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Mining-Induced Sediment Alterations and their Effects on Benthic Community Structure in Kottakayal Wetland, South Kerala, India

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Abstract

In aquatic ecosystems, bottom sediments play a vital role in regulating and sustaining various ecological processes. Bottom sediments influence the primary and secondary productivity, mobilize nutrients and act as sinks. This study investigates the temporal and spatial variations in sediment characteristics and benthic macro-invertebrate communities in Kottakayal, a wetland in South Kerala, India. Sediment samples were collected using Van Veen grab from six sampling sites and analyzed for its texture, temperature, pH and organic carbon. Macrofauna were sieved, identified and quantified in terms of biomass and abundance. The sediment texture was predominantly sandy loam, with seasonal variations. Higher silt and clay particles were noticed during pre-monsoon and post-monsoon at the sites which were affected by mining activities. Twenty macro-invertebrate species representing the phyla Mollusca, Arthropoda and Annelida were recorded. Abundance and biomass were high during the monsoon. Correlation analysis revealed positive links between organic carbon and Pelecypoda, Polychaeta and total benthos but negatively associated with depth and clay content. Substratum instability resulting from clay mining at sites 4 and 5 led to reduced abundance. The results underscore the role of sediment quality in benthic community structuring and fisheries potential, thereby emphasizing the need for sustainable mining practices.

Keywords: Benthic macro-invertebrates; Kottakayal; Sediment texture; Organic carbon; Clay mining; Sediment characteristics; Wetland; Fisheries potential; Benthic abundance

Introduction

Bottom sediments contribute in mobilizing and accumulating nutrients within a water body and form the major component of an aquatic ecosystem. It acts as sink for nutrients thereby affecting the primary and secondary productivity of the ecosystem. Physico-chemical characteristics of bottom sediment influence biotic components. There exists a reciprocal interaction between biotic and abiotic components that ultimately determine the nature of the ecosystem (Corenblit et al., 2008). On realizing the significant role played by bottom sediments in aquatic ecosystem keen interest has been shown by investigators to analyze the physical and chemical properties of sediments and their impact on biotic component and overlying water.

Organic matter determines the distribution and abundance of aquatic organism. Dissolved form of organic matter regulates the nutrient content that is required for plant growth, whereas the particulate form of organic matter present as detritus influences benthic organism distribution (Rossi, 2006). Biological activity and fertility of the overlying water column is indicated by the organic carbon content of the sediment. It also reveals the organic pollution status of the water body (Hudson et al., 2007). Sediments play a great role in organic matter degradation and nutrient cycling in aquatic ecosystem (Simcic, 2005).

Knowledge of physico-chemical properties of bottom sediment and water column is inevitable in evaluating the trophic structure of an aquatic ecosystem (Frascari et al., 2002). The effect of macrofauna on the distribution of contaminants and their input to the water column were well documented (Delmotte et al., 2007; French and Turner, 2008). The physical structure, species distribution and biogeochemical properties of bottom sediments are shaped by the bacteria, benthic invertebrates and macrophytic inhabitants (Rabaut et al., 2007). Benthic productivity depends on water quality which in turn is affected by sediment properties (Nupur et al., 2013). Since water quality and benthos are interrelated they are used as indicators of water quality (Azrina et al., 2006). With the increase in the realization of the significant role of benthic organisms in trophic structuring a detailed study of bottom fauna is essential. Moreover, it is essential in assessing the fisheries potential of the ecosystem.

Materials and Method

Study area

Kottakayal lies in Grid no. 58D/09 of Survey of India Toposheet, between 8°51'35.236" to 8°54'11.144" North Latitude and 76°40'31.547" to 76°43'4.784" East longitude near Pallimon-Ithikkara confluence. Kottakayal has an area of 2.32 Km². It flows through Adichanalloor, Thrikovilvattom and Nedumpana panchayats. Kottakayal belongs to Ithikkara block. As Kottakayal is situated at low lying area the chances of ecological degradation are fairly high. The present investigation is designed to analyses the various ecological aspects of this water body. Six sampling stations were selected (Fig. 1). Sites 1, 2, 3, 4 and 5 are located to the south of Kundumon Bridge whereas site 6 is to the north of Kundumon Bridge.

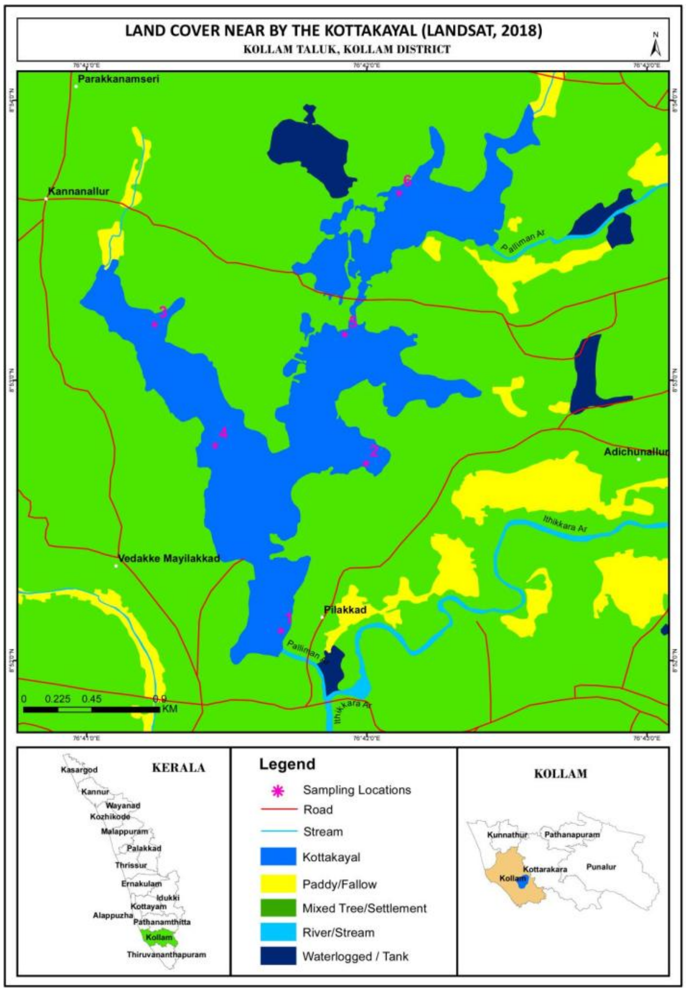

Fig. 1. Location map of the study area with the sampling sites marked

Sampling

Sediment samples were collected using Van Veen Grab of size 0.2 m² for analyzing different parameters. A mercury thermometer was used to determine the sediment temperature in the field. Sediment pH was recorded at field using an electronic portable pH meter. Sediment samples were stored in labelled plastic covers for further analysis in the laboratory. Triplicate grab samples were taken to ensure precision in sampling macro benthos. These samples were washed through a sieve of mesh size 500µm at sampling stations and those retained were collected and preserved in 5% neutral formalin mixed with Rose Bengal stain for subsequent identification (Buchanan et al., 1984). Organic carbon was assayed by titrimetric determination (Walkley and Black, 1934).

Texture Analysis

Samples were dried in hot oven at 95°C. The percentage of sand, silt and clay respectively was determined by pipette analysis (Krumbein and Pettijohn, 1938).

Macrobenthos

Macrobenthic samples were sorted into different benthic groups by hand-picking. The sieved sediment samples which were fixed in 5 % formalin and rose Bengal were transferred to white plastic trays for distinguishing easily the benthic groups (Buchanan et al., 1984). The number of individuals per group was assessed. Identification of insects, molluscs, crustaceans and annelids were done using standard reference (Bouchard, 2012; Day, 1967; Fauchald, 1977; McAlpine et al., 1981; Yong and Yule, 2004). Biomass was estimated by taking the wet weight of the organisms in groups and expressed in mg m^{-2}.

Statistical analysis

Descriptive statistics like mean and standard deviation were calculated using MS Excel Software. One way ANOVA was performed to check the significance of difference at 1% and 5% level of significance. Correlation of different physicochemical parameters with different groups of benthic macro-invertebrates was done using SPSS

Results

Sediment characteristics

Sediment grain size distribution

Seasonal variation in the percentage of sand, silt and clay in bottom sediment at different study site is represented in table 1. During pre-monsoon period site 1 had 26.61% sand, 41.95% silt and 31.44% clay. Site 2 had 63.36% sand, 28.48% silt and 6.16% clay. Site 3 had 62.16% sand, 26.59% of silt and 11.25% of clay. Site 4 had 44.6% sand. 45% silt and 10.18% clay. Site 5 had 59.98% sand, 10.81% silt and 29.21% clay. Site 6 had 55% sand, 34.9% silt and 10.1% clay (Table 1).

During monsoon period the percentage of sand, silt and clay at site 1 was 24.92%, 39.08% and 36% respectively. Site 2 had 57.85% of sand, 35.79% of silt and 6.36% of clay. Site 3 had 60% of sand, 25.01% of silt and 15% of clay. Site 4 had 10.59% of sand, 58.91% of silt and 30.5% of clay. Site 5 had 66.7% sand, 16.95% silt and 16.35% of clay. Site 6 had 72.53% of sand, 16.81% of silt and 10.66% of clay (Table 1).

During post-monsoon period site 1 had 22.85% of sand, 43.39% of silt and 33.76% of clay. Site 2 had 60.13% of sand, 34.4% of silt and 5.37% of clay. Site 3 had 61.81% of sand, 27.39% silt and 10.8% of clay. Site 4 had 7.14% of sand, 57.33% silt and 35.53% of clay. Site 5 had 76.7% of sand, 9.14% of silt and 14.15% of clay. Site 6 had 60.86% of sand, 37.98% of silt and 1.16% of clay (Table 1).

Table 1. Seasonal variation in percentage of sand, silt and clay in bottom sediment

Pre-monsoon						
Grain size	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**
Sand (%)	26.61	63.36	62.16	44.6	59.98	55
Silt (%)	41.95	28.48	26.59	45	10.81	34.9
Clay (%)	31.44	6.16	11.25	10.18	29.21	10.1
Monsoon						
Grain size	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**
Sand (%)	24.92	57.85	60	10.59	66.7	72.53
Silt (%)	39.08	35.79	25.01	58.91	16.95	16.81
Clay (%)	36	6.36	15	30.5	16.35	10.66
Post-monsoon						
Grain size	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**
Sand (%)	22.85	60.13	61.81	7.14	76.7	60.86
Silt (%)	43.39	34.4	27.39	57.33	9.14	37.98
Clay (%)	33.76	5.37	9.89	35.53	14.15	1.16

Texture analysis of sediment samples from different study sites had revealed that the chief texture of lake sediment was sandy loam. It was noted that during pre-monsoon season sediment texture of site 1, 2, 3, 4, 5 and 6 was clay loam, sandy loam, sandy loam, loam, sandy clay loam and sandy loam respectively (Fig. 2).

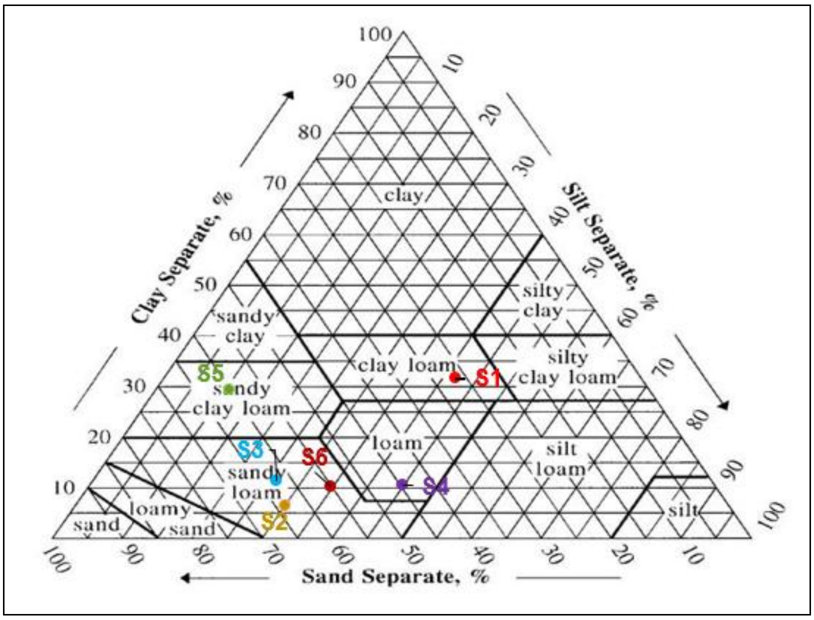

Fig. 2. Sediment texture during pre-monsoon period

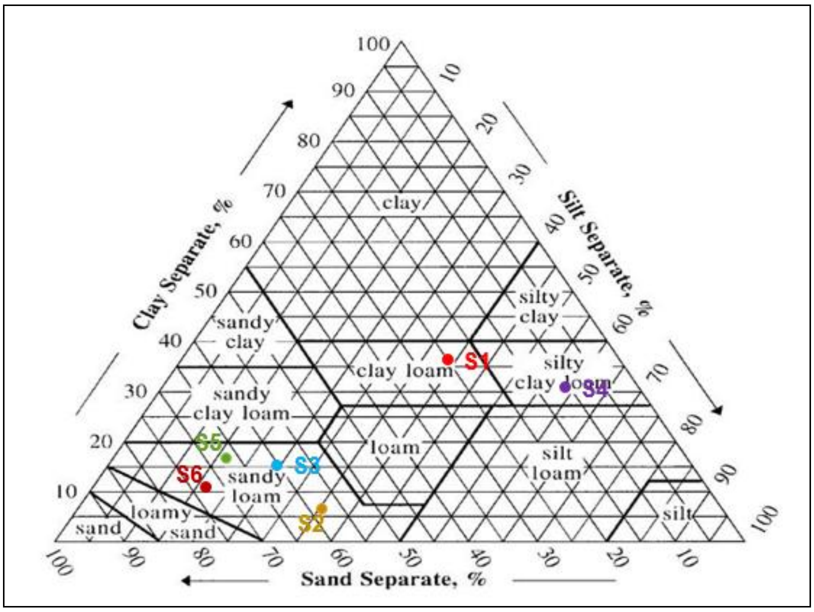

Fig. 3. Sediment texture during monsoon period

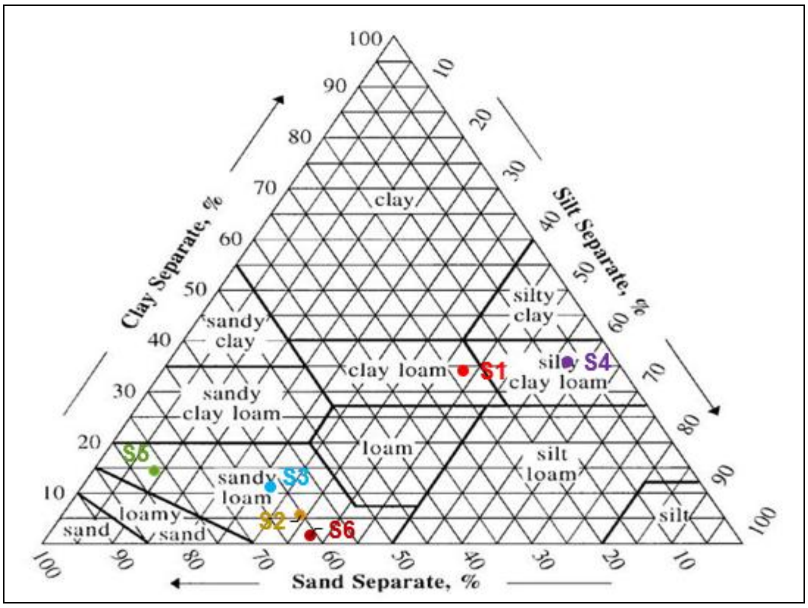

Fig. 4. Sediment texture during post-monsoon

In monsoon season site 1 had clay loam texture, site 2 had sandy loam texture, site 3 had sandy loam texture, site 4 had silty clay loam texture, site 5 had sandy loam texture and site 6 had sandy loam texture (Fig.3). During post-monsoon period site 1 had clay loam texture, site 2 had sandy loam texture, site 3 had sandy loam texture, site 4 had silty clay loam texture, site 5 and site 6 too had sandy loam texture (Fig. 4). There was more silt content in the sediment collected from site 4 all through the study. This might be due to the excessive clay mining that prevailed in that area.

Sediment temperature

Mean sediment temperature recorded during 2015-2017 was 28.16±0.66 °C. Table 2 shows the mean variation in sediment temperature of the lake during the study period.

Table 2. Mean variation and ANOVA of sediment temperature

Stations	Pre-monsoon	Monsoon	Post-monsoon	Mean ±SD	
Site 1	30.18±1.18	28.08±0.38	28.75±1.92	29±0.88	F value (0.76) p value (0.681)
Site 2	28.98±1.65	27.58±0.98	28.13±2.46	28.23±0.58	
Site 3	27.9±1.82	26.35±0.82	27.25±2.59	27.17±0.64	
Site 4	28.48±1.11	26.65±1.3	28.25±1.92	27.79±0.81	
Site 5	28.35±1.53	26.85±1.43	28.58±2.01	27.93±0.77	
Site 6	29.8±0.79	28.5±0.57	28.25±2.17	28.85±0.68	
Mean ±SD	28.95±0.81	27.34±0.78	28.2±0.48	28.16±0.66	
F value (4.89)* p value (0.01)					

Sediment temperature was maximum during the pre-monsoon period. The average sediment temperature during pre-monsoon was 28.95±0.81 °C. During monsoon season the average sediment temperature recorded was 27.34±0.78 °C. Lowest mean value was observed during monsoon period. Sediment temperature recorded during the post-monsoon period was 28.2±0.48 °C. The highest mean value of sediment temperature was recorded in site 1, which was 29±0.88 °C. Site 3 had the lowest average value of sediment temperature of 27.17±0.64 °C. Mean sediment temperature of site 2 was 28.23±0.58 °C, site 4 was 27.79±0.81 °C, site 5 was 27.93±0.77 °C and site 6 was 28.85±0.68 °C. Results of ANOVA revealed that there was no significant difference in sediment temperature between stations (p= 0.681). There was significant difference in sediment temperature between seasons (p=0.01) (Table 2).

Sediment pH

Mean sediment pH recorded during 2015-2017 was 7±0.07. Table 3 shows the mean variation in sediment pH of the lake during the study period.

Table 3. Mean variation and ANOVA of sediment pH

Stations	Pre-monsoon	Monsoon	Post-monsoon	Mean ±SD	
Site 1	6.93±0.19	7.08±0.39	6.93±0.13	6.98±0.07	F value (1.99) p value (0.091)
Site 2	7.13±0.16	7.15±0.26	6.93±0.13	7.07±0.1	
Site 3	7.03±0.18	7.15±0.15	7±0	7.06±0.06	
Site 4	7.03±0.18	7.13±0.25	6.98±0.18	7.05±0.06	
Site 5	7±0.14	7.13±0.26	7±0	7.04±0.06	
Site 6	6.75±0.43	6.7±0.37	6.95±0.09	6.8±0.11	
Mean ±SD	6.98±0.12	7.1±0.07	6.92±0.1	7±0.07	
F value (0.88) p value (0.419)					

Sediment pH was maximum during the monsoon period. The average sediment pH during monsoon was 7.1±0.07. During pre-monsoon season the average sediment pH recorded was 6.98±0.12. Lowest mean value was observed during post-monsoon period. Sediment pH recorded during the post-monsoon period was 6.92±0.1. The highest mean value of sediment pH was recorded in site 2, which was 7.07±0.1. Site 6 had the lowest average value of sediment pH of 6.8±0.11. Mean sediment pH of site 1 was 6.98±0.07, site 3 was 7.06±0.06, site 4 was 7.05±0.06 and site 5 was 7.04±0.06. Results of ANOVA revealed that there was no significant difference in sediment pH between stations (p= 0.091) and between seasons (p=0.419) (Table 3).

Organic carbon

Mean organic carbon recorded during 2015-2017 was 2±0.5%. Table 4 shows the mean variation in organic carbon of the lake during the study period. Organic carbon was maximum during the monsoon period. The average organic carbon during monsoon was 2.25±0.52%. During pre-monsoon season the average organic carbon recorded was 1.16±0.2%. Lowest mean value was observed during post-monsoon period. Organic carbon recorded during the post-monsoon period was 1.5±0.71%. The highest mean value of organic carbon was recorded in site 5, which was 2.97±0.38%. Site 3 had the lowest average value of organic carbon of 1.32±0.9%. Mean organic carbon of site 1 was 1.88±0.36%, site 2 was 2.08±0.54%, site 4 was 2.28±0.47% and site 6 was 1.64±0.46%.

Table 4. Mean variation and ANOVA of organic carbon

Stations	Pre-monsoon	Monsoon	Post-monsoon	Mean ±SD	
Site 1	1.76±0.53	2.36±1.08	1.51±0.69	1.88±0.36	F value (4.1)** p value (0.003)
Site 2	2.15±0.57	2.71±0.44	1.39±0.54	2.08±0.54	
Site 3	0.89±0.31	2.58±0.78	0.5±0.39	1.32±0.9	
Site 4	2.46±0.29	2.74±0.35	1.64±1.07	2.28±0.47	
Site 5	2.49±0.43	3.41±0.72	3±0.51	2.97±0.38	
Site 6	1.16±0.2	2.25±0.52	1.5±0.71	1.64±0.46	
Mean ±SD	1.16±0.2	2.25±0.52	1.5±0.71	2±0.5	
F value (5.96) p value (0.004)**					

Results of ANOVA revealed that there was significant difference in organic carbon between stations (p= 0.003) and between seasons (p=0.004) (Table 4). Organic carbon was maximum during the monsoon period in all the study sites. Highest value of organic carbon was observed at site 5 during monsoon period and the lowest value was recorded at site 3 during post-monsoon period. Organic carbon was greater during pre-monsoon period than during post-monsoon period at sites 1, 2, 3 and 4. While organic carbon at sites 5 and 6 during post-monsoon was greater than during pre-monsoon season.

Benthic macro-invertebrate fauna

The benthic macro-invertebrate fauna of Kottakayal was represented by 20 species belonging to 3 phyla – Mollusca, Arthropoda and Annelida (Table 5). Benthic macro-invertebrates were found to be abundant during the monsoon months of the study period in all the sites selected for study. Site 6 showed slight difference; there was maximum abundance of benthic macro-invertebrates in the pre-monsoon months than in the monsoon and post- monsoon periods.

Table 5. Benthic macro-invertebrates identified from different sites of Kottakayal

S. No.	Phylum	Class	*Species*
1	Mollusca	Pelecypoda	*Villorita cyprinoides*
2	Mollusca	Gastropoda	*Melania tuberculata*
3	Mollusca	Gastropoda	*Lymnaea stagnalis*
4	Mollusca	Gastropoda	*Pila globosa*
5	Mollusca	Gastropoda	*Planorbis sp.*
6	Arthropoda	Insecta	*nymph of dragonfly*
7	Arthropoda	Insecta	*nymph of mayfly*
8	Arthropoda	Insecta	*nymph of damselfly*
9	Arthropoda	Insecta	*nymph of ranatra*
10	Arthropoda	Insecta	*Chironomus larva.*
11	Arthropoda	Insecta	*Ablabesmyia larva*
12	Arthropoda	Insecta	*Ceratopogonidae larva*
13	Arthropoda	Malacostraca	*Tanaid sp.*
14	Arthropoda	Malacostraca	*Parathelphusa sp.*
15	Arthropoda	Malacostraca	*Cardina sp.*
16	Arthropoda	Malacostraca	*Macrobrachium sp.*
17	Arthropoda	Malacostraca	*Exopalaemon sp.*
18	Annelida	Polychaeta	*Capitella sp.*
19	Annelida	Polychaeta	*Polychaete worm*
20	Annelida	Oligochaeta	*Oligochaete worm*

Benthic Biomass

Mean biomass of benthic macro-invertebrates recorded during 2015-2017 was 6.18±2.69 g m^{-2}. Table 6 shows the mean variation in benthic biomass of the lake during the study period. Biomass of benthic macro-invertebrates was maximum during the monsoon period. The average biomass during monsoon was 8.66±5.67 g m^{-2}. During pre-monsoon season the average benthic biomass was 2.45±1.48 g m^{-2}. Lowest mean value was observed during pre-monsoon period. Benthic biomass recorded during the post-monsoon period was 7.44±3.02 g m^{-2}. The highest mean value of benthic biomass was recorded in site 2 which was 14.92±9.75 g m^{-2}. Site 5 had the lowest average value for benthic biomass of 1.87±1.04 g m^{-2}. Mean benthic biomass of site 1 was 7.44±6.31 g m^{-2}, site 3 was 7.28±3.1 g m^{-2}, site 4 was 1.99±1.16 g m^{-2} and site 6 was 3.58±0.65 g m^{-2}.

Table 6. Mean variation and ANOVA of benthic biomass

Stations	Pre-monsoon	Monsoon	Post-monsoon	Mean±SD	
Site 1	2.03±167	16.29±5.1	4±1.9	7.44±6.31	F value (1.66)* p value (0.023)
Site 2	0.69±0.59	14.61±5.08	29.47±5.19	14.92±9.75	
Site 3	4.3±2.94	11.55±6.48	5.99±3.01	7.28±3.1	
Site 4	2.29±1.36	3.23±1.28	0.44±0.16	1.99±1.16	
Site 5	0.91±0.47	3.31±1.37	1.39±0.9	1.87±1.04	
Site 6	4.48±1.3	2.95±1.42	3.32±1.32	3.58±0.65	
Mean ±SD	2.45±1.48	8.66±5.67	7.44±3.02	6.18±2.69	
F value (1.46)* p value (0.027)					

Results of ANOVA revealed that there was significant difference in benthic biomass between stations (p= 0.023) and between seasons (p=0.027) (Table 6.). Benthic biomass was maximum during the monsoon period in all the study sites except at site2 and site 6. Biomass was minimum during pre-monsoon period. Highest value of benthic biomass was observed at site 2 during post-monsoon period and the lowest value was recorded at site 4 during post-monsoon period.

Correlation analysis

Correlation analysis was performed to understand the effect of sediment parameters on abundance of different groups of benthic macro-invertebrates. Pelecypoda exhibited positive correlation ($r = 0.39, 0.68$; $p < 0.05$) with gravel and organic carbon of the sediment (Table 7). Gastropoda had weak positive correlation ($r= 0.01$; $p < 0.05$) with organic carbon and strong positive correlation ($r = 0.80$, $p < 0.05$) with gravel content. Polychaeta had much stronger positive correlation with gravel and organic carbon respectively ($r = 0.42, 0.52$; $p < 0.05$). Oligochaeta showed weak negative correlation ($r= -0.379$, $p< 0.01$) with depth. It had strong positive correlation ($r= 0.52, 0.61$; $p< 0.05$) with sand and organic carbon. It exhibited weak negative correlation ($r= -0.36$, $p< 0.05$) with clay. Benthic organism in total had weak negative correlation ($r= -0.391$, $p< 0.01$) with depth and clay ($r= -0.30$, $p< 0.05$) and positive correlation ($r= 0.57$, $p< 0.05$) with organic carbon (Table 7).

Table 7. Correlation analysis of benthic macro-invertebrates with sediment parameters

	Pelecypoda	Gastropoda	Insecta	Malacostraca	Polychaeta	Oligochaeta	Benthos total
Depth	0.147*	-0.286*	-0.309**	0.027	-0.363**	-0.379**	**-0.391****
Gravel	0.39*	0.80*	-0.04	-0.05	0.42*	0.27	**0.22**
Sand	0.04	0.11	0.16	-0.10	0.2	0.52*	**0.32**
Silt	0.07	-0.01	-0.13	0.04	-0.05	-0.17	**0.01**
Clay	-0.14	-0.24	-0.13	0.15	-0.30*	-0.36*	**-0.30***
Sediment temp.	-0.27	-0.01	0.21	-0.11	0.14	0.24	**0.01**
Sediment pH	0.05	-0.10	0.19	0.10	-0.02	-0.11	**0.02**
Organic carbon	**0.68***	**0.01***	**0.05**	**0.14**	**0.52***	**0.61***	**0.57***

***Significant at 0.05 level **Significant at 0.01 level**

Discussion

Water temperature was found to have negative correlation with the distribution of bivalves in Kottakayal. Distribution of aquatic species are determined by environmental factors like temperature, pH, transparency, hardness and DO (Mansor et al., 2012; Prasanna and Ranjan, 2010). Molluscs and annelids had close dependence on water temperature, pH, depth, sediment organic carbon and sediment organic matter, whereas arthropods had less dependence (Sharmin et al., 2018). It was noticed that depth of the water body had a negative correlation with the abundance of groups like Mollusca and Arthropoda and there was no correlation between abundance of Class Malacostraca and depth of the water body. Similarly, there was much stronger positive correlation with organic carbon and abundance of class Pelecypoda, Gastropoda, Polychaeta and Oligochaeta than with class Insect and Malacostraca.

Mining and dredging affect suspension feeders negatively. Mining and dredging discharge unwanted materials which causes smothering of shells and loosening of substratum making it unsuitable for clam settlement (Paul et al., 2017). Survival rate of bivalves declined due to sedimentation of entrenched material in dredging areas of

Vembanad Lake (Paul et al., 2017). Habitat destruction caused due to mining and dredging activities have ultimately affected clam culture. Clay and sand mining has adversely affected the distribution and abundance of bivalve, *Villorita cyprinoids* in Kottakayal, whose abundance was minimum during the pre-monsoon period when clay mining was its maximum. Benthic abundance and biomass were minimum at site 4 and 5, which were the major sites of clay and sand mining.

Disturbance in bottom substratum and water might lead to death and migration of benthic organisms. The unstable nature of bottom substratum due to mining activities prevalent in site 4 and 5 could be a reason for their low benthic abundance. Station 4 had much more silt content which could be another reason for low numerical abundance of benthic fauna in this region. Total absence of benthos in regions dominated by silt was reported by (Geetha et al., 2010) in their works conducted in Cochin estuary. They also added that unstable nature of substratum and pollution results in low benthic abundance. Low biomass at sites 4, 5 and 6 has resulted in low fisheries potential in these sites. The destruction of substratum caused by mining activities has been held responsible for the low benthic biomass especially at site 4 and 5 which were the prime sites of clay and sand mining.

Sediment texture, organic content and grain size were found to influence polychaete distribution. Greater was their density in coarse sediment (Maciolek and Blake, 2009). Polychaetes were found to have positive correlation with organic carbon. Abundance of polychaete was comparatively higher in pre-monsoon and post-monsoon months than in monsoon. The reason for this difference in abundance might have been the heavy rainfall during monsoon months that lowered the chloride content of the water body. During pre-monsoon months the chloride content was enhanced by high temperature causing greater evaporation of water body. Recolonization of polychaetes might have occurred during post-monsoon months and this might have been the reason for its greater abundance during that season.

Abundance of macrobenthos especially that of polychaete, was greater in sediments that had sand, silt and clay in almost equal proportions. Least number of macrobenthos were observed in sediments with clay as the major component in the present investigation. There was complete absence of organisms on thick clay substrate and greater abundance on loose substrate (Musale and Desai, 2011). Alterations in the sediment texture was pronounced at site 4 and site 5 mainly during the pre-monsoon season due to uncontrolled clay and sand mining in these sites. Sediment size determines the organic matter present in it. Fine grain sediments have much greater organic matter than coarse grained sediments (Shein et al., 2006). Greater the organic carbon, greater is the organic matter in sediments. The role of sediment texture in controlling the organic matter was well established by the works of (Sarkar et al., 2016), in different parts of Vembanad Lake. Organic carbon content was high in fine sediment fractions (Li and Pang, 2014). Organic carbon in sediment is enriched by dense vegetation and plankton bloom (Krishna et al., 2013). In shallow littoral water organic matter in the sediments serves as important nutrient source (Suomela et al., 2005). A significant positive correlation was observed between organic carbon and clay content in sediments (Aminayanaba & Lawal, 2017). The main reason for the increase in organic carbon with increase in silt and clay content in sediments is due to the similarity in the settling velocity of both organic constituents and fine particles (Hibino et al., 2013). Sediment organic content is greatly influenced by salinity. Higher the salinity lesser is the organic content in sediments (Zenteno-Palma et al., 2018). Carbon content and nitrogen were found to be proportional to clay content and organic carbon in lake sediments (Mwamburi, 2018).
The main factor that influenced sediment geochemistry is sediment texture. Silt and clay fractions had positive correlation with organic carbon content whereas sand had negative correlation (Renjith and Chandramohanakumar, 2007). These parameters were found to exhibit negative correlation with sand. Benthic macro-invertebrate abundance was positively correlated with organic carbon content (Hyland et al., 2005).

Conclusion

The study demonstrates that physico-chemical properties of sediments, especially organic carbon and texture, significantly influence benthic macro-invertebrate distribution and biomass in Kottakayal. Sediment size determines the organic matter present in it, with fine grained sediments containing more organic matter than coarse grained sediments. Greater the organic carbon, greater is the organic matter in sediments. Mining and dredging discharge unwanted materials which causes smothering of shells and loosening of substratum rendering it unsuitable for clam settlement. Consequently, these activities negatively affect suspension feeders and have adversely affected the distribution and abundance of the bivalve, *Villorita cyprinoids* in Kottakayal. Seasonal peaks in monsoon reflect nutrient enrichment, while correlations underscore influence of organic matter on key groups like molluscs and annelids. Targeted conservation strategies, including mining regulation and sustained monitoring, are imperative to safeguard biodiversity and ecosystem of this wetland.

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Author Contributions
JRF led concept formation; conducted field investigation; collected data; performed laboratory analyses; carried out formal data analysis; drafted the original manuscript; and prepared visualizations and figures. SR reviewed and edited the manuscript, validated the results, and approved the final version.

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