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Research Article

Physico-Chemical Properties and Species Diversity of Crustacean Zooplankton in Ikarama River, Yenagoa, Bayelsa State, Nigeria

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Abstract— This study was aimed at investigating the physicochemical properties and species diversity of crustacean zooplankton in Ikarama River. It was carried out from 16th of September to 18th of August. Four stations were examined consecutively, moving from a point higher up in the stream to a point lower down. The distance between each station was approximately 400 metres. The water was tested for seventeen different physicochemical parameters according to the AOAC's official techniques of analysis and the Standard Method for the Examination of Water and Wastewater. The Air and water surface temperatures results ranged from 28.0^{o}C to 29.5^{o}C. Transparency (1.8 m – 1.9 m) and Total suspended solids (70.5 mg^{-1}-75.0 mg^{-1}) showed inverse relationship. Depth ranged from 65 cm to 80 cm, while turbidity ranged from 50 NTU to 55 NTU. TDS ranged between 65 mg^{-1} and 72 mg^{-1}, total solids ranged between 6.1 mg^{-1} and 7.0 mg^{-1}. pH values ranged from 5.5 to 6.5. Dissolved oxygen value ranged from 8.5 mg^{-1} to 10.0 mg^{-1}, while the BOD_5 (2.9 mg^{-1} and 4.5 mg^{-1}) indicated no form of pollution or stress on the water body. Conductivity and chloride values ranged from 9.0 µscm^{-1} to 10.7 µscm^{-1} and 60.0 mg^{-1} to 60.5 mg^{-1} respectively. The water of River Ikarama was relatively low in its assemblage of crustacean zooplankton. A total of 11 crustacean zooplankton species belonging to 9 genera in 5 families and 3 orders were obtained during the study period. The family Cyclopoidae was the dominant group in the order Cyclopoida while the family Chydoridae was the only family recorded in the order *Cladocera*. All the eleven taxa were recorded in all stations. In all stations, the *Copepoda* were more abundant than the *Cladocera* and *Harpacticoida*. The study also established that the overall density of copepod was not significantly different (P<0.05) between the study stations. All the species recorded were almost evenly distributed in all the stations. No evidence of water pollution recorded in any of the stations sampled. The river was relatively homogenous across the different stations and all the parameters were within the WHO recommended standards for domestic use.

Keywords— Physico-chemical parameters, Ikarama River, Zooplankton, *Copepoda*, *Harpacticoida*, *Cladocera*, *Cyclopoida*, *Chydoridae*,

1. Introduction

Water is a vital resource for humans and serves as a habitat for a diverse range of aquatic species [1], including microscopic plankton, microbes [2], plants, and huge aquatic animals [1]. Worldwide, it has been estimated that over 250 million individuals are afflicted with waterborne illnesses annually, resulting in 10 million deaths across all age groups [3]. The uncontrolled growth of cities, fast-paced industrial development, and excessive use of chemical fertilisers in agricultural areas contribute to the decline in both the quantity and quality of water [4, 5], leading to a depletion of aquatic wildlife [6]. Zooplankton are fragile microorganisms that form an exquisite collection of tiny floating animals. These creatures have a crucial function in the pelagic food chain as they regulate the development of phytoplankton and serve as a source of food for larvae and juvenile fishes [6].

Zooplankton refers to the animal component of plankton. They inhabit both freshwater and saltwater environments and can be found in various types of water bodies, such as lakes, rivers, ponds, streams, rice-fields, reservoirs, temporary water bodies and irrigation canals. These animals are heterotrophic and lack the ability to produce organic matter through synthesis. Zooplankton have a crucial role in shaping the functioning of aquatic ecosystems, including energy flow, food chains, matter cycling and food webs. In fish nutrition, they typically have a significant impact [7]. In their study, Suresh et al. [8] emphasised the significant influence of many environmental conditions on the characteristics of water, which in turn have a profound impact on the growth and abundance of zooplankton populations. Therefore, the quality of their environment has a direct impact on the quantity, clustering, and biomass of zooplankton. The morphology and physiology of aquatic species are shaped by the prevailing physical and chemical circumstances of their environment, and are subject to alteration in response to heightened human impact [7].

Commonly, physicochemical, biological, and microbiological metrics are examined when evaluating water quality [9, 10]. This study provides insight into the abiotic and biotic condition of the ecosystem [11]. The physico-chemical characteristics of water bodies fluctuate in concentration periodically, perhaps seasonally, daily, or even hourly. These fluctuations may be correlated with the water usage pattern and precipitation levels [12]. The river systems frequently fail to meet acceptable standards for various purposes. Rivers, due to their function in transporting municipal and industrial wastes as well as runoff from agricultural land in their extensive drainage basins, are very susceptible to contamination [13-15]. The majority of zooplankton species have a worldwide distribution. According to Rajagopal et al. [11], the distribution of zooplankton populations is influenced by various factors, including changes in meteorological conditions, physico-chemical parameters, and vegetation cover [16, 17].

Planktonic algae is consumed by a diverse range of larval and adult zooplankton. Subsequently, they serve as a food source for fish, aquatic insects, and various other aquatic species. Zooplankton consists of organisms that are mostly immobile or have limited mobility compared to the surrounding water. They passively move with the flow of water, and are vulnerable to contaminants, alterations in land use, and other modifications that take place in the aquatic ecosystem. The primary categories of zooplankton include protozoans, rotifers, cladocerans, copepods, ostracods, and meroplankton. Rotifers are considered the most sensitive sensors of water quality among zooplankton. Therefore, it is crucial to conduct both qualitative and quantitative evaluations of zooplankton, as emphasised by Sheeba & Ramanujan [18].

The structure of this study is as follows: Section 1 provides an overview of the physical and chemical properties as well as the variety of species found in crustacean zooplankton. Section 2 presents the relevant research that has been conducted in this field. Section 3 outlines the experimental methods and key procedures used in the study. Section 4 presents the results obtained and thoroughly discusses them in relation to previous studies. Section 5 concludes the research work and suggests future directions for further investigation.

2. Related Work

Reports have indicated the presence of zooplankton in various rivers in Nigeria. Ogbeibu & Obanor [19] conducted a study to examine the effects of the creation of a reservoir on the population of crustacean zooplankton in the Agudama River. The study demonstrated that the presence of impoundment promotes the proliferation and maturation of crustacean zooplankton communities in flowing water habitats. Previous studies on physicochemical compositions of various river water in conjunction with the distribution of crustacean zooplankton populations in various water bodies has been reviewed [20-27]. However, there has been no previous research conducted in the Ikarama River or any other river within Okordia town in Yenagoa Local Government Area of Bayelsa State. Hence, this novel study will establish a benchmark for future investigations in Okordia and its surrounding areas.

3. Experimental Method/Procedure/Design

3.1 Description of the Study Area

The study was carried out from 16th of September to 18th of August on Ikarama River that lies within Okordia and Bisini communities, both in Yenogoa Local Government Area of Beyelsa State. River Ikarama takes its course from River Nun in Opokuma Clan in Bayelsa State Nigeria (30^o-6.45^o N and 6.20^o -6.45^o E). This region is located inside the renowned rainforest zone of Nigeria, characterised by a rainy season spanning from March to October and a dry season lasting from November to February. Rainfall data were collected from the office of the Nigerian Meteorological Agency, Yenogoa City, Bayelsa State for the study area from September to August. Monthly minimum and maximum temperatures and monthly means of relative humidity for 10:00am and 4:00pm between the months of September to August were also collected from the office of the Nigerian Meteorological Agency station, shown in Figure1.

During this period the daily rainfall ranged from 0.0 mm to 96.9 mm, while the monthly mean relative humidity for 10 am was 85.3% and that for 4:00 pm was 69.7%. The average minimum monthly temperature for the period ranged from 22.8^{o}C to 25.0^{o}C while the average monthly maximum temperature for the period ranged from 27.8^{o}C to 30.0^{o}C. The geological characteristics of the study area, similar to the remainder of the Niger Delta basin. The lithostratigraphic unit in question is known as the Bayelsa formation, and it has been proposed that the bottom portion of this formation dates back to the Miocene epoch. The geological formation present in Bayelsa is known as the Tertiary Scarp. The Okordia settlement is predominantly rural, relying on the River Ikarama as a primary source of water for residential purposes. No major industry is sited in this area. This region is primarily a rainforest, although many areas of Bayelsa State have been greatly subjected to deforestation and other human activities, Yenogoa Local Government Area especially at Okordia seems to be relatively pristine. Along the bank of the river, the major vegetation is mainly rainforest and some fringing plants including Indian bamboo (*Bambusa* sp). Riparian settlements in this area are thinly populated. Farming and fishing are the major occupations of the people.

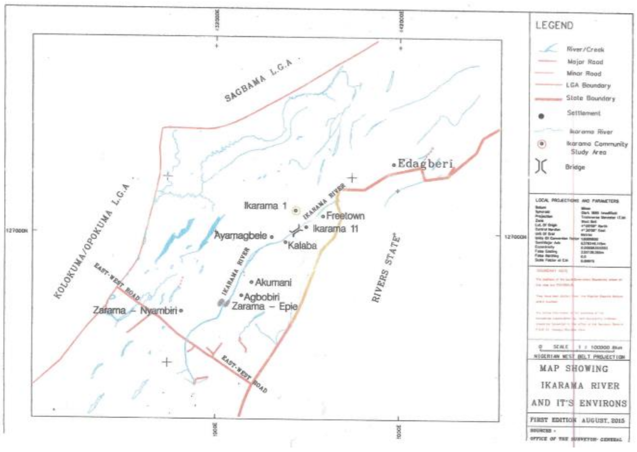

Figure 1: Map showing Ikarama River in Okordia clan, Yenagoa, Bayelsa State [19]

3.2 Sampling Stations

Sampling was conducted on a monthly basis between September and August. Four sampling stations were selected for study along the main course of the river from upstream to downstream with a distance of 400 metres between stations as shown in by Figure 1. The entire stretch of the river is fresh water, and the selection of sampling stations was governed primarily by the activities occurring in the area. Due to the limited length of the river within the Okordia community and also inaccessibility, the research was conducted across a distance of approximately 1200 meters. Two of the stations (3 and 4) witnessed the most human effect mainly in the form of bathing and laundry activities. Station 1 witnessed no human activity throughout the study period, while Station 2 witnessed occasional human activity.

3.3 Collection of Water Samples and Analysis

Triplicate water samples were obtained from each of the four sampling locations. Using sample vials, they were collected against the flow of the water. Before transporting the samples to the lab for water analysis, they were placed in an opaque bottle with a sterile well label and placed in a fridge with ice. The four sampling stations were visited once every month from 16th of September to 18th of August. During this period a total number of 12 sampling visits were made in all the stations between 10:00 am to 2:00 pm, on each sampling day.

3.4 Collection of Crustacean Samples

Crustacean zooplankton samples were obtained from undisturbed regions of the water using both quantitative and qualitative sampling techniques. To perform quantitative sampling, a 100 litre water sample was run through a 55 µm mesh size Hydro-Bios plankton net. The net was manually pulled against the water current for a duration of 15 minutes at each location. The collected samples were promptly preserved in 4% formalin solution, which is a recommended preservative for zooplankton and phytoplankton by UNESCO [28]. The preservation was done in 250 ml plankton vials. Floating and littoral weeds were also in a bucket containing 3 litres of 10% formalin, vortexed vigorously and rinsed in another plastic bucket of water, both buckets were filtered through the plankton net and the plankton samples were stored in the 250 ml bottles containing 4% formalin solution.

The collected crustacean zooplankton specimen were classified into their respective taxa and transferred into separate vials using a binocular dissecting microscope (American Optical Corporation, Model 570), a Hydro-Bios micropipette, and a No. 01 tungsten needle. The specimens were then preserved using a 4% formalin solution. The counting process was conducted by utilising a sorting petri dish positioned beneath a dissecting microscope. Representative specimens were mounted in 100% glycerine on clean slides. Using tungsten needle the specimens were properly arranged on the slides, covered with clean cover slips and subsequently sealed with nail vanish. Some specimens were also dissected using sharpened needles and relevant diagnostic features of the specimen displayed and mounted in glycerine. The slides were sealed with nail vanish and the specimens were drew using a camera lucida Cladocera [29].

3.5 Determination of Physicochemical Properties

During the research period, *in situ* observations were made for the physical parameters. These physical features were air and water temperature, depth, transparency, current velocity, which were all carried out at each station *in-situ*. On the other hand, the laboratory measured turbidity, conductivity, and solids (total, suspended, and dissolved solids) in addition to chemical properties like chloride, sodium, and potassium according to the rules set out by the Association of Official Analytical Chemists and the Standard Method for the Examination of Water and Wastewater [30].

3.6 Determination of Species Diversity

3.6.1 Margalef's Diversity Index

The formula for calculating Margalef's diversity index, as stated by Margalef [31], was used.

$$d = \frac{S-1}{Log_e N}$$

Where,
d = Margalef's diversity index
S = number of species
N = number of individuals

3.6.2 Shannon-Wiener Index [31]

The average diversity of a sample is quantified by a measure, which was determined by the following equation:

$$H' = (-P_1 InP_1) + (-P_2 InP_2) + \cdots$$

Where
H' = Shannon-Wiener index
P = total proportion of each species in sample

3.6.3 Measurement of Berger- Parker Dominance Index [31]

Examines the relationship between the number of different species and their population sizes. It considers only the most prevalent species in the sample and was calculated as:

$$D = \frac{Nmax}{S}$$

Where
Nmax = the number of individuals of the most abundant species,

S = the total number of observed species.

3.6.4 Number of Occurrence Index (NOI)

This represents the total number of individuals pertaining to each species as a proportion of the overall number of individuals in the catch [31].

$$NOI = \frac{C}{D} \times \frac{100}{1}$$

Where,

C = number of individual of each species in the catch,

D = total number of individual of all species in the catch.

3.7 Statistical Analysis

The data acquired in this study underwent conventional statistical analysis using methods such as standard deviation, percentages, and one-way analysis of variance (ANOVA). The substantial disparity was established with a 95% degree of confidence.

4. Results and Discussion

4.1 Results of the Physical Properties of Water

The results shows that station 1 reported the lowest temperature, while station 2 recorded the highest temperature. The surface water temperature varied between 28^{o}C and 29^{o}C. The air temperatures exhibited greater variability and were generally higher compared to the surface water temperature at all the sampled stations. The analysis revealed that there was no statistically significant disparity in temperature (F = 0.955, P > 0.05) among all sites (Table 1). Table 1 also displays the depth results of the different stations over the course of the study period. Station 4 exhibited a shallow average depth, whereas station 3 had a comparatively greater average depth. The minimum depth recorded was 65 cm at station 4, while the maximum depth of 80 cm was reported at station 2. The analysis revealed a substantial disparity in the depth measurements among the several sites (F = 129.380, P < 0.001). The Secchi disc transparency and turbidity values are displayed in Table 1 below, the transparency values of water at all the stations were consistently high, with a recorded value from 1.8 -1.9 m. The statistical analysis revealed a no disparity in transparency values among the several stations (F = 4.4.89, P < 0.01). The turbidity values exhibited a negative correlation with transparency. Elevated levels of turbidity were observed. Station 4 recorded the highest value of 55 NTU, while station 1 had the lowest value of 50 NTU. The turbidity analysis revealed no statistically significant variation across all the stations (F = 0.335, P > 0.05).

The conductivity of a water body serves as a measure of the overall amount of ions present, which in turn shows the level of freshness of the water body. The study indicates the conductivity values were relatively low. However, higher value 10.7 µscm-1 were recorded at station 4. Conversely, the lowest value of 9.0 µscm-1 was reported at station 1. Table 1 illustrates the pattern of change in the total solids. The highest solid load 7.0 mgl-1 was seen in station 4 while the lowest concentration of 6.2 mgl-1 was likewise observed at station 1. The One-way ANOVA test indicates that there was no statistically significant disparity in the total solid values. The suspended particle load over the course of the study period was presented in Table 1. Elevated levels of suspended matter were documented throughout all the stations. The maximum concentration of suspended particles was seen at station 3 and 4, measuring 75 mgl-1. The minimum concentration of 70.5 mgl-1 was recorded at station 1. There was no statistically significant difference (P>0.05) in the values of suspended solids reported during the monitoring period. The dissolved solids readings varied between 65 mg-1 station 2 and 72 mg-1 at station 3. The differences in pH and total alkalinity among the various sampling locations throughout the study period shows a moderate level of acidity to neutrality, ranging from 5.5 to 6.5. There was also no statistically significant difference (F = 0.769, P > 0.05) across all stations. The study found that the water had consistently high levels of oxygen during the whole study period. The highest concentration of 10.0 mg/l was observed at station 2, while the lowest concentrations of 7.5 mg/l were recorded at station 4. The ANOVA analysis revealed that there was no statistically significant variation in the dissolved oxygen values among the different stations (F = 2.203, P>0.05). The minimum BOD_5 values observed during the sample period were 2.9 mg/l at stations 1 while the maximum value recorded was 4.5 mg/l at station 4. The ANOVA analysis revealed that there was no statistically significant difference (F = 1.128, P>0.05) among all stations (Table 1).

Table 1: Physical and Chemical Properties of Water Samples from Ikarama River

Parameters	Sampling Stations				WHO Standard Limit
	RISS 1	RISS 2	RISS 3	RISS 4	
	Upstream	Semi-upstream	Midstream	Downstream	
Temp. (°C)	28±3.2	29±3.5	29.3±3.5	29.5±3.0	30
Depth (CM)	70±3.0	80±2.5	75±2.4	65±2.5	-
Transparency (M)	1.8±0.3	1.9±1.0	1.9±0.5	1.9±0.5	-
Turbidity (NTU)	50±4.0	51±3.0	53±3.5	55±4.0	5.0
pH	6.5±2.2	5.5±2.0	6±2.0	6.5±2.5	6.5-8.0
Total Alkalinity (mg/-1)	2.9±1.5	4.5±1.8	4.7±1.0	3.5±1.5	150
Conductivity (µscm-1)	9.0±1.3	9.5±2.0	10.5±1.0	10.7±1.5	100
Total Solid (mg/l)	6.1±0.8	6.2±1.0	6.5±2.0	7.0±1.5	-
TSS (mg/l)	70.5±3.0	70.6±2.5	75±2.0	75±2.7	-
TDS (mg/l)	70±4.0	65±3.5	72±4.2	69±3.0	-
DO (mg/l)	8.5±0.6	10±1.3	9.5±0.8	7.5±2.0	3.0
BOD_5 (mg/l)	2.9±1.3	3.2±2.0	3.3±0.5	4.5±1.0	6.0
Salinity/Chloride (mg/l)	60.2±2.5	60.3±3.0	60.5±2.0	60±2.0	-

Na (mg/l)	2.9±1.0	2.5±1.0	2.6±1.1	3.0±1.0	200
K (mg/l)	16±0.5	16.5±1.0	18±1.0	17±1.0	-

Key: Data are triplicate determinations of Mean±SD, RISS1,2,3 & 4- River Ikarama Sampling Station 1,2,3 & 4, WHO- World Health Organization, Temp.- Temperature, TSS- Total Suspended Solid, TDS- Total Dissolved Solid, DO- Dissolved Oxygen, BOD_5- Biochemical Oxygen Demand, Na- Sodium, K- Potassium

The physico-chemical properties of Ikarama River exhibited seasonal fluctuations, while some of these properties could not be attributed to any specific seasonal impact. The fluctuations in both the time and location of air and water temperature were predominantly influenced by environmental conditions and the timing of sample collection. The low atmospheric temperature observed around January was likely caused by the North East trade wind, commonly known as the Harmattan, which sweeps across the Sahara. This syndrome is characteristic of tropical weather [3]. Therefore, it is anticipated that the dry season will yield comparatively higher water temperatures compared to the wet season. The findings were in line with the research conducted by Sati & Paliwal [6].

In the study station 2 registered the greatest depth, whereas station 4 registered the lowest depth throughout the duration of the investigation. The recorded transparency values suggested that station 2, 3 and 4 were areas with high transparency, meaning that they had clear water. Conversely, the turbidity readings were greater at stations 4. This condition is correlated with the concentration of suspended particulates in the water [32]. Turbidity, in contrast, exhibits a continuous pattern observed in the majority of Nigerian inland lakes, as reported by Reference [32] and [33]. The rise in phytoplankton proliferation, which will decrease transparency, may potentially contribute to reduced transparency levels. The turbidity readings varied between 50 NTU and 55 NTU at all stations. Turbidity is the quantification of water's capacity to transmit light, which is influenced by the concentration of suspended particles in the water. In their study, reference [6] found that the effect of human activity on total suspended solids is inconsistent, and the highest level of turbidity occurs when suspended solids from both the stream and the sea mix in an estuary. Nevertheless, reference [33] documented that the upstream stations in Warri River consistently exhibited greater values than the downstream stations during the dry season, across most months.

The pH range of 5.5 – 6.5 observed in this investigation suggests that the water had a comparatively high acidity level. Typically, run-off streams from mostly lateritic forest soils exhibit lower pH values. The range identified in this study is similar to the ranges documented in other Nigerian inland water bodies, as reported by references [32], [33], and [34]. The pH levels observed in this investigations did not exhibit any noticeable seasonal pattern. This observation aligns with the findings of references [34] and [6]. The pH of water often governs the characteristics of carbon dioxide present in the water. Carbon dioxide in its unbound form is typically found in pH ranges of 5.5– 6.5. At higher pH levels, carbonate and bicarbonates become more prevalent [32]. An observed alkalinity values ranged from 2.9 mgl-1 to 4.7 mgl-1. Alkalinity is a measure of the presence of carbonate and bicarbonate ions in water at a moderate level. However, these values are rather low when compared to the levels seen in other water bodies in Nigeria. For example, at Eleiyele Reservoir in Ibadan, as high as 80mgl-1 was recorded. In River Osun, the value was 62 mgl-1, and at Okomu Forest River, it was 31.5mgl-1 [33]. Nevertheless, prior studies conducted by references [6] and [34] have demonstrated a resemblance in the low alkalinity measurements. Alkalinity readings may vary due to the breakdown of organic matter and its conversion into minerals, as well as the accumulation of salts during the process of evaporation [33]. Furthermore, a study conducted by reference [33] has documented a correlation between decreasing distance from the seas and increasing alkalinity values in the Warri River.

Conductivity is a metric that quantifies the collective presence of ions in water, indicating its overall level of ionic abundance. The pH of water is primarily regulated by the presence and concentration of sodium. The observed conductivity values were moderately varied from 9 µscm-1 to 10 µscm-1. Values exhibited a comparatively lower levels during the months of the rainy season, likely as a result of the diluting impact. This finding aligns with the research conducted by references [3] and [33] on water bodies in Okomu Wildlife reserve.

The investigation reported suspended solids (total) ranging from 70.5 mgl-1 to 75 mgl-1. Similar high values have been documented in other parts of Nigeria, specifically in Egborge [35]. There was a noticeable seasonal variation in the observed values. The phenomenon of seasonality has been documented by multiple researchers in diverse aquatic environments in Nigeria [36]. This may be attributed to the increased runoff and influx of allochthonous materials into the water bodies during the sampling seasons. The suspended particles have the potential to settle on the river bed, which can suffocate the organisms living on the bottom and cause the water body to become filled with sediment. This might potentially result in the annihilation of plant and animal species, thereby jeopardising the natural food chain for fish. According to a report [37], suspended solids can be deadly to fish when present at concentrations of up to 30 mg/l of suspended matter.

Conversely, the concentration of dissolved solids varied from 7.5 mg/l to 10 mg/l. Consistent with prior studies, the rainy season months in Nigeria typically exhibit greater values compared to the dry season months, which is a regular occurrence in inland waters across the country. The impact of rainfall in reducing the concentration of dissolved solids has been extensively established. While large levels of dissolved solids (> 600 mgl-1) in water can potentially be detrimental, their impact on water density is negligible and can be disregarded [38].

The average range of total solids in all stations was generally mild. While dissolved solids made up the majority of the total solids, suspended solids also made a significant contribution to the overall amount of solids. The observed values of dissolved oxygen throughout this study varied between 7.5 mg/L and 10.0 mg/L. This indicates that the water had a high level of oxygenation during the research period. This is because the flow velocity has the potential to enhance the concentration of dissolved oxygen in the flora composition, the degree of organic pollution, and the population density of fauna [37]. According to references [39], [40], and [41], the abundance of oxygen in a water body can be attributed to in-situ primary generation, the movement of air facilitated by wind, and turbulence caused by waves. According to reference [36], the Warri River has high levels of dissolved oxygen because to its quick flow, which promotes the mixing of water and the replenishment of dissolved oxygen. The River Ikarama is abundant in submerged vegetation, which results in the release of oxygen into the water through photosynthesis by algae and other aquatic plants, providing compensation. Therefore, the ecosystem of a river will undergo significant changes when there is a variation in the levels of dissolved oxygen.

The study stations exhibited biochemical oxygen demand (BODs) values ranging from 2.9 mgl-1 to 4.5 mgl-1. It frequently indicates the presence of water that has been contaminated with organic pollutants. The minimum value was recorded at station 1, while the maximum value was reported at station 4. Rivers with a BOD_5 level below 6 mgl-1 are considered to have medium to good quality water and are free from pollution. From this perspective, it can be argued that Ikarama River is not contaminated by organic pollutants. Organic pollution is defined as the situation when the quantity of organic material above a specific limit, causing the river's oxygen levels to be insufficient for the necessary breakdown process [42]. Organic contamination commonly arises from the discharge of sewage in affluent countries and the sewage systems in underdeveloped ones. With the exception of the Ikarama community, there are no other significantly sizable villages located along the Ikarama River. Due to the absence of a sewage system, the quantity of organic waste entering River Ikarama is insufficient to result in organic pollution.

The salinity (chloride) measurements indicate that the water at all study locations has a perfect absence of salt. The values exhibited a notable degree of similarity to those seen in the upper sections of the Warri River [32]. The irregular higher values seen in the study may be attributed to the underutilization of this nutrient by a smaller-than-expected population during this time period. Prior researchers have suggested that the proliferation and biochemical processes of phytoplankton contribute to the depletion of essential plant nutrients, such as nitrates, in water [43]. Another potential reason contributing to the observed trend is the discharge of untreated human waste into the nearby watershed, which is then carried by runoff into a very limited water volume. On a similar manner, the ash resulting from the combustion of plants on the nearby farms is carried into the river with the flow of water. Plant leaching and the decomposition of dry leaf litter are additional sources of nitrates in water bodies [43].

The investigation reported sodium values ranging from 2.5 mg-1 to 3.0 mg-1. The values in question exhibit a modest level of elevation when compared to other freshwater bodies in Nigeria [44]. In this study, the Potassium levels ranged from 16 mg-1 to 18 mg-1, exhibiting a consistent seasonal pattern. The dominant cations in the River Ikarama are Na <K. Similarly, in the River Niger, the most common order is Na > K. In Oguta Lake, the order of dominance is also Na > K [33]. The data obtained exhibited a resemblance to the prevailing pattern observed in African water bodies, where sodium emerges as the predominant cation [45]. The levels of physical and chemical factors in the water of River Ikarama were found to be lower than the recommended limit set by the World Health Organisation for drinking water and household use.

4.2 Results of Crustacean Zooplankton Compositions

The study revealed that the Crustacea (Cyclopoida, Harpacticoida and Cladocera) community of the water body (River Ikarama) comprised of eleven taxa distributed into the nine genera, five families, three orders, and two subclasses (Tables 2).

Table 2: Crustacean Compositions in Ikarama River

Zooplankton	Sampling Stations			
	RISS 1	RISS 2	RISS 3	RISS 4
Alona eximia	4±0.02	8±0.01	6±0.02	5±0.01
Alona quadrigularis	8±0.01	7±0.02	8±0.02	8±0.01
Grimaldina brazzai	4±0.01	8±0.1	5±0.02	3±0.02
Diaphanosoma excisum	7±0.1	6±0.02	6±0.1	10±1.0
Mesocyclops ogunnus	87±0.2	57±0.5	57±1.0	97±2.0
Microcyclops varicans	67±0.5	77±1.0	57±01.5	87±2.0
Thermocyclops oblongatus	87±2.0	77±2.5	57±1.5	47±1.0
Cryptocyclops bicolor	32±1.5	21±0.5	17±1.0	19±0.5
Ectocyclops phaleratus	77±3.5	77±3.0	77±3.0	77±2.5
Bryocamptus birsteini	20±2.0	14±1.5	11±0.5	12±0.3

Key: Data are triplicate determinations of Mean±SD, RISS1,2,3 & 4- River Ikarama Sampling Station 1,2,3 & 4.

Species richness refers to the total number of different species that exist within a given ecosystem. This index does not utilise relative abundances. It fails to consider the relative abundance and spatial arrangement of each species within the local aquatic community. A species richness index was employed to quantify the species abundance at the sampling stations. The index corresponds to Margalef's index (d). The computed data reveals that the species richness (D) differs in all stations. Station 3 recorded the highest (2.28), this was followed by station 4 (2.21) while stations 2 and 1 recorded 2.20 and 2.12 respectively (Figure 2).

An ecological diversity index is a statistical tool designed to quantify the level of biodiversity within an environment. Any population where every member is a member of a different species can be assessed using diversity indices in a more general sense. All stations' species diversity was characterised using three different diversity indices. This is a reference to the Shannon-Wiener diversity index (H1), the evenness index (E), and Simpson's dominance index (C). The Simpson Index is a quantitative metric that takes into consideration both the diversity and the proportion of each species in a biodiversity sample within a local aquatic community. The index operates under the assumption that the proportion of individuals in a given area is indicative of their significance to biodiversity. Ecosystems with values close to zero are quite diverse and heterogeneous, whereas those with values near to one are more homogeneous. When calculating the health of an aquatic ecosystem, the Shannon-Wiener index takes both the total number of species and the relative abundance of each species into account. It is related to the Simpson's index. The index is derived from the field of information science. In the ecological literature, this measure has also been referred to as the Shannon index and the Shannon-Weaver index. Comparing one or all of these indicators of biodiversity can demonstrate alterations in water quality conditions within a local community. The Evenness index measures how closely related species' abundances are to one another. The evenness is one when all species have identical proportions. However, if the abundance of species varies greatly, with some being rare and others being common, the evenness value increases. Table 3 displays the various indices across all stations.

Table 3: Species Diversity in Ikarama River

Diversity Indices	Sampling Stations			
	RISS 1	RISS 2	RISS 3	RISS 4
Shannon diversity (H^1)	2.165±0.5	2.213±0.3	2.300±0.2	2.231±0.3
Evenness index (E)	0.903±0.01	0.953±0.02	0.959±0.03	0.952±0.03
Simpson's index	0.146±0.001	0.116±0.003	0.113±0.002	0.114±0.003

According to the Shannon-Wiener diversity (H1) and Evenness index (E) in Table 4, Station 3 had the highest diversity, followed by Station 2, Station 4, and Station 1. In terms of Simpson's Dominance index, Station 1 had the highest dominance, followed by Station 2, Station 4, and Station 3 as the least dominant.

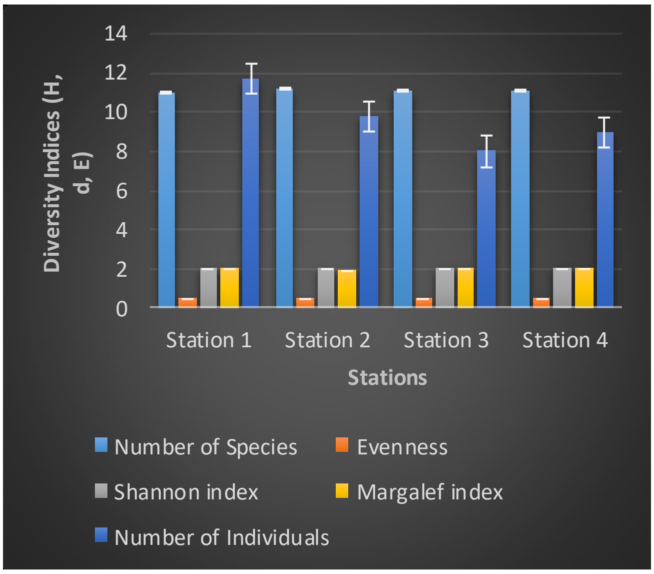

Figure 2: Shows the Ecological Indices of Zooplankton Community in all Stations

The River Ikarama has a relatively low abundance of crustacean zooplankton in its water. The majority of the species documented in this location have been previously documented in other parts of Nigeria [46, 47, 33]. This is unsurprising given that the colonisation of streams largely relies on creatures with extensive distributional capabilities. The invertebrate community in a lotic ecosystem is a stable collection of species that are found in similar habitats, regardless of their geographical location. Analogous taxa, frequently belonging to the same family or generic group, are commonly found in similar environmental niches, as observed by reference [45].

This study identified a total of eleven species of crustacean zooplankton, belonging to nine different genera, five families, three orders, and two subclasses. The community structure of the current Ikarama River was found to have a lesser number of documented taxa compared to temperate streams, as reported by reference [45]. The habitat is a crucial component in the field of ecology, encompassing several essential factors that affect an organism's life strategy, fitness, and adaptive radiation. Resource partitioning, predation, spatial variation in trophic circumstances, habitat area, substrate stability, and tolerance to physiochemical conditions are all influential elements in the dispersion of species between habitats in freshwater environments.

According to reference [44], the arrangement of the immediate substrate of occupation plays a crucial role in determining the distribution as a sanctuary. However, it is indisputable that factors including as temperature, dissolved oxygen, pH, and current velocity are crucial in regulating the presence and dispersion of stream fauna. Many studies focusing on the dispersal of stream fauna often prioritise certain characteristics related to either an individual species or a group of species. Nevertheless, this technique is imprudent as it frequently overlooks the interplay effects of multiple components. Hence, it is crucial to thoroughly analyse all significant elements and their combined impacts while examining the distributional characteristics of the Ikarama River community. Reference [33] documented the presence of 25 species of Cladocera in a stream located within the Okomu Forest Reserve. The Jamieson River documented a notable diversity of organisms, including 34 species of Cladocera and 17 species of Copepoda. The species mentioned in this study are commonly found in tropical regions and have been documented in the West African Sub-Region [33, 6].

5. Conclusion and Future Scope

This study found that several physical and chemical characteristics of the Ikarama River in Yenagoa LGA, Bayelsa State, such as water temperature, clarity, suspended particles, and turbidity, were affected by seasonal changes. The temperatures results ranged from 28.0°C to 29.5°C. Transparency (1.8 m – 1.9 m) and Total suspended solids (70.5 mg^{-1}-75.0 mg^{-1}) showed inverse relationship. Depth ranged from 65 cm to 80 cm, while turbidity ranged from 50 NTU to 55 NTU. TDS ranged between 65 mg^{-1} and 72 mg^{-1}, total solids ranged between 6.1 mg^{-1} and 7.0 mg^{-1}. pH values ranged from 5.5 to 6.5. Dissolved oxygen value ranged from 8.5 mg^{-1} to 10.0 mg^{-1}, while the BOD_5 (2.9 mg^{-1} and 4.5 mg^{-1}) indicated no form of pollution or stress on the water body. Conductivity and chloride values ranged from 9.0 μscm^{-1} to 10.7 μscm^{-1} and 60.0 mg^{-1} to 60.5 mg^{-1} respectively. Nevertheless, these levels fell within the acceptable range set by the World Health Organisation (WHO), suggesting that the water body under investigation was not contaminated. The water quality in the river also meets the requirements set by WHO. The water of River Ikarama was relatively low in its assemblage of crustacean zooplankton. A total of 11 crustacean zooplankton species belonging to 9 genera in 5 families and 3 orders were obtained during the study period. The family Cyclopoidae was the dominant group in the order Cyclopoida while the family Chydoridae was the only family recorded in the order *Cladocera*. All the eleven taxa were recorded in all stations. However, when contrasted with other bodies of water in Nigeria, this figure was very small. The moinids and calanoids were entirely absent from the water samples analysed. The need for further studies, especially on the microbial constituents and heavy metals of the bottom sediments, fish, composition and diversity of both micro and macro flora and the factors influencing the ecology of microbenthic fauna is imperative to provide a very detailed baseline data for the Ikarama River, coupled with an account on the possible anthropogenic impacts. The need for a more extensive study in this area is highly recommended.

Data Availability
Data is available on request from the corresponding author.
Study Limitations: None.

Conflict of Interest
The authors report no conflicts of interest with this research. The experiment was conducted impartially and the outcomes were interpreted simply. Data was collected independently.

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Authors' Contributions
Author-1 conducted a thorough examination of existing literature and developed the study. Author-2 participated in the formulation of the protocol, oversaw the trial, and conducted data analysis. Author-3 composed the initial version of the manuscript. All writers conducted a thorough examination and made revisions to the manuscript, ultimately giving their approval to the final edition.

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