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Assessment of Zooplankton and Physico-chemical Parameters of Upper River Benue, Adamawa State, Nigeria

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ABSTRACT: *Between January and June, 2022 some physico-chemical and biological conditions of Upper River Benue were assessed at five selected sites on monthly basis between 6:00 – 10:00a.m. A total of 9.849 ×10^4 organisms/L was recorded for zooplankton abundance. Rotifera was observed to have a total abundance of 39.9%, followed by Cladocera contributed a total of 33.45%, while the least was Decapoda gave 1.37%. The higher number of taxa (25) was recorded at site V. The abundance of individuals was highest at site IV. Twenty-seven species (27) species of zooplankton were identified during the study period ranging from elven Rotifera, nine Cladocera, five Copepoda, one Ostracoda and one Decapoda. The order of dominance of the zooplankton of Upper River Benue is Rotifera>Cladocera>Copepoda>Ostracoda>Decapoda with Brachionus caudate, Bosmina longirostis and daphnia being the most dominant (6.94%) of the total zooplankton of Upper River Benue. The physico-chemical parameters results revealed that temperature, pH, electrical conductivity, transparency, dissolved oxygen, free $CO_{2,}$ alkalinity were within recommended acceptable limit except ammonia, phosphorus and nitrogen were higher than recommended acceptable limit. However, no significant difference was found between the seasons in terms physico-chemical paraneters and zooplankton distribution (P>0.05). The study showed the reservoir to be eutrophic with moderate water quality, high ecological and pass chemical status, with diverse assemblages of zooplankton. It was recommended that there should be continuous monitoring of the biological and physico-chemical status of the river to ascertain the long-term impact of anthropogenic inputs to take remedial measures so as to ensure the health of aquatic life.*

KEYWORDS: Physicochemical parameters, zooplankton and Upper River Benue

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INTRODUCTION

The fundamental principle behind biological indicator theory is that organisms provide information about their habitats. A biological indicator (or bio-indicator) is a taxon/taxa selection based on its sensitivity to a particular attribute and then assessed to make inferences about that attribute. In other words, they are a surrogate for directly measuring abiotic features or other biota. Bioindicators are evaluated through presence/absence, ecosystem level, as opposed to being limited to an individual species or population (Kovacs *et al*. 1992, Echoke *et al*., 2018).

Zooplankton includes all major groups of animal members of the drifting planktons found in freshwater. They form the microscopic animals (Redmond, 2008) that play an important role in an aquatic food chain as they are largely consumed by fishes and other higher organisms in food chain. Zooplankton has been recommended as regional bioindicators of lake eutrophication, acidification (Echoke *et al*., 2018) watershed disturbances by agriculture (Dodson *et al*., 2005, 2007) or logging and wildfire (Patoine *et al*., 2002). Zooplankton density has also been reported to vary depending on the availability of nutrients and the stability of the water (Redmond, 2008).
Several studies have shown that physical and chemical condition of aquatic ecosystems determine the occurrence, diversity and density of both flora and fauna in any given habitat, which may change with season of the year (Aoyagui and Bonecker, 2004; Ayodele and Adeniyi, 2006). In view of the foregoing, this study was conducted in Upper River Benue in order to assess some of its physico-chemical parameters as they affect the dynamics of its zooplanktonic organisms presently lacking or scanty and hence serving as a means of providing a baseline data in the field of plankton dynamics in the River.

MATERIALS AND METHODS

Study Area

Adamawa State is located at the North Eastern part of Nigeria. It lies between latitude 7° and 11° N of the equator and between longitude 11° and 14° E of the Greenwich meridian. It has an altitude of 185.9 and covers a land area of about 38,741km. It shares boundary with Taraba State in the south and west, Gombe state in its northwest and Borno state to the north. Adamawa state has an international boundary with Cameroon Republic along its Eastern border. The Benue which is the major river in the state rises from the highlands of Cameroon and flows south- ward to join the River Niger at Lokoja (Figure 1). Two seasonal periods are being experienced in the state: the wet and the dry seasons. The months of May to October constitute the wet season. During this period no place receives less than 60mm of rain. The months of November to April constitute the dry season. It experiences harmattan between the months of November to February. March and April are the hottest months (42.78°), while November and December are the coldest months (11.11°) Adebayo and Tukur (1999), (UBRDA, 1985).

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Upper River Benue is the main source of water for irrigation, fishing, domestic and industrial purposes in the state. The main sources of water apart from rainfall are surface and ground water. The river is well dissected by network of rivers. The river is approximately 1,400 km long and it is almost navigable during the summer months (Adebayo and Tukur (1999). This study was conducted in the Upper River Benue. Upper Benue River in this study was divided into five Sites (I, II, III, IV and V). Site I is Boronji, at this site, human activities such as fishing, irrigation , washing, sand collection and other domestic activities are taking place regularly. Site II is Opposite Customs Office, at this site, agricultural activities, domestic, industrial, fishing and other activities are taking place., Site III is Near the Bridge, at this site, agricultural activities, fishing, dumping of refuse and other activities are taking place., Site IV Close to Inlet to Lake Geriyo, at this site, agricultural activities, fishing and other activities are taking place and Site V is One hundred fifty meters away from site IV, at this site, agricultural activities, fishing and other activities are taking place. The study was conducted at the Upper River Benue and the study sites were include sites (I, II, III, IV and V) water samples and zooplankton was collected from the above mentioned sites.

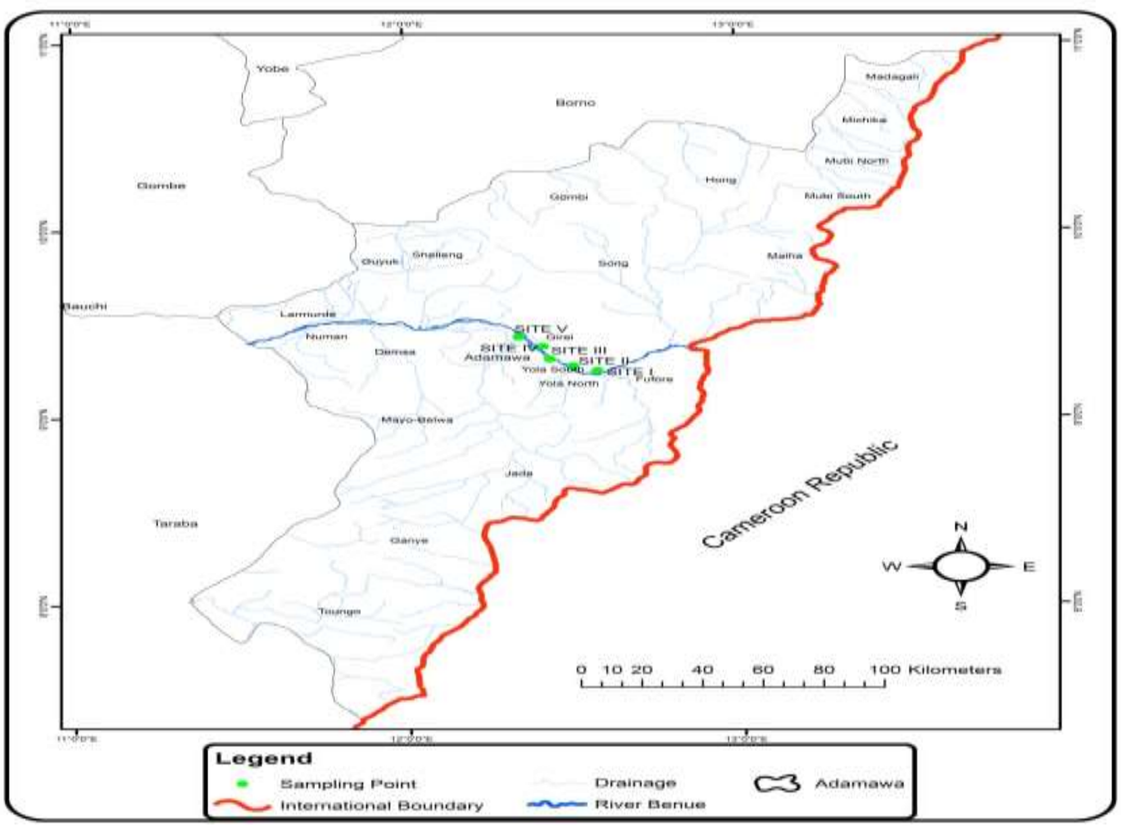

Fig 1: Map of Adamawa State Showing Study Area and Sampling Sites

Duration of Sampling

The study was conducted for the period of six months (i.e from January-June, 2022). Water and Zooplankton samples were collected monthly for six months.

Zooplankton Samples Collection

Zooplankton samples were collected from five sites (sites I, II, III, IV and V) by towing a 55µm mesh Hydrobios plankton net tied to a boat driven at low speed just below water surface for 5 minutes at the sampling stations. The samples were immediately fixed in 4% formalin and transported to the laboratory in labeled 250 ml bottles with screw caps where it was allowed to settle after which decantation method was used to reduce to 10ml. In the laboratory, 0.1 ml was pipetted carefully into 50 x 9 mm petri dishes and carefully positioned over the chamber for viewing, specimens were sorted and examined under a binocular dissecting microscope (American Optical Corporation, Model 570) during which counting and identifications was using taxonomic keys by Prescott (1982), Kadiri (1988), Kemdirim (2001) and Offem *et al.* (2011).

Density was expressed as the number of individuals per sample volume (ind/l). The zooplankton Community composition was done by calculating the species diversity index (H) (Ogbeibu, 2004). Density of organisms was estimated from the count records of the final concentrate volume in relation to the original volume of water sediment.

Cells/ml= N × 1000 ml × V

Where N=number of cells/unit counted, V= Volume of concentrate viewed.

Water Samples Collection and Preservation

Water samples for physicochemical studies were collected from five sites (I, II, III, IV and V) below the water surface. Water samples were taken in triplicates at each sampling sites using sample bottles. Sample bottle of 200ml was dipped below the water surface. The bottle was filled to the brim and covered immediately to avoid air bubbles inside. Water samples were preserved using chemical reagents before being transported to the laboratory for processing. Water samples were collected in labelled and fixed sampling bottles. Temperature, transparency, electrical conductivity, hydrogen ion concentration (pH), dissolved oxygen were determined *insitu* while other parameters, alkalinity, free carbondioxide, ammonia, phosphorus and nitrogen were determined in the laboratory as described by APHA (1995).

Data Analysis

Physicochemica parameters data were subjected to ANOVA while Biological indices such as Margalef's index (d); Shannon-Weiner Index (H) and Evenness (E) were used in the calculation of taxa richness, diversity and evenness. Margalef's Index (D) is a measure of species richness and is expressed as;

D = <u>S-1</u> ………… (1)

N

Where;
S is the number of species in sample
N is the number of individuals in the sample

Shannon Weiner's Index (H'): is a species abundance and evenness and is expressed as;

$$H' = \frac{N \ln N - (ni \ln ni)}{N} \quad \ldots\ldots\ldots\ldots (2)$$

Where;
N is the total number of individuals in the sample,
ni is the total number of individual species in the samples,
ln is natural logarithm.
Species Equitability or Evenness (E) were determined by the equation

$$E = \frac{H'}{\text{In } S} \quad \ldots\ldots\ldots\ldots (3)$$

W here;
H is the Shannon and wiener's index
S is the number of species in sample.
Shannon and wiener (1949); Margalef (1967).

RESULTS

Physicochemical Parameters of Waters from Upper River Benue

The mean variation of physicochemical Parameters of water measured from different Sites of Upper River Benue is presented in table 1. The lowest Temperature value of 26.11°C was observed in Site II while highest Temperature value of 31.50°C was observed in Site IV. Monthly mean Temperature value ranged from 26.54°C to 30.34°C which were recorded in January and April respectively (Table 2). There was a significant variation between Sites and Months ($P<0.05$). The lowest pH value of 7.59 was obtained in Site I while highest pH value of 8.49 was obtained in Site V. Monthly mean pH variation ranged from 7.43 to 8.52 which were recorded in January and May (Table 2). There was no significant variation between Sites and months ($P>0.05$). The lowest Conductivity value of 94.91µS/cm was recorded in Site IV while the highest Conductivity value of 194.08µS/cm was recorded in Site II. Monthly mean variation of Conductivity value ranged from 98.97µS/cm to 171.87µS/cm which was recorded in the months of June and April (Table 2). There was a significant variation between Sites and months ($P<0.05$).

The lowest Transparency level of 18.71cm was recorded in Site I while the highest Transparency value of 31.43cm was recorded in site III. The Monthly mean variation of transparency value ranged between 19.93 to 25.78cm which were recorded in the Months of May and March (Table 2). There was a significant difference between Sites and Months ($P<0.05$). The lowest Dissolved Oxygen value of 5.23mg/l was observed in Site IV while highest Dissolved Oxygen value of 8.90mg/l was observed in Site V. The Monthly mean variation ranged from 5.58g/l to 8.53mg/l which were obtained in the months of May and January, (Table 2). There was no significant in variability between Sites ($P>0.05$). But there was a significant variability between sites and months ($P<0.05$). The lowest Total Ammonia value of 0.11mg/l was observed in site II while the highest Total ammonia value of 0.20mg/l was observed in site III. The monthly mean variation in Total Ammonia ranged from 0.09mg/l to 0.28mg/l which were seen in the months of January and April (Table 2). Ammonia differed significantly between Sites and Months ($P<0.050$).

The lowest Phosphorus value of 1.92mg/l was recorded in Site I while the highest Phosphorus value of 3.01mg/l was recorded in Sites V. The monthly mean variation of Phosphorus ranged from 1.71mg/l to 3.06mg/l which were obtained in the months of June and April (Table 2). Phosphorus did not differed significantly between Sites ($P<0.05$). But there was a significant variability between months ($P<0.05$). The lowest Nitrogen value of 2.75mg/l was recorded in Site I while Site II recorded the highest Nitrogen value of 4.11mg/l. The monthly mean variation in Nitrogen ranged from 2.65mg/l to 4.73mg/l which were seen in the months of January and April respectively, (Table 2). Nitrogen differed significantly between Sites and Months ($P<0.05$). The lowest Total Alkalinity value of 96.67mg/l was recorded in Site V while the highest value of 104.24mg/l was recorded in Site III. The monthly mean variation of Total Alkalinity ranged from 89.64mg/l to 117.13mg/l which was recorded in January and May, (Table 2). There was significant difference in variability between Sites and Months ($P>0.05$). The lowest Free CO_2 value recorded was 0.57/mg/l in site IV while the highest free CO_2 value recorded was 0.84/mg/l in site II. The monthly variation of free CO_2 ranged from 0.51 to 0.95mg/l which was recorded in the months of January and May respectively, (Table 2). There was significance difference between Sites and months ($P<0.05$).

ZooPlankton Composition, Abundance and Their Range in Upper River Benue

Overall, 5 groups of zooplankton were seen in the Upper River Benue (table 3). The Observed zooplankton groups in this study were Rotifera, Copepoda, Cladocera, Ostracoda and Decapoda. A total of 21, 23, 24, 23, and 25 species were recorded in Sites I, II, III, IV and V respectively with abundance values of 9.849×10^4 cells/m3. Twenty seven species (27) species of zooplankton were identified during the study period ranging from elven Rotifera, nine Cladocera, five Copepoda, one Ostracoda and one Decapoda. The Zooplankton species are arranged in order of their abundance as summarised in tables 3. The Table also presents the relative abundance and distribution of various plankton species identified at river. The high relative abundance of Zooplankton species were observed in site Site-IV, Site-III, Site-V, with relative abundance of 2068 (21.00%), 2038 (20.69%) and 2026 (20.57%) respectively while its least relative abundance were in Site-II, Site-I with relative abundance of 2000 (20.31%), 1717 (17.43%) respectively.

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Diversity Indices of Zooplankton in Upper River Benue

A summary of the diversity and dominance indices calculated for the three sites is shown in Table 4. Taxa richness calculated as Margalef index (d) was least in site V (3.0202) followed by sites IV and II which accounted for (3.0303) and (3.0377) respectively while the site I and III accounted for the highest diversity (3.0959) and (3.3189) respectively. The pattern for Shannon diversity index (H), site I was least (1.0365) followed by site V and II which accounted for (1.0388) and (1.0447) while site IV and III accounted for the highest diversity (1.0456) and (1.0686) respectively. Equitability was least in site I (0.1807) followed by site II (0.2121) while site V and III recorded the highest diversity (0.2181) and (0.2211) respectively. The five sites had more or less equal dominance and diversity levels with insignificantly different indices values.

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Table 1 Mean Variation of Physicochemical Parameters of Water from different Sites of Upper River Benue (Jan.-June, 2022)

SITES	Temperature ºC	pH	Conductivity µs/cm	Transparency cm	Dissolved oxygen $_2$ mg/l	Ammonia mg/l	Phosphorus mg/l	Nitrogen mg/l	alkalinity mg/l	free CO_2 mg/l
ST-I	27.19±0.57	7.59±0.38	137.10±9.59	18.71±2.59	7.32±0.21	0.18±0.03	1.92±0.23	2.75±0.41	99.74±6.09	0.66±0.03
ST-II	26.11±0.56	8.33±0.40	194.08±10.52	29.22±3.50	7.55±0.23	0.11±0.01	2.21±0.11	4.11±0.32	113.21±6.59	0.84±0.07
ST-III	28.19±0.59	8.41±0.44	113.25±11.33	31.43±4.45	6.61±0.25	0.20±0.05	2.43±0.31	3.91±0.33	104.24±4.57	0.71±0.05
ST-IV	31.50±0.55	7.40±0.39	94.91±14.21	25.82±2.91	5.23±0.21	0.14±0.02	2.93±0.12	3.80±0.23	99.09±4.53	0.57±0.03
ST-V	29.10±0.59	8.49±0.43	154.40±13.69	19.25±3.30	8.90±0.29	0.15±0.03	3.01±0.29	3.95±0.41	96.67±5.51	0.64±0.06
mean	28.42	8,04	138.75	24.88	7.12	0.16	2.50	3.70	102.59	0.68

Table 2 Monthly Variation of Physicochemical Parameters of Waters from Upper River Benue (Jan.-June, 2022)

Months	Temperature ºC	pH	Conductivity µs/cm	Transparency cm	Dissolved oxygen $_2$ mg/l	Ammonia mg/l	Phosphorus mg/l	Nitrogen mg/l	alkalinity mg/l	Free CO_2
Jan	26.54±0.59	7.43±0.27	107.480±9.42	22.98±2.00	8.53±0.25	0.09±0.03	1.77±0.37	2.65±0.32	89.64±4.71	0.51±0.02
Feb	27.55±0.59	7.71±0.17	131.67±9.96	24.87±1.75	7.66±0.25	0.10±0.03	2.62±0.37	3.73±0.41	93.29±5.02	0.61±0.02
Mar	29.70±0.59	8.50±0.22	166.78±8.77	25.78±2.00	7.48±0.25	0.18±0.03	2.96±0.32	3.54±0.39	99.16±4.36	0.72±0.02
Apr	30.34±0.59	8.42±0.35	171.87±9.93	33.79±2.00	6.53±0.25	0.28±0.03	3.06±0.37	4.73±0.42	107.11±5.21	0.69±0.02
May	28.77±0.59	8.52±0.37	155.77±9.82	19.93±2.00	5.58±0.25	0.19±0.03	2.93±0.37	4.25±0.43	117.13±4.81	0.95±0.02

Jun	27.60±0.59	7.70±0.27	98.97±9.96	21.98±2.00	6.98±0.25	0.11±0.03	1.71±0.37	3.31±0.40	109.23±5.01	0.60±0.02
mean	28.42	8.04	138.75	24.88	7.12	0.16	2.50	3.70	102.59	0.68

Table 3: Zooplankton Composition, Abundance and Distribution at the Different sites in Upper River Benue (Jan.-June, 2022)

S/no	Taxa/Species Identified	ST-I	ST-II	ST-III	ST-IV	ST-V	Total	Percentage	
1	**Rotifera**								
	Brachionus caudata	138	119	129	155	142	683	6.94	
	Brachionus pticotilis	-	54	17	41	27	139	1.41	
	Testidunella patina	43	69	59	62	47	280	2.84	
	Rotararia sp.	-	-	59	-	78	137	1.39	
	Keratella cochlearis	111	109	99	145	135	599	6.08	
	Asplanchia Sp	157	129	131	147	118	682	6.92	
	Asphlanchna brightwelli	-	53	-	-	-	53	0.54	
	Rotifer vulgaris	77	100	99	74	88	438	4.45	
	Philodina	85	108	77	137	116	523	5.31	
	Notholca Sp	14	43	58	35	51	201	2.04	
	Trichocera Sp	28	34	43	56	39	200	2.03	**(39.95%)**
2	**Cladocera**								
	Bosmina longirostis	141	133	152	148	109	683	6.94	
	Macrocyclop Sp	23	66	33	39	43	204	2..07	
	Alona	34	-	-	23	-	57	0.58	
	Daphnia *daphnia*	129	132	153	160	109	683	6.94	
	Chydonis Sp	43	19	64	-	56	182	1.85	
	Ceriodaphnia dubia	98	131	110	103	126	568	5.77	
	Bosmina Bosmina	-	-	-	35	45	80	0.81	
	Simocephalus Sp	99	106	127	118	107	557	5.66	

	Moina	-	79	56	78	67	280	2.84	**(33.45%)**
3	**Copepoda**								
	Diaptomus nigerianus	128	107	137	145	105	622	6.32	
	Monocalamus macruru	-	-	33	-	51	84	0.85	
	Mesocyclops edax	122	108	115	97	104	546	5.54	
	Dicyclops	111	137	121	113	98	580	5.89	
	Nauplius Sp	93	97	88	79	102	459	4.66	**(23.26%)**
4	**Ostracoda**								
	Cypridopsis Sp	28	27	43	59	37	194	2.01	**(2.01%)**
5	**Decapoda**								
	Penenus Sp	15	40	35	19	26	135	1.37	**(1.37%)**
	Total	1717	2000	2038	2068	2026	9849		
	Percentage	17.43%	20.31%	20.69%	21.00%	20.57%			100

Table 4. Diversity indices of Zooplankton of Upper River Benue (Jan.-June, 2022)

SITES	**Site I**	**Site II**	**Site III**	**Site IV**	**Site V**	**Total**
Total number of species	21	23	24	23	25	
Total number of Individuals	1717	2000	2038	2068	2026	9849 cells/L
Margalef's Index (d)	3.0959	3.0377	3.1358	3.0303	3.0202	15.3592
Shannon-Wiener Index(H′)	1.0365	1.0447	1.0686	1.0456	1.0388	5.2342
Equitability Index (E)	0.1807	0.2121	0.2211	0.2195	0.2181	1.0515

DISCUSSION

Physico-chemical parameters of Upper River Benue

The mean Temperature in study fluctuated between 26.11±0.56-31.50±0.55^{0}C which were observed at different Sites were within the acceptable limit recommended by FEPA (2003) and higher than FEPA (1991) emission standard of 30°C. As water temperature increases, the rate of chemical reactions generally increases together with the evaporation and volatilization of substance. The metabolic rate of aquatic organisms is also related to temperature and in warm water respiration rate increases leading to increase in oxygen consumption and increase in decomposition of organic matter (Chapman and Kimtack, 1996). The lowest and highest temperature recorded in the months of January and April respectively could be attributed to the effect of harmattan (Ezra, 2000). In addition, the relatively higher temperatures recorded during the warmer months could be due to increased solar radiation during the period (Ezra, 2000).

Similarly, the mean pH recorded at all the sites were within the acceptable limit of 6.5 – 8.5 recommended for inland and drinking water quality (Antoine and Al-Sa'adi, 1982; WHO, 2004) which could also be attributed to unusual effluent discharges into the river system from the surrounding houses and industries. Moreover, despite the effluent discharges in addition to agricultural run offs (with varying pH conditions) into the river, the relatively stable pH recorded during this research seems to corroborate with the report Ibrahim (2003) that rivers can self-purify themselves of pollution.

The means of electrical conductivity from the river ranged 94.91±14.21 to 194.08±10.52µScm-1 at site I- V respectively. This indicated the highest conductivity at site II can directly be associated with the inflow of industrial effluent, and the conductivity at site II being higher than all sites this could probably be attributed activities associated with the site or as a result of local variations. There was a significant variability between Sites and months ($P<0.05$). The significance difference in Conductivity as observed in this study could be linked to sewage material and leaching of inorganic material as suggested by Chapman and Kimstach (1996). USEPA (1991) reported that discharge can change the conductivity of river because of their makeup.

Moreover, the transparency appeared to be extremely low, which might be largely responsible for the very low zooplankton densities recorded during the study period as Dejen *et al.* (2004) had earlier reported that silt held in suspension in turbid water interferes with filter feeding mechanisms of crustaceans and this affects their reproduction success. Similarly, Hart (1986) reported that transparency values above 0.30 - 0.35M appeared to be necessary for the development of sufficient and suitable zooplankton to benefit fishery and none of the transparency values recorded during this study was up to the above minimum of 0.30M.

The values of DO at all sites was not a bio-limiting factor in the river as their means were all above the minimum of 5.00mg/L required for the survival of aquatic organisms and drinking water quality (FEPA, 1991) and (Campbell and Wilberger, 2001). However, the values of DO at all sites could be one of the reasons why high zooplankton recovery at all sites. The high mean DO values recorded in the dry season could partly be due to effect of harmattan wind that facilitates mixing of the surface water with atmospheric oxygen in the river.

Ammonia ranged between 0.11±0.01-0.20±0.05mg/l between Sites and 0.09±0.03-0.28±0.03mg/l between months. These were higher than 0.03 mg/l recommended by Alabaster and Lloyd (1982). Highest Ammonia was observed in Site III. The highest Ammonia recorded in Site III could be attributed to agricultural runoff, industries, waste and sewage discharged in the water body from the metropolis. This is similar to the study carried out by Ja'afaru (2002) who reported that highest Ammonia value in water could be attributed to waste and sewage discharged from the metropolis in the water body as observed in Site III. Ammonia in water is released as an end product of decomposition of organic matter and also as excretory product of some aquatic animal (Saxena, 1990). Ammonia is an important nutrient of phytoplankton (Philips, 1985). The high total ammonia observed during the period of the study might be due to decomposition of organic materials in river. The highest ammonia value was recorded in the month of April. The highest value in April could be as a result of high concentration of dissolved salts and other elements in water body due to reduced volume of water and also inorganic fertilizers which are used during the dry season farming could add to the level of Ammonia in water.

The monthly mean values of phosphorus recorded during the period of research are at variance with 0.04 to 0.05mg/l observed by Kolo and Yisa (2000) in river Suka. The high value observed mighty be as results of reduced volume of water and agrochemicals used around the river. The mean Nitrate value recorded in all the Sites were above the recommended level for aquatic life. Johnson and Covic, (1998) stated that Nitrate level greater than 1mg/l is not good for aquatic life and the Federal Protection Act (2003) recommended level less than 1mg/l. WHO (1984) recommended nitrate level of 1.0mg/l. The highest value was obtained could be due to decomposition of organic effluent and waste released into the water body. Uguwamba *et al*. (2011) reported that the level of nitrate in water could be attributed to decomposition of organic effluent and waste water released in the water body. The mean value of nitrogen recorded during the period of the study is higher than 0.44 to 1.21mg/l, reported by Abubakar (2006) in lake Geriyo. The higher nitrogen observed could be due to surface run-off, agricultural activities as well as the decomposition of organic matter. Ufodike *et al*. (2001) made similar observations for Dokowa Mine Lake. Ibrahim *et al.,* (2009) stated that high nitrogen concentration in rivers, streams and lake is related to inputs from agricultural lands.

Alkalinity is the measure of buffering capacity of water which is the ability of water to withstand changes to pH. Alkalinity values in this study suggest that the river has the ability to withstand drastic pH change. Alkalinity in the Sites ranged from 96.67±5.51-113.21±6.59 mg/l while the monthly values ranged between 89.64±4.71-117.13±4.81mg/l. The highest alkalinity value reported in the month of April. The higher values of alkalinity observed in May could be as a result of evaporation and high concentration ions in the water. Hart and Zabbey (2005); Davies *et al*. (2009) reported higher concentration of total alkalinity during the dry season for Woji Creeks in Niger Delta.

The values of free CO_2 obtained were within the safety limit of 10mg/l observed by Haruna (1992). The higher zooplankton recorded the river could be as result of low CO_2 recorded. The decline may be attributed to the utilization of CO_2 by the planktons for primary production (Ufodike and Garba, 1992). Low concentration of CO_2 could be as result of the presence of aquatic plant which release oxygen to the water during photosynthesis.

Zooplankton composition, distribution and abundance of Upper River Benue

The distribution and diversity of zooplankton in aquatic ecosystems depends mainly on the physico-chemical properties of water. Pollution of water bodies by different sources will result in drastic changes in zooplankton potential of the ecosystem. Zooplankters are known to accumulate chemicals by direct absorption from water and through food intake (Raut and Shembekkar, 2015). The variability in the number of zooplankton species observed in this study may be attributed to changes in environmental parameters and the seasons of sampling.

The order of dominance of the zooplankton assemblages of river are commonly constituted by Rotifera, Copepoda, Cladocera, Ostracoda and Decapoda. Aminu and Saidu, (2001) observed these groups in Lake Chad. It was also observed that Rotifera was observed to have a total abundance of 39.9%, followed by Cladocera contributed a total of 33.45%, while the least was Decapoda gave 1.37%. Lamai and Kolo, (2003) studied the zooplankton of Dan-Zaria dam and also observed about 40 taxa dominated by the Rotifers (35.38%), Protozoa (27.03%) Cladocerans (25.54%) and the Copepoda (12.05%). *Rotifera* constituted the major group in river. Similar high dominance of rotiferas was reported by Adeyemi, (2012) in Ajelo stream, Imoobe, (2011) in Okhuo River and Omowaye *et al.* (2011) in Ojofu Lake. The five faunistic groups recorded in this study are characteristics of tropical river systems and is also similar to that of Edward and Ugwumba, 2010 in their study of Egbe reservoir. The dominance of rotifer may be due to predation pressure from planktivorous fishes that selectively prey on larger sized zooplankton and then on their reproductive success as well as short developmental rates under favourable conditions in most freshwater systems (Akin-Oriola, 2003; Imoobe and Adeyinka, 2009). Varying number of zooplankton species and populations were reported by different authors in different water bodies in Nigeria.

The number of zooplankton taxa recorded in the sites could be ordered as V>III>II>IV>I, while the abundance pattern in these sites could be summarized as IV>III>V>II>I. The zooplanktons community composition, structure, density and diversity and horizontal distribution have been greatly affected by the presence of the less homogenous environment within the river, which reduces the number of colonizing taxa. The dominance of the Rotifers in terms of taxa representation is attributable to the freshness of the river in the study area. This conforms to Okorafor *et al*. (2012) in the Shore of Great Kwa River, Calabar, Nigeria.

Species diversity and richness indices of zooplankton of Upper River Benue

The low Shannon-Weiner diversity value (5.2342) and a relatively high Margalef diversity level (15.3592) recorded were due to the fact that the former incorporates evenness of distribution while the later only measures species richness. Thus, the low Shannon-Weiner diversity value was as a result of the much higher relative abundance of the Rotefera taxa than other zooplankton taxa. The comparable number of zooplankton taxa as well as insignificantly different zooplankton abundance and diversity levels of sites indicates uniform distribution of zooplankton in the study area. The low species diversity may be attributed to fluctuation in some physicochemical parameters. These factors could probably cause disruption of life cycle, reproductive cycle, food chain and migration or imposed physiological stress on even the tolerant zooplankton (Adakole and Annune, 2003).

CONCLUSION

The study revealed that zooplankton composition, abundance and diversity were influenced by changes in water quality as shown by changes in species composition, assemblages and abundance at the various sites. Results of the studies showed that the value of physicochemical parameters obtained were not all within the recommended ranges some are higher than the recommended safety limits. The overall results showed that changes in water quality of the river have significant effects on the structure of zooplankton assemblages. This feature could be used for bio-monitoring of the river's health to ensure the protection of the aquatic biota.

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