



Research Paper

Seasonal Dynamics of Zooplankton Assemblages in Relation to Physicochemical Characteristics of River Rima, Sokoto State, Nigeria

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How to Cite

Musa, R. & Haliru, J. (2026) Seasonal Dynamics of Zooplankton Assemblages in Relation to Physicochemical Characteristics of River Rima, Sokoto State, Nigeria. *Journal of Fisheries and Zoological Sciences*, 1(4), 15-21. <https://doi.org/10.65385/JFZS0026>

ISSN: 3108-1991 (online)

Article History

Received 15 August 2026

Accepted 30 September 2026

First Online 12 October 2026

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Keywords

Physicochemical
Seasonal Variation
Zooplankton
Taxa
River Rima

Abstract

This study was conducted in Kwakwalwa area of River Rima Sokoto, Sokoto state, Nigeria. It aimed at assessing abundance of zooplankton and its relationships with some physicochemical parameters. Three sampling stations were identified as station A (shoreline site), B (Fishing activities area) and C (Farming and irrigation site). The sampling was carried out monthly, between April 2018 to March 2019. The mean average of seasonal physicochemical parameters were, DO (4.41 mg/L), water temperature (27.03 °C), pH (6.83), TDS (6.0 mg/L), Turbidity (19.58 cm), EC (127.05 µS/cm), phosphate (0.19mg/L) and nitrate (1.01 mg/L). The difference in physicochemical parameters between the three stations of the river was not significant except for turbidity, where there were significant ($P < 0.05$) differences between stations B (20.39) and C (25.71). Nine species of zooplankton were discovered which includes 2 species of each from Rotifera and Cladocera and 5 species of Copepoda. The percentage relative abundance of each zooplankton groups from all the seasons recorded was in the following order, Copepods > Rotifers > Cladocerans. Further studies are warranted on the continuous monitoring of this water body to know the future impact of climate change on distribution of zooplankton which can help to identify the sensitive and sentinel species to formulate the effective conservation strategies.

1. Introduction

Tropical rivers characteristically tend to show seasonal fluctuations in surface water levels due to changes in their hydrological regimes (Joshua et al., 2018). In the tropics, seasonal variations in meteorological variables directly affect the physical and chemical composition of river ecosystems (Mandal et al., 2021). For example, during the dry season, water volume typically decreases due to high evaporation rates, which consequently reduces dissolved oxygen solubility and elevates solute concentrations (Lidon et al., 2018). These dynamics in physicochemical variables critically affect zooplankton communities and other resident aquatic biota (Makwinja et al., 2021). Despite their ecological importance, studies on tropical rivers remain limited (Kayitesi et al., 2022). While a few historical studies, such as Edema et al. (2002), demonstrated that seasonal variations in hydrobiology are driven by fluctuations in water levels, a significant knowledge gap persists regarding how seasons and specific physicochemical parameters interact to influence zooplankton diversity, composition, and abundance in freshwater ecosystems (Ismail et al., 2022).

Owing to the seasonal distribution of rainfall, River Rima experiences periodic flooding, which introduces significant amounts of terrestrial detritus and pollutants. Furthermore, the river serves as a major drainage channel, receiving domestic waste and industrial effluents from surrounding areas. Despite these pressures, River Rima plays a vital socioeconomic role for local communities, supporting activities such as fishing, bathing, laundry, car washing, and waste disposal. These anthropogenic disturbances, coupled with seasonal fluctuations in water levels, strongly influence water quality parameters and can drastically alter the ecosystem's trophic state (Yakubu et al., 2000). Because zooplankton respond rapidly to even minor fluctuations in the physical and chemical conditions of their environment, they serve as ideal bioindicators for evaluating seasonal impacts on water quality and trophic dynamics (Zhao et al., 2019). Zooplankton occupy a pivotal position in aquatic ecosystems, serving as a critical energetic link between primary producers (phytoplankton) and higher trophic levels, such as fish (Gajbhiye, 2002).

Because individual species exhibit different responses to environmental disturbances, their occurrence and abundance are increasingly recognized as useful indicators of ecosystem condition (López & Sedeño, 2015). The productivity and community structure of zooplankton are governed by complex interactions between physicochemical conditions and biological processes, with environmental factors playing an important role in determining the composition of zooplankton assemblages (Mustapha, 2010). Therefore, investigating zooplankton communities in shallow tropical freshwater systems such as the Rima River is important for establishing appropriate ecological management strategies, evaluating water quality, and supporting sustainable fisheries. In this context, the present study provides baseline information on the zooplankton community of the Rima River and examines its association with prevailing water-quality conditions in the Kwalkwalwa area. Specifically, the study aimed to assess seasonal changes in physicochemical parameters and determine their influence on the taxonomic composition, abundance, and diversity of zooplankton in the Rima River, Sokoto State.

2. Materials and Methods

2.1 Study Area

The study was carried out in three stations of Kwalkwalwa area of River Rima in Wamakko Local Government Area of Sokoto state, Nigeria. Sokoto lies between longitudes 408'E and 605'E, and latitudes 120N and 13058'N (Mamman, 2000). The climate of Sokoto is tropical continental, with much of the rains between June and September, while the long dry season is from October and May (Umar and Ismaila, 2017). River Rima flows in a South-western direction over 100km and joins the major River Sokoto to form the Sokoto-Rima river system. The Sokoto-Rima River Flows South-westerly in a direction up to Zogirma, where it changes direction and run southwards before emptying into River Niger (Shinkafi and Ipinjolu, 2010; Shinkafi and Ipinjolu, 2012; Shinkafi *et al.*, 2013). The River is seasonal, usually over flooding its banks during the rainy season in August and September, and up to October at times (Mock *et al.*, 1963).

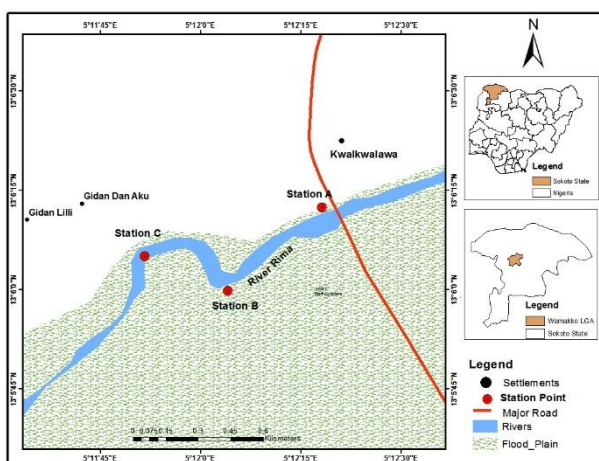


Figure 1: A map showing sampling stations

2.2 Sampling Design

After the preliminary survey of River Rima in Kwalkwalwa area for sampling collection, three sampling stations (A, B and C) were selected randomly. Two seasons were observed (dry and rainy season). The sampling points were identified and marked using a geographical positioning system (GPS).

STATION A: shoreline with high concentrations of human and livestock activities such as consumption, washing, bathing and other domestic activities, with the following coordinates;

(Latitudes 13°7'.236N, longitudes 5°12.356'E, and Water depth 0.68m)

STATION B: Fishing activities area, with (Latitude 13°7.138'N, longitude 5°13. 075'E and Water depth 2.43 m).

STATION C: as well as areas where run-off from where all seasonal agricultural activities are concentrated or Farming and irrigation, (latitude 13°7.114'N, longitude 5°12.125'E and Water depth 0.93m).

2.3 Samples Collection

Sampling at the selected stations was carried out monthly, for period of one year. Water and zooplankton were collected from these sampling stations for the period of the study. The plankton and water sample were collected from the selected stations in the river for 12 months. Samples were collected every month in the morning hours (6.00 A.M to 7.00 A.M).

2.3.1 Water Sample Collection

Water samples were collected in one litre capacity plastic bottles, between 6 to 7 am, from all the sampling locations, for a period of 12 months. The bottle was immersed into the river to collect water at the hypolimnion layer early in the morning. Temperature, pH and turbidity of the water were measured immediately at the field. Water sample collected was taken to Agrichemical laboratory Usmanu Danfodiyo University, Sokoto, for the determination of dissolved oxygen (DO), Conductivity, presence of Total Dissolved Solids (TDS), Nitrate – Nitrogen (NO_3^-) and Phosphate – Phosphorus (PO_4^{3-}) (Magami *et al.*, 2015).

2.3.1.1 Determination of Temperature

Glass mercury thermometer was dipped into each of the plastic containers containing the river water samples immediately the water was collected from the sampling station. The mercury level on the thermometer was raised and when the indicator reached a stable position, the value of the temperature reading(s) was observed and recorded in degrees centigrade (°C) (APHA and Wef, 1998). The process was repeated in triplicate and an

average was taken to minimize the error.

2.3.1.2 Determination of Hydrogen-ion-concentration (pH)

pH electrode of digital pH meter was calibrated into buffer solution of pH, the Calibration was done by wiping the electrode with a dry cotton wool after removing it from the beaker of distilled water in which it suspends. It was then being put into the buffer solution and the pH meter was switched on and adjusted gently using the slope until the reading was exactly 7.00. The meter was switched off and the electrode removed from the buffer solution, rinsed with distilled water, and wiped again with piece of dry cotton wool. The pH meter was then dipped into the river water sample(s) and then switched on. The reading of the pH meter was recorded when it stopped reading the pH of the water (APHA, 1998). The process was repeated for each of the river water sample while determining its pH value, with calibrated electrode each time rinsed with the distilled water and wiped with a piece of dry cotton wool before taking pH reading of another sample (APHA and WEF, 1998).

2.3.1.3 Determination of Turbidity

Turbidity of water samples was determined using Secchi disc of 25 cm by disappearance and reappearance method. The turbidity was computed according to Hilt et al. (2013).

2.3.1.4 Determination of Electrical Conductivity (EC)

Glass electrode of electrical conduct meter was rinsed with distilled water and then wiped with a dry cotton wool piece. It was then dipped into the river water sample and the conduct meter switched on. The reading of the water was recorded after it stopped reading. The meter was then switched off and the electrode was removed from inside the river water, rinsed with distilled water and wiped with dry cotton wool before being dipped into another sample for measuring the electrical conductivity. The procedure was repeated for each river water sample (APHA and WEF, 1998).

2.3.1.5 Determination of Total Dissolve Solids (T.D.S)

A clean dry and empty evaporating dish was weighed and its constant weight was recorded as (W_1) g. Fifty centimeter (50cm^3) of the water sample was poured into the dish (the water was filtered before pouring in to the dish). The dish was then placed in to a water bath and water was allowed to evaporate. The dish was then placed in the oven (at 100°C) for 5 minutes and transferred to a desiccator where it was left for another 5 minutes and finally reweighed. The weight was recorded as (W_2) g (APHA and WEF, 1998).

Weights of the total dissolve solids (TDS) in Mg/L

$$TDS = \frac{(W_2 - W_1) \text{g} \times 1000}{V}$$

2.3.1.6 Determination of Dissolved Oxygen (DO)

200 ml of water sample was carefully transferred into a conical flask. 1 ml of manganese sulphate solution was added followed by 1 ml of alkaline azide reagent. The resulting mixture was titrated against 0.025 N sodium thiosulphate to the end point where there was color change. The titre value was recorded as DO (APHA and WEF, 1998).

2.3.1.7 Determination of Nitrates

For nitrate, 50 ml of water sample and 4 ml of salicylic acid/sulphuric acid were added in the digestion flask and swirled thoroughly to achieve homogenous mixture. 0.5 g of sodium thiosulphate was added and the mixture was heated cautiously until frothing has ceased. 1.1 g of potassium sulphate catalyst mixture was added and heated until the digestion mixture became clear. The mixture was boiled for up to 2 hours. It was ensured the temperature did not exceed 400°C . The digested mixture was allowed to cool and 20 ml distilled water was added slowly while shaking. 10 ml of boric acid was added, diluted with 20 ml distilled water and the flask was placed under the condenser of the distillation apparatus. 20 ml of sodium hydroxide was added through the funnel of the apparatus. About 50 ml of condensate was distilled and a few drops of Boric acid indicator added. This was titrated with 0.01 mol/L sulphuric acid to a violet end point. The titre values were recorded and used to calculate nitrate content (AOAC, 2003)

Concentration of NO_3^- in Mg/L was calculated using the following relationship.

$$\text{Nitrate} = \frac{\text{Average titre value} \times 1000}{V}$$

2.3.1.8 Determination of Phosphate (PO_4)

2 ml of water sample was measured in a 50 ml volumetric flask was added and 2ml of PO_4 extract was added followed by 2 ml of ammonium molybdate and then 1 ml of freshly diluted stannous chloride solution. These were made up to 25 ml volume with distilled water and mixed thoroughly. After 5 - 6 minutes and before 20 minutes, the colour intensity (absorbance) was measured at a wavelength of 660 nm in a Spectrophotometer (AOAC, 2003)

$$\text{PO}_4 = \frac{\text{Abs} \times 0.61 \times 25}{30.97}$$

2.3.2 Zooplankton Sample Collection

Standard plankton net was used. It's conical in shape and has a net ring made up of stainless-steel round in shape with mouth size of 25cm in diameter. A nylon material was attached to it (which is the filtering area of the net). The harvest net with a cup attached to its end was towed vertically over the river water to collect the sample. The content was then transferred into 100ml

plastic bottles and was fixed using 5% of formalin (10 ml), the aqueous solution of formaldehyde to preserve the zooplankton (Goswami, 2004). The bottles were kept in cooler boxes and transported to the Biological science laboratory Usmanu Danfodiyo University, Sokoto, for identification of zooplankton (Magami *et al.*, 2014; Magami *et al.*, 2015; Maishanu *et al.*, 2018).

2.3.2.1 Zooplankton Identification

For taxonomic identification, the plankton was identified by referring the (Dhanapathi, 2003; Dussart, 1995; Reddy *et al.*, 1994 and Michael and Sharma 1988). Different groups of zooplanktons were segregated and separated under a binocular stereo zoom dissection microscope using a fine needle and brush. Individual species of plankton was mounted on microscopic slides with a drop of 20% glycerin after staining with eosin and rose Bengal. The identification of zooplankton was made referring the standard manuals, text books and monographs (Edmondson, 1959; Sharma *et al.*, 1987; Altaff, 2004). Using a compound microscope and photomicrograph with Inverted Biological Microscope for quantitative zooplankton study, A sedge-wick rafter cell was used which is 50 mm long, 20mm wide and 1mm deep. 1 ml of zooplankton sample was transferred to the cell with a dropper. The air bubbles were avoided while transferring the sample to the cell. Before counting the zooplankton, it was ensured that all the organisms have settled down and counted under light microscope. At least 3 such counting was made for each group. The average values were taken of each month for one year, (i.e., during 2018-2019). Total number of plankton present in 1 litre of water sample was calculated (Santhanam *et al.*, 1989) using the following formula:

$$N = n \times v / V$$

Where,

N = Total number of plankton per liter of water filtered

n = Average number of plankton in 1 ml of plankton sample

v = Volume of plankton concentrated (ml) and

V = Volume of total water filtered (liter)

The population of each group of zooplankton was expressed in average, number of individuals per litre (ind./l) APHA (2005).

2.4 Statistical Analysis

Seasonal Variation of zooplankton taxa abundance and Physicochemical Parameters data were subjected to statistical analysis through one-way ANOVA in each of the station and subsequent post hoc multiple comparison with DMRT by adopting SPSS (v20.0). A multiple regression analysis was used to investigate the cause and effect between the zooplankton abundance and physico-chemical parameters. The $P < 0.05$ were considered statistically significant by 95%.

3. Results

3.1 Physicochemical analysis

The result of Physicochemical Parameters of the sampling Stations is presented in Table 1. Based on the species composition and abundance of zooplankton as effects by physico-chemical parameters, the means of physicochemical did not differ for the three (3) studied stations except for turbidity, where there was significant ($P < 0.05$) differences between sites B (20.39) and C (27.91). This is likely due to human activities such as logging, transportation of farm produce, fishing, laundry, irrigation and bathing which have added to the turbidity experienced in station A and C.

3.2 Zooplankton Taxa abundance in River Rima, Kwakwalwa area

Totally, 9 species of zooplankton were recorded during the study period (Tables 3). Of these, 2 species were contributed by Rotifera, 2 Cladocera and 5 Copepoda. Under the phylum Rotifer, the identified species were *Filinia longiseta* and *Asplanchna intermedia*. The Cladocerans were *Moina brachiate* and *Moina micrura*. The Copepods identified were *Heliodiaptomus viduus*, *Eucyclops speratus*, *Mesocyclops hyalinus*, *Mesocyclops leuckarti* and *Thermocyclops hyalinus*.

4. Discussion

4.1 Physicochemical Parameters of the sampling Stations

The physico-chemical parameters of zooplankton communities together form a comprehensive ecosystem and there is interaction between the zooplankton and those physico-chemical parameters. These interactions are directly or indirectly subjected to the complex influences (Basawarajeshwari *et al.*, 2015). The higher turbidity recorded from station C of the river is probably due to improper agriculture practices and fishing. Agricultural activities along the catchment of the river lead to erosion and hence high turbidity in the river from the runoff. High turbidity has been reported in Birim river basin in Ghana (Ansah and Asante, 2000)

4.2 Seasonal Variation of zooplankton taxa abundance

The zooplankton is a major factor of aquatic ecosystem and changes in their abundance, species composition and seasonal variation have cascading effects at higher trophic levels (Khalifa *et al.*, 2015). The most of researcher have been reported on the rise in zooplankton species richness in the lakes ecosystem (Khalifa *et al.*, 2015) on size and with of lake depth (Keller and Conlon, 1994). Zooplankton community structure is influenced strongly by biotic-abiotic factor (water temperature, competition and predation) in freshwater ecosystem Keller and Conlon, 1994). Similar to that of the present study, seasonal variation in zooplankton have been reported in number of freshwater bodies (Altaff, 2004; Manickam *et al.*, 2012; Manickam *et al.*, 2014).

Table 1: Physicochemical parameters of the sampling stations

Parameters	Sample stations			
	A	B	C	SE
Temperature (°C)	27.48 ^a	26.96 ^a	26.78 ^a	0.04
pH	6.97 ^a	6.91 ^a	6.74 ^a	1.76
DO (mg/l)	4.81 ^a	4.75 ^a	4.93 ^a	1.00
EC (µS/cm)	139.88 ^a	121.67 ^a	118.57 ^a	43.97
Turbidity (cm)	25.71 ^{ab}	20.39 ^b	27.91 ^a	0.01
TDS(mg/l)	5.83 ^a	5.75 ^a	6.43 ^a	2.22
Nitrate(mg/l)	0.96	0.98	0.94	1.23
Phosphate (mg/l)	0.15 ^a	0.19 ^a	0.18	0.62

Table 2: Seasonal Variation of zooplankton taxa abundance and percentage relative Abundance of River Rima, Kwalkwalwa area

Family and Species	Abundance (ind L-1) and Relative Abundance (%)				
	Early Wet Season (Apr' 2018- Jun' 2018)	Late Wet Season (Jul' 2018- Sep' 2018)		Early Dry Season (Oct' 2018- Dec' 2018)	Late Dry Season (Jan' 2019- Mar' 2019)
Cladocera	90 ^b (18.75%)	120 ^a (19.35%)		50 ^d (18.75%)	80 ^c (19.35%)
<i>Moina brachiata</i>	30 ^b (6.24%)	100 ^a (16.12%)		20 ^c (6.24%)	30 ^b (3.23%)
<i>Moina micrura</i>	60 ^a (12.51%)	20 ^d (3.23%)		30 ^c (12.51%)	50 ^b (16.12%)
Copepod	260 ^b (54.17%)	300 ^a (48.39%)		190 ^d (54.17%)	250 ^c (48.39%)
<i>Eucyclops speratus</i>	100 ^b (21.75%)	110 ^a (17.73%)		70 ^c (14.58%)	100 ^b (17.83%)
<i>Thermocyclops hyalinus</i>	40 ^b (9.46%)	70 ^a (11.27%)		20 ^d (6.25%)	30 ^c (6.44%)
<i>Heliodiaptomus viduus</i>	40 ^b (9.46%)	50 ^a (8.06%)		40 ^b (10.42%)	40 ^b (8.04%)
<i>Mesocyclops hyalinus</i>	50 ^a (11.42%)	30 ^c (4.83%)		30 ^c (8.33%)	40 ^b (8.04%)
<i>Mesocyclops leuckarti</i>	50 ^a (11.42%)	40 ^b (6.5%)		30 ^c (8.33%)	40 ^b (8.04%)
Rotifer	150 ^b (32.26%)	200 ^a (35.26%)		90 ^d (27.08%)	130 ^c (27.08%)
<i>Filinia longiseta</i>	60 ^b (13.22%)	120 ^a (20.67%)		50 ^c (14.48%)	60 ^b (12.5%)
<i>Asplanchna intermedia</i>	90 ^a (19.04%)	80 ^b (17.73%)		40 ^c (12.6%)	80 ^b (16.65%)

Table 3: List of zooplankton species recorded in River Rima, Kwalkwalwa area during the study period

Group	Family	Genus	Species
Cladocera	Moinidae (Goulden, 1968)	<i>Moina</i> Baird, 1850	<i>Moina brachiata</i> Jurine, 1820 <i>Moina micrura</i> Kurz, 1875
Copepoda	Diaptomidae (Baird, 1850) Cyclopoidae (Dana, 1853)	<i>Heliodiaptomus</i> Kiefer, 1932 <i>Eucyclops</i> Claus, 1893 <i>Mesocyclops</i> Claus, 1893 <i>Thermocyclops</i> Kiefer, 1927	<i>Heliodiaptomus viduus</i> Gurney, 1916 <i>Eucyclops speratus</i> Lilljeborg, 1901 <i>Mesocyclops hyalinus</i> Rehberg, 1880 <i>Mesocyclops leuckarti</i> Claus, 1857 <i>Thermocyclops hyalinus</i> Rehberg, 1880
Rotifera	Filiniidae (Bartos, 1959) Asplanchnidae (Harring & Myers, 1933)	<i>Filinia</i> Bory & Vincent, 1824 <i>Asplanchna</i> Gosse, 1850	<i>Filinia longiseta</i> Ehrenberg, 1834 <i>Asplanchna intermedia</i> Hudson, 1886

In the present study, the copepods dominated in terms of species number followed by rotifers. Copepods were dominant during the present study in both the four seasons in Kwalkwalwa area of River Rima. The dominance of copepods among zooplankton in fresh water has been also reported in Lake Victoria (Ngupula, 2013). Presently copepoda result was agreement with some earlier workers. (Sivakumar and Altaff, 2004; Manickam *et al.*, 2014). Some genera of copepod are cosmopolitan in distribution, while others are restricted to some continents (Brooks, 1959; Williamson, 1991). In the present study, the cyclopoids showed higher relative abundance in both the seasons compared to other zooplankton. Similar findings have been reported by Silva (1998) in Patricio *et al.* (2010); Waya and Mwambungu (2004) in Chilean inland waters and Lake Victoria respectively. *Cyclopoids* can survive in most kinds of fresh water habitats in the Neotropics. This can be explained by their feeding behavior; they are grasping feeders that generally eat variety of food than other zooplankton (Irvine and Waya, 1992), while the calanoids are limited by their selective and herbivorous nature. Dominance of rotifera in rivers was reports by Edema *et al.* (2002). In the present study, the dominance of rotifera may be attributed to pressure from planktivorous fishes that preferentially prey on micro-crustaceans. Rotifers appear to be protected from predation owing to their diminutive size, which offer low caloric value as prey besides being not easily visible to the predators. The increase in abundance of rotifera between early wet season and late wet season must have been prompted by increase in pH. Cladocera constituted the lowest contribution among all zooplankton in the present study. In contrast, Cladocera were among dominant taxa in Lake Nguru, Nigeria. (Edema *et al.*, 2002)). Low abundance of cladocera during the study may be associated with increase in predation by juvenile fishes and the fluvial nature of the river, which makes it difficult for a stable population to be established. Cladocera made very low contribution to the total zooplankton abundance in the early dry season. Adverse environmental condition, inter-specific competitions and predation by juvenile fishes may have been responsible for low abundance recorded by Cladocera in the late dry season. (Edema *et al.*, 2002) reported that cladoceran are more vulnerable to predation owing to their large size, conspicuous eyes and their mode of movement making them more attractive prey easy targets for capture.

4. Conclusion

Based on the analysis of zooplankton species composition and abundance as affected by physico-chemical parameters, the mean values of the physico-chemical variables did not differ significantly among the three studied stations, with the exception of turbidity. For turbidity, there was a significant difference ($P < 0.05$) between Station B (20.39 NTU) and Station C (27.91 NTU). Furthermore, this study concluded that copepods dominated in terms of species richness, followed by rotifers. Copepods remained dominant

across all four seasons in the Kwalkwalwa area of River Rima.

5. Statements and Declarations

Ethical Approval: Not applicable

Conflict of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding statement: No any Financial support

Acknowledgements: Not applicable

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