EQA - International Journal of Environmental Quality
ISSN 2281-4485 - Vol. 53 (2023): 49-58
Journal homepage: https://eqa.unibo.it/

published by

Comparative assessment of physico-chemical conditions and zooplankton diversity of Anambra River in Anambra State, Nigeria

Jonathan Chimezie Anyanwu*, Daniel Madueke Nwafor, Chijioke Ndukwe Uyo, Chris Chibuzor Ejiogu

Department of Environmental Management, Federal University of Technology, Owerri, Nigeria.

* Corresponding Author Email: anyanwujonathan7@gmail.com

Article info
Received 28/1/2023; received in revised form 5/2/2023; accepted 25/2/2023
DOI: 10.6092/issn.2281-4485/16319

Abstract
An assessment of Physico-chemical parameters and zooplankton diversity of Anambra River in Anambra State was conducted for a period of eight months from February 2021-September 2021. Water samples were collected from three sampling stations of the river every month in sterilized containers during the course of the study. The study stations are Umueri (S1), Anam (S2) and Otuocha (S3). The samples were analysed for both Physico-chemical attributes and zooplankton diversity. Zooplankton species were determined following standard procedures. A total of twenty three species of zooplankton were encountered in Anambra River. The abundance of zooplankton in Anambra was in the order: Protozoa (28.57%) > Crustacea (27.14%) > Insecta (26.67%) > Rotifera (17.62%). There were 66, 79 and 65 zooplanktons recorded for Station 1 (S1), Station 2 (S2) and Station 3 (S3) respectively in Anambra River. 8 zooplankton species cut across the 3 stations while 1(*Lacane species*)**,** 2(*Chaoborus species* and *Microcodon species*) and 1(*Sphaerophysa species*) species were unique to Station 1 (S1), Station 2 (S2) and Station 3 (S3), respectively. Anambra River recorded high diversity indices value for Cruataceans = 1.779 and least value for Rotifera = 0.6365. The physico-chemical attributes of the river were investigated by measuring the degree of correlation with the plankton diversity. The zooplankton diversity of the river correlated significantly ($p<0.05$) with physico-chemical parameters. The result revealed a deterioration of water quality of the river due to industrial, commercial and anthropogenic activities. The status of zooplankton diversity of Anambra River was low indicating that the river is highly polluted and the water chemistry has direct effect on plankton diversity. Rotifera showed less number of zooplankton abundance in most of the sites in the river. Nutrient enrichment of the river, as a result of farming activities, industries, discharge of domestic wastes and effluents, has altered the structure of zooplankton community of the river. There is need for urgent management and conservation strategies to protect and restore the water quality of the river.

Keywords: *Anthropogenic, Deterioration, Diversity, Physicochemical, Zooplankton***.**

Introduction

The pivotal role of plankton in aquatic food web cannot be overemphasized. Their importance as food to juvenile and adult fish is well known (Ogbeigbu, 2001). Plankton serves as bioindicator and is also an important tool for understanding water pollution status. Zooplankton is a group of drifting organisms that help to evaluate the ecological status of water bodies. Due to their short life span and wide distributions, they act as "ecological indicators". Thus, planktonic organisms are also regarded as ideal bioindi-

DOI: 10.6092/issn.2281-4485/16319

icators for assessing the environmental status of wetlands (Wijeyaratne and Nanayakkara, 2000; Chaparro-Herrera et al., 2021).

The diversity and seasonal variation studies of zooplankton are of great importance in water bodies because they are the intermediate link between phytoplankton and fish. It has been reported that zooplanktons are predators of phytoplankton and are very sensitive to changes in environmental conditions (Eisner *et al.,* 2014; Xiong *et al.,* 2016). Zooplanktons are integral component of the food chain, and they occur in all water bodies and are important to nutrient recycling and regeneration of primary production. According to Dudgeon *et al.* (2006), factors such as anthropogenic activities and climate change are obstructing the stability of most freshwater ecosystems; thereby causing a loss in diversity of zooplankton (Geist, 2011; Alahuhta *et al.,* 2019). A lot of research has been carried out on diversity of various types of plankton many of which have been associated with far ranging ecological and economic impacts (Sharma and Mankodi, 2011; Priyanka Malhotra, 2014; Kamlesh, Prahlad Dube (2018); Kumar and Khare, 2015; Pimentel *et al.,* 2005; Gollasch, 2006; Connelly *et al.,* 2007; Cuhel and Aguilar, 2013). There are some researches on zooplankton assemblage which show relations between zooplankton and environmental parameters in various water systems (Makarewicz *et al.,* 1998; Tackx *et al.,* 2004; El-Bassat and Taylor, 2007; Arimoro and Oganah, 2010; Ahmad *et al.*, 2011; Sharma, 2011). Plankton diversity and physico-chemical parameters are an important criterion for

evaluating the suitability of water for drinking and other purposes (Fouzia and Amir, 2013), this is because plankton community is a dynamic system which represents the base-line of the food chain in the aquatic ecosystem that would quickly respond to changes in the physical and chemical properties of the water environment (Imoobe and Adeyinka, 2009).

Materials and Methods

Study Area

The study area is Anambra River and environs. The river is in Anambra state of Nigeria. Anambra State lies between Longitudes 6°35'E and 7°2'E, and Latitudes 5°40'N and 6°45'N. The climate is tropical with an average yearly rainfall of 2000mm and mean temperature of 27.6°C. Heavy rainfall occurs within the months of April to October while the months of November to February have scanty rainfall, higher temperature and low humidity.

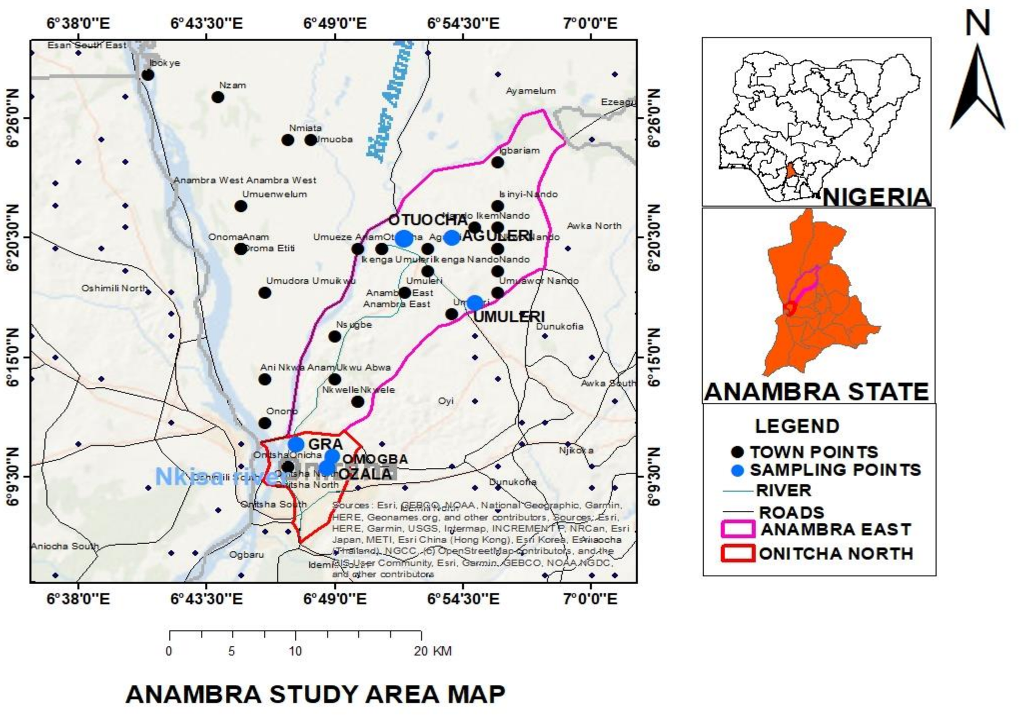

Figure 1
Study area

DOI: 10.6092/issn.2281-4485/16319

The Anambra River is a tributary of River Niger which is the third largest river in Africa after the Nile River and the Congo River. The river flows 210 kilometres (130 mi) into the Niger River and is the most important feeder of the River Niger below Lokoja.
The flow of the Ọmambala River is released into the Atlantic through various outlets forming the 25,000-square-kilometre (9,700 sq mi) Niger Delta region (*Shahin, 2002).* The Anambra River is located in Anambra East Local Government Area, which comprises Umueri (Umuleri), Aguleri and Umuoba Anam. Otuocha houses the local government headquarters. The people are predominantly farmers and fishermen.

Collection of samples

The zooplanktons were collected with the use of plankton nets of size 50 μm which was used to drag through horizontally and vertically on the lake. The sampling was done in the morning before 8:00 am between the months of April to September, 2021. Pour-through method was used to collect the samples. A 10-liter graduated bucked was used to collect water at a depth of about 30cm below the water surface and then poured into a plankton net of mesh size 50 μm, this was done 10 times to make a total of 100 litres of filtered water. The collected zooplankton were then carefully transferred into properly labeled storage containers, 4% of formalin was then added to serve as a preservative for the zooplankton. The samples were taken to the laboratory for further analysis.
The water samples were collected with sterile containers, properly labeled, stored in a refrigerator and taken to the laboratory within 72 hours of collection for analysis of physicochemical parameters of the lake.

Sample identification

Identification of the zooplankton was done with the use of a compound microscope. A dissecting microscope was used for sorting and counting the number of species. After they were taken to the laboratory, each preserved zooplankton sample was poured into a graduated centrifuge tube and centrifuged using a 'Gallen Kamp- Medico' model (90) centrifuge. This was allowed to settle and the supernatant decanted. After decanting the concentrated zooplankton was analyzed.

The Specimens were mounted on glass slides and examined at 25-100X magnification. A pipette was used to place the concentrated zooplankton on a glass slide with a cover slip and then viewed under a compound. The zooplanktons were then identified (qualitative analysis) and counted (quantitative analysis) using standard identification keys and taxonomic guide (Pennak, 1979; Jeje and Fernando, 1986). The general body shape, the color (Opaque or translucent), the relative length of appendages (e.g. antennae, legs) and setae (hair-like processes) were features used in identification of the zooplankton species. The above processes were repeated five times, in order to determine the abundance and diversity of phytoplankton and zooplankton at the three stations (S1, S2 and S3) of Anambra River.

Determination of parameters

The Physico-Chemical parameters measured were temperature, pH, turbidity, conductivity, nitrate, phosphate, BOD, COD, dissolved oxygen, total suspended solids, total dissolved solids, total solids, total alkalinity, total hardness, potassium, sodium, chloride and calcium. Temperature was determined *in situ* by using the mercury in glass thermometer in centigrade scale. A multi-purpose pH meter model D46 (pH/MV/^{O}C meter) was used to determine the pH of the water samples. Turbidity of the samples was measured in the laboratory using the LABTECH DIGITAL turbidity meters. The specific conductance of the samples was measured using the battery operated conductivity bridge model MC-1 mark V Electronic switchgear at room temperature. Total Dissolved Solids, Total Suspended Solids and Total solids were measured by gravimetric analysis. Total Alkalinity, Total Hardness, Calcium, Chloride, Dissolved Oxygen, Chemical Oxygen Demand, and Biological Oxygen Demand were analyzed by the titration method. Potassium and Sodium were determined by Flame photometer; while Phosphate and Nitrate were analyzed by UV-visible spectrophotometer.

Results and Discussion

The mean result of physico-chemical parameters at different sampling points in Anambra River is shown in Table 1. The mean values of temperature varied from 27.9^{0}C at S3 to 28.4^{0}C at S1. The mean values of pH ranged from 7.57 at S1 to 7.89 at S3. The mean values of TS varied from 14.8 mg/L at S1 to

DOI: 10.6092/issn.2281-4485/16319

22.36 mg/L at S3. The turbidity values ranged from 3.6 to 4.7 FTU. Conductivity values ranged from 12.8 at S1 to 22.3 µohmCm^{-1} at S3. The mean TDS values varied from 9.89 mg/l at S1 to 18.26 mg/l at S3. The mean TSS values ranged from 3.62 mg/l at S2 to 4.91 mg/l at S1. The mean values of TS varied from 14.8 mg/l at S1 to 22.36 mg/lat S3. The mean total alkalinity values ranged from 18.2 mg/l at S2 to 23.4 mg/l at S1. The mean values of total hardness varied from 44.8 mg/l at S3 to 52.2 mg/lat S2. The mean calcium values ranged from 3.62 mg/l at S3 to 9.15 mg/l at S2. The mean values of chloride varied from 4.14 mg/l at S1 to 5.62 mg/l at S2.

The mean dissolved oxygen values ranged from 6.2 mg/l at S3 to 6.4 mg/l at S1. The mean values of COD varied from 5.8 mg/l at S1 to 6.5 mg/l at S3. The mean values of BOD ranged from 20.29 mg/l at S1 to 20.70 mg/l at S3. The mean values of phosphate varied from 0.001 mg/l at S1 to 0.005 mg/l at S3. The mean values of potassium ranged from 1.45 mg/l at S2 to 2.17 mg/l at S3. The mean values of nitrate varied from 1.9 mg/l at S1 to 2.8 mg/l at S3. The mean values of sodium varied from 2.01 mg/l at S3 to 2.5 mg/l at S2

Table 1
Mean values of the physico-chemical characteristics of Anambra River

Parameters	Stations		
	S1	S2	S3
Temperature ^{0}C	28.4	28.0	27.9
pH	7.57	7.60	7.89
Turbidity (FTU)	3.6	3.9	4.7
Conductivity µohmCm^{-1}	12.8	20.8	22.3
TDS mg/l	9.89	16.43	18.26
TSS mg/l	4.91	3.62	4.10
TS mg/l	14.8	20.05	22.36
Total Alkalinity mg/l	23.4	18.2	20.7
Total Hardness mg/l	45.0	52.2	44.8
Calcium mg/l	7.20	9.15	3.62
Chloride mg/l	4.14	5.62	5.00
DO mg/l	6.4	6.3	6.2
COD mg/l	5.8	6.2	6.5
BOD mg/l	20.29	20.30	20.70
Phosphate mg/l	0.001	0.0002	0.005
Potassium mg/l	1.62	1.45	2.17
Nitrate mg/l	1.9	2.5	2.8
Sodium mg/l	2.1	2.5	2.01

A total of twenty three species of zooplankton were encountered in Anambra River (Table 2). Station 2 had the highest number of individual species (79) while Station 1 and Station 3 had 66 and 65 individuals of species respectively. The most abundant zooplankton species in the river was Anopheles larvae with the highest number (15) found in Station 3 (S3) which happened to be the point of greatest pollution in the river, accounting for 17.6% while the least were *Chaoborus Spp* (2), *Sphaerophysa species* (3), *Lacane Spp* (3), *Microcodon Spp* (3), Nauplius Spp (4) and *Brachionus caudatus* (4), accounting for less than 2% respectively. Station 3 (S3) had the highest number of individual species (27) belonging to the Class protozoa, followed by Station 2 (S2 = 20), while Station 1 (S1) had the least number of individual species (13). For the crustaceans, the highest number of species (25) was recorded in S2, followed by S1 (21). S3 recorded the lowest value (11) of individual species of the crustacean group. The highest number (16) of individual species of the Rotifera was recorded in Station 1, followed by Station 2 (15), while the least value (6) was recorded in Station 3. Also, the highest number (21) of individual species of the Insecta was recorded in Station 3, followed by Station 2 (19), while the least value (16) was recorded in Station 1.

DOI: 10.6092/issn.2281-4485/16319

Table 2
Distribution of Zooplankton (Unit/l) in Anambra River during the study period

ZOOPLANKTON	S1	S2	S3	Total
Protozoans				
Paramaecium caudatum	0	5	8	13
Amoeba species	3	6	5	11
Sphaerophysa species	0	0	3	3
Carchesium polypium	2	6	2	10
Paramaecium Aurelia	5	3	7	15
Arcella species	3	0	2	5
Total	13	20	27	60
Crustaceaa				
Mesocyclops species	6	4	0	10
Nuplius larvae	0	0	0	0
Zoea larvae	0	2	3	5
Macrocyclops species	5	3	0	8
Daphnia species	3	6	2	11
Diaphanosoma species	0	2	3	5
Nauplius species	3	1	0	4
Cyclops species	4	7	3	14
Total	21	25	11	57
Rotifera				
Diurella species	2	5	2	9
Keratella quadrata	0	0	0	0
Microcodon species	0	3	0	3
Brachionus caudatus	2	2	0	4
Gastropus hyptopus	0	0	0	0
Epiphanes macrourus	4	3	0	7
Lacane species	3	0	0	3
Asplachna species	5	2	4	11
Total	16	15	6	37
Insecta				
Chaoborus species	0	2	0	2
Siphlonurus species	2	1	4	7
Anopheles larvae	10	12	15	37
Chironomus larvae	4	4	2	10
Total	16	19	21	56

The result of diversity index of Zooplankton in Anambra River (Table 3) revealed that Protozoans showed minimum value of zooplankton diversity index in Station 1 (1.332) and maximum value in Station 3 (1.652). Protozoans showed the highest value (0.2781) for species Dominance_D in Station 1 and the least value (0.2126) in Station 3. Evenness ranged from 0.8699 in Station 3 to 0.9678 in Station 2. Crustaceans showed minimum value of zooplankton diversity index in Station 1 (1.373) and maximum value in Station 2 (1.779). Crustaceans showed the highest value (0.2562) for species Dominance_D in Station 3 and the least value (0.1904) in Station 2. Evenness ranged from 0.8467 in Station 2 to 0.9868 in Station 3. Rotifera showed minimum value of zooplankton diversity index in Station 3 (0.6365) and maximum value in Station 2 (1.547). Rotifera showed the highest value (0.5556) for species Dominance_D in Station 3 and the least value (0.2266) in Station 1. Evenness ranged from

DOI: 10.6092/issn.2281-4485/16319

0.9365 in Station 1 to 0.9449 in Station 3. Insecta showed minimum value of zooplankton diversity index in Station 3 (0.7801) and maximum value in Station 2 (1.01). Insecta showed the highest value (0.5556) for species Dominance_D in Station 3 and the least value (0.4571) in Station 2. Evenness ranged from 0.6865 in Station 2 to 0.8201 in Station 1.

Table 3. *Diversity index of Zootoplankton at different sampling points in Anambra River*

Parameters	Number of Species			Shannon_H			Dominance_D			Evenness_e^H/S		
Sites	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
Protozoans	13	20	27	1.332	1.354	1.652	0.2781	0.265	0.2126	0.9474	0.9678	0.8699
Crustaceans	21	25	11	1.571	1.779	1.373	0.2154	0.1904	0.2562	0.9627	0.8467	0.9868
Rotifera	16	15	6	1.544	1.547	0.6365	0.2266	0.2267	0.5556	0.9365	0.9397	0.9449
Insecta	16	19	21	0.9003	1.01	0.7801	0.4688	0.4571	0.5556	0.8201	0.6865	0.7273

The results of correlation analysis of physico-chemical parameters of the river (Tables 4) revealed that temperature correlated highly positively with pH (r = 0.73361) and also highly positively correlated with BOD, COD and Na in Anambra River. pH correlated negatively with temperature (r =-0.40635) and highly positively correlated with turbidity, EC, TDS, TS, Ca, T Alk and nitrate in Anambra River. Turbidity correlated highly negatively with Temperature (r =-0.83088) and highly positively with TSS, DO, BOD, Cl^- and sodium in Anambra River. EC was found to be highly negatively correlated with temperature (r = -0.99909) and highly positively correlated with turbidity, BOD, COD, K and Na in Anambra River. TDS was found to be highly negatively correlated with temperature (r = -0.99981) and correlated highly positively with turbidity, EC, BOD, COD and Na in Anambra River (Table 8). TSS correlated highly positively with temperature (r = 0.84347), COD, Ca, PO_4 and K in Anambra River. TSS also correlated highly negatively with pH, EC and TDS in Anambra River (Table 8). TS correlated highly negatively with temperature (r = -0.99367) and with TSS (r = -0.7776) and correlated highly positively with turidity, EC, TDS, BOD and Na in Anambra River. DO highly positively correlated with temperature (r = 0.77028), with TSS, COD, Ca, PO_4, K, and NO_2, and highly negatively correlated with pH, EC and TDS in Anambra River. BOD correla ted negatively with temperature (r = -0.30571) and highly negatively with TSS and DO in Anambra River (Table 4). COD correlated positively with temperature (r = 0.35105) and correlated highly positively with pH, Cl^-, THD and K in Anambra River. COD also correlated highly negatively with turbidity and negatively with EC, TDS, TSS, TS and DO in Anambra River (Table 3.4). Also, Cl^- correlated highly negatively with temperature (r = -081366), with TSS and DO in Anambra River, and also correlated highly positively with pH, EC, TDS, TS, BOD, Ca, PO_4, K and NO_2 in Anambra River. Ca correlated with temperature (0.65465), correlated highly positively with COD and correlated highly negatively with turbidity and TS in Anambra River (Table 4). Ca also correlated negatively with EC, TDS, and Cl^- in Anambra River (Table 4). T.Alk was found to be highly negatively correlated with temperature (-0.96862) and Ca (r = 0.82199) but negatively correlated with TSS, DO and COD in Anambra River. THD correlated highly positively with temperature (0.99419), TSS, DO, PO_4, K and Na in Anambra River. THD correlated highly negatively with turbidity, EC, TDS, TS and Cl^- in Anambra River. THD also correlated negatively with pH and BOD, in Anambra River. PO_4 correlated negatively with temperature (r = -0.52911), pH, BOD, Cl^- and THD and correlated highly negatively with COD and Ca in Anambra River. PO_4 also correlated highly positively with turbidity and T.Alk in Anambra River. K correlated negatively with temperature (r = -0.467), pH, BOD, Cl^-, and THD, correlated highly positively with turbidity and T.Alk in Anambra River. K correlated negatively with temperature (r = -0.467), pH, BOD, Cl^-, and THD,

DOI: 10.6092/issn.2281-4485/16319

Table 4. *Correlation analysis of physico-chemical parameters of Anambra River*

	Temp	pH	Turb	EC	TDS	TSS	TS	DO	BOD	COD	Cl^-	Ca	T Alk	T HD	PO_4	K	NO_2	Na
Temp		0.73361	0.37568	0.02721	0.012313	0.36102	0.07169	0.44024	0.80221	0.77165	0.39494	0.54563	0.15991	0.068649	0.64505	0.69067	0.33333	0.89809
pH	-0.40635		0.89071	0.7064	0.74592	0.37259	0.8053	0.29337	0.068605	0.49474	0.33866	0.72077	0.89351	0.66496	0.62134	0.57573	0.93306	0.16448
Turb	-0.83088	-0.17083		0.40289	0.36337	0.7367	0.30399	0.81592	0.82211	0.39597	0.77062	0.16995	0.21577	0.44433	0.26937	0.31499	0.042347	0.72623
EC	-0.99909	0.44502	0.80634		0.039523	0.33381	0.0989	0.41303	0.775	0.79886	0.36773	0.57284	0.18712	0.041439	0.67226	0.71788	0.36054	0.87088
TDS	-0.99981	0.3886	0.84148	0.99807		0.37333	0.059377	0.45255	0.81452	0.75934	0.40725	0.53332	0.14759	0.080962	0.63274	0.67835	0.32102	0.9104
TSS	0.84347	-0.83357	-0.4019	-0.86565	-0.83292		0.43271	0.079216	0.44119	0.86733	0.03392	0.90665	0.52093	0.29237	0.99392	0.94831	0.69435	0.53707
TS	-0.99367	0.30109	0.88814	0.98796	0.99565	-0.77776		0.51193	0.8739	0.69996	0.46663	0.47394	0.088216	0.14034	0.57336	0.61898	0.26164	0.96978
DO	0.77028	-0.89569	-0.28514	-0.79682	-0.7578	0.99227	-0.69374		0.36197	0.78811	0.045296	0.98587	0.60014	0.37159	0.91471	0.8691	0.77357	0.45785
BOD	-0.30571	0.9942	-0.27581	0.34612	0.28724	-0.76932	0.19678	-0.84266		0.42614	0.40727	0.65216	0.96212	0.73356	0.56274	0.50712	0.86446	0.095879
COD	0.35105	0.71292	-0.81272	-0.31072	-0.36909	-0.2069	-0.45404	-0.32672	0.78421		0.83341	0.22602	0.61175	0.8403	0.1266	0.080986	0.43832	0.33026
Cl^-	-0.81366	0.86181	0.35256	0.83776	0.80227	-0.99858	0.74318	-0.99747	0.80225	0.25871		0.94057	0.55486	0.32629	0.96	0.91439	0.72827	0.50315
Ca	0.65465	0.42469	-0.96458	-0.62176	-0.66915	0.14611	-0.73545	0.0222	0.5196	0.93763	-0.093217		0.38572	0.61428	0.099425	0.14504	0.2123	0.55628
T Alk	-0.96862	0.16649	0.94311	0.95712	0.97325	-0.68348	0.99041	-0.5876	0.059471	-0.57276	0.64364	-0.82199		0.22856	0.48515	0.53076	0.17343	0.942
T HD	0.99419	-0.50232	-0.76616	-0.99788	-0.99192	0.89638	-0.9758	0.83444	-0.40641	0.24823	-0.8715	0.56949	-0.93624		0.7137	0.75932	0.40198	0.82944
PO_4	-0.52911	-0.56034	0.91181	0.49237	0.54542	0.0095425	0.62111	0.13357	-0.64617	-0.98029	-0.062783	-0.98783	0.72341	-0.43471		0.045612	0.31172	0.45686
K	-0.467	-0.6182	0.88007	0.4288	0.48402	0.081101	0.56341	0.20418	-0.69915	-0.99192	-0.13407	-0.97416	0.67213	-0.36912	0.99743		0.35733	0.41124
NO_2	0.86603	0.10495	-0.99779	-0.84387	-0.87553	0.46187	-0.91673	0.34822	0.21131	0.77219	-0.41398	0.94491	-0.96312	0.80718	-0.8825	-0.84657		0.76858
Na	-0.1594	0.96681	-0.4169	0.20143	0.14027	-0.66476	0.047452	-0.75234	0.98868	0.86843	0.7036	0.64191	-0.090974	-0.26472	-0.75337	-0.79851	0.35556	

Temp = Temperature, Turb = Turbidity, EC = Electrical Conductivity, TDS = Total Dissolved Solids, TSS = Total Suspended Solids, TS = Total Solids, DO = Dissolved Oxygen , BOD = Biological Oxygen Demand, COD = Chemical Oxygen Demand, Cl^- = Chloride, Ca = Calcium, T Alk = Total Alkalinity, T HD = Total Hardness, PO_4 = Phosphate, K = Potassium, NO_2 = Nitrate, Na = Sodium

NO_2 correlated highly positively with temperature (0.86603), COD, Ca, THD and Na, and also correlated highly negatively with turbidity, EC, TDS, TS, T.Alk, PO_4 and K in Anambra River. Na correlated negatively with temperature (-0.1594), turbidity, TSS, T.Alk, PO_4 and K; and also correlated highly negatively with DO and K in Anambra River (Table 4). Na correlated highly positively with pH, BOD, COD and Cl^- in Anambra River. Table 5 shows the relationship between physicochemical parameters and zooplanktonic biomass in Anambra River. The zooplanktons were the protozoans, Insecta, Rotifera and Crustaceans. In Anambra River the Protozoans correlated highly positively with temperature, pH, EC, BOD, K, NO2 and Na. There was no negative correlation between Protozoans and physicochemical properties in Anambra River. In Anambra River Insecta correlated highly positively with temperature (0.87461) and EC (0.84664) but correlated positively with other parameters and negatively with TDS (-0.63673) (Table 5). In Anambra River Rotifera correlated negatively with temperature, EC and TDS and correlated highly positively with TS, DO, BOD, Cl^- Ca and PO_4. There was low positive correlation between Rotifera and pH, turbidity, TSS, COD, T.Alk, THD, K and NO_2 in Anambra River (Table 5). Inverse correlation was observed between crustaceans and most of the parameters in Anambra River. Crustaceans correlated negatively with temperature, pH, EC, TDS, TS, DO, BOD, COD, Cl^-, Ca, THD, PO_4, K and NO_2 but correlated positively with turbidity, TSS and T.Alk and Na (Table 5).

DOI: 10.6092/issn.2281-4485/16319

Table 5. *Pearson Correlation (r-values) calculated between zooplankton diversity and physico-chemical parameters of Anambra River*

	Temp	pH	Turb	EC	TDS	TSS	TS	DO	BOD	COD	Cl^-	Ca	T Alk	T HD	PO_4	K	NO_2	Na
Protozoans	0.90523	0.76965	0.22946	0.83636	0.003989	0.54223	0.006725	0.010287	0.87238	0.079716	0.21617	0.029598	0.50492	0.003666	0.009196	0.084871	0.93636	0.75159
Insecta	0.87461	0.66921	0.32416	0.84664	-0.63673	0.68697	0.005264	0.010572	0.001613	0.57473	0.36119	0.003028	0.65295	0.005597	0.033552	0.10294	0.30378	0.8229
Rotifera	-0.2215	0.12938	0.26344	-0.23529	-0.15684	0.31499	0.94474	0.85209	0.78958	0.63401	0.93635	0.98805	0.48458	0.51115	0.88603	0.5201	0.50283	0.077888
Crustaceans	-0.6055	-0.73129	0.4953	-0.60416	-0.57818	0.24792	-0.55977	-0.41896	-0.61572	-0.06338	-0.87277	-0.80663	0.49541	-0.67509	-0.53855	-0.6055	-0.73129	0.4953

Temp = Temperature, Turb = Turbidity, EC = Electrical Conductivity, TDS = Total Dissolved Solids, TSS = Total Suspended Solids, TS = Total Solids, DO = Dissolved Oxygen , BOD = Biological Oxygen Demand, COD = Chemical Oxygen Demand, Cl^- = Chloride, Ca = Calcium, T Alk = Total Alkalinity, T HD = Total Hardness, PO_4 = Phosphate, K = Potassium, NO_2 = Nitrate, Na = Sodium

Planktons exist under a wide range of environmental conditions, and are sensitive to physicochemical changes in their marine environment (Hays *et al.,* 2005). It has been reported that many species of zooplanktons are limited by dissolved oxygen, temperature, salinity and other physico-chemical factors (Esenewo, Ugwumba & Akpan, 2017; Jeje & Fernando, 1986). Four groups of Zooplanktons were identified in Anambra River. Protozoa, Crustacea and Insecta constituted the most dominant groups in Anambra River. The abundance of zooplankton in Anambra River was in the order: Protozoa (28.57%) > Crustacea (27.14%) > Insecta (26.67%) > Rotifera (17.62%). The most commonly seen zooplankton species in Anambra River were *Paramecium species, Cyclops, Anopheles larvae*. The most commonly encountered protozoans were *Paramecium caudatum, Paramecium aurelia* and *Amoeba spp*. The Crustaceans frequently encountered were *Mesocyclops spp, Daphnia spp* and *Cyclops spp*. The rotifers commonly seen in Anambra River were *Epiphanes macrourus, Diurella spp* and *Asplachna spp*; while the commonly found insect species were *Anopheles* larvae and *Chironomus* larvae. The result of zooplankton analysis in Anambra River (Table 3) revealed that high values of Shannon-Wiener Index_H were recorded for Crustaceans (1.779) and low values for Rotifera (0.6365). Highest values for species dominance_D were recorded for Rotifera (0.5556) and Insecta (0.5556) and lowest for Protozoans (0.2126). Evenness ranged from (0.6865) for Insecta to (0.9868) in Cruataceans.

Conclusions

The variations in physicochemical parameters and plankton diversity and abundance of the rivers are reflections of the anthropogenic activities around the drainage basins of the rivers which impact significantly on the water quality. Contrasted hydro and biological characteristics were observed among the different sampling stations of the river in the course of the study. The study revealed that the river sustains dense populations of zooplankton species. However, the density of zooplanktons is greater in Sampling Station 2. Overall, plankton diversity was higher in Sampling Station 2 compared to other stations, and the reason can be adduced to the fact that Station 2 had conditions that were more adaptable for species diversity compared to other stations which were exposed to greater degree of pollution. The physicochemical parameters of Anambra River have been significantly impacted by human activities thus resulting in reduction of zooplankton diversities.

References

AHMAD U., PARVEEN S., KHAN A.A., KABIR H.A., MOLA H.R.A., GANAI A.H. (2011) Zooplankton population in relation to physicochemical factors of a sewage fed pond of Aligarh (UP), India. Biology and Medicine*,* 3(2):336-341. ISSN:09748369

ALAHUHTA J., ERŐS T., KÄRNÄ O-M., SOININEN J., WANG J., HEINO J. (2019) Understanding environmental change through the lens of trait-based, functional, and phylogenetic biodiversity in

DOI: 10.6092/issn.2281-4485/16319

freshwater ecosystems. Environ Rev., 27(2):263–273. https://doi.org/10.1139/er-2018-0071

ARIMORO F., OGANAH A. (2010) Zooplankton community responses in a perturbed tropical stream in the Niger Delta, Nigeria. The Open Environmental and Biological Monitoring Journal, 3: 1-11. https://doi.org/10.2174/1875040001003010001

CHAPARRO G., O'FARRELL I., HEIN T. (2019) Multi-scale Analysis of Functional Plankton Diversity in Floodplain Wetlands: Effects of River Regulation. *Sci. Total Environ.* 667, 338–347. https://doi.org/10.1016/j.scitotenv.2019.02.147

CONNELLY N.A., O'NEILL C.R., KNUTH B.A., BROWN T.L. (2007) Economic impacts of zebra mussels on drinking water treatment and electric power generation facilities. Environmental Management, 40:105–112. https://doi.org/10.1007/s00267-006-0296-5.

CUHEL R.L., AGUILAR C. (2013) Ecosystem transformations of the Laurentian Great Lake Michigan by nonindigenous biological invaders. Annual Review of Marine Science, 5:289–320. https://doi.org/10.1146/annurev-marine-120710-100952.

DUDGEON D., ARTHINGTON A.H., GESSNER M. O., KAWABATA Z.I., KNOWLER D.J., LEVEQUE C., NAIMAN R.J., PRIEUR-RICHARD A-H., SOTO D., STIASSNY M.L.J. (2006) Freshwater biodiversity: importance, threats, status and conservation challenges. Biol Rev Camb Philos Soc., 81(2):163–182. https://10.1017/S1464793105006950.

EISNER L.B., NAPP J.M., MIER K.L., PINCHUK A.I., ANDREWS A.G. (2014) Climate-mediated changes in zooplankton community structure for the Eastern Bering Sea. Deep-Sea Res. 109:157–171. https://doi.org/10.1016/j.d sr2.2014.03.004

EL-BASSAT R.A., TAYLOR W.D. (2007) The zooplankton community of Lake Abo Zaabal, a newly-formed mining lake in Cairo, Egypt. African Journal of Aquatic Science, 32(2):1-8. https://doi.org/10.2989/AJAS.2007.32.2.10.207

ESENOWO I.K., UGWUMBA A.A.A., AKPAN A.U. (2017) Evaluating the Physico-chemical Characteristics and Plankton Diversity of Nwaniba River, South-South Nigeria. Asian Journal of Environment & Ecology, 5(3):1-8. https://doi.org/10.9734/AJEE/2017/39038

FOUZIA I., AMIR K. (2013) Comparative Assessment of Physico-chemical conditions and Plankton diversity of River Tons and Asan in Dehradun District of Uttarakhand. Advances in Applied Science Research, 4(2):342-355. ISSN: 0976-8610

GEIST J. (2011) Integrative freshwater ecology and biodiversity conservation. Ecol Indicat., 11(6):1507–1516. https://doi.org/10.1016/j.ecolind.2011.04.002

GOLLASCH S. (2006) Overview on introduced aquatic species in European navigational and adjacent waters. Helgoland Marine Research, 60:84–89. https://doi.org/10.1007/s10152-006-0022-y

HAYS G.C., RICHARDSON A.J., ROBINSON C. (2005) Climate change and marine plankton. TRENDS in Ecology and Evolution, 20(6):337-344. https://doi.org/10.1016/j.tree.2005.03.004

IMOOBE T.O.Y., ADEYINKA, M.L. (2009) Zoo-plankton-based assessment of the trophic state of a tropical forest river in Nigeria. Archives of Biological Sciences, Belgrade, 61 (4):733-740. https://doi.org/10.2298/ABS0904733I

JEJE C.Y., FERNANDO C.H. (1986) A Practical Guide to the Identification of Nigerian Zooplankton (Cladocera, Copepoda, and Rotifera). Published by Kainji Lake Research Institute (KLRI), New Bussa.

KUMAR M., KHARE P.K. (2015) Diversity of plankton and their seasonal variation of density in the Yamuna River at Kalpi, District Jalaun, U. P. India. Journal of Global Biosciences, 4(7):2720-2729. ISSN 2320-1355

MAKAREWICZ J.C., BERTRAM P., LEWIS T.W. (1998) Changes in phytoplankton size-class abundance and species composition coinciding with chemistry and zooplankton community structure of Lake Michigan, 1983 to 1992. Journal of Great Lakes Research, 24(3): 637- 657. ISSN 0380-1330

MEENA K., PRAHLAD D. (2018) A critical review of zooplanktonic studies of Lentic water bodies of India. Int. journal of environmental sciences, 7(3):79-83. ISSN: 2277-1948

OGBEIBU A.E. (2001) Distribution, density and diversity of dipterans in a temporary pond in Okumu forest reserve southern Nigeria. Tropical Ecology, 42(2):259–268. https://doi.org/10.4314/jas.v16i1.20002

PENNAK R.W. (1978) Freshwater invertebrates of united studies. 2nd Edn., John wiley and sopejler,B.(1946)-Regional ecological studies of Swedish fresh water zooplankton Zool. Bidrag. Uppsala, 36:407-515.

DOI: 10.6092/issn.2281-4485/16319

https://doi.org/10.4319/lo.1980. 25.2.0383a

PIMENTEL D., ZUNIGA R., D. MORRISON D. (2005) Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecol. Econ. 52:273–288. https://doi.org/10.1016/j.ecolecon.2004.10.002

PRIYANKA MALHOTRA (2014) Species Diversity and Distribution of Zooplankton of Western Yamuna Canal in Yamunanagar (Haryana) India with Special Reference to Industrial Pollution. International Research Journal of Environment Sciences, 3(8): 61-63. E-ISSN: 2319-1414

SHAHIN M. (2002) Hydrology and water resources of Africa. Springer. pp. 307–309. ISBN 1-4020-0866-X

SHARMA B.K. (2011) Zooplankton diversity of two floodplain lakes (pats) of Manipur, Northeast India. Opuscula Zoologica, 42(2):185-197. http://opuscula-zoologica-42-2-185-197

SHARMA K. N., MANKODI P.C. (2011) Study on plankton diversity of Narmada River, Gujrat. Journal of current sciences, 16 (1):111-116. ISSN: 0972-6101

TACKX M.L.M., PAUW N.D., MIEGHEM R.V., AZEMAR F., HANNOUTI A., DAMME S. V., FIERS F., DARO N., MEIRE P. (2004) Zooplankton in the Schelde Estuary, Belgium and The Netherland. Spatial and temporal patterns. *Journal of Plankton Research,* 26(2): 133-141. https://doi.org/10.1093/plankt/fbh016

WIJEYARATNE W.M.D.N., NANAYAKKARA D.B.M. (2020) Monitoring of Water Quality Variation Trends in a Tropical Urban Wetland System Located within a Ramsar Wetland City: A GIS and Phytoplankton Based Assessment. *Environ. Nanotechnology, Monit. Manage,* 14:100323. https://doi.or/10.1016/j.enmm.2020.100323

XIONG W, LI J, CHEN Y, SHAN B, WANG W, ZHAN A. (2016). Determinants of community structure of zooplankton in heavily polluted river ecosystems. Sci Rep. 6(1):22043–22243. https://doi.or/10.1038/srep22043