Influence of Water Quality on Zooplankton Community Structure of Etim Ekpo River, Akwa Ibom State, South-South, Nigeria

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Abstract: A stretch of Etim Ekpo River was studied in three stations from May, 2018 to February, 2019 to ascertain the level at which water quality influence zooplankton community structure. Samples were collected on monthly basis, between the hours of 8.00 am and 12.00 am each sampling day. Water samples were collected with sterile plastic bottles (1 litre), and it was carefully analyzed in the laboratory following standard laboratory analytical procedures. Water temperature, DO, pH, EC and TDS were determined in situ using Hanna Portable Meter (H19811-5 MODEL). Zooplankton samples were collected by filtering 100 litres of water samples through 50µm mesh size plankton nets. The mean range values of water temperature were 26.55-26.81 ^{0}C, EC 43.14-57.42 µs/cm, pH 6.5-6.7, TDS 33.18-38.10 mg/L, DO 3.16-6.31mg/L, BOD 1.13-2.63mg/L, hardness 50.50-55.31 mg/L, phosphate 3.15-5.35 mg/L, and nitrate 3.35-6.86 mg/L. A total number of 11 species of zooplankton were identified, comprising of 835 individuals, belonging to 3 taxonomic groups. The species encountered were dominated by Cladocera (52.0%) and the lowest was Copepoda (19.6%). Station 2 recorded the highest number of zooplankton species (39.2%), followed by station 3 (33.3%), and station 1 had the least (27.5%) in terms of abundance. Higher zooplankton species were recorded during dry season over the wet season. There was a significant difference in physicochemical parameters obtained between dry and wet season ($p<0.05$). Low species of zooplankton recorded in station 1 and 3 when compared to station 2 indicate that water quality had an influenced on the zooplankton community structure of the study area.

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1. Introduction

The aquatic ecosystems are the medium for transformation, regeneration and for the survival of aquatic organisms, ranging from microscopic planktons to large aquatic animals. Pollution of aquatic ecosystem from both non-point and point sources has a wide ecological impacts on water quality and its inhabitants. Water quality is described according to their physical and chemical characteristics, which may or not affects the survival, reproduction and growth of aquatic biota.

Variations in water quality parameters due to pollution affect resident species leading to alteration in biotic community structure with the most vulnerable dying off leaving behind tolerant species (George and Atakpa, 2015). Studies have reported that aquatic organisms are usually low in diversity, and abundant in extremely polluted water, due to low amount of dissolved oxygen contents. The plankton community is a dynamic system that would quickly respond to changes in the physical and chemical properties of the water environment, as they represent the base-line of the food chain in the aquatic ecosystem (Adeyinka and Imoobe, 2009).

Moreover, they are serving as a tool to measure continuous and chronic effects of pollution, stream degradation from water runoff due to point and non-point discharge. The present investigation was to ascertain the level at which water quality of Etim Ekpo River influence the zooplanktons community structure. The major anthropogenic activities identify within the river include agricultural activities, sand mining, fishing and other domestic activities such as laundry and bathing which are capable of altering the water quality. As a consequence, the plankton community of the River may be affected in terms of abundance and diversity.

2. Material and Methods

2.1 Study Area

Etim Ekpo River is located in Akwa Ibom State, South-South Nigeria and lies between Latitude 5^0 01''7' N and Longitude 7^0 61''7' E (Figure 1). The river has its origin from Inyang-udo Nwanquo, flows in East-west direction to Ukanafun River. The human activities here include intensified agricultural practice, sand mining, fishing and other domestic activities such as laundry and bathing. The river received wastes from point and non-point sources through surface runoff. The region has a clear distinguished between wet season (April and October) and dry season (November and March).

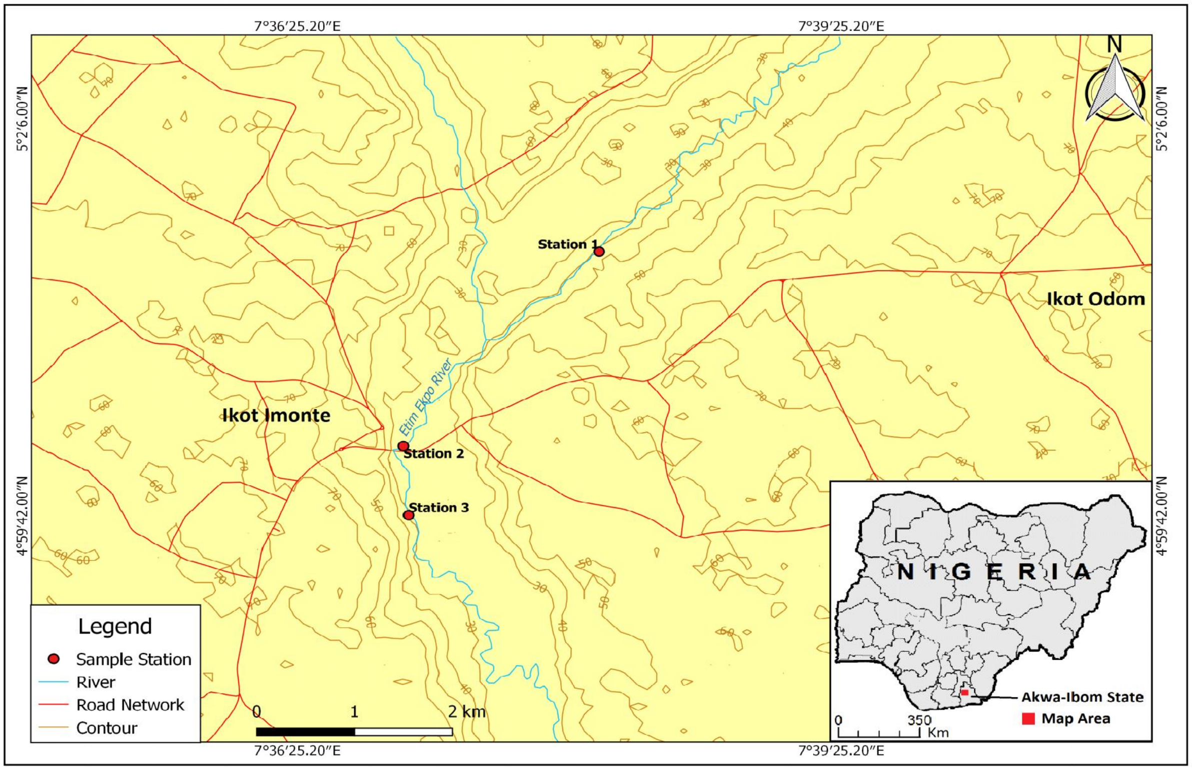

Figure 1: Map of the Study Area Showing the Sampling Locations

2.2 Samples Collection and Analysis

Water samples for physico-chemical analysis were collected once monthly at three selected sampling stations along the river course. Station 1 (Uruk Ata Ikot Isemin), station 2(Utu Etim Ekpo), and station 3 (Uruk Ata Ikot Ekpor) from May, 2018 to February, 2019 and between the hours of 8.00am and 12.00 noon each sampling day. The water samples were collected using a sterilized plastic bottles (one litre), and was analyzed base on the principles and procedure outlined in standard methods for the examination of physico-chemical parameters in water (APHA, 2005). Water temperature, DO, pH, EC, TDS were determined *insitu* using Hanna portable meter sampler (H19811-5 Model). Phosphate and nitrate were determined with a digital colorimetric meter (Atomic absorption spectrometer).

Zooplankton samples were collected by filtering 100 litres of water samples through plankton nets (50µm mesh size) and fixed with 4% formaldehyde. In the laboratory, quantitative sample from the three sampling stations were concentrated to 10ml; 1ml from the 10ml was dropped unto the slide using an adjustable volume pipette. The sample was allowed to settle for at least 10 minutes to ensure that zooplankton is settled into a single layer before examined under a compound microscope at various magnifications, and all individual zooplankton were identified and enumerated to the lowest taxonomic group, based on the identification guide of Edmondson (1966), Newell and Newell (1963), Shield (1995), Jeje and Fernando (1986).

2.3 Zooplankton Community Structure Assessment

Zooplankton community structure was evaluated by using ecological indices like diversity indices (Shannon-winner index), richness (margalef index) and evenness index according to Ogbeigbu (2005).

2.3.1 Shannon - wiener diversity Index

Shannon - wiener diversity index takes into account of species richness and proportion of each species within the aquatic community. It express as:

$$H = -\sum_{i=1}^{S} \text{Pilnpi}$$

Where S = number of individuals of one species
N = number of all individuals in the sample
In = logarithm in base e
Pi = S/N

2.3.2 **Evenness Index (e)**

Evenness Index (e) measured the degree of uniformity of species. It express as:

$$E = \frac{H}{Ins}$$

Where: H = the number derived from Shannon-wiener index
S = the number of species in the sample
In = the natural logarithm.

2.3.3 **Margalef's index (d)**

Margalef's index (d) measured the richness of species in each sampling station. It express as:

$$d = \frac{s-1}{In\ (N)}$$

Where S = the number of species
N = the number of individuals in the sample.
In = the natural logarithm

2.4 Statistical Analysis

Statistical package for Social Sciences (SPSS) version 20 was employed to compute Mean, variance and standard error in the data. Also, two-way analysis of variance (ANOVA) and Least Significant Difference (LSD) test were employed to separate significant differences in mean values computed for stations while paired sample t-test was used to compare the season. The probability level was set at p = 0.05. Diversity indices of macro-invertebrates were calculated using Shannon-wiener diversity index (H), margalef's index (d) for species richness and pielou evenness index (E) for species equitability or evenness. All calculations of diversity indices were made using PAST (Paleontological Statistics, Version 3.0) software.

3. Results

3.1 Physico-chemical Parameters

The spatial mean and standard error of physico-chemical characteristics across the stations is shown in table 1, while seasonal variations of physicochemical parameter for the three stations during the study period are presented in Table 2, 3 and 4 respectively.

Table 1: The Spatial Mean and Standard error of Physicochemical Parameters across the Sampling Stations During the Duration of Study.

PARAMETERS	ST.1	ST.2	ST.3
Temp. ^{0}C	$26.68^a \pm 0.32$	$26.81^a \pm 0.26$	$26.55^a \pm 0.31$
EC (µs/cm)	$57.42^a \pm 0.12$	$43.14^b \pm 0.41$	$54.14^a \pm 0.34$
pH	$6.7^a \pm 0.19$	$6.6^a \pm 0.27$	$6.5^a \pm 0.26$
TDS (mg/l)	$38.10^a \pm 0.34$	$33.18^a \pm 0.74$	$37.12^b \pm 0.16$
DO (mg/l)	$3.16^a \pm 0.18$	$6.31^b \pm 0.26$	$4.14^a \pm 0.10$
D (mg/l)	$2.25^a \pm 0.16$	$1.13^b \pm 0.03$	$2.63^a \pm 0.13$
Hardness (mg/l)	$50.50^a \pm 2.33$	$55.31^a \pm 2.18$	$53.19^a \pm 2.07$
Nitrate (mg/l)	$6.86^a \pm 0.12$	$3.35^b \pm 0.04$	$5.96^a \pm 0.36$
Phosphate (mg/l)	$5.35^a + 0.63$	$3.15^a \pm 0.37$	$4.83^a \pm 0.44$

±Standard error, means with different subscripts along the same row are significantly different at (p< 0.05).

Table 2: Seasonal Variations in Physicochemical Characteristics in Station 1 During the Duration of Study.

Parameters	Wet Season	Dry Season	t-value	WHO
Temp.^{0}C	25.38 ± 0.34	28.20 ± 0.58	2.836*	24-30^{0}C
EC	18.13 ± 0.48	13.39 ± 0.31	-2.294*	1200 us/cm
Ph	7.90 ± 0.14	6.5 ± 0.03	1.953	6.5-8.5mg/l
TDS	23.49 ± 0.17	18.16 ± 0.74	-3.406*	500mg/l
DO	2.87 ± 0.67	4.42 ± 0.76	1.137*	>5.0mg/l
BOD	3.79 ± 0.25	2.10 ± 0.18	-1.330*	3.0mg/l
Hardness	45.18 ± 2.13	60.70 ± 0.37	2.039*	100mg/l
Phosphate	5.13 ± 0.61	3.21 ± 0.25	-2.763*	5.0mg/l
Nitrate	6.21 ± 0.88	5.13 ± 0.22	-3.942*	10mg/l

±= Standard Error, *Significant at p<0.05

Table 3: Seasonal Variations in Physicochemical Characteristics in Station 2 During the Duration of Study.

Parameters	Wet Season	Dry Season	t-value	WHO
Temp.^{0}C	26.24±0.21	28.33±0.41	2.865*	24-30^{0}C
EC	9.16 ± 0.39	9.28 ± 0.55	1.654	1200 us/cm
Ph	7.16 ± 0.75	6.80 ± 0.16	2.033	6.5-8.5mg/l
TDS	18.60±0.30	15.45±0.23	-3.202*	500mg/l
DO	4.53±0.13	5.40±0.57	2.264*	5.0mg/l
BOD	2.24±0.18	1.80±0.36	-1.033	3.0mg/l
Hardness	30.60±1.20	50.45±4.12	2.687*	100mg/l
Phosphate	3.10±0.31	2.54±0.35	-.803	5.0mg/l
Nitrate	2.14±0.42	2.36+0.10	-.3.671	10mg/l

±= Standard Error, *Significant at p<0.05

Table 4: Seasonal variations in physicochemical characteristics in Station 3 During the Duration of Study.

Parameters	Wet Season	Dry Season	t-value	WHO
Temp.^{0}C	26.18 + 0.67	28.50 + 0.35	2.842*	24-30^{0}C
EC	20.19 + 0.78	13.41 + 0.32	-3.370*	1200 us/cm
Ph	7.0 + 0.18	6.8 + 0.21	1.743	6.5-8.5mg/l
TDS	24.18 + 0.33	16.03 + 0.63	-2.793*	500mg/l
DO	3.50 + 0.64	4.18 + 0.17	4.013*	5.0mg/l
BOD	2.83 + 0.61	2.48 + 0.53	-2.841	3.0mg/l
Hardness	50.38 + 4.04	70.33 + 6.30	-1.832*	100mg/l
Phosphate	4.50 + 7.41	3.88 + 74	-2.102*	5.0mg/l
Nitrate	6.42+0.87	5.13+0.13	-3.414*	10mg/l

±= Standard Error, *Significant at p<0.05.

3.2 Zooplankton Community Structure

The spatial and temporal distribution and seasonal variation of zooplankton community are presented in Table 5. A total of 11 species, comprising of a total of 835 individual belonging to three (3) taxonomic groups were encountered and identified during the study duration. Cladocera had the highest number of individual species (434) with relative abundance of 52.0%, followed by Rotifer (237) and Copepoda (164) with relative abundance of 28.4% and 19.6% respectively. Spatial distribution showed that station 2 recorded the highest number of individuals (372), with relative abundance of 39.2%, followed by station 3 (278) with relative abundance of 33.3%, while station 1 recorded the least species of zooplankton of about 230 individuals forming (27.5%). Seasonally, compositions of zooplankton in all the stations were generally higher in dry season (511) than in wet season (324).

3.3 Diversity Indices of Zooplankton Community

The species diversity indices of zooplankton of Etim Ekpo River is presented in Table 6. The margalef's index ranged from 1.737 to 1.827, station 2 recorded the highest (1.827), while station 1 recorded the least (1.738). Shannon-wiener index values ranged from 0.680 to 0.748, station 2 had the highest value (0.748), while station 1 had the least value (0.680). Evenness index value was higher in station 2 (0.311), and the least was recorded in station 1 (0.284).

Table 5: Composition, Percentage Abundance and Zooplankton Distribution in Etim Ekpo River During the Study Period

SPECIES	STATION 1			STATION 2			STATION 3			TO	% ABUNDANCE
	WS	DS	TO	WS	DS	TO	WS	DS	TO		
CLADOCERA											
Alona affinis	11	15	26	25	40	65	21	26	47	138	
Daphnia pulex	13	11	24	18	14	32	7	13	20	76	
D. magna	8	13	21	14	19	33	6	14	20	74	
D. longis	11	6	17	13	8	21	18	26	44	82	
Moina dubia	-	18	18	18	12	30	-	16	16	64	
TOTAL	**43**	**63**	**106**	**88**	**93**	**181**	**52**	**95**	**147**	**434**	**52.0**
ROTIFERA											
Asplanchna Priodonta	5	33	38	6	7	13	12	19	30	81	
Filinia maior	18	12	30	18	10	28	4	9	13	71	
Trichocera similis	6	4	10	3	13	16	6	15	21	47	
Notholia labis	1	6	7	2	10	12	5	14	19	38	
TOTAL	**30**	**55**	**85**	**29**	**40**	**69**	**27**	**56**	**83**	**237**	**28.4**
COPEPODA											
Cyclopoida spp.	-	29	29	21	25	46	3	27	30	105	
Eucyclops speratus	3	7	10	18	13	31	10	8	18	59	
TOTAL	**3**	**36**	**39**	**39**	**38**	**77**	**13**	**35**	**48**	**164**	**19.6**
Total no. of individual	**76**	**154**	**230**	**156**	**171**	**327**	**92**	**186**	**278**	**835**	
% Abundance			**27.5**			**39.2**			**33.3**	**100**	

WS= wet season. DS=dry season. TO= total

Table 6: Diversity indices of zooplankton fauna During the Study Period

Ecological Indices	**ST1**	**ST2**	**ST3**
Number of Individuals	230	327	278
Number of species	11	11	11
Margalefs index 9d)	1.738	1.827	1.776
Shannon-wiener (H)	0.680	0.748	0.710
Evenness Index (e)	0.284	0.311	0.296

4. Discussion

The values of physicochemical parameters obtained in this study was observed to have significant influence on the distribution and abundance of zooplankton community structure of Etim Ekpo River. The spatial mean values of temperature were observed to vary across the stations during the study period. The values seasonally showed slight variations; higher values were recorded during the dry season. This corroborates with the findings of George and Atakpa (2015) in Cross River estuary, Nigeria. A similar trend was reported by Ekpo *et al.* (2012) in Ikpa River, Nigeria. This increase in temperature values in dry season may be allied to intense solar radiation when compared to the wet season where rainfall is predominant. Statistical analysis showed significant difference ($p<0.05$) in all the three stations between the dry and wet seasons values.

The mean value of EC spatially recorded was high in station 1 and 3, these could be traceable to the wide discharge of dissolved constituents in these stations. The remarkable increase in EC in wet season in station 1 and 3 is possibly due to high rainfall which leads to subsequent runoffs of dissolved constituents such as nitrate, phosphate and chloride from the surrounding land into the body of water. Low value of this parameter in station 2 could be an indication of inactive deposition of these factors in station 2. This trend agrees with the reports of Ekpo *et al.* (2012), for Ikpa River and contradicts with the reports of George and Atakpa (2015) in Cross River Estuary, and Essien-Ibok *et al.* (2010) for Mbo River. Seasonally, significant differences were observed

($p<0.05$) in station 1 and 3 between the dry and wet seasons.

The spatial mean values of pH vary across the stations. According to Wang and Qin (2006), pH is an important hydrological parameter influencing the growth and distribution of aquatic biota. The pH values recorded in this study are within the ranged reported by Zakariya *et al.* (2013) in Lower Niger River and George and Atakpa (2015) in cross River Estuary, Nigeria. Slightly alkaline values recorded across the stations in wet season could be traceable to the influx of more acidic forming substance through surface run-off into the river. The pH values obtained in this study corroborates with the findings of Esenowo *et al.* (2017) in Nwaniba River and Akpan, (1991) for Qua Iboe River. Increase and decrease in pH values have been reported to affect aquatic organisms (Morrison *et al,* 2001). Statistically, there was no significant differences between the two seasons during the study period.

The mean value of TDS spatially recorded in this study is in line with the finding of Essien–Ibok *et al.* (2010) and Akpan (2004). The high value of TDS in station 1 and 3 when compared to station 2 may be linked to the deposition of allochthonous substances in those stations. Wet season values of TDS were higher than the dry season in all the stations; this is traceable to the high precipitation which resulted in influx of these allochthonous substances into the river through surface run-off. This corroborates with the finding of George and Atakpa (2015) in Cross River Estuary, Nigeria. Statistically, the mean values between the dry and wet seasons showed significant difference ($p<0.05$).

The high mean value of DO recorded in station 2 could possibly be due to the exposure of this station to enough sunlight and atmospheric air resulting in an increase in the rate of photosynthesis by the submerged plants in the water column at this station when compared to the other stations. Also, may attributed to the fact that this station was not exposed to domestic and agricultural waste discharges that would have used-up the dissolved oxygen for biodegradation by microbes. Seasonally, DO values were higher in dry season than in the wet season; this may be credited to excessive runoff water carrying various types of inorganic and organic wastes into the river. Wastes degradation by micro-organisms could have contributed to the reduced dissolved oxygen values noticeable during wet season. The result obtained in this study is not in line with the findings of Akpan (1993), Essien-Ibok *et al*. (2010), and Ikpi *et al*. (2013). These scholars reported higher dissolved oxygen values during the wet season and attributed it to increased flow that enabled diffusion and mixing of atmospheric oxygen into the water. Statistically, the mean values between the dry and wet seasons showed significant differences ($P<0.05$).

The BOD values recorded were found to have slight variations between the stations and seasons. Elevated BOD value during wet season in station 1 is an indication of high organic waste contents which required a high amount of dissolved oxygen for biodegradation of these wastes. This trend may be attributed to the negative impacts of rainfall which caused the increased inputs of decomposable organic matters via run-off in this station. This assertion is in agreement with Adesalu *et al.* (2010), who reported that increase in rainfall increases the BOD of an aquatic ecosystem. BOD values obtained in this study were significantly different seasonally only in station 1.

Total hardness was found to have slight variations in values across the stations during the study period. Seasonally, higher values of total hardness were recorded during dry season than in wet season. The low values of this parameter across the stations in the wet season may be attributed to the influence of rainfall which diluted the Ca^{2+} and Mg^{2+} cations, hence causing a decrease in this parameter. Ekpo *et al.* (2012) made similar assertions in their study in Ikpa River and Ufodike *et al.* (2001) for Dokowa Mine Lake. Statistically, there was significant different between dry and wet seasons in all the stations in total hardness values.

The mean phosphate and nitrate values were observed spatially and seasonally to be high in station I and 3. This may be linked to the fact that these stations are exposed to inorganic and organic wastes containing phosphate and nitrate in high concentrations. Higher values of these parameters recorded during wet season may also be traceable to be influenced by high precipitation which leached domestic and agricultural wastes from the surrounding farmland into the river at these stations. The low values during the dry season could probably be as a result of the absence of the above factors. This assertion is in agreement with Clement *et al.* (2010), Dapan *et al.* (2016), Mustapha (2008) and contradicts with the findings of Akpan and Akpan (1994), Jonah *et al.* (2015) and Ibrahim *et al.* (2009) where they observed a higher value of these parameters during the dry season.

The findings of the present study revealed that the water quality characteristics have a negative influence on zooplankton community structure. Water quality is a determinant factor in zooplankton distribution and abundance. In this study, a total of 835 individuals belonging to 3 taxonomic group were identified. The 11 taxa (species) of zooplanktons recorded in this study is similar to the number of taxa reported by Aneni and Hassan (2003) in Kudeti and

Onineke streams, Ibadan, Nigeria and Ohimain *et al.* (2002) in Warri River, Niger Delta, Nigeria. The 11 taxa reported in this study is low when compared with 44 species reported by Eyo *et al.* (2013) in the Great Kwa River, Cross River State, and 51 reported by Imoobe (2011) in a tropical forest river in Edo State, Nigeria. These differences in species composition may be attributed to the ecological differences in habitat structure and period of investigation, water quality, food availability and predators. Of the three taxonomic group of zooplankton recorded in this study, cladocera recorded the highest number of species (5), followed by rotifera (4) and copepod (2) with their relative abundance of 52.0%, 28.4% and 19.6% respectively. Poongodi *et al.* (2009) reported that cladocerans dominated the total population of zooplankton followed by rotifer, copepod, and protozoan in a related study.

The dominance of cladoceran in this study may be ascribed to their ubiquitous nature and high complex reproductive cycle due to the alternation of diploid parthenogenesis. The reduction in species composition could be influenced by environmental factors such as anthropogenic activities such as sand dredging, alteration of riparian zone and alteration of water quality. Also, determined by the availability of the primary producers which in turn are controlled by necessary and adequate quantity and quality of nutrients. Eutrophication leading to lowered dissolved oxygen concentration could limit the number of species to those able to tolerate these conditions.

In this study, high zooplanktons species in station 2 may be attributed to the low degree of anthropogenic wastes discharge in this station when compared to other stations. Low species recorded in station 1 and 3 could be attributed to some environmental stress imposed on these stations. These factors probably might have caused disruption of the life cycle, reproductive cycle, food chain and subsequently migrations of zooplankton species. Also, this reduction in species richness and diversity observed in these stations could be attributed to the increased turbidity, declined oxygen, high total suspended solid and toxic effect of dredging in these stations. Dredging also caused rapid depletion of dissolved oxygen in the water column through re-suspension of anoxic sediments containing organic matter. Dredging according to Edokpayi and Nkwoji (2007) resulted in substratum instability and increased siltation. Suspended silt has the ability of reducing light penetration and primary productivity which will affect the zooplankton community structure.

This agrees with the reports of Ohimain *et al.* (2002) for Warri River, Niger Delta, Nigeria, where they recorded low zooplankton species in an area influenced by anthropogenic activities and sand dredging. High species of zooplankton recorded during dry season may be attributed to low degree of inorganic and organic wastes discharge when compared to wet season, and low species diversity during the wet season may be attributed to high precipitation which resulted in influx of allochthonous materials into the river through surface run-off. This agreed with the report of Yakubu (2004) who noted that filling out the river channel results in increase in volume of water flowing through the channel, thus affecting the concentration of zooplankton.

Rainfall have been reported to be the primary steering factor affecting the abundance of zooplanktons and its population dynamics (Kizito and Nauwerck, 1995 and Akin-Oriola, 2003). According to Ishag (2013), the diversity indices are all based on two assumptions. Stable community structure has high diversity value while unstable ones have low diversity value (UNEP, 2006). The ecological indices of zooplankton community show that highest Shannon, margalef and evenness values were recorded in station 2 which suggest that this station was stable, while station 1 had low values for these aforementioned indices. This low value are believed to have emanated from severe stress imposed by anthropogenic activities in the station resulting in an unstable environment for zooplankton survival.

5. Conclusion

Based on the results of findings which shows that anthropogenic activities within the study area resulted in alteration of the basic water quality parameters which in turn had severe influence on the zooplankton community structure and distribution of the River. Zooplankton abundance and distribution in this study were influenced by the water quality characteristics such as DO, TDS, BOD, and nutrients concentration in both spatial and seasonal regimes. The high zooplankton diversity recorded in station 2 when compared to other stations indicate that the station is stabilize and devoid from anthropogenic perturbations. Zooplankton plays vital role in the functioning of any ecosystem has they occupy the first trophic level in aquatic food chain. Therefore, the productivity of any ecosystem is primarily dependent on the zooplankton community of that particular ecosystem. It is on this note that this study recommends the need to create educational awareness to the inhabitants of the study area and the general public on the need for sustainable management of aquatic ecosystem for healthy productivity.

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