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EFFECTS OF ORGANIC CARBON AND DISSOLVED OXYGEN ON SPECIES DIVERSITY OF LITTORAL BENTHOS IN SITES AROUND THE RUMUEME CREEK IN THE UPPER BONNY ESTUARY

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ABSTRACT

A study was conducted to evaluate the organic carbon and dissolved oxygen (DO) conditions of surface sediments and water samples and their effects on species diversity of the littoral macrofauna around the Rumueme Creek in the upper Bonny Estuary. Sediment, water and benthic samples were collected from five sampling stations for four months (August – November). Mean sediment organic carbon ranged from 2.67 ± 0.58 – 16.00 ± 5.00% and was significantly higher at the site (STN 4) under the influence of an abattoir compared to all other sites. Mean DO of surface water fell in the range 3.50 ± 0.50 – 6.50 ± 0.42 mg/l. Differences in mean DO were not significant between study sites, but periods. Significantly higher mean DO value was obtained in August and September than the other two months. Species diversity of littoral benthos was characteristically low across study sites, and ranged from 0.10 – 1.74. Both organic carbon and DO concentration were not found to be linearly related to species diversity. It was concluded that rather than sediment organic carbon and DO conditions, there may be other underlying environmental factors responsible for the low species diversity recorded.

Keywords: Organic Carbon, Dissolved Oxygen, Species Diversity, Macrofauna

INTRODUCTION

Organic pollution of tidal creeks in the upper Bonny Estuary of the Niger Delta, Southern Nigeria, arising from activities of waterfront settlements and abattoirs has generated much concern in recent years. Near the discharge point, organic pollutants modify the abundance and species diversity of aquatic biota (Nicolaidou *et al*., 1993). A number of studies have reported low species diversity of benthic communities following incidents of organic pollution (Leppakoski, 1975; Rosenberg, 1980; Kraft & Sypniewski, 1981). However, evidence from research shows that normal biota re-establishes downstream away from the immediate influence of organic pollution. In this study, the effect of organic inputs on littoral benthos in sites around the Rumueme Creek in the Upper Bonny Estuary was investigated. Since the last two and half decades, the volume of sewage discharged into tidal creeks in the upper Bonny Estuary has increased tremendously, and has implication for organic pollution of the area. In addition to this source, the Rumueme Creek also receives considerable organic inputs from the Rumueme Abattoir, waterfront settlement, Nigerian Agip Oil Company (NAOC) jetty, and numerous latrines that line the littoral fringes of the area.

Some of the first signs of organic pollution include toxic algal blooms and associated deoxygenation of surface waters (Degobbis *et al*., 1979; Rosenberg, 1980). A surface water of good quality has dissolved oxygen (DO) values exceeding 2 mg/l. Rosenberg (1980) reported abrupt changes in abundance, biomass, and species diversity of benthic fauna at

values below 2 mg/l in estuaries in Northern Europe. Within the Niger Delta, some studies have been conducted in the past to investigate the nutrient status and DO conditions of surface waters. In relation to species composition of plankton community, Chinda *et al.* (1993) investigated the nutrient status of the Elechi Creek in the upper Bonny Estuary. In similarly related studies, Ewa (1988) and Ombu (1987) both reported high organic carbon in sediments from sites around the upper limits and main channel of the Bonny Estuary respectively. However, more studies are still required to cover the network of tidal creeks in the area, since a number of these creeks may have come under increased anthropogenic influence in recent years. This has become imperative since geometric increase in human population and industrial activities in Port Harcourt is doing so along side the quantity of wastes discharged into surface water systems.

Littoral benthos has been used as sentinel organisms to detect potential heavy metal and organic pollution in various studies around the world. Their abundance and species diversity leave behind ecological signatures that are indicative of impacts of human activities. In the current study, the littoral benthos of the Rumueme Creek was investigated in relation to nutrient conditions and DOES concentrations of surface water samples in the area.

MATERIAL AND METHODS

Study Area

Samples were collected from five sampling sites around the Rumueme Creek in the upper Bonny Estuary (Fig 1), consisting of four potentially contaminated sites and one relatively uncontaminated reference site. The waterfront settlements behind the Rivers State University of Science and Technology and along Rumueme Waterside were potentially contaminated sites and were designated as STN 1 and STN 3 respectively. STN 2 and STN 4 were under the immediate influence of the NAOC jetty and Rumueme Abattoir respectively, while STN 5 was located further upstream of the tidal inlet at low tide and was regarded as a reference site.

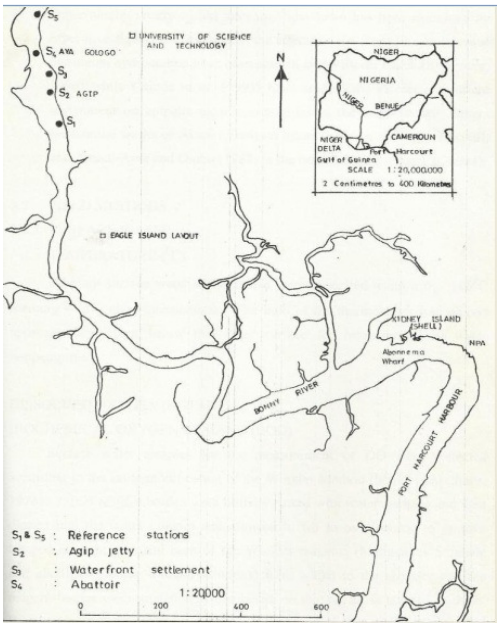

Fig 1 Map of the Study Area Showing the 5 Study Sites around the Rumueme Creek in the Upper Bonny Estuary

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Field Methods

Surface water samples for the measurement of DO concentration were collected in 250 ml (white) reagent bottles in each of the study sites, by dipping bottle into the water column and allowing it to fill to overflowing so as to remove trapped air bubbles before replacing the cover. Samples were fixed by adding 2 ml each of Winkler 1 and 2 reagents. Three replicate samples of surface sediments for the determination of organic carbon were also collected from the depth of 10 cm. Samples were stored in foil paper and transported to the laboratory for analysis. Five replicates of benthic samples were collected during the low tide by excavating to the depth of 10 cm, the area covered by a 0.1^{-2} quadrat (Ekweozor, 1985), mixed into a slurry in a bucket, and poured through a sieve of 1 mm mesh (Soulsby *et al*., 1978; Ekweozor, 1985). Material retained on the sieve was washed into 1l plastic container and preserved in 10% buffered formalin (Canfield *et al*., 1994) to which was added eosin.

Laboratory Methods

In the laboratory, Winkler titrations were carried out on DO samples by titrating with standard sodium thiosulphate solution (0.0250 N). Sediment samples were air-dried by thinly spreading them on flat surface for 7 days before being transferred to a hotbox oven where they were oven-dried to constant dry weight at 40 °C for 48 h. Samples were then ground in porcelain, homogenized and screened on a sieve of 1 mm mesh. Finely ground samples in porcelain crucibles were dried at 110 °C for 8 h in a PYROLABO oven and later cooled to room temperature in a dessicator. 1 g sample was then heated in previously weighed porcelain crucible at 550 °C for 1 h in a PYROLABO electric muffle furnace (APHA, 1989). Crucible was reweighed after allowing to cool in a dessicator. The mass of sample left after ignition was determined by subtracting the final weight from the initial weight of sample. Sediment organic carbon was then determined as % organic content. Excess silt or mud and formalin were removed from the benthic sample by washing sample through a sieve of fine mesh size made of silk. Sorting was done in a shallow white tray containing water. The benthic invertebrate fauna were sorted into separate vials and preserved in 70 % ethanol. Taxonomic identification was carried out in the laboratory of the Institute of Pollution Studies (IPS) of the Rivers State University of Science and Technology, Nkpolu-Oroworukwo, Port Harcourt. Samples were identified as far as local identification keys would allow.

Data Analysis

Analysis of variance (ANOVA) was carried out to evaluate if a significant difference exists in the means of organic carbon of sediment and DO concentrations of surface water between sampling sites as well as sampling periods at the 95 % significance level using SPSS for windows version 10.0. Replicate were collected only for sediment (n = 3) and benthic samples (n = 5), but not for DO samples. Where ANOVA indicated a significant difference, pairwise comparisons were conducted using Tukey test (Fowler & Cohen, 1990) to determine pairs of significant means. Bivariate linear regression analysis was also carried out to evaluate the effect of sediment organic carbon and DO conditions on the species diversity of littoral macrofauna.

RESULTS

Sediment Organic Carbon Content

Sediment organic carbon content was generally higher at STN 4 and STN 5 than at STN 1, STN 2, and STN 3 (Fig 2). The mean organic carbon content of sediment at STN 4 in

September was more than double the values obtained in sediments at STN 1 – STN 3 in all the months. The ANOVA on mean sediment organic carbon content between the sampling periods was not significant, $F(3,40) = 0.95$, $p > 0.05$, (Table 1). ANOVA showed significant differences in mean sediment organic carbon content between the sampling sites, $F(4,40) = 19.61$, $p < 0.05$ (Table 1). Sampling site accounts for ≈ 66 % of the total variance of sediment organic carbon. Sediments at STN 4 and STN 5 had significantly higher organic carbon content than all the other sites (Tukey, $p < 0.05$). ANOVA indicated no significant interaction between sampling periods and sampling sites, $F(12,40) = 1.15$, $p > 0.05$ (Table 1).

Dissolved Oxygen Concentration

Mean dissolved oxygen (DO) concentration of surface water was slightly higher at STN 1 and STN 5 than at all the other sites, and August and September mean values were also somewhat higher than those of the other months (Fig 3). The ANOVA on mean DO concentrations between the sampling periods was significant, $F(3,12) = 17.69$, $p < 0.05$ (Table 2). Mean DO concentration in August was significantly higher than October and November values. Significantly higher value was also recorded in September compared to November (Tukey, $p < 0.05$). Differences in mean DO concentrations between sampling sites were not significant, $F(4,12) = 2.79$, $p > 0.05$ (Table 2).

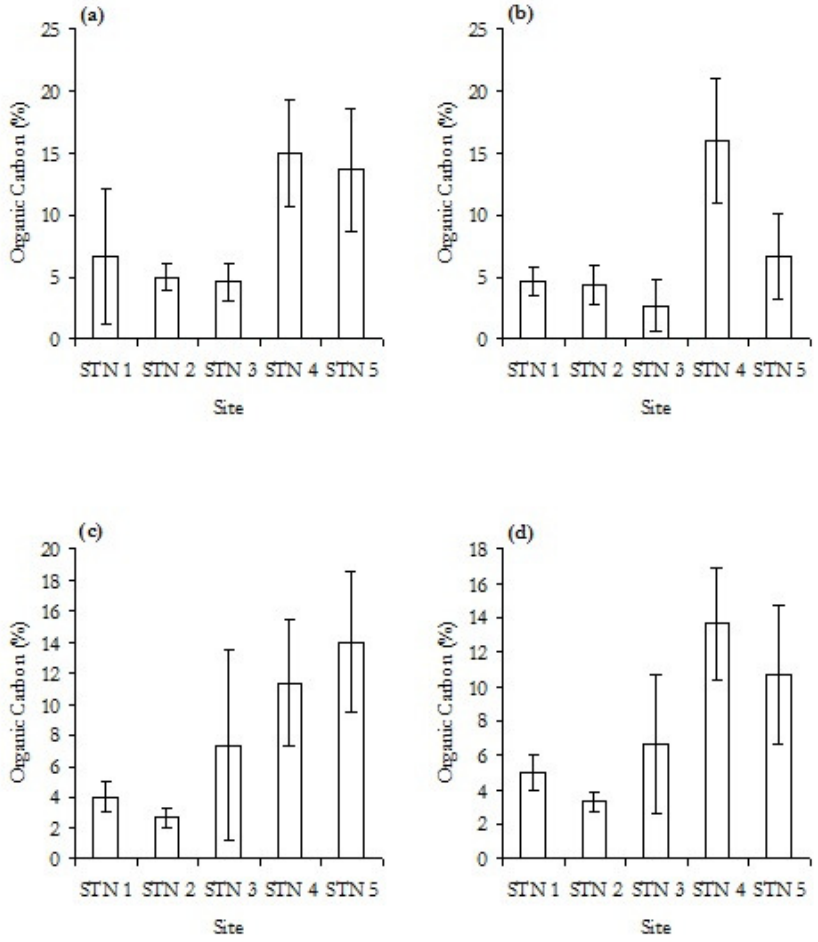

Fig 2 Organic Carbon Content (%) ($\bar{x}$ ± SD, n = 3) of Sediment Samples from Sites Around the Rumueme Creek in the upper Bonny Estuary for (a) August, (b) September, (c) October, and November

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Table 1 Two-Way Analysis of Variance (ANOVA) on Organic Carbon (%) of Sediment Samples from Sites around the Rumueme Creek in the upper Bonny Estuary

Source of Variation	*df*	*MS*	*F*	*p-value*
Site	4	239.4	19.61	< 0.05 *
Period	3	11.62	0.95	> 0.05
Interaction	12	13.99	1.15	> 0.05
Error	40	12.21		

* Significant at $p < 0.05$

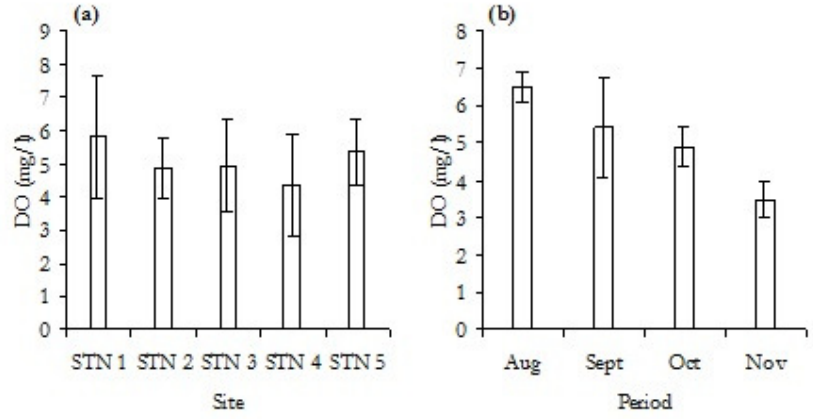

Fig 3 Concentration of DO (mg/l) ($\bar{x}$ ± SD) in Surface Water Samples from Sites around the Rumueme Creek in the Upper Bonny Estuary Showing (a) Spatial Variations in DO and (b) Temporal Variations in DO

Table 2 Two-Way Analysis of Variance (ANOVA) on Concentrations of DO (mg/l) in Surface Water Samples from Sites around the Rumueme Creek in the upper Bonny Estuary

Source of Variation	*df*	*MS*	*F*	*p-value*
Site	4	1.22	2.79	> 0.05
Period	3	7.77	17.69	< 0.05 *
Error	40	12.21		

* Significant at $p < 0.05$

Species Diversity

The benthic macroinvertebrate community around the Rumueme Creek was represented by 3 major macrofaunal groups including polychaetes, crustaceans, and mollusks. “Others” were represented by certain insect larvae and fish fry. The benthic sample consisted of a total number of 5,780 individuals, over 5,500 of which were polychaetes (n = 5,535), while benthic enumeration of the rest came up to 245 individuals. The study recorded a total number of 22 species, approximately 23 % and 46 % of which were polychaetes and

crustaceans respectively. The rest of the species were relatively evenly distributed across the molluscs (14 %) and "others" (18 %). Measurements of the Shannon-Weaver diversity index (H') in sites around the Rumueme Creek varied from a minimum at STN 2 (0.10) to a maximum at STN 1 (1.74). Diversity values at STN 1, STN 4, and STN 5 were comparatively higher than those of STN 2 and STN 3 (Fig 4).

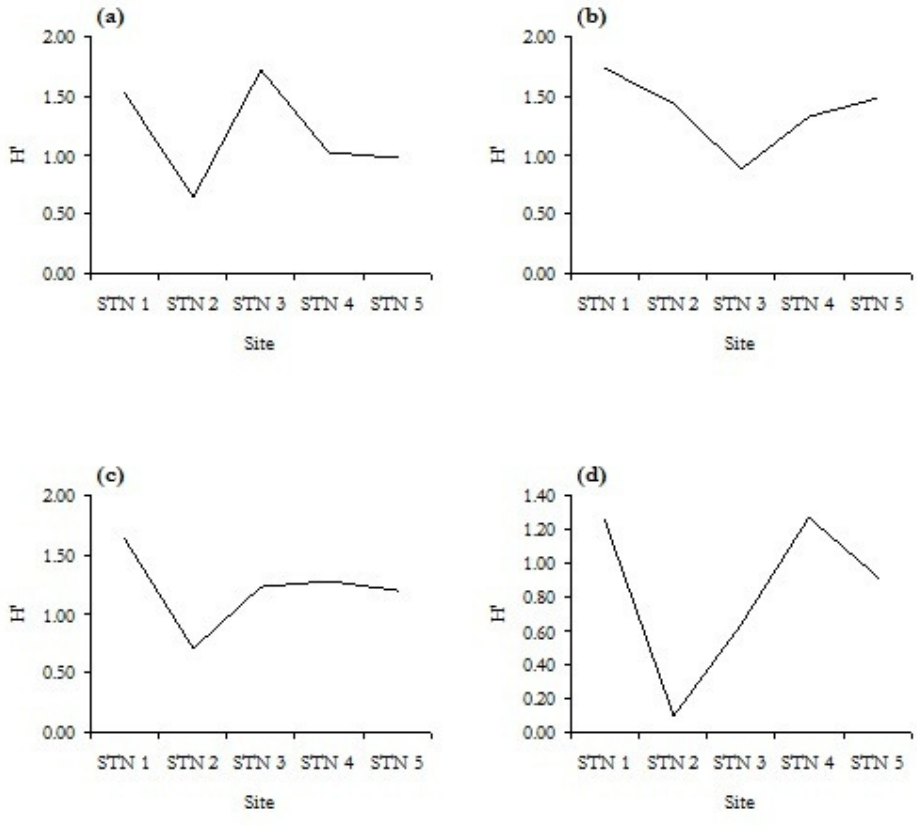

Fig 4 Shannon-Weaver Diversity Index (H') for Species of Littoral Macrofauna in Benthic Samples from Sites around the Rumueme Creek in the upper Bonny Estuary for (a) August, (b) September, (c) October, and (d) November

Effect of Organic Carbon and Dissolved Oxygen (DO) on Species Diversity (H')

The results of the bivariate linear regression to evaluate the relationship between sediment organic carbon and H' are as shown in Table 3. The regression equation is:

$H' = 0.008 organic\ carbon + 1.087$

Results of the *t*-test associated with the independent variable clearly indicate that the two variables are not linearly related such that as sediment organic carbon increases H' also increases and vice versa, $t(18) = 0.357$, $p > 0.05$ (Table 3). The 95 % confidence interval for the slope, -0.038 to 0.053, contains the value of zero which further indicates that sediment organic carbon is not significantly related to H'. A very weak positive correlation which was not significant was detected between the two variables ($r = 0.084$, $p > 0.05$), and indicates that sediment organic carbon accounts for merely 0.7% of the total variance of H'. Table 4 reports results of the bivariate linear regression between DO and H', with the regression equation given as:

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$H' = 0.122DO + 0.529$

The linear relationship between DO and H' was not significant, $t(18) = 1.78$, $p > 0.05$ (Table 4). The 95% confidence interval for the slope, -0.022 to 0.265, also indicates that DO is not significantly positively related to H'. A correlation of r = 0.387 ($p > 0.05$) between the two variables indicates a weak positive correlation, in which DO accounts for approximately 15% of the total variance of H'.

Table 3 Linear Regression Analysis Showing the Relationship between Organic Carbon (%) of Sediment and H' of Littoral Macrofauna around the Rumueme Creek in the Upper Bonny Estuary

	Coefficients		*t-Stat*	*P-value*	*95% Confidence Interval for B*	
	B	*Standard Error*			*Lower Bound*	*Upper Bound*
Intercept	1.087	0.197	5.528	0.000	0.674	1.500
Organic Carbon	0.008	0.022	0.357	0.725	-0.038	0.053

Table 4 Linear Regression Analysis Showing the Relationship between DO (mg/l) of Surface Water and H' of Littoral Macrofauna around the Rumueme Creek in the Upper Bonny Estuary

	Coefficients		*t-Stat*	*P-value*	*95% Confidence Interval for B*	
	B	*Standard Error*			*Lower Bound*	*Upper Bound*
Intercept	0.529	0.358	1.477	0.157	-0.223	1.282
Dissolved Oxygen	0.122	0.068	1.783	0.091	-0.022	0.265

DISCUSSION

Sediments with values of organic carbon exceeding 1% are said to have high organic carbon content (Griggs, 1978). Sediment organic carbon around the Rumueme Creek had mean values that ranged from 2.76 ± 0.58% to 16.00 ± 5.00%, and are therefore indicative of high organic carbon content. This result agrees with reports of previous investigations in which sediment organic carbon in the range 17.67 – 32.05% and 3.68 – 26.07% were reported by Ombu (1987) and Ugbomeh (1987) respectively in the main channel of the Bonny Estuary. Mean values reported by Ewa (1988) in sites around the upper Bonny Estuary fell in the interval 9.08 – 28.01% . The higher sediment organic carbon at STN 4 could be attributed to organic wastes discharged from the Rumueme Abattoir which is relatively closer to this site. Sediment organic carbon seemed to decrease with increasing distance from the abattoir, as relatively lower values were recorded at STN 1 and STN 2. Although STN 5 appeared to be relatively sheltered from the influence of the abattoir and other human activities, it also recorded relatively higher organic carbon values, most of which is suspected to come from the breakdown of mangrove plants and nutrient-bound particles transported to this site by tidal current. Pollution by organic matter or petroleum hydrocarbons is reflected by DO concentrations of surface water. Organic pollutants stimulate and are gradually removed by microbial activity. The increased microbial activity deoxygenates the water downstream from the discharge (Rosenberg, 1980). DO concentration of surface water around the Rumueme Creek varied from 3.50 ± 0.50 to 6.50 ± 0.42 mg/l. In an earlier study conducted in the Niger Delta, Nigeria, Ugbomeh (1987) also reported similar values (3.35 – 6.65 mg/l) in Port

Harcourt and Ford point transects. The results of the present study are also congruent with Zarkanellas (1979) who recorded a mean winter value of 4.75 mg/l in the Elefsis Bay, Greece. Chronic oil spills at STN 2 (NAOC jetty) and the discharge of organic wastes at STN 4 and STN 5 probably contributed to the lower DO values recorded at these sites, compared to those of the relatively uncontaminated reference site (STN 5).

The degree of speciation of the littoral benthic fauna around the Rumueme Creek was considerably low as only 22 species of the four macrofaunal groups (polychaetea, crustacean, mollusca, and "others"), predominated by the polychaetes, were recorded in the study. Out of the total number of 5,535 individuals enumerated, 5.500 were polychaetes in which *Nereis sp* and *Notomas sp* showed characteristically high relative abundance. Polychaetes alone accounted for over 90% of the littoral benthos of the study area, while the rest of the taxa accounted for < 5%. Akani (1994) also reported a similar trend in the upper Bonny Estuary. Whereas Ombu (1987) recorded 28 species in the central Bonny Estuary, Akani (1994) and Ekweozor (1996) reported 61 species and 15 species in their respective studies conducted in sites around the upper reaches of the Bonny Estuary.

Large amounts of organic matter are a physiological prerequisite for polychaetes to maintain population growth (Tsutsumi, 1987; Chesney & Tenore, 1985) but also induces organic pollution stress to marine organisms. Only opportunistic species tolerant to organic pollution (Pearson & Rosenberg, 1978) and oil spills would normally grow to higher population densities. Results of this study, however, do not indicate that the low species diversity of littoral benthos around the Rumueme Creek was due to organic pollution induced by high organic carbon content. Changes in DO conditions are usually reflected by local biota. At a DO value of 2 mg/l, Rosenberg (1980) reported abrupt changes in species diversity in estuaries in Europe. The present study reported recorded mean values exceeding 2 mg/l, which were not also significantly related to H' of the study area.

CONCLUSION

Sediments keep records of a variety of organic or inorganic wastes discharged into the estuarine environment. Species diversity of littoral macrofauna was characteristically low across sampling sites. Contamination of the Rumueme Creek with organic waste has not reached levels at which nutrient conditions and DO concentrations pose a threat to the benthic community structure of the creek. The low species diversity recorded in this study was not attributed to elevated organic carbon of sediment and variations of DO concentrations. Besides these two independent variables, there may be other underlying environmental factors, the study of which could provide useful explanation regarding the low species diversity of littoral macrofauna of the creek.

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