Original Research Article

Assessment of Zooplankton Communities and Water Quality of River Katsina-Ala at Kwantan-Sule

ABSTRACT

This study investigated zooplankton species and water quality of River Katsina-Ala at Kwantan-Sule, Guma Local Government Area of Benue State, Nigeria. Zooplankton samples were collected twice for 4 weeks between October and November, 2017 using a 55 µm mesh plankton net. Water quality parameters were determined *in-situ* and *ex-situ* using standard procedures. A total of 144 zooplankton specimens were identified during the study period. They were distributed among 6 classes: Cladocera (46%), Diptera (24%), Copepoda (13%), Ephemerophyta (10%), Arachnida (4%) and Protozoa (3%). The zooplankton diversity indices were: Shannon-Weiner (2.286), Simpson (0.875) and Margalef (2.213). Mean values of physico-chemical parameters were; temperature (27.23±0.23 ^{0}C), dissolved oxygen (5.45±0.00 mg/L), biochemical oxygen demand (2.10±0.10 mg/L), pH (7.80±0.01), electrical conductivity (29.75±0.25 µScm^{-1}), transparency (37.06±1.06 cm) and total hardness (0.11±0.00 mg/L). The river contained moderate abundance and varied zooplankton species. The water quality parameters of the ecosystem were favourable for aquatic life to thrive. There is need to carry out a temporal and spatial assessment of the river in order to ascertain its ecological health.

Key words: Zooplankton, Water parameters, Diversity, Kwantan-Sule

INTRODUCTION

Zooplankton are important component of aquatic ecosystems (Mishra, 2020). They serve as a crucial link between primary producers such as phytoplankton and higher trophic levels including fish and other freshwater organisms (Karakuş *et al*., 2022; Declerck and de Senerpont Domis, 2023). The energy transfer within food webs is mediated by these primary consumers (Sánchez *et al*., 2024), thus playing a significant role in nutrient cycling with much influence on phytoplankton dynamics (Richon and Tagliabue, 2021; Ratnarajah *et al*., 2023). These processes contribute to the overall ecosystem productivity and biogeochemical processes in aquatic ecosystems (Lomartire *et al*., 2021; Karakuş *et al*., 2022). The diversity and abundance of zooplankton are essential indicators of ecosystem health (Muñoz-Colmenares *et al*., 2021; Choi *et al*., 2023). High zooplankton diversity often reflects a stable and healthy environment whereas changes in their populations can indicate environmental stressors such as pollution or habitat degradation (Kumar *et al*., 2018; Bakhtiyar *et al*., 2020). Studies on zooplankton biodiversity in freshwater are needed to provide relevant information on species richness, ecological interactions which a required for proper ecosystem conservation and management (Xiong *et al*., 2020). More so, zooplankton are vital for fisheries and aquaculture as they serve as a major food source for juvenile fish and their population dynamics can affect fish productivity (Karakuş *et al*., 2022). They are important for the effective management of fishery resources (Shao *et al*., 2019). Zooplankton are sensitive to changes in environmental variables such as nutrient availability, temperature, and dissolved oxygen. This makes them bioindicators for assessing water quality and detecting pollution (Arazu & Ogbeibu, 2017). Their swift response to shifting water conditions makes them dependable tools for monitoring ecosystem health (Li *et al*., 2022). A proper understanding of zooplankton abundance and diversity is therefore necessary for advancing ecological research which is a gateway to biodiversity protection in order to ensure the sustainable management of aquatic ecosystems.

The water quality parameters in freshwater ecosystems play significant role in maintaining ecological health, supporting fisheries, ensuring safe water for human consumption, and sustaining economic activities (Sun *et al*., 2021; Omokaro *et al*., 2024). Freshwater bodies are critical for life and serve as critical habitats for a variety of aquatic organisms including zooplankton species of significant economic and ecological value (Iyiola *et al*., 2022). Some of these parameters such as temperature, dissolved oxygen (DO), pH, turbidity, and nutrient levels are crucial in establishing the health and productivity of these ecosystems (Opadokun *et al*., 2015; Uzomah *et al*., 2021). Water quality has a direct influence on the growth, reproduction, and survival of zooplankton species (Malik *et al*., 2020). Changes in physical and chemical parameter, for instance reduced DO or extreme pH fluctuations can impair physiological processes in these primary consumers (Zhang *et al*., 2024). This by implication leads to reduced population sizes and diminished fishery yields. Increase in nutrient levels can equally lead to eutrophication with a resultant effect of algal blooms that deplete oxygen thereby disrupting food chains (Glibert, 2017; Devlin and Brodie, 2023). Thus, the survival of aquatic fauna and other organisms are threatened. Apart from ecological implications, poor water quality affects socio-economic benefits derived from fisheries. Polluted freshwater ecosystem often experience the collapse of fish stocks with a negative implication on the livelihoods of communities that depend on fishing for income and food security (Andrews *et al*., 2021). Despite numerous researches (Adadu *et al*., 2019; Barau *et al*., 2020; Shima *et al*., 2023) on plankton communities in freshwater ecosystems in the North Central Nigeria, studies focusing Katsina-Ala tributary of River Benue on the abundance and diversity of zooplankton however remain scarce which prevents the ability to monitor changes in water quality and assess ecological health effectively. The current study aims to assess the abundance and diversity of zooplankton of the River at Kwantan-Sule and equally evaluate its water quality parameters. These findings will contribute to understanding the ecological status of the water body and its potential for fisheries development. Moreover, the study serves as a reference point for future monitoring and research in Nigerian freshwater systems.

MATERIALS AND METHODS

Study Location

The study was conducted in River Katsina-Ala one of the major tributaries of River Benue. It is located between latitude 7^0 38' and 7^0 52' N and longitude 8^0 50' and 9^0 05' E. It runs from Katsina – Ala through Buruku and Guma Local Government Areas of Benue State and empties into the Lower River Benue (Dam *et al*., 2020). The River experiences tropical climatic condition, with distinct wet and dry seasons (Iwar *et al*., 2023). It is used for fishing and domestic activities and it also serves as means of transportation for the surrounding populace.

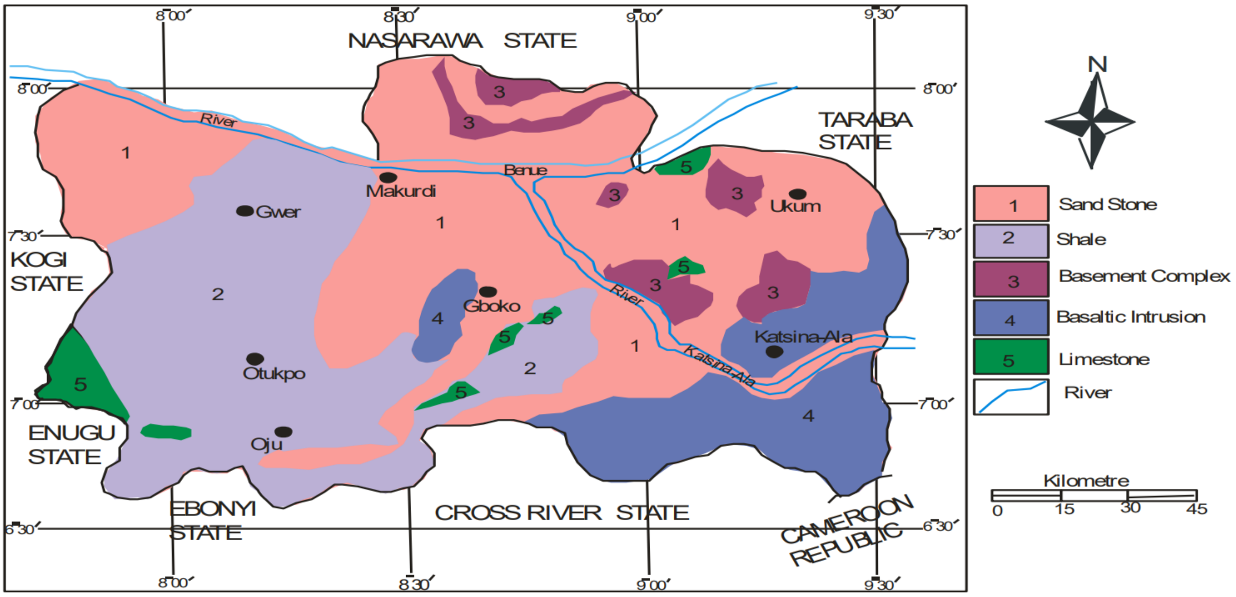

Figure 1: Geology Map of Benue State

Source: Imadojemu and Apelebiri (2024).

Sample Collection

A purposive sampling method was used to collect zooplankton samples for 4 weeks between Ocotober and November, 2017 at Kwantan-Sule landing site of River Katsina-Ala. Zooplankton were sampled twice a week giving a total of 8 samplings. Samples were collected in the morning (before 8:00 am) using 55 µm mesh size standard plankton net by dragging the net through water at a distance of 5 m according to Dimowo (2013). The plankton net used was conical in shape with an area of 108 m^2. By dragging through a distance of 5 m, the volume of water filtered was 540 m^3 (540,000 litres). The samples were transferred into 250 ml labeled plastic bottles and preserved with 4% formalin solution for analysis (Kelso *et al*., 2012). Samples were transported to the Multipurpose Laboratory in the Department of Fisheries and Aquaculture, Federal University of Agriculture, Makurdi. In the laboratory, zooplankton samples were centrifuged using a Gallen Kamp-medico Centrifuge according to Solomon *et al*. (2009). Centrifuged samples were taken using a pipette and 2 drops (cm^3) of the zooplankton sample were placed on a glass slide and covered and viewed for identification under a light microscope using zooplankton identification key by Lynne (2004)

Zooplankton Abundance and Diversity Analyses

Zooplankton abundance was calculated as number of organism per m^3 using the formula;

$$\text{Density} = \frac{\text{N x 100}}{\text{Initial volume of water filtered}} \quad \text{(Ogbeibu and Obanor, 2002)} \qquad (1)$$

Where N = number of organism per sample.

The Shannon-Weiner, Simpson and Margalef indices were used to analyze the diversity and structure of zooplankton in the river according to Sina and Zulkarnaen (2019). The Shannon-Weiner index was calculated to assess overall species diversity. This index accounts for both the species richness and their relative abundance, which gives higher values in ecosystems with many evenly distributed species. The formula is given as:

$$H' = \sum_{i=1}^{s} pilnpi \quad (2)$$

where H` is the species diversity index, S is the number of species, and pi is the proportion of individual, of each species belonging to the i^{th} species of the total number of individuals.

The Simpson's Index was also utilized to measure species dominance;

$$D = \sum_{i=0}^{s} pi^2 \quad (3)$$

S - species richness

pi - proportion of species

Where values closer to 1 indicate lower dominance, which implies greater evenness within the ecosystem. This index assessed whether certain species were particularly dominant or if there was a more balanced species distribution. The Margalef's Richness index was further used to estimate species richness by normalizing the species count against the total number of individual fish. A higher score of Margalef's index shows a richer community of species. The formula is given as:

$$D_{ma} = \frac{S-1}{ln\ N} \quad (4)$$

S – species richness

N – total abundance

Water Quality Parameters

The physico-chemical parameters of River Katsina-Ala was determined both *in-situ* and *ex-situ*. A Multi-parameter water quality monitor (PHT-027) was used to measure hydrogen ion concentration and electrical conductivity (µS/cm) *in-situ* at the sampling station. Temperature (^{0}C) was measured using an alcohol in glass thermometer (0 – 100^{0}C) while secchi disc was used to determine water transparency (cm). Water samples were collected into pre-washed and sterilized plastic bottles for laboratory analysis. Standard procedures were then used to analyze the samples for a variety of other chemical parameters (APHA, 1998).

Statistical Analysis

Zooplankton percentage abundance, diversity indices and analysis of variance of water quality parameters were performed using Minitab Application.

RESULTS

A total of 144 zooplankton individuals were identified during the study period comprising of 12 species from 6 classes (Table 1). The zooplankton species included 4 species of class cladocera (*Bosmina*, *Ceriodaphia*, *Daphnia* and *Diaphanosoma*), 2 copepods (*Branchipus* and *Diaptomus*), 2 species from the class ephemerophyta (*Baetis* and *Stenonema*) and 2 dipteran species (*Chironomus* and *Simulium*) were identified. Also identified was 1 species each from the classes Arachnida (*Argyroneta*) and Protozoa (*Paranema*). The class cladocera was dominated by *Daphnia* (53.73 %), followed by *Bosmina* (22.39 %), *Diaphanosoma* (13.43 %) and then *Ceriodaphnia* (10.45 %). Diptera was dominated by *Chironomus* (52.94 %), followed by *Simulium* (47.06 %). The class copepoda was dominated by *Branchipus* (63.16 %), followed by *Diaptomus* (36.84 %) while class ephemerophyta was dominated by the species *Stenonema* (57.14 %), followed by *Baetis* (42.86%). Some of the zooplankton identified during the study period are presented in figure 2. Results from Figure 3 showed that the class cladocera were most prevalent (46 %), followed by diptera (24 %), copepoda (13 %), ephemerophyta (10 %), arachnida (4 %) and protozoa (3 %).

Table 2 shows a comprehensive data on the richness and distribution of zooplankton species in River Katsina-Ala. The Shannon-Weiner index of 2.286 recorded showed a moderate zooplankton species diversity which indicates a balanced distribution in the ecosystem. This value indicates the ability of the river to support a considerable number of fish species with each species occupying a specific ecological niche. The Simpson index (1-D) recorded for the study was 0.875 which suggested a low species dominance, where no single species disproportionately influenced the community structure. The Margalef Richness index of 2.213 indicated low species richness. Figure 4 shows weekly variations in diversity indices where the highest diversity was recorded during Week 3 which could be linked to optimal dissolved oxygen (DO) levels and moderate temperatures.

Table 1: Abundance and Composition of Zooplankton population

S/N	Class	Species	Weeks				Total Abundance cm^3	% Abundance
			1	**2**	**3**	**4**		
1.	Cladocera		12	23	15	17	67	
		Bosmina	3	4	0	8	15	22.39
		CerioDaphnia	0	4	3	0	7	10.45
		Daphnia	7	15	9	5	36	53.73
		Diaphanosoma	2	0	3	4	9	13.43
		Total percent						**100**
2.	copepoda		4	3	8	4	19	
		Branchipus	0	0	8	4	12	63.16
		Diaptomus	4	3	0	0	7	36.84
		Total percent						**100**
3.	Ephemerophyta		3	1	7	3	14	
		Baetis	0	1	5	0	6	42.86
		Stenonema	3	0	2	3	8	57.14
		Total percent						**100**
4.	Diptera		0	7	13	14	34	
		Chironomus	0	6	4	8	18	52.94
		Simulium	0	1	9	6	16	47.06
		Total percent						**100**
5.	Arachnida		0	4	2	0	6	
		Argyroneta	0	4	2	0	6	100
		Total percent						**100**
6.	protozoa		4	0	0	0	4	
		Paranema	4	0	0	0	4	100
		Total percent						**100**
Total	**6**	**12**	**23**	**38**	**45**	**38**	**144**	

a b c

d e f

Figure 2: A Cross section of some identified zooplankton species

Hint: a-Copepoda: *Branchipus,* b-Diptera: *Simulium*, c-Cladocera: *Daphnia*, d- Ephemeroptera: *Baetis*, e- Ephemeroptera: *Stenonema*, f- Cladocera; *Ceriodaphnia*

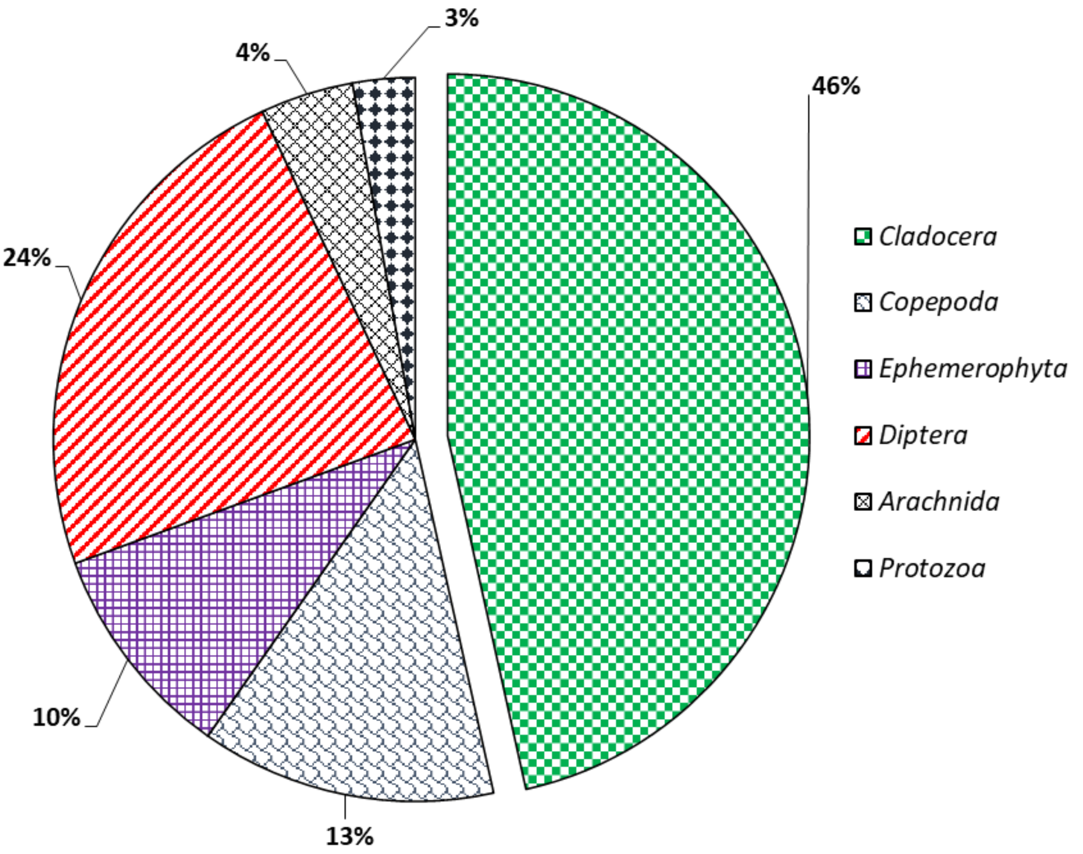

Figure 3: Percentage composition of zooplankton classes of River Katsina-Ala at Kwantan-Sule

Table 2: Diversity Indices of Zooplankton of River Katsina-Ala at Kwantan-Sule

Diversity Indices	Sampling Period				
	Week 1	**Week 2**	**Week 3**	**Week 4**	**Total**
Taxa S	6	8	9	7	12
Individuals	23	38	45	38	144
Dominance D	0.194	0.221	0.144	0.159	0.124
Simpson 1-D	0.805	0.778	0.855	0.840	0.875
Shannon H	1.714	1.761	2.048	1.889	2.286
Evenness	0.925	0.964	0.861	0.944	0.819
Margalef	1.595	1.298	2.102	1.649	2.213
Equitability J	0.956	0.847	0.932	0.970	0.919
Berger Parker	0.304	0.394	0.200	0.210	0.250

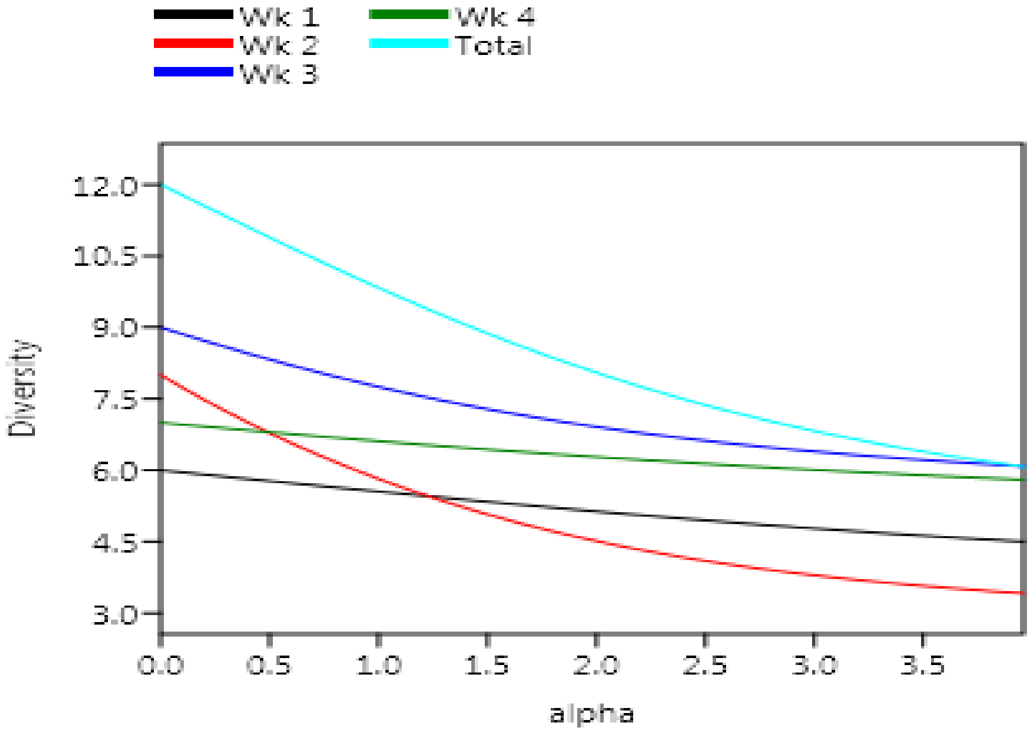

Figure 4: Weekly zooplankton species diversity

The values of water quality parameters are presented in Table 3. The surface water temperature of the water body ranged between 26.50±0.50 ^{0}C and 28.50±0.05 ^{0}C for Week 1/Week 4 and Week 2, respectively with no significant variation (P > 0.05). The mean surface temperature recorded during the period was 27.23±0.23 ^{0}C. Dissolved oxygen levels ranged from 5.05±0.15 mg/L in Week 4 to 5.80±0.10 mg/L in Week 1, with a mean value of 5.45±0.00 mg/L. There was a statistically significant differences across the sampling months (P = 0.02). The pH values of the study showed a statistical difference (p < 0.01). The highest value was recorded in Week 4 (8.20±0.04) while the lowest value was recorded in Week 1 (7.38±0.03) with a mean value of 7.80±0.01. Electrical conductivity fluctuated significantly across the months (p < 0.01) with the least value recorded in Week 2 (26.50±0.50 µS/cm) while the highest value was recorded in Week 4 (35.00±1.00 µS/cm) with a mean of 29.75±0.25 µS/cm. Water transparency varied significantly (p < 0.01) from 31.25±0.75 cm in Week 1 to 47.50±1.50 cm in Week 4 with a mean of 37.06±0.06 cm. A mean value of 2.10±0.10 mg/L was recorded for biochemical oxygen demand (BOD) with the least value recorded in Week 4 (1.70±0.20 mg/L) while the highest value was recorded in Week 3 (2.35±0.05 mg/L). Significant differences were noted across the months (p = 0.05) which indicated variations in organic matter decomposition. Similarly, there was statistically significant variation (p = 0.05) in the values recorded for total hardness. The lowest value of 0.09±0.00 mg/L recorded in Week 1 while the highest value of 0.13±0.01 mg/L Week 2, with a mean of 0.11±0.00 mg/L.

Table 3: Water Quality Parameters of River Katsina-Ala at Kwantan-Sule

Water Quality Parameters	Mean	Sampling Period				P-Value
		Week 1	Week 2	Week 3	Week 4	
Temperature (^oC)	27.23±0.23	26.50±0.50	28.50±0.50	27.45±0.45	26.50±0.50	0.11^{ns}
Dissolved Oxygen (mg/L)	5.45±0.00	$5.80±0.10^{a}$	$5.70±0.10^{ab}$	$5.27±0.07^{bc}$	$5.05±0.15^{c}$	0.02
Biochemical Oxygen Demand (mg/L)	2.10±0.10	$2.25±0.05^{a}$	$2.10±0.10^{ab}$	$2.35±0.05^{a}$	$1.70±0.20^{b}$	0.05
pH	9.80±0.01	$9.38±0.03^{c}$	$9.75±0.05^{b}$	$9.89±0.04^{b}$	$10.20±0.04^{a}$	<0.01
Electrical Conductivity (µS/cm)	29.75±0.25	$28.00±1.00^{b}$	$26.50±0.50^{b}$	$29.50±0.50^{b}$	$35.00±1.00^{a}$	<0.01
Transparency (cm)	37.06±0.06	$31.25±0.75^{c}$	$32.25±1.25^{c}$	$37.25±0.75^{b}$	$47.50±1.50^{a}$	<0.01
Total Hardness (mg/L)	0.11±0.00	$0.09±0.00^{b}$	$0.13±0.01^{a}$	$0.12±0.01^{ab}$	$0.12±0.00^{ab}$	0.05

Means on the same row (sampling period) with different superscript are statistically significant (p<0.05

DISCUSSION

The zooplankton community of River Katsina-Ala at Kwantan-Sule is moderately diverse. The class Cladocera was most dominant with *Daphnia* occurring most. This means that this group of zooplankton were well adapted to the environmental variables of the river. The filter-feeding behaviour of *Daphnia* and the ability of the species to thrive in habitats with adequate phytoplankton availability could be the reason for its predominance (Beisner and Thackeray, 2024). The result of the current study corroborates the findings of Barau *et al*. (2020) in the upper Benue River at Mayo-Ranewo, Taraba State where copepods were dominant because of the presence of macrophytes and favourable water conditions. Similarly, the zooplankton assemblage in River Katsina-Ala at Kwantan-Sule also agrees with findings in other Nigerian rivers such as River Niger (Arazu & Ogbeibu, 2017) and River Ogun (Dimowo, 2013) where the class Cladocera and Copepoda were dominant. The absence of Rotifera in this study is however dissimilar with findings from Dimowo (2013) in River Ogun and Adudu *et al*. (2019) in River Okpokwu in Benue State where Rotifers, particularly the genus *Brachionus*, were dominant. The explanation to this discrepancy may be as a result of the differences in nutrient input as Rotifers have been reported to thrive in nutrient-rich waters, whereas River Katsina-Ala appeared to have limited nutrient availability, thus reducing their presence. The presence of Diptera specifically *Chironomus* could be due to the presence of substantial organic matter levels in the river. Chironomid larvae are often associated with detrital environments which suggests some amount of organic enrichment (Martins *et al*., 2021). This finding agrees with Barau *et al*. (2020), who reported a significant presence of pollution-tolerant genera in the Benue River system. Nevertheless, the non-existence of significant pollution indicators like Rotifers in this study could be due to relatively low organic pollution compared to the River Okpokwu, where nutrient levels supported higher zooplankton abundance during the dry season (Adudu *et al*., 2019).

Diversity indices provide in-depth comprehension into the health of the freshwater ecosystem and zooplankton community structure. The value recorded for Shannon-Weiner index showed moderate diversity with an even distribution of species which is a representation of a stable ecosystem capable of supporting numerous trophic interactions. Comparatively, Shima *et al*. (2023) recorded slightly higher diversity indices in the Lower River Benue which could be due to wider variations in environmental variables and habitat complexity. Furthermore, the Simpson index recorded in this study indicated low species dominance which is a shows balanced ecosystem. The moderate Margalef richness index recorded however showed that species richness in the ecosystem is limited. It could be that environmental or anthropogenic factors may be acting against zooplankton species recruitment in the river. The weekly variations in diversity were highest in Week 3 which could be influenced by increased dissolved oxygen levels and moderate temperatures. Weinstock *et al*. (2022) stated that zooplankton diversity is better enhanced under favorable conditions. In a reversed trend, the lower diversity recorded in Week 1 may be associated with reduced dissolved oxygen. This means that the zooplankton species in the river were sensitive to fluctuations in environmental variables.

Water quality parameters have been reported to have influence on zooplankton abundance and diversity. The temperature range during the study period was within the optimal limit for reproduction and survival of zooplankton. This finding corroborates findings by Opadokun *et al*. (2015), who asserted that similar temperature ranges in Lekki Lagoon were responsible for improved plankton productivity. The dissolved oxygen levels were also adequate for aquatic life to thrive even though the varied levels had influence on zooplankton diversity. Shima *et al*. (2023) reported a positive correlation between dissolved oxygen and plankton abundance in the Lower River Benue, affirming its critical role in maintaining aquatic ecosystems. The pH levels recorded were also optimal for the zooplankton to survive. Barau *et al*. (2020) and Adudu *et al*. (2019) however, reported lower ranges of pH which supported higher zooplankton diversity. Electrical conductivity range in the river showed the ionic concentrations were moderate and suitable for zooplankton communities. Also, the water transparency recorded during the study period signifies moderate productivity and light penetration. These factors are essential for phytoplankton growth which serve as food for zooplankton (Opadokun *et al*., 2015).

Conclusion

The findings of the study provided information on the abundance and diversity of zooplankton and water quality of River Katsina-Ala. The river has moderate zooplankton species diversity and a balanced species distribution. The favourable dissolved oxygen and temperature levels shows that the ecosystem is stable and is capable of supporting aquatic life. This is reflected in the dominance of Cladocera and Diptera. The peculiar absence of Rotifers in the river and the moderate richness index could mean that there is low availability.

Recommendation

There is need to conduct an elaborate temporal and spatial assessment of the zooplankton community for comprehensive documentation of the ecological status of River Katsina-Ala. Continuous monitoring of the ecosystem is also necessary to detect early signs of ecological changes which could stem from anthropogenic activities such as nutrient runoff and organic pollution.

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