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Distribution and Diversity of Phytoplankton in Lower River Benue, Makurdi, Nigeria

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Abstract: The study was designed to determine the distribution and abundance of phytoplankton in River Benue at Makurdi, Benue state. Studies were carried out from September 2014-August 2015 with sample collection from four different sites along the river. Twenty six species of phytoplankton were identified. Chlorophyta species were dominant with 50%, followed by bacciliarophyta (25%), dinophyta (5%), euglenophyta (3%), chrysophyta (1.5%) and rhodophyta (0.5%). High population density and biomass of plankton was observed during the months of dry season. Shannon weiner index ranged between 3.74-3.79 across the sites and the Lower River Benue at Makurdi was classified as highly diversed as values of Shannon weiner index were above 3.5 at all sampled sites. There significant variations observed in water quality and plankton abundance at different sample sites and seasons.

Key words: Abundance, diversity, fresh water plankton, physico-chemical parameters, River Benue, classified

INTRODUCTION

Plankton (singular plankter) is any drifting organisms (animals, plants, archaea or bacteria) that inhabit the pelagic zone of oceans, seas or bodies of fresh water. Plankton is defined by their ecological niche rather than phylogenetic or taxonomic classification. They provide a crucial source of food to larger, more familiar aquatic organisms such as fish and Crustacean (Thurman and Burton, 1997). Plankton typically flows with water currents. While some forms are capable of independent movement and can swim hundreds of meters vertically in a single day (a behaviour called diel vertical migration). Their horizontal position is primarily determined by the surrounding currents. This is in contrast to nekton organisms such as squid fish and marine mammals that can swim against the ambient flow and control their position (Emiliani, 1991). Though many planktonic species are microscopic in size, plankton includes organisms covering a wide range of sizes, including large organisms such as jellyfish.

Plankton are primarily divided into broad functional (or trophic level) groups: Phytoplankton (from Greek phyton or plant), autotrophic, prokaryotic or eukaryotic algae that live near the water surface where there is sufficient light to support photosynthesis. Among the more important groups are the diatoms, cyanobacteria, dinoflagellates and coccolithophores.

Phytoplankton constitutes the basic components of the aquatic food chain. They act as primary producers and represent themselves as a direct food source for other aquatic animals. Phytoplankton comprises photosynthetic prokaryotes which are major contributors of biomass and primary productivity in oligotrophic ecosystems (Partensky *et al*., 1999). These organisms are crucial to life in the aquatic environment because they make up the base of the freshwater food chain.

Phytoplankton and zooplankton are good indicators for changes in nutrient pollution over time because they respond quickly to changes in nutrient input to rivers. The biological analysis of coastal waters, especially the phytoplankton analysis will describe clearly about the pollutant materials impact on the aquatic life and a decrease in biological diversity.

MATERIALS AND METHODS

Description of the study area: River Benue is a freshwater flowing through Nigeria and it is the second largest river in Nigeria and measures approximately 310,000 ha. It is about 1.488 km in length with alluvia fertile flood plains on either banks (Okayi *et al*., 2001). Makurdi the capital city of Benue State is located on Latitude 7041'N and Longitude 80 28'E. The length of the River Benue within Makurdi and major settlement runs through is approximately 671 m (Udo, 1981) (Fig. 1).

Experimental design: Four sampling sites were selected along lower River Benue at Makurdi. The sampling sites were named A-D. Samples were taken at interval of 2 km away up to the wadata market. Sampling site A issurrounded by farmlands at the river bank. Site B is downstream of site A, at the effluent outlet of Benue Breweries Limited (BBL). Sampling site C was selected at

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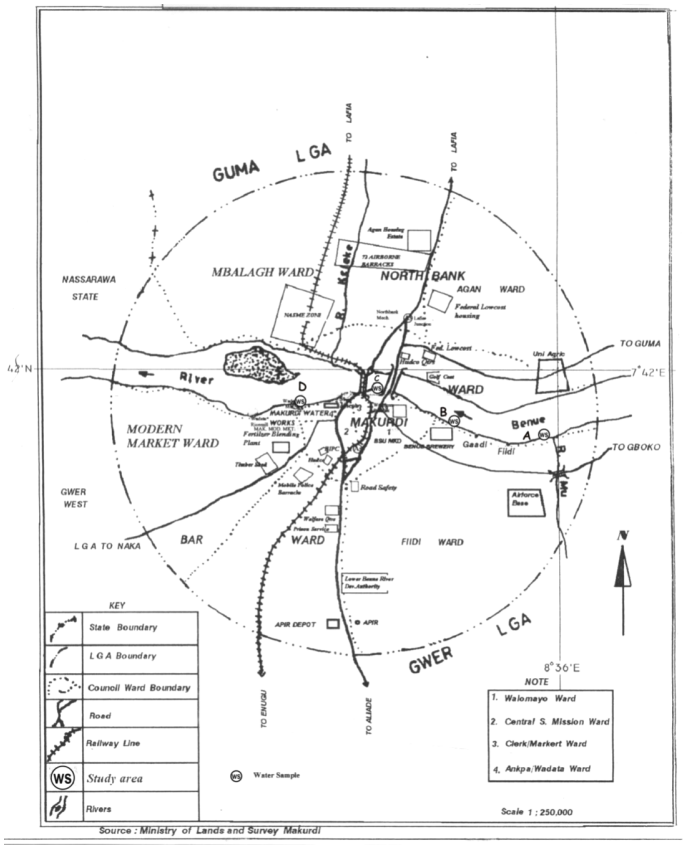

Fig. 1: Map of makurdi showing River Benue and sampling sites

downstream of site B where there is a mix of run-off from farmland, abattoir and domestic wastes. Sampling site D is further downstream where there is heavy refuse disposal from residential area and a multipurpose market. Water samples for various analyses were collected at intervals from September 2014-August 2015 by 7-9 am daily.

Collection of water samples: Water samples were collected from the surface with a Idm^3 water sampler and stored in 1 L screw-capped plastic containers and stored in a refrigerator at 4±1°C prior to analysis. Separate water samples were collected in amber glass bottle (300 mL) with glass stoppers for BOD determination and in 250 mL dissolved oxygen bottles at each station and fixed according to Winkler's method using Manganous Sulphate and Alkaline Potassium iodide reagents for dissolved oxygen determination. The samples were preserved as recommended by APHA (1989) for the different parameters measured. The time lapse between sample collection, preservation and analysis was a week for each set of samples.

Water analyses: Temperature, pH, electrical conductivity and total dissolved solids were measured using multi parameter checker (HANNA 3100 Model) by dipping the probes into the water until the screen showed a fixed reading as described by the manufacturers. Dissolved Oxygen was determined using DO meter (HANNA Model HI 9146) in which the probe was inserted into the water until DO reading in ppm (mg/L) was recorded as described by the manufacturers.

Sampling of phytoplankton: Plankton nets were immersed below water surface and then towed through the water for qualitative plankton sampling. The content of the bottle of the same capacity was brought to the laboratory for further study, 4% of formalin was used for preservation of zooplankton and phytoplankton.

Enumeration of phytoplankton: Quantitative estimations were made using the new improved Naeubaour counting chamber. Before a qualitative enumeration of different organisms in each group was carried out each zooplankton and phytoplankton sample was concentrated

to a 250 mL volume of water using pipette. After shaking the bottle thoroughly, 10 mL was put to petri-disc and the 1 mL was quickly drawn with a wide-bore dropper. The sample was then introduced carefully into the counting chamber with a cover slip and observed under light micro scope.

The count of 3 drops was averaged and the number of each zooplankton and phytoplankton in the entire collection was calculated per liter of water using the following formula; Number of organisms per liter = organism in 1 mL of concentrate/volume of water filtered ×volume of concentrate. Identification of phytoplankton species was carried out based on the keys provided by Palmer (1980).

Community structure analysis

Species richness index (D): The species richness index (d) according to Margalef (1951) was used to evaluate the community structure.

$$d = 1/N$$

Where:

d = Species richness index
S = Number of species in a population
N = Total number of individuals in S species

Shannon and wiener diversity index (H_s): Shannon and Wiener diversity index (H_s) (Shannon and Weiner, 1949) which Ogbeibu (2005) presented as: The Shannon and Wiener diversity index (H_s):

$$H_s = \frac{N\log N - \sum p_i \log p_i}{N}$$

Where:

H_s = Shannon and Wiener diversity Index
I = Counts denoting the ith species ranging from 1-n
p_i = Proportion that the ith species represents in terms of numbers of individuals with respect to the total number of individuals in the sampling space as whole
N = Total abundance

Species equitability: Species equitability or evenness index (j) (Lloyd and Ghelardi, 1964) as presented by Ogbeibu (2005). The species equitability/evenness index (j)

$$j = \frac{H_s}{\text{Log}_2 S}$$

Where:

J = Equitability index
H_s = Shannon and Weiner index
S = Number of species in a population

Data analysis: Mean and standard error values were obtained for each of the physical-chemical parameters. Data collected for the environmental parameters were subjected to one way analysis of variance (ANOVA). The linear correlation analysis was carried out on the water parameters and plankton to verify if there is any significant relationship.

RESULTS AND DISCUSSION

Monthly distribution and abundance of phytoplankton species: Table 1, reveals the monthly distribution and abundance of phytoplankton during the study period. The months of March-May recorded the highest abundance of phytoplankton while August-October reveals the least mean values of abundance. *Oedogonium* sp. recorded the highest mean value of abundance among all the sampled species during the period of study. Most of the identified species differ significantly ($p<0.05$) in their mean values of abundance between the months.

Table 2, shows the distribution and abundance of phytoplankton species at various sample sites. The result from the table shows that none of the sample sites recorded all the species of phytoplankton identified. *Oedogonium* sp. and *Cladophora* sp. recorded the highest mean abundant values of 6±0.55 and 6±0.57 at site B. Eighteen species from the 26 identified species did not differ significantly ($p>0.05$) between sample sites in their mean values of abundance.

Phytoplankton species composition: The phytoplankton of lower River Benue was dominated by Chlorophyta, followed by Bacilliarophyta Cyanophyta Dinophyta, Euglenophyta, Chrysophyta, and Rhodophyta, this result is similar with the findings by Aguoru and Audu (2012) and Akoma (2008) (Table 3-6 and Fig. 2 and 3).

Chlorophyta have been reported by many researchers to be dominant in phytoplankton composition as it is in the present study (Akoma, 2008, Adeyemi *et al*., 2009, Aguoru and Audu, 2012) and the overwhelming pressure of bright sunshine, isothermal water column and extensive catchment area draining calcium rich agricultural land (Silva, 2007). The maximum number of phytoplankton species was recorded at site C (New bridge), this may be due to available nutrients and favourable water quality which promote growth of phytoplankton. While the minimum number of phytoplankton species was recorded at site B (Benue Brewery) which might be due to brewery effluents and other discharges that empty into the river, this agrees with the work of Fikrat *et al.* who studied effect of physical and chemical properties of river water in shatt Al-Hilla on phytoplankton communities.

Table 1: Monthly distribution and abundance of phytoplankton in River Benue at Makurdi

	Months											
Class/Species	September	October	November	December	January	February	March	April	May	June	July	August
Chlorophyta												
Oedogonium sp.	2±0.63^{a}	2±0.85^{a}	4±1.22^{ab}	5±1.26^{ab}	5±0.50^{ab}	5±1.83^{ab}	6±1.19^{ab}	6±1.76^{ab}	7±1.19^{ab}	4±1.31^{ab}	4±0.48^{ab}	2±0.25^{a}
Cladophora sp.	3±0.48^{a}	1±0.48^{b}	4±1.60^{a}	4±1.55^{a}	4±0.63^{a}	3±0.91^{a}	5±1.65^{a}	4±1.31^{a}	4±1.70^{a}	3±1.60^{a}	3±1.11^{a}	2±0.75^{a}
Ulothrix sp.	3±1.29^{a}	1±0.48^{a}	4±1.19^{a}	3±1.64^{a}	2±1.31^{a}	2±1.03^{a}	4±1.65^{a}	2±0.85^{a}	4±1.65^{a}	4±1.76^{a}	4±1.38^{a}	1±0.71^{a}
Spyrogyra sp.	2±1.11^{a}	1±0.29^{a}	2±1.08^{a}	2±1.18^{a}	3±1.38^{a}	2±0.91^{a}	4±1.19^{a}	3±1.60^{a}	3±1.31^{a}	2±1.03^{a}	2±1.19^{a}	1±0.48^{a}
Mongeotia sp.	1±0.41^{a}	1±0.25^{a}	2±0.25^{ab}	1±0.48^{a}	1±0.48^{a}	1±0.41^{a}	2±0.25^{ab}	1±0.48^{a}	2±0.85^{ab}	1±0.00^{a}	3±1.25^{b}	1±0.50^{a}
Zygnema….	1±0.48^{a}	0.00^{a}	0.00^{a}	1±0.71^{a}	1±0.41^{a}	0.00^{a}	1±0.41^{a}	1±0.41^{a}	1±0.41^{a}	1±0.50^{a}	1±0.75^{a}	0.00^{a}
Volvox sp.	0.00^{a}	1±0.25^{b}	0.00^{a}	1±0.25^{ab}	1±0.48^{ab}	0.00^{a}	1±0.25^{ab}	1±0.29^{ab}	1±0.25^{ab}	0.00^{a}	1±0.25^{ab}	1±0.25^{ab}
Gonatozygon sp.	0.00^{a}	1±0.29^{a}	1±0.29^{a}	1±0.25^{ab}	1±0.29^{ab}	1±0.41^{ab}	1±0.29^{a}	2±0.85^{b}	1±0.48^{ab}	1±0.41^{ab}	1±0.25^{ab}	1±0.41^{ab}
Cosmarium sp.	0.00^{a}	0.00^{a}	1±0.50^{a}	1±0.29^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}
Pediasrum sp.	0.00^{a}	0.00^{a}	0.00^{a}	1±0.29^{ab}	1±0.25^{ab}	1±0.29^{ab}	0.00^{a}	1±0.41^{ab}	2±0.85^{b}	1±0.29^{ab}	0.00^{a}	0.00^{a}
Baccilliarophyta												
Coscinodiscus sp.	2±0.29^{ab}	2±0.41^{ab}	3±0.50^{b}	3±0.65^{b}	3±0.48^{b}	3±0.50^{b}	2±0.41^{ab}	3±0.50^{b}	3±0.63^{b}	2±0.41^{ab}	1±0.48^{a}	2±0.48^{ab}
Aulacoseira sp.	1±0.41^{a}	1±0.41^{a}	3±0.29^{b}	2±0.48^{ab}	3±0.65^{b}	3±0.50^{b}	3±0.71^{b}	2±0.65^{ab}	1±0.58^{a}	1±0.41^{a}	1±0.48^{a}	1±0.25^{a}
Flagillaria sp.	2±0.50^{ab}	1±0.25^{a}	3±0.65^{bc}	2±0.91^{ab}	3±0.48^{bc}	1±0.63^{a}	4±0.65^{c}	2±0.82^{ab}	1±0.25^{a}	1±0.41^{a}	2±0.85^{ab}	1±0.48^{a}
Nitachia sp.	1±0.29^{ab}	1±0.49^{ab}	2±0.49^{b}	1±0.25^{ab}	2±0.63^{b}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	1±0.41^{ab}	1±0.25^{ab}	1±0.29^{ab}
Navicula sp.	1±0.41^{a}	1±0.29^{a}	1±0.48^{a}	1±0.48^{a}	0.00^{a}	1±0.95^{a}	1±0.40^{a}	0.00^{a}	0.00^{a}	1±0.25^{a}	1±0.29^{a}	1±0.29^{a}
Diatoma sp.	1±0.48^{ab}	0.00^{a}	0.00^{a}	1±0.29^{ab}	1±0.58^{ab}	1±0.41^{ab}	1±0.50^{ab}	2±0.41^{b}	1±0.50^{ab}	1±0.25^{ab}	0.00^{a}	0.00^{a}
Melosira sp.	0.00^{a}	0.00^{a}	0.00^{a}	1±0.29^{a}	0.00^{a}	0.00^{a}	0.00^{a}	1±0.29^{a}	1±0.41^{a}	1±0.29^{a}	0.00^{a}	1±0.48^{a}
Cyanophyta												
Merismopedia sp.	2±0.58^{ab}	2±0.41^{ab}	3±0.75^{b}	3±1.08^{b}	4±0.85^{c}	4±1.32^{c}	2±0.75^{ab}	3±1.15^{b}	2±0.63^{ab}	3±0.65^{b}	3±0.75^{b}	1±0.71^{a}
Chroococcus sp.	1±0.48^{a}	1±0.41^{a}	2±0.65^{a}	2±0.63^{a}	2±0.85^{a}	1±0.48^{a}	2±0.85^{a}	2±0.85^{a}	1±0.25^{a}	1±0.48^{a}	1±0.71^{a}	2±0.65^{a}
Oscillatoria sp.	1±0.29^{a}	1±0.41^{a}	1±0.48^{a}	1±0.48^{a}	1±0.50^{a}	0.00^{a}	1±0.48^{a}	0.00^{a}	1±0.48^{a}	1±0.25^{a}	1±0.50^{a}	1±0.25^{a}
Anaboena sp.	0.00^{a}	1±0.29^{a}	0.00^{a}	1±0.29^{a}	1±0.29^{a}	1±0.50^{a}	0.00^{a}	0.00^{a}	1±0.29^{a}	0.00^{a}	0.00^{a}	0.00^{a}
Euglenophyta												
Euglena sp.	0.00^{a}	1±0.29^{ab}	1±0.29^{ab}	1±0.48^{ab}	2±0.29^{b}	1±0.29^{ab}	1±0.25^{ab}	1±0.29^{ab}	1±0.41^{ab}	1±0.29^{ab}	0.00^{a}	1±0.29^{ab}
Phacus sp.	0.00^{a}	0.00^{a}	1±0.41^{a}	1±0.41^{a}	1±0.29^{a}	1±0.25^{a}	1±0.29^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	1±0.29^{a}
Chrysophyta												
Synura sp.	0.00^{a}	0.00^{a}	1±0.41^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	1±0.75^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}
Rhodophyta												
Batrachospe Rmum sp.	0.00^{a}	1±0.29^{a}	1±0.29^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	1±0.50^{a}	0.00^{a}	0.00^{a}	0.00^{a}
Dinophyta												
Dinophysis sp.	1±0.48^{ab}	1±0.25^{ab}	3±0.50^{c}	0.00^{a}	3±0.29^{c}	3±0.65^{c}	0.00^{a}	2±0.62^{bc}	3±0.29^{c}	2±0.63^{bc}	0.00^{a}	1±0.48^{ab}

*Mean on the same row with different superscripts differ significantly, ($p<0.05$); $^{a-c}$Significant values

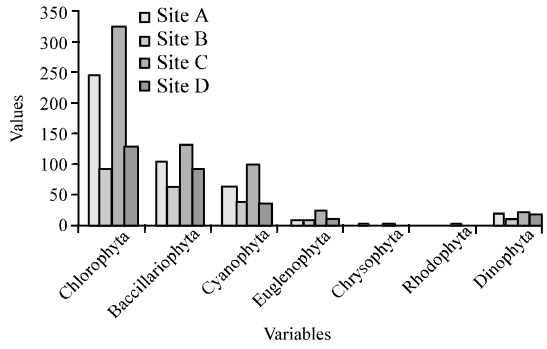

Fig. 2: Distribution and abundance of phytoplankton groups at sampled sites in River Benue at Makurdi

Turbidity correlated negatively with phytoplankton abundance in this study which indicates that higher turbidity level reduces phytoplankton production. The observation in River Benue is similar with the findings of Karlman (1982) that the abundance of phytoplankton increases with low turbidity which is normally associated

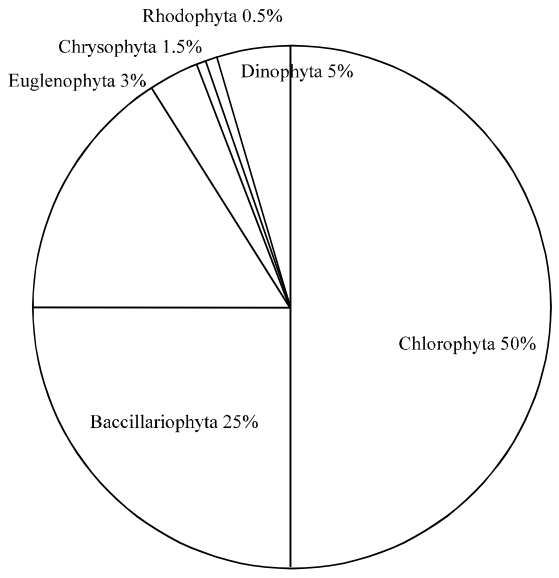

Fig. 3: Distribution of phytoplankton groups in River Benue at Makurdi

Table 2: Location abundance of phytoplankton in River Benue at Makurdi

Class/Specie	Site A	Site B	Site C	Site D
Chlorophyta				
Oedogonium sp.	5±0.92^{b}	3±0.38^{a}	6±0.55^{b}	3±0.34^{a}
Cladophora sp.	4±0.67^{b}	1±0.18^{a}	6±0.57c	2±0.42^{a}
Ulothrix sp.	3±0.82^{b}	0.00^{a}	5±0.58c	2±0.36^{b}
Spyrogyra sp.	3±0.79^{b}	0.00^{a}	4±0.46b	1±0.18^{a}
Mongeotia sp.	1±0.48^{a}	2±0.31^{a}	2±0.22^{a}	1±0.21^{a}
Zygnema….	1±0.26^{ab}	0±0.00^{a}	2±0.22b	0.00^{a}
Volvox sp.	1±0.19^{a}	1±0.19^{a}	1±0.11^{a}	1±0.15^{a}
Gonatozygon sp.	1±0.36^{a}	0.00^{a}	1±0.17^{a}	1±0.15^{a}
Cosmarium sp.	0.00a	0.00^{a}	0.00^{a}	0.00^{a}
Pediasrum sp.	1±0.36^{a}	0.00^{a}	1±0.19^{a}	0.00^{a}
Baccilliarophyta				
Coscinodiscus sp.	3±0.34^{b}	1±0.23^{a}	3±0.22^{b}	2±0.18^{ab}
Aulacoseira sp.	1±0.37^{a}	1±0.21^{a}	2±0.30^{a}	2±0.35^{a}
Flagillaria sp.	2±0.52^{a}	1±0.23^{a}	2±0.32^{a}	2±0.30^{a}
Nitachia sp.	1±0.38^{a}	1±0.15^{a}	1±0.27^{a}	1±0.19^{a}
Navicula sp.	1±0.35^{a}	1±0.15^{a}	1±0.21^{a}	0.00^{a}
Diatoma sp.	1±0.30^{a}	1±0.23^{a}	1±0.21^{a}	0.00^{a}
Melosira sp.	0.00^{a}	0.00^{a}	1±0.19^{a}	0.00^{a}
Cyanophyta				
Merismopedia sp.	3±0.58^{bc}	1±0.23^{a}	4±0.28c	2±0.15^{ab}
Chroococcus sp.	2±0.44^{a}	1±0.22^{a}	2±0.22^{a}	1±0.26^{a}
Oscillatoria sp.	1±0.19^{a}	0.00^{a}	1±0.25^{a}	1±0.19^{a}
Anaboena sp.	0.00^{a}	0.00^{a}	1±0.17^{a}	0.00^{a}
Euglenophyta				
Euglena sp.	0.00^{a}	1±0.15^{a}	1±0.19^{a}	1±0.15^{a}
Phacus sp.	0.00^{a}	0.00^{a}	1±0.22^{a}	1±0.15^{a}
Chrysophyta				
Synura sp.	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}
Rhodophyta				
Batrachospermum sp.	0.00^{a}	0.00^{a}	1±0.19^{a}	0.00^{a}
Dinophyta				
Dinophysis sp.	2±0.48^{a}	1±0.28^{a}	2±0.37^{a}	2±0.31^{a}

*Mean on the same row with different superscripts differ significantly ($p<0.05$); $^{a-c}$Significant values

with dry season while the higher turbidity associated with the rainy season results in a decrease in its abundance. The result of this study further revealed the effect of turbidity on phytoplankton abundance at the study sites. Site B (Benue Brewery) and D (Wadata Market) with highest mean turbidity values recorded low phytoplankton abundance while site C (New bridge) and A (Airforce base) with low turbidity values recorded highest phytoplankton abundance. During the rainy months, flushing disturbs the standing crop of plankton. However, when the destabilizing effects wean away, the nutrient inputs favours an accelerated plankton growth in the dry season. Temperature correlated positively with phytoplankton as increase in temperature increases phytoplankton growth. The temperature recorded during the period of study corresponds with that of Grass *et al.* who reported on the liminological investigation of the River Nile, this also agrees with the result of an earlier study in River Benue that reported surface water temperature mean value of 28.20±0.060 C (Eneji *et al*., 2012).

The population of pytoplankton in water undergoes variation both in structure and function related to the physico-chemical changes in their environment (Palmer, 1980). The growth and reproduction of phytoplankton are affected by the hydrogen ion concentration of the surrounding water. The pH values of this study were positively correlated with the phytoplankton.

Table 3: Monthly water quality parameters of River Benue at Makurdi

Months	Temp.°C	pH (mg/L)	DO (mg/L)	BOD (mg/L)	Alkalinity (mg/L)	Conductivity (mg/L)	TDS (mg/L)	Turbidity (mg/L)	Air Temp.°C
September	27.81±0.70^{c}	6.41±0.08^{e}	5.61±0.08^{b}	1.61±0.14^{ab}	9.28±0.20^{d}	36.25±1.98^{c}	19.88±2.10^{b}	70.10±5.54^{b}	24.29±0.44^{f}
October	27.74±0.18^{c}	6.54±0.14^{de}	5.43±0.16^{b}	2.00±0.21^{a}	9.45±0.23^{d}	45.38±3.25^{bc}	23.13±1.16^{bcd}	67.76±4.28^{b}	26.94±0.17^{d}
November	27.35±0.24^{c}	7.86±0.04^{a}	6.09±0.19^{a}	1.80±0.29^{ab}	10.08±0.23^{c}	50.63±4.76^{b}	25.38±2.66^{bcd}	47.99±3.84^{c}	25.30±0.17^{e}
December	27.66±0.21^{c}	7.94±0.02^{a}	6.43±0.10^{a}	1.74±0.20^{ab}	11.25±0.12^{b}	49.12±4.68^{b}	24.38±2.40^{bcd}	25.14±0.88^{d}	27.09±0.26^{d}
January	29.79±0.21^{a}	7.74±0.14^{ab}	6.31±0.12^{a}	1.75±0.29^{ab}	12.10±0.15^{a}	45.75±1.83^{bc}	22.75±0.85^{bcd}	21.59±2.59^{d}	29.09±0.21^{a}
February	29.86±0.27^{a}	7.89±0.08^{a}	6.43±0.19^{a}	1.50±0.06^{ab}	12.40±0.19^{a}	45.50±3.20^{bc}	22.63±1.57^{bcd}	19.71±2.94^{d}	27.53±0.09^{cd}
March	29.78±0.11^{a}	7.10±0.09	6.08±0.23^{ab}	1.63±0.14^{ab}	11.49±0.22^{b}	45.75±5.10^{bc}	22.75±2.90^{bcd}	17.63±2.64^{d}	28.35±0.13^{b}
April	28.75±0.24b	7.40±0.07^{c}	6.21±0.14^{a}	1.48±0.07^{b}	12.08±0.08^{a}	40.38±2.38^{c}	20.13±1.25^{bc}	19.94±0.50^{d}	28.76±0.06^{b}
May	28.44±0.27^{b}	7.74±0.03^{ab}	6.20±0.11^{a}	1.51±0.05^{ab}	12.53±0.21^{a}	44.50±3.06^{bc}	23.13±1.51^{bcd}	25.49±1.22^{d}	27.73±0.17^{bc}
June	28.40±0.22^{bc}	7.54±0.06^{bc}	6.23±0.11^{a}	1.75±0.06^{ab}	11.64±0.06^{b}	46.13±2.80^{bc}	26.38±3.24^{bcd}	46.55±5.19^{c}	27.93±0.08^{bc}
July	28.13±0.06^{bc}	7.58±0.11^{bc}	5.81±0.10^{b}	1.74±0.19^{ab}	10.88±0.13^{c}	52.50±2.70^{b}	28.63±1.45^{bc}	60.18±4.76^{b}	27.80±0.08^{bc}
August	27.09±0.30^{c}	6.79±0.18^{d}	4.83±0.28^{c}	1.91±0.18^{ab}	8.11±0.36^{e}	76.88±6.48^{a}	37.69±2.81^{a}	84.25±1.96^{a}	26.76±0.12^{d}

*mean in the same column with different superscripts differ significantly ($p<0.05$); pH: hydrogen ion. DO: Dissolved Oxygen. BOD: Biochemical Oxygen Demand. TDS: Total Dissolved Solids. Temp°C: Temperaturel; $^{a-c}$significant values

Table 4: Water quality parameters of River Benue at Makurdi

Site	Temp.°C	pH (mg/L)	DO (mg/L)	BOD mg/L (mg/L)	Alkalinity (mg/L)	Conductivity	TDS (mg/L)	Turbidity(mg/L)	AirTemp.°C
SITE A	28.79±0.34^{a}	7.40±0.16^{a}	6.14±0.11^{b}	1.40±0.05^{b}	10.78±0.49^{a}	39.50±2.09^{b}	21.04±1.52^{b}	34.53±6.37^{a}	27.37±0.46^{a}
Site B	28.24±0.28^{a}	7.35±0.18^{a}	5.88±0.16^{a}	1.86±0.09^{a}	10.97±0.43^{a}	49.83±3.05^{a}	25.17±1.52^{ab}	45.25±7.03^{b}	27.15±0.41^{a}
Site C	28.07±0.35^{a}	7.40±0.18^{a}	6.10±0.18^{b}	1.59±0.06^{b}	11.00±0.37^{a}	54.13±3.80^{c}	27.52±1.89^{a}	41.26±6.53^{a}	27.28±0.42^{a}
Site D	28.50±0.26^{a}	7.36±0.13^{a}	5.77±0.16^{a}	1.95±0.10^{a}	11.01±0.37^{a}	49.46±3.19^{a}	25.21±1.51^{ab}	47.73±7.65^{b}	27.39±0.34^{a}

*Mean in the same column with different superscripts differ significantly ($p<0.05$); pH: Hydrogen ion. DO: Dissolved Oxygen. BOD: Biochemical Oxygen Demand. TDS: Total Dissolved Solids. Temp°C: Temperature; *Significant values

Table 5: Correlations between phytoplankton abundance and water quality parameters in River Benue at Makurdi

Phytoplankton	Temp.°C	pH (mg/L)	DO (mg/L)	BOD (mg/L)	Alkalinity (mg/L)	Conductivity (mg/L)	TDS (mg/L)	Turbidity (mg/L)	Air Temp. °C
Oedogonium sp.	0.258	0.460*	0.598*	-0.427*	0.490*	-0.283	-0.277	-0.588*	0.343*
Cladophora sp.	0.132	0.329*	0.489*	-0.442*	0.253	-0.146	-0.114	-0.427*	0.111
Ulothrix sp.	0.064	0.196	0.297*	-0.324*	0.186	-0.037	0.064	-0.221	-0.006
Spyrogyra sp.	0.307*	0.170	0.422*	-0.391*	0.309*	-0.174	-0.201	-0.413*	0.149
Mongeotia sp.	0.009	0.141	0.122	-0.160	0.117	-0.039	0.087	-0.112	-0.021
Zygnema....	0.111	0.118	0.292*	-0.278	0.264	-0.016	0.109	-0.286*	0.152
Volvox sp.	-0.096	0.091	0.091	0.136	-0.094	0.147	0.047	0.090	0.201
Gonatozygon sp.	0.053	0.196	0.241	-0.180	0.157	-0.005	0.007	-0.191	0.298*
Cosmarium sp.	-0.136	0.297*	0.359*	0.109	0.189	0.092	0.120	-0.194	-0.040
Pediasrum sp.	0.268	0.300*	0.397*	-0.213	0.479*	-0.225	-0.212	-0.426*	0.340*
Coscinodiscus sp.	0.070	0.336*	0.298*	-0.191	0.142	-0.060	-0.101	-0.283	0.211
Aulacoseira sp.	0.255	0.238	0.344*	0.119	0.230	0.070	0.012	-0.375*	0.158
Flagillaria sp.	0.168	0.152	0.216	-0.094	0.147	-0.052	-0.086	-0.292*	0.151
Nitachia sp.	-0.128	0.238	0.074	-0.053	-0.032	0.049	0.062	0.006	0.004
Navicula sp.	-0.120	0.112	0.263	-0.257	-0.072	-0.039	-0.055	-0.104	-0.173
Diatoma sp.	0.272	0.144	0.472*	-0.337*	0.351*	-0.234	-0.261	-0.415*	0.213
Melosira sp.	-0.177	0.182	0.083	-0.212	0.039	0.201	0.163	0.005	0.154
Merismopedia sp.	0.154	0.231	0.484*	-0.419*	0.342*	-0.143	-0.136	-0.416*	0.154
Chroococcus sp.	0.108	0.133	0.170	-0.355*	0.057	0.048	-0.049	-0.228	0.114
Oscillatoria sp.	-0.321	0.055	0.043	0.106	-0.054	0.216	0.255	0.090	-0.132
Anaboena sp.	-0.034	0.201	0.295*	-0.086	0.216	0.029	0.084	-0.156	0.044
Euglena sp.	0.161	0.198	0.108	-0.194	0.282	0.103	0.085	-0.246	0.275
Phacus sp.	-0.037	0.304*	0.194	-0.008	0.162	0.362*	-0.200	0.259	-0.037
Synura sp.	-0.121	0.199	0.234	-0.234	0.128	-0.104	-0.162	-0.248	0.066
Batracho spermum sp.	-0.134	0.076	0.141	-0.101	0.077	-0.018	-0.070	-0.027	-0.096
Dinophysis sp.	0.076	0.276	0.253	-0.081	0.306*	-0.069	-0.054	-0.214	0.131

*There is significant relationship between water quality parameter and phytoplankton abundance ($p<0.05$); pH: Hydrogen ion. DO: Dissolved Oxygen. BOD: Biochemical Oxygen Demand. TDS: Total Dissolved Solids. Temp.°C: Temperature

Table 6: Relative species diversity, distribution and abundance of phytoplankton in the River Benue at Makurdi

	Site A		Site B		Site C		Site D	
Class/Species	No.	Percentage	No	Percentage	No.	Percentage	No.	Percentage
Chlorophyta								
Oedogonium sp.	63	13.86	32	14.72	70	11.2	33	11.22
Cladophora sp.	53	11.66	15	6.9	66	10.6	23	7.82
Ulothrix sp.	48	10.56	5	2.3	65	10.4	25	8.5
Spyrogyra sp.	36	7.92	4	1.84	50	8	15	5.1
Mongeotia sp.	15	3.3	18	8.28	21	3.36	10	3.4
Zygnema....	7	1.54	3	1.38	20	3.2	3	1.02
Volvox sp.	6	1.32	6	2.76	10	1.6	7	2.38
Gonatozygon sp.	13	2.86	5	2.3	12	1.92	6	2.04
Cosmarium sp.	1	0.22	0	0	4	0.64	4	1.36
Pediasrum sp.	7	1.54	5	2.3	7	1.12	2	0.68
Baccilliarophyta								
Coscinodiscus sp.	30	6.6	17	7.82	32	5.12	26	8.84
Aulacoseira sp.	14	3.08	14	6.44	26	4.16	27	9.18
Flagillaria sp.	24	5.28	11	5.06	26	4.16	27	9.18
Nitachia sp.	11	2.42	6	2.76	14	2.24	8	2.72
Navicula sp.	12	2.64	6	2.76	14	2.24	3	1.02
Diatoma sp.	9	1.98	6	2.76	14	2.24	1	0.34
Melosira sp.	3	0.66	3	1.38	7	1.12	5	1.7
Cyanophyta								
Merismopedia sp.	40	8.8	17	7.82	48	7.68	18	6.12
Chroococcus sp.	22	4.84	15	6.9	27	4.32	6	2.04
Oscillatoria sp.	6	1.32	4	1.84	15	2.4	11	3.74
Anaboena sp.	0	0	2	0.92	10	1.6	3	1.02
Euglenophyta								
Euglena sp.	4	0.88	7	3.22	13	2.08	6	2.04
Phacus sp.	3	0.66	2	0.92	9	1.44	6	2.04
Chrysophyta								
Synura sp.	5	1.1	1	0.46	5	0.8	2	0.68
Rhodophyta								
Batrachospermum sp.	0	0	1	0.46	6	0.96	1	0.34
Dinophyta								
Dinophysis sp.	19	4.18	12	5.52	21	3.36	19	6.46
Total abundance	451	100	217	100	612	100	298	100
Margalef index	4.37		4.39		4.42		4.37	
Shannon Weinner index	4.27		4.29		4.33		4.26	
Pielou index (Evenness	2.06		2.02		2.11		2.07	

The dissolved oxygen values of this study were positively correlated with phytoplankton. The result has also shown that high phytoplankton density correspond with high dissolved oxygen content, this is also in agreement with the findings of Jana. In general, the plankton biomass in River Benue was not very high probably due to low amount of nutrients indicated by low values of alkalinity, conductivity and TDS in all the sampling sites during this study period.

Diversity of phytoplankton species: The phytoplankton species of the river were highly diverse as indicated by the values of Shannon-Wiener diversity index across the sites. The value of the index during the study ranges from 4.26 at site C (wadata market) to 4.33 at site C (new bridge). These values fall within the range stated by MCDonald (2003) that the values above 3.5 have high diversity and species richness. This result shows that all the sampled sites have high species diversity and evenness as indicated by the values obtained. The present study is implicating that liminological processes affecting the net phytoplankton species diversity operated almost equally at all the study sites.

CONCLUSION

The study revealed the values of different physico chemical conditions from four sites of River Benue. The values obtained fall within the recommended limits of WHO. (2004) and Anonymous (2007) for drinking water. However, the results from the study revealed that, site B (Benue breweries) and site D (Wadata market) were more affected by enormous human activities having the highest turbidity levels, lowest dissolved oxygen, highest BOD levels which resulted to low plankton abundance. The abundance of plankton was related to water quality, the physico-chemical condition of site C (new bridge) was more favourable to support aquatic life and therefore recorded the highest plankton abundance. The plankton abundance was in accordance with the water quality of every sampled site.

The result from the diversity indices showed that the Lower River Benue is highly diverse and species rich. It has great potentials for fisheries production owning to its abundant zooplankton and phytoplankton assemblage and content. Although, the river was polluted at some points especially Benue breweries and Wadata market sites. The human activities have not been sternly impacted on the river. It is believed that continuous pollution of the water sources by activities may lead to its inability to support life as time goes.

RECOMMENDATIONS

Based on the study, it is therefore, recommended that the authorities of Benue breweries should work more on pre-treating the effluents or waste water before discharging into the River Benue to keep the quality favourable for fisheries production. Anaerobic treatment is a widely applied method for treatment of brewery effluents. It would be good for the biological treatment of brewery waste water.

A law should be strongly enforced to curtail in discriminate dumping of refuge in the river at the Wadata market as well as providing sanitary facilities around the area.

The government should provide waste treatment techniques within the Makurdi metropolis to reduce unwanted materials into the water through run off.

The various authorities controlling the water body should monitor the human activities in and around River Benue, since, it is a major source of pollution.

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