The zooplankton and environmental characteristics of Yardantsi Reservoir, Gusau, Nigeria

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Abstract

Zooplankton play an important role in the faunal biodiversity of aquatic ecosystems as they assist in transferring algal energy to higher trophic levels through grazing and also eliminate harmful algae from water. The zooplankton and environmental characteristics of Yardantsi Reservoir were studied in order to provide essential information on this important ecosystem that serves as domestic and irrigation water supply, and fishing ground. Samples for water quality and zooplankton analyses were collected from the reservoir from May, 2015 to April, 2017 using standard methods. Three groups of zooplankton (Copepoda, Cladocera and Rotifera) comprising of thirteen genera were encountered. Rotifera (36.69%) and Cladocera (34.44%) were numerically dominant during the rainy and dry seasons, respectively. The highest zooplankton abundance (5646), species richness (11), Shannon-Weiner index (2.25) and Margalef's index (1.16) were observed during the rainy season. Axes 1 and 2 of the principal component analysis (PCA) explained 74.82% and 11.89% of the zooplankton-environmental variable relationship. *Diaphanosoma* sp, *Eubranchipus* sp, *Kellicottia* sp and *Macrothrix* sp were mostly influenced by NO_3, BOD, depth, pH and dissolved oxygen while *Cyclops* sp and *Daphnia* were mostly influenced by changes in alkalinity, hardness and chloride. *Brachionus patulus,* the dominant species in the reservoir was mostly influenced by PO_4-P. The study shows that the reservoir is slightly polluted and it is essential to adopt effective management strategies such as reduced agricultural run-offs and riparian animal grazing to prevent further deterioration of water quality.

Keywords: Zooplankton abundance, pollution, Yardantsi Reservoir.

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Introduction

Zooplankton encompasses an array of macro and microscopic animals and they comprise representatives of almost every group in the animal kingdom particularly the invertebrates. They occur in the pelagic environment either as adults (holoplankton) or eggs and larvae (meroplankton) and they play a vital role in the aquatic food chain. The herbivorous zooplankton feed on phytoplankton and in turn constitute important food to animals in higher trophic levels including fishes (Magami 2011). The pelagic fishes such as sardines, mackerels and silver bellies consume mostly plankton (Magami 2011). These fishes mostly breed in areas where the planktonic organisms are abundant to enable the juveniles to get sufficient food for survival and growth (Goswami 2004).

The biota inhabiting aquatic ecosystems are a function of the nature of the physical and chemical characteristics of these ecosystems, thus providing a direct, holistic and integrated measure of the integrity of the ecosystems (Linstead *et al* 2012). Therefore, the ultimate monitor of the aquatic ecosystem is the aquatic life itself (Brabets and Ourso 2013).

Zooplankton are identified as important components of an aquatic ecosystems. They help to regulate algal and microbial productivity through grazing and also play essential role in the transfer of primary productivity to fish and other aquatic consumers (Okogwu 2010). By grazing on phytoplankton and bacteria they contribute in improving water quality; therefore, zooplankton are considered indicators of water quality (Okogwu 2010).

Zooplankton have close relationship with their surrounding environment throughout their life cycles and demonstrate rapid changes in population when the environment is polluted. They are therefore potential indicator species for water pollution (Azma and Anis 2016). Recent studies have shown that the diversity and abundance of zooplankton are sensitive to changes in environmental variables such as dissolved oxygen, electrical connectivity, flood pulses, lake morphometry and pH (Okogwu *et al* 2010). Zooplankton and other aquatic organisms require a healthy aquatic environment for maximum productivity and this is achievable when

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the physico-chemical parameters are at the optimum level (Jabbi 2018).

Two basic approaches are used for the assessment of water quality. The first involves evaluation of the physical and chemical variables of aquatic ecosystem to provide an insight on the water quality (Thangaradjou *et al* 2012). The second approach is biological assessment, which provides a direct measure of ecological integrity by the use of response of biota to changes in the environmental conditions (Joshi *et al* 2013). The quality of any given water body is therefore governed by its physical, chemical and biological factors, all of which interact with one another and greatly influence its productivity (Ajana *et al* 2006; Anagoa *et al* 2013; Ugwumba and Esenowo 2020). Bhuyan *et al* (2003) stated that over the years, activities to preserve the water quality and ecosystem of man-made reservoirs have been encouraged. Biological monitoring has now become an important branch of applied ecology where the scientific and economic interests of the society meet in the management of aquatic ecosystems (Salmaso *et al* 2014). Accelerated eutrophication of many reservoirs is as a result of human activities, thereby changing the status and quality of surface water (Jabbi *et al* 2018). This study aims to assess the zooplankton composition, distribution and abundance as well as the environmental variables of Yardantsi Reservoir, Gusau in order to proffer methods of effectively managing the reservoir.

Materials and methods

Study area

Yardantsi Reservoir is located in Gusau Local Government Area of Zamfara State, Nigeria, located between latitude 12°10'12.86"-12°17'02.40"N and longitude 6°39'50.83"-6°66'41.20"E (Jabbi *et al* 2018) and occupies an area of 3,364km^2 (Figure 1). The mean annual rainfall in the area is 990mm. The vegetation is the Sudan Savannah species, mostly dominated by grasses and small trees (Ibrahim and Magami 2016). The reservoir was constructed purposely to provide water for domestic uses to Gusau populace as well as to improve irrigation and fishing activities in the area (ECANL 1990; Jabbi *et al* 2018).

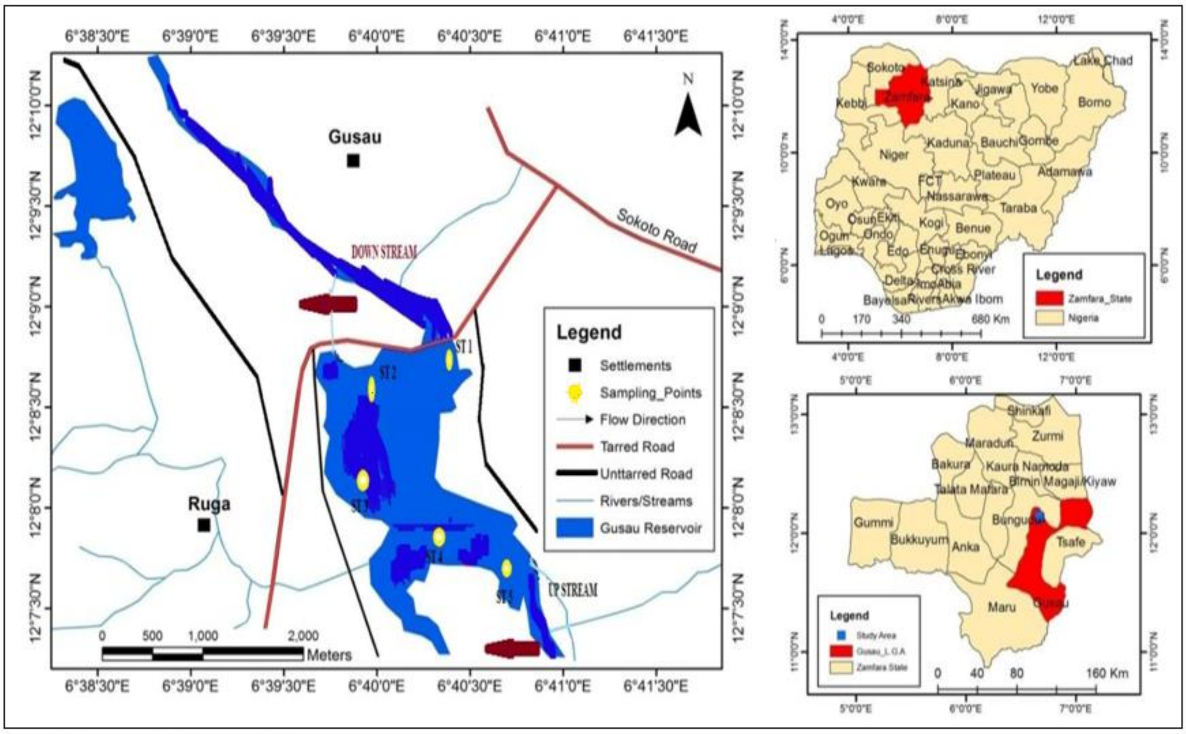

Figure 1. Map of Yardantsi Reservoir showing the sampling sites with insert of maps of Zamfara State and Nigeria

Sample collection and preservation

Water samples for physicochemical and plankton analyses were collected from five stations in the reservoir from May 2015 to April 2017**.** Temperature, total dissolved solid (TDS), conductivity (EC) and pH were measured *in-situ* using HANNA Combo pH/EC/Temperature meter (HI 98129). Transparency was measured at each site using a 30cm diameter Secchi disc. Water depth was determined using a calibrated pole. Water samples for dissolved oxygen (DO) analysis were collected in amber coloured BOD bottles and fixed using Winklers reagents I and II. The DO level was determined titrimetrically in the laboratory. Water samples for biochemical oxygen demand (BOD) were also collected using BOD bottles, incubated for 5days and the oxygen level determined. The BOD was estimated as the initial oxygen level minus the 5-day oxygen level. Water samples for determination of alkalinity, hardness, nitrate-nitrogen, phosphate-phosphorus, sulphate and chloride were collected using one-litre plastic bottles. The samples were transported to the laboratory and the analytes determined by the appropriate standard methods of GEMS (2004) and APHA (2005). All samples were collected and analysed in replicates.

Plankton samples were collected at each site by horizontal towing of 0.01mm mesh plankton net with an opening of 20cm diameter over a distance of 5m. The samples were preserved in 4% buffered formaldehyde and then taken to the Hydrobiology Laboratory of Department of Biology, Ahmadu Bello University, Zaria for further analysis. Plankton were identified microscopically using the taxonomic keys of Jeje and Fernando (1986). Counting was done using the Sedgwick-Rafter chamber. The total number of plankton per litre was then calculated using the Goswami (2004) formula:

$$N = \frac{n \times v \times 1000}{V}$$

Where N=total number of zooplankton individuals per litre of water filtered, n=Average number of zooplankton individuals in 1ml of plankton sample, v=Volume of zooplankton concentrate (ml) and V=Volume of water filtered (l)

The volume of water filtered was estimated using the formula below:

$$V = \pi r^2 d$$

Where r=radius of the mouth of the net, d=Length of the water column traversed by the net.

Species richness and diversity were calculated by Margalef (Margalef 1974) and Shannon-Weiner indices (Shannon and Weaver 1949):

Margalef 's Index $D = \frac{S-1}{log_e N}$

Where S= number of species and, N= total number of individuals

Shannon-Weiner Index (H) $= \sum[(Pi) \times \log (Pi)]$

Where Pi = proportion of individuals of i-th species in a whole community Pi = ni /Nn, ni= number of individuals of a given species and N = total number of individuals in a community.

Data analysis

Seasonal changes in environmental variables and zooplankton was tested with analysis of variance (ANOVA). Plankton-environment relationship was determined using Principal Component Analysis (PCA). All statistical analyses were performed using Palaeontological statistics (PAST) software, version 2.17c (Hammer *et al* 2013).

Results

Environmental variables

Mean water temperature (26.62±0.34°C), depth (2.12±0.05m) and pH (7.61±0.15) were significantly lower during the dry compared to the rainy season ($p<0.001$). Contrariwise, mean transparency (48.82±1.08cm), TDS (96.00±1.95ppm), conductivity (186.32±3.84 µS/cm), DO (7.80±0.11), BOD (2.71±0.09mg/L), alkalinity, hardness nitrate, phosphate, sulphate and chloride were significantly higher during the dry than the rainy season ($p<0.001$) as shown in Table 1.

Zooplankton

Thirteen zooplankton taxa belonging to Copepoda, Cladocera and Rotifera were identified (Table 2). The Cladocerans were the most dominant group during the dry season while rotifers predominated the rainy season period (Table 2 and Figure 2). The results showed the following order of abundance: Cladocera>Rotifera>Copepoda in the dry season and Rotifera>Cladocera>Copepoda in the rainy season. The dominant taxa were *Brachionus patulus, Cyclops* sp., *Eurycercus* sp and *Daphnia* sp. The highest zooplankton abundance (5646 individuals), number of taxa (11), Shannon-Weiner (2.25) and Margalef's indices were observed in June (Figures 2 and 3). The lowest number of taxa (8), Shannon-Weiner (1.91) and Margalef's indices (0.88) were recorded in October (Figure 3).

Table 1: Mean (±SE) seasonal variation in environmental variable of Yardantsi Reservoir, Gusau

	Seasons		
Environmental variables	Dry Season	Rainy Season	P-value
Temperature (°C)	26.62±0.34	30.12±0.17	0.000
TDS (ppm)	96.00±1.95	63.70±3.68	0.000
EC (µS/cm)	186.32±3.84	108.05±5.43	0.000
pH	7.61±0.15	7.96±0.13	0.091
Transparency (cm)	48.82±1.08	22.07±0.87	0.000
Depth (m)	2.12±0.05	2.65±0.04	0.000
DO (mg/l)	7.80±0.11	6.91±0.10	0.000
BOD (mg/l)	2.71±0.09	2.48±0.05	0.017
Alkalinity (mg/l)	40.57±0.69	27.87±0.51	0.000
Hardness (mg/l)	59.20±1.01	32.18±0.94	0.000
NO_3-N (mg/l)	2.28±0.08	4.44±0.07	0.000
PO_4-P (mg/l)	123.72±1.44	173.48±2.78	0.000
Sulphate (mg/l)	31.62±1.45	71.80±1.82	0.000
Chloride (mg/l)	74.08±1.67	37.64±0.96	0.000

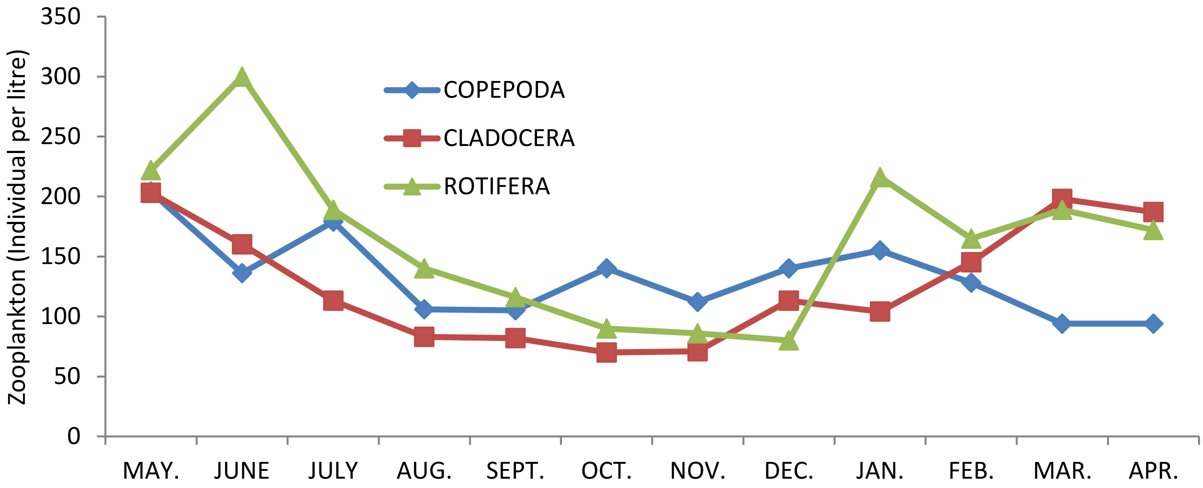

Figure 2. Mean Monthly Variations of Various Groups of Zooplankton of Yardantsi Reservoir, Gusau

Table 2: Seasonal variations in abundance (number of individuals/litre) of different zooplankton of Yardantsi Reservoir, Gusau

Zooplankton	Dry Season		Rainy Season	
	No./l	%	No./l	%
Copepoda	666	32.13	927	27.88
Cyclops sp.	217[a]	10.47	322[b]	9.68
Diaptomus sp.	249[a]	12.01	301[b]	9.05
Eubranchipus sp.	0[a]	0.00	116[b]	3.49
Thermocylops sp.	200[a]	9.65	188[a]	5.65
Cladocera	714	34.44	1178	35.43
Ceriodaphnia sp.	89[a]	4.29	247[b]	7.43
Daphnia sp.	282[a]	13.60	307[a]	9.23
Diaphanosoma sp.	32[a]	1.54	209[b]	6.29
Eurycercus sp.	215[a]	10.37	314[b]	9.44
Macrothrix sp.	96[a]	4.63	101[b]	3.04
Rotifera	693	33.43	1220	36.69
Brachionus patulus	405[a]	19.54	605[b]	18.20
Chromogaster sp.	114[a]	5.50	189[b]	5.68
Kellicottia sp.	17[a]	0.82	188[b]	5.65
Keratella quadrata	157[a]	7.57	238[b]	7.16
Total	2073		3325	

Mean values with same superscript along the rows were not significantly different ($p<0.05$)

Principal component analysis (PCA)
The first two PCA components accounted for 86.70% of zooplankton-environmental variables association in Yardantsi Reservoir (Table 3). *Chromogaster* sp, *Diaphanosoma* sp, *Eubranchipus* sp, *Kellicottia* sp and *Macrothrix* sp were mostly influenced by NO_3, BOD, depth, pH and DO (Figure 4) while *Cyclops* sp and *Daphnia* were mostly influenced by changes in alkalinity, hardness and chloride. *Brachionus patulus* was mostly influenced by PO_4-P.

Discussion

The zooplankton abundance and diversity of Yardantsi Reservoir were higher than some reservoirs such Shagari as reported by Magami (2011) but 25% lesser than Makwaye Reservoir (Balarabe 1989). The seasonal variation of zooplankton population in the reservoir may be attributed to variations in the environmental variables as these variables also showed significant seasonal variations. Such trends have been reported in Ehoma Lake (Okogwu 2010; Okogwu *et al* 2010), in Awba Reservoir (Anago *et al* 2013) and in a temple pond (Sharma *et al* 2013). Seasonal changes in environmental variables may directly or indirectly alter the reproduction time and rate as it affects availability of food, competition, predation and mortality of zooplankton. Similar observation was reported by Balarabe (1989) during the study on limnology and zooplankton of Makwaye Reservoir.

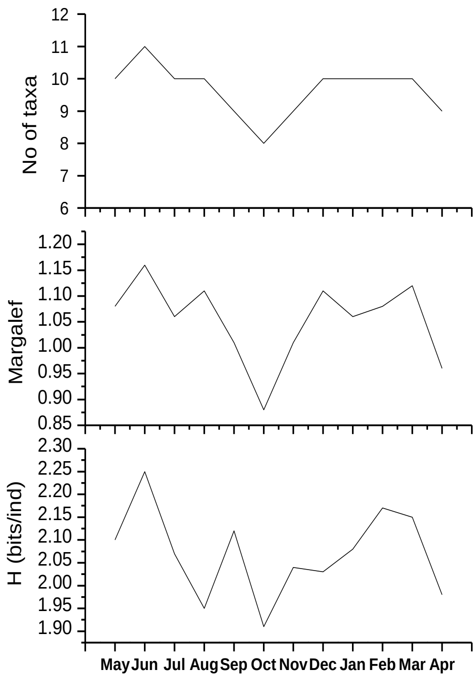

Figure 3. Changes in the number of taxa, Margalef's and Shannon-Weiner indices in Yardantsi Reservoir during the study period

Table 3: Summary of Principal Component Analysis

Principal Component (PC)	Eigenvalue	% Variance
1	17166.40	**74.82**
2	2727.78	**11.89**
3	1108.6	**4.83**
4	765.37	**3.34**
5	491.48	**2.14**
6	223.54	**0.97**
7	167.07	**0.73**
8	109.91	**0.48**
9	91.92	**0.40**
10	62.43	**0.08**
11	17.46	**0.05**

Previous studies have shown that the diversity and abundance of zooplankton are sensitive to changes in environmental variables such as PO_4-P and temperature (Okogwu 2010; Magami 2011; Jabbi 2018). These variables could affect food availability and selectively reduce the population of some zooplankton species (Sharma *et al* 2013), which may explain the decline in copepod population during the rainy season. Furthermore, hydrological changes (increase in flow rate) during the rainy season could also affect zooplankton directly by reducing residence time and indirectly by flushing the preferred food (Okogwu 2010). Such changes could be responsible for the low density and diversity of copepods recorded during the rainy season. Balogun *et al* (2004) observed high abundance and diversity of rotifer during peak abundance of chlorophytes (preferred food) in Makwaye Reservoir. They thus attributed the success of rotifers in the reservoir to the chlorophytes. In an earlier study, Pennak (1978) reported that Cladocerans feed on algae preferably chlorophytes, protozoa and organic detritus. Availability of these food items will invariably influence cladoceran population.

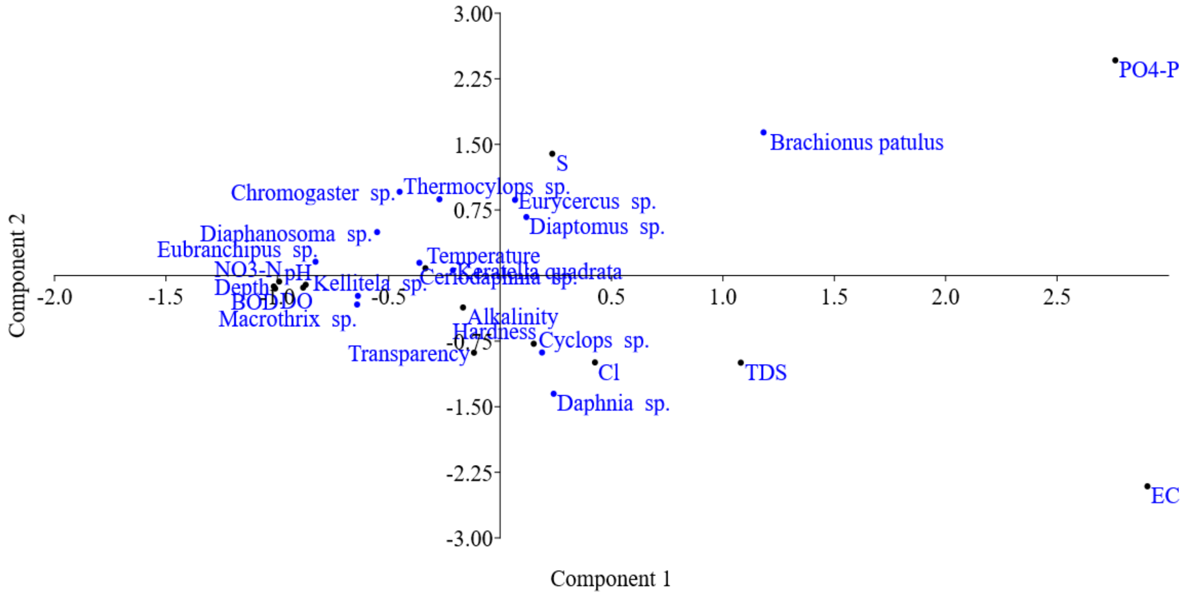

Figure 4. Principal Component Analysis (PCA) for Zooplankton and environmental variables of Yardantsi Reservoir, Gusau

Shannon-Weiner diversity index, which ranged from 1.905 to 2.248 and Margalef diversity index, which ranged from 0.877 to 1.158 revealed that Yardantsi Reservoir is slightly polluted. According to Maiti (2004), Margalef and Shannon-Weiner indices value above three (3) indicates clean water, whereas lower values indicate pollution and the higher the value, the greater the diversity. Low species richness and diversity values during the rainy season could be attributed to high flush rate, reduced reproduction successes and paucity of preferred food as suggested in previous studies (Nkwoji *et al* 2013; Alhassan 2015; Jabbi 2018). The Shannon Weiner diversity index values in the dry season, which was generally lower than the rainy season values could be attributed to the effect of dredging going on at the time of this study, which distorted their habitat and dilution during rainy season which makes the habitat more favourable.

Conclusion

Three groups of zooplankton namely: Cladocera, Copepoda and Rotifera comprising of thirteen species were recorded in Yardantsi Reservoir in this study, with Rotifera having the highest abundance for both dry and rainy seasons. Margalef and Shannon-Weiner diversity indices were found to be less than three in both seasons; this revealed that the reservoir was slightly polluted during the period of study.

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