

Original Article

Environmental filtering of benthic communities along the sediment trophic gradient in Ashtamudi Ramsar wetland of Kerala

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Abstract: Ashtamudi Lake, a Ramsar-designated tropical estuarine wetland in Kerala, exhibits marked environmental gradients from marine to freshwater influence that strongly shape benthic community structure. To assess the role of sediment physico-chemical characteristics in regulating benthos, sediment and faunal samples were collected from five different locations during the post-monsoon season of the year 2023. Sediment analysis revealed marked differences, with pH values indicating overall acidic conditions (4.8-6.3), and organic carbon, nitrogen, and potassium increasing gradually toward inner stations such as Kidapram and Cherikadavu, reflecting terrestrial run-off and depositional enrichment. A total of 67 benthic taxa were recorded, with Neendakara showing the highest richness (47 species), dominated by marine families, while inner sites supported estuarine - freshwater tolerant families such as Veneridae and Corbiculidae. Richness indices (Margalef and Menhinick) showed progressive decline towards inland, and Pearson correlations indicated strong positive relationships of richness with nitrogen ($r = 0.76$), organic carbon ($r = 0.67$), and potassium ($r = 0.61$), as well as a moderate negative association with pH ($r = -0.46$). Cluster and ordination analyses (Jaccard similarity and CCA) also highlighted ecological layering from marine to freshwater regions in sediment quality status. This study highlights sediment trophic gradients and organic enrichment as key environmental filters structuring benthic diversity, underscoring the need for sediment management to maintain the ecological integrity of Ashtamudi Lake.

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Introduction

Estuarine wetlands are among the most productive and vulnerable ecosystems in the world, functioning as critical transition zones between marine and freshwater environments (Day et al., 1989). Sediments of estuarine systems act as major reservoirs of nutrients and pollutants, thereby supporting a wide variety of benthic organisms and maintaining trophic structure and ecosystem functioning (Kristensen et al., 2012; Riera et al., 2018). Benthic macrofauna are widely recognized as sensitive ecological indicators due to their rapid responses to changes in sediment physicochemical parameters, such as organic carbon, pH, and nutrient enrichment (Gray et al., 1992; Alves et al., 2020). Understanding sediment-benthos linkages thus provides essential insights into ecosystem health, resilience, and functioning (Borja et al., 2000).

Ashtamudi Lake is a Ramsar-designated tropical estuarine wetland on the southwest coast of India. It has been subjected to increasing anthropogenic pressures in recent decades, including nutrient loading, aquaculture, retting, and tourism (Joseph and Nair, 2019; Devi et al., 2024). The post-monsoon period is particularly critical in this dynamic system, when terrestrial run-off causes spatial changes in sediment quality and creates environmental gradients ranging from marine-influenced outer locations to freshwater-impacted inner regions (Kumar and Khan, 2019). Only a few studies have attempted to relate sediment nutrient status to benthic faunal distribution and diversity patterns in this lake (Sukumaran et al., 2025). Such assessments are vital for identifying regions prone to eutrophication and biodiversity loss, and for guiding management strategies within Ramsar wetlands (Onyena et al., 2023).

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This study investigates five locations across Ashtamudi Lake during the post-monsoon period, examining the interactions between sediment physicochemical characteristics and patterns of benthic faunal richness. The study seeks to explain how nutrient enrichment, organic matter accumulation, and pH variability shape the spatial patterns in benthic richness and assemblage composition, using multivariate statistical analyses including Canonical Correspondence Analysis, Jaccard similarity clustering, and correlation coefficients. The insights from this study help improve understanding of sediment-benthos interactions in tropical estuarine systems and provide a scientific foundation for conservation planning and sediment quality management in Ashtamudi Lake.

Materials and Methods

Study area and site selection: Ashtamudi Lake ($8^{\circ}56' - 9^{\circ}02'N$; $76^{\circ}31' - 76^{\circ}37'E$), a tropical estuarine Ramsar wetland situated in the Kollam district of Kerala, India, is influenced by seawater from Arabian Sea tides at its western mouth and terrestrial run-off from the eastern catchments (Fig. 1). Five representative ecosites were selected along the estuarine gradient from marine to freshwater influence: Neendakara (outer marine zone), Puthenthuruthu and Asramam (intermediate estuarine zones), Cherikadavu and Kidapram (inner freshwater-influenced zones). Sampling was carried out during the post-monsoon season (December 2023).

Sediment sampling and analysis: Surface sediment samples (0-5 cm) were collected in triplicate at each site using a grab sampler, homogenised, and transported to the laboratory under cool conditions. Subsamples were air-dried, sieved (0.5 mm), and analysed for pH and electrical conductivity (EC) using a calibrated multiparameter meter (Eutech PC 2700). Organic carbon (OC) was estimated by the Walkley-Black oxidation method, and total nitrogen (N), phosphorus (P), and potassium (K) were quantified by Kjeldahl digestion, Olsen's extraction, and flame photometry, respectively (Jackson, 1973). Mean values were computed for each station and expressed

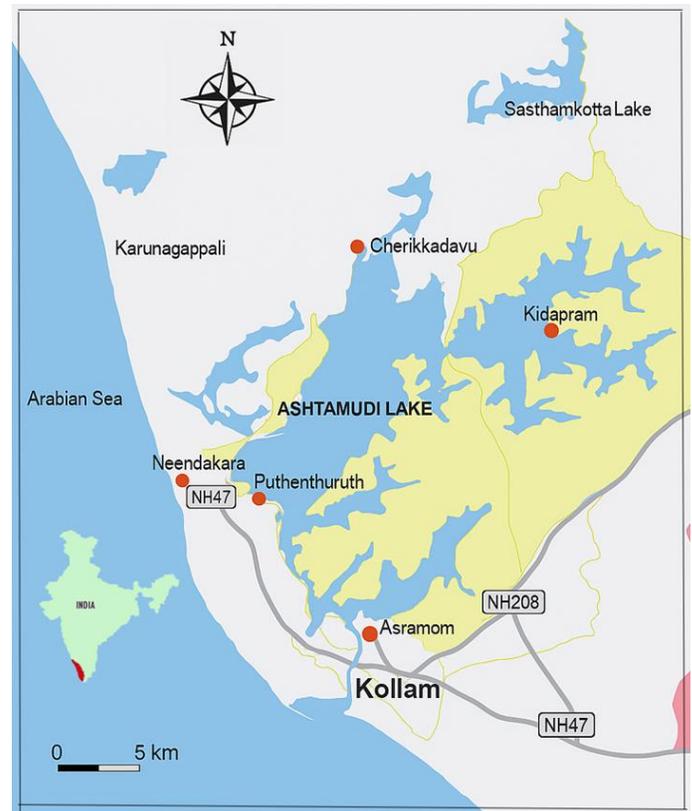


Figure 1. Study area with sampling locations.

in standard units.

Benthic faunal collection and identification: Benthic organisms were sampled using a Van Veen grab (0.04 m² area) at each site. Triplicate grabs were sieved through a 0.5 mm mesh, and the retained fauna were preserved in 5% buffered formalin. Organisms were sorted and identified to species level under a microscope using standard taxonomic keys (Nielsen, 1995; Rao and Rao, 2012). A presence-absence matrix (species × sites) was constructed for analysis.

Diversity indices and correlation statistics: Species richness (S) was calculated for each station. Richness-based diversity indices like Margalef's index ($d = (s-1) / \ln N$), and Menhinick's index ($DMn = (s-1) / \sqrt{N}$), were computed using presence-absence matrix data. Pairwise relationships between richness and sediment variables were examined through Pearson's correlation coefficients using Microsoft Excel 2019. A radar plot and a Canonical Correspondence Analysis (CCA) biplot were used to visualise variations in benthic assemblages in relation to sediment quality across the Lake using PAST software v4.03 (Hammer

Table 1. Average value of sediment quality of selected locations across Ashtamudi Lake

Parameter	Neendakara	Puthenthuruthu	Asramam	Kidapram	Cherikadavu	Standard Error (average)
pH	5.1	6.3	4.8	4.8	5.0	0.30
EC ($\mu\text{S}/\text{cm}$)	0.0031	0.013	0.003	0.006	0.003	0.00032
OC (%)	1.99	2.28	0.83	3.72	3.43	0.16
Nitrogen (Kg ha^{-1})	674.98	831.04	439.08	1384.48	1050.56	50.78
Phosphorus (Kg ha^{-1})	11.70	9.68	14.52	3.52	9.68	0.57
Potassium (Kg ha^{-1})	179.87	1351.84	212.43	917.32	251.05	33.83

et al., 2001).

Cluster and similarity analyses: To evaluate faunal similarity among stations, a Jaccard similarity matrix was generated from the benthic presence-absence matrix. Hierarchical agglomerative clustering using the UPGMA linkage method (Sokal and Michener, 1958) was performed to trace grouping patterns amongst sites. Similarity dendrograms were prepared to discern ecological affinities along the estuarine gradient.

Results

Sediment physico-chemical characteristics: The analysis of sediment physico-chemical parameters across the five ecosites of Ashtamudi Lake during the post-monsoon season revealed marked spatial variability in acidity, conductivity, organic matter, and nutrient concentrations (Table 1). pH value of the sediment samples across the five locations of Ashtamudi Lake indicates overall acidic sediment conditions in the post-monsoon period. Electrical conductivity (EC) was highest at Puthenthuruthu and notably low at Neendakara, Asramam, and Cherikadavu. Organic carbon content exhibited marked spatial variation, with the highest concentration recorded at Kidapram, followed closely by Cherikadavu, reflecting increased deposition of organic matter. In contrast, Asramam exhibited very low organic carbon content, indicating a nutrient-poor sediment regime.

During the analysis of macronutrients, heterogeneity across locations was observed. Nitrogen

was markedly elevated at Kidapram and Cherikadavu, suggesting terrestrial run-off into these relatively enclosed zones. The lowest nitrogen concentration was observed at Asramam, coinciding with its low organic carbon levels. Similarly, potassium concentrations peaked sharply at Puthenthuruthu and Kidapram, whereas Neendakara recorded the lowest potassium level. Phosphorus values showed comparatively narrow variation, with elevated content at Asramam, contrasting with depletion at Kidapram, which may be due to varying sediment redox conditions. This analysis revealed that the post-monsoon sediment quality profile indicates increased nutrient enrichment and organic accumulation toward the inland ecosites, particularly Kidapram and Cherikadavu, reflecting a gradient from marine-dominated to land-influenced conditions within Ashtamudi Lake.

Multivariate patterns in sediment quality: The radar chart in Figure 2 illustrates clear spatial variation in sediment quality parameters across the five ecosites of Ashtamudi Lake. Kidapram and Cherikadavu show pronounced spikes in nitrogen and potassium, indicating enrichment of organic and nutrient inputs in the lake's inner zones. Puthenthuruthu shows the highest organic carbon and moderately high nutrient concentrations, reflecting its transitional estuarine nature. Neendakara and Asramam rank lower across most chemical parameters, suggesting comparatively less nutrient-loaded, more marine-influenced sediment conditions. This radar pattern highlights a gradient from nutrient-poor outer sites to nutrient-

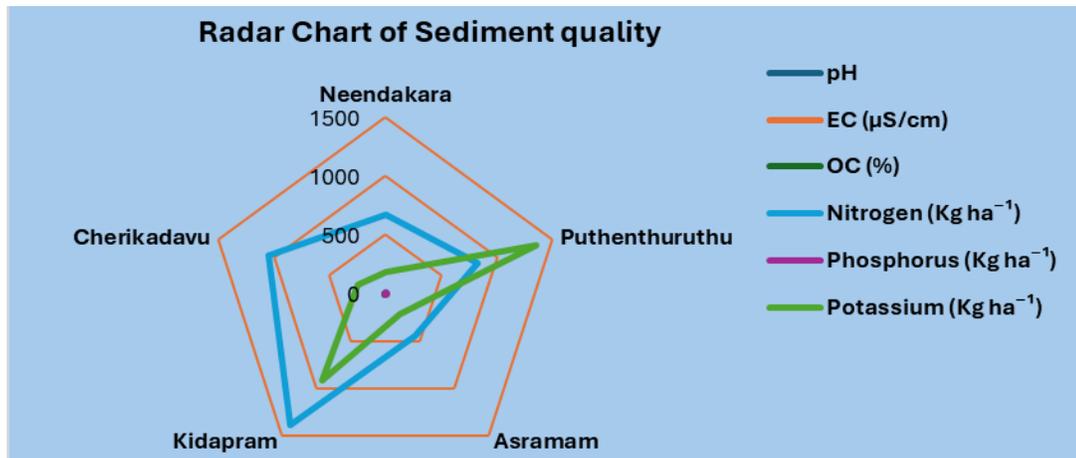


Figure 2. A radar chart showing the sediment quality.

enriched inner stations, consistent with increasing terrestrial influence towards the lake's interior.

Benthic faunal diversity and zonation: A total of 67 benthic taxa were recorded from the five locations of Ashtamudi Lake during the post-monsoon survey. This diversity shows clear spatial differences in composition and salinity preference. Neendakara is located near the mouth of the lake, where coastal water intrusion exhibited the highest richness, with 47 species, dominated by true marine molluscs, particularly representatives of *Conidae*, *Muricidae*, *Buccinidae*, and *Naticidae* (Table 2). Puthenthuruthu and Asramam, situated in the intermediate region, supported transitional assemblages of marine and estuarine benthic species, with 15 and 13 taxa, respectively. Benthic taxa reported from these locations included *Cerithidea cingulata*, *Perna viridis*, *Littorina* spp., and *Crassostrea madrasensis*, indicating euryhaline tolerance and brackish-water conditions.

The inner-lake locations, such as Cherikadavu and Kidapram, with reduced salinity and increased terrestrial influence, exhibited a distinct shift toward estuarine- and freshwater-tolerant taxa, including *Villorita cyprinoides*, *Marcia opima*, *Meretrix* spp., *Paphia* spp., and *Trisodos tortuosa*. Notably, freshwater-adapted *Villorita cyprinoides* was consistently present in all inner locations, highlighting progressive dilution gradients. The diversity pattern clearly shows a shift from marine to freshwater conditions across Ashtamudi Lake. The Neendakara

region reported the highest number of marine species, while Kidapram and Cherikadavu represent inner zones with nutrient-rich sediments that support freshwater-tolerant species. This variation in community structure reflects the influence of water flow and salinity gradients, as well as sediment quality, on benthic faunal diversity and distribution in Ashtamudi Lake.

Comparative analysis of sediment quality and benthic diversity: The comparative analysis of sediment characteristics and benthic composition across Ashtamudi Lake suggests a clear sediment-mediated distribution of fauna. Marine-based locations such as Neendakara and Asramam, with comparatively low organic carbon and macronutrient levels, were dominated by stenohaline marine taxa, suggesting that benthic diversity in these regions is maintained by periodic seawater flushing along with lower trophic stress. The freshwater-influenced locations like Kidapram and Cherikadavu exhibited markedly elevated nitrogen, potassium, and organic matter, indicating a conspicuous shift in the benthic community towards estuarine-freshwater adapted taxa. The replacement of marine molluscs by Veneridae, Littorinidae, and Corbiculidae families in the inner estuary reflected the filtering role of sediment trophic enrichment on community composition. The Puthenthuruthu region, with an intermediate trophic status, exhibited mixed characteristics, including moderate nutrient accumulation and a transitional assemblage of marine

Table 2. Presence-absence matrix of Benthic Fauna in Five locations of Ashatamudi Lake.

No	Family	Species Name	Neendakara	Puthenthuruthu	Asramam	Cherikadavu	Kidapram
1	Architectonicidae	<i>Architectonica laevigata</i>	✓				
2	Arcidae	<i>Trisodos tortuosa</i>		✓	✓	✓	✓
3	Balanidae	<i>Balanus amphitrite</i>	✓				
4	Buccinidae	<i>Babylonia spirata</i>	✓				
5		<i>Babylonia zeylanica</i>	✓	✓			
6	Bursidae	<i>Bufo naria echinata</i>	✓	✓			
7		<i>Bufo naria rana</i>	✓				
8		<i>Bursa rana</i>	✓				
9	Cardiidae	<i>Fragum unedo</i>	✓				
10	Conidae	<i>Conus bayani</i>	✓	✓	✓		
11		<i>Conus eburneus</i>	✓				
12		<i>Conus inscriptus</i>	✓				
13		<i>Conus loroisii</i>	✓				
14		<i>Conus monile</i>	✓				
15		<i>Conus pulcher</i>	✓	✓			
16	Coralliophilidae	<i>Coralliophila meyendorffi</i>	✓				
17	Corbiculidae	<i>Villorita cyprinoides</i>		✓	✓	✓	✓
18	Dentaliidae	<i>Fissidentalium vernelei</i>	✓	✓			
19	Donacidae	<i>Donax cuneatus</i>	✓				
20	Fasciolariidae	<i>Fusinus colus</i>	✓				
21		<i>Fusinus longicaudatus</i>	✓				
22		<i>Latirus cariniferous</i>	✓				
23	Ficidae	<i>Ficus ficus</i>	✓	✓			
24		<i>Ficus subintermedius</i>	✓				
25	Harpidae	<i>Harpa conoidalis</i>	✓				
26	Littorinidae	<i>Littorina scabra</i>		✓	✓	✓	✓
27		<i>Littorina undulata</i>		✓	✓	✓	✓
28		<i>Nodilittorina leucostica</i>		✓	✓	✓	
29	Muricidae	<i>Murex carbonnieri</i>	✓				
30		<i>Murex tenuirostrum</i>	✓				
31		<i>Murex ternispina</i>	✓				
32		<i>Murex trapa</i>	✓				
33		<i>Murex virgineus</i>	✓	✓			
34		<i>Rapana rapiformis</i>	✓				
35	<i>Thais haemastoma</i>	✓					
36	Mytilidae	<i>Perna viridis</i>		✓	✓	✓	
37		<i>Perna indica</i>		✓	✓		
38		<i>Musculista arcuata</i>		✓	✓	✓	
39	Nassariidae	<i>Bullia vitatta</i>	✓				
40		<i>Nassarius dorsatus</i>	✓				
41		<i>Nassarius stollatus</i>	✓				
42	Naticidae	<i>Eunaticina papilla</i>	✓				
43		<i>Natica lineata</i>	✓		✓		
44		<i>Polinices didyma</i>	✓				
45	Neritidae	<i>Nerita costata</i>	✓				
46	Olividae	<i>Oliva oliva</i>	✓				
47	Ostreidae	<i>Crassostrea madrasensis</i>		✓	✓	✓	
48	Pholadidae	<i>Pholas orientalis</i>		✓	✓	✓	
49	Potamididae	<i>Telescopium telescopium</i>		✓	✓		
50		<i>Cerithidea cingulata</i>		✓	✓		

Table 2. Continued.

51		<i>Terebralia palustris</i>		✓			
52	Ranellidae	<i>Ranella olearium</i>	✓				
53	Strombidae	<i>Tibia curta</i>	✓				
54	Tellinidae	<i>Tellina angulata</i>		✓	✓	✓	✓
55	Terebridae	<i>Duplicaria duplicata</i>	✓	✓			
56	Thaisidae	<i>Thais mutabilis</i>			✓	✓	
57	Tonnidae	<i>Tonna dolium</i>	✓				
58		<i>Lophitoma indica</i>	✓				
51	Turridae	<i>Turricula javana</i>	✓				
60		<i>Turritella acutangula</i>	✓				
61	Turritellidae	<i>Turritella attenuata</i>	✓	✓			
62		<i>Marcia opima</i>		✓	✓	✓	✓
63		<i>Meretrix casta</i>		✓	✓	✓	✓
64		<i>Meretrix meretrix</i>		✓	✓	✓	
65	Veneridae	<i>Paphia ala-papilionis</i>			✓	✓	✓
66		<i>Paphia malabarica</i>		✓	✓	✓	✓
67		<i>Paphia textile</i>			✓	✓	

Table 3. Spatial variation in Benthic Richness and Diversity Indices among selected locations.

Site	S (Richness)	Margalef (d)	Menhinick (DMn)
Neendakara	47	7.95	6.85
Puthenthuruthu	32	7.08	5.66
Asramam	33	7.17	5.74
Cherikadavu	33	7.17	5.74
Kidapram	28	6.64	5.29

and estuarine species.

Diversity indices and spatial richness trends: The analysis based on richness and diversity indices revealed a clear spatial variability across the five locations of Ashtamudi Lake (Table 3). Neendakara recorded the highest species richness, followed by Puthenthuruthu, Asramam, and Cherikadavu, while Kidapram recorded the lowest. Correspondingly, Margalef's index ranged from 6.64 at Kidapram to 7.95 at Neendakara, indicating that diversity declined progressively from the marine-dominated station towards the inner freshwater-influenced habitats. Menhinick's index showed a comparable trend in Neendakara and Kidapram, signifying reduced taxonomic variety under the environments of estuarine and freshwater sediment. This pattern indicates that benthic diversity is greatest in the marine-influenced mouth of the lake and decreases towards the nutrient-rich, organically loaded inner regions, where environmental stress and sediment filtering reduce faunal richness.

Correlation between richness and sediment quality: Correlation analysis conducted in this study

revealed that benthic species richness was positively associated with nutrient enrichment and sediment organic content (Table 4). Richness showed the strongest positive correlation with sediment nitrogen, followed by organic carbon and potassium, indicating that nutrient-rich, organically accumulated substrates tend to support higher benthic taxonomic diversity. A weak positive correlation was observed with phosphorus and conductivity, suggesting minimal influence of ionic concentration on taxonomic richness in this study. The pH value exhibited a moderate negative correlation, pointing to slightly higher richness under more acidic post-monsoonal sediment conditions.

Similarity and cluster analysis of benthic communities: Hierarchical clustering, coupled with Jaccard similarity and UPGMA, grouped the five ecologically distinct lake locations into two major assemblages (Table 5). Neendakara, dominated by marine taxa, formed a distinct, isolated cluster (Jaccard values ≤ 0.29), reflecting its oceanic influence. The remaining locations clustered progressively along an estuarine freshwater gradient,

Table 4. Pearson correlation between sediment variables and benthic species richness.

Sediment Variable	r-value (Pearson)	Direction
pH	-0.46	Negative
Organic Carbon (%)	+0.67	Positive
Nitrogen (kg/ha)	+0.76	Positive
Phosphorus (kg/ha)	+0.19	Weak Positive
Potassium (kg/ha)	+0.61	Positive
EC ($\mu\text{S}/\text{cm}$)	+0.08	Very Weak Positive

Table 5. Similarity Matrix of Benthos family in selected locations.

Sites	Neendakara	Puthenthuruthu	Asramam	Cherikadavu	Kidapram
Neendakara	1.00	0.29	0.18	0.10	0.10
Puthenthuruthu	0.29	1.00	0.82	0.71	0.67
Asramam	0.18	0.82	1.00	0.74	0.70
Cherikadavu	0.10	0.71	0.74	1.00	0.80
Kidapram	0.10	0.67	0.70	0.80	1.00

with Puthenthuruthu and Asramam showing high similarity (0.82) due to shared euryhaline families, including Veneridae, Littorinidae, Potamididae, and Mytilidae. Cherikadavu and Kidapram formed the tightest subcluster (0.80), characterized by freshwater-tolerant families (Veneridae and Corbiculidae), indicating increased terrestrial input and reduced salinity.

The dendrogram illustrates a strong spatial zonation of benthic fauna corresponding to the hydrological and sedimentary range of the Lake. Figure 3 shows the branching sequence from Neendakara \rightarrow Puthenthuruthu/Asramam \rightarrow Cherikadavu/Kidapram, reflecting a gradient from saline marine to oligohaline freshwater conditions, mirroring hydrological and sediment quality transitions within Ashtamudi Lake.

Canonical correspondence analysis: The CCA biplot revealed a clear separation of locations in the lake along sediment quality gradients (Fig. 4), in which Neendakara was associated with higher pH and lower nutrient loads, supporting marine tolerant taxa, while Kidapram and Cherikadavu clustered with elevated nitrogen, organic carbon, and potassium, indicating nutrient-enriched, depositional habitats favouring tolerant assemblages. Puthenthuruthu and Asramam occupied intermediate positions reflecting transitional sediment conditions. All these analyses suggest that benthic community structure in Ashtamudi Lake is primarily governed by sediment

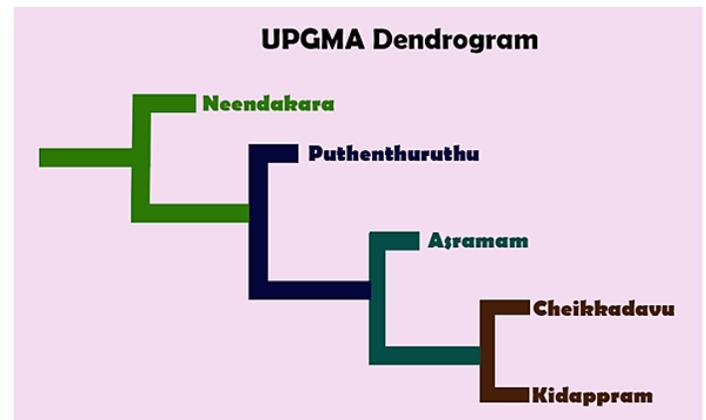


Figure 3. Visual interpretation of cluster pattern.

trophic status and organic enrichment.

Discussions

The present study highlights the strong influence of sediment physico-chemical gradients on the spatial structure of benthic communities in Ashtamudi Lake during the post-monsoon period. The distinct enrichment of organic carbon, nitrogen, and potassium toward the inner stations, such as Kidapram and Cherikadavu, reflects enhanced terrestrial runoff, detrital trapping, and reduced flushing, conditions typically associated with nutrient buildup in tropical estuarine systems (Naidu et al., 2021). The seawater-influenced location Neendakara was characterised by lower nutrient concentrations and higher benthic richness, dominated by stenohaline taxa, consistent with observations that well-oxygenated, coarse-grained marine sediments support a more diverse

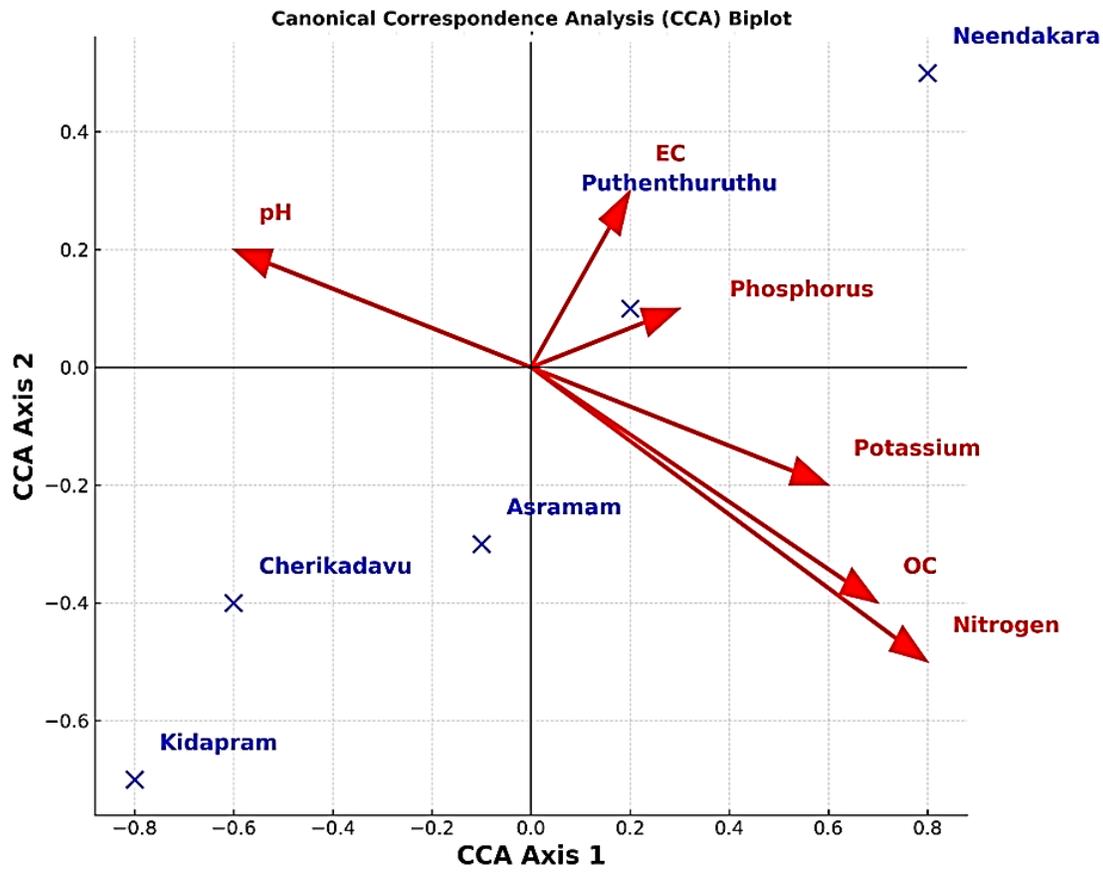


Figure 4. CCA biplot depicting the influence of sediment parameters on benthic community structure across Ashtamudi Lake.

macrofauna (Riera et al., 2018).

Benthic richness was highest in the outer estuarine location and declined progressively toward the nutrient-rich inner regions, indicating a negative diversity response to organically enriched substrates, possibly due to hypoxia or the accumulation of labile organic matter (Ramakrishnan and Mohanachandran, 2020). A positive correlation of richness with nitrogen and organic carbon, however, implies that moderate enrichment enhances food availability and promotes the presence of opportunistic taxa, whereas excessive enrichment at Kidapram may reduce species diversity due to habitat stress. The negative relationship between pH and richness further supports earlier findings that mild acidity in estuary sediments promotes nutrient solubility but, beyond a threshold, may inhibit sensitive taxa, thereby shifting the community towards tolerant forms such as Veneridae and Corbiculidae (Yuan et al., 2022). Cluster analysis and Jaccard similarity corroborated the segregation of

sampling sites into two major benthic assemblages: a marine-dominated group (Neendakara) and an estuarine - freshwater influenced group (Puthenthuruthu to Kidapram), revealing the importance of sedimentary and hydrological gradients in determining species turnover patterns (Kumar and Khan, 2019).

CCA clearly demonstrates that benthic community distribution in Ashtamudi Lake is strongly regulated by sediment quality gradients, with nutrient enrichment and organic accumulation as the dominant drivers of species-environment relationships. The segregation of locations along nutrient axes suggests that terrestrial inputs and depositional processes enhance the prevalence of tolerant taxa, whereas seawater-influenced sediments support more diverse assemblages. Such environments and biological linkages are well studied in tropical estuaries, where the availability of organic carbon and nitrogen shapes benthic functional composition and habitat adaptation

(Alves et al., 2020; Sukumaran et al., 2025). Moreover, the spatial partitioning indicated by the CCA underscores the utility of multivariate ordination tools in identifying ecological thresholds that conventional diversity indices may overlook, thereby strengthening the role of benthos as effective bioindicators of sediment health (Gray et al., 1992; Borja et al., 2016).

The results of the present analysis underscore that benthic community organisation in Ashtamudi Lake is tightly linked to sediment condition. Nutrient enrichment, organic matter accumulation, and pH collectively act as major environmental filters that shape faunal composition and richness in the benthic community. These findings suggest that monitoring sediment quality parameters can serve as a powerful tool for predicting benthic ecological health, and any continued increase in nutrient loading could potentially alter the biotic integrity of this Ramsar-designated estuary.

Conclusions

The post-monsoon survey of Ashtamudi Lake revealed that nutrient dynamics and gradients play a key role in shaping benthic community structure across the five ecosites. Neendakara, situated at the mouth of the estuary, supported the highest richness and was dominated by true marine families, whereas the inner stations Kidapram and Cherikadavu exhibited nutrient-enriched sediments and were dominated by benthic taxa tolerant to estuarine and freshwater habitats. Transitional zones, such as Puthenthuruthu and Asramam, exhibited mixed assemblages of euryhaline species, reflecting intermediate trophic and hydrological conditions. Multivariate statistical analyses, including CCA biplots, radar plots, and cluster analysis, revealed a clear marine-to-freshwater ecological gradient, with a strong association between sediment quality and benthic faunal assemblages. These findings emphasize that benthic distribution patterns in Ashtamudi Lake are driven by the interplay of hydrological connectivity, organic enrichment, and salinity fluctuations, stressing the importance of sediment

monitoring for assessing estuarine ecological health. This study concluded that sediment quality is a primary regulator of benthic community dynamics in Ashtamudi Lake, with a clear spatial gradient reflecting the gradual transition from marine to freshwater influence. The results concluded that variations in organic carbon, macronutrients, and pH make distinct ecological niches that determine both richness and taxonomic composition. The results of this study substantiate that benthic diversity can serve as an effective bioindicator of sediment health in Ashtamudi estuarine systems, based on cross-analysis of benthic faunal patterns and sedimentary conditions using multivariate approaches.

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Data Availability: The datasets generated and/or analysed during the current study are available from the corresponding author upon reasonable request.

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