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Study on Phytoplankton community in Thane Creek along Maharashtra Coast, India

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Abstract

The current study classified the study regions as ecologically distinct based on hydrobiology and necessity of monitoring, owing to the occurrence of blooms and eutrophication. The ecological well-being of estuarine systems holds importance in light of their socioeconomic significance and susceptibility to heightened anthropogenic pressures. This study, conducted between January 2023 and April 2023, assessed Phytoplankton dynamics along Thane creek, west coast of India. The Thane Creek system possesses characteristics of a macrotidal estuary which experienced high nutrient levels. The tidal action influences the ecosystem known for its importance as a breeding ground for commercially valuable fish and crustaceans. According to the findings, the markedly higher nitrate and phosphate levels in the macro-tidal estuaries during Month of April indicated anthropogenic contributions from domestic and industrial effluents, cause change in creek's physico - chemical properties which significantly impacted the Phytoplankton community structure. Nutrient enrichments favored higher phytoplankton standing stock leading to low DO levels, Also nutrient enrichment can lead to the proliferation of plankton that can govern the diversity and distribution of phytoplankton along the salinity gradient environment. Chlorophyll-a concentration, which showed notable spatiotemporal variation throughout the research region, was used to estimate phytoplankton biomass. The dominance of diatoms in the phytoplankton community indicates a shift in community composition from centric to pinnate forms, which is influenced by tidal dynamics. Species such as *Navicula longissimi*, *Pleurosigma elongatum*, *Cerataulina dentata* and *Skeletonema costatum* were predominant throughout the study area.

Keywords: Estuaries, Phytoplankton community, Thane creek, Chlorophyll-*a*

Introduction

Brackish waters, characterized by their intermediate salinity levels, occupy a unique ecological niche between freshwater and marine environments which comprises estuaries and creeks. "An estuary is a semi Enclosed coastal body of water having a free connection to the open sea and within which the sea water is measurable while the seawater is measurably diluted with freshwater deriving from the land drainage" derived from book [1]. These intriguing aquatic habitats are a captivating blend of both worlds harbouring a diverse array of species adapted to withstand the challenges posed by fluctuating salinity. These ecosystems are regularly inundated by tides and can be divided into three zones, namely the upper intertidal zone (where the mangroves grow) which is submerged mostly during peak tides, the lower subtidal zone that is always submerged under water and the middle intertidal mudflat zone that gets submerged during high tide. The inhabitants of this region, due to their diel changes in submergence, exposure and desiccation are known to be hardy and diverse. These inhabitants classified the estuaries based on tidal range. Microtidal estuaries were identified as having a small tidal range of 0 to 2m. Mesotidal estuaries with intermediate tidal ranges of 2m to 4m [2-3]. Similarly, macrotidal estuaries have a tidal range greater than 4m. Based on the classification by tidal propagation, author mentions in his study that classified Indian estuaries into three types based on the geomorphological characteristics [4]. The most commonly observed type contains a prominent channel, river at the head and sea at the mouth. A common feature to all the estuaries of India is that they come under the intense precipitation during the monsoon. After monsoon they go through a dry period with hardly any freshwater discharge. As a result, the estuaries show the difference in physical parameters such as salinity variation and sediment transport during the wet and the dry season. Because of the seasonality induced by the Monsoon Indian estuaries are known as the monsoonal estuaries. The Indian coastline is bordered by many ecologically diverse estuaries, though sharing the typical tropical nature, but is distinct in its tidal features, freshwater flow regimes and geomorphological characteristics [5]. Further, the estuarine systems adjoining the nearshore environments are dynamic ecosystems where freshwater influx controls the environmental variability. The monsoon exerts additional stress to the area bringing drastic variations in salinity and nutrients. Because of the conflicting interactions, this zone permits the growth and survival of selected adaptive biota which can withstand the extreme variations in environmental parameters.

Phytoplankton, the primary producers of food in the ocean, are the basis of life. They convert sunlight energy into chemical energy, which is consumed by larger animals like fish, whales, squid, shellfish, and birds. Phytoplankton also enter the microbial loop, where bacteria absorb decomposing phytoplankton chemicals. They serve as food sources for smaller sea organisms, sustaining larger ones.

Classification of plankton based on size (Schutt et al., 1892; Gajbhiye et al., 2002)

Ultraplankton 0.2-2µm (Marine viruses, small eukaryotic bacteria, protozoans)

Nanoplankton 2-20µm (Heterotrophic nanoflagellates feeding on bacteria)

Microplankton 20-200µm (Ciliates)

Mesoplankton 200-2000µm (Copepods, Decapod larvae, Polychaete larvae, Ostracods)

Megaplankton >2000 µm (Jellyfish)

Methodology

Study area:

Thane creek (Long. 72 ° .55′ to 73 ° .02′ E and Lat. 19 ° .00′ to 19 ° .15′ N) is a mangrove fringed tropical coastal ecosystem along the central west coast of India. The creek is 26 km long which extends northwards from the Bombay harbour bay and joins the Ulhas River by a minor connection near Thane city. The creek is narrow and shallow in the north where Ulhas river flows into it through a minor connection and is broader and deeper towards the sea. Due to the geomorphic head near Thane city, the creek receives negligible fresh water flow from the Ulhas River.

Domestic wastewater and a variety of industrial effluents result in the anthropogenic fluxes of pollutants along the eastern and western banks of Thane Creek.

Table 1: Details of the sampling stations

Location	Station Code	Co-ordinates	
		Latitude	Longitude
Kopri	T1	19°11'9.59"N	72°59'9.44"E
Upper Vashi	T2	19° 4'36.79"N	72°58'14.28"E
Seawood	T3	18°59'35.01"N	72°58'46.88"E

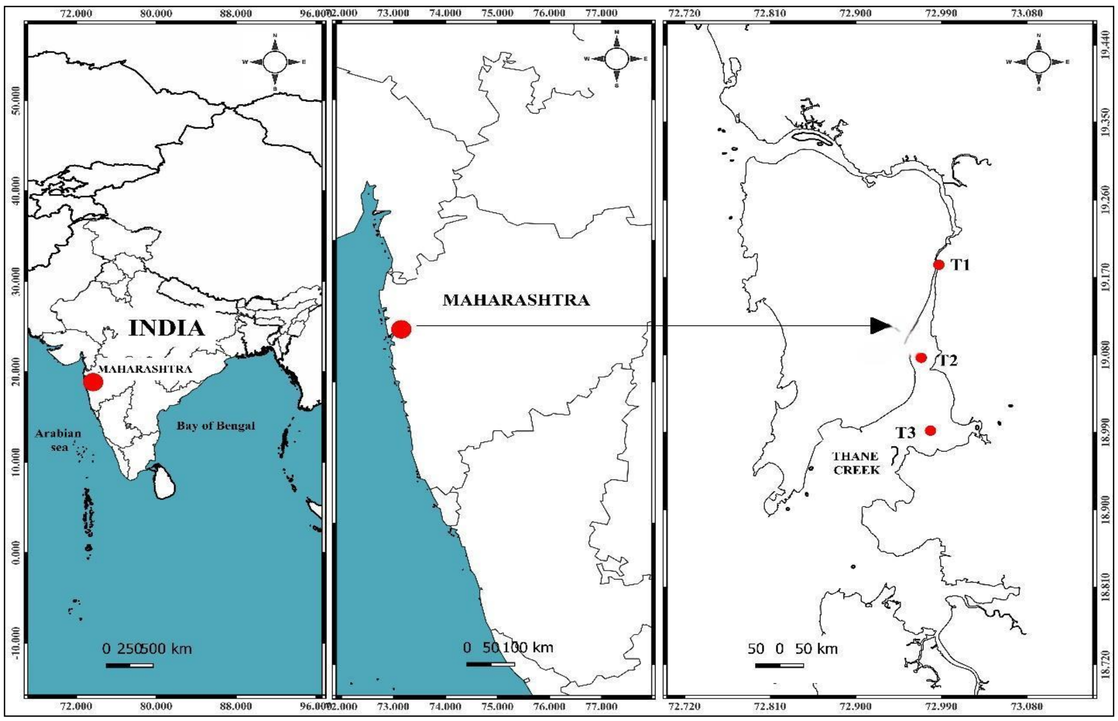

Figure 1: Study area and sampling locations

Sampling strategy

The sampling stations were classified as upper, middle and lower creek station T1(Kopri) was the first station from Ulhas river side where, The Ulhas river meets The Thane creek, 2nd station T2 (Upper Vashi) where minor streams are connected to the Thane creek and 3rd station T3 (Seawood) which it was nearest to the sea. Sampling was carried out during January 2023 and April 2023. **(Refer table no. 1 and figure no. 1**) Samples for the environmental Parameters, chlorophyll *a* (biomass) and phytoplankton taxonomy were collected from surface level.

Method of water sample collection:

The surface creek water samples were collected from different sampling locations. The sampling bottles were pre washed with low grade alcohol.

Methodology for physicochemical parameters of water

1. **Environmental Parameters:**

Water Temperatures were measured using a handheld mercuric thermometer. The **pH** of water samples was assessed with a pH meter (Model: EUTECH-pH 700), calibrated with standard buffers prior to use. **Salinity** was calculated using the Argentometric method. A known volume of water was titrated with silver nitrate in the presence of potassium chromate, with the formula applied:

$$Salinity = 0.03 + (1.805 \times Chlorinity)$$

2. Chemical Analysis:

Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD):
DO and BOD were measured using Winkler's method. The calculations followed:

$$DO\ or\ BOD = B.R \times Normality\ of\ Na2S2O3 \times 8 \times 1000 / Volume\ of\ sample$$

Total Suspended Solids (TSS):

TSS was determined by filtering a water sample through a pre-weighed filter. The filter was dried at 103–105°C until weight stabilization, and the increase represented TSS.

3. Nutrient Analysis:
Nitrite-Nitrogen (NO2-N): Measured by the method of Bendschneider and Robinson (1952) [6].
Nitrate-Nitrogen (NO3-N): NO3-N was quantitatively reduced to nitrite using amalgamated cadmium granules, maintaining stable pH with ammonium chloride buffer [7].
Ammonia-Nitrogen (NH4-N): Determined via the indophenol blue method shown in [8].
Phosphate-Phosphorus (PO4-P): Inorganic phosphate was determined by forming a reduced phospho-molybdenum blue complex.
Silicate-Silica (SiO4-Si): Dissolved silicate was analyzed based on the formation of yellow silico-molybdic acid, reduced to a blue complex and measured at 810 nm standard procedure mentioned in [7].

4. Biological Parameters:
Estimation of Chlorophyll a, phytoplankton density and assemblage
Phytoplankton sampling was carried out in Thane creek water. Water samples are collected from each station at surface level and the collected Phytoplankton samples were transferred into 500mL plastic containers and preserved with Lugol iodine solution and kept away from the sunlight. chlorophyll- *a* is collected in a 500mL amber colour bottle and then Sample were filtered through Whatman GF/F filter paper (47 mm diameter; pore size 0.7 µm) and extracted in 90% acetone overnight at 4°C. Phytoplankton Biomass calculated the concentration of chlorophyll *a* according to the equation shown in Paper [9].

Chlorophyll *a* = 11.4*K*[(E665o − E750o) − (E665a − E750a)]*Ve /L*Vf

Where:
L = Cuvette light-path in centimeter.
Ve = Extraction volume in milliliters.
Vf = Filtered volume in liter.
R = Maximum absorbance ratio of E665o/E665a in the absence of phaeopigments = 1.7
K = R / (R − 1) = 2.43. Concentrations are in unit mg m^{-3}

The quantitative analysis involves the estimation of the number of each phytoplankton species in one litre of seawater. Quantitative analysis was performed using a Sedgewick Rafter (**Figure 2**) counting cell under a Leica DM2000 microscope, whereas qualitative analysis was made of the following standard identification key ([10]; [11]). For the calculation of the total number of phytoplankton cells per litre, the following formula by [12] was used. The samples were analysed for identifying different groups that were present in the sample. Made 100 ml. Stempel pipette was used to obtain a 10 ml sample and analysed. The 10 ml sample in Sedgwick Rafter chamber.

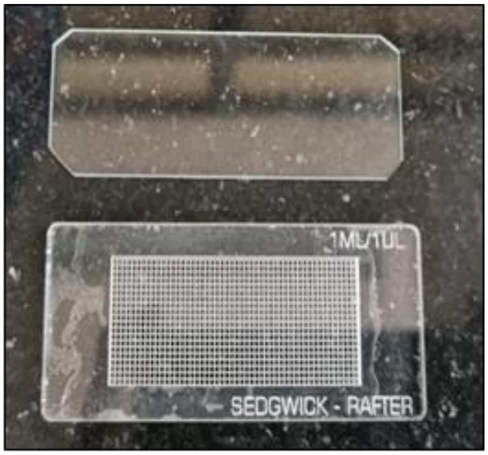

Figure 2: Sedgwick Rafter counting chamber

Then counting for both major and minor groups was done under a stereo zoom microscope (Make: LEICA; Model S6D). When a specimen of a particular group was seen a tally mark was made on the datasheet and different groups were counted simultaneously. The abundant group was assigned as the major group, and the less abundant group was assigned as a minor one. Taxonomic identification of phytoplankton by standard identification manual [10].

Statistical analysis

The statistical software PRIMER 6 is used for univariate statistical analysis and plotting of data and the correlation work calculated using software STATISTICA., MICROSOFT EXCEL 10, OriginPro 10.0 were used for suitable graphical representation.

Univariate analysis

The univariate analysis uses diversity indices, which attempt to combine the data on abundance within a species in a community into a single number. The state of the community can be understood by this method.

Shannon-Weiner diversity index: Shannon-Weiner diversity index is used here for comparing species diversity across location and seasons. It is denoted by $H'(\log_2)$.

$$H'(\log_2) = -\sum P_i \ln P_i$$

Where, $P_i = S/N$; **S**-Total number of individuals of one species; **N**-Total number of individuals present in sample; **ln** – logarithm of base e

Simpson's diversity index: Simpson's diversity index is used here to measure the species number and abundance in a sample. It is denoted by $(1-\lambda)'$.

$$(1-\lambda)' = 1- (\sum n (n-1)/ N(N-1)).$$

Where, **n**- Number of particular species; **N**- Total number of individuals present in sample

Margalef's species richness index: Margalef's species richness is used for measuring species richness in the sample population. It accounts for the total number of species. It is denoted by d.

$$d= (S-1)/ \ln N$$

Where, **S**- Total number of species in a sample; **N**- Total number of individuals present in sample; **ln**- natural logarithm

Measurement of evenness: Pielou's evenness is used here to calculate species evenness in the population. It measures the relative abundance that forms the richness of the area. It is denoted by J´.

$$J'= H/ \ln \log(S)$$

Where, **H**- Shannon-Wiener index, **S**- Total number of species in a sample

Results

Hydrography of Creek Waters: Each hydrographic parameter has its role in an ecosystem. The knowledge about these parameters was important in understanding the dynamics of the ecosystem. The parameters considered are atmospheric temperature, surface water temperature, surface water salinity, pH, dissolved oxygen, biochemical oxygen demand, The study area was categorized into Thane creek. The stations T1, T2 and T3 fell under Thane creek.

Physico-chemical Parameters

The water temperature has varied in the ranges of 35 ºC with highest values in the April Month. An average temperature of 25 ºC and 33 ºC were observed during January 2023 and April 2023 respectively. The lowest temperature was noted in January having a value of 24 °C at T2 and the highest temperature was noted during April at T3 which was 35°C. **(Figure 3)**. The **pH** range for the month of January and April was found to be varying between 7-7.5. The lowest pH i.e. 7 was observed at T1 and T2 in the month of April. The highest pH was observed in the month of January i.e. 7.5 at T3 showed no variation in pH in both the months. The average pH was 7.4 and 7.2 during the months of January and April respectively. **(Figure 3)**. **Salinity** (SS) ranged from 22.40 PPT to 35.2 PPT between January and April. The average salinity in the two months ranged from 29.6 PPT to 30.28 PPT with little variation. Both months had an upward tendency, from 26.64 to 34.50 PPT and 22.40 to 35.20 PPT, respectively. **(Figure 3)**.

Total Suspended Solids- In the current investigation, suspended solids varied from 22 to 265 mg/L between January and April. The average for January was 112 mg/L, while the average for April was 41 mg/L. **(Figure 3)**. As there was continual mixing of waters and diverse sources of water discharges in the stream, no distinctive patterns were noticed.

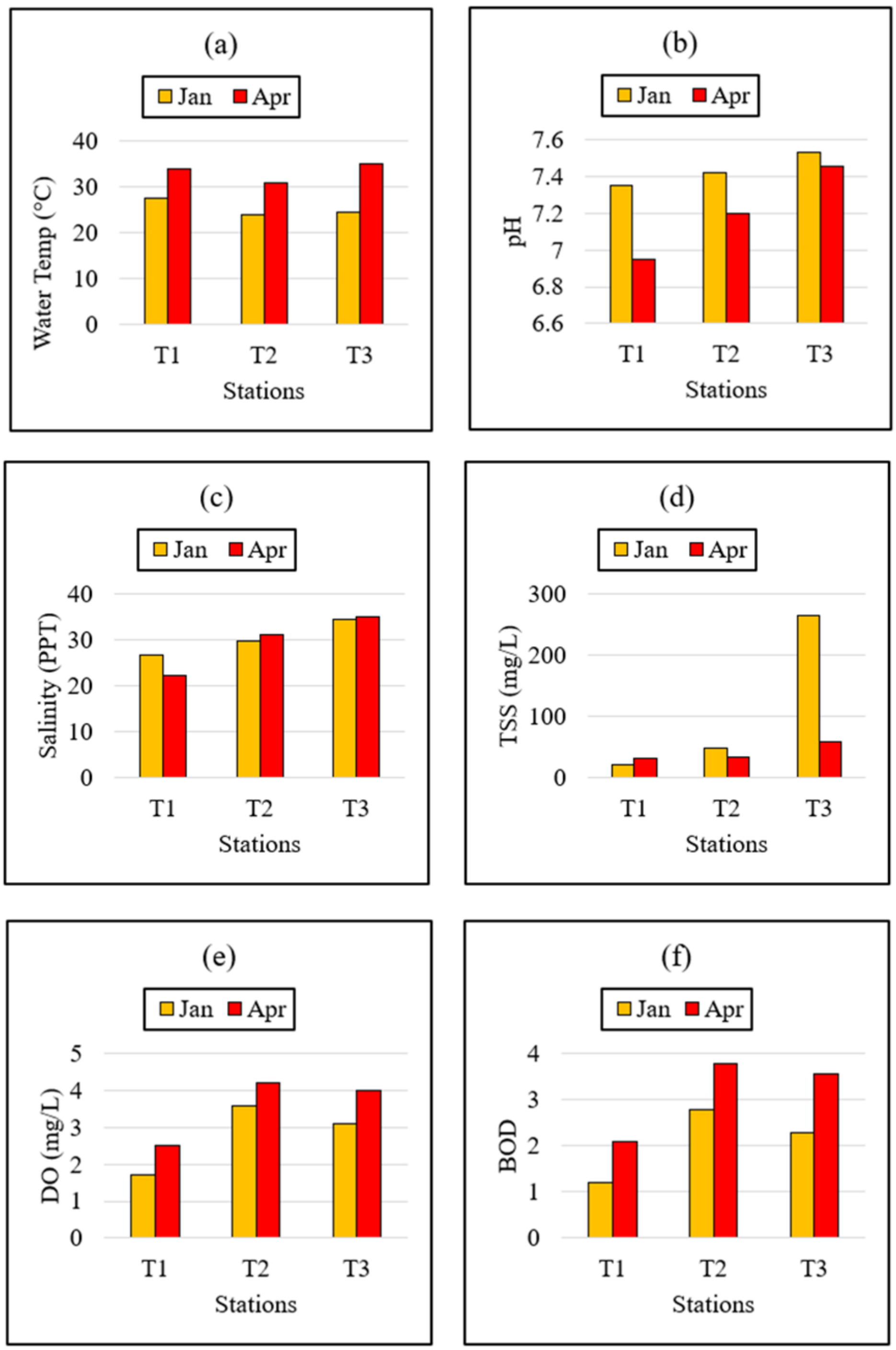

Fig. 3: Distribution of (a) Water Temparture (b) pH (c) Salinity (d) TSS (e) DO (f) BOD in the study region during January 2023 and april 2023

Dissolved Oxygen (DO)- In current study, DO values ranged from 1.7 mg/L to 4.2 mg/L. The lowest value was recorded at T1 in January month and highest at T2 in April month. In the January month the values range from 1.7mg/L to 3.6 mg/L with an average of 2.8 mg/L. In April the values ranged from 2.5mg/L to 4.23 mg/L with an average of 3.6 mg/L. T2 collectively showed high dissolved oxygen levels in the study area. **(Fig. 3)**.

Biological Oxygen Demand (BOD) for the months of January and April ranged from 1.2 mg/L to 3.8 mg/L. The lowest BOD levels at T1 were 1.2 mg/l in January and 2.1 mg/l in April. The highest BOD concentrations were 2.8 mg/l at T2 in January and 3.8 mg/l at T2 in April. Between January and April, The average BOD was 2.1 mg/l and 3.2 mg/l, respectively. **(Fig. 3).**

Phytoplankton Community Analysis

Phytoplankton Biomass: Chlorophyll *a* (Chl-*a*)

During January 2023, Chl-*a* along the upper thane creek waters ranging between 2.16 mg/m^3 and 7.17 mg/m^3. The highest Chl-*a* observed at station T1 and lowest data at station T3. There is a decreasing trend of Chl-*a* distribution towards the creek mouth region. On an average Thane creek observed a Chl-*a* concentration of 5.41 mg/m^3 During January month Similarly, during April 2023, The maximum Chl-*a* concentration was observed at station T1 with a value of 7.01 mg/m^3 and minimum at the station T2 with a Chl-*a* concentration of 3.13 mg/m^3. The average Chl-*a* concentration at Thane creek is 5.52 mg/m^3 in April month. Spatio temporal variation of Chl *a*. **(shown in figure 4).**

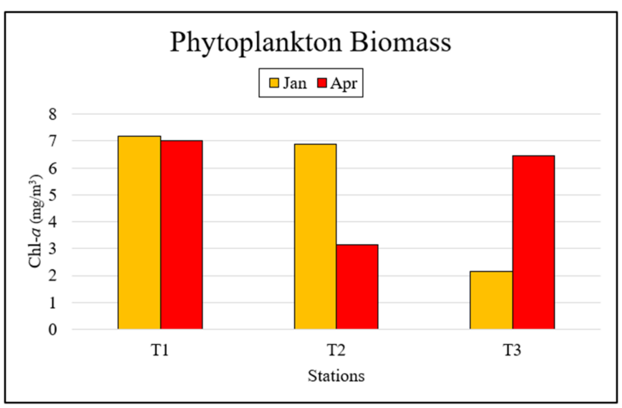

Figure 4: Variation in Chl-a concentration between T1-T3 in January 2023 and April 2023

Nutrients

Nitrate: Nitrate values varied from 38.1 µmolL^{-1} to 49.5µmolL^{-1} being the lowest and highest concentrations found during the study period. The lowest value was observed at T2 in January and the highest at T3 in April. The average value for January is 40.7 µmolL^{-1} and for April is 45.5µmolL^{-1}. No significant fluctuation was observed in both the months.

Nitrite: Nitrite values ranged from 27.6 µmolL^{-1} to 41.2 µmolL^{-1} in January and April respectively. The lowest value recorded as 27.6 µmolL^{-1} is at T3 in the month of January. The highest value was 41.2 µmolL^{-1} recorded at T1 in April. The average value for January was 29.1 µmolL^{-1} and for April was 38.1. The difference in values for both months is significant i.e. 9 µmolL^{-1} and the decreasing trend was observed toward the seaward (lower creek) site for both months.

Ammonium: The ammonium values ranged from 31.2µmolL^{-1} to 33.8µmolL^{-1} in January. The lowest value was observed at T2 and highest at T1. The average value for January month is 32.4 µmolL^{-1} and for April is 32.5 µmolL^{-1}. No significant difference was observed in both the months.

Phosphate: The average concentration of phosphate for the month of January and April was 4.0 µmolL^{-1} and 3.2 µmolL^{-1} respectively. The phosphate values ranged from 2.1 µmolL^{-1} to 5.2 µmolL^{-1} in April and January respectively. April Showed the lowest range i.e. 2.1 – 3.8 µmolL^{-1} and January month showed the highest range i.e. 3.2 – 5.2 µmolL^{-1}. No significant fluctuation was observed in both the months.

Silicate: The concentration of Silicate varied from 10.5µmolL^{-1} to 40.57 µmolL^{-1} in January and April months. The highest concentration was seen at T1 in April and lowest at T3 in January. The average concentration for January was 27.4 µmolL^{-1} and for April was 31.5 µmolL^{-1}. The decreasing trend was observed toward the seaward site for both months. **(Figure 5).**

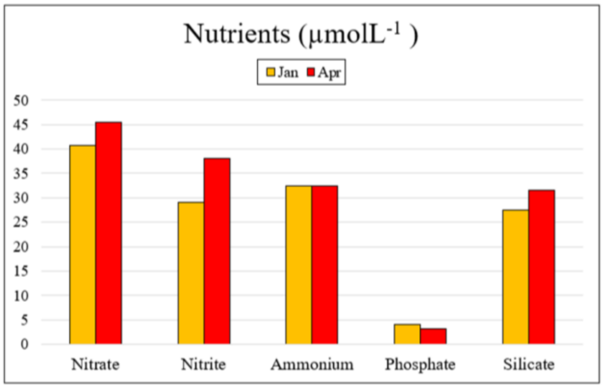

Figure 5: Variation in Nutrients Concentration in January 2023 and April 2023

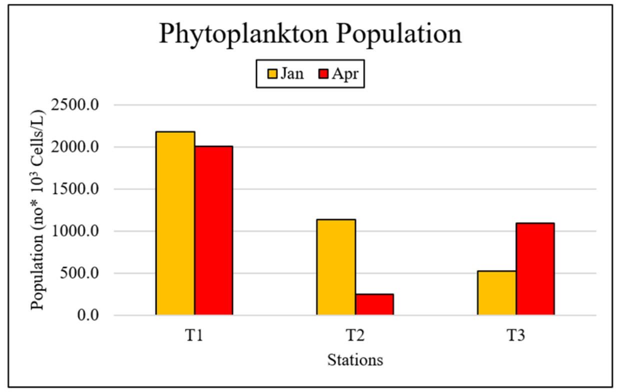

Figure 6: Variation of Phytoplankton population (no X10^3 Cell/L) in January 2023 and April 2023

Phytoplankton Population

Phytoplankton population ranged from 522.3 * 10^3 Cells/L to 2175.7 * 10^3 Cells/L in January 2023 in the study area. The maximum phytoplankton population was observed at station T1 with a value of 2175.7 * 10^3 Cells/L and minimum at the station T3 with a value of 522.3*10^{3}Cells/L. The average Biomass of Phytoplankton in Thane creek is 1279.1 * 10^3 Cells/L in Jan. 2023. Similarly, Phytoplankton population ranged from 246 * 10^3 Cells/L to 2001.8 * 10^3 Cells/L Cells/L in April 2023. The station T1 recorded the highest phytoplankton counts of 2001.8 * 10^3 Cells/L, while the station T2 recorded the lowest with a cell count of 246 * 10^3 Cells/L. At Thane Creek, the average phytoplankton population is 1112.3 * 10^3 Cells/L. (**Figure 6**)

Phytoplankton Diversity

A total of 30 species of phytoplankton belonging to 17 genera and a total of 11 phytoplankton orders were identified from the study area namely *Coscinodiscales, Leptocylindrales, Rhizosoleniales, Thalassiosirales, Triceratiales, Hemiaulales, Lithodesmiales, Corethrales, Naviculales, Bacillariales, Fragilariales* were identified. The major and only class that contributed to the total phytoplankton abundance were Bacillariophyceae (Diatoms). The diatoms community was mainly composed of Centric diatoms and Pennate diatoms.

Phytoplankton diversity during January 2023

Thane Creek is more dominated by Pennate forms of diatoms (76%) *Pleurosigma* sp. (34.2%) followed by *Navicula* sp. (22.3%) and *Pseudo-nitzschia* sp. (14%) and in Centric Diatoms (24%) and *Skeletonema* sp. (16.1%) was dominated in January 2023 **(Refer Figure 7 and 8)**.

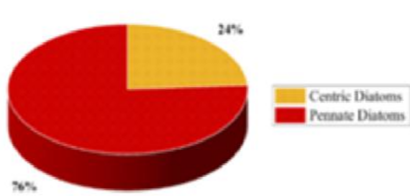

Figure 7: Percentage composition of major subclasses of diatoms at Thane creek during January 2023

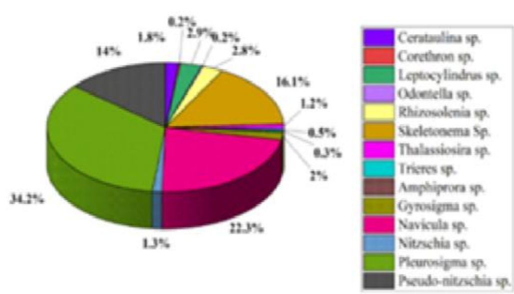

Figure 8: Percentage composition of major genus of diatoms at Thane creek during January 2023

Phytoplankton diversity during April 2023

During April 2023, The pennate diatoms *Navicula* sp. (25.4%) *Pseudo-nitzschia sp. (13.9%)* and Centric Diatoms (79%) of *Leptocylindrus sp.* (22.5%) followed by *Gyrosigma sp*. (9.3%) were dominant in Thane creek in April 2023 **(Refer Figure no . 9 and 10)**.

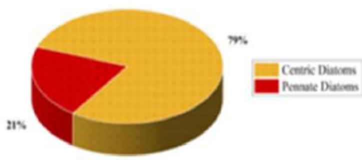

Figure 9: Percentage composition of major subclasses of diatoms at Thane creek during April 2023

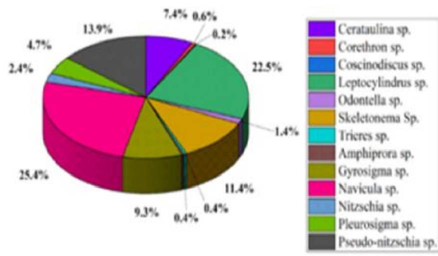

Figure 10: Percentage composition of major genus of diatoms at Thane creek during April 2023

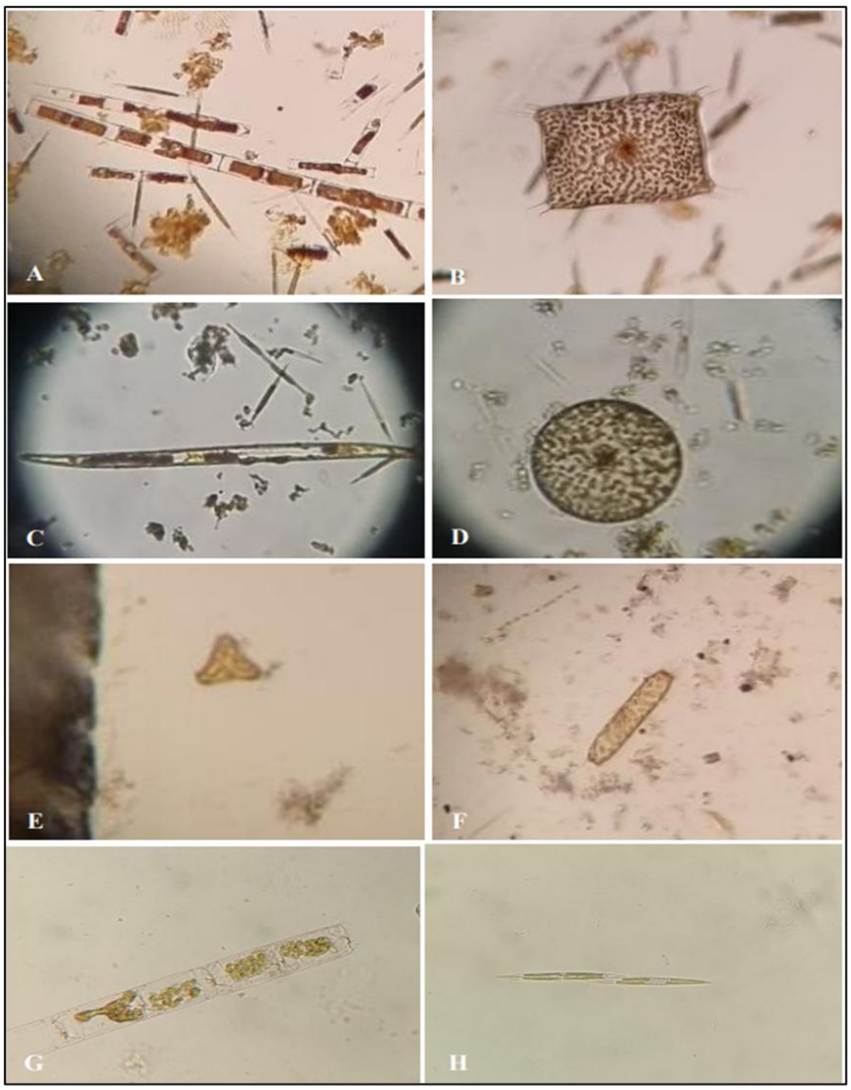

Figure 11: Phytoplankton identified from the study area

A: *Cerataulina pelagica* **B:** *Odontella sinesis* **C:** *Nitzschia logissima* **D:** *Coscinodiscus centralis*

E: Triceratium **F:** *Corethron criophilum* **G:** *Leptocylindrus danicus* **H:** *pseudo-nitzschia lineola*

Statistical Analyses

Diversity indices

The Phytoplankton diversity of the study area was calculated using **PRIMER7** software. Species richness was measured using Margalef's richness (d). The highest richness was observed in April at T1 with d=1.9. The January month was found to be less rich in diversity when compared with April. The lowest richness was observed during the April month at T3 with d=0.57. For measuring evenness- Pielou's evenness (J′) was used, the evenness during January month ranged between J′=0.55 to 0.85 and for April month it ranged between J′=0.34 to 0.9. During January highest evenness was seen at T3 (0.85). The average evenness observed for January month was J′=0.74 and for April was J′=0.66. For measuring diversity of the study area Shanon - Weiner H′(log2) index was used. The highest H′(log2) was recorded during the April month at T2 with H′(log2) =2.84, this area was found to be highly diverse in January. The least diverse area was T3 in April (H′(log2) =0.75. The average H′(log2) for January and April were H′(log2) = 2.20 and H′ (log2) = 1.85 respectively. Simpson's index (1-λ) was also calculated and the average value for January and April months was (1-λ) = 0.84 and (1-λ) = 0.76 respectively. (**Fig. 12**)

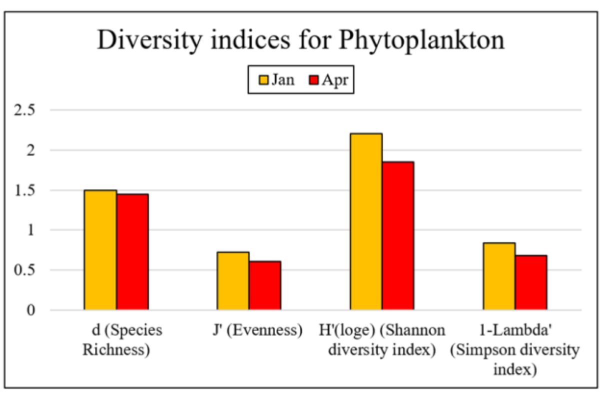

Figure 12: Diversity Indices of phytoplankton at study area

Discussion

The study done on Physico chemical parameters shows the following results, having observed a similar wide range of temperature (17 – 35 °C) in the shallow region of Thane creek near Thane city during the period 1991 – 93 [13]. Although many may be less tolerant, tropical aquatic species are thought to have a maximum threshold limit of 35 °C. Temperatures in the current research ranged from 24.4 to 34.2 °C, which is within the tropical estuarine waters' threshold limits. According to the study done on Thane creek shows the higher temperatures in April may be caused by increased solar radiation, whereas the lower temperatures in January may be caused by cold breezes and land runoffs [14].

In January, the pH, which gauges the amount of hydrogen ions in water, averaged 7.4. The interaction of evaporation, precipitation, and freshwater inflow causes variations in salinity, a crucial component of marine and estuarine biota. As is typical in estuary salinity distribution, the average salinity for January and April was 30.28 PPT and 29.63 PPT, respectively, showing a spatial gradient towards the estuarine mouth [15]. The seaward rise in surface salinity indicates that Thane Creek's water column was well-mixed [16].

Total suspended solids (TSS) include phytoplankton and zooplankton, silt, clay, agricultural waste, and inorganic and organic components from industrial effluents and domestic sewage. The range of TSS values was 22 mg/L to 265 mg/L. Because of the increased turbidity caused by this loading, the photic zone's depth is decreased.

The oxygen in the water can be quickly reduced by decomposing bacteria [17]. According to The Greek and Eastern Churches shows the bacterial decomposition can cause anoxic conditions in aquatic environments [18]. Dissolved oxygen deficiency as an index of deteriorated water quality, has been widely used in estuarine and coastal waters [19]. The top stations of the research region showed DO levels below 2.5 mg/L, which were deemed hypoxic in Thane Creek [20]. During the January 2023 and April 2023 Station T1 DO values are 1.7 mg/L and 2.5 mg/L Respectively. There is no widely accepted quantitative definition for hypoxia.

In the present investigation N03-N varied between 0.126 to 3.168 mg/l with an average of 0.96 mg/l. Similar and exceptionally higher values were recorded in the earlier studies on Thane creek and were attributed to pollution load shown in [20]. In the present study low NO3-N values were recorded during January 2023 and high values were observed during April 2023. shortage of nitrogen is responsible for even stopping the growth of phytoplankton. On the contrary, enhanced anthropogenic nitrogen inputs to estuaries and coastal seas may affect the nitrogen cycle in these ecosystems and disturb their functioning [21]. The disturbances include eutrophication, changes in phytoplankton community structure, enhanced production and release of nitrous oxide [22].

Earlier studies on the Thane creek near Thane city observed maximum Si03- Si to be 34.82 mg/l. [20]. It has been consistently observed in past studies since 1980. This could be due to the reason that the rocks and the earth crust of Thane region is said to be derived from volcanic rocks which are rich in silica shown in [23]. The other reason could be the sand dredging activity in Ulhas river which is connected to Thane creek. If we try to trace the reason, it becomes apparent that in the past few years there has been a tremendous increase in human activities such as the construction of bridges & roads, solid waste disposal along the mangrove swamps and other reclamation activities. Because of these activities siltation in the creek has significantly increased.

Study done on the Thane creek the concentration of P04-P in general was much higher as compared to 0.09 mg/l, [24]. According to a study done, nutrient loading is one form of anthropogenic stress to estuarine ecosystems, and in shallow systems the responses are more rapid and distinct than deeper waters [25]. It can be seen in a research paper that in the past 20 years there is a gradual but significant rise in the PO4-P concentration indicating the growing pollution in the creek which is shown in the research paper [13].

An earlier study done in a cochin backwaters observed that the salinities progressively decreased from the mouth to the riverine end in Ashtamudi estuary [26]. Similar observations were made in the Malad creek and Thane creek respectively [13] . In the present investigation also, a similar trend was observed. Salinity at Station T1 on the riverine side was 26.64 ppt. which steadily increased to 34.5 ppt. at Station T3 on the seaward side. In January 2023. Same trend was shown in April 2023.

Thane creek being highly nutrient rich DO values below 2.5 mg/l were considered to be hypoxic which is shown [20]. A report showed high dissolved oxygen in Malad creek at the seaward end compared to the riverine end and attributed it to the difference in the sewage load. In the present study station-wise comparison indicated an increasing trend of DO concentration from the riverine to the seaward end. The lower dissolved oxygen at the riverine end can be attributed to accumulation of the pollutants, as this part is narrow, shallow and much away from the mouth, so the pollutants are not properly flushed out. According to the research paper, cultural eutrophication (i.e. anthropogenically induced) results in anoxic or hypoxic conditions and is cited as the most important environmental problem. [13]

Phytoplankton biomass was estimated using chlorophyll-a concentration, which exhibited remarkable spatio-temporal variation throughout the study area. The average chlorophyll-a values in this study aligned with those reported by study showing a positive correlation with silica and temperature [27]. During the study's period average chlorophyll-*a* values were in accordance with those of study done in 2023 [28]. Higher chlorophyll *a* in Thane and Amba during post monsoon indicates the role of higher nutrient concentration in supporting the higher phytoplankton biomass. As in current findings Thane Creek receives a huge quantum of wastes through wastewater treatment facility (WWTF) of Municipal Corporation of Greater Mumbai, Thane Municipal Corporation, Thane-Belapur Industrial Association, Maharashtra Industrial Development Corporation, City Industrial Development Corporation and several industries [29]. Two commercial ports, Mumbai (MbPT) and Jawaharlal Nehru (JNPT) Ports are located towards the mouth of Mumbai Bay or Harbour. Domestic wastewater and a variety of industrial effluents result in the anthropogenic fluxes of pollutants along the eastern and western banks of Thane Creek. Anthropogenically derived nutrient inputs from sewage/domestic discharges and industrial effluents lead to elevated concentration of chlorophyll a and phytoplankton density this relation shown in Research paper [30].

Summary and Conclusion

A total of 30 species of phytoplankton belonging to 17 genera were identified from the study area namely *Coscinodiscales, Leptocylindrales, Rhizosoleniales, Thalassiosirales, Triceratiales, Hemiaulales, Lithodesmiales, Corethrales, Naviculales, Bacillariales, Fragilariales.* Thane Creek is more dominated by Pennate forms of diatoms (76%) among them *Pleurosigma* sp. (34.2%) were more dominated followed by *Navicula* sp. (22.3%) and *Pseudo-nitzschia* sp. (14%) and in Centric Diatoms (24%) and *Skeletonema* sp. (16.1%) was only dominated in January 2023. During April 2023, The Thane Creek is more dominated by Centric Diatoms (79%) among them *Leptocylindrus sp*. (22.5%) were more dominated followed by *Gyrosigma sp.*(9.3%) and in pennate diatoms (21%) among them *Navicula* sp. (25.4%) were more dominant followed by *Pseudo-nitzschia sp.* (13.9%). Current study shows *Pleurosigma* sp. (34.2%) and *Leptocylindrus sp*. (22.5%) were dominant in January 2023 and April 2023. Both species of Phytoplankton act as a pollution indicator. Anthropogenically produced nutrients along the creek and more nutrients load less fresh water influx from the Ulhas river, which could result in a phytoplankton bloom and the dominance of a single species. Similar results were also observed in [31]. This study is not a seasonal study. It was conducted in the months of January 2023 and April 2023. These months are generally called transitional months between two seasons that cause variability in Solar radiation and high evaporation rate as well as another climatic condition that may cause variability in Physico-Chemical Parameters. As mentioned above, the creek receives negligible fresh water flow from the Ulhas river. Domestic wastewater and a variety of industrial effluents result in the anthropogenic fluxes of pollutants along the eastern and western banks of Thane Creek. That explains the higher chlorophyll *a* concentration and lower DO at station T1. Phytoplankton abundance showed positive correlation with the nutrients values which indicates high availability of nutrients in Upper creek to Lower creek because of the increasing phytoplankton assemblages at Upper creek. The value of DO in Thane Creek during the study period is much lower. That leads to the upper part of the Thane Creek showing hypoxic condition.

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