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Zooplankton community structure of a tropical lake in a Northcentral State, Nigeria

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Abstract. One of the biological components that play a vital role in the ecological integrity of an aquatic ecosystem is zooplankton. These organisms are good indicators of stressors, especially anthropogenic stressors in their environment. Thus, there is a need to study the diversity in a diversified freshwater lake (Dangana Lake) in order to provide baseline information and knowledge on the status of the lake for proper and adequate water preservation and conservation. In addition to the zooplankton structure determination, the study also examined the physicochemical parameters of the Lake. Three sampling sites were identified with distinct characteristics where water and zooplankton samples were collected for physicochemical analyses and biotic identification using standard protocols. Sampling was conducted for a duration of eight months. The monitored physicochemical parameters, i.e., temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD_5) and pH revealed no significant difference ($p>0.05$) among sampling sites. However, significance ($p<0.05$) amongst sampling sites was recorded in electrical conductivity, nitrate and phosphate. Seasonally, there was a significant difference ($p<0.05$) among sampling months in all the monitored parameters. A total of ten species of zooplankton were recorded with four species each of rotifera and copepoda and two species of cladocera. The order of abundance of zooplankton population was rotifera (56.39%), copepoda (29.18%) and cladocera (14.42%). Zooplankton population was significantly ($p<0.05$) higher during the dry season than in the rainy season. The Canonical correspondence analysis (CCA) revealed a strong correlation between the zooplankton and physicochemical parameters. Ipso-facto, the lake exhibited spatiotemporal changes in zooplankton composition and physicochemical parameters during the sampling period.

Keywords: Anthropogenic activities, Dangana Lake, Physicochemical parameters, Zooplankton

1 Introduction

Freshwater ecosystems provide distinctive environments that improve ecological status and the survival of many biotic components (Mohammed *et al.* 2021, Oparaku *et al.* 2022). Systematic monitoring of freshwater resources (rivers, streams, lakes, springs, and ponds) is required to ensure their socioeconomic function (Mohammed *et al.* 2020). According to Arimoro *et al.* (2015) there is global rise in freshwater environment research as it relates to the conservation of its inhabitants. Thus, the contamination of freshwater ecosystems by various anthropogenic activities is becoming an important concern owing to the damage it poses to productivity, environmental sustainability, and social and economic development in Africa (Arimoro and Keke 2016). The activities in the freshwater bodies such as laundry, agricultural operations and hydropower generation introduces pollutants that result in changes observed in the aquatic habitat (Adamu *et al.*, 2020; Adamu *et al.*, 2018; Kun *et al*. 2015).

Freshwater bodies such as Lakes and reservoirs are valuable resources that possess tremendous economic value as they provide many benefits to nearby settlements, such as means of flood control, recreation, aquatic life support, domestic water supply, irrigation and industrial water supply (Maishanu *et al.*, 2022; KDHE 2011). Monitoring freshwater bodies such as lake helps to create information on species richness in the ecosystem, as well as information on the health status of the water body being studied (Adamu *et al.*, 2020; Ajuzie 2012). Zooplankton such as rotifers, copepods, and cladocerans are environmental stressor indicators and quick responders (Pawlowski *et al.* 2016, Xiong *et al.* 2019). They contribute to aquatic ecosystem biodiversity. According to Xiong *et al.* (2020), zooplankton are widely accepted and indispensable bioindicators in the ecological conservation and management of aquatic ecosystems. Despite their ecological importance, zooplankton richness and diversity are threatened (Oparaku *et al.* 2022). This is exacerbated when variables impacting zooplankton populations remain unknown (Mimouni *et al.* 2018), particularly in areas where zooplankton are regarded as species of low ecological significance (Noble and Hassall 2015). Zooplankton communities are used as bioindicators of environmental changes because they have short life cycles and can respond quickly to shifts in physicochemical variables (Kuczyńska-Kippen *et al.* 2020, Yuezhao *et al.* 2021, Li and Chen 2022). Zooplankton also play a key role in the energy transfer between primary producers and other top trophic levels, and responds differently to environmental degradation (Chiba *et al.* 2018, Lomartire *et al.* 2021, Makwinja *et al.* 2021). Studies have revealed that anthropogenic activities and climate change are presently threatening the stability of most freshwater ecosystems (Oparaku *et al.* 2022), resulting in a decrease in zooplankton diversity (Alahuhta *et al*. 2019).

Therefore, understanding the impact of environmental drivers on zooplankton communities is critical in assessing the ecological integrity of a tropical lake impacted by various anthropogenic activities. Thereof, this study was aimed at investigating the composition, distribution pattern, abundance and community structure of the zooplankton fauna of Dangana lake Lapai, Niger State, Nigeria.

2 Materials and Methods

2.1 Description of study area and sampling sites

This study was carried out at Dangana lake (Fig. 1), Lapai, Lapai Local Government of Niger State, Nigeria. Dangana lake is located within longitude $6°36^{1}29.6^{1}$E and latitude $9°02^{1}12.02$N with the elevation of 159 m above sea level.

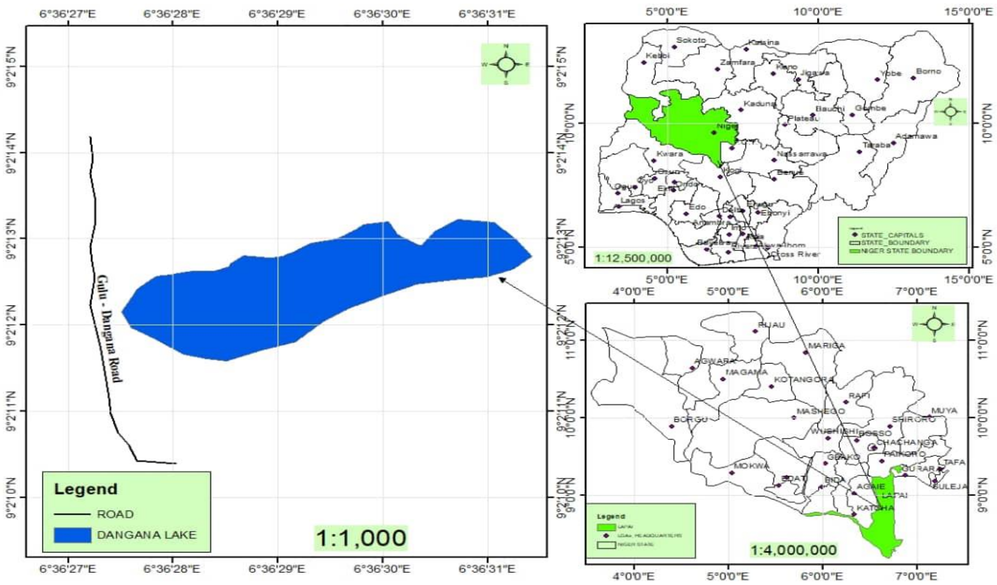

Fig. 1: Geographical location of Dangana Lake Lapai, Niger State, Nigeria

The area lies in the savannah region of Central Nigeria with mixed vegetation, the common ones of which include Malaina (*Gmeilana arborea*), locust beans (*Parkia biglobosa*), neem (*Azadirachta indica*) and other few native trees and grasses. The climate presents two distinct seasons, a rainy season between May to September, and a dry season (October-April) completely devoid of rain. The characteristics of the three sampling sites are shown in Table 1.

Table 1: Sampling site characteristics of Dangana lake during the sampling period.

Sampling site	Description
Site A	The entry point of water entry into the lake, where the lake receives its water sources from nearby wetlands and has few human activities taking place.
Site B	This site is dominated with high anthropogenic activities. Various human activities in this site include laundry, car wash and other domestic activities.
Site C	This site is free of human activities; It has an opening which allows water to move out of the lake when there is excess water in the lake due to flood or excessive rainfall

2.2 Sampling technique

Determination and analysis of physicochemical parameters

Water samples for physicochemical parameters were collected monthly between March and October, 2019 within the seasons: dry season (March to May) and rainy season (June to October) from the three selected sampling sites in the lake. The water temperature, dissolved Oxygen (DO), conductivity and pH were measured in-situ using a multipurpose Meter (HANNA model 1910), whereas, BOD_5, nitrate and phosphate were determined by the methods described in APHA (2012).

Zooplankton sample collection and analysis

Samples of zooplankton were collected at the same time as sampling water for physiochemical analyses using a modified hand trawling approach. At each station, a 50 μm mesh size plankton net was horizontally trawled for zooplankton sampling for twenty minutes at four distinct points within the sampling sites as described in Yagit (2006). Using labeled plastic containers, samples were stored in a 4% formalin solution and sent to the laboratory for examination and identification.

In the laboratory, 1 mL of each of the three samples taken per station was analysed. The plastics holding zooplankton samples were thoroughly shaken to achieve an even distribution of the zooplankton. Thereafter, a drop of the 1 mL mixed samples was deposited into a glass slide coated with a coverslip for identification and enumeration using a compound microscope (mag: 10×10) and validated (mag: 10×40) by manually counting. This was done twice for each of the three plastics holding zooplankton samples, one for each plastic container (Tash 1971). The specimens were identified by comparing them to plankton identification charts (Needhem and Needhem 1975, Shiel 1995, Fernando 2002, Botes 2003, Perry 2003, Witty 2004). The zooplankton individuals recorded per station for the eight-month sampling period were added to give the total number of zooplankton individuals collected in the entire study period.

2.3 Statistical analyses

Descriptive statistics (mean, range, and standard deviation) for each physicochemical variable per station were calculated. The statistical differences in zooplankton metrics between stations and seasons were calculated using two-way analysis of variance (ANOVA). The impact of stations and months on physicochemical characteristics were also calculated. Tukey Posthoc test was used to compare means. Species abundance, species richness, taxonomic dominance, evenness index, Simpson dominance index, Shannon Weiner index, and Margalef's index of the zooplankton were calculated. Canonical correspondence analysis, the link between physicochemical characteristics assessed and zooplankton species composition and abundance were determined. The Monte-Carlo permutation test with 1000 permutations was used to establish the CCA significance. All statistical analyses were conducted using the Paleontological Statistical Package (PAST) software, version 4.0.

3 Results

3.1 Physicochemical parameters

The physicochemical parameters of sampling sites of Dangana lake, Lapai Niger state for a period of eight months (March-October in 2019) is presented in Table 2. There was no significant difference (P>0.05) in water temperature, DO, BOD_5 and pH among all the sampling sites. However, electrical conductivity, nitrate and phosphate differ significantly (P<0.05) among sampling sites.

Table 2. Mean summary of physicochemical parameters of Dangana Lake, Lapai Niger State Nigeria.

Parameters	Stations			Probabilities	
	Site A	Site B	Site C	Stations	Months
Water temperature (°C)	26.41 ± 0.38^a	26.65 ± 0.74^a	23.50 ± 0.90^a	0.72	5.81E-06
DO (mg/L)	4.02 ± 0.10^a	3.98 ± 0.15^a	4.13 ± 0.20^a	0.54	0.00
BOD_5 (mg/L)	3.00 ± 0.14^a	3.08 ± 0.18^a	3.12 ± 0.19^a	0.37	3.40E-07
pH	6.88 ± 0.17^a	7.05 ± 0.12^a	6.98 ± 0.11^a	0.13	1.29E-06
Conductivity (μS/cm)	86.43 ± 8.57^b	91.42 ± 9.04^a	94.80 ± 8.54^a	0.02	1.97E-08
Nitrate (mg/L)	0.68 ± 0.08^b	0.76 ± 0.08^a	0.67 ± 0.09^a	0.00	8.25E-12
Phosphate (mg/L)	0.90 ± 0.10^a	1.04 ± 0.12^a	0.85 ± 0.10^b	7.38E-05	3.51E-11

Note: values are Mean ± standard error; Each parameter with the different superscript letters across sampling site showed significant differences (p<0.05, Tukey post hoc test), while parameters with same superscript letters showed no significant differences (p>0.05).

There was a significant difference (P<0.05) among sampling months in all the physicochemical parameters measured. The water temperature recorded the highest mean value of 26.65 ± 0.74°C in sampling site B and the least mean water temperature value of 23.5 ± 0.90°C was recorded in site C. Site B recorded the least mean value of 3.98 ± 0.15 mg/L in dissolved oxygen concentration whereas site C recorded the highest mean value of 4.13 ± 0.20 mg/L. Mean BOD was 3.00 ± 0.14 mg/L in site A and 3.12 ± 0.19 mg/L in site C. The mean pH mean value was lowest in site A (6.88 ± 0.17) and highest (7.05 ± 0.12) in Site B. Other monitored physicochemical parameters are presented in Table 2.

3.2 Zooplankton structural assemblage

A total of ten species of zooplankton in three divisions were identified in Dangana Lake, Lapai Niger state. The groups encountered were copepoda (4 species), rotifera (4 species) and Cladocera (2 species) (Table 3). The percentage abundance of rotifera, copepoda and cladocera were 56.39, 29.18 and 14.42 respectively.

Table 3: Zooplankton composition, distribution and percentage abundance in Dangana Lake, Lapai during the sampling periods

Division	Species	Code	Site A	Site B	Site C	%
Copepoda	*Diaptomus gracilis*	DIA	6	6	16	
	Cyclops sp	CYC	6	8	6	
	Microcyclops varicans	MIC	10	7	6	
	Mesocyclops sp	ZOC	7	8	3	
	Total		29	29	31	29.18
Rotifera	*Keratella* sp	KER	29	20	31	
	Lecane sp	LEC	5	21	9	
	Notholca sp	NOT	10	4	9	
	Brachionus variabalis	BRA	11	6	17	
	Total		55	51	66	56.39
Cladocera	*Daphnia* sp	DAP	8	7	5	
	Ceriodaphnia sp.	CER	12	3	9	
	Total		20	10	14	14.42

Zooplankton distribution in all sampling sites recorded higher abundance in the dry season months (March to May) compared to the rainy season months (June to October) as presented in Figure 2.

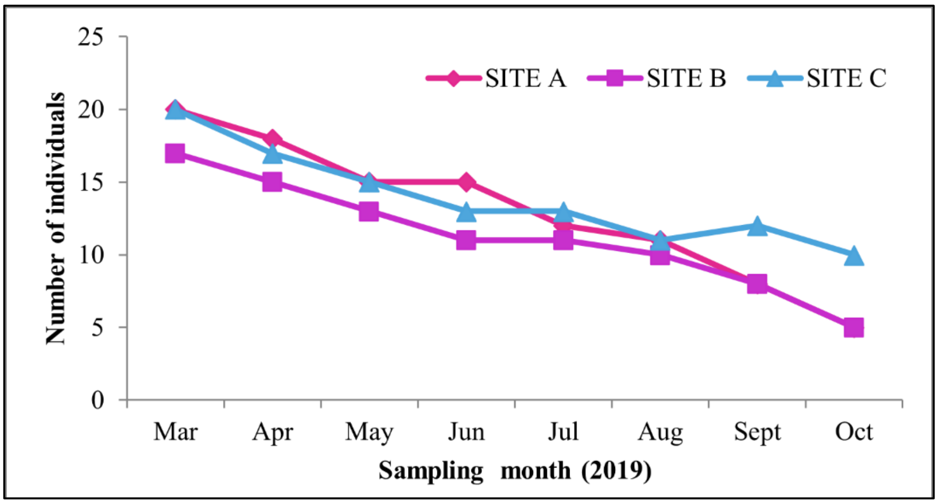

Fig 2: Monthly distribution of zooplankton in Dangana lake

3.3 Ecological indices of zooplankton in Dangana Lake Lapai, Niger State Nigeria

The diversity indices of zooplankton in each of the sampling sites are presented in Table 4. There were 10 identified zooplankton in each of the sites with 104, 90, 111 individuals recorded in sites A, B and C respectively. Shannon and Evenness index followed a similar trend with site A>B>C. Margalef's index was highest in site B (2.00) and 1.988 and 1.91 for site A and C respectively.

Table 4: Zooplankton diversity indices value of Dangana lake Lapai Niger State, Nigeria.

Indices	Site A	Site B	Site C
Taxa_S	10	10	10
Individuals	104	90	111
Dominance_D	0.1402	0.1437	0.1506
Shannon_H	2.147	2.114	2.087
Evenness_e^H/S	0.8561	0.8283	0.8057
Margalef	1.938	2.00	1.911

3.4 Association of zooplankton distribution and physicochemical parameters

The total Zooplankton compositions were observed to show an association with the mean physicochemical parameters measured of the lake as shown in Fig 3. CCA ordination Axis 1 account for 71.73% of species variation with eigen value of 0.0905 while Axis 2 showed 28.27% specie variation with eigen value of 0.0356 as presented in Table 5. The most significant association between physicochemical parameters was observed for Biochemical oxygen demand, Conductivity, pH, nitrate, phosphate and temperature. These parameters were strongly positively correlated with *Diaptomus gracilis*, *Lecane* sp., *Brachionus variabalis*, *Keratella* sp., *Cyclops* sp., *Daphnia* sp., *Microcyclops varicans*, and *Mesocyclops* sp. However, *Notholca* sp. and *Ceriodaphnia* sp. correlated negatively with the measured physicochemical parameters.

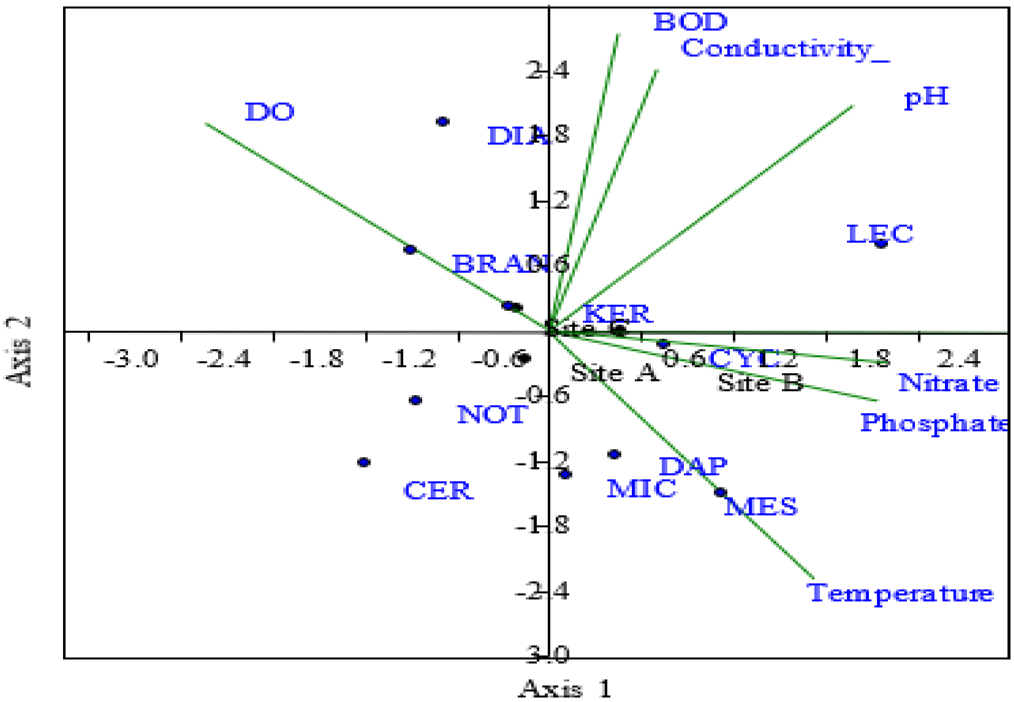

Fig 3: Canonical correlation analysis ordination plot of physicochemical parameters and Zooplankton species of Dangana Lake Lapai, Niger state

Table 5: Weighted intra-set correlation of Eigen value of CCA axis.

	Axis1	Axis2
%	71.73	28.27
eigen value	0.090504	0.03566
DO	**-0.74766**	0.636934
BOD_5	0.129254	0.995598
pH	0.672748	0.763448
Conductivity	0.050073	0.999897
Nitrate	0.999159	**-0.00527**
Phosphate	0.980827	**-0.15969**

4 Discussion

4.1 Physicochemical parameters

The monthly trend in the concentrations of DO, BOD_5, pH, nitrate and phosphate in the lake shows a similar trend to that earlier reported in inland waters in Nigeria (Akindele *et al*. 2013, Yusuf 2020, Mohammed *et al.* 2021). All the monitored physicochemical parameters show spatial and temporal changes between sampling months, and this could be a result of some natural factors and different anthropogenic activities taking place around the lake (Mustapha 2009). The water temperature of the lake falls within the normal temperature range of 20 to 30°C required by aquatic organisms for metabolic activities (Mustapha 2009). Moderate water temperature was observed throughout the sampling period due to high rainfall and minimum amount of sunlight.

The DO and BOD_5 concentration observed in this study were high in the months which falls within the rainy season than in the dry season, this could be due to an increase in the volume of water in the rainy season as well as an increase in the flow of organic matters into the lake though surface runoff (Davies *et al.* 2009, Raji *et al.* 2015). Water pH value obtained from Dangana Lake slightly falls within the recommended pH range of 6.5-8.5 for productivity in natural waters (Raji *et al.* 2015). High pH and moderate temperature, on the other hand, have been reported to boost primary production in an aquatic environment, which supports zooplankton growth and survival (Mustapha 2009). The high conductivity values observed during the rainy season could be attributed to a high amount of dissolved and suspended solid materials present in the water which results in an increase in dissolved cations such as calcium, magnesium and sulphate concentration in the sampling sites (Arimoro and Keke 2016).

Nitrates and phosphate are among the limiting factors in the aquatic environment (Arimoro *et al.* 2015). The high mean phosphate value and nitrate value measured in the lake also improve primary production. The availability of nutrients impacts the shape and number of zooplankton (Oparaku *et al.* 2022). An increase in phosphate and nitrate concentrations in aquatic environments has been related to anthropogenic activity; as a result, eutrophication is unavoidable (Andong *et al.* 2019). It has shown that nutrients have a bigger influence on most freshwater biota than temperature (Birk *et al.* 2020), but another study discovered that the effect of temperature on aquatic invertebrates was stronger under nutrient constraint (Pomati *et al.* 2019).

4.2 Zooplankton structural assemblage and diversity

Most of the zooplankton groups observed in this study appears to be the normal inhabitants of lakes, streams, ponds and artificial impoundment in the tropics

(Mustapha 2009, Arimoro and Oganah 2010, Tanko *et al.* 2016, Iloba *et al.* 2019). Zooplankton composition and abundance in any aquatic ecosystem are important in water quality monitoring. Zooplankton populations are threatened due to different human activities such as domestic waste, agricultural waste such as runoff manure and fertilizers from nearby farms (Anago *et al.* 2013). The differences in zooplankton distributions and assemblage in this study may be due to sampling space, time and the dynamic nature of aquatic systems (Iloba 2019). Changes in zooplankton populations in Dangana lake could be attributed to different species having their nutritional requirement of different temperature, pH, DO, BOD_5 and nutrients (Chia *et al*. 2012). High nutrient level, high concentration of nitrate, and phosphate favor the growth of Baccillariophyta which forms the major diet of zooplankton (Chia *et al.* 2012). Zooplankton are an important component in the dynamics of aquatic environment and its productivity (Iloba 2019). Plankton abundance and distribution are affected by seasonal changes of both physical and chemical parameters as well as phytoplankton in aquatic environments (Norris and laws 2017, Adamu *et al.* 2021).

Zooplankton were dominated by the rotifers in this study, and this could be attributed to their reproduction pattern which is parthenogenetic and short development rate under favorable aquatic condition (Akin-Ariola 2003, Tanko *et al.* 2016). The low abundance of copepoda, and cladocera groups could be attributed to low abundance of aquatic macrophytes, which may increase the rate of predation by fishes in the lake (Arimoro and Oganah 2010, Edegbene *et al.* 2022). The zooplankton diversity and abundance reported in this study is similar to the abundance and diversity pattern that is reported by Akindele and Olutona (2014) in the headstream water of Aiba Reservoir, Iwo, Nigeria. In this study, the monthly dynamics of the abundance and composition of zooplankton correlates with the season as higher populations were recorded during the dry season. The low abundance of zooplankton population observed in the rainy season could best be attributed to an influx of materials into the water body which may lead to further growth dilution of nutrients required for essential growth in the lake and surrounding environment (Yusuf 2020).

The taxonomic richness of zooplankton ecological parameters in this research region was rather high in number (9 zooplankton types) than that reported by Abdul *et al.* (2016). The taxonomic distribution was also relatively even, in contrast to the eleven zooplankton taxa distribution in certain Nigerian riverine systems (Abdul *et al.* 2016). The high connection reported in the CCA model between zooplankton and measured physicochemical parameters may imply that zooplankton taxonomic assemblages in the Dangana lake were influenced by the majority of the prevailing environmental conditions. Earlier research found that environmental factors had varying effects on zooplankton populations in Nigerian rivers (Arimoro and Oganah 2009, Abdul *et al.* 2016). However, when compared to other studies in Nigeria, this study had lower taxonomic richness and evenness of zooplankton (Arimoro and Oganah 2009, Abdul *et al.* 2016, Edegbene *et al.* 2022).

5 Conclusion

The lake exhibits spatio-temporal changes in zooplankton composition and the monitored physicochemical parameters during the sampling period. Anthropogenic activities throughout the sample locations altered the water quality and zooplankton assemblages and their organization. Furthermore, the three taxonomic groupings of zooplankton in this study were Cladocera, Copepoda, and Rotifera. Zooplankton communities respond differently to environmental conditions.

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References

Abdul WO, Adekoya EO, Ademolu KO, Omoniyi IT, Odulate DO, Akindokun TE, Olajide AE 2016. The effects of environmental parameters on zooplankton assemblages in tropical coastal estuary, southwest Nigeria. *Egyptian Journal of Aquatic Research* 42: 281–28 7.

Adamu KM, Mohammed YM, Mohammed H, Ebesi EJ. Jimoh YO. 2021. Spatio-temporal Assessment of Phytoplankton and Physicochemical Parameters of Dangana Lake, Lapai, Niger State Nigeria. *Journal of Applied Life Science International* 24(12): 39-48. DOI: 10.9734/JALSI/2021/v24i1230277

Adamu KM, Muhammad H, Ahmad SU, Ahmad MM, Mohammed YM 2020. Diversity of Bacteria and Fungi associated with freshwater fishes from Mijawal River, Nasarawa, Nigeria. *Journal of Applied Sciences and Environmental Management* 24(6): 1085-1092. DOI:10.4314/jasem.v24i6.22

Adamu KM, Adebola MO, Iloba IK, Jonathan JD, Abdullahi AS, Onyemata EK, Ikomi BR 2018. Are fungi isolated from water and fish samples in Lapai-Agaie dam, Nigeria pathogenic to human health? *Production, Agriculture and Technology* 14(2): 58-67.

Ajuzie CC. 2012. Aspect of biodiversity studies in a small rural tropical reservoir (Lamingo Reservoir) in Jos, Nigeria. *World Rural Observation* 4(1): 23-33

Akindele EO, Adeniyi IF, Indabawa I. 2013. Spatio-temporal assessment and water quality characteristics of Lake Tiga, Kano, Nigeria. *Research Journal of Environmental and Earth Sciences* 5(2): 67-77.

Akindele EO, Olutona GO. 2014. Water Physicochemistry and Zooplankton Fauna of Aiba Reservoir Headwater Streams Iwo, Nigeria. *Journal of Ecosystems* 10(5): 54-65.

Akin-Oriola GA. 2003. Zooplankton association and environmental factors in Ogupa and Ona Rivers Nigeria. *Review of Biology of the Tropics* 51(2): 391-398.

Alahuhta J, Erlos T, Kearnea OM, Soininen J, Wang J, Heino J. 2019. Understanding environmental change through the lens of trait-based, functional, and phylogenetic biodiversity in freshwater ecosystems. *Environ Review* 27(2): 263-273.

Anago IJ, Esenowo IK, Ugwumba AAA. 2013. The Physico-chemical and Plankton Diversity of Awba Reservoir University of Ibadan Nigeria. *Research Journal of Environment and Earth Science* 5(1): 638-644.

Andong FA, Ezenwaji NE, Melefa TD, Hinmikaiye FF, Nnadi OV, Oluwafemi O. 2019. Assessment of the physical and chemical properties of Lake Oguta (Nigeria) in relation to the water quality standard established by the Nigerian Federal Ministry of Water Resources. *Advance Oceanography and Limnology* 10:74–78

APHA (American Public Health Association). Standard Methods for the Examination of Water and Wastewater. WEF and AWWA. 20th Edition; 1998: USA.

Arimoro FO, Keke UN. 2016. The intensity of human-induced impact on the distribution and diversity of Macroinvertebrates and water quality of Gbako River, North Central Nigeria. *Energy Ecology and Environment*, 2: 143–154.

Arimoro FO, Odume NO, Uhunoma SI, Edegbene AO. 2015. Anthropogenic impact on water chemistry and benthic macroinvertebrate associated changes in a southern Nigeria stream. *Environment Monitoring Assessments*, 187: 1-14.

Arimoro FO, Oganah AO. 2009. Zooplankton community responses in a perturbed tropical stream in the Niger Delta, Nigeria. *The Open Environmental & Biological Monitoring Journal, 3*(1), 1–11. https:// doi. org/ 10. 2174/18750 40001 00301 0001

Arimoro FO, Oganah AO. 2010. Zooplankton community response in a perturbed tropical stream in the Niger Delta Nigeria. *The Open Environment and Biological Monitoring Journal*, 3: 1-11.

Birk S, Chapman D, Carvalho L, Spears BM, Andersen HE, Argillier C, Auer S, Baattrup-Pedersen A, Banin L, Beklio_glu M, et al. 2020. Impacts of multiple stressors on freshwater biota across spatial scales and ecosystems. *Nature Ecology and Evolution* 4(8):1060–1068.

Botes L. 2003. Phytoplankton identification catalogue, Saldanha Bay South Africa, Globallast monograph Series no7. IMO London pp 10-86

Chia AM, Adelanwa MA, Ladan Z, Lortsuun DN, Adanyi SE, Stephen BJ. 2012. Interaction of *Ipomoeaaquatica* and *ultricularia* reflex a with phytoplankton densities in a small water bodies in Northern Nigeria. *Oceanology and Hydrobiology studies* 41(2): 39-47.

Chiba S, Batten S, Martin CS, Ivory S, Miloslavich P, Weatherdon LV. 2018. Zooplankton monitoring to contribute towards addressing global biodiversity conservation challenges. *Journal of Plankton Research* 40(5): 509–518. https:// doi. org/ 10. 1093/ plankt/ fby030

Davies OA, Abowei JFN, Tawari CC. 2009. Phytoplankton community of Elechi Creek, Niger Delta, Nigeria - A nutrient polluted tropical creek. *American Journal of Applied Sciences* 6(6): 1143-1152.

Edegbene AO, Abdullahi Y, Akamagwuna FC, Ogidiaka E, Osimen EC, Omovoh BO. 2022. Are zooplankton useful indicators of ecological quality in Afrotropical ephemeral stream impacted by human activities? *Environmental Monitoring Assessment* 194: 399 https://doi.org/10.1007/s10661-022-10061-4

Fernando CH. 2002. A Guide to Tropical Freshwater Zooplankton; Identification, Ecology and Impact on Fisheries, Backhuys Publishers, Leiden, The Netherlands.

Iloba KI. 2019. Water Properties and Zooplankton Diversity of Aghalokpe Wetland in Delta State, Nigeria. *Science World Journal* 14(1): 164-170.

Iloba KI, Akawo N, Anani C. 2019. Sand dredging impact on macrobenthic invertebrates of a hallowed river in Delta state of Nigeria. *Science World Journal* 14(1): 171-176

KDHE (Kansas Department of Health and Environment) 2011. Water Quality Standard White Papers. Chlorophyll-A Criteria For Public Water Supply Lakes or Reservoirs. Pp 1-12. Retrieved from https://www.kdhe.ks.gov/DocumentCenter/View/13305/Chlorophyll-a-Criteria-for-Public-Water-Supply-Lakes-or-Reservoirs-January-10-2011-PDF

Kuczyńska-Kippen N, Špoljar M, Zhang C, Pronin M. 2020. Zooplankton functional traits as a tool to assess latitudinal variation in the northern-southern temperate European regions during spring and autumn seasons. *Ecological Indicators* 128: 106629. https:// doi. org/ 10. 1016/j. ecoli nd. 2020. 106629

Kun L, Chunguang H, Jie Z, Zhenxing Z, Hongyong X, Zhongqiang W, Haijun Y, Lianxi S, 2015. Long-term changes in water quality and Macroinvertebrates communities of a subtropical river in south China. *Water* 7: 63-80

Li Y, Chen F. 2020. Are zooplankton useful indicators of water quality in subtropical lakes with high human impacts? *Ecological Indicators* 113: 106167. https://doi.org/10.1016/j.ecolind.2020.106167.

Lomartire S, Marques JC, Goncalves AMM. 2021. The key role of zooplankton in ecosystem services: A perspective of interaction between zooplankton and fish recruitment. *Ecological Indicators* 129: 107867. https:// doi. org/ 10. 1016/j. ecoli nd. 2021. 107867

Maishanu F, Adamu KM, Mohammed YM 2022. Anthropogenic impact on some water quality characteristics of Wupa River, Federal Capital Territory, Abuja, Nigeria. *Issues in Biological Sciences and Pharmaceutical Research* 10(3): 30-38.

Makwinja R, Mengistou S, Kaunda E, Alamirew T. 2021. Spatial distribution of zooplankton in response to ecological dynamics in tropical shallow lake: Insight from Lake Malombe, Malawi. *Journal of Freshwater Ecology* 36(1): 127–147. https:// doi. org/ 10. 1080/ 02705 060. 2021.19430 19

Mimouni EA, Pinel-Alloul B, Beisner BE, Legendre P. 2018. Summer assessment of zooplankton biodiversity and environmental control in urban waterbodies on the Island of *Montreal Ecosphere* 9(7): e02277–19.

Mohammed YM, Arimoro FO, Ayanwale AV, Adama BS, Keke UN, Auta YI, Umar BL. 2020. Seasonal changes in the abundance of benthic macroinvertebrates & physico-chemical condition of Moussa stream Bida, Nigeria. *Tropical Freshwater Biology* 29(1): 57-70.

Mohammed YM, Arimoro FO, Ayanwale AV. Adamu KM, Keke UN, Abubakar MD, Achebe AC. 2021. The current state of water quality and benthic invertebrate fauna in Chikke Stream (North-Central Nigeria). *Ukranian Journal of Ecology* 11(3): 26-34.DOI: 10.15421/2021_136

Mustapha MK. 2009. Zooplankton assemblage of Oyun Reservoir, Offa, Nigeria. *Review Biol Trop* 57(4): 1027–1047.

Needhem JG, Needhem PR. 1975. A Guide to the Study of Freshwater Biology, San Francisco, Itode-Day publishers.

Noble A, Hassall C. 2015. Poor ecological quality of urban ponds in Northern England: causes and consequences. *Urban Ecosystem* 18(2):649–662.

Norris B, Laws EA. 2017. Nutrients and phytoplankton in a shallow Hypereutic Urban lake, prospects for restoration. *Water* 9(431): 2-11.

Oparaku NF, Andong FA, Nnachi IA, Okwuonu ES, Ezeukwu JC, Ndefo JC. 2022. The effect of physicochemical parameters on the abundance of zooplankton of River Adada, Enugu, Nigeria. *Journal of Freshwater Ecology* 37(1): 33-56. DOI: 10.1080/02705060.2021.2011793

Pawlowski J, Lejzerowicz F, Apotheloz-Perret-Gentil L, Visco J, Esling P. 2016. Protist metabarcoding and environmental biomonitoring: time for change. *European Journal Protistology* 55(Pt A):12–25.

Perry R, 2003. A Guide to the marine plankton of southern California, UCLA Ocean globe [online], 3rd edition. Available at: http://www.msc.ucla.edu/Oceanglobe [Accessed on: 02/03/2019].

Pomati F, Shurin JB, Andersen KH, Tellenbach C, Barton AD. 2019. Interacting temperature, nutrients and zooplankton grazing control phytoplankton size-abundance relationships in eight Swiss Lakes. *Frontier in Microbiology* 10:3155–3172.

Raji MIO, Ibrahim YKE, Tytler BA, Ehinmidu JO. 2015. Physicochemical Characteristics of Water Samples Collected from River Sokoto, Northwestern Nigeria. *Atmospheric and Climate Sciences* 5: 194-199.

Shiel RJ. 1995. *A guide to identification of rotifers, cladocerans and copepods from Australian inland waters.* Identification Guide Series No. 3. Co-operative Research Centre for Freshwater Ecology, Albury, NSW, 144 pp

Tanko D, Chia MA, Nuhu G. 2016. Zooplankton community structure and dynamics during the transition from dry to rainy season: A case study of Kufena Inselberg (Rock) pool Zaria Nigeria. *The Zoologist* 14: 7-13

Tash JC. 1971. The zooplankton of fresh and brackish water of the cape Thompson area Northern Alaska. *Hydrobiologia*, 38(1): 93-121.

Witty LM 2004. *Practical Guide to Identifying Freshwater Crustacean Zooplankton*. 2nd Edition, Cooperative Freshwater Ecology Unit, Sudbury, 50 p.

Xiong W, Huang X, Chen Y, Fu R, Du X, Chen X, Zhan A. 2020. Zooplankton biodiversity monitoring in polluted freshwater ecosystems: a technical review. *Environmental Science and Ecotechnology* 1:1–11.

Xiong W, Ni P, Chen Y, Gao Y, Li S, Zhan A. 2019. Biological consequences of environmental pollution in running water ecosystems: a case study in zooplankton. *Environment and Pollution* 252: 1483–1490.

Yagit S. 2006. Analysis of zooplankton community by the Shannon-weaver index in Kesikkopru Dam Lake Turkey. *Tarim Bilimeleri Dergisi* 12(2): 41-46.

Yuezhao L, Chen H, Song L, Wu J, Sun W, Teng Y. 2021. Effects on microbiomes and resistomes and the source-specific ecological risks of heavy metals in the sediments of an urban river. *Journal of Hazardous Materials 409*, 124472. https:// doi. org/ 10. 1016/j. jhazm at.2020. 124472

Yusuf ZH. 2020. Phytoplankton as bioindicators of water quality in Nasarawa reservoir, Katsina State Nigeria. *Acta Limnologica Brasiliensia* 32(4): 17-29.