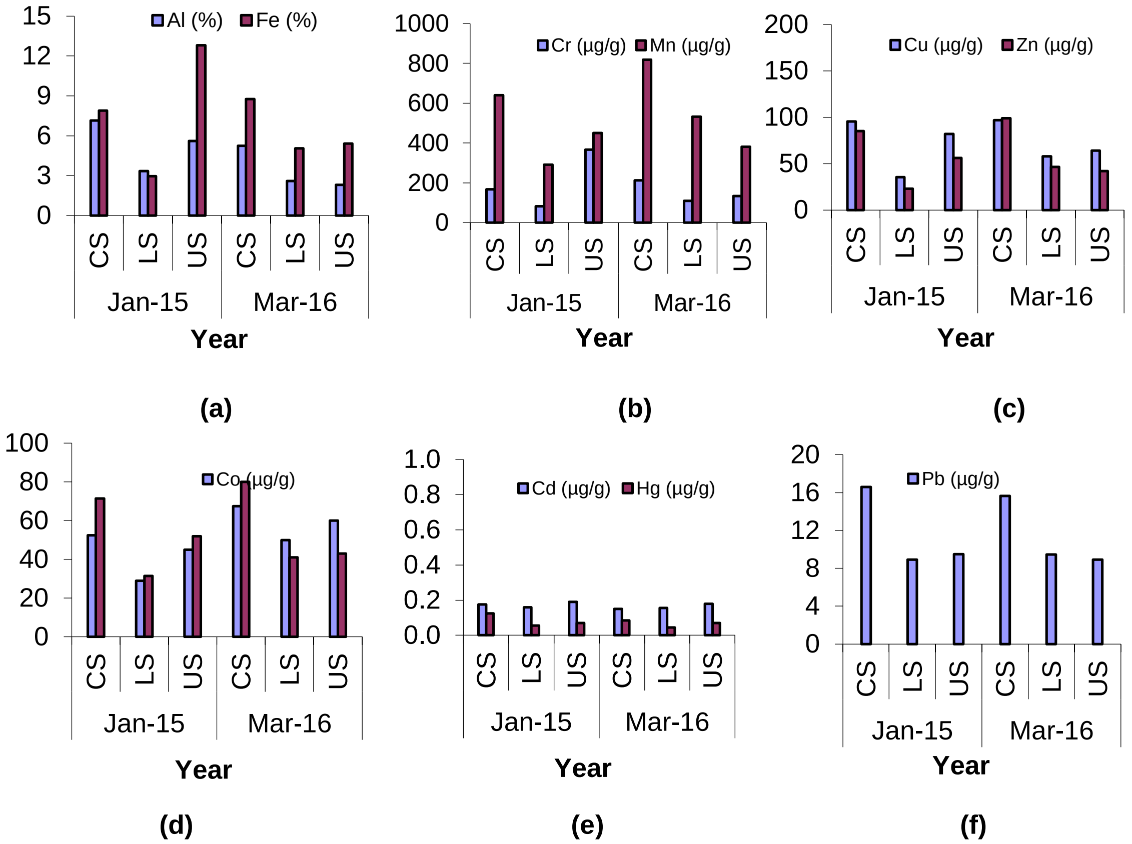


Figure 8.2.42: Comparison of sediment quality of Achara Creek measured during 2007- 08 and 2015-16.

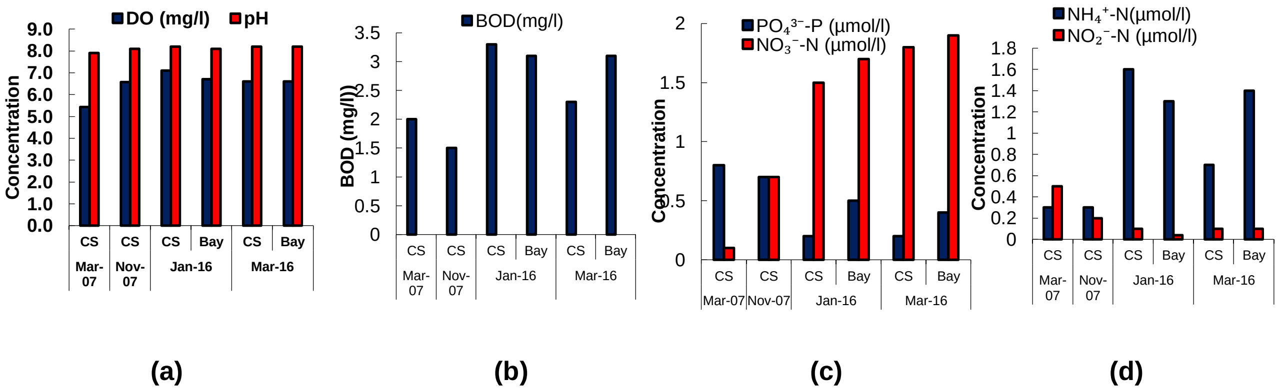
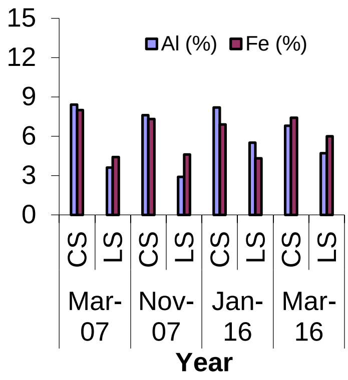
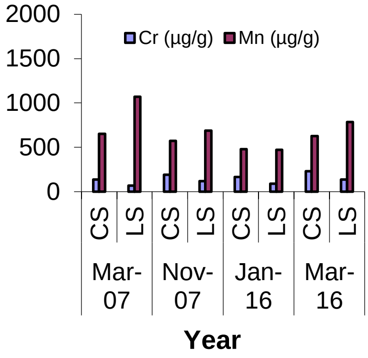
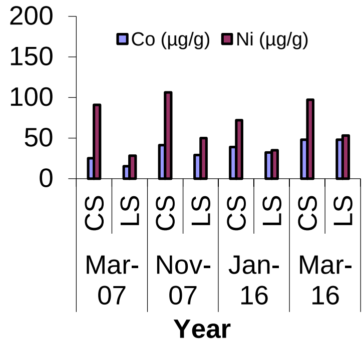


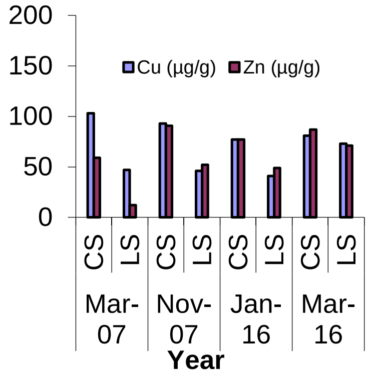
Figure 8.2.43: Comparison of water quality of Malvan measured during 2007-08 and 2015-16.

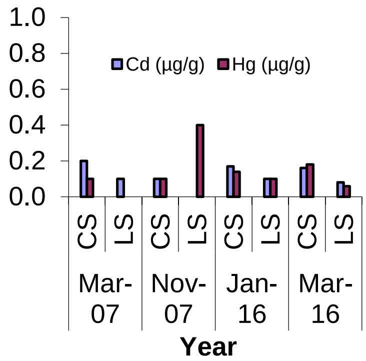


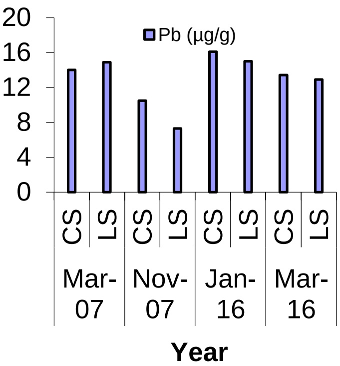




(a) **(b)** **(c)**







(d) **(e)** **(f)**

Figure 8.2.44: Comparison of sediment quality Malvan measured during 2007- 08 and 2015-16.

REFERENCES

APHA (2005): Standard Methods for water examination, American public Health Association; 21:1207

Carmelo R. Tomas, Edited 1996 Identifying marine Phytoplankton Published by Academic Press 858pp.

Feller, R. J. & Warwick, R. M. 1988 Energetics. In Introduction to the Study of Meiofauna (Higgins, R. P. & Thiel, H., eds). Smithsonian Institution Press, Washington, DC, pp. 181–196.

Grasshoff, K., Ehrhardt, M., Kremling, K. 1983, Methods of Sea Water Analysis. Second revised and extended ed. Weinheim Verlag Chemie 419pp.

Holme, N.A., McIntyre, A.D.,1984. Methods of Study of Marine Benthos Blackwell Scientific Publications, London 16-399pp.

IOC-UNESCO 1984 Manual for monitoring oil and dissolved dispersed petroleum hydrocarbons in marine waters on beaches. Manual and Guide No 13, 35pp.

Kenneth.W, Bruland, Franks,R,P., 1979 Sampling and analytical methods for determination of Copper, Cadmium, Zinc and Nickel at Nanogram per litre level in Sea-Analytica Chimica Acta 105, 233-245pp.

Loring D H and Rantala, RTT, 1992 Manual for the geochemical analyses of marine sediments and suspended particulate matter. Earth Sci Rev, 32 235-283pp.

Ram, A., Rokde, M.A., Borole, D.V., Zingde, M.D., 2003. Mercury in sediments of Ulhas estuary. Marine Pollution Bulletin 46, 846-857.

USEPA, 1979: Method for Chemical analysis of water and wastes. EPA-600/4-79-020,294pp

Walkely, A and I.A Black 1934. An Examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil sc 37:29-37pp.

Wieser W (1960) Benthic studies in Buzzards bay. II. The meiofauna. Limnol Oceanogr 5:121–137