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Some aspects of limnology on a stretch of the lower Benue river, Makurdi, Benue state, Nigeria

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Abstract
The study investigated the physicochemical parameters, abundance and diversity of plankton community index of the lower Benue River. The physicochemical parameters encountered in this study include DO, BOD, pH, Alkalinity, Hardness, Phosphorous, Air temperature, Water temperature, Co_2, Chloride, Nitrate, TDS and Transparency. This study shows significant differences in physic-chemical properties of all parameters determined in the three sample sites. It was also observed that physico-chemical parameters affect distribution, occurrence and diversity of the plankton. Eighteen species of five families of phytoplankton were identified ranging from six species of Bacilliarophyceae, five species of Chlorophyceae, three species of Cyanophyceae, two species of Chrysophyceae and two species of Euglenophyceae. Also 14 species of four families of zooplankton were identified during the study period ranging from three species of Copepoda, four species of Monogononta, three species of Branchiopoda and four species of Insecta. It was observed that some sensitive species of plankton were low in abundance at some sampling sites due to gradual disappearance as the water becomes polluted while other tolerant ones survived the pollution stress and relocated to downstream off the point of discharge.
Therefore, the lower Benue River is a rich ecological ecosystem with high plankton diversity that can sustain fishery development.

Keywords: limnology, physicochemical parameters, phytoplankton, zooplankton and lower Benue river

Introduction

Limnology is a branch of hydrology that study the freshwater, especially lakes and ponds (both natural and manmade) including their biological, physical and chemical aspects (Delince, 1992) [9]. It can also be defined as the study of productivity and functional relationships of freshwater communities as they are affected by their physical, chemical and biotic environment. Therefore, limnological information of rivers provides the indices of usefulness of the water resources. The major physical quality determinants of water are temperature and turbidity; dissolved oxygen, hydrogen ion concentration and hardness influence the chemical quality; which contribute to the formation of biological water characteristics. Studying water quality of a river could help to protect and maintain the aquatic ecosystem and other resources the river provides to the society.

Rivers are water ways that provide water resources for domestic, industrial and agricultural purposes. Thus, the importance of rivers to both artisanal and culture fisheries cannot be overemphasized as many fish farmers depend on them for sustained production although the extent to which rivers can play this important role depends largely on the qualities of water that support growth of plants and animals. Therefore, the supply of adequate and good quality water is a limiting factor in successful fisheries production and management (Ngwenya, 2006) [21]. Kumar *et al*. (2011) [18] also reported that water quality generally refers to the parameters of water which are to be present at optimum levels for suitable growth of plants and animals.

Microscopic plants and animals are collectively called plankton. Plankton inhabits oceans, seas, lakes, and ponds. Local abundance varies horizontally, vertically and seasonally. The primary cause of this variability is the availability of light. All plankton ecosystems are driven by the input of solar energy, confining primary productivity to surface waters, and to geographical regions and seasons having abundant light. Phytoplankton are drifted by water current and are not visible to the naked eyes, but can be observed under a microscope. As these plant microscopic organisms multiply, they are eaten directly by some fish or mostly by other microscopic aquatic animals called zooplanktons.

Plankton also serves as food for larger aquatic organisms like insects, worms and molluscs which are in turn eaten by fish.

Phytoplankton are the plantlike organisms that are found in aquatic environments, they are the primary producers which serves as food majorly for zooplankton which in turn serves as an important source of food to crustaceans and fish (Thurman, 1997) [26]. They therefore, serve as a major source of organic carbon in rivers and may represent an important source of oxygen in low-gradient aquatic ecosystem. An assessment of phytoplankton community and abundance will enhance the understanding of biological productivity and fish population dynamics as they are known to serve as the food base that supports aquatic life (Abohweyere 1990) [1]. Although phytoplankton distribution and abundance are largely influenced by the light and nutrient, alteration of their natural environment by man can greatly distort this equilibrium. These may explain why plankters are used as bio-indicators to monitor aquatic pollution.

The species assemblages of the zooplankton are indications of environmental quality and ecological changes as they respond to disturbances such as nutrient load, sediment input, contaminant densities and acidification (Jude *et al*., 2005) [17]. Zooplanktons are not only useful as bio-indicators to help detect pollution load, but they are also helpful in ameliorating polluted waters (Mukhopadhyay *et al*., 2007) [20].

Relative species abundance describes how common or rare a species is relative to other species in a given community and usually described for single trophic level (Lawson and Olusanya, 2010) [19].

Human advancement is always on the increase as population grows, hence the need for regular investigation of the limnological factors especially water quality parameters and plankton composition of the river. It is against this backdrop that this study was carried out.

Materials and Methods

Description of study area

River Benue is a freshwater flowing through Nigeria and the second largest river in the country after River Niger. The river originated from the Adamawa mountains of Cameroun, bounding the Nigeria frontier and flows eastward through the Nigeria territory before joining River Niger at Lokoja, Kogi State, Nigeria (Okayi *et al*., 2001) [23].

Benue State has a tropical climate with two marked seasons; the wet season characterized with heavy rainfall between April and October and dry season (with high temperature) between November and April (Banks *et al*., 1985) [9]. River Benue has features of a matured river with plains stretching for several kilometers. The greater of this plain is flooded during the rainy season and forms breeding ground for many fish species, most especially if its bank is full. The area of River Benue is 129,000ha (Welcomme, 1971) [28], and there can be as much as 25m difference the high and low water levels (Okayi, *et al*., 2001) [23].

Makurdi, the capital of Benue State, North Central Nigeria, is a town that lies between Latitude 7^{o}44'N and Longitude 8^{o}32'E covering an area of 820 km^2 with an estimated population of 348,990 people (National Population Commission of Nigeria, 2011). The main drainage system is River Benue with other smaller tributaries traversing the town. The vegetation type in Makurdi is guinea savannah with annual rainfall between 150 -180m and temperature of 26 ^{o}C - 40 ^{o}C.

Three sampling stations were selected along lower River Benue at Makurdi. The sampling sites were A, B and C. sampling site A is the outlet of Benue Breweries Limited on the bank of River Benue. Site B was downstream of site A (under the new bridge). Here we have irrigation farming whereby, runoff is washed into the river and has the potential to impact on the water. Sampling site C is further downstream at Wadata market, makurdi. Sampling C borders the Wadata market refuse dump site. People are seen carrying their domestic activities like bathing, washing and at times defecating. There is a functional abattoir close to site C and water from the river is used to wash dung, debris and blood from slaughtered animals. In all the three sites, there are enormous human impacts on the river which may favour the growth and survival of zooplankton and phytoplankton and consequently fish abundance which justified the selection of the sites for this study.

Physico-chemical parameter analysis

The physico-chemical parameters determined were: DO, BOD, pH, Alkalinity, Hardness, Phosphorous, Air temperature, Water temperature, Co2, Chloride, Nitrate, TDS and Transparency.

Dissolved oxygen was determined on the field using dissolved oxygen meter model: DO-5509, to determine the BOD, four samples were collected from each sites in BOD bottles. The DO content of the samples was determined immediately and recorded as initial DO. After which the samples were incubated in an incubator at 20 ^{o}C for five days. At the end of the five days, the oxygen content of the incubated samples was determined using the same dissolved oxygen meter model: DO-5509 and recorded as final DO. The BOD content of the test samples is then determined as BOD= initial DO-final DO.

Both air and water temperature was determined on the field using a PHT-027 Multi-parameter water quality checker.

Total Dissolved Solids was determined in situ using a PHT-027 Multi-parameter water quality checker,

The pH of the water samples was determined using a B. Bran scientific pH -meter (ppH-25 model). Total hardness and chloride were determined using a Freshwater aquaculture test kit (MODEL AQ-2), while phosphate was determined according to according to APHA (1985) [7] using spectrophotometer (spectromi 21D) at wavelength of 882 mm.

The degree of transparency of sampling points was obtained using a secchi disc with graduated rope. The transparency of the water body was computed as follows:

$$(d1+d2)/2 \text{ (cm)}$$

Where d1 = depth at which secchi disc disappears, d2 = depth at which secchi disc reappears

Alkalinity was determined by taking 100 ml of the water samples in conical flask to which three drops of methyl orange indicator was added. The solution was titrated against 0.01m sulphuric acid until the colour changed from orange to pale pink. The volume of standard 0.01m sulphuric acid used was noted and recorded as the volume of alkalinity in parts per million (ppm or mg/L).

To determine free CO_2, 100ml of the sample was placed in the conical flask, 8 drops of phenolphthalein indicator was added and titrated against 0.01ml NaOH solution until the solution turned to pale pink. The volume of the NaOH used was recorded as free CO_2 (mg/L) calculated using:

$$\frac{\text{Volume of titrant x N x 44000}}{\text{Sample volume used (ml)}}$$

Where N = Normal NaOH

Nitrate was determined using APHA (1995) [6]. 100ml of the sample was collected in an evaporation dish. It was heated to dryness on a heating mantle. 2ml of phenol-disulphoic acid was added and stirred to mix very well with the sediment. 5-10ml of distilled water was added. 10-15ml of ammonium hydroxide solution was added to form a yellow solution. Then the absorbance was read at 543mm wavelength on a spectrophotometer using 4cm glass curvet. Value is in mg/l.

Sampling and Plankton Analysis:

Sampling was carried out twice a week for five weeks from August 25th to October 2nd, 2020. Sampling was done in the morning before 8.00am. The range of phytoplankton and Zooplankton at these three stations were determined by counting and identifying them using standard identification keys.

Pour through method was used to collect the samples. A 10-liter graduated bucket was used to collect the water at a depth of about 30cm below the water surface, poured into the plankton net and repeated 10 times to make a total of 100 litres of water filtered. The collected plankton were carefully poured into a plankton bottle, fixed with 5% formalin, corked and labeled properly and taken to the laboratory for further analysis. In the laboratory, each preserved plankton sample was poured into a graduated centrifuge tube and centrifuged using a Gallen Kamp-medico Centrifuge. This was to allow the plankton to settle and the supernatant was then decanted. After decanting, the concentrated plankton was then analyzed. A dropping pipette was used to place the concentrated plankton a glass slide, covered with a cover slip and viewed under a light microscope. The plankton was counted (quantitative analysis) and then identified using standard identification keys and chart (Jeje, 1986) [15]. This process was repeated five times.

All data on the physicochemical parameters and biological studies were analyzed using analysis of variance (ANOVA). Correlation among parameters was done to determine relationship between variables (Gomez and Gomez, 1984) [12]. The effect of significance in ANOVA was tested using Fisher protected LSD to distinguish difference between means.

The estimation of species abundance and diversity of plankton among the stations were done using species Shannon Weiner index and Marglef's index.

Results

The physic-chemical parameters recorded at the three stations in the dry season were: DO 5.6-6.7mg/L, BOD 1.1-2.40mg/L, Free CO2 7.6-9.10mg/L, Air temperature 19-220C, Water temperature 26-290C, TDS 44.5-46.5ppm, Transparency 50-52cm, pH 7.6-7.8, Total Alkalinity 6-12mg/L. CaCo3, Hardness 26.20-26.30 mg/L. CaCo3, Chloride 12-12.10mg/L, Nitrate 0.78-0.85mg/L, Phosphate 0.12-0.16mg/L. the mean values are as showed in Table 1.

Table 1: Mean water quality parameters across the three stations of the lower Benue river

Parameters	Station A	Station B	Station C	P value
DO	5.8 ± 0.16	5.9 ± 0.19	5.8 ± 0.14	0.98
BOD	2.14 ± 0.14	1.8 ± 0.13	1.9 ± 0.15	0.87
Free CO_2	8.02 ± 0.19	8.1 ± 0.31	8.2 ± 0.24	0.52
Air Temp.	21.1 ± 0.47	21.2 ± 0.45	22.1 ± 0.46	0.91
Water Temp.	27.3 ± 0.39	27.5 ± 0.46	28 ± 0.43	0.53
TDS	43.63 ± 1.42	45.48 ± 2.36	434.56 ± 1.46	0.70
Transparency	51.51 ± 3.75	50.38 ± 3.54	51.04 ± 3.91	0.98
pH	7.7 ± 0.10	7.7 ± 0.08	7.7 ± 0.10	0.41
Alkalinity	8.7 ± 1.30	9.0 ± 1.12	9.0 ± 1.10	0.79
Hardness	25.23 ± 0.75	25.28 ± 0.76	25.27 ± 0.73	1.00
Chlorine	12.02 ± 0.12	12.03 ± 0.20	12.06 ± 0.18	0.37
Nitrate	0.81 ± 0.01	0.80 ± 0.02	0.81 ± 0.02	0.87
Phosphate	0.15 ± 0.01	0.16 ± 0.01	0.15 ± 0.01	0.97

TDS = Total dissolved solids; DO = Dissolved oxygen; BOD = Biological oxygen demand

Eighteen species of phytoplankton were identified ranging from six species of Bacilliarophyceae, five species of Chlorophyceae, three species of Cyanophyceae, two species of Chrysophyceae and two species of Euglenophyceae. Also 14 species of zooplankton were identified during the study period ranging from three species of Copepoda, four species of Monogononta, three Branchiopoda and four species of Insecta. The phytoplankton are arranged in order of their abundance but the zooplankton are not as showed in Tables 2 and 3 respectively.

Table 2: Percentage species composition and abundance of phytoplankton in the sampling stations of the lower Benue river

Phytoplankton families/species	Station A		Station B		Station C		% By family
	No.	%	No.	%	No.	%	
Bacilliarophyceae							
Cyclotella comta	125	21.70	142	5.88	42	5.14	50.20
Aulaco Seira sp	238	41.32	437	18.10	211	25.83	
Fragillaria sp	51	8.85	605	25.06	136	16.65	
Nitzchia sp	25	4.34	124	5.14	104	12.73	
Coscinodiscus sp	117	20.31	570	23.61	232	28.40	
Navicula sp	20	3.47	536	22.20	92	11.26	
Chlorophyceae							29.61
Mougeotia sp	105	24.25	160	16.23	82	9.92	

Ulothrix tenuissima sp	33	7.62	230	23.33	184	22.25	
Cladophora sp	106	24.48	261	26.47	236	28.54	
Spirogyra sp	57	13.16	129	13.08	85	10.28	
Oedoganium sp	132	30.49	206	20.89	240	29.02	
Cyanophyceae							15.55
Chroococcus sp	141	50.54	269	39.04	57	27.01	
Merismopedia sp	107	38.35	352	51.09	106	50.24	
Oscillatoria sp	31	11.11	68	9.87	48	22.75	
Chrysophyceae							2.08
Asterionella sp	25	48.08	29	37.31	20	51.28	
Synura sp	27	51.92	38	56.72	19	48.72	
Euglenophyceae							2.56
Phacus sp	26	30.59	21	33.33	15	32.61	
Euglena sp	59	69.41	42	66.67	31	67.39	
Total abundance	1425		4219		1940		
Shannon Weinner index	3.80		4.34		4.31		
Margalef index	4.02		4.60		4.42		

Table 3: Percentage species composition and abundance of zooplankton in the sampling stations of the lower Benue river

Zooplankton	Station A		Station B		Station C	
	No.	%	No.	%	No.	%
Copepoda						
Mesocyclops sp	14	35.90	15	24.59	9	25.71
Diaptomus sp	11	28.21	25	40.98	15	42.86
Bryocamptus minutes	14	35.90	21	34.43	11	31.43
Monogononta						
Trichocerca sp	35	22.01	14	18.42	23	27.71
Branchionus falcatus	62	38.99	23	30.26	26	31.33
Branchionus angularis	26	16.35	14	18.42	12	14.46
Polyarthra sp	36	22.64	25	32.89	22	26.51
Branchiopoda						
Chydorus sp	20	31.25	21	30.88	18	32.73
Bosmina sp	15	23.44	16	23.53	13	23.64
Diaphnia puplex	29	45.31	31	45.59	24	43.64
Insecta						
Chironomid sp	24	26.09	34	27.42	21	25.93
Gerris remigis	20	21.74	36	29.02	20	24.69
Gyrinus sp	31	33.70	36	29.02	24	29.63
Corixid sp	17	18.48	18	14.52	16	19.75
Total abundance	349		329		254	
Shannon Weinner index	4.53		4.50		4.54	
Margalef index	4.41		4.20		4.40	

Discussion

This study shows significant differences in physic-chemical properties of all parameters determined in the three sample sites.

The Dissolved oxygen concentrations in the lower Benue River were above the value of 5.0 mg L-1 recommended by FEPA (2003) [10]. The higher values of Dissolved oxygen concentrations in the river may be due to change in season, and rainfall pattern.

Also, the range of values recorded for temperature (Air and Water) in the river falls within the range recommended by the Federal Environmental Protection Agency (FEPA, 2003) [10] in an aquatic environment or ecosystem. Any increase in temperature decreases the DO (Vincy *et al*., 2012) [27].

pH of rivers, dams and other water bodies is a significant parameter which determines distribution of aquatic organisms particularly fish (Altaf *et al*., 2013) [5]. According to WHO, normal range of pH for water is 6.5-8.5 (Zaigham *et al*., 2012) [30]. The range of value recorded for pH in the lower Benue River agrees with the range recommended by the World Health Organization (2008) [29] for the culture of fish but disagrees with the reported work of Altaf *et al*., (2013) [5] who reported lower pH values in their work.

It was observed in the present study, that low total alkalinity was recorded. The findings are in conformity with Sani (2015) [25] who reported low values of total alkalinity in Challawa River and Wassai Dam in Kano State, Nigeria. Low values recorded during this study could be due to low photosynthetic activity. Water with low alkalinity less than 75 mg/L especially surface water and rainfall is subject to changes in pH due to dissolved gasses that may be corrosive to metallic materials.

The fairly high total dissolved solids in the river under study could be attributed to the rising water level of the river because of increased inflow from point and non-point discharges during the rainy season, increase in colloidal suspension from effluent discharged into the river may have increased the total dissolved solids and in turn raised turbidity and reduce transparency of the water. This agrees with the reported work of Ajit and Padmaker (2013) [3].

Water containing hardness concentration up to 60 mg/l are called 'soft' water and those containing 120-180mgL-1 as 'hard' water (WHO 2008) [29]. In this study, the value of Total hardness obtained is lower when compared to that reported by Rafiullah *et al*. (2012) [24] and below the value recommended by FEPA (2003) [10].

It was also observed that physic-chemical parameters affect distribution, occurrence and diversity of the plankton. This agrees with the findings of Okayi *et al*. (2001) [23] and Agouru and Audu (2012) [2] who both worked on river Benue. All the Sites except B showed some signs of pollution because of anthropogenic activities as indicated by the concentration of BOD, Free CO_2 and total alkalinity values of the test water samples. Site B where irrigation farming usually occur, did not show signs of toxicity as one would expect that the runoff water may support plankton growth through eutrophication.

The high number of phytoplankton species recorded in this study could be due to available nutrients and other physical and chemical factors which promote growth of phytoplankton. The family Bacillariophyceae was the most dominant followed by Chlorophyceae, Cyanophyceae, Euglenophyceae and Chrysophyceae. This observation is similar to the findings of Gabriel *et al*. (2013) [11]. The dominance of Bacillariophyceae both in respect to species number and population density in the lower Benue River is in line with the observation of Jaˈafaru (2015) [14]. Commonly, in an aquatic system where there is no heavy nutrient inputs possibly from run-off or human inputs, Bacillariophyceae are usually the predominant, but when nutrient levels is high such that eutrophication occurs, then the Chlorophyceae could become more abundant than Bacillariophyceae (Akin-Oriola, 2003) [4].

Temperature and the availability of food are about the most important factors controlling the abundance of zooplankton in water. Higher temperature regimes during the study period coupled with high level of food in the water as a result of high primary productivity (phytoplankton), can be responsible for the high populations of zooplankton recorded. The zooplankton population dominated by ciliates in the present study was regarded as a booster of all year round food for fish in the river. Similar findings were observed by Gabriel *et al*. (2013) [11]. There are also indications that zooplankton differ in their response to variations in season, water depth and type of bottom sediments of the water body. The abundance of zooplankton varies according to limnological features and trophic state (Jeppensen *et al*., 2002; Imoobe and Adeyinka, 2010) [13, 16]. The population of zooplankton was generally high in the river during the study period. The lower Benue River is highly rich in taxa and dominance of zooplankton. Among the zooplankton, Rotifers of genus Brachionus were most abundant.

It was observed that some sensitive species of plankton were lower in abundance at some sampling sites due to gradual disappearance as the water becomes polluted while other tolerant ones survived the pollution stress and relocated to downstream off the point of discharge. This is in agreement with the work of Ogbeibu and Edutie (2002) [22]. Based on the findings of this study, the Makurdi corridor of the lower Benue River is rich in plankton with high abundance and diversity. The lower Benue River is a rich ecological ecosystem with high plankton diversity that can sustain fishery development. Also, the variation in the abundance and kind of zooplankton found in the different stations is an indication that there may be variations in the kind and levels of stresses in the different courses of the same water bodies and this could exert some impacts on the characteristics of the organisms that are found in this water body.

Despite the impacts of global warming on natural resources, the lower Benue River is still very safe for fish production and domestic use. Nevertheless, the impact of various anthropogenic stressors can be felt over time, and as such care should be taken to minimize their effects. The use of the water body with reckless abandon around the sampling sites will result in the water not being able to support aquatic life, destruction of breeding grounds of plankton and other aquatic lives, erosion of the river bank, as well as disruption of the particular habitat that may affect the entirety of the aquatic ecosystem within the area of study. However, continuous monitoring of water quality and stricter conservation measures are needed to maintain a healthy aquatic environment.

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