Physicochemical Properties and Zooplankton Community Structure of Okamini Stream, Port Harcourt, Nigeria

Otene, B.B[1*], Alfred-Ockiya, J.F[2] & Amadi, F[3]

[1&3]*Department of Fisheries and Aquatic Environment, Rivers State University, Port Harcourt, Nigeria*
[2]*Department of Fisheries and Aquatic Sciences, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria*
**Correspondence Author*

***Abstract: -* The physicochemical properties and zooplankton composition and diversity in Okamini Stream were studied between April and June, 2018. Surface water and zooplankton samples were collected from three stations and analyzed using standard method. The result showed that phosphate (PO_4) showed significant difference across the stations and parameters such as pH, DO BOD etc fell slightly below the permissible limit of world health organization (WHO) of 6.5-7.5, 15mg/l and 10mg/l respectively. A total f 476 zooplankton from 4 families dominated by protozoa was identified. Station 1 had the highest abundance while station 2 had the lowest zooplankton. Margalef and Shannon- wiener indices were consistently high across the stations for protozoa than other taxa. Simpson dominance index (D) was highest in station 2 (copepod) and lowest in station 1 (protozoa). Evenness index was consistently high in station 1 across the taxa. Okamini stream from the Shannon-wiener index (1-2) is moderately polluted. It was suggested that adequate measure should be taken to avoid further discharge of wastes into the stream so as to prevent further degradation of the area.**

***Key words:* physicochemical properties, zooplankton composition and diversity, Okamini Stream, Port Harcourt**

I. INTRODUCTION

The steadily increasing demand for water in recent decades poses various problems, both qualitative and quantitative (Ramdani *et al*.,2012).Changes in land use and management practices can have a considerable impact on water quality parameters (Brainwood *et al*.,2004). Due to the tremendous development of industry and agriculture, the disposal of untreated public sewage water, and agricultural runoff, the water quality and its biotic resources are in continuous deterioration (Otene and Ockiya, 2019a&b, Otene and Nnadi,2019,Venkatesan, 2007; Elmaci *et al*.,2008). Among the surface water resources, estuarine/brackish, fresh and marine water are found predominantly in the Niger Delta region. Irrespective of the water source, they harbor several aquatic biodiversity including plankton (phytoplankton, zooplankton and algae), fishes, aquatic mammals, sea birds etc (Izah *et al.*,2016). Knowledge of the characteristics of a habitat, its species composition and the physico-chemical and biological factors that directly or indirectly affect the inhabitants are essential for a proper appraisal of the ecology of the aquatic animal species.

Zooplankton acts as a link between the phytoplankton and whole food chain of the aquatic environment (Ogamba, *et al*., 2005). Zooplankton have been noted to function as intermediaries between fish and lower trophic levels (Arazu and Ogbeibu (2017) such as macro crustaceans, insects, small fish (Iloba and Ruejoma, 2014). Zooplankton feed predominantly on algae and bacteria and in turn fall prey to several invertebrates and fish predators (Arazu and Ogbeibu (2017). Zooplankton community is the major route for energy flux in the plankton based food web making them to become an important element in the functioning of aquatic ecosystems (Santos-Wisniewski *et al.* 2006).Zooplankton which is a vital component of the aquatic environment are used as indicator organisms in aquatic ecosystem against environmental quality especially with regard to pollution, water quality, eutrophication and other environmental problems (Abdul *et al*.,2016, N'da *et al*.,2015, 28) and biological production including fish yield (Edward and Ugwumba, 2010). In general, the characteristics of zooplankton community structure are characterised by the intrinsic factors such as surface area, depth, trophic level, colour of water and the biological community of the lake (Rahkola-Sorsa 2008).

The mechanisms underlying variability in species composition and geographical distributions of zooplankton biodiversity are complex in running water ecosystems (Cottenie,2005' Brown & Swan,2010' De Bie, 2012' Heino,2012). Some studies showed that the dispersal capacity of organisms determined local community structure (Lindstrom & Langenheder,2012' Astorga, 2012) while others illustrated that local environmental factors, such as water temperature, pH, salinity, trophic state or combinations of these factors were responsible for shaping local community structure (Van der Gucht,2012' Duggan,2002).

Okamini stream play so many vital roles in the lives of the inhabitant since it creates ready incentives for capture fisheries, transportation of fuel, wood production, domestic waste disposal and small scale aquaculture). These environmental services are being seen by environmentalist as source of threat (Otene and Ockiya,2019a&b).The ecology of aquatic environments has been widely studied in several water bodies in Niger Delta but very few limnological studies have been made on the freshwater ecosystem of Okamini (Otene *et al*.,2019). Therefore, this present study is designed to investigate the physicochemical parameters and zooplankton community structure of Okamini Stream. The possible implication of zooplankton absence and presence as well as its abundance will also be discussed.

II. MATERIALS AND METHODS

Study Area

Okamini stream is a tributary of New Calabar River which lies between longitude 006° 53' 53.086"E and latitude 04° 53' 19.020"N in Choba, Rivers State, Nigeria (Figure 1.1). However, the entire river course is situated between longitude 7° 60'E and latitude 5° 45'N in the coastal area of the Niger Delta and empties into the Atlantic Ocean. There are industries, dredging sites; weekly market and fishing activities going on alongside numerous other human activities. The New Calabar River region has an annual rainfall between 2000 -3000 mm (Abowei, 2000) and is a rare tidal freshwater body.

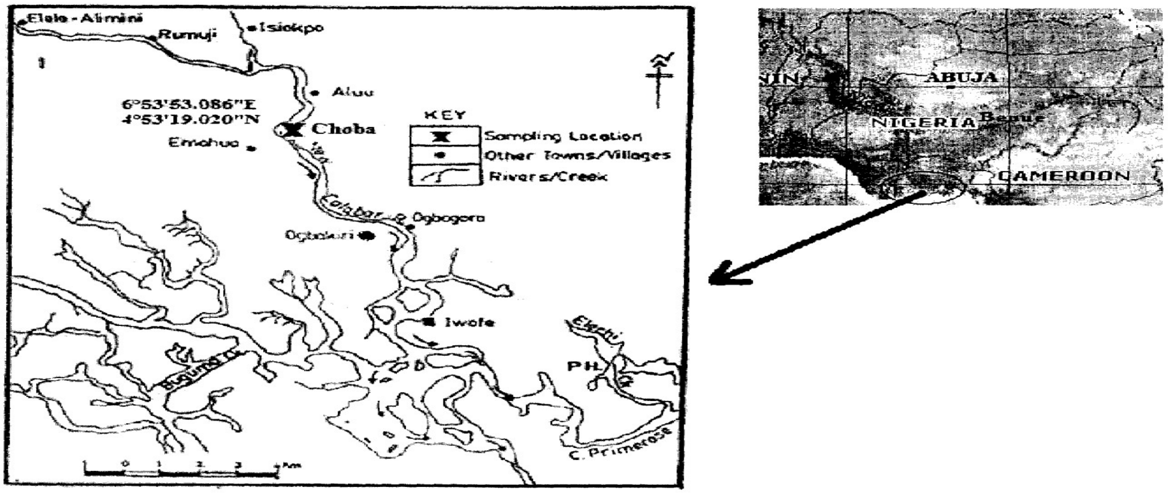

Fig. 3.1: Map of the study area

(Source: Nzeako *et al.*, 2014)

Sampling Stations and Collection

Three sampling stations were established within the area considering the activities in the area at least 500m apart. The water samples were collected using 1 liter sampling container. The sampling was carried out between April and June 2018. The samples collected were carefully labeled and transported to the Laboratory for further analysis.

Collection and Analysis of Samples

Samples for physicochemical parameters and phytoplankton were collected monthly between April and June 2018. Surface water samples were analysed for the physiochemical parameters; temperature, pH, salinity, DO, BOD, P04, $N0_3$, and So_4 according to the standard method (APHA, 1998).

Phytoplankton samples were collected using plankton net of 250µm mesh size and preserved in 2ml of 37.00% formaldehyde following standard method (APHA, 1998). The phytoplankton were enumerated using 10vm counting chamber filled with the concentrated sample and examined under a compound microscope (APHA, 1998). Identification was done using the descriptive keys of Han (1978), Prescott (1982), Kadiri (1993) and Kemdirim (2001).

Calculation

Abundance of zooplankton was estimated individual/ml of the original sample using the equation:

$$D = \frac{T(1000 \times Vc)}{AN \times Vs}$$

Where

D = Density of Phytoplankton (individual/ml)

T = Total number of plankters counted

A = Area of grid in mm^2

N = Number of grids employed

1000 = Area of counting chamber in mm^2

Vc = Volume of concentrate

Vs = Volume of sample (Boyd, 1981, APHA, 1998)

Ecological/Statistical Analysis

Three ecological statistics used in this study to ascertain the diversity indices include the following:

Margalef Index(d): This index measures species richness of an area and is expressed as :

d= (S-1)/lnN

Where;

d= Species richness index

S= Number of species in the sample

N= Number of individuals in the samples (Margalef, 1951)

Shannon Wienner's Index (H): This measures species abundance and evenness in an area and is expressed as:

$$H= H^{I} \text{or } H(s) = \sum_{r=i}^{n} P_i \log P_i$$

S = Total number of species observed

N = Total number of individuals (sample size)

Pi = Proportion of individuals of each species in the station.

Note: If we take N to be the sample size (total number of individuals) and f to be the number of individuals of i^{-th} species in a station

Pi = fi/N

Then, $H(s) = \frac{n \log n - \sum fi \log fi}{n}$ (Magurran, 1988)

Simpson Dominance Index(D): This measures the dominant species in an area. This is expressed as:

D= Ƹn(n-1)/N(N-1)

Where

n is number of species of zooplankton in the sample

N is total number of individuals in a species

Evenness/Equitability Index (E)= This measures evenly distributed species are in an area and is expressed as:

H/lnS

Where

H= Shannon Wienner Index

lnS= natural log of number of species of phytoplankton in the sample

Analysis of variance (ANOVA), Duncan Multiple Range Test (DMRT) and correlation coefficient were also used to analyse the data for significant difference, mean separation and relationship between the variables using SPSS software package, verson 17 and Microsoft excel (2003).

III. RESULTS

The spatial and temporal mean values of physicochemical parameters are as shown in table 1 and 2. Temperature ranged between 28.60 and 30.50°C with the overall mean value of 29.53 ± 0.67°C. The highest and lowest temperature values were observed in stations 1 and 3 respectively (Table 1). pH ranged between 5.1 and 6.4 with the overall mean value of 5.89 ± 0.40 (acidic condition). The highest pH value (6.10 ± 0.36) was recorded in the month of may (table 2) and station 2. DO ranged between 5.50 and 6.50mg/l with the overall mean value of 5.96 ± 0.34 mg/l. Station 2 had the highest DO value (6.17 ± 0.35mg/l) while the lowest value was observed in station 1. The highest value of DO (6.07±0.38mg/l) was observed in April and June respectively. BOD value ranged from 1.6 – 2.90mg/l with the mean value of 2.43 ± 0.46mg/l. The highest BOD value was recorded in station 1 while the lowest was observed in station 3. The mean values for the water nutrients, $P0_4$ (0.82 ± 0.40mg/l), NO_3 (0.37 ± 0.13mg/l) and SO_4 (1.90 ± 0.48mg/l) were all outside the permissible limit by WHO, SON and EPA (table). There was no significant difference ($P \leq 0.05$) among the water parameters studied spatially and temporally except phosphate value which varied significantly across the Stations.

Table 1. Spatial mean values and Permissible limits of Water Parameters Studied

Param/Stations	1	2	3	Overall Mean	Permissible limit		
					WHO	SON	EPA
Temperature (0C)	29.83±0.90[a]	29.43±0.29[a]	29.33±0.81[a]	29.53±0.67[a]	25	Ambient	NS
pH	5.70±0.56[a]	6.23±0.15[a]	5.73±0.15[a]	5.89±0.39[a]	6.5-7.5	6.5-8.5	6.5-8.5
Salinity(‰)	0.07±0.15[a]	0.06±0.26[a]	0.07±0.01[a]	0.06±0.15[a]	NS	NS	NS
DO (mg/l)	5.83±0.21[a]	6.17±0.35[a]	5.90±0.45[a]	5.96±0.34[a]	15	NS	NS
BOD (mg/l)	2.53±0.55[a]	2.53±0.40[a]	2.23±0.55[a]	2.43±0.46[a]	10	NS	NS
PO_4 (mg/l)	1.27±0.21[a]	0.67±0.35[b]	0.53±0.15[b]	0.82±0.40[b]	0.5	0.01-0.03	NS
NO_3(mg/l)	0.38±0.10[a]	0.30±0.10[a]	0.43±0.18[a]	0.37±0.13[a]	10	10	10
SO_4 (mg/l)	1.83±0.59[a]	1.57±0.21[a]	2.18±0.51[a]	1.86±0.48[a]	200	100	250

Difference in superscript across the row shows significant difference

Table 2. Temporal mean values and Ranges of physicochemical Parameters Studied

Parameters/Months	April	May	June	Range
Temperature (0C)	29.67±0.50 [a]	29.53±0.70 [a]	29.40±0.98 [a]	28.6-30.50
pH	5.93±0.15 [a]	6.10±0.36 [a]	5.63±0.55 [a]	5.10-6.4
Salinity(‰)	0.05±0.02 [a]	0.07±0.10 [a]	0.07±0.01 [a]	0.03-0.08
DO (mg/l)	6.07±0.38 [a]	5.77±0.25 [a]	6.07±0.42 [a]	5.50-6.50
BOD (mg/l)	2.53±0.40 [a]	2.43±0.50 [a]	2.33±0.64 [a]	1.60-2.90
PO_4 (mg/l)	0.73±0.35 [a]	0.67±0.47 [a]	1.07±0.40 [a]	0.30-1.50
NO_3(mg/l)	0.37±0.21 [a]	0.45±0.50 [a]	0.30±0.50 [a]	0.20-0.60
SO_4 (mg/l)	1.80±0.61 [a]	1.97±0.47 [a]	1.82±0.56 [a]	1.40-2.50

Difference in superscript across the row shows significant difference

Table 3

Para	**Tem ^{0}C**	**pH**	**Salinity $^0/_{00}$**	**DO mg/l**	**BOD mg/l**	**PO4 mg/l**	**NO3 mg/l**	**SO4 mg/l**
Temp	1.00							
pH	-0.474 0.099	1.000						
Salinity	-0.406 0.139	0.029 0.471	1.000					
DO	-0.636* 0.033	0.338 0.187	-0.291 0.224	1.000				
BOD	0.713* 0.015	-0.032 0.468	-0.006 0.494	-0.645* 0.30	1.000			
PO4	0.226 0.280	-0.462 0.152	0.158 0.342	-0.021 0.478	0.009 0.491	1.000		
NO3	-0.076 0.432	0.105 0.394	0.499 0.086	-0.638* 0.32	0.197 0.306	-0.242 0.265	1.000	
SO4	-0.699* 0.018	0.053 0.446	0.458 0.108	0.097 0.402	-0.581 0.051	-0.211 0.293	-0.544 0.065	1.000

* shows significant difference at $P \leq 0.001$

Table 3 showed the correlation matrix of the physicochemical parameters with one another. Temperature showed significant correlation strongly and positively with biochemical oxygen demand and negatively with dissolved oxygen and sulphate.

Zooplankton composition and abundance are as shown on tables 4 and 5. A total count of 476 ind/ml consisting of 28 species of zooplankton from the 4 families/taxa. Protozoan (11) rotifer (6), cladocera (5), and copepod (6) dominated by protozoa were recorded during the period of study. Zooplankton abundance was of the sequence, Protozoa > Cladocera > Copepoda > Rotifera for the taxa and 1 > 3 > 2 spatially (table 4). The highest zooplankton abundance was recorded in station 1 (211) while the lowest was observed in Station 2 (112) table (5). *Cyclop species* (copepod) had the highest count (29 ind/ml) while *onchacamptus mohammed* (protozoa) had the lowest count (5 ind/ml). All the species were present in all the stations. Cladocera correlated positively and strongly with rotifera (0.939) at $P \leq 0.005$ while copepod correlated negatively and weakly with rotifer – 0.157 and cladocera (-0.228) respectively.

Table 4. Spatial and Temporal Values of Zooplankton(Composition & Diversity)

S/N	**Protozoa**	**Stn 1**	**Stn 2**	**Stn 3**	**Total**
1	*Amoeba species*	6	1	3	**10**
2	*Canthocyclops viridis*	14	5	4	**23**
3	*Arcella mirata*	6	3	13	**22**
4	*Centropyxis aculeata*	8	6	4	**18**
5	*Epistrylis species*	6	8	4	**18**
6	*Frontonia leucus*	6	3	6	**15**
7	*Onchacamptus mohammed*	3	2	0	**5**
8	*Trintimopsis synensis*	4	1	2	**7**
9	*Nitocra lacustris*	9	4	6	**19**

10	*Temora longicomis*	5	5	4	**14**
11	*Vorticella mayerii*	12	2	5	**19**
	Subtotal	**79**	**40**	**51**	**170**
	Rotifera				
1	*Allonela excisa*	12	0	6	**18**
2	*Branchioonus leydigi*	6	3	8	**17**
3	*Colurrella uncinata*	4	2	5	**11**
4	*Roteria species*	5	3	3	**11**
5	*Pedialina mira*	9	2	8	**19**
6	*Lepadella palella*	5	2	5	**12**
	Subtotal	41	12	35	**88**
	Cladocera				
1	*Bosmina species*	9	7	9	**25**
2	*Alona affins*	11	4	12	**27**
3	*Daphnia pulex*	6	5	11	**22**
4	*Microthrix species*	8	1	8	**17**
5	*Moina dubia*	12	8	4	**24**
	Sub total	46	25	44	**115**
	Copepoda				
1	*Acanthocyclops viridis*	5	11	9	**25**
2	*Canthocamptus carcinatus*	10	6	1	**17**
3	*Cyclop species*	11	11	7	**29**
4	*Mesochra suifunensis*	6	2	0	**8**
5	*Centropages typicus*	5	1	4	**10**
6	*Paracyclops fimbriatus*	8	4	2	**14**
	Subtotal	45	35	23	**103**
	Grand total	**211**	**112**	**153**	**476**

Key: Stn mean Station

Table 5. Zooplankton Family/Taxa in the Study Area

S/n	Family/taxa	No. Of species	Abundance	Percentage (%)
1	Protozoa	11	170	35.714
2	Rotifera	6	88	18.487
3	Cladocera	5	115	24.160
4	Copepoda	6	103	21.639
	Total	28	476	100.00

Table 6. Diversity indices of Zooplankton in the Study area

Indices	Station	Protozoa	Rotifera	Cladocera	Copepoda
Shannon Wiener(H)	**1**	2.307	1.761	1.582	1.74
	2	2.200	1.590	1.477	1.547
	3	2.042	1.742	1.554	1.384
Margalef/Richness(S)	**1**	2.299	2.693	1.045	1.313
	2	2.711	2.415	1.243	1.406
	3	2.543	1.688	1.057	1.595
SimpsonDominance (D)	**1**	0.097	0.188	0.193	0.165
	2	0.133	0.136	0.267	1.389
	3	0.112	0.158	0.202	0.253
Evenness/Equitability(E	**1**	0.962	0.983	0.983	0.972
	2	0.955	0.924	0.918	0.863
	3	0.851	0.972	0.411	0.772

Table 7. Correlation Coefficient of Zooplankton Diversity Indices in the Study Area

	Shannon Wiener	Margalef Index	Simpson Dominance	Evenness
Shannon Wiener	1.00			
Margalef Index	0.676*	1.00		
	0.016			
Simpson Dom.	-0.325	-0.295	1.00	
	0.303	0.353		
Evenness	0.327	0.371	-0.075	1.00
	0.300	0.235	0.816	

*Correlation is significant at the 0.05 level (2 tail).

Table 6 showed the diversity indices of zoozplankton per stations in the area. The diversity indices studied were Shannon Wiener, Margalef Simpson Dominance and evenness indices. Shannon wiener index varied from 2.042 (station 3) to 2.307 (station 1) with respect to protozoa while other taxa such as rotifera, cladocera and copepoda collectively ranged from 1.384 to 1.761. According to Mason (1988), Shannon Wiener values ranging between 1- 2 as in this study characterizes moderate pollution.

Margalef index ranged between 2.299 in station 1 and 2.711 in station 2 for protozoa while others collectively ranged between 1.057 and 1.595. For rotifer, it ranged from 1.688 to 2.693 in station 3 and 1 respectively. This showed that protozoa and rotifera had the highest species richness.

Simpson Dominance index ranged between 1.389 (station 2) for Copepoda and 0.097 (station 1) for protozoa.

Evenness index ranged between 0.411 and 0.983 across the entire zooplankton taxa with values below 1 (unity). Evenness index was consistently high in station 1 compared to others across the zooplankton studied.

Table 7 showed correlation between the zooplankton taxa. There was strong and positive significant correlation between Margalef index (0.676) and Shannon-wiener index while Simpson index showed weak and negative non significant correlation with Shannon wiener (-0.325) and Margalef (-0.295) index.

IV. DISCUSSION

The physiochemical parameters showed that the mean value of temperature in this study is in agreement with that reported in Niger Delta water bodies (Davies, 2011, Davies *et al,* 2009) but exceeded the permissible limit (25^0C) by World Health Organization (WHO). The temperature value (29.53 ± 0.67˚c) obtained in this study is also in line with the finding of Nasir *et al*, (2017) from a nearby River water in Ilorin. The acidic pH condition observed in this study is in agreement with that reported by Onyeme *et al* (2016) from Otamiri-Oche River in Etche which was attributed to high rate of degradation in the area thus increasing hydrogen ion concentration. The DO range obtained in this study is within the permissible limit of WHO and Federal Environmental Protection Agency (FEPA). Chang (2005) opined that DO as an indicator of organic pollution is very important to the ecological health of a stream and an adequate life. The non significant difference observed across the stations in this study could favour the activities of organisms in the respective area. The BOD value did not exceed the maximum (permissible) limit. According to Ubwa *et al* (2013), increase in BOD lead to a decrease in DO due to high rate of consumption.

The mean concentration of the water nutrient (PO_4) above the permissible limit in this study indicates pollution or stress. The presence of phosphate concentration in the area above the possible limit could be attributed to continuous entry of domestic sewage rich in phosphate additive (station *et al*, 2016). The presence of nitrate in this study below the permissible limit is contrary to the finding of Uzoekwe and Oghosanine (2011) a range within the permissible limit. Sulphate concentration in this study is also below the permissible limit of WHO which is in complete disagreement with the finding of Muniyan and Ambedkar (2011) who reported a range within the permissible limit.

The occurrence and distribution of zooplankton species is of great significance in fresh water habitats (Manoharan *et al* 2015). According to Jeppesen *et al* (2002) the abundance and diversity of zooplankton vary according to limnological features and the status of freshwater bodies.

The result of this study is contrary to the 42 species of zooplankton from 12 families/taxa reported by Manoharan *et al*, (2015) from a surface water in india. The dominance of zooplankton group in this study by protozoa is also in disagreement with the finding of other studies (Barrabin, 2000, Saler, 2014, Ismail and Adnan, 2016) where rotifers dominated the group. The dominance of zooplankton by protozoa in this study contradict the finding of Kemdirim (2000) who reported most abundant to be copepod and(Balogun, 2010, Schafer and Alber, 2007, Adesalu *et al,* 2010, Nwankwo, 2004) cladocera while Akin-Oriola (2003), Saidu *et al*, (2009) reported that copepod dominated.

The 28 species of zooplankton made up of 486 ind/ml observed in this study is considered low compared to the 53 species made up of a total of 1681 cells m^{-1} reported by Imaobong (2013) in a tropical rain forest Rivers in Niger Delta. Zooplankton group or family dominated by protozoa in this study is also contrary to the finding of Imaobong (2013) where rotifers dominated while a protozoon was the least. Ogbeibu *et al* (2001) and Imoebe and Adeyinka (2010) opined that zooplankton community structure has been used as indicator of nutrient and pollution status of water bodies. The presence of *Daphnia pulex* in this study contradict the assertion by Imoobe and Adeyinka (2010) that the genus *Daphnia* is always absent in most of the tropical waters. The most dominant species of zooplankton in this study is *cyclop species* (rotifera) while the least was *Onchacamptus species* (protozoa) against the least (*Conodius species*) reported by Davies *et al*, (2009). The dominance of this study by protozoa is in line with the finding of Adeyemi *et al*, (2009) who reported protozoa as the most abundant. The high abundance of zooplankton in station 1 than others could be attributed to high concentration of water nutrients in the station. This observation is in line with the assertion that zooplankton are favoured in nutrient rich environment particularly estuaries.

According to Mason (1988) Shannon-Wiener index ranging between 1 and 2 as in this study characterizes moderate pollution. Shannon wiener index obtained in this study is lower than the value (3.90) reported by Antal and Jospeh (2015) in great Kwa River, Cross River State which was attributed to environmental factors. The low value of Shannon-wiener and Margalef indices observed in this study could be attributed to less number of species and environmental degradation due to anthropogenic activities as opined by Ravera (2001). The higher values of Shannon-Winer and Margelef with respect to protozoa across the stations satisfied the assertion by Davies and Otene (2009) that they are indicators of environmental pollution. The higher Simpson dominance index observed in stations 2 for copepod and low value in station 1 for protozoa clearly satisfied the assertion by Whitaka (1965) that Simpson diversity index is usually higher where community is dominated by less number of species and when the dominance is shared by large number of species. The consistently high value of evenness in station 1 could be attributed to absence of stress hence the presence of all the species studied in the station.

The positive and strong correlation between cladocera and rotifer showed that cladocera are dependent on rotifer while the strong and positive correlation between Margalef and Shannon Wiener indices in this study is in agreement with the finding of Shah and Pandit (2013) in Wular Lake, India.

In unpolluted systems, ecological indicators show discrete arrangement or pattern downstream with the concentrations of most nutrients and number of species tending to increase progressively downstream (Giller and Malmqvist, 2002 and Vannote *et al* 1980). The observed trend deviated remarkably from the trend which could be attributed to anthropogenic paturbations especially in station 2 which altered the stability of the ecosystem.

V. CONCLUSION AND RECOMMENDATION

This study showed that Okamini stream is not fully stressed but experiencing some level of disturbance especially station 2 since some parameters exceeded the permissible limit of WHO and the presence of some indicator species of zooplankton. Adequate measures should therefore be taken to avoid further introduction of untreated waters into the area.

REFERENCES

[1]. Abdul, W.O., Adekoya, E.O., Ademolu, K.O., Omoniyi, I.T., Odulate, D.O., Akindokun, T.E. and Olajide, A.E. (2016). The effects of environmental parameters on zooplankton assemblages in tropical coastal estuary, South-west, Nigeria. *Egyptian Journal of Aquatic Research*, 42, 281–287.

[2]. Adesalu, T., Bagbe, M. and Keyede, D. (2010).Hydrochemistry and phytoplankton compositions of two tidal creeks in southwestern Nigeria. *International Journal of Tropical Biology* (58). 3:827 -840.

[3]. Akin–Oriola, F.A. 2003. Zooplankton associations and environmental factors in Ogunpa and Ona Rivers, Nigeria. *Rev. Biol. Trop,* 51(2): 391– 398.

[4]. Antai, E. E and Joseph, A. P (2015). Planktonic Abundance and Diversity In Great KWA River, Cross River State, Nigeria. IJISET - *International Journal of Innovative Science, Engineering & Technology*, 2(9),www.ijiset.comISSN 2348 – 7968.

[5]. APHA (1998) Standard methods for the examination of water and wastewater, 17th ed. Washington, DC, American Public Health Association.

[6]. Arazu, V.D.N. and Ogbeibu, A.E.(2017). The composition, abundance and distribution of zooplankton Of River Niger at Onitsha stretch, Nigeria. *Animal Research International*,14(1): 2629 –2643.28.

[7]. Astorga, A, Jari, O., Miska L., Janne S, Risto, V and Timo, M *(2012).* Distance decay of similarity in freshwater communities: do macro- and microorganisms follow the same rules? *Global. Ecol. Biogeogr.* 21, 365–375.

[8]. B.B. Otene & Nnadi, P.C. (2019**).** Water Quality Index and Status of Minichinda Stream, Port Harcourt, Nigeria. *IIARD International Journal of Geography and Environmental Management* ISSN 2505-882, 5(1).www.iiardpub.org.

[9]. B.B. Otene and J.F. Ockiya (2019**)**. Assessment of water Quality Index (WQI) and Suitability for Consumption of Elele-Alimini Stream, Port Harcourt. *Global Scientific Journal,*7(2) 2320-91- 86. www.globalscientificjournal.com.

[10]. Balogun, K. and Ladigbolu, I. A. (2010). Nutrients and Phytoplankton production dynamics of a tropical harbor in relation to water quality indices. *Journal of American Science.* 6(9); 261 – 275.

[11]. Barrabin.J.M(2000).The rotifers of Spanish reservoirs: Ecological, systematical and zoogeographical remarks. *Limnetica.*; 19:91–144.

[12]. Brainwood, M.A., Burgin, S., Maheshwari, B. (2004): Temporal variations in water quality of farm dams: impacts of land use and water sources. – Agricultural Water Management 70: 151–175.

[13]. Brown B. L. & Swan C. M (2010). Dendritic network structure constrains metacommunity properties in riverine ecosystems. *Journal of Animal Ecology*. 79, 571–580.

[14]. Chang, H(2005). Spatial and Temporal variations of water quality in the Han River and its tributaries. *Water, air and soil pollution*,161(1-4), 267-284.

[15]. Cottenie, K (2005). Integrating environmental and spatial processes in ecological community dynamics. *Ecol. Lett*. 8, 1175–1182.

[16]. Davies, O. A., Abowei, J.F.N. and Otene, B. B. (2009). Seasonal Abundance and Distribution of Plankton of Minichinda Stream, Niger Delta, Nigeria. *American Journal of Scientific Research*, 2: 20-30.

[17]. Davies, O.A & Otene, B.B (2009). Zooplankton Community of Minichinda Stream, Port Harcourt, Rivers State, *European Journal of Scientific Research,* 26(4),490 – 498 .ht tp: // www.eurojournals.com/ejsr.htm.

[18]. De Bie,T.L. De Meester,1L., Brendonck,1K., Martens, B. Goddeeris, D. Ercken, H. Hampel, L. Denys,L. Vanhecke,K. Van der Gucht, J. Van Wichelen,W. Vyverman and

S. A. J. Declerck (2012). Body size and dispersal mode as key traits determining metacommunity structure of aquatic organisms. *Ecol. Lett*. 15, 740–747.

[19]. Duggan I. C., Green J. D. & Shiel R. J (2002). Distribution of rotifer assemblages in North Island, New Zealand, lakes: relationships to environmental and historical factors. *Freshwater Biol*. 47,195–206.

[20]. Edward, J.B. and Ugwumba, A.A.A. (2010). Physico-chemical parameters and plankton community of Egbe Reserviour, Ekiti state, Nigeria. *Research Journal of Biological Sciences*, 5(5), 356 – 367.

[21]. Elmaci, A., Topac, F.O., Ozengin, N., Teksoy, A., Kurtoglu, S., Baskaya, H.S. (2008): Evaluation of physical, chemical and microbiological properties of lake Uluabat, *Turkey– Journal of Environmental Biology* 29: 205–210.

[22]. Giller P.S. & Malmqvist B. (1998). The Biology of Streams and Rivers. Oxford University Press, New York,

[23]. Heino J. *et al.(2012).* Environmental heterogeneity and β diversity of stream macroinvertebrate communities at intermediate spatial scales. *Freshw. Sci*. 32, 142–154 (2012).

[24]. Iloba, K.I. and Ruejoma, M.G.O. (2014). Physico-Chemical Characteristics And Zooplankton Of Ekpan River, Delta State, Nigeria. International Journal of Applied Biological Research, 6(1): 8–30.

[25]. Imaobong, E. (2013). Effect of physico-chemical parameters on zooplankton species and density of a tropical rainforest in Niger delta, Nigeria using canonical analysis. *The International Journal of Engineering and Science*2(4):13-21.

[26]. Imoobe, T.O.T. and Adeyinka, M.L. 2010. Zooplankton-based assessment of the trophic state of a tropical forest river. *International Journal of Fisheries and Aquaculture*, (I.J.F.A), 2(2): 64-70

[27]. Izah, S.C., Chakrabarty, N. and Srivastav AL. (2016). A Review on Heavy Metal Concentration in Potable Water Sources in Nigeria: Human Health Effects and Mitigating Measures. *Exposure and Health,* 8:285–304.

[28]. Jeppesen, E., Jensen, J.P. and Sondergaard, M. 2002. Response of phytoplankton, zooplankton and fish to re-oligotrophication: an 11-year study of 23 Danish lakes. Aquatic Ecosystems Health and Management. 5: 31-43.

[29]. Kadiri, M.O. (1993). Seasonal changes in the phytoplankton biomass of a shallow Tropical reservoir. *Nigerian Journal of Botany*, 6, 167–175.

[30]. Kelly, M. G. (1998). Use of the trophic diatom index to monitor eutrophication in rivers. *Water Res.* 32: 236 – 242.

[31]. Kemdirim, E. C. (2000): Diel rhythm of plankton and physico-chemical parameters in Kangimi reservoir, Kaduna State, Nigeria. *Journal of Aquatic Sciences* 15: 35-39.

[32]. Kemdirim, E.C.(2001).Checklist of phytoplankton of Shedam Reservoir in Plateau State . *Nigerian Journal of Science.* 16:61-63.

[33]. Lindstrom E. S. & Langenheder S(2012). Local and regional factors influencing bacterial community assembly. *Environment. Microbiol*. Rep. 4, 1–9.

[34]. Magurran, A.E (1988). Ecological Diversity and its Measurement. Croom Helm, London, p.179.

[35]. Manoharan, J., D. Varadharajan, B. Thilagavathi and S. Priyadharsini, (2015). Biodiversity and abundance of benthos along the South East Coast of India. *Adv. Applied Sci. Res*., 2: 554-562.

[36]. Margalef, R (1951). Diversidad de species en las commundales naturals. Publicaciones del instituto de biologia aplicada 6: 59-72.

[37]. Mason, C.F (1988). Biology of Fresh Water Pollution. Longman scientific and technical.

[38]. Muniyan, M. & Ambedkar, G. (2011). Seasonal variations in physicochemical parameters of water collected from Kedilam River, at VisoorCuddalore district, Tamil Nadu, India. *International Journal of Environmental Biology,* 1(2), 15-18.

[39]. N'da, S.A., Etilé, R.N., N'zi, K.G., Berté, S. and N'douba, V. (2015). Composition and Distribution of Zooplankton Relationship to Environmental Factor in a Tropical River: (Bagoe, Côte d'Ivoire). *International Research Journal of Biological Sciences,* 4(11), 1- 11.

[40]. *Nasir Abdus-Salam, Olamide S.A and Mojeed O. B.(2017).* Assessment of the Impact of Petroleum Depot Effluents on a Nearby River Quality. *European Scientific Journal, 13(36)*

[41]. Nwankwo, D. I. (2004). Studies on the Environmental preference of blue-green algae (cyanophyta) in Nigeria coastal Water. *The Nigeria Environmental Society Journal,* 5(1): 44-51.

[42]. Ogamba, E.N., Ekweozor, I.K.E. and Daka, E.R. (2005). The influence of human activities of the zooplankton of Elechi Creek complex in the Niger Delta. *African Journal of Pollution Health,*4(2): 31 –38.27.

[43]. Rahkola-Sorsa M. University of Joensuu (2008). The structure of zooplankton community in large boreal lakes and assessment of zooplankton methodology. PhD diss.

[44]. Ramdani, A., Djellouli, H.M., Aït Yala, N., Taleb, S., Benghalem, A., Mahi, C., Khadraoui, A. (2012): Physico-Chemical Water Quality in Some Regions of Southern Algeria and Pretreatment Prediction. – Procedia Engineering 33: 335–339.

[45]. Ravera, O (2001). A comparison between diversity, similarity and biotic indices applied to the macroinvertebrate community of a small stream: The Ravella river (Como Province, Northern Italy). *Aquatic Ecol*. 35:97–107.

[46]. Saler S. (2004). Observation on the seasonal variation of rotifer fauna of Keban Dam Lake (Cemisgezek Region). *Science and Engineering Journal of Firat University* 16(4):695–701.

[47]. Santos-Wisniewski M, Rocha O, Guntzel A, Matsumura-Tundisi T (2006). Aspects of the life cycle of Chydorus pubescens Sars, 1901 (Cladocera, Chydoridae) *Acta Limnologica Brasiliensia,*18(3):305–310.

[48]. Schaefer, S. C. and Alber, M (2007). Temporal and Spatial trends in nitrogen and phosphorous inputs to the watershed of the Altamaha River, Georgia, USA. *Bioeochemistry* 86: 231-249.

[49]. Shah. J.A, Pandit AK (2013). Relation between physico–chemical limnology and crustacean community in Wular Lake of Kashmir Himalaya. *Pak J Biol Sci.* 16(19):976-983.

[50]. Ubwa, S. T., Atoo, G. H., Offem, J. O., Abah, J. & Asemave, K.(2013). An assessment of surface water pollution status around Gboko abattoir. *African Journal of Pure and Applied Chemistry*, 7(3),31-138.

[51]. Uzoekwe, S. A. & Oghosanine, F. A. (2011). The effect of refinery and petrochemical effluent on water quality of Ubeji creek Warri, Southern Nigeria. *Ethiopian Journal of Environmental Studies and Management,* 4(2), 106-118.

[52]. Van Der Gucht **,** K **(**Ugent**)** , K, Cottenie, K Muylaert, N Vloemans, S Cousin, S Declerck, E Jeppesen, Jm Conde-Porcuna, K Schwenk, G Zwart, (2007) . The Power Of Species Sorting: Local Factors Drive Bacterial Community Composition Over A Wide Range Of Spatial Scales. P. Natl. Acad. Sci. Usa 104, 20404–20409.

[53]. Vannote R.L., Minshall G.W., Cummins K.W., Sedell J.R.& Cushing C.E. (1980) The river continuum concept.*Canadian Journal of Fisheries and Aquatic Sciences*,37,130–137.

[54]. Venkatesan, J. (2007): Protecting Wetlands. – Current Science 93: 288–290.

[55]. Whittaker RH (1965). Dominance and diversity in land plant communities. Science (Washington, D.C.), 147:250–260.