Assessment of Physicochemical Characteristics and Fish Diversity in the Vamsadhara Estuary, Andhra Pradesh, India

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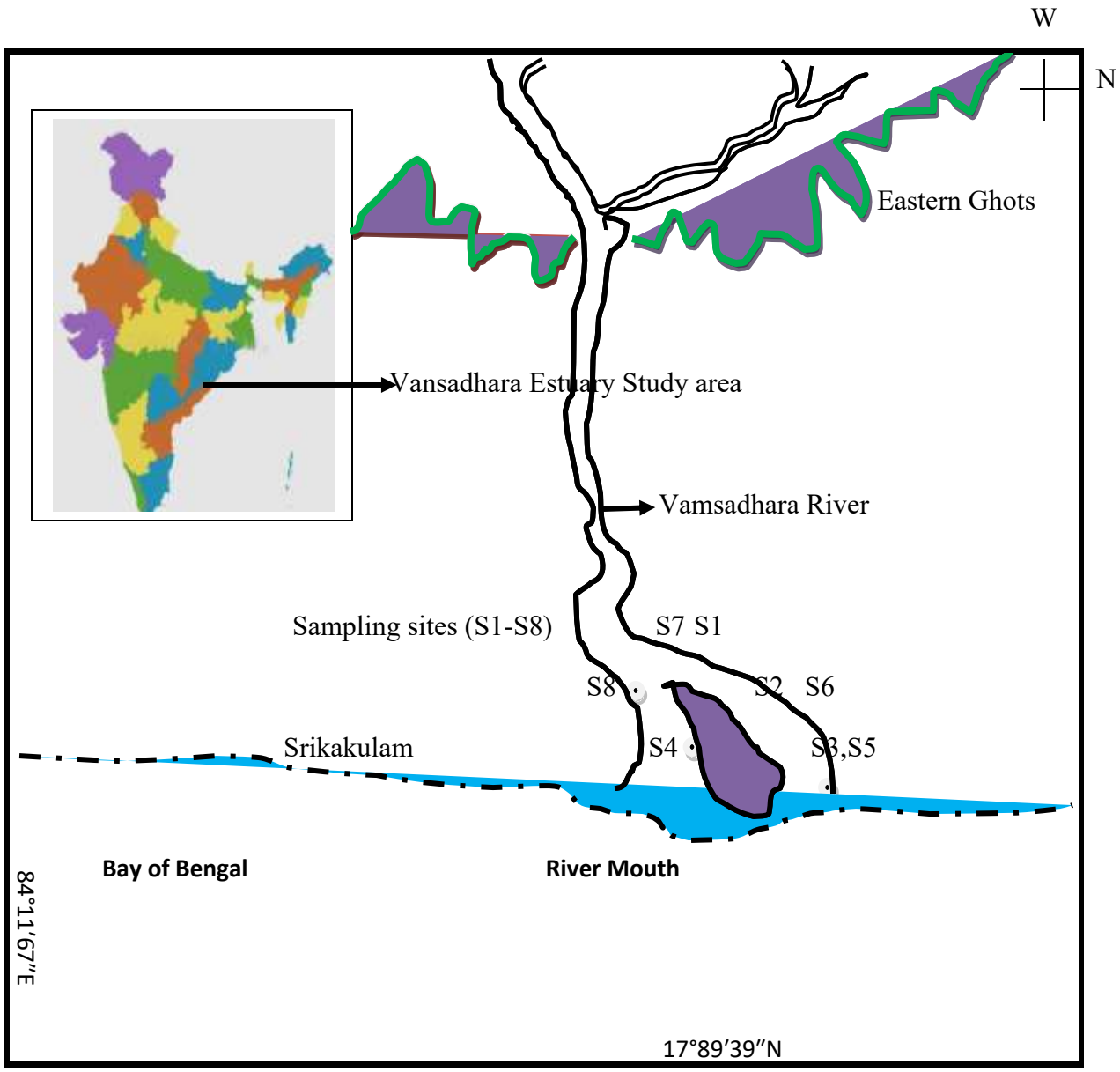
Abstract:

Estuaries are facing a wide range of human-induced impacts due to uncontrolled developmental activities, both direct and indirect. Social anthropogenic activities play a major role in influencing water quality in estuarine ecosystems. Physico-chemical changes tend to accumulate in various organs of estuarine organisms, especially ichthyofauna, which may enter the human metabolic system through the food chain, causing serious health hazards. Ichthyofaunas in estuaries are influenced by various physico-chemical parameters such as temperature, pH, salinity, dissolved oxygen (DO), and others. The present study was carried out to analyze various physico-chemical parameters along with ichthyofaunal samples collected from eight sites (S1–S8) over a period of one year, from August 2024 to July 2025, in the Vasadhara estuary on the east coast of India. Environmental parameters such as temperature, salinity, pH, dissolved oxygen, nitrates, and silicates were measured. In the study area, atmospheric temperature varied from 26.8 °C to 34.3 °C, while surface water temperature ranged from 24.2 °C to 32.5 °C. The monthly mean values of hydrogen ion concentration (pH) varied from 7.2 to 8.3. Other parameters showed the following ranges: salinity 5.8 to 34.5 ppm, dissolved oxygen 4.2 to 6.9 mg/L, phosphorus 0.41 to 2.26 mg/L, nitrate 0.65 to 3.89 mg/L, silicate 32 to 98 mg/L, and total alkalinity 152 to 217 mg/L in the estuary. A total of 892 fish specimens were collected from the various sites, belonging to six orders and five families. In the study area, *Mugilcephalus* was the dominant species, accounting for 24.32% of the total ichthyofaunal composition.

Key words: Vamsadhara estuary, Ichthyofauna diversity, Physicochemical parameters.

Fig: 1: Study area map along with Longitudinal and latitudinal direction:



1. Introduction:

The Vamsadhara estuary is located on the eastern coastal side of India, approximately 15 km away from Srikakulam town, Andhra Pradesh. Surface water fluvial ecosystems play a major role in transporting water along with nutrients across surrounding regions of the Earth and are significant components of the global water cycle.

Water resources are of considerable importance due to their multiple uses, such as residential supply, drinking and domestic purposes, irrigation for agriculture, transportation, infrastructure development, recreation, hydroelectric power generation, and other economic activities (1). Pollution of aquatic ecosystems poses a serious threat to mankind, both directly and indirectly, through food chains and food webs (1).

Estuaries are dynamic environmental hubs that receive large quantities of materials from industrial sites and urban drainage systems, as reported by Light et al. (2). Coastal resources and natural defense structures are being destroyed, and coastal areas are decreasing due to urbanization and industrialization (3). Industrial effluents and agricultural wastes are considered primary sources contributing to increased nutrient loads in nearby aquatic bodies.

India is endowed with a long coastline of approximately 8,516 km, of which nearly 6,000 km consists of estuaries, brackish waters, creeks, lagoons, and lakes. Large industries located near coastal regions have become a major threat to estuarine and coastal water environments (4).

Eutrophication is a major concern in aquatic environments, leading to excessive algal growth and blooms. These conditions reduce dissolved oxygen levels, resulting in mortality of aquatic flora and fauna and ultimately causing a loss of biodiversity. Natural inputs such as precipitation, erosion, and weathering, along with anthropogenic influences including urban, industrial, and agricultural activities, are intensifying water exploitation.

Environmental fluctuations in aquatic systems, such as dissolved oxygen (DO), salinity, temperature, stratification, water movement, topography, and nutrient characteristics, determine the composition of biota (5). Shore waters and estuaries exhibit physiological changes due to seasonal variations, local rainfall conditions, tidal incursions, biotic and abiotic processes, and variations in freshwater inflow, all of which influence nutrient cycling in coastal environments (6).Physico-chemical fluctuations in water bodies are largely controlled by the natural distribution of aquatic flora and fauna (7, 18). In recent decades, numerous investigations have reported the widespread dispersal of various contaminants that ultimately pollute water systems worldwide (2–3). This global expansion of contamination is expected to have serious impacts on biodiversity and human health. Several studies have reported physic-chemical parameters of the Bay of Bengal waters in recent years (19, 20).

The abundance and diversity of aquatic flora and fauna, including larvae, juveniles, and adults, are strongly influenced by physic-chemical conditions such as temperature, salinity, turbidity, and pH, which vary seasonally due to freshwater inflow (21, 22). Many authors have documented the influence of these physico-chemical parameters on aquatic organisms such as plankton, fungi, fish, shrimp, crabs, and their larval stages (23–25).

The present study evaluates seasonal variations in physico-chemical parameters and identifies water quality degradation caused by anthropogenic activities, including agriculture, aquaculture, and industrial practices, in the Vamsadhara River estuary.

2. Methods and Materials:

2.1. Study Area

The Vamsadhara Estuary is one of the highly biodiverseichthyofaunal estuaries along the east coast of India. The Vamsadhara estuarine system comprises eight sampling sites (S1–S8). It is located between longitudes 84°11′67″E and latitudes 17°89′39″N and extends over a stretch of approximately 3.4 to 4 km along the Bay of Bengal (**Fig: 1)**

Analysis of Physico-Chemical Parameters:

For the analysis of physicochemical parameters, both surface and bottom water samples were collected from the Vamsadhara estuary. Atmospheric and water temperatures were measured using a standard calibrated thermometer with an accuracy of ±0.5°C. The pH values were recorded using an Elico pH meter (Model LI-120). Dissolved oxygen and salinity were estimated following Winkler's method and the Mohar–Knudsen titration procedure, respectively (Strickland and Parsons, 1972).

Nutrient and surface water samples were collected in disposable polyethylene bottles and immediately transported to the laboratory using ice boxes. Filtration was carried out using a Millipore filtration system. The filtered samples were subsequently analyzed for total nitrate, silicate, and phosphorus following standard methods described by Strickland and Parsons (1972). Total alkalinity was determined by acid-based titration methods.

2.2. Statistical Analysis

Physico-chemical data collected during the study period from August 2024 to July 2025 were subjected to statistical analysis. Correlation analysis was performed among the parameters, and graphical representations were used to interpret the variations and relationships between the measured variables.

Collection and Identification of Fish Diversity from the Vamsadhara Estuary

A cast net measuring 2.5 m in length, with mesh sizes varying from 7 mm at the base to 15 mm at the apex, was employed to estimate fishery potential and to collect fish samples throughout the study period. At each sampling site, the net was operated 8–10 times during each collection. The

collected specimens were identified up to the species level. Finfish identification was carried out following standard taxonomic keys described by Day (1889a, b) and Nelson (2006).

3. Results

The average physico-chemical parameters of water samples from the Vamsadhara estuary were recorded over a one-year period from August 2024 to July 2025. In the present study, correlation coefficient (r) values were analyzed among environmental parameters such as atmospheric and surface water temperature, pH, dissolved oxygen, phosphate, nitrate, silicate, and alkalinity.

Seasonal variations in rainfall were categorized into four seasons: Southwest monsoon (June–September), Northeast monsoon (October–December),Post-monsoon (January–March), and summer (April–May). The study results are presented in (**Table:3**), and the correlation analysis among parameters is shown in (**Table: 2**)

a) Temperature

In the present study, both atmospheric and surface water temperatures were analyzed. Atmospheric temperature ranged from 26.8°C to 34.3°C, with a mean ± SD of 30.5°C ± 2.4. The minimum temperature was recorded in December, while the maximum was observed in May. Correspondingly, surface water temperature ranged from 24.2°C to 32.5°C, with the lowest and highest values recorded in December and May, respectively (**Fig: 3**), (**Fig: 4**)

b) PH

pH is an important factor influencing water quality along with other dissolved constituents. In the present study, the highest and lowest pH values were recorded in May 2025 (8.3) and December 2024 (7.2), respectively (**Fig: 5**).

c) Salinity

Salinity depends on factors such as water turbidity, pH, and dissolved oxygen. The highest salinity value was recorded in May 2025 (34.5), while the lowest was observed in December 2024 (5.8). This variation may be attributed to high evaporation, low rainfall, and reduced freshwater inflow during summer months (**Fig: 6**).

d) Dissolved Oxygen (DO)

Dissolved oxygen is one of the most important factors for the survival of aquatic life. The highest DO concentration was recorded in August 2024 (6.9 mg/L), while the lowest value was observed in January 2025 (4.2 mg/L). Higher DO values may be related to increased phytoplankton abundance (**Fig: 7**).

e) Phosphate

Phosphate is a nutrient required in low concentrations by aquatic organisms and is released mainly from organic debris and lime. In the present study, the highest phosphate concentration was recorded in September 2024 (2.26 mg/L), while the lowest value was observed in June 2025 (0.41 mg/L) (**Fig: 8**).

f) Nitrate

Nitrate concentration plays a significant role in regulating phytoplankton abundance. Nitrate concentration was highest in October 2024 (3.89 mg/L) and lowest in June 2025 (0.65 mg/L) (**Fig: 9**).

g) Silicate

In the present study, the highest silicate concentration was recorded during the monsoon season, particularly in October 2024. This increase may be attributed to the transport of silicate from the upper river substrates into the estuarine region during monsoonal runoff (**Fig:10**).

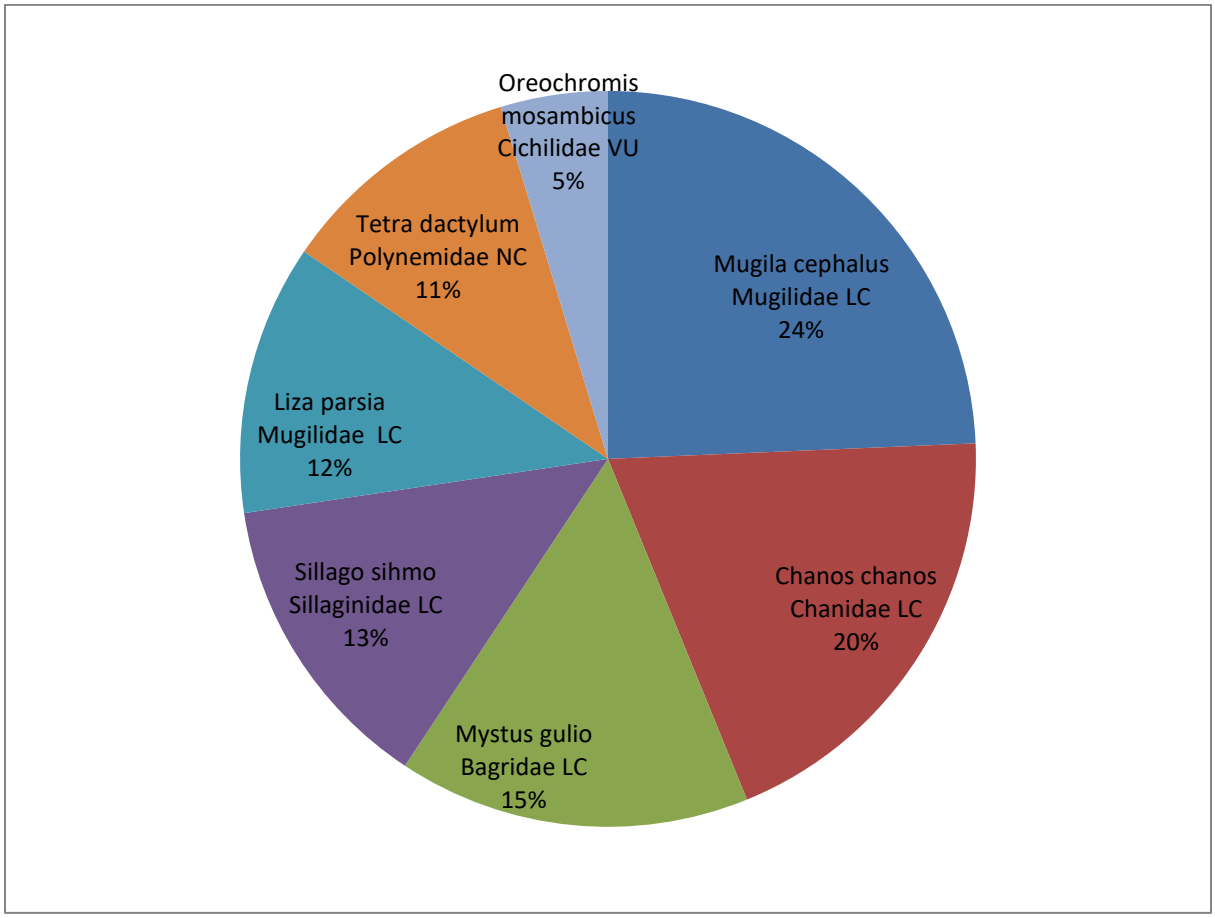
h) Alkalinity

The highest total alkalinity value (217 mg/L) was recorded in May 2025, while the lowest value (152 mg/L) was observed in July 2025 (**Fig: 11**).

Table: 1: Ichthyofauna diversity in the sampling sites (S1-S8) of the vamsadhara estuary in srikakulam district:

Fish diversity	Family	IUCN status	Observation frequency
Mugilacephalus	Mugilidae	LC	217
Chanoschanos	Chanidae	LC	174
Mystusgulio	Bagridae	LC	138
Sillagosihmo	Sillaginidae	LC	119
Liza parsia	Mugilidae	LC	106
Tetra dactylum	Polynemidae	NC	96
Oreochromismosambicus	Cichilidae	VU	42

Fig: 2: Diversity of Ichthyofauna in vamsadhara estuary during August-2024 to july-2025:



Ichthyofaunal Diversity of the Vamsadhara Estuary

A total of 892 fish specimens were collected from the Vamsadhara estuary during the study period. These specimens belonged to 6 orders and 5 families (**Table:1**). Mugilcephalus was the dominant species, accounting for 24.32% of the total catch. This was followed by Chanoschanos (19.50%), Mystusgulio (15.47%), Sillagosihama (13.34%), Liza parsia (11.88%), Tetra dactylum (10.76%), and Oreochromismossambicus (4.70%).

4. Discussion

Estuaries serve as valuable natural resources for human populations, providing significant ecological and economic benefits. These ecosystems are extensively exploited for their resources and are increasingly subjected to pressure from anthropogenic activities in adjacent coastal areas. Physico-chemical parameters of water play a major role in structuring Ichthyofaunal communities in aquatic ecosystems such as coastal waters, mangrove swamps, and estuaries.The survival, occurrence, density, and growth of juvenile finfish and shellfish are largely influenced by water salinity and temperature (21, 22). In the present study, monthly meteorological variations and physico-chemical parameters including temperature, pH, dissolved oxygen, phosphate, nitrate, silicate, and alkalinity along with changes in atmospheric conditions and rainfall, were recorded in the Vamsadhara estuary from August 2024 to July 2025.

Surface water temperature is influenced by various internal and external factors such as freshwater influx, rainfall, solar radiation, evaporation, internal water circulation, cooling processes, and tidal flow.

Table:2: Correlation coefficient (r) values between the environmental parameters.

Parameters	At. temp	W. temp	PH	Salinity	DO	Phosphate	Nitrate	Silicate	Alkalinity
At. temp	1								
W. temp	0.919	1							
PH	0.016	0.793	1						
Salinity	0.716	0.745	0.138	1					
DO	-0.0838	-0.087	0.349	-0.762	1				
Phosphorous	-0.1846	-0.192	-0.352	0.279	0.055	1			
Nitrate	-0.189	-0.196	-0.302	-0.171	0.172	0.722	1		
Silicate	-0.8749	-0.84	-0.069	-0.032	-0.062	0.451	0.82	1	
Alkalinity	0.032	0.036	-0.805	-0.022	-0.053	-0.07	0.459	-0.009	1

Table: 3: Cumulative chemical parameters analysis of the water sampling from 8 sites (S1-S2):

Chemical parameters	**Observed values**		**Mean ± SD**
	Minimum	**Maximum**	

Atmos-Temperature-0^{c}	26.8	34.3	30.5±2.22
water-Temperature- 0^{c}	24.2	32.5	28.35±2.44
Water-PH	7.2	8.3	7.75±0.29
Salinity-ppt	34.5	5.8	20.15±10.86
Dissolved oxygen-mg/l	4.2	6.9	5.5±1.06
Phosphorus-mg/l	0.41	2.26	1.33±0.54
Nitrates-mg/l	0.65	3.89	2.27±0.52
Silicate-mg/l	32	98	65±22.23
Total Alkalinity (mg/l	152	217	184.5±18.7

Air temperature variation also followed a pattern similar to surface water temperature. Higher air temperature values were recorded during the summer season (May 2025), while lower values were observed during the Northeast monsoon period (December 2024). This decrease in temperature during the monsoon months may be attributed to strong land–sea breeze circulation accompanied by precipitation. During this period, cloudy skies and rainfall gradually reduced atmospheric temperature to minimum levels (43).

According to the present study, water temperature gradually increased from the Northeast monsoon period (October–November) to the post-monsoon and summer seasons and slowly decreased during the Southwest monsoon period (June–September), influenced by atmospheric conditions and solar radiation. Similar findings were reported by Tangaraj (1984) (46). In the present study, air temperature ranged between 28°C and 35°C, with the minimum recorded during the Northeast monsoon period (December 2024) and the maximum during the summer season (May 2025). The mean ± SD of surface water temperature was 28.35 ± 2.44°C.

Hydrogen ion concentration (pH) is one of the major factors influencing aquatic ecosystems. In the present study, only slight variations in pH were observed in water samples. pH is controlled by solvent properties and is an important chemical factor (43–Divas). It also plays a major role in determining alkalinity and carbon dioxide acid–base equilibrium (44). Higher pH values recorded during summer may be attributed to increased seawater intrusion and enhanced biological activity (45). Elevated photosynthetic activity can increase pH due to bicarbonate utilization and carbonic anhydrate degradation, resulting in pH values up to 8.3 (33–Rajkumar et al., 2009). In the present study, the lowest pH value (7.2) was recorded in December 2024, while the highest value (8.3) was observed in May 2025. The mean ± SD pH value was 7.75 ± 0.29. During the monsoon season, pH values may be influenced by freshwater inflow, heavy rainfall, organic matter input, and decomposition processes (31–Rangathaman and Patil, 1995; 32–Upadhyay, 1998).

Marked seasonal variations in salinity were observed during the study period. Minimum salinity was recorded during the Northeast monsoon in December 2024, and it gradually increased during the post-monsoon period, reaching a maximum in May 2025. The average mean ± SD salinity value was 20.15 ± 10.86. High variations in salinity were attributed to ion and nutrient exchange driven by tidal flow, while lower salinity values were observed during periods of increased freshwater inflow (9–10). Salinity acts as a limiting factor in the distribution of living organisms, and its dilution and evaporation significantly influence coastal ecosystems (11–12). Generally, salinity remains low during winter and reaches maximum levels during summer (10).

Dissolved oxygen is an important parameter reflecting the physical and biological processes of aquatic systems. Factors such as monsoon floods, photosynthetic activity, and wind action influence dissolved oxygen levels (42–Nedumaran et al., 2011). In the present study, lower dissolved oxygen concentrations were recorded during summer, while higher values were observed during the monsoon period. The mean ± SD dissolved oxygen concentration was 5.5 ± 1.06 mg/L.

In the present study, the highest phosphate concentration (2.26 mg/L) was recorded in August 2024, while the lowest value (0.41 mg/L) was observed in June 2025. Elevated phosphate levels during the monsoon season may be due to the upwelling of seawater into the estuarine creek (39). Lower phosphate concentrations during summer may result from reduced freshwater inflow and increased utilization by phytoplankton (40). Phosphate levels are generally highest during winter and lowest during summer (41).

The highest nitrate concentration was observed in October 2024 (3.89 mg/L), while the lowest value was recorded in June 2025 (0.65 mg/L). The mean ± SD nitrate concentration was 2.24 ± 0.52 mg/L. Increased nitrate levels may be attributed to ammonia oxidation, phytoplankton activity, excretory processes, and nitrogen recycling mechanisms (16–17). Lower nitrate concentrations during summer compared to monsoon seasons may be due to increased salinity and reduced freshwater inflow (16–17).

Peak silicate concentrations recorded during the monsoon period may be attributed to heavy freshwater inflow carrying silt and siliceous materials from the upper reaches of the river. Similar observations were reported by Qasim et al. (1969) (29) and Ansari and Roygopal (1974) (27) in the Cochin backwaters, Nair et al. (1984) (38) in the Ashtamudi estuary, and Prabha Devi (1986) (28) in the Coleroon estuary. In the present study, silicate concentration showed a negative correlation (r = - 0.0328) with salinity, which has also been reported earlier in the Vellar estuary (36–Chandram and Ramamoorthi, 1984; Tangaraj, 1984) and Kerala backwaters (30–Sarala Devi et al., 1991).

Water alkalinity and hardness determine the suitability of water for domestic and industrial purposes based on the presence of nitrate, bicarbonate, chloride, sulphate, calcium, and

magnesium (19). Total alkalinity mainly depends on carbonate and bicarbonate concentrations in water (13). In the present study, the highest alkalinity value (217 ppm) was recorded in May 2025, while the lowest value (152 ppm) was observed in July 2025. Safari et al. (14) reported that industrial wastewater discharge influences increased alkalinity and pH by elevating carbonate and bicarbonate concentrations through the degradation of flora, fauna, and organic waste in estuarine environments (15).

Biodiversity studies play an important role in understanding species composition and the abundance of individuals within a particular ecosystem (37–Ramaiyan et al., 1986). In the present study, only seven fish species were recorded among the 892 collected specimens, indicating relatively stable environmental conditions in the study area. Similar high diversity under favorable environmental conditions was reported by Morton (1989) (35) in the Cochin estuary and Chandran (1982) (34) in the Vellar estuary.

Fig: 3: Monthly variations of atmospheric temperature during August 2024 to July-2025:

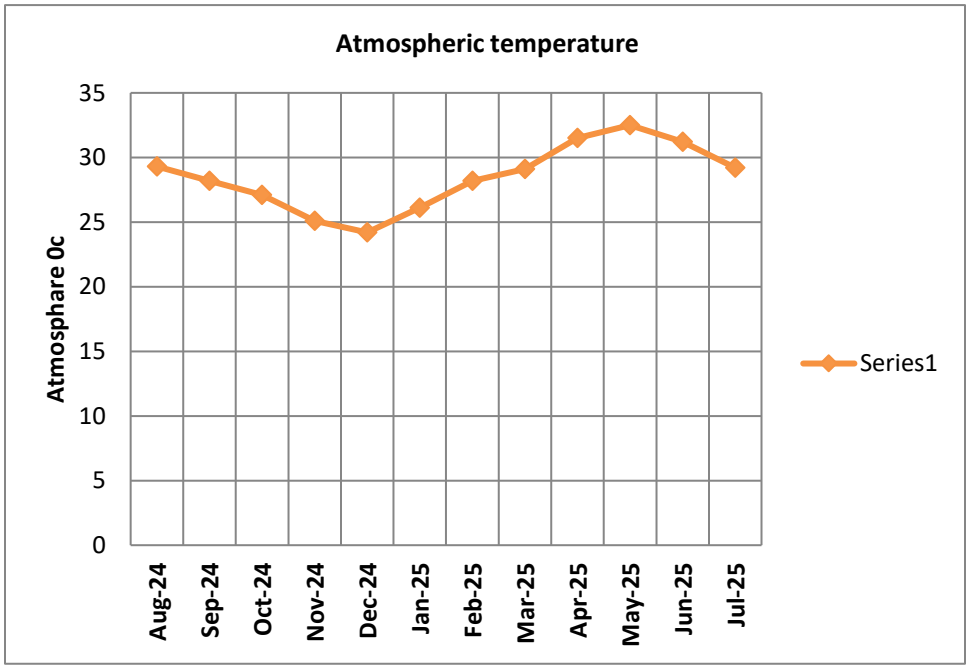


Fig: 4: Monthly variations of Water temperature during August 2024 to July-2025:

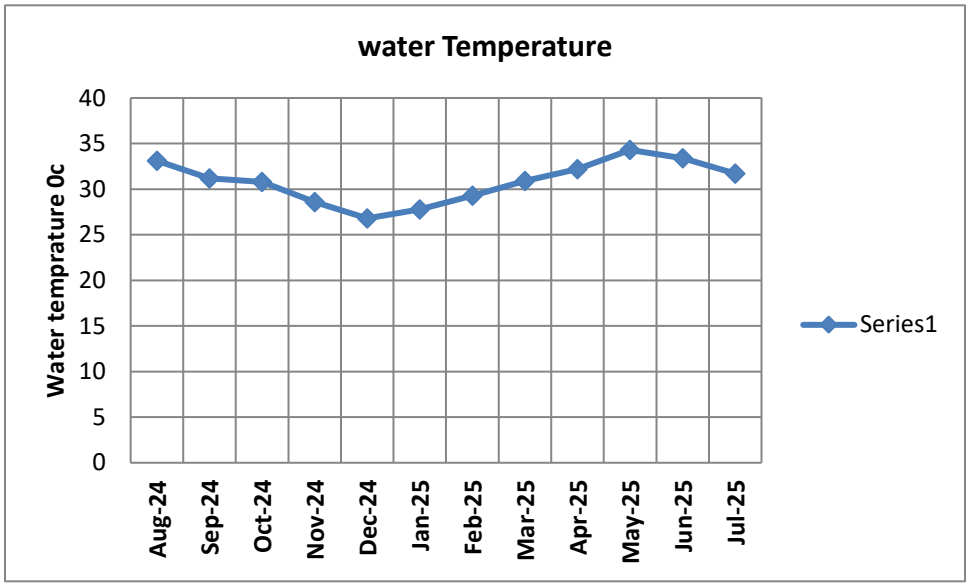


Fig: 5: Monthly variations of Water PH during August 2024 to July-2025:

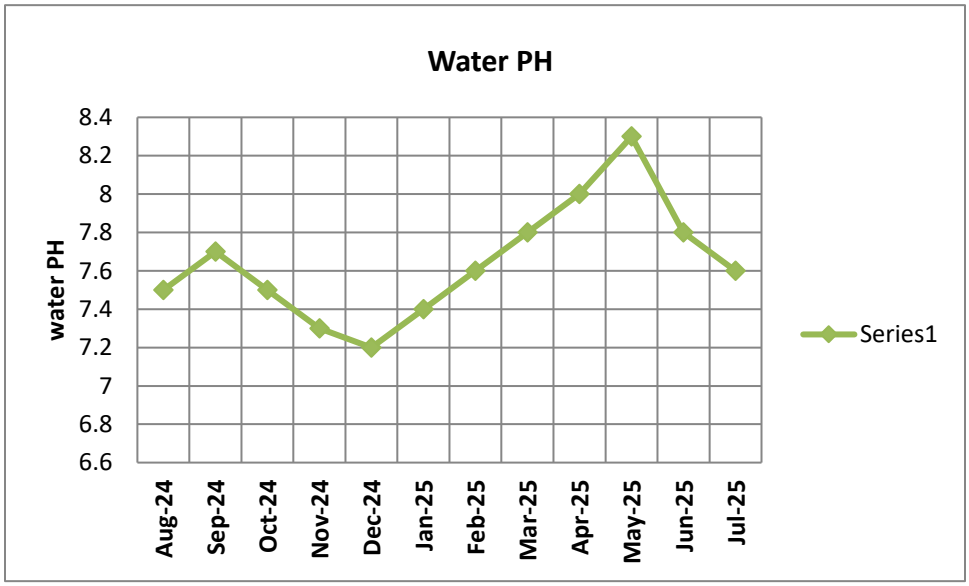


Fig: 6: Monthly variations of Water Salinity during August 2024 to July-2025:

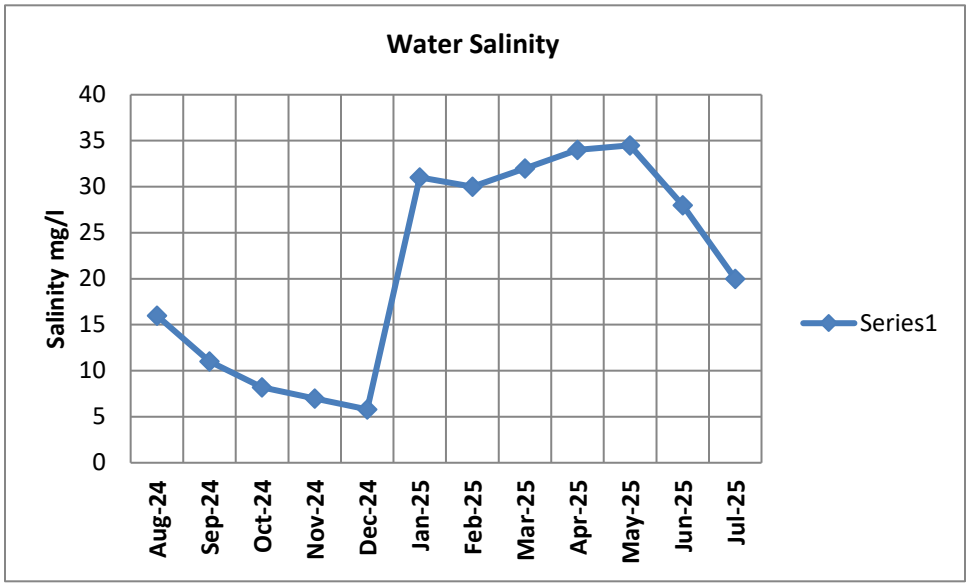


Fig: 7: Monthly variations of Dissolved oxygen during August 2024 to July-2025:

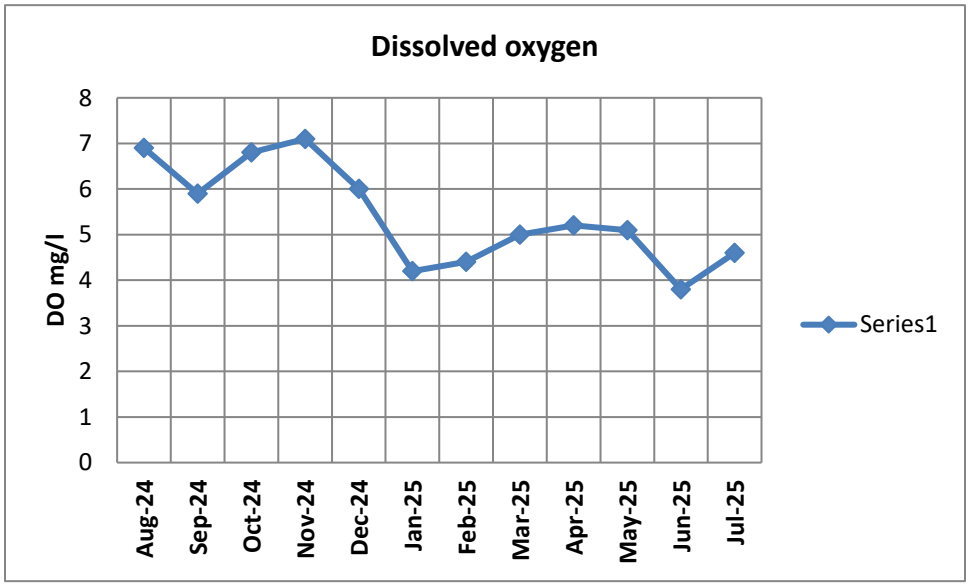


Fig: 8: Monthly variations of Phosphorous during August 2024 to July-2025:

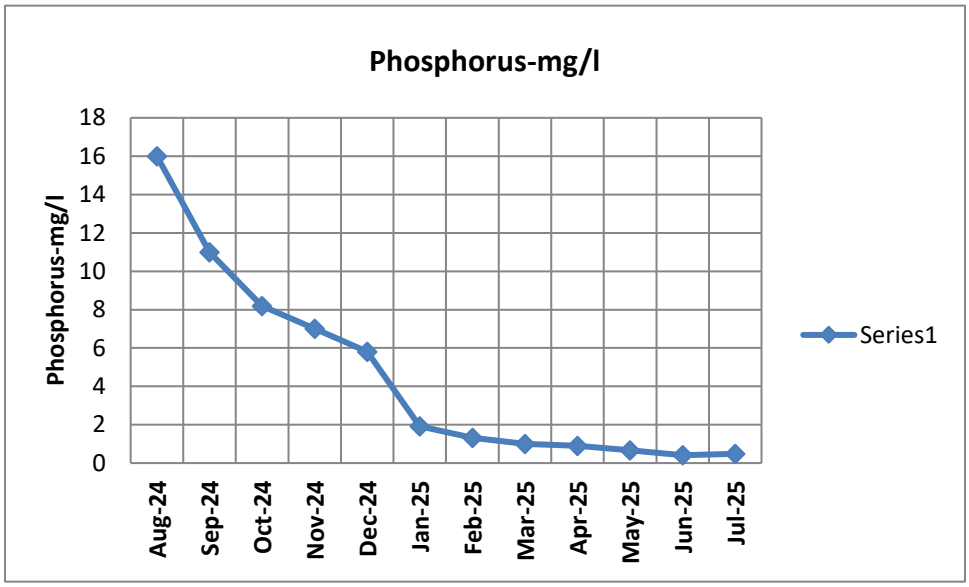


Fig: 9: Monthly variations of Nitrates (mg/l) during August 2024 to July-2025:

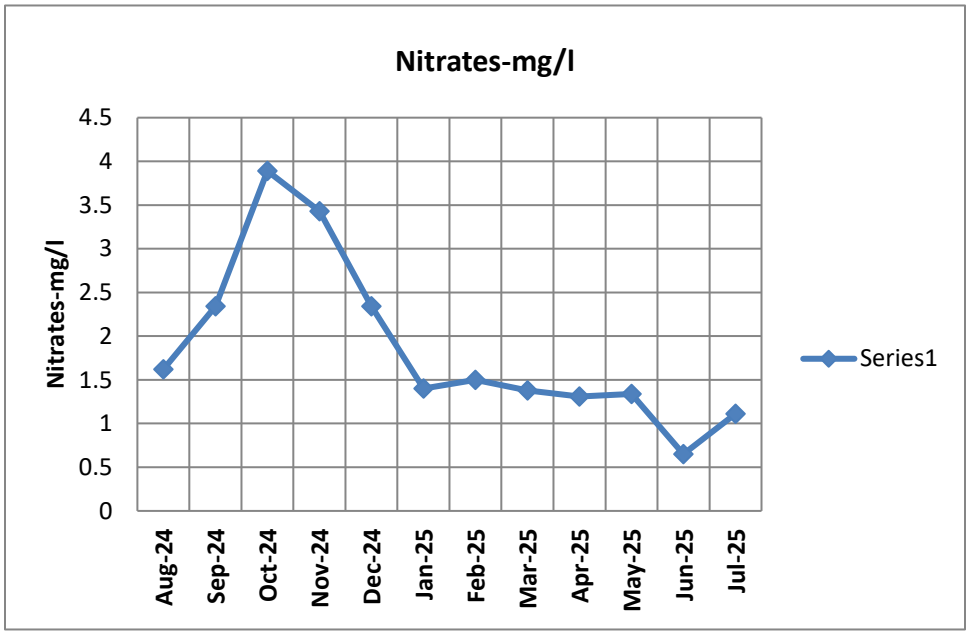


Fig:10: Monthly variations of Silicates(mg/l) during August 2024 to July-2025:

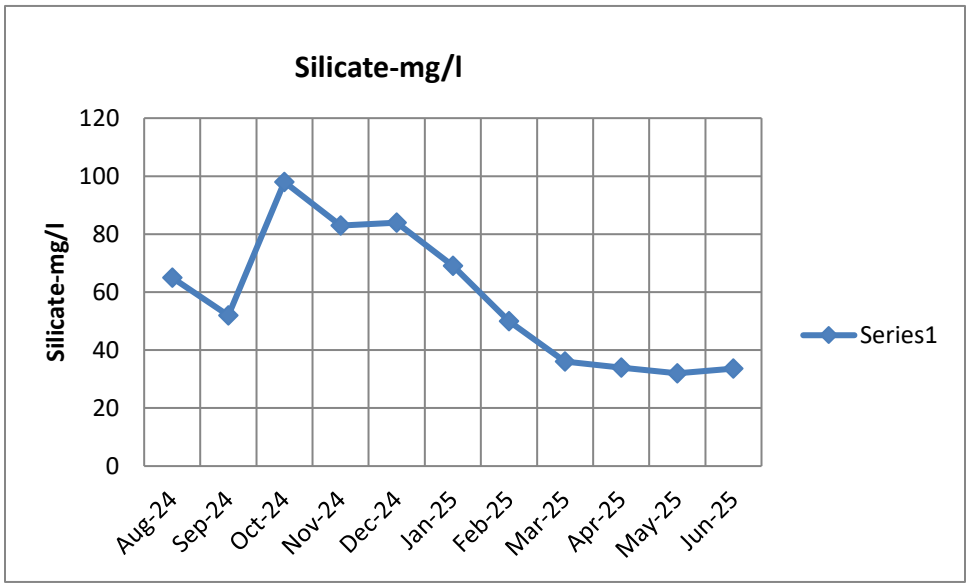
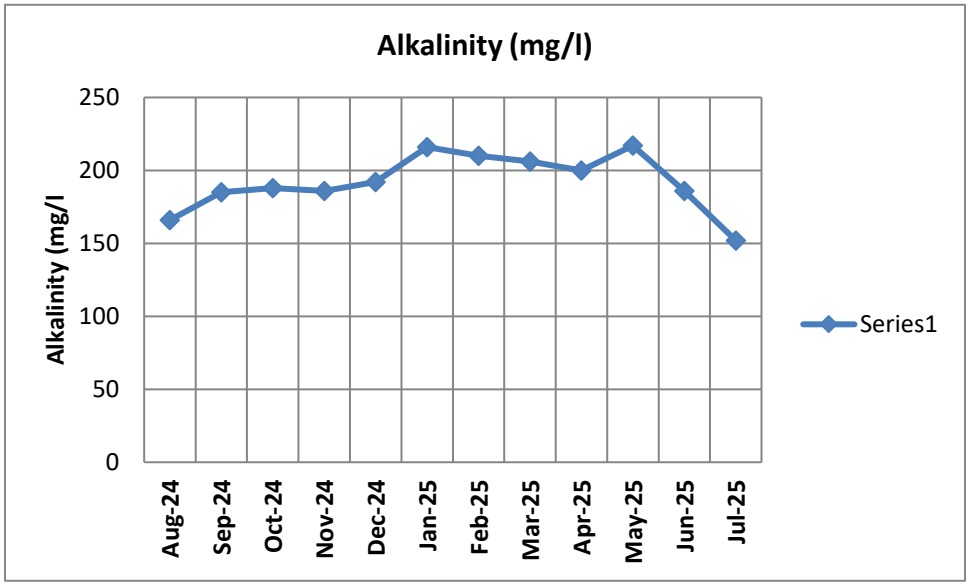


Fig: 11: Monthly variations of Alkalinity (mg/l) during August 2024 to July-2025:



5. Conclusion

The present study concludes that the water quality and physico-chemical parameters of the Vamsadhara estuary are moderate in nature, and these conditions are largely dependent on the

intensity and distribution of rainfall. However, an imbalance in physico-chemical parameters may occur if indiscriminate anthropogenic activities, industrial pollutants, and improper disposal of drainage waste are not effectively controlled.

The ichthyofaunal diversity observed in the present study is comparable with earlier findings reported by Shanmugan (1985) (26) from the Vellar estuary. The physico-chemical parameters recorded in the present investigation indicate that the Vamsadhara estuary is currently not heavily polluted, although there is a possibility of gradual accumulation of metals over time.

The study further reveals that the estuarine environment is strongly influenced by annual monsoon cycles, particularly rainfall patterns and freshwater inflow, which play a crucial role in regulating water quality and ichthyofaunal diversity.

Conflict of Interest

The authors declare no conflict of interest.

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