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Water Quality Assessment Based on Physicochemical Properties, Zooplankton Distribution and Composition of Owan River, Edo State, Nigeria

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ABSTRACT: With the increasing anthropogenic activities at Owan River, the suitability of the river for commercial and domestic activities deserves prominent attention. Hence, the objective of this paper was to investigate the physicochemical properties, zooplankton distribution and composition to assess the water quality of the Owan River, Edo State, Nigeria using standard methods. The zooplankton and water samples were collected from three (3) stations along the river and analysed at laboratory for taxonomic and diversity index. In the study, 18 taxa of Zooplankton comprising 32 individuals were encountered. The overall abundance was significantly higher ($P > 0.05$) in station 2 than in Stations 1 and 3 which were not significantly different ($P < 0.05$) from each other. Besides the Rotifers which were not found Cladocera and Copepods dominated low water level; contributed 53.13% and 46.87% by species and 37.50% and 18.75% relative abundance respectively. Among the Cladocera, Chydoridae and Cyclopoid Copepods were dominant in all the stations. There was no significant different ($P <0.05$) among the zooplankton encountered. Taxa richness (d) was highest at Stations 1 and lowest at Stations 3. The general diversity (H) showed that station 1 had the highest diversity followed by station 2 and 3 respectively. The evenness index (E) showed that the maximum evenness was in station 3 and minimum in station 2. The analysis concluded that the river was not stressed beyond her carrying capacity, and did not exhibit harmful environmental conditions detrimental to commercial and domestic activities. Based on its physical, chemical characteristics and zooplankton diversity index, the Owan River was deemed suitable for such activities.

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Aquatic ecosystems are sometimes disturbed by several physical and chemical stressors that significantly have cascading effects on biodiversity. In the future, the loss of biodiversity and its effects are predicted to be greater for aquatic ecosystems than for terrestrial ecosystems (Sala *et al*., 2000). Rivers are subjected to various natural processes taking place in the environment, such as the hydrological cycle. As a consequence of unprecedented development, human beings are responsible for choking several aquatic fauna to death. Storm water runoff and discharge of sewage into rivers are two common ways that various undesirable substances enter the aquatic ecosystems resulting in the pollution of those systems (Addo-Bediako *et al*., 2021). Zooplankton are small animals that float freely in the water column of lakes, rivers and oceans and whose distribution is primarily determined by water currents and mixing (Wetzel 1983). The zooplankton community of most lakes ranges in size from a few tens of microns (Protozoa) to greater than 2 mm (macrozooplankton) (Goswami 2004). The zooplankton community is a dynamic system that responds promptly to environmental changes, therefore, to understand such changes or to draw comparisons between natural systems and those that suffer disturbances, some knowledge of the

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structure of the community and of the main processes involved in nutrient cycling and production is required (Rocha *et al.*, 1997). Zooplankton communities are highly sensitive to environmental variation because changes in their abundance, species diversity, or community composition can provide important indications of environmental change or disturbance. They play a pivotal role in aquatic food webs because they are important food for fish and invertebrate predators, and they graze heavily on algae, bacteria, protozoa, and other invertebrates. Zooplankton communities are highly diverse and occur in almost all lakes and ponds. They are rarely important in rivers and streams because they cannot maintain positive net growth rates in the face of downstream losses (Rusak *et al.*, 2002). The use of zooplankton community structure as an indicator of the wellbeing of lakes dates to as early as the Birge-Juday era, 1879-1910 (Frey, 1963).

The Owan River has been subjected to domestic and human activities because of numerous settlements on the stretch of the river. The region is notable for its intensive cocoa farming, plantain production and other types of crop farming. A vast number of these farms are located along the riverbank. These farms are also heavily treated with agrochemicals to protect and boost the crops yield. However, these agrochemicals find their way into the river through surface run-off that contaminates the water. A substation of the Cocoa Research Institute of Nigeria were researches to improve cocoa production is carried out is sited near the river. There has been little or no documented work done before on the physio-chemical parameter, composition and distribution of zooplankton of this river. Hence, the objective of this paper was to investigate the physicochemical properties, zooplankton distribution and composition to assess the water quality of the Owan River, Edo State, Nigeria.

MATERIALS AND METHODS

Study Site: The study was carried out on a stretch of Owan River (Figure 1) , about 20km from Benin City, along the old Ondo-Benin express (6º45'24" N, 5º43'54" E) fig 1 within the tropical rainforest belt of Southern Nigeria. The river flows in a southwesterly direction through Okpokhumi, and Sabongida into the river Osse which later flows through the Gwato creeks into the Benin River, which empties into the Atlantic Ocean.

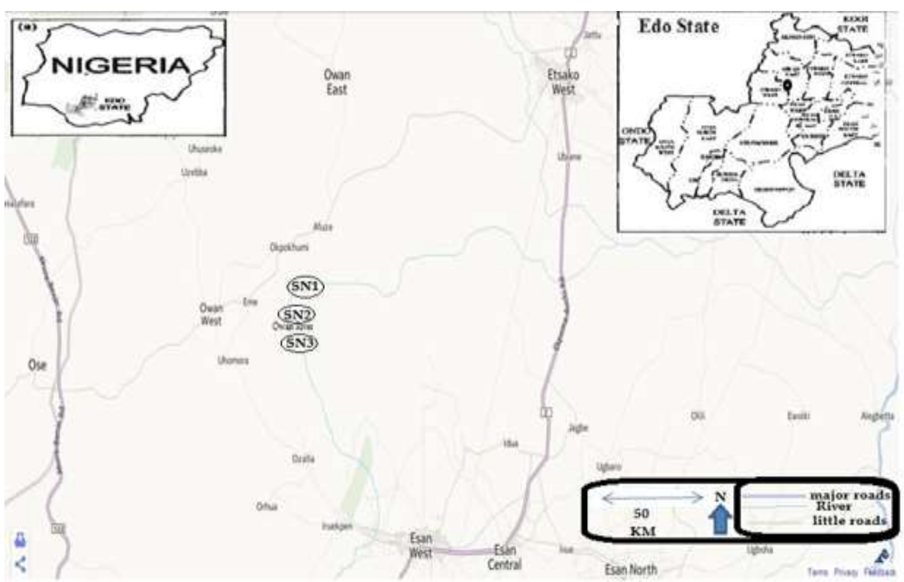

Fig 1: Map of study area showing sampling stations
Drawn by: Ukrakpor Ajiri, Department of Geography & Regional Planning, University of Benin, Benin City

The study area is composed mostly of secondary rainforest vegetation that has suffered extensive deforestation. Among other forms of plant life, palm trees (*Elaies guinensis*), shrubs, and floating *Salvinia* sp., Lemma sp., and water hyacinth (*Eichorrnia crassipes*) are common in the area. The climate in the study area is typically tropical with a pronounced seasonality of rainy and dry periods. The rainy season is from April to October, with peak rainfall occurring during the months of June to August, while the dry season extends from November to March. Although the onset of the season from year to year, it is still relatively stable.

Three stations were selected for sampling: an upstream, a mid-course and a downstream section. The downstream section (station 1) was located about 20m downstream from the old Ondo-Benin expressway bridge. This sampling station has a de-vegetated bank exposed to flowing water and direct effects of sunlight. The most conspicuous human activities noticed at the station were washing, bathing, transportation of goods via boats. The midcourse section (station 2) was located about 150m from the old Ondo-Benin expressway. The riverbank here has luxuriant vegetation, with canopies that shade the station from direct sunlight. Bamboo (*Bambusa bambusa*), palm trees (*Elaies guinensis*). Human activities noticed includes fishing, fetching of drinking water by villagers. The upstream (station 3) was located about 300m away from the bridge. The station is open directly to sunlight. There are several aquatic macrophytes like *Lemna* sp., *Salvina* sp. and *Eichorrnia crassipes.*

Sampling Periodicity: Sampling occurred monthly on sections of the Owan River between January to June 2013. Station 1, 2, and 3 were made in this order between 08.00hrs and 11.00hrs, on each sampling day.

Sampling ***Periodicity:*** Sampling occurred monthly on sections of the Owan River between January to June 2013. Station 1, 2, and 3 were made in this order between 08.00hrs and 11.00hrs, on each sampling day.

Data collection and analysis for Physical and chemical parameters: Surface water samples were collected at the three stations using 3.5-litre Van Dorn water sampler in triplicate and homogenized before being subsampled for physical and chemical analyses. Air and water temperatures were taken *in situ* using the 0 - 50^{0}C Mercury-in-glass thermometer. Conductivity, total dissolved solids (TDS), and pH were taken *in situ* using HACH portable digital meter. Other physical and chemical parameters were measured based on the procedures suggested by American Public Health Association, 1975. Turbidity values in NTU (Nephelometric Turbidity Units) were read from the Spectronic 210 Spectrophotometer (Milton Roy) at room temperature.

Zooplankton samples: Qualitative zooplankton samples were collected with the aid of the 55μm Hydrobios plankton net anchored to a boat moving at a low speed just below the water surface for 5 minutes at each station. Quantitative samples, on the other hand, were collected by filtering 100 litres of water were filtered through 55μm Hydrobios plankton net. All samples collected were preserved in 4% buffered formalin solution as suggested by UNESCO, 1983. The zooplankton specimen collected were sorted out into their various taxa and placed into different vials, under a binocular dissecting microscope (American Optical Corporation, Model 570) with the help of a Hydro-Bios micropipette and No. 01 tungsten needle and fixed with 4% formalin solution again. Identification and Counting was done using a sorting petri dish under a dissecting microscope with the help of various relevant literatures (Jeje and Fernando, 1986, Gabriel, 1986). Basic statistical measurement of diversity indices was used to describe zooplankton community structure. Three indices of species diversity were used: the Shannon-Wiener index, Margalef's index and the evenness index expressing the degree of uniformity in the distribution of individuals among the taxa in the collections. The SPDIVERS BASIC program for diversity indices was used to determine diversity, while the inter-station comparison was carried out to test for significant differences in the abundance of zooplankton using one-way analysis of variance (ANOVA).

RESULTS AND DISCUSSION

A summary of the physical and chemical conditions at the study stations is presented in Table 1. The water temperature ranged between 25.10 and 33.70^{o}C throughout the study, with the highest mean temperature value (28.85 ± 1.13^{o}C) recorded at the mid-section station 2. Turbidity, which is a function of dissolved and suspended particulates in the water, had values which ranged from a minimum of 3.3 NTU (Station 2) to a maximum of 13.5 NTU recorded at Station 1. Generally, though the river was scarcely clear at all the stations sampled, and there was no significant difference ($P > 0.05$). The water was generally fresh, with conductivity values ranging from 48.30 to 150.00 μS Cm^{-1}. The buffering capacity measured as alkalinity was low, and a weakly acidic to weakly alkaline pH range of 6.10 - 7.90 was observed across the stations. The concentration of calcium and magnesium salts combined with various anions (usually carbonates), which constitutes the total hardness of water, was also generally low, indicating the river to be a soft water river. Mean dissolved oxygen concentration was high (4.90 to 6.80 mg/l), while the mean BOD_5 was low (1.90 to 4.50 mg/1). The mean suspended solids were relatively high (12.48 ±1.31mg/l) as there were significant difference ($P<0.05$) across the stations. Levels of the essential primary productivity nutrients – nitrate (0.0 to 0.4 mg/l), sulfate (0.1 to 1.4 mg/l), and phosphate (0.1 to 1.20 mg/1) – were low. Forest ecosystems readily immobilize phosphorus [10], thus limiting its input to the river. The river's watershed, combined with the lack of residential housing or farms surrounding the river, probably limiting nutrient input.

Zooplankton species: Eighteen species of zooplankton were recorded during the 6-month sampling period of the study (Table 2). The greatest diversity was observed among Cladocera with 10 species in 3 families, a pattern that is common in tropical freshwaters, whether in lakes, ponds, reservoirs, rivers, or streams.

Table 1: Mean (+SE) values of some physical and chemical conditions of the study stations on Owan River from January- June 2013 (minimum and maximum in parenthesis)

Parameter	Station 1 $\bar{X} \pm S.E$	Station 2 $\bar{X} \pm S.E$	Station 3 $\bar{X} \pm S.E$	P-value	FMEnv
Air Temp °C	30.167±0.98 (27.00 – 32.50)	29.233±1.06 (26.4 – 32.80)	29.900±1.466 (25.00 -35.00)	P>0.05	-
Water Temp °C	28.63±0.79 (26.00 -31.20)	27.767±0.670 (25.10 -29.70)	28.850±1.136 (25.4 -33.70)	P>0.05	<40
pH	6.77±0.15 (6.50 - 7.30)	6.78±0.14 (6.50 – 7.30)	6.91±0.31 (6.10 – 7.90)	P>0.05	6-9
EC (µS/cm)	96.22±13.16 (54.40 – 150.00)	77.75±10.96 (48.30 – 120.00)	77.267±6.67 (53.00 – 95.80)	P>0.05	≤1000
Salinity g/l	0.04±0.01 (0.00 – 0.10)	0.04±0.01 (0.00 -0.10)	0.03±0.01 (0.00 – 0.00)	P>0.05	200
Colour Pt.Co	11.22±2.04 (5.20 -18.90)	8.33±1.57 (5.80 – 15.70)	9.23±1.55 (5.60 – 16.30)	P>0.05	-
Turbidity (NTU)	8.78±1.52 (3.80 -13.50)	5.91±1.13 (3.30 – 11.20)	6.85±1.32 (4.70 – 13.20)	P>0.05	5
TSS (mg/l)	12.48±1.31 (9.10 – 16.80)	8.80±0.44 (7.30 -10.50)	10.03±0.73 (7.60 – 11.80)	P>0.05	≤5
TDS (mg/l)	48.28±6.71 (27.30 -76.00)	39.08±5.61 (24.20 – 61.00)	38.33±3.30 (26.10 - 47.90)	P>0.05	1000
TS(mg/l)	60.77±7.03^{A} (42.50 – 92.80)	47.88±5.76^{B} (33.60 – 71.50)	48.37±2.85^{B} (37.90 – 55.60)	P<0.05	30
DO (mg/l)	5.32±0.99 (4.90 – 6.90)	5.50±0.23 (4.90 – 6.40)	5.65±0.23 (5.1 – 6.70)	P>0.05	≥5
BOD (mg/l)	2.73±0.34 (1.90 – 4.20)	2.62±0.26 (1.90 – 3.80)	3.10±0.33 (2.10 – 4.50)	P>0.05	≤5
COD(mg/l)	29.35±8.48 (4.80 – 64.50)	21.67±4.84 (6.40 – 39.10)	23.63±7.83 (4.80 – 58.20)	P>0.05	40
HCO3(mg/l)	45.75±5.16 (30.50 – 61.00)	44.73±6.43 (30.50 – 73.20)	33.55±7.51 (12.20 – 61.00)	P>0.05	500
Ca (mg/l)	4.82±0.82 (2.30 – 7.40)	3.02±0.64 (1.10 – 5.10)	3.73±0.74 (1.90 – 5.90)	P>0.05	-
Mg (mg/l)	1.15±0.25 (0.60 – 2.30)	0.76±0.12 (0.30 – 1.10)	0.92±0.13 (0.50 – 1.40)	P>0.05	-
Sodium (mg/l)	1.31±0.19 (0.70 – 1.30)	0.99±0.23 (0.40 – 1.90)	1.20±0.14 (0.80 -1.80)	P>0.05	-
Potassium mg/l)	0.62±0.15 (0.20 – 1.10)	0.52±0.16 (0.10 – 1.00)	0.55±0.14 (0.20 – 1.10)	P>0.05	-
Chloride (mg/l)	38.25±7.38 (8.80 – 64.10)	29.92±6.26 (10.50 – 55.20)	29.10±4.48 (17.70 – 47.00)	P>0.05	600
Phosphate mg/l)	0.52±0.21 (0.10 – 1.20)	0.34±0.14 (0.10 – 0.90)	0.43±0.18 (0.40 – 1.10)	P>0.05	5
Ammonuim Nitrogen (mg/l)	0.18±0.04 (0.10 – 0.40)	0.12±0.04 (0.00 – 0.30)	0.15±0.05 (0.00 -0.30)	P>0.05	-
Nitrate (mg/l)	0.20±0.5 (0.00 – 0.40)	0.06±0.01 (0.00 – 0.10)	0.11±0.05 (0.00 – 0.40)	P>0.05	20
Sulphate (mg/l)	0.99±0.18 (0.20 – 1.40)	0.54±0.16 (0.2 – 0.90)	0.58±0.16 (0.10 – 0.11)	P>0.05	500

***NOTE**: Similar letters indicate means that are not significantly different (P>0.05); P>0.05 = Not significantly different; P<0.05 = significantly different*

The community in a habitat is therefore said to have reached a compromise with the prevailing environmental conditions (Bishop, 1973). Aquatic communities are greatly influenced by water chemistry and nature of the conditions. Determining the precise contribution of each factor influencing the abundance and distribution of a particular taxon is difficult (Dance and Hynes, 1980). The zooplankton encountered in this study (table 3; figure 2) was limnetic and indicative of a typical tropical assemblage (Jeje and Fernando, 1986, Egborge, 1981, Egborge *et al*., 1994, Idris and Fernando, 1981 and Ogbeibu *et al*., 1996). Similar environmental niches riches harbour analogues taxa often of the same family or generic group whenever such habitats are found (Bishop, 1973). In this study, 32 individuals of zooplankton were encountered. These were made up of 12 species of cladocera and 6 species of copepods. However, rotifers were not recorded in this study. The paucity of zooplankton species in the study area reflects the fact that flowing water is a poor habitat for zooplankton (Dudgeon, 1995 and Idris and Fernando, 1981). Studies on lotic ecosystem have implicated the poor diversity of tropical crustacean zooplankton (Egborge, 1981 and Ogbeibu *et al*., 1996). Changes in the availability of suitable algal food because of nutrient enrichment of the water as well as prey-predator interactions can be responsible for the reduction in zooplankton species number and diversity (Imoobe *et al*., 2008). In this study, Cladocera are more diverse and predominant than the copepods. There were 12 species and 17 individuals, Copepods were 6 species and 15 individuals. The dominance of Cladocera over Copepods agreed with the study of Omoigberale and Ogbeibu, 2007 and Ogbeibu *et al*., 1996 which recorded 11 species of Cladocera, 5 species of Copepods and 16 species of Cladocera, 6 species of Copepods respectively. The order cladocera was represented by 3 families namely: Moinidae (1), Chydoridae (10)*, and* Daphinidae (1). These families are like those found in the works of Ogbeibu *et al*., 1996 of a temporary pond Southern Nigeria and Ogbeibu and Obanor, 2002 in a Southern impounded River.

Table 2: Distribution, abundance, and frequency of occurrence of the zooplankton

Species Composition	Freq. of Occurrence	Relative Abundance %
Alona davidi	36	*11.11*
Alona karua	18	5.55
Alona quadrangularis	18	5.55
Alona rectangula elegans	18	
Alona rectangula rectangula	36	11.11
Alonella exisa	18	5.55
Chydorus pubescens	36	11.11
Chydorus sphaericus	18	5.55
Chydorus reticulatus	18	5.55
Chydorus sphaericus	18	5.55
Oxyurella ciliata	18	5.55
Moina reticulata	54	16.67
Simocephelus vetulus	18	5.55
COPEPODA		
Crytocyclops bicolor	18	5.55
Halicyclops troglodytes	18	5.55
Microcyclops varicans	90	27.78
Eucyclops agiloides	90	27.78
Tropocyclops prasinusi	36	11.11

Table 3: Total individuals (N), total taxa (S), Margalef richness (d), evenness (E), and Shannon diversity (H') for the study area averaged over all sampling dates.

Number of individuals (N)	23
Number of Species (S)	18
Margalef's index (d)	2.87
Shannon-wiener index (H^{I})	0.91
Evenness (E)	2.87

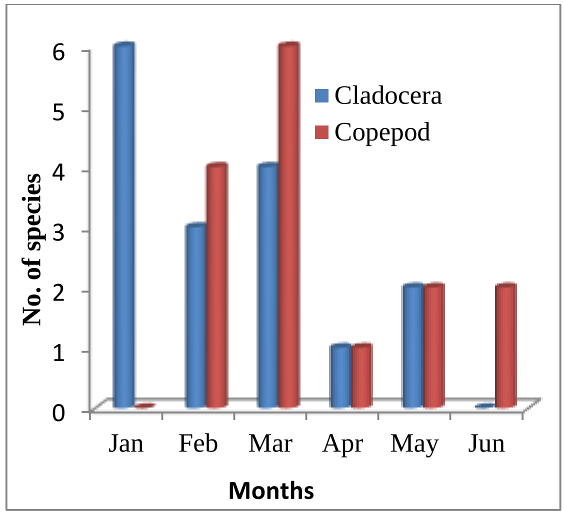

Fig. 2: Showing the spatial distribution of zooplankton of the Owan River during the study period.

These various families are typically fresh water Cladocera (Dumont, 1981 and Egborge, 1981). The dominant family in this study was Chydoridae containing 13 individuals. This agrees with the studies of Egborge, 1981 Ogbeibu and Obanor, 2002 Ogbeibu *et al*., 2001, Omoigberale and Ogbeibu, 2007 and Ogbeibu *et al*, 1996 where Chydoridae was recorded as the most dominant family. Edema *et al*., 2002 recorded all the Cladocera species that was encountered in Okhuo River from family Chydoridae. The dominance of Chydoridae is said to be a characteristic of tropical freshwater zooplankton. Adeyemi *et al*., 2009 reported 2 species of cladocera which comprises *Daphnia* sp. and *Diaphanosoma* sp. from a study of zooplankton in Gbedikere Lake. Imoobe and Adeyinka, 2009 carried out a zooplankton – based assessment of the trophic state of a trophical forest where they reported 12 species of Cladocera comprising; *Alona rectangula, Bosmina longirostris, Bosminopsis deitersi, Ceriodaphnia cornuta, Chydorus sphaericus, Diaphanosoma excisum, Echinisca triseralis, IIyocryptus spinifer, Kurzia longirostris, Macrothrix spinosa, Moina micrura* and *Simocephalus vetulus*. The paucity of Cladocera in these works is like the one recorded in this study.

In this study, *Moina reticulata* was the most abundant species having 3 individuals. *Alona davidi*, *Alona rectangula rectangula* and *Chydorus pubescens* had 2 individuals each. Moreso in this study, the copepods encountered comprised of 6 species and 15 individuals which accounted for 46.86% of the total zooplankton recorded. The copepods were solely represented by the Cyclopoids which include 6 species: *Crytocyclops bicolor* (1), *Halicyclops troglodytes* (1), *Microcyclops varicans* (5), *Thermocyclops neglectus* (5), *Eucyclops agiloides* (1) and *Tropocyclops prasinusi* (2).

This study generally is like the findings of Omoigberale and Ogbeibu, (2007) in Ovia River Benin axis and Ogbeibu *et al*., (2001) in Ovia River were *Thermocyclops neglectus*, and *Microcyclops varicans* were recorded, both were the most dominant copepod. However, this study is also like the findings of Ogbeibu *et al*., (2001) who recorded Microcyclops varicans as the most abundant in Ovia River. The family Cyclopoidae amongst the copepods is the most dominant in the tropical freshwaters (Battegazzore *et al*., 1992 and Tsui and Mccart, 1981). These agree with findings of Egborge (1981) and Burgis (1973) in Lake Asejire, Jeje and Fernando (1986) in Kainji Lake and Omoigberale & Ogbeibu (2007) in Osse River, but in contrast to this study, Ogbeibu and Egborge (1995), Morgan and Boy (1982) which reported the dominance of calanoid in temporary fresh ponds. Moreso, Gabriel (1986) recorded that Harpaticoids were least abundant in Warri River.

Nevertheless, in this study, there was a distinct seasonality of crustacean zooplankton, which corresponded maximally with period of early dry season. Also, other similar findings including Etta (1974); Robinson and Robinson (1971); Proszynska (1966); Burgis (1971 and 1973) in Ibadan University fishpond (Nigeria), lake Chad (Nigeria), Volta (Ghana) and George (Uganda) respectively. In contrast, the maximum crustacean zooplankton was reported during the peak of rainfall by Ogbeibu *et al*., (2001) in Ovia River and Imevbore (1967). All these confirm the belief of Damas (1964) that plankton maxima in the tropics may occur at any period of the year depend on the physiochemical and biological conditions of the ecosystem.

No rotifer was recorded in this study, this is nothing unusual because the sampling stations were a typical lotic environment. Lotic waters are known to harbour very few zooplankton. This is similar to Ogbeibu and Edutie (2002) who reported 45 species of zooplankton from Ikpoba River, out of which only 17 species were found downstream (i.e. in the lotic area) while the remaining 28 species were recorded in the reservoir upstream. Wetzel (1983) associated high population density of rotifers with the presence of submerge macrophytes. The discharges of high load of organic wastes significantly reduce the water transparency and dissolved oxygen level. Exogenous substances of organic origin are known to increase water colour, turbidity, suspended and dissolved solids and thus reduce transparency, these factors have therefore inhibit the growth of macrophytes in this station. (Mason, 1981; Ogbeibu and Victor, 1989)

*Conclusion***:** This study shows the qualitative and quantitative sampling of Owan River, Owan, Edo State. The diversity and abundance of zooplankton in the study area shown clearly that the water was uncompromised with anthropogenic activities. All the physical and chemical parameters recorded were within the acceptable limits and the zooplankton recorded were a typical of lotic freshwater body. I strongly recommend that future work on this river should cover longer length of the river and take longer duration that will span from dry season through the rainy season periods.

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REFERENCES

Adeyemi, SO; Adikwu, IA; Akombu, PM; Iyela, JT (2009). Survey of zooplanktons and Macroinvertebrates of Gbedikere Lake, Bassa, Kogi State, Nigeria. *Inter. J Lakes. Rivers*. 2(1): 37-44.

Addo-Bediako, A; Nukeri, S; Kekana, M (2021). Heavy metal and metalloid contamination in the sediments of Spekboom River, South Africa. *Appl. Water Sci*. 11, 133.

American Public Health Association, (1975). “Standard Methods for Examination of Water and Wastewater”, 14th Edition, Washington, DC. 473pp. DOI: https://doi.org/10.1007/s13201-021-01464-8.

Battegazzore, M; Peterson, JRC; Moretti, G; Rossaro, B (1992). An evaluation of the environmental quality of the River Po using macroinvertebrates. *Arch Hydrobiol.*125: 175-206. DOI: https://10.1127/archiv-hydrobiol/125/1992/175.

Bishop, JE (1973). Limnology of a small Malayan River Sungai Goombak. Monographiae biologicae 22, Junk the Hague, the Netherlands. DOI: https://10.1126/science.183.4120.65.

Burgis, MJ (1971). An ecological study of the zooplankton in Lake George in Uganda (Doctoral Dissertation, University of London), UK. DOI: http://erepository.uonbi.ac.ke:8080/xmlui/handle/123456789/56893.

Burgis, MJ (1973). Observation on the cladocera of lake George Uganda J. zool. London. 170: 339-349. DOI: https://doi.org/10.1111/j.1469-7998.1973.tb01382.x

Damas, H (1964). Le plankton sequelques lacs d' afrique central.*Verh.Int. verein. Theo. Angewe. Limnol. 1*5: 128-138. DOI: https://doi.org/10.1080/03680770.1962.11895512.

Dance, KW; Hynes, HBN (1980). Some effects of agricultural land use on stream insect communities. Environmental Pollution Series A, *Ecological and Biological*. 22(1): 19-28. DOI: https://doi.org/10.1016/0143-1471(80)90078-1.

Downing, JA; McCauley, E (1992). The nitrogen: phosphorus relationship in lakes. *Limnology and Oceanography*,*37*(5), 936-945. DOI: https://doi.org/10.4319/lo.1992.37.5.0936

Dudgeon, D (1995). The ecology of rivers and streams in tropical Asia. In: *ecosystems of the world 22, rivers and stream ecosystems*, 615-657.

Dumont, HJ (1981). Cladocera and free living Copepoda from the Futajalon and adjacent mountain areas on West Africa. *Hydrobiol*. 85: 97-116. DOI: https://doi.org/10.1007/BF00006620

Edema, CU; Ayeni, JO; Aruotor, A (2002). Some observation on the zooplankton and macrobenthos of the Okhuo River, Nigeria. *Journal of Aquatic sciences*.17(2): 145-149.

Egborge, ABM (1981). The composition, seasonal variation and distribution of zooplankton in Lake Asejiri, Nigeria. *Revue. Zool. Afr*. 95: 137- 165.

Egborge, ABM (1987). Salinity and the distribution of Cladocera in Warri River, Nigeria. *Hydrobiologia*. 145: 159-167. DOI: https://doi.org/10.1007/BF02530276

Egborge, ABM; Onwudinjo CC; Chigbu, PC (1994). Cladocera of Coastal Rivers of Western Nigeria. *Hydrobiol*, 272: 39-46. DOI: https://doi.org/10.1007/BF00006511

Etta, EE (1974). Pathways of energy flow in a community of invertebrate in a tropical fish pond. M.sc Thesis. University of Ibadan. Nigeria. 150pp.

Frey, DG (1963). Wisconsin: the Birge-Juday era, In: *Limnology in North America* (Ed.D. G. Frey), The University of Wisconsin Press, Madison, WI.3-54pp.

Gabriel, C (1986). Copepod Warri River, Nigeria. Ph.D Thesis, University of Benin, Benin City, Nigeria.

Goswami, SC (2004). Zooplankton Methodology, Collection & Identification, *a field manual*, first edition, National Institute of Oceanography, Dona Paula, New delhi, India. 26pp. DOI: http://drs.nio.org/drs/handle/2264/95

Idris, BAG; Fernando, CH; (1981). Cladocera of Malaysia and Singapore with remarks on some species, *Hydrobiol*. 77: 233-256.

Imevbore, AMA (1967). Hydrology and plankton of Eleiyele reservoir. Ibadan, Nigeria. *Hydrobiologia*. 30: 154-176. DOI: https://doi.org/10.1007/BF00135017

Imoobe, TOT; Tawari-Fufeyin P; Ejoh, AS (2008). Community structure of crustacean zooplankton in Ekpan Creek, a perturbed tributary of Warri River, Niger Delta, Nigeria. *African Scientist* 9 (4): 123-134.

Imoobe, TOT; Adeyinka, ML (2009). Zooplankton-based assessment of the trophic state of a tropical forest river in Nigeria. *Archives of Biological Sciences*. 61(4): 733-740. DOI: https://doi.org/10.2298/ABS0904733I

Jeje, CY; Fernando, CH (1986). *A practical guide to the identification of Nigerian zooplankton*. Kainji Lake Research institute, 142pp.

Mason, CF (1981). *Biology of freshwater pollution*. Longman. U.K. 239pp.

Morgan, NC; Boy, V (1982). An ecological survey of standing waters in North West Africa: Rapid Survey and classification. *Biological conservation* 24(1): 5- 44. DOI: https://doi.org/10.1016/0006-3207(82)90045-3

Neves, IF; Rocha, O; Roche, KF; Pinto, AA; (2003). Zooplankton community structure of two marginal lakes of the river Cuiabá (Mato Grosso, Brazil) with analysis of Rotifera and Cladocera diversity. *Brazilian Journal of Biology*, *63*, 329-343. DOI: https://doi.org/10.1590/S1519-69842003000200018

Ogbeibu, AE; Egborge, ABM (1995). Hydrological studies of water bodies in the Okomu Forest Reserve (Santuary) in Southern Nigeria. 1 Distribution and Diversity of the invertebrate fauna. *Tropical Freshwater Biology*, 4:1-27.

Ogbeibu, AE; Victor, R (1989). The effect of road and bridge construction on bankroot macrobenthic invertebrates. *Environ. Pollut.* 56: 58-100. DOI: https://doi.org/10.1016/0269-7491(89)90168-1

Ogbeibu, AE; Imoobe, TOT; Edokpayi, CA (1996). Zooplankton of a Temporary Pond in a threatened Nigeria Forest Reserve. *Trop. Freshwater Biol* .5: 13-30.

Ogbeibu, AE; Ezemonye, LIN; Uyigue, E (2001) The crustacean zooplankton of the Ovia River, Southern Nigeria. Niger. *J. Appl. Sci.*19:36-42.

Ogbeibu, AE; Obanor, DO (2002). Studies on the crustacean of impounded southern Nigeria River. *Bio.Science Res. Comm.* 14(6): 250-286.

Ogbeibu, AE; Edutie, LO (2002). Impact of Brewery Effluent on the Water Quality and Rotifers of Ikpoba River, Southern Nigeria. *Afr. J. Aquatic. Environ. Pollut. Health*.1 (1): 1-12.

Omoigberale, MO; Ogbeibu, AE (2007). Environmental impact of oil exploration and production on the crustacean zooplankton of Osse River Southern Nigeria. *Pak. J. Sci. Ind. Res.*50(4): 266-272. DOI: https://doi.org/10.4314/gjes.v6i1.2484

Proszynska, M (1966). Aquaculture study of the cladocera and copepods in the Volta lake, University of Ghana. Volta Basin *Res. Proj. Tech. Rep.* 251pp.

Robinson, AH; Robinson, PK (1971). Seasonal distribution of zooplankton in the Northern basin of Lake Chad. *J. Zool. Lond*. 163(1): 25-61. DOI: https://doi.org/10.1111/j.1469-7998.1971.tb04523.x

Rocha, O; Matsumura-Tundisi, T; Sampaio, EV (1997). Phytoplankton and zooplankton community structure and production as related to trophic state in some Brazilian lakes and reservoirs. *Verh. Int. Verein. Limnol*. 26(2): 599-604. DOI: https://doi.org/10.1080/03680770.1995.11900788

Rusak, JA; Yan, ND; Somers, KM; Cottingham, KL; Micheli, F; Carpenter, SR; Frost, TM; Paterson, MJ; Mcqueen, DJ (2002). Temporal, spatial and taxonomic patterns of crustacean zooplankton variability in unmanipulated north-temperate lakes. *Limnology and Oceanography*, 47(3): 613-625. DOI: https://doi.org/10.4319/lo.2002.47.3.0613

Sala, OE; Chaplin, FS; Armesto, JJ; Berlow, E; Bloomfield, J; Dirzo, R; Huber-Sanwald, E; Huenneke, LF; Jackson, RB; Kinzig, A; Leemans, R; Lodge, DM; Mooney, HA; Oesterheld, M; Poff, NL; Sykes, MT; Walker, BH; Walker, M; Wall, DH (2000). Global biodiversity for the year 2100, *American association for the advancement of science.* 287 (5459): 1770-1774. DOI: https://doi.org/10.1126/science.287.5459.1770

Tsui, TP; McCart, P (1981). Effects of stream crossing by a pipeline on the benthic macrovertebrates of small mountain stream. *Hydrobiologia.* 79:271pp. https://doi.org/10.1007/BF00006324

UNESCO, (1974). Reviews of methods used for quantitative Zooplankton sampling, UNESCO Technical paper in marine Science. 18:1-27.

Wetzel, RG (1983). *Limnology*. Second edition. WB Saunders College Publishing, USA, 743pp.