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Water quality and zooplankton community of the Eme River, Umuahia, Southeast Nigeria

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ABSTRACT. Aquatic ecosystems and biota are often adversely affected by anthropogenic activities. Consequently, zooplanktons have been used to monitor anthropogenic impacts because of their sensitivity to their environment. Water quality and zooplankton community of the Eme River, Umuahia, was assessed between December 2017 and November 2018. The study was carried out in six stations in relation to human activities. Human activities in the watershed were dominated by sand mining. A quantitative filtration method was used for the zooplankton sample collection while standard sample collection and analytical methods were used for the water samples. The zooplankton species recorded were 27 while the most abundant zooplankton group was Rotifera. A known pollution indicator, *Daphnia pulex*, had the highest number of individuals. The effects of human activities in the watershed were reflected in the results of some of the physicochemical parameters of the river. The zooplankton assemblage and community structure also reflected the effects of human activities in the river. Combined effects of human activities and season contributed to the relatively low zooplankton abundance recorded particularly in some downstream stations. The impacts of sand mining on water quality and zooplankton were more remarkable in the downstream stations (4 – 6) where the activity was intense while a large number of children swimming and related activities during the dry season had some impacts in station 1. The dominance of indicator and tolerant species indicated that the river was undergoing eutrophication. Sand mining among other observed anthropogenic activities was a major contributor to the nutrient enrichment in the river. The major water quality parameters influencing the zooplankton community structure was revealed by canonical correspondence analysis.

Keywords: zooplankton, diversity, anthropogenic impact, bioindication, water quality, sand mining

1. Introduction

The water quality of the rivers is of considerable importance because they are generally used for multiple purposes (Venkatramanan et al., 2014). Freshwater bodies across the world have been subjected to intense human activities that have degraded the quality and utility of the water (Amah-Jerry et al., 2017). Water pollution is a serious problem in developing countries; adequate monitoring of water quality is necessary to appraise the suitability, assist management and control (Kozaki et al., 2020). The quality of the aquatic ecosystem and the ecological effects of human activities can be predicted by the assessment of its biological communities (Santos and Ferreira, 2020). One of the essential biological communities found in lotic freshwater ecosystems is zooplankton. Zooplankton is microscopic animals that serve as an important link in

the conversion of energy from producers to consumers; playing an essential role in the aquatic food webs (Sharma et al., 2010; Schmidt et al., 2020). Zooplanktons are weak swimmers and usually drift along with the currents (Prygiel and Coste, 1993). They strongly respond to environmental changes and are used in the assessment of the conditions in aquatic ecosystems (Primo et al., 2015). Temporal and spatial variations of physicochemical environmental conditions often lead to dramatic and rapid changes in zooplanktons because they have a short life span and fast regeneration (Pace and Orcutt, 1981). Environmental parameters (dissolved oxygen (DO) and nutrients) are important for the presence and distribution of zooplankton. Low values of DO would limit their development. Nutrients (NH_4^+ and PO_4^{3-}) are important for their growth while pH and total suspended solids (TSS) are essential for their distribution (Duc et al., 2016). The efficiencies

of trophic transfer from phytoplankton to zooplankton and from zooplankton to fish depend largely on the taxa of zooplankton available in an aquatic ecosystem (Hairston and Hairston, 1993). A decline in zooplankton diversity in aquatic ecosystems will ultimately affect higher trophic levels. This will result in loss of species, habitat or even ecosystems and ecosystem services if there is no control (Gaygusuz and Dorak, 2013). Some anthropogenic activities take place at the Eme River, of which illegal and indiscriminate sand mining is the major. The objective of this study was to assess the water quality and zooplankton diversity vis-à-vis anthropogenic activities.

2. Materials and methods

2.1. Study area

The Eme River is located in Umuahia, Abia State, Nigeria. It originated in Uzuakoli, flowed through some communities and fell into the Imo River at Onuimo. The section studied is from Ofeme to Umudiawa across the Port Harcourt - Enugu expressway in Umuahia; about 3.25km in length and situated between latitude 5°38' and 5°37'N and longitude 7°25' and 7°26'E (Fig. 1). The study area is characterized by mean annual rainfall (4000mm), high relative humidity (>70%) and high temperature (29-31°C). There are two main seasons in the area: wet (June to November) and dry (December to May), with double maximum rainfalls recorded in July and September. "August break" is a short period of dryness usually occurring in between the peaks.

2.2. Sampling stations

Six sampling stations were selected in the river based on accessibility and human activities. Five of the stations were within the dredged section, except for station 1. Station 1 is upstream, and the reference site is located in Mbato, Ofeme community. The substrate is muddy. A large number of children was observed swimming during the dry season up to early rains due to the proximity to the village, easy accessibility and low water depths. Other activities observed include washing of clothes and extraction of water for domestic purposes during the dry season. Station 2 is about 1.84 km downstream of station 1 and located at the outsketch of Ofeme community at Eme – Ihite. The substrate is a mixture of sand and stones. It was a less active or abandoned sand mining site, and minimal washing of clothes, swimming and extraction of water for domestic purposes were observed during the dry season. Station 3 is located at Eme – Ihite, towards the expressway, about 419.67 m downstream of station 2. Large clayey boulders dominated the substrate. The only activity observed was periodic boat movements of sand miners across the station. Station 4 is about 490.26 m downstream of station 3 and is located in the Umudiawa community across the expressway. The substrate was sandy. An intensive sand mining and two sand landing sites were located upstream of the station. Station 5 is about 200.22 m downstream of station 4, within the Umudiawa community. Sand mining was observed because the substrate is sandy. Station 6 is about 300.14 m downstream of station 5, within Umudiawa community. The substrate was sandy. Sand mining was observed in the river channel and banks.
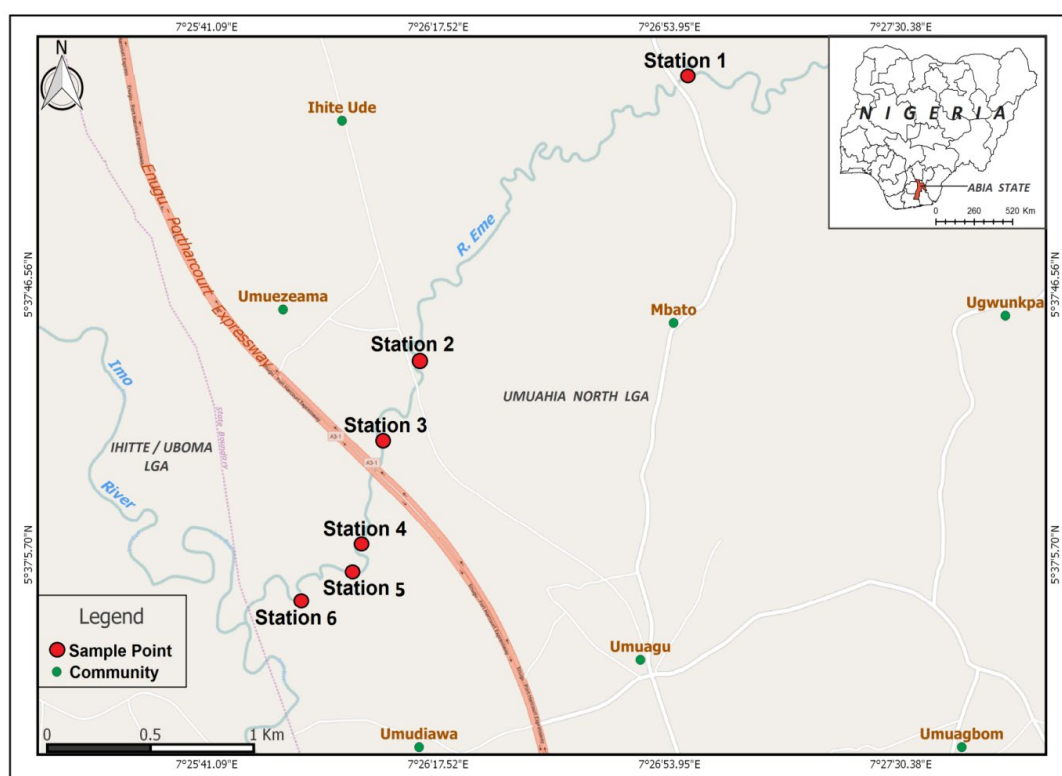

Fig.1. Map of Umuahia, Abia State, Nigeria, showing the sampling stations on the Eme River.

2.3. Samples collection and analysis

This study was carried out between December 2017 and November 2018. Samples for water quality and zooplankton analyses were collected once a month. One litre water sampler was used for the sample collection, transferred into sterilized 1 litre plastic bottles and taken to the laboratory for analyses in ice chests. Water temperature (mercury-in-glass thermometer), flow velocity (floatation method), transparency (Secchi disk), pH, electrical conductivity, and total suspended solids (pH/EC/TDS Meter- HANNA 3100 model) were determined in situ while others were determined in the laboratory using standard methods described by APHA (2012) - dissolved oxygen and biochemical oxygen demand (Winkler's method with azide modification method), nitrate (UV spectrophotometric method), and phosphate (Stannous Chloride Method).

The quantitative filtration method was used for zooplankton sample collection. One hundred litres of water from undisturbed sections of each station were collected and filtered through a 55 μm Hydro-Bios plankton net as a composite sample. The net content was poured into plankton bottles (250 mL) and preserved in a 4% formalin solution. A subsample (1 mL) of the preserved sample was taken using a pipette. The collected sample was put on the Sedgwick-rafter counting chamber and viewed under a light binocular microscope (Nikon 400 binocular microscope) using a low magnification of x10. The zooplankton was sorted into different groups, and the cells per ml were counted. The identification was done to the lowest practicable taxonomy using key literature by Jeje and Fernando (1986) and Dang et al. (2015).

2.4. Data analysis

The results were summarized using a descriptive statistic package of Microsoft Excel. One-way ANOVA was used to test for statistical differences among the stations while Tukey's pairwise test was used for post hoc analysis. The zooplankton community structure was analysed using Margalef (D), Shannon-Weiner (H) and Evenness (E) indices while canonical correspondence analysis (CCA) was used to determine the relationship between the zooplankton groups and some environmental variables.

3. Results and discussion

3.1. Spatial and temporal variations of physico-chemical parameters

The summary of the physicochemical parameters is presented in Table 1. The water temperatures were moderate and ranged between 22.0 and 28.5°C. The lowest value was recorded in station 1 (May 2018) while the highest value was recorded in station 6 (April 2018). The ambient surface water temperatures were influenced by seasons and sampling periods. An early rain event was responsible for the lowest temperature recorded in May 2018 while the highest temperature in

April 2018 was due to the dry season. Air temperatures are the major determinant of surface water temperatures (Park et al., 2016), and water temperature is a critical factor in some biotic and abiotic processes in the aquatic environment (Dugdale et al., 2018).

The flow velocity was moderate (0.21 - 0.85 m/s). Station 1 had the lowest value in April 2018, and the highest one was recorded in station 3 in December 2017. Stations 2 and 3 were significantly higher (F = 31.59; $P < 0.05$). Flow velocity can significantly influence the self-purification capacity of a waterbody (Chapman and Kimstach, 1996). Flow velocity can considerably affect the composition, abundance and distribution of aquatic biota (Brooks et al., 2005; Oldmeadow et al., 2010). CCA also showed that flow velocity was a strong negative factor especially in station 3. Increased flow velocity and river discharge can result in low species composition and abundance due to low residence time, especially in the wet season (Anyanwu et al., 2013).

The turbidity values ranged between 0.5 and 9.4 NTU; some exceeded the acceptable limit (5 NTU) of the Federal Ministry of Environment (FMEnv., 2011) in all the stations. The turbidity values exceeding limits in all the stations, especially between December 2017 and March 2018, could be attributed to the cumulative effect of receding flood and anthropogenic activities. The lowest and highest values were both recorded at station 4 in March and February 2018, respectively. High turbidity values were recorded at station 1 during the dry season due to a large number of children swimming, bathing, washing, and extraction of water for drinking. The station was shallow during the dry season and located close to the community. However, relatively higher values were recorded at stations 4 – 6 between May and November 2018 because of the effect of sand mining activities that increased with the intensity of rains (Anyanwu and Umeham, 2020). This was more remarkable in station 4 that was immediately downstream of sand mining and landing sites with a steady decline further downstream (Seiyaboh et al., 2013). CCA also showed that turbidity had a negative effect on zooplankton at station 4.

The pH values were acidic (4.3 - 6.3) and did not comply with the acceptable limit. FMEnv. (2011) recommended 6.5 to 8.5 for aquatic life. The lowest pH was recorded at station 2 (June 2018) while the highest was recorded at station 1 (September 2018). These low pH values could be due to both geogenic (Anyanwu and Emeka, 2019) and anthropogenic influences (Akankali et al., 2017). Seiyaboh et al. (2013) reported that sand mining contributes to low pH in water bodies. Extremes of pH cannot be tolerated by most aquatic organisms. Aquatic biota is very sensitive to pH levels lower than 5, which may result in death (Kale, 2016).

The electrical conductivity (EC) values ranged between 45.2 and 168.4 μS/cm. The lowest value was recorded at station 2 (March 2018) while the highest value was recorded at station 5 (January 2018). The electrical conductivity (EC) values were moderate, but the upstream stations (1 – 3) were significantly (F = 29.59; $p < 0.05$) lower than the downstream stations

Table 1. Summary of physicochemical parameters of the Eme River, Umuahia, Nigeria.

Parameter	Stn 1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	P-value	FMEnv.
	X ± SEM	X ± SEM	X ± SEM	X ± SEM	X ± SEM	X ± SEM		
Water temperature (°C)	24.8 ± 0.59	24.9 ± 0.54	24.8 ± 0.53	24.9 ± 0.51	24.4 ± 0.53	24.8 ± 0.53	P > 0.05	< 40
	(22.0-28.0)	(22.5-28.2)	(23.0-28.2)	(23.2-28.4)	(23.0-28.3)	(22.9-28.5)		
Turbidity (NTU)	4.2 ± 0.61	3.5 ± 0.52	3.0 ± 0.48	5.0 ± 0.72	3.9 ± 0.61	4.1 ± 0.56	P > 0.05	5
	(1.5-9.3)	(1.3-8.1)	(0.6-5.4)	(0.5-9.4)	(0.7-7.8)	(0.9-6.9)		
Flow velocity (ms⁻¹)	0.35 ± 0.02[a]	0.56 ± 0.04[b]	0.71 ± 0.02[c]	0.36 ± 0.02[a]	0.37 ± 0.02[a]	0.45 ± 0.03[a]	P < 0.05	-
	(0.21-0.49)	(0.37-0.80)	(0.63-0.85)	(0.24-0.46)	(0.28-0.50)	(0.26-0.58)		
pH	5.69 ± 0.11	5.43 ± 0.13	5.42 ± 0.10	5.53 ± 0.10	5.49 ± 0.10	5.55 ± 0.10	P > 0.05	6.5 – 8.5
	(5.0 – 6.3)	(4.3 – 5.9)	(4.9 - 6.1)	(5.0 – 6.1)	(5.1 – 6.2)	(5.1 - 6.1)		
Electrical conductivity (µScm⁻¹)	86.0 ± 4.40[a]	71.3 ± 4.43[a]	65.7 ± 3.50[a]	130.4 ± 5.86[b]	115.4 ± 6.04[b]	119.6 ± 5.38[b]	P < 0.05	-
	(55.6-115.8)	(45.2-95.4)	(49.6-88.7)	(90.3-160.2)	(88.5-168.4)	(87.1-148.4)		
Dissolved oxygen (MgL⁻¹)	3.7 ± 0.38	3.6 ± 0.34	3.7 ± 0.40	3.9 ± 0.46	3.6 ± 0.37	3.8 ± 0.42	P > 0.05	6
	(2.3-5.7)	(2.2-5.9)	(1.8-6.1)	(1.6-6.1)	(2.0-5.5)	(1.8-5.8)		
Biochemical oxygen Demand (MgL⁻¹)	1.7 ± 0.14[ab]	1.5 ± 0.08[b]	1.7 ± 0.12[b]	2.6 ± 0.37[ac]	1.9 ± 0.20[ab]	2.1 ± 0.25[ab]	P < 0.05	3
	(1.0-2.5)	(1.1-1.9)	(1.1-2.4)	(0.8-4.3)	(1.0-3.2)	(0.9-3.9)		
Nitrate (MgL⁻¹)	2.9 ± 0.30[a]	2.2 ± 0.17[a]	1.6 ± 0.12[a]	4.5 ± 0.20[c]	2.6 ± 0.37[ab]	2.9 ± 0.27[b]	P < 0.05	9.1
	(1.8-4.9)	(1.3-3.2)	(1.1-2.4)	(3.4-5.6)	(1.2-5.3)	(1.9-5.2)		
Phosphate (MgL⁻¹)	1.3 ± 0.08[a]	0.8 ± 0.10[a]	0.7 ± 0.07[a]	3.4 ± 0.18[b]	2.8 ± 0.22[bc]	2.9 ± 0.21[bc]	P < 0.05	3.5
	(1.0-1.9)	(0.5-1.7)	(0.4-1.2)	(2.8-4.6)	(1.9-4.3)	(2.0-4.5)		

Note. a, b, c, d, e – Means with different superscripts across the rows are significantly different at p < 0.05; SEM – Standard error of the mean; FMEnv. (2011) – National environmental (surface and groundwater quality control) regulations (2011).

(4 – 6) due to the effects of sand mining activities in the downstream stations. Sand mining activities increase the levels of EC in surface water (Rehman et al., 2016) and usually contribute to an increase in water pollution. The relatively higher EC values recorded in station 1 compared to stations 2 and 3 could be attributed to perturbation from a large number of children swimming during the dry season as well as allochthonous inputs in the wet season from increased runoffs.

Dissolved oxygen is an essential parameter used in the assessment of water quality (Kale, 2016), and its level is very important to support biodiversity in aquatic ecosystems. Only two of the dissolved oxygen values exceeded the acceptable limit (6 mg/L) set by FMEnv (2011). The values ranged from 1.6 to 6.1 mg/L; the lowest one was recorded in station 4 (November 2018), and the highest – in stations 3 (January 2018) and 4 (February 2018). Most of DO values were below the acceptable limit, especially in station 4 due to anthropogenic impact (sand mining). Rao et al. (2013) reported that some environmental impacts associated with sand mining activities such as re-suspension of nutrients and chemicals, altered water flow and increased water temperature can contribute to the depletion of oxygen in the water. CCA showed that dissolved oxygen was one of the major positive factors influencing the zooplankton community.

Biochemical Oxygen Demand (BOD) is another important parameter used in evaluating the health and self-purification capacity of freshwater bodies. BOD ranged between 0.8 and 4.3 mg/L; the lowest and highest values were recorded in station 4 in November 2018 and February 2018, respectively. Some of the

values, especially in the downstream stations (4 – 6), exceeded the acceptable limit (3 mg/L). Station 4 was significantly different (F = 3.43; $p < 0.05$) from stations 2 and 3. This is also due to sand mining activities. Akankali et al. (2017) observed that sand mining activities greatly increase the release and circulation of organic matter from the sediments into the water column, which can contribute to an increase in BOD levels.

Nitrate occurs naturally in many environments at moderate levels, except for those under the impact (Chapman and Kimstach, 1996). The nitrate values (1.1 - 5.6 mg/L) were within the acceptable limit. The lowest value was recorded in station 3 (June 2018) while the highest value was recorded in station 4 (February 2018). Higher values were recorded in the downstream stations (4 – 6), which could be caused by sand mining activities. In particular, station 4 was significantly higher (F = 14.62; $p < 0.05$) than the others. Akankali et al. (2017) recorded higher values (10.7 - 12.4 mg/L) in the Okoro Nsit stream, South South Nigeria that is also subjected to intense sand mining activities. The effect of a large number of children swimming during the dry season and allochthonous inputs during the wet season could be responsible for the elevated values in station 1 compared to stations 2 and 3.

Phosphate exhibited the same trend as nitrate. The values ranged between 0.4 and 4.6 mg/L, with the lowest values recorded in June and July 2018 (station 3) and the highest values in September 2018 (station 4). The values of the downstream stations (4 – 6) exceeded the acceptable limit set by FMEnv. (2011) and were significantly (F = 56.71; $p < 0.05$) higher

than the upstream stations (1 – 3) values. This could be also caused by sand mining activities. Akankali et al. (2017) recorded lower values (2.5 to 3.6 mg/L) in the Okoro Nsit stream, South South Nigeria. Relatively higher phosphate values were also recorded in station 1 compared to stations 2 and 3 as observed for nitrate and attributed to the same factors.

3.2. Zooplankton composition, abundance and distribution

The zooplankton species composition, abundance and distribution are presented in Table 2. A total of 3382 zooplankton individuals were recorded. The most abundant group was Rotifera (1064 individuals/L or 31.5%) followed by Cladocera (961 individuals/L or 28.4%), Protozoa (741 individuals/L or 21.9%), and Copepod (616 individuals/L or 18.2%). Rotifera was also reported as the dominant group in other Nigerian rivers subjected to intense sand mining

(Ekwu and Udo, 2014; Ekpo et al., 2015). Small size, parthenogenesis and rapid reproduction of rotifers under favourable conditions (nutrient-enriched water) could be responsible for their high abundance (Levine et al., 1999). Other factors include their morphological variations and adaptations (Wetzel, 2001) as well as their diverse feeding habits (Mustapha, 2009). Rotifers minimize competition through niche exploitation and food utilization owing to their ability to migrate vertically, which could also be responsible for their dominance (Ekpo et al., 2015).

The number of species recorded was higher than 4 and 8 species recorded in the Odot stream and Ikpa River, respectively, in the Niger Delta, Nigeria, which were also subjected to sand mining activities (Ekwu and Udo, 2014; Ekpo et al., 2015). The relatively low zooplankton abundance could be attributed to anthropogenic impact exacerbated by seasonal influences. Arimoro and Oganah (2010) recorded a higher abundance (4322 individuals/1) in the Orogodo River of the Niger Delta, Nigeria, perturbed by abattoir effluent and sand mining activities.

Table 2. Species composition, abundance and distribution of zooplankton in the Eme River, Umuahia, Nigeria.

Group	Taxa	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Total	RA (%)
Copepoda	*Campthocamptus staphylinus*	26	21	14	33	22	22	138	4.08
	Eucyclops speratus	10	22	39	29	12	32	144	4.26
	Microcyclops varicans	21	27	22	11	16	21	118	3.49
	Sinodiaptomus sarsi	23	20	20	0	3	22	88	2.6
	Mesochra suifunensis	24	18	26	16	10	34	128	3.78
Cladocera	*Alona affins*	12	19	25	27	34	13	130	3.84
	Daphnia longis	20	26	23	10	20	35	134	3.96
	D. pulex	25	25	35	27	37	26	175	5.17
	D. magna	26	26	25	12	22	28	139	4.11
	Moina dubia	44	22	19	20	26	35	166	4.91
	M. micrura	11	18	22	20	22	15	108	3.19
	Diaphanosoma Brachyurum	21	15	19	27	20	7	109	3.22
Rotifera	*Keratella cochlearis*	20	20	21	14	15	14	104	3.08
	Brachionus capsuliflorus	20	26	12	25	23	35	141	4.17
	B. plicatilis	16	24	18	25	17	30	130	3.84
	Asplanchna priodonta	27	19	25	27	31	22	151	4.47
	Notholca labis	15	36	14	11	33	22	131	3.87
	Synchaeta pectinata	26	23	30	23	21	29	152	4.49
	Conochilus umcormis	25	23	25	21	6	28	128	3.79
	Ascomorpha ecaudis	29	30	20	13	17	18	127	3.76
Protozoa	*Paramecium candatum*	15	21	13	12	24	20	105	3.11
	Difflugia candatum	14	18	22	15	17	7	93	2.75
	Didinium bolbanic	26	25	22	8	8	14	103	3.05
	Tintinnopsis lacustris	17	27	12	20	23	25	124	3.67
	Amoeba radiosa	11	17	12	13	11	23	87	2.57
	Vorticella radians	20	30	17	24	18	32	141	4.17
	Arcella nitrata	19	21	25	15	3	5	88	2.60
	Total	**563**	**619**	**577**	**498**	**511**	**614**	**3382**	

The most abundant zooplankton recorded was *Daphnia pulex* (Cladocera) with 175 individuals/L (5.17% of the total zooplankton abundance). *Daphnia pulex* is the most common cladoceran found almost in all permanent and eutrophic freshwater environments (Miller, 2000). The large body sizes of *Daphnia* makes it possible for them to graze on large quantities and diverse forms of phytoplankton; contributing to their predominance among the cladocerans (Mustapha, 2009), and their composition and abundance is also dependent on food supply (Miller, 2000).

Spatially, the most abundant individuals (619 individuals/L or 18.3%) were recorded in station 2 followed by station 6 (614 individuals/L or 18.2%), station 3 (577 individuals/L or 17.1%), station 1 (563 individuals/L or 16.6%), station 5 (511 individuals/L or 15.1%), and station 4 (498 individuals/L^{-1} or 14.7%). Little or no human activities were responsible for the high zooplankton abundance in station 2 while sand mining activities were responsible for the low abundance in station 4. Arimoro and Oganah (2010) recorded lower abundance in station 3, where sand mining occurred in contrast to station 1 (control) with no activity recorded. Station 6 showed signs of recovery after the impacts. Arimoro and Oganah (2010) observed that sensitive species usually disappears when water becomes polluted and recovers quickly downstream of the impact source while tolerant species survive stress associated with pollution and flourish. Ko et al. (2020) also reported a significant recovery in the number of species and individuals after dredging operations. High flow velocity could be also responsible for the relatively lower abundance in station 3. Planktonic organisms are continuously washed downstream by flowing water; therefore, their development is usually affected (Redden et al., 2009).

3.2.1. Zooplankton community structure

In the assessment of pollution and waterbody productivity using plankton, diversity indices have an important application (Hastuti et al., 2018). It is general knowledge that species diversity and richness are usually reduced as the perturbation increases; though some tolerant species tend to flourish (Xu et al., 2005). The zooplankton groups showed varied responses to the effects of anthropogenic activities as reflected in their community structures (Table 3).

Generally, Rotifera was the most abundant group while Copepoda was the least one. The abundance ranged between 63 individuals/L (copepoda, station 5) and 201 individuals/L (Rotifera, station 2). Lower abundance was recorded in stations 4 (Cladocera and Rotifera) and 5 (Copepoda and Protozoa). Highest abundance was recorded in stations 2 (Rotifera and Protozoa), 5 (Cladocera) and 6 (Copepoda). The abundance though varied among the groups was relatively higher at the less perturbed stations (1 – 3) while lower abundances were recorded in the more perturbed stations (4 and 5) and station 6 showing signs of recovery (Ko et al., 2020).

Rotifera and Copepoda had the highest and lowest Shannon-Weiner diversity index (H), respectively. Among the Rotifera, station 2 had the highest value (2.059), and station 5 – the lowest value, (1.992) followed by station 4 (2.033). The highest Shannon-Weiner diversity index (H) was recorded in station 2 (1.600), and the lowest one – in station 4 (1.300) among the Copepoda. The Shannon-Weiner diversity indices were all low (1 – 2), indicating some level of pollution. Station 2 had relatively higher values in all the zooplankton groups while station 6 showed signs of recovery in some groups. Water bodies are classified

Table 3. Community structure of zooplankton in the Eme River, Umuahia.

Group	Biodiversity indices	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Copepoda	Individuals	104	108	121	89	63	131
	Shannon-Weiner (H)	1.567	1.6	1.552	1.3	1.468	1.587
	Evenness (E)	0.9583	0.9906	0.9445	0.9175	0.8685	0.9779
	Margalef (D)	0.8613	0.8543	0.8341	0.6684	0.9655	0.8205
Cladocera	Individuals	159	151	168	143	181	159
	Shannon-Weiner (H)	1.85	1.928	1.925	1.888	1.916	1.833
	Evenness (E)	0.909	0.9822	0.9795	0.9442	0.971	0.8934
	Margalef (D)	1.184	1.196	1.171	1.209	1.154	1.184
Rotifera	Individuals	178	201	165	159	163	198
	Shannon-Weiner (H)	2.055	2.059	2.042	2.033	1.992	2.044
	Evenness (E)	0.9755	0.9797	0.9628	0.955	0.9162	0.965
	Margalef (D)	1.351	1.32	1.371	1.381	1.374	1.324
Protozoa	Individuals	122	159	123	107	104	126
	Shannon-Weiner (H)	1.913	1.927	1.905	1.895	1.809	1.804
	Evenness (E)	0.9678	0.9813	0.9596	0.9504	0.872	0.868
	Margalef (D)	1.249	1.184	1.247	1.284	1.292	1.241

with Shannon-Weiner diversity Index as clean (>4.5), slightly polluted (4.5-3), moderately polluted (3-2), heavily polluted (2-1), and highly polluted (<1) according to Zheng et al. (2007).

Margalef Species Richness index had a similar trend with Shannon-Weiner Diversity Index (H) among the groups; though, there were differences in the spatial variations. Among the Rotifera, station 4 had the highest value (1.381) followed by station 5 (1.374) while the relatively unperturbed station 2 (1.300) and station 6 (1.324) had lower values. The highest Margalef Species Richness index among the Copepoda was recorded in station 5 (0.9655), and the lowest − in station 4 (0.6684). The values were generally low in all the stations and among the groups indicating some level of perturbation (Shah and Pandit, 2013). The more perturbed stations had higher values than the less perturbed stations, especially among Rotifera and Protozoa. Meng et al. (2020) explained this observation that the Margalef index concentrates on the richness and taxonomic composition instead of community abundance.

The evenness index did not show any trend, though the highest values were recorded in station 2 in all the groups while the lowest values were recorded in stations 5 (Copepoda, 0.8685 and Rotifera, 0.9162) and 6 (Cladocera, 0.8934 and Protozoa, 0.8680). The evenness index indicates how the organisms are evenly distributed in a sample (Kaparapu and Geddada, 2013). Evenness values were relatively higher in station 2 in all the groups, indicating the effect of the anthropogenic activities in the other stations. However, flow velocity could be responsible for the values recorded in station 3 (Redden et al., 2009) and anthropogenic activities other than sand mining in station 1. Generally, the upstream stations (1 – 3) were relatively higher, indicating the negative impact of sand mining in the downstream stations (4 – 6).
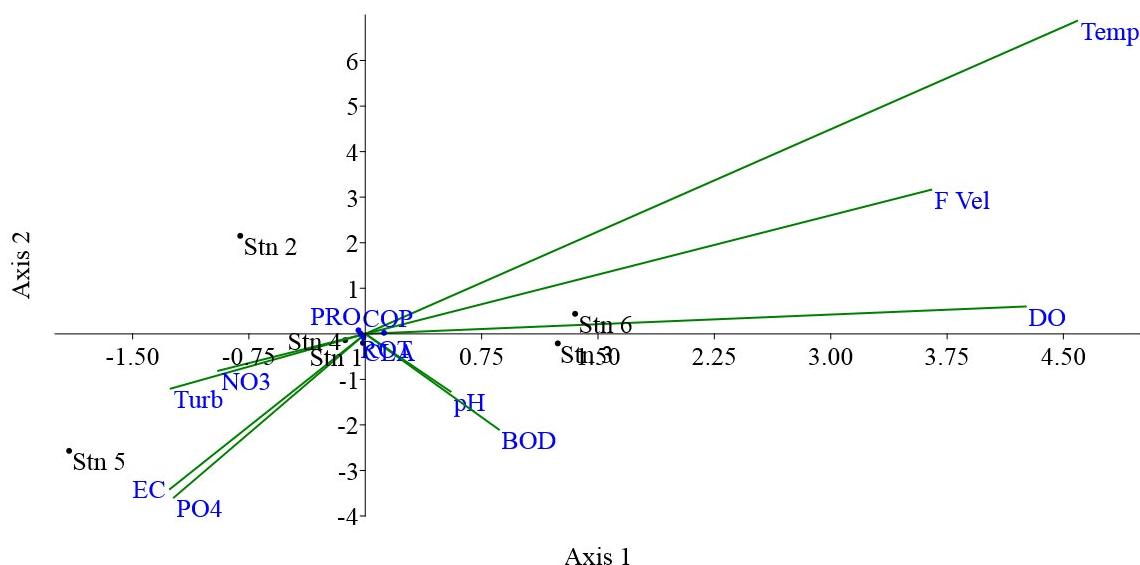
3.2.2. Relationship between zooplankton groups and environmental variables

CCA showed that water temperature, flow velocity and dissolved oxygen exerted a greater positive influence on the relative abundance of the zooplankton groups compared to the higher negative influence exerted by electrical conductivity, phosphate and turbidity (Fig. 2). Flow velocity exerted a positive influence on Copepoda while biochemical oxygen demand exerted a negative influence on Rotifera and Cladocera. Spatially, dissolved oxygen exerted a positive influence on stations 3 and 6 while electrical conductivity, phosphate and turbidity exerted a negative influence on stations 1 and 4.

Conclusions

Some of the physicochemical parameters showed that the river was perturbed by the anthropogenic activities in the watershed especially in the downstream stations where sand mining was intense. The zooplankton assemblage and community structure also indicated some levels of perturbation. The relatively low zooplankton abundance, especially in some downstream stations, could be due to anthropogenic impact exacerbated by seasonal influences. The presence of some eutrophic indicators and tolerant species especially cladocerans showed that the river was undergoing eutrophication. Sand mining among other observed anthropogenic activities was a major contributor to the nutrient enrichment in the river. Therefore, it needs to be regulated.

Fig.2. Canonical correspondence analysis (CCA) ordination showing relationships between zooplankton groups, stations and environmental variables. BOD – biochemical oxygen demand, DO - dissolved oxygen, Turb - turbidity, Temp - water temperature, NO_3 – nitrates, PO_4 - phosphates, EC – electrical conductivity, FVel – flow velocity, ROT – Rotifer, COP – Copepod, CLA – Cladocera, and PRO – Protozoa.

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Conflict of interests

The authors declare that they have no competing interests.

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