

# Plankton Community Dynamics in the Pasur River Estuary: Correlations with Physicochemical Parameters, Nutrients, and Chlorophyll-a

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**ABSTRACT:** This investigation is centered on plankton communities in relation to physicochemical parameters, chlorophyll-a, and nutrients in the Pasur River Estuary, a crucial aquatic resource hub on the southwestern coast of Bangladesh. Water temperature was consistent throughout the stations, while salinity (4.86–5.08 ppt) and pH (6.67–6.92) values fluctuated slightly. Turbidity was high (211–265 NTU), and the DO value ranged between 3.3 mg L<sup>-1</sup> and 4.7 mg L<sup>-1</sup>. The nutrient dynamics (ammonium: 22.94 µg/L, silicate: 218.25 µg/L, and phosphate: 7.64 µg/L) exhibited higher levels toward the river mouth and decreased seaward, except for phosphate. Chlorophyll-a (mean 5.13 µg/L) was largely controlled by nutrient dynamics, particularly ammonium concentration. Pearson correlation analysis was employed to examine the interrelationships among physicochemical variables, nutrients, chlorophyll-a, and plankton assemblages, revealing complex ecological linkages that regulate community structure and abundance. *Coscinodiscus* sp. and *Metridia* sp. were the most dominant among phytoplankton and zooplankton, respectively. The structural composition and density are attributed to the physicochemical and nutrient parameters from the perspective of spatial fluctuations. As this study was based on a single-season dataset, the findings represent a preliminary yet valuable baseline for understanding plankton–environment interactions in the Pasur River Estuary. The research provides essential baseline data for fisheries and bioresource management and emphasizes the need for multi-seasonal, long-term monitoring and ecosystem modeling to better capture the estuarine dynamics.

**Keywords:** Pasur River; Nutrient; Chlorophyll-a; Phytoplankton; Zooplankton; Sundarbans

## INTRODUCTION

The plankton community, mostly composed of phyto-, zoo-, and bacterioplankton, inhabits the euphotic zone and forms a crucial component of aquatic ecosystems as primary producers, consumers, and decomposers (Reynolds and Padisák, 2013; Yuan et al., 2018). The role of plankton is decisive for productivity as a whole (Song et al., 2004), especially to support fishery resources via the grazing food chain (Karina et al., 2021). Nutrients are the most crucial abiotic factors in marine ecosystems, as they are necessary for biological production and plankton growth (Smayda, 2001). The biomass of phytoplankton, represented by chlorophyll-a (Chl-a) concentration, is an important indicator of the functionality of any aquatic ecosystem. Chl-a is

indispensable for photosynthesis in phytoplankton, and therefore its measurement is directly linked to plankton biomass (Karina et al., 2021).

Tropical and subtropical tidal mangrove estuaries and creeks are home to a wide variety of plankton species (Cornils et al., 2007). These regions are particularly interesting for studying plankton community dynamics due to fluctuating hydrological conditions and salinity (Islam et al., 2006). Fluctuations in physicochemical components in estuarine ecosystems strongly affect plankton communities due to their short life cycles (Taipale et al., 2019). Climate cycles, including seasonal and interannual patterns, influence nutrient availability, which in turn determines plankton community structure. Elevated levels of primary production and nutrient dynamics, coupled with other physicochemical and biotic factors, significantly influence the taxonomic composition of the community structure (Hasan et al., 2022; Kumar et al., 2020). Additionally, changes in monsoonal patterns, rainfall intensity, tidal flow, and nutrient outflow affect photosynthesis, growth,

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composition, and diversity of phytoplankton (Hilaluddin et al., 2020).

Studies across the globe have shown that factors such as temperature, turbidity, and salinity, along with nutrients including  $\text{NO}_3^-$ -N,  $\text{PO}_4^{3-}$ -P, and  $\text{NH}_4^+$ , play a crucial role in shaping plankton communities (Jiang et al., 2015; Santos et al., 2022; Smits et al., 2023). Roy et al. (2016) investigated the influence of environmental factors on biotic communities in aquatic ecosystems, and the effects of salinity on aquatic biota in the estuaries of the Bay of Bengal appear to be particularly strong (Strauss et al., 2023). These global findings provide valuable ecological perspectives, regional conditions often modify the strength and direction of such relationships. The coastal and estuarine waters of Bangladesh, located at the intersection of major rivers and the Bay of Bengal, present one of the most dynamic interfaces where these interactions can be examined under unique ecological settings.

The coastal region of Bangladesh experiences pronounced variability in plankton–environment interactions due to the combined influence of freshwater discharge, tidal exchange, and saline intrusion (Sarker et al., 2021). The Sundarbans, the world’s largest single-unit mangrove ecosystem (10,000 sq. km), supports a rich variety of plankton. A handful of studies have been conducted on plankton communities and environmental parameters in the Indian part of the Sundarbans (Basu et al., 2022; Bhattacharjee et al., 2025; Bhutia et al., 2024; Gogoi et al., 2021). In contrast, plankton studies in the Bangladesh part (6,000 sq. km) remain limited.

It is essential to examine how global ecological principles in terms of plankton and environmental parameter interactions manifest under the local conditions of the Bangladesh part of the Sundarbans to bridge this global-to-local knowledge gap. Earlier studies in the Pasur River have explored certain aspects of plankton communities, most focused on either phytoplankton or zooplankton, or considered only a limited set of environmental parameters (Ahmed et al., 2019; Bir et al., 2015; Rahaman et al., 2013). Very few have included zooplankton, and none have addressed the integrated relationships among phytoplankton, zooplankton, and key physicochemical and nutrient parameters such as temperature, salinity, turbidity, dissolved oxygen, nitrate, phosphate, and silicate. The present study fills this gap by simultaneously examining

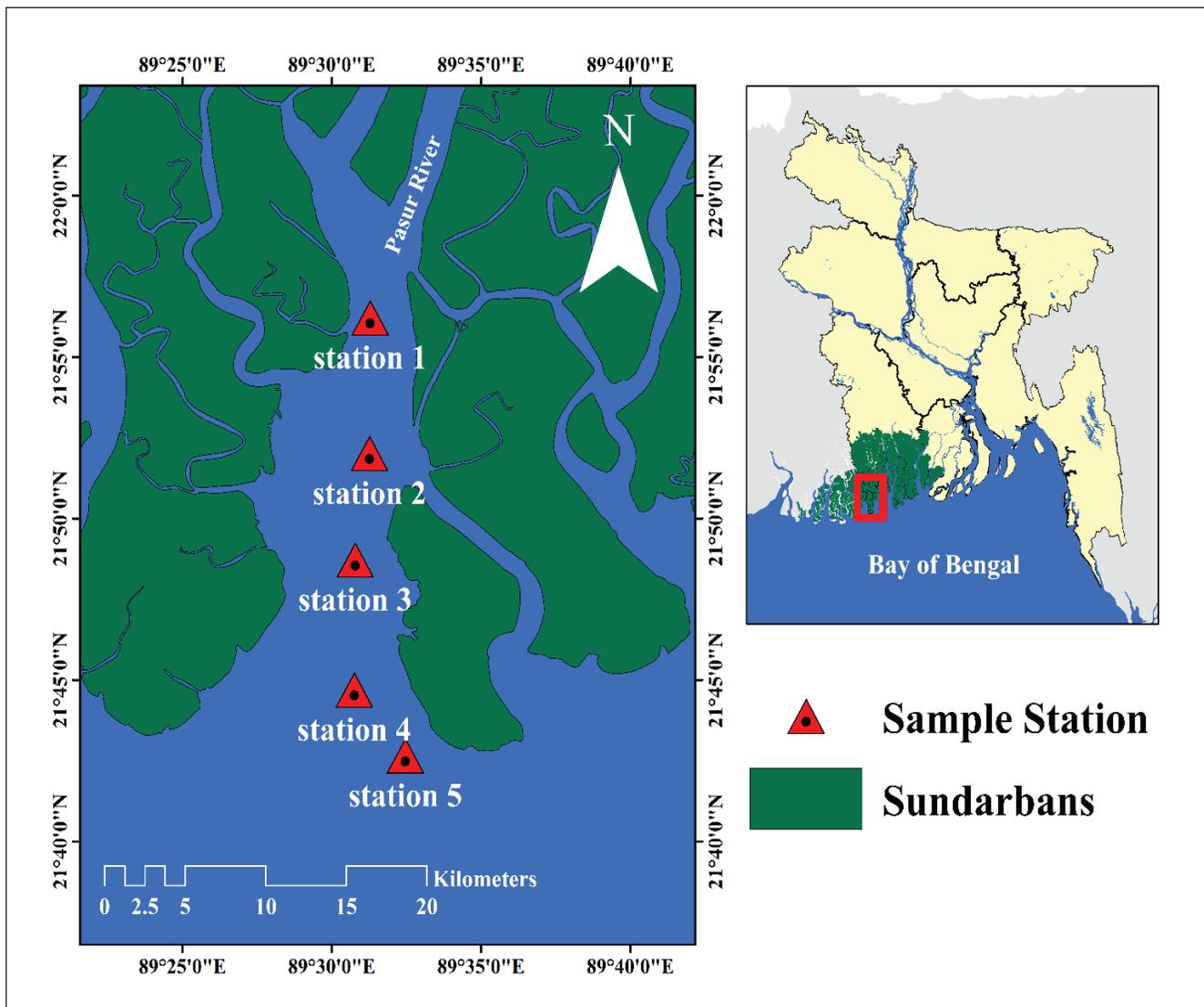
phytoplankton and zooplankton communities and exploring their interlinked relationships with multiple environmental drivers. This integrated approach provides a more comprehensive understanding of the ecological dynamics of the Pasur River estuary.

In the fiscal year 2023–2024, nearly 17.5% of the total shipping activities of Bangladesh occurred through Mongla Port (Elahi, 2024). Additionally, the Pasur River estuary supports the Sundarbans mangrove forest, which is a critical hub for regional biodiversity and livelihoods, including honey collection, sustainable wood harvesting, fisheries, and ecotourism (Kabir et al., 2019). The estuary, enriched with vital fishery resources (around 322 species), contributes significantly to the livelihoods of communities in southwestern Bangladesh (Habib et al., 2020). Its nutrient-rich waters enhance fish productivity, supporting both local consumption and commercial fisheries (Hasan et al., 2022). Given its ecological and economic importance, the Pasur River estuary serves as an ideal site to investigate how plankton community dynamics reflect the broader environmental health of the Sundarbans ecosystem. Therefore, this study examines the structure of plankton communities (both phytoplankton and zooplankton) in the Pasur River estuary and explores their interrelationships with key physicochemical and nutrient parameters to provide a comprehensive understanding of estuarine ecological dynamics.

## MATERIALS AND METHOD

### Study Area

Pasur River Estuary (PRE) was selected as the study area for the present investigation. The Pasur River is a part of the Ganges-Brahmaputra-Meghna (GBM) delta and the largest river in the region (Hasan et al., 2022). It has significantly encompassed both ecological and economic aspects due to the port city of Khulna. The estuary is crucial for dynamic nutrient cycling, primary production, and aquatic biota (Hasan et al., 2022). The enriched water resources are used in the shrimp culture and broad-scale aquaculture (Kabir et al., 2019). Moreover, it is a major transportation route in the southwestern part of the country, supporting trade and commerce (Shefat, 2020). The second-largest shipping port, Mongla, Bangladesh, is also situated in this estuary. For simplicity, the whole study area was divided into five zonations (Fig. 1).



**Figure 1:** Study Area Map of Pasur River Showing the Sampling Locations and the Location of Sundarbans Mangrove Forest

### Sampling and Laboratory Analysis

Samples for the present study were collected covering the monsoon season (September 2022) of Bangladesh from five stations (Fig. 1). The total depth of the water column at the stations ranged from approximately 8 to 15 m, depending on tidal conditions. A Wildco-1520 (Cole-Parmer India; capacity 1.5 L) water sampler was used to collect composite (integrated) water samples from the surface layer (0–0.5 m), representing the approximate euphotic zone of the river (Hasan et al., 2022). Each integrated sample consisted of subsamples collected from three random surface points at the

station, which were then mixed thoroughly to obtain a representative composite sample. Sampling was conducted between 08:00 and 10:00 a.m. (Local time) to minimize diurnal variation in physicochemical properties and phytoplankton activity. The water was then immediately vacuum-filtered through a 0.45  $\mu\text{m}$  membrane filter and kept in a dark environment until laboratory analysis. At each sampling station, a well-calibrated conductivity-temperature-depth (CTD) meter (Seabird Electronics, SBE 19 plus) was employed in situ to measure water temperature ( $^{\circ}\text{C}$ ), turbidity (NTU), dissolved oxygen (DO, mg/L), and pH using specific sensors.

Dissolved macronutrients, namely, ammonium ( $\text{NH}_4^+$ ), silicate ( $\text{SiO}_4^{2-}$ ) and inorganic phosphate ( $\text{PO}_4^{3-}$ ) were determined by following the standard spectrophotometric procedures using a double-beam spectrophotometer (Shimadzu UV-Visible 1800, Japan) outlined by Grasshoff et al. (2009). In order to measure Chl-a levels, a fluorometer (Turner Designs, Trilogy) was used following the method developed by Marker (1980). This method consisted of twofold extraction followed by hot and cold treatments. Equation 1 was used for the quantification of Chl-a.

$$\text{Chlorophyll-a} = \frac{29.6 (E_b - E_a) \times v}{V \times l}; \quad (1)$$

Here,  $E_b$  = optical density before adding 2M HCl,  $E_a$  = optical density after adding 2M HCl,  $v$  = extracted volume of the pigment in ml,  $V$  = filtered volume of sample water in liters, and  $l$  = path length of the cuvette used to measure optical density in cm.

Phyto- and zooplankton samples were collected at each station by filtering 100 liters of water through 65  $\mu\text{m}$  and 100  $\mu\text{m}$  mesh-sized plankton nets, respectively. The collected concentrates of phyto- and zooplankton were preserved by adding the desired amount of commercial formaldehyde (buffered) to reach a final concentration of 2 and 4%, respectively. The photomicrographs of plankton were captured using a research microscope (Novel, N10E, China); they were taxonomically identified, and the abundance was calculated following Jahan et al. (2024) by the equation:

$$N = \frac{c \times V_1}{V_2 \times V_3}; \quad (2)$$

Here,  $C$  = number of organisms,  $V_1$  = concentrated sample volume, and  $V_2$  = counted sample volume,  $V_3$  = water filtrate volume

### Quality Control and Assessment

Comprehensive quality control measures were implemented during both field sampling and laboratory analysis to ensure data reliability. At each station, three independent water samples were collected for each parameter to serve as field replicates. Each sample was analyzed in duplicate in the laboratory to ensure analytical consistency and accuracy. Field blanks and spike samples were employed to validate sampling and analytical procedures, preventing contamination and

verifying recovery rates. The results presented in this manuscript represent the mean values of all replicates. For clarity and to focus on spatial and temporal patterns of physicochemical parameters, nutrients, chlorophyll-a, and plankton densities, error bars are not shown in the figures. Analytical-grade reagents and pre-cleaned equipment were consistently used to maintain precision and reproducibility throughout the study.

### Statistical Analysis

Pearson's correlation analyses were conducted to explore the relationships among physicochemical parameters (salinity, pH, dissolved oxygen, turbidity), nutrients ( $\text{NH}_4^+$ ,  $\text{SiO}_4^{2-}$ ,  $\text{PO}_4^{3-}$ ), chlorophyll-a, and plankton densities (phyto- and zooplankton). All analyses were performed using Python 3.13 with the pandas, numpy, and scipy libraries. The dataset comprised five sampling stations ( $n = 5$ ), each representing spatial variability across the Pasur River Estuary. Pearson correlation coefficients were used to assess the strength and direction of relationships between variables, with significance levels set at  $p < 0.05$ . Correlation matrices were visualized using seaborn's heatmap function to provide an integrated view of the relationships. Given the limited sample size, correlations were interpreted as indicative ecological trends rather than definitive statistical inferences.

## RESULTS AND DISCUSSION

### Physicochemical Parameters

Water temperature was around 29°C throughout the sampling stations. Surface water temperature in the Pasur River Estuary showed uniformity on a spatial scale. The temperature homogeneity can be attributed to the shallow depth of the estuary that enables consistent heating and cooling (USEPA, 2015). This temperature stability likely supports uniform metabolic activity among plankton taxa across sites (Schulte, 2015). Similar to temperature, salinity variation was indistinct, ranging from 4.86 to 5.08 ppt (Fig. 2a). This subtle salinity variation provides an improper habitable condition for marine and brackish diatoms due to their salinity tolerance capacity, while it's preferable for freshwater diatoms (Stenger-Kovács et al., 2023). The heavy rainfall and the resultant freshwater inflow from the land during the monsoon and post-monsoon seasons moderately reduced the salinity (Zinat et al.,

2021). Moreover, the pH value ranged between 6.67 and 6.92 (Fig. 2b), a favorable condition for plankton communities, though lower values are also reported by Shefat et al. (2020) in the same study area. This consistent pH level is suitable for the growth of fish and other aquatic life (Zinat et al., 2021). The measured value of turbidity ranged between 211 and 265 NTU (Fig. 2c), which might hinder light availability for phytoplankton and hamper photosynthesis (Soballe, 1988). Moreover, it can lead to physical stress for

zooplankton as well (Zhou et al., 2018). Dissolved oxygen (DO) determines the amount of oxygen available for aquatic organisms (Bozorg-Haddad et al., 2021). The maximum and minimum DO values were at station 1 (4.7 mg/L) and station 3 (3.3 mg/L), respectively (Fig. 2d). Phytoplankton, depending on photosynthesis, may thrive in low-oxygenated conditions (Dhar and Baghel, 2015). Moreover, zooplankton might respond negatively to the oxygen stress as well (Karpowicz et al., 2020).

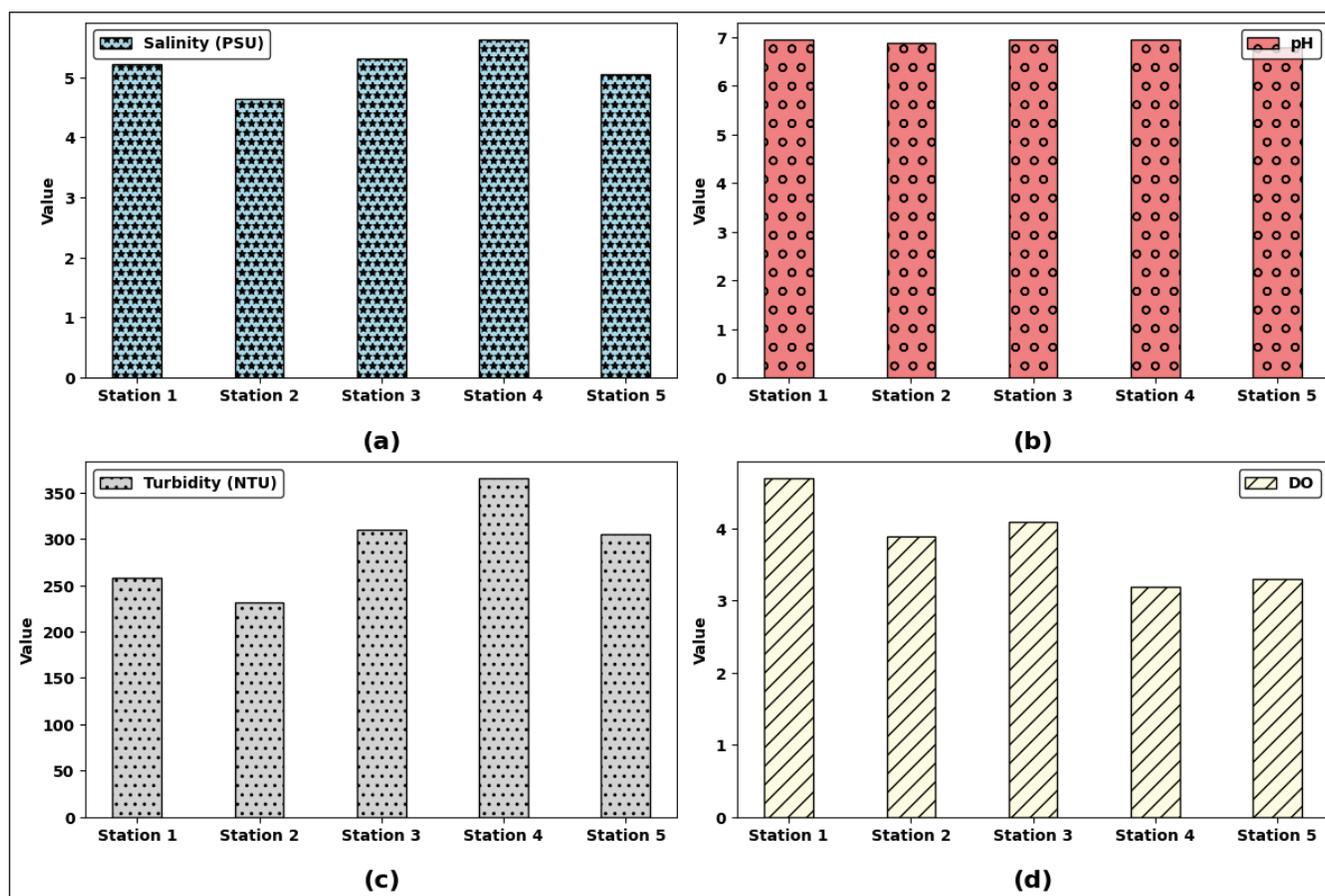


Figure 2: Physicochemical Parameters of the Sampling Station

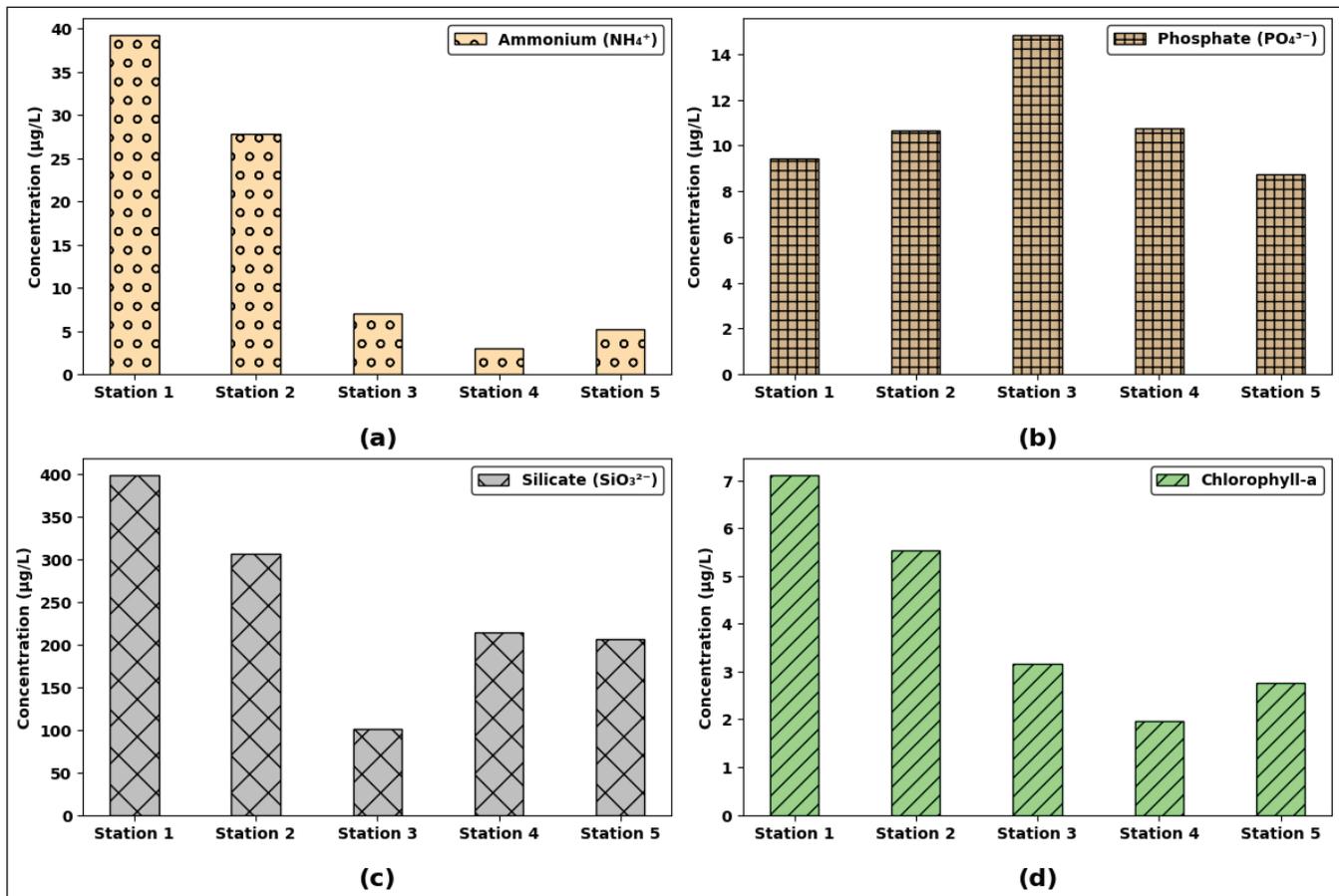
## Nutrients

Three crucial nutrient components (ammonium, silicate, and phosphate) of the water sample were assessed that might influence plankton growth and abundance. Ammonium at the study locations ranged from 5.13 to 38.22  $\mu\text{g/L}$ , with an average value of 22.94  $\mu\text{g/L}$  (Fig. 3a). Elevated levels of ammonium ( $\text{NH}_4^+$ ) at Station 1, decreasing towards Station 4, and a slight increase at Station 5 suggest substantial nutrient input from

riverine discharge and land runoff (Arndt et al., 2011). The documented processes of tidal flushing indicate that they carry  $\text{NH}_4^+$  dominated nutrients in the Pasur River estuary in general. Moreover, the surrounding regions engage in nitrogen-based fertilizer for agriculture and aquaculture, which might enrich the ammonium in Station 1 (Rahaman et al., 2013). However, Shefat et al. (2020), in his research in the same study area, found a higher level of ammonium, which can be attributed to the temporal differences, as the sampling times

differ from the present investigation. Such nutrient enrichment near the upstream region found in the current investigation provides favorable conditions for

phytoplankton proliferation, as reflected in the higher cell densities observed in the same zone.



**Figure 3:** Spatial Variation of Nutrients and Chlorophyll

Silicate at the study locations ranged from 95.64 to 399.34 µg/L (Fig. 3b), with an average of 218.25 µg/L. It demonstrated a declining pattern from station 1 to station 3 and then a moderate increase until station 5. High concentrations at Station 1, decreasing seaward, may be linked to sediment resuspension and diatom dynamics (Yin et al., 2000). The silicate-enriched sediment transportation might explain the higher silicate concentration that decreases towards the Bay of Bengal. The PRE had a very high silica concentration. Dissolved silica is a vital nutrient required for diatomaceous plankton growth, especially for frustule formation (Kumar et al., 2020). Silica plays a very important role in regulating the community composition of phytoplankton (Sospedra et al., 2018). A drop in silica levels could be observed where diatoms flourish (Kumar et al., 2020).

Dissolved inorganic phosphate (DIP) at the study locations ranged from 8.97 to 11.44 µg/L, with an average of 7.64 µg/L (Fig. 3c). It demonstrated an increasing trend from Station 1 to Station 3, then a moderate decline until Station 5, indicating localized variations in nutrient sources or biological uptake. The highest phosphate concentration can be attributed to sediment resuspension and unique water flow and mixing (Wang et al., 2020). Generally, the average DIP concentration was significantly higher in the tidal mangrove creeks than in PRE. The phosphate bioavailability depends upon sedimentary organic matter breakdown, riverine loadings, and adjacent coastal water intrusion into the estuary during flood tide (Kumar et al., 2020).

The decreasing trend in both nutrients and plankton abundance from Station 1 to Station 3 in general reflects a typical estuarine-to-marine transition, where nutrient

availability diminishes with increasing distance from terrestrial input sources (Jiang et al., 2015).

### Chlorophyll-a

Chl-a concentration showed spatial variation among the five stations (Fig. 3d), exhibiting similar trends with nutrients (except phosphate), ranging from 2.76 to 7.10  $\mu\text{g/L}$ , with a mean of 5.13  $\mu\text{g/L}$ . This pattern indicates a positive interaction of Chl-a and nutrients. Though Chl-a concentration is not always equivalent to primary production because that also depends on favorable environmental conditions related to temperature, light, nutrient availability, and the abundance of secondary producers in the ecosystem (Hilaluddin et al., 2020). However, it's an indirect measure of phytoplankton biomass and the trophic state of estuarine and oceanic waters (Hasan et al., 2022). Mangrove creeks, which are known for nutrient outwelling to adjacent areas, especially during spring tides, are closer to Station 1. This nutrient influx promotes phytoplankton growth and may lead to elevated Chl-a concentrations. Notably, sampling for the present study was conducted during September, which is a month of high spring tides (Gonzalez, 2022). Though Station 3 is closer to those creeks too, however, it faces sediment disturbance, which can inhibit photosynthesis and consequently decline phytoplankton, which may explain the lower level of chl.-a (Roy et al., 2016). Generally, Chl-a concentration is lower in the PRE (Hasan et al., 2022).

### Composition and Abundance of Plankton Community

#### Phytoplankton

The phytoplankton community was mainly dominated by centric diatoms (Bacillariophyceae). A total of four species of phytoplankton were observed under three genera (Fig. 4). Fluctuations in phytoplankton abundance (cells/L) during the study are shown in Figure 5, ranging from 2500 to 75000 cells/L. It demonstrated an increased abundance at the upstream, while a decline was observed closer to the sea. During monsoon months, phytoplankton abundance in general is found to be lowest as the water column remains remarkably stratified to a large extent due to heavy rainfall, high turbidity caused by runoff, reduced salinity, lower pH and TDS, overcast skies, and cool conditions (Zinat et al., 2021). *Asteromphalus* sp. and *Coscinodiscus* sp.

were distinct genera found in this study, where the latter was dominant. Phytoplankton cell density variation is a little higher than the value (2500–7500 individuals per liter) found in the study of Zinat et al. (2021) in the same study area. Moreover, *Asteromphalus hyalinus* and *Coscinodiscus* sp. were distinct species in the investigation. *Coscinodiscus* sp. was dominant in the present study as well as that reported by Hasan et al. (2022) in the same investigation zone. This indicates the favorable status of primary production and carbon fixation in the study area (Giangrande et al., 2020). Bacillariophyceae was the most abundant group in this study. Diatomaceous algae are dominant in mangrove waters, which could be due to the fact that diatoms (Bacillariophyceae) can tolerate the widely changing hydrographical conditions (Islam et al., 2017; Zinat et al., 2021).

#### Zooplankton

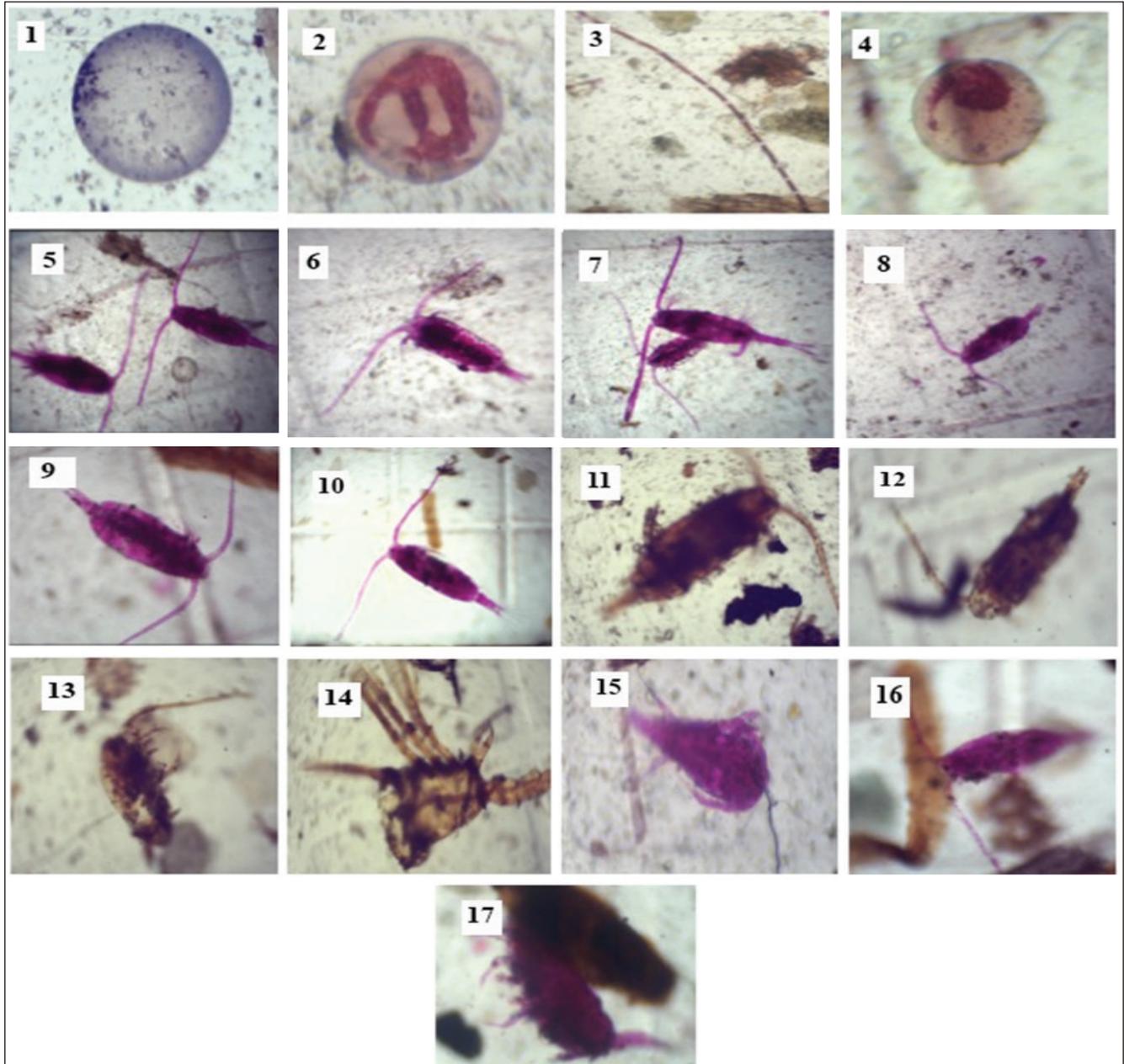
The zooplankton composition in the current study estimated about 13 species belonging to 8 genera. The qualitative taxonomy is a bit lower than in the Pasur-Sibsa and Baleshwari River Estuaries (Majumdar et al., 2022). It might be due to the shorter range and duration of sampling in the current study. Species belonging to Metridia and copepods were most dominant, whereas species belonging to Evaden and Candacia were least abundant (Fig. 4). This investigation found the abundance of zooplankton to be 2000–10000 cells/L (Fig. 5). Hilmi et al. (2020) reported the density to be between 261 and 2204 individuals/L, which is notably lower than the finding of this study. The findings of this study showed a decreasing trend from downstream towards the Bay of Bengal. *Metridia* sp. and *Oithona* sp. were notably higher in this study compared to Majumdar et al. (2022) for the common genera. However, *Acartia negligens* was common at the species level and coincided in the quantitative estimate as well. Mangrove ecosystems are suitable habitats to support the growth of zooplankton as nursery grounds, feeding grounds, and spawning grounds. The zooplankton density was influenced by the responses of the surrounding river mouth, organic matter and nutrients, and mangrove ecosystem (Hilmi et al., 2020).

#### Correlation of Plankton Genera and Physiochemical Parameters

The correlation analysis in Figure 6 provides a comprehensive view of the interconnectedness among

physicochemical parameters (temperature was excluded as it remained nearly constant), nutrient components, chlorophyll-a, phytoplankton, and zooplankton, revealing key ecological insights. The color gradient bar ranges from blue (negative correlation) to red (positive correlation), with the intensity representing the

correlation strength. Among the parameters and plankton species those holding a strong to moderate correlations with statistical significance were discussed focusing on ecological implication. It provides preliminary ecological insights into plankton–environment linkages within the Pasur River Estuary.



**Figure 4:** Photomicrographs of Phytoplankton (1–4) and Zooplankton (5–17) Communities upto Species Level (1. *Coscinodiscus* sp.; 2. *Asteromphalus hyalinus*; 3. *Melosira granulata*; 4. *Coscinodiscus* sp.; 5. *Acartia negligens*; 6. *Metridia* sp.; 7. *Oithona plumifera*; 8. *Paraeuchaeta norvegica*; 9. *Labidocera trispinosa*; 10. *Metridia longa*; 11. *Candacia armata*; 12. *Labidocera trispinosa*; 13. copepod sp.; 14. copepod nauplii; 15. *Evaden* sp.; 16. *Acartia* sp.; and 17. *Metridia lucens*)

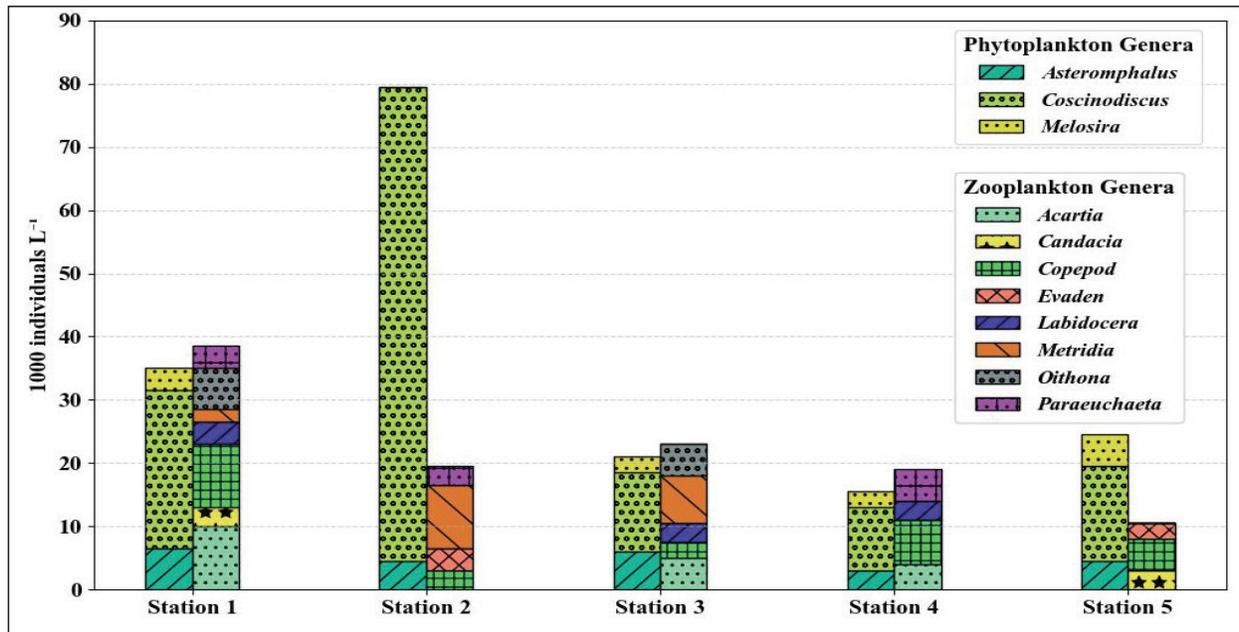


Figure 5: Abundance and Distribution of Phytoplankton and Zooplankton

### Influence of Physicochemical Parameters

Within the phytoplankton community, *Coscinodiscus* sp. showed a very strong negative correlation ( $|r| > 0.75$ ;  $p < 0.05$ ) with salinity, indicating its affinity for brackish conditions. Conversely, *Asteromphalus* sp. displayed a moderate negative correlation ( $|r| \approx 0.50$ – $0.75$ ) with turbidity but not in a significant way ( $p > 0.05$ ). *Asteromphalus* sp. also demonstrated a strong positive correlation ( $|r| > 0.75$ ;  $p < 0.05$ ) with dissolved oxygen (DO), suggesting its preference for oxygen-rich environments. Among zooplankton, *Acartia* sp. showed a moderate positive correlation with salinity, consistent with its tolerance of broad salinity gradients but preference for brackish waters. In contrast, *Evaden* sp. was strongly negatively correlated ( $|r| > 0.75$ ;  $p < 0.05$ ) with salinity, while *Labidocera* sp. exhibited a strong positive correlation ( $|r| > 0.50$ ;  $p < 0.05$ ). Unlike phytoplankton, zooplankton were highly responsive to pH. *Labidocera* sp. both exhibited strong positive correlations ( $|r| > 0.75$ ;  $p < 0.05$ ) with pH, consistent with evidence that pH significantly affects copepod survival and genotoxicity (Halsband et al., 2021). *Acartia* sp. and *Oithona* sp. had a very strong positive relationship ( $|r| > 0.75$ ;  $p < 0.05$ ) with DO, indicating that oxygen availability exerts bottom-up control on zooplankton abundance.

### Influence of Nutrients

Marine microbiota, including plankton community, are crucially shaped by the bioavailability of nutrients (Farias et al., 2024). Most of the phytoplankton, including *Asteromphalus* sp. and *Coscinodiscus* sp., exhibited a moderate increase ( $|r| \approx 0.50$ ;  $p < 0.05$ ) with the availability of ammonium. *Coscinodiscus* sp. was moderately positive in connection to silicate. This aligns with diatoms' requirement for silica to build frustules and their reliance on ammonium (Arumugham et al., 2023). However, phosphate was the least significant factor in the phytoplankton community, affecting only *Melosira* sp. in a moderately positive ( $|r| \approx 0.50$ ;  $p < 0.05$ ) way. It suggests a possible phosphate limitation or competition, where high phosphate is associated with other taxa or trophic states. *Acartia* sp., *Copepod* sp., and *Oithona* sp. responded moderately ( $|r| \approx 0.50$ ;  $p < 0.05$ ) with ammonium increases in a positive way in the zooplankton community. Notably, the intensity of moderateness was similar for all. Interestingly, silicate availability affected none of the species in the zooplankton community. Notably, phosphate availability impacted the zooplankton community in a negative way. For example, *Candacia* sp. showed a strong negative correlation ( $|r| > 0.75$ ;  $p < 0.05$ ); *Copepod* sp. demonstrated a moderately negative correlation as well ( $|r| \approx 0.50$ ) however the interaction is not

statistically significant ( $p > 0.05$ ); moreover, *Metridia* sp. demonstrated a moderate positive correlation ( $|r| \approx 0.50$ ;  $p < 0.05$ ). It suggests phosphate-rich but nitrogen-limited conditions may not favor copepod productivity. Alternatively, phosphate could serve as a signal of ecological states less conducive to copepod success.

### Influence of Chlorophyll-a

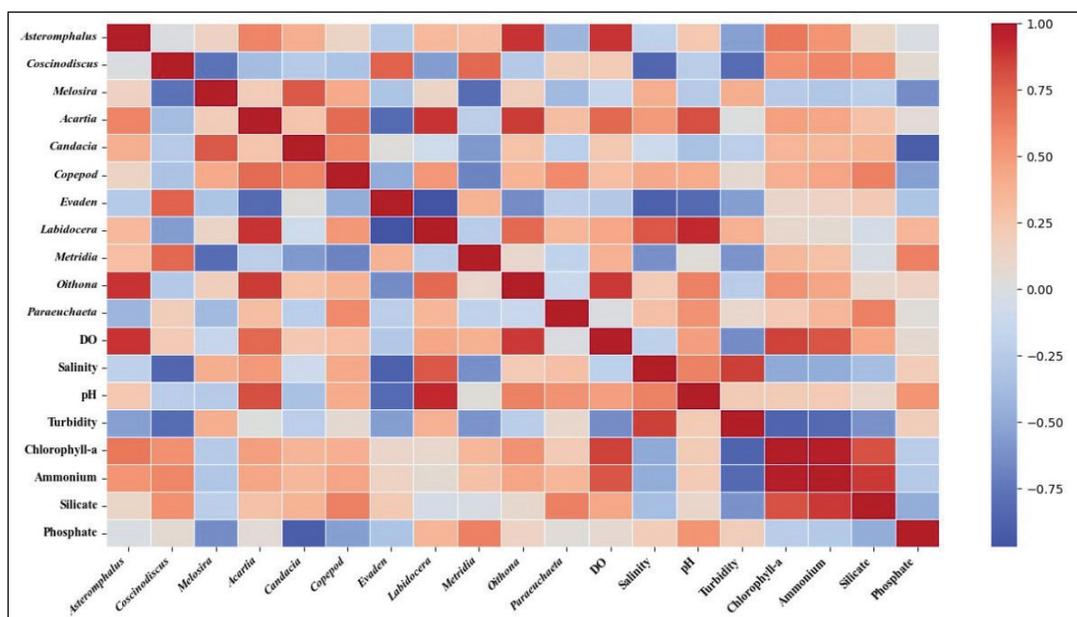
*Asteromphalus* sp. ( $|r| > 0.50$ ;  $p < 0.05$ ) and *Coscinodiscus* sp. ( $|r| \approx 0.50$ ;  $p < 0.05$ ) from the phytoplankton community positively correlated with chlorophyll-a, supporting the idea that chlorophyll-a is a proxy for phytoplankton biomass; it's a pigment necessary for photosynthesis contained in phytoplankton (Bock et al., 2022; Shen et al., 2020). Zooplankton species, including *Acartia* sp. ( $|r| \approx 0.50$ ;  $p < 0.05$ ) and *Oithona* sp. ( $|r| \approx 0.50$ ;  $p < 0.05$ ), exhibited a moderate correlation with chlorophyll-a, which might be explained by the predation and grazing effect. The consumption of phytoplankton leads to a decline in chlorophyll-a (Lomartire et al., 2021).

### Interactions within and between Plankton Communities

The correlation network revealed complex inter- and intra-community relationships. Among phytoplankton, *Coscinodiscus* sp. and *Melosira* sp. were strongly negatively correlated ( $|r| > 0.75$ ;  $p < 0.05$ ), indicating

competitive exclusion or niche differentiation (Trombetta et al., 2021). In the zooplankton community, *Acartia* sp. and *Copepod* sp. showed strong positive co-occurrence ( $|r| > 0.75$ ;  $p < 0.05$ ), suggesting shared feeding niches and functional guild behavior (Shi et al., 2025). Conversely, *Acartia* sp. and *Evaden* sp. exhibited negative associations ( $|r| > 0.75$ ;  $p < 0.05$ ), indicating prey partitioning or resource competition. However, *Acartia* sp. and *Oithona* sp. were strongly positively associated ( $|r| > 0.75$ ;  $p < 0.05$ ), suggesting synergistic coexistence in similar ecological niches.

A cross-trophic interaction between the phytoplankton and zooplankton community was also observed. *Asteromphalus* sp. showed strong positive co-occurrence ( $|r| > 0.75$ ;  $p < 0.05$ ), with *Oithona* sp. and moderate correlation with *Acartia* sp., suggesting close trophic coupling. *Coscinodiscus* sp. correlated strongly ( $|r| > 0.75$ ;  $p < 0.05$ ), with *Evaden* sp. and *Metridia* sp., likely due to feeding dependencies or microbial food chain interactions (Trombetta et al., 2021). Conversely, *Coscinodiscus* sp. had a moderate negative ( $|r| \approx 0.75$ ;  $p < 0.05$ ), relationship with *Labidocera* sp., indicating possible avoidance or predator-prey tension. *Melosira* sp. exhibited a strong positive association with *Candacia* sp. but an inverse relation with *Metridia* sp., reflecting selective grazing or size-based feeding preferences (Meyer et al., 2002).



**Figure 6:** Correlation of Plankton Communities and Environmental Variables

## Implications and Insights for Policymakers

This study highlighted the ecological relationships between plankton communities, nutrients, and key water quality parameters in the Pasur River Estuary. The findings provide essential baseline information that can help policymakers and managers monitor the condition of this ecologically and economically important system. Understanding these relationships is important for designing effective monitoring programs and early warning systems for ecosystem changes. Plankton are central to the aquatic food web and play a crucial role in carbon cycling and energy transfer. Insights from this research can therefore guide better management of fisheries and other aquatic resources, as plankton abundance directly affects fish and crustacean stocks (Jia et al., 2022; Ashaari et al., 2024). The study also identifies key species and their associations with environmental factors, which can support more focused conservation and resource management initiatives. Overall, the outcomes contribute to informed, ecosystem-based decisions for sustaining aquatic biodiversity and community livelihoods.

## CONCLUSIONS

This research enlightens about the plankton community dynamism with respect to the physicochemical parameters, nutrients, and chlorophyll-a. The occurrence, structure, and abundance of the species belonging to the phytoplankton as well as the zooplankton communities were dynamically dependent on all physicochemical parameters, nutrients, and chlorophyll-a. DO and phosphate were the most dominant among environmental and nutrient parameters, respectively. Among the phytoplankton community, the most dominant were *Asteromphalus* sp. and *Coscinodiscus* sp. Both species were strongly influenced by DO and ammonium in a positive way. *Acartia* sp. was the most dominant amongst the zooplankton. Despite the fluctuating environmental conditions, this estuary was observed to support a productive plankton community. Primarily, diatoms dominated the plankton community, reflecting a higher amount of primary productivity, while copepods thrived amongst the zooplankton, supported by the mangrove aquatic ecology. The plankton communities were shaped by nutrient dynamics, with strong phytoplankton-nutrient correlations, coupled with zooplankton-phytoplankton-

physical factor interactions. These findings highlighted the interconnection and indispensability of the environmental, nutrient, and biological parameters. It is important to note that this study was conducted during a single season (monsoon, September 2022), and therefore the results represent a temporal picturesque of the Pasur River Estuary. Seasonal variations in temperature, salinity, nutrient availability, and plankton dynamics are expected, which may influence the observed patterns of phytoplankton and zooplankton abundance, community structure, and their correlations with environmental variables. These findings provide valuable baseline data and preliminary ecological insights, future studies covering multiple seasons and years are necessary to capture temporal variability and to validate the trends observed here. The current research will be a valuable reference, especially to the fisheries management and mariculture sectors in the Pasur River Estuary. Future research is recommended to focus on long-term investigation on all the parameters in a greater spatial range with a modeling simulation approach for better understanding of the aquatic ecosystem dynamics.

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