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Spatial-seasonal variation in species composition, abundance, distribution and diversity of Cladocera zooplankton in the Okhuaihe River at Ikpe, Benin City, Edo state, Nigeria

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Cladocera, generally known as water fleas, are microcrustaceans that assist as biological indicators of water quality. This study observed the spatial-seasonal variation in the species composition, abundance, distribution, and diversity of Cladocera in the Okhuaihe River, Ikpe, Benin City, Nigeria, from August 2021 to January 2022. By means of standard methods, six families encompassing 75 individuals were documented. Station 4 recorded the highest abundance (64 individuals), while station 1 had the lowest (three individuals). Chydoridae (33.33%) was the most dominant family, trailed by Sididae (26.67%), Moinidae (16.00%), Daphniidae (14.67%), Bosminidae (8.00%), and Macrothricidae (1.33%). Species richness and diversity were at their peak in station 4 and lowest in station 2. Evenness was highest in station 1, while dominance peaked in Station s. Daphniidae exhibited a positive correlation with turbidity, while Macrothricidae correlated positively with sulphate and turbidity. The study established that the Okhuaihe River maintains good water quality, with a Cladocera community characteristic of tropical freshwater habitats, but with low diversity. The diversity of Cladocera did not fully mirror the physicochemical conditions. Continuous monitoring is suggested to detect water quality deviations early, as subsequently increased anthropogenic activities could negatively influence and impact species abundance, richness, and diversity.

Keywords: Cladocera, physicochemical, diversity, abundance, monitoring

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INTRODUCTION

Cladocerans are considered important bioindicators in freshwater for various ecological variables owing to their taxa specificity to such changes in their ambient environment. They show rapid response to changes in the pH of the water indicating their sensitivity to acidity and alkalinity (Zawiska et al., 2013; Zawisza et al., 2016). Cladocera have an important role in the freshwater ecosystem as they are the intermediate organism between phytoplankton and higher organisms. The structure of the Cladocera community is determined by the aquatic food web and not the water, unlike other aquatic organisms such as benthos and nekton (Berta et al., 2019). An increase in plant nutrients (eutrophication) leads to an increase in the Cladocera communities, that is, they are more abundant in phytoplankton-rich waters. However, this increase results in high predation pressure, most nekton that are planktivorous are size-specific; feeding on large-sized cladocerans, living behind the small-sized Cladocera such as *Bosmina longirostris*, which ultimately leads to an upsurge in their population (Hunt, Matveev, 2005). Meanwhile, in waters having poor nutrient (oligotrophic waters), the population of cladocerans are reduced, excluding *Leptodora*, *Bythotrephes* and *Polyphemus*; these species of Cladocera strive with filter feeders/microfiltrators for smaller particles (Brooks, Dodson, 1965). Nektons are not the only predators of cladocerans: there are invertebrate predators as well, like adult cyclopoid copepods, carnivorous cladocerans and insects (de Bernardi et al., 1987).

Suhett et al., (2015) considered cladocerans important bio-indicators for estimating the toxicity of pesticides and other environmental pollution in fresh water. Superior attention has been given to Cladocera across ecological studies, predominantly to those dealing with environmentally influenced stress from its many factors like biochemical, molecular, physiological, toxicological, etc.

Information on the scientific study, diversity, and distribution of different species of Cladocera in Nigeria is limited; even as they carry out an essential role (alongside other zooplankton) in conveying primary production into fish production (Jeje, 1989). Even though the Zooplankton including the Cladocera fauna of the Okhuaihe River has been widely studied in some sections of the river, particularly along the Benin-Agbor Road (Ogbeibu, Ogiesoba-Eguakun, 2019), no report on the diversity or the taxonomy of Cladocera at the Ikpe section of the river along Benin-Abraka road has been made. The Okhuaihe River at Ikpe is under the influence of numerous environmental stresses, due to which a wide fluctuation can be expected in the diversity of the Cladocera communities here. It is for this reason that this study was carried out to establish the diversity, relative abundance, and composition of the Cladocera community. The objective of this paper was to investigate spatial-seasonal variation in the species composition, abundance, distribution, and diversity of Cladocera zooplankton in the Okhuaihe River at Ikpe, Benin City, Edo State, Nigeria, and the relationship between the physicochemical water quality and the structure of the Cladocera zooplankton community.

MATERIALS AND METHODS

The study was carried out at four stations along the Okhuaihe River in Ikpe village, Ikpoba-Okha Local Government Area of Edo State, Nigeria. The section of the river studied runs across the Benin-Abraka express road, 30 kilometres from Benin City, with an average elevation of –8.48 m below sea level to 1.87 m above sea level. The Okhuaihe River is one of the major rivers that flows into the Ossiomo River, which empties into the Atlantic Ocean. It is situated in the tropical rainforest of Southern Nigeria. The Okhuaihe community today has a population of over 500 inhabitants, mainly the Ijaws and Urhobos. Major activities of the population include farming, fishing, local gin production, palm wine production, timber and lumber production (Fig 1).

The climate condition of the study area was characterised by rainy/wet seasons and

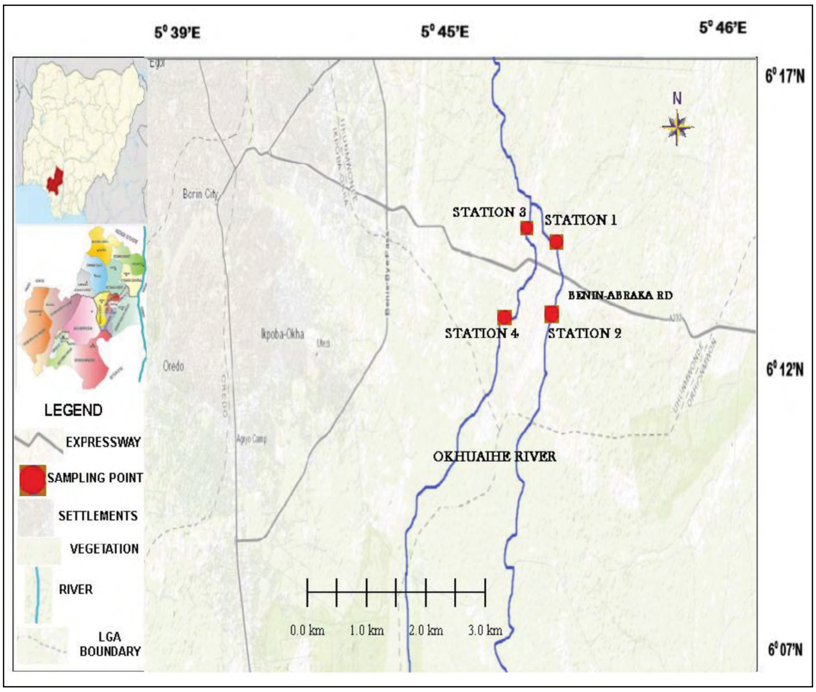

Fig. 1. Map of the Okhuaihe River displaying the sampled areas

dry seasons. The physicochemical properties of the river changes with seasons. In the wet season, there is a high flow rate, high turbidity due to influx, decreased transparency, and increased depth, especially after heavy rainfall; in the dry season, there is a low or no flow rate and increased transparency (Ekhator et al., 2013). The period of the rainy season is usually from April to October, and the dry season is from November to March, with temperatures ranging between 22 and 31°C (Olomukoro, 1983).

The vegetation of the study area comprises mainly raffia palms (*Raphia farinifera*), sensitive plants (*Mimosa pudica*), Bahama grasses (*Cynodon dactylon*), Stubborn grasses (*Sida acuta*), ferns (Polypodiophyta), wild cocoyam plants (*Colocasia esculenta*), plantain trees (*Musa sapientum*), coconut trees (*Cocos nucifera*). Floating and submerged macrophytes such as water hyacinth (*Eichhornia crassipes*) were observed in the river.

Sampling was carried out at four stations of the river.

Station 1 was located about 500 m before the Orhionmwon bridge, at latitude 6° 12' 25.19" N and longitude 5° 45' 17.12" E. The marginal vegetation was made up of raffia palms, sensitive plants, stubborn grasses, Bahama grasses, ferns, water hyacinths, and wild cocoyam plants. The river at this point was transparent, but the bed of the river was muddy. Fingerlings could be seen swimming, while anthropogenic activities include timber and lumber production, fishing, palm wine and local gin (ogogoro) production, laundry, swimming, and spiritual activities.

Station 2 was located opposite station 1, 500 m before the Orhionmwon bridge, at latitude 6° 12' 24.18" N and longitude 5° 45' 15.99" E. It was surrounded by canopy trees, raffia palms, sensitive plants, ferns, plantain trees, wild cocoyam plants, and water hyacinths. A bathroom, a warehouse made of palm fronds and bamboo were seen on the site. Water in this station was quite transparent but had a moderate flow rate and presence of algae. Human activities like washing, cooking, bathing, and spiritual activities were obvious.

Station 3 was located 200 m from station 4 at latitude 6° 12' 28.76" N and longitude 5° 45' 8.55" E. The water was transparent and had a high flow velocity compared to other stations. The vegetation at this station includes plantain trees, raffia palms, coconut trees, and wild cocoyam plants, also submerged and floating macrophytes. A shrine was seen in the middle of the water, which was transparent with a higher flow velocity compared to other stations. Activities at this station includes timber and lumber production, cooking, fishing, and spiritual activities.

Station 4 was located 100 m to station 1 at latitude 6° 12' 29.93" N and longitude 5° 45' 3.84" E. The water was highly turbid and had the lowest flow velocity compared to the other stations. The marginal vegetation surrounding this station includes raffia palms, palm kernel trees, plantain trees, wild cocoyam plants, with the presence of algae, ferns and floating macrophytes. Human activities include lumber and timber production, spiritual activities, and broom-making.

Sample collection

Sampling was carried out between 0800 hours and 1200 hours each sampling day and were collected monthly for a period of six months (August 2021 to January 2022).

Zooplankton collection

Zooplankton samples were collected from the four stations using the qualitative sampling method which involved using 55 µm Hydrobios plankton net, which was towed by hand against the water current for about 5 min. The water collected was poured into a sampling bottle and preserved in 4% formalin solution as recommended by UNESCO (1974).

In the laboratory, the samples from the four stations were concentrated to 25 ml using a net of a very small mesh size, after which the samples were taken in succession into a Petri dish and viewed under the microscope. The zooplankton samples were sorted out for cladocerans, counted, and identified under a binocular compound microscope with a magnification ×40. The cladocerans seen were carefully picked out using a sorting pin and a micro-pipette. Accurate counts of each taxon of the cladocerans found were taken and kept in well labelled transparent sample bottles and preserved in 4% formalin for future references. Parts of the organism like the number and orientation of segments on the antenna, caudal rami, rostrum, post-abdomen, antennules were used to identify the cladocerans using appropriate identification keys (Jeje, Fernando, 1986; Karuthapandi, Rao, 2016).

Comparisons between the stations were carried out to test for significant differences in the abundance of cladocerans using parametric analysis of variance (ANOVA). Here, significant value ($p < 0.05$) was obtained in the ANOVA, Duncan multiple range (DMR) test was performed to determine the location of significant differences using SPSS 20.0 and Microsoft Excel for Windows. The abundance score for species abundance was estimated by calculating the relative abundance (percentage) of each species as given in the formula by Meye and Ikomi (2008).

Cladocerans collected at the sampling stations were subjected to diversity indices. The following indices were evaluated: Margalef's Index for species richness, Shannon-Wiener Index (H') for general species diversity, and Evenness index (E). These indices which express the degree of uniformity in the distribution of individuals among the taxa in the collections are based on the proportional abundances of the individual species in the samples. High values of Margalef's Index, Evenness index, and Shannon-Wiener index indicate high diversity. PAST (Paleontological Statistics) software package for education and data analysis was used to compute the diversity (Hammer et al., 2001).

RESULTS AND DISCUSSION

Community structure

The Cladocera samples collected from the study areas were analysed to assess the taxa composition, distribution, abundance, diversity and dominance of the species. The data acquired are used to evaluate the spatial distribution of the Cladocera community of the Okhuaihe River. Cladocera recorded in this study comprises members of the families Daphniidae, Chydoridae, Bosminidae, Macrothricidae, Sididae, and Moinidae.

Composition, distribution, abundance and dominance of the Cladocera community

The overall taxa composition, abundance and distribution of the Cladocera community are presented in Table 1 and percentage relative abundance is graphically represented in Fig. 2. Daphniidae accounted for 14.67% of the total number of individuals, Chydoridae 33.33%, Bosminidae 8.00%, Macrothricidae 1.33%, Sididae 26.67%, and Moinidae 16.00%.

The spatial distribution of the different families of Cladocera when subjected to Chi-square goodness of fit test showed highly significant difference in the density ($p < 0.01$) for the family Chydoridae and no significant difference in the density ($p > 0.05$) for families Daphniidae,

Table 1. **Checklist of Cladocera fauna (phylum: Arthropoda, subphylum: Crustacea, class: Branchiopoda, order: Cladocera)**

Family	Organism	Author
Daphniidae	*Daphnia longispina*	Muller, 1776
	Ceriodaphnia rigaudi	Richard, 1894
Chydoridae	*Alona davidi davidi*	Richard, 1895
	Alona monacantha	Sars, 1901
	Alona setulosa	Megard, 1967
	Alonella globulosa	Daday, 1898
	Chydorus sphaericus	Leach, 1816
	Euryalona orientalis	Daday, 1898
Bosminidae	*Bosmina longirostris*	Muller, 1785
Macrothricidae	*Macrothrix spinosa*	King, 1853
Sididae	*Diaphanosoma brachyurum*	Lievin, 1848
	Diaphanosoma excisum	Sars, 1885
	Diaphanosoma sarsi	Richard, 1894
Moinidae	*Moina micrura*	Kurz, 1875

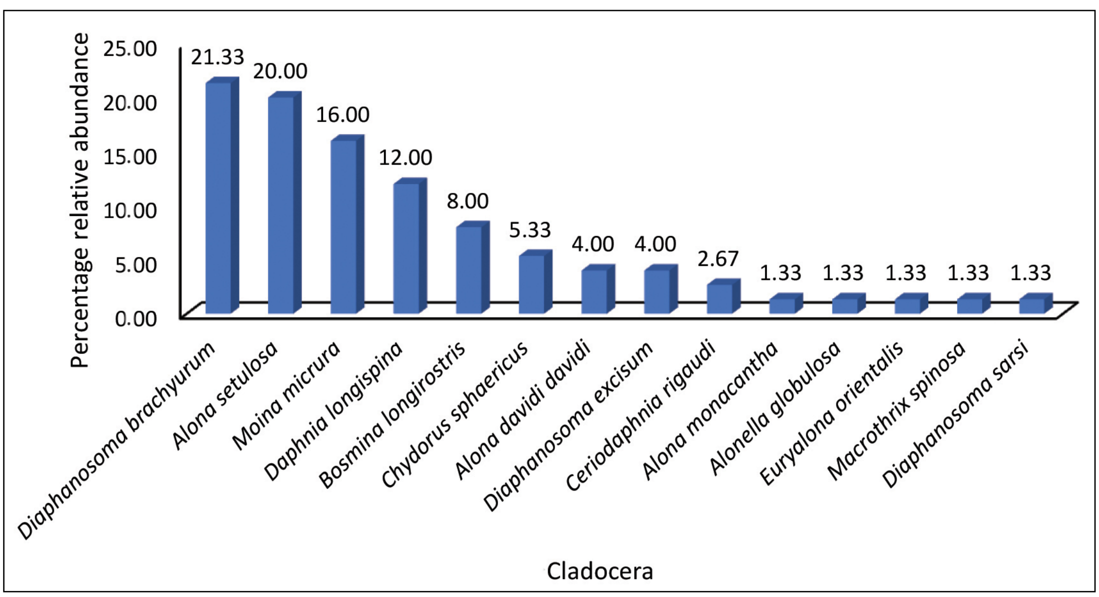

Fig. 2. Percentage of relative abundance of Cladocera in the Okhuaihe River

Bosminidae, Macrothricidae, Sididae, and Moinidae (Table 2).

Season-wise, the highest number of Cladocera species were recorded in October 2021 (34 individuals), closely followed by September 2021 (19 individuals) and November (14 individuals); the lowest number of species was recorded in August 2021 (two individuals), closely followed by December 2021 (three individuals), and January 2022 (three individuals) (Fig. 3).

Relatively, Cladocera species varied in relation to seasons. There was higher total abundance of Cladocera species in the rainy season and lower total abundance of Cladocera species in the dry season.

Table 2. **Composition, abundance and distribution of Cladocera**

Family	Organism	Station 1	Station 2	Station 3	Station 4
Daphniidae	*Ceriodaphnia rigaudi*	0	0	0	2
	Daphnia longispina	0	0	3	6
Chydoridae	*Alona davidi davidi*	1	0	1	1
	Alona monacantha	0	0	0	1
	Alona setulosa	0	3	1	11
	Alonella globulosa	0	0	0	1
	Chydorus sphaericus	0	0	0	4
	Euryalona orientalis	0	0	0	1
Bosminidae	*Bosmina longirostris*	0	1	0	5
Macrothricidae	*Macrothrix spinosa*	0	0	1	0
Sididae	*Diaphanosoma brachyurum*	0	0	0	16
	Diaphanosoma excisum	0	0	0	3
	Diaphanosoma sarsi	0	0	0	1
Moinidae	*Moina micrura*	2	0	0	10

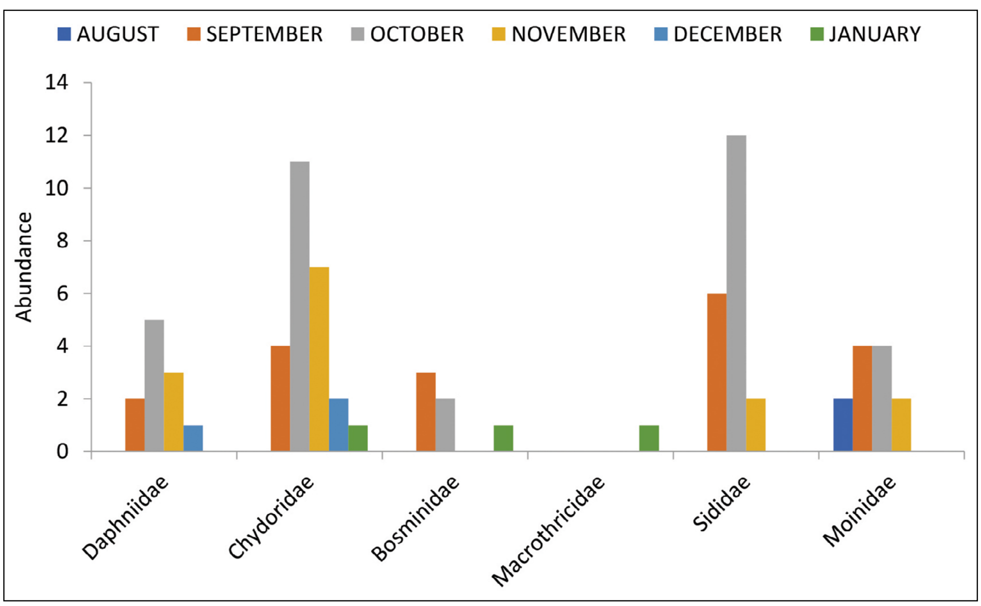

Fig. 3. Seasonal distribution of Cladocera across the sampling months

Diversity indices

Dominance, Shannon-Wiener, Evenness, and Margalef's indices were used in assessing the occurrence of Cladocera (Table 3). The measure of species richness as indicated by Margalef's index showed the highest value with an index of 2.908 at station 4 and lowest value with an index of 0.721 at station 2. The general diversity computation (Shannon-Wiener index) showed that station 4 had the highest diversity among the study stations with an index of 2.147. This was followed by station 3 with the value of 1.242, while the least diverse of the study station was station 2 with an index of 0.562.

Evenness was highest in station 1 (0.945), which was closely followed by station 2 (0.877). Station 3 had evenness of 0.866 which was closely followed by station 4 with the lowest value of 0.6582. Dominance was highest at station 2 (0.625), closely followed by station 1 (0.556). Station 3 had a value of 0.333, while the lowest value was recorded at station 4 (0.149) (Table 4).

Correlation analysis

Correlation analysis was carried out to test the relationship between the abundance and variations of Cladocera in the physiochemical parameters of water. A positive significant correlation was observed between the concentration of turbidity and the abundance of Daphniidae. Macrothricidae exhibited positive and significant correlations with sulphate and turbidity.

Table 3. **Spatial distribution of Cladocera**

Cladocera composition across the stations					
Taxa	**Station 1**	**Station 2**	**Station 3**	**Station 4**	***p* value**
Daphniidae	0	0	3	8	$p > 0.05$
Chydoridae	1	3	2	19	$p < 0.01$
Bosminidae	0	1	0	5	$p > 0.05$
Macrothricidae	0	0	1	0	$p > 0.05$
Sididae	0	0	0	20	$p > 0.05$
Moinidae	2	0	0	10	$p > 0.05$
Total	3	4	6	62	

Note: $p < 0.01$ = high significant difference, $p > 0.05$ = no significant difference.

Table 4. **Diversity indices of Cladocera in the study area**

Diversity indices	Station 1	Station 2	Station 3	Station 4
Taxa_S	2	2	4	13
Individuals	3	4	6	62
Dominance_D	0.556	0.625	0.333	0.149
Shannon_H	0.637	0.562	1.242	2.147
Simpson_1-D	0.444	0.375	0.667	0.851
Evenness_e^H/S	0.945	0.877	0.866	0.6582
Margalef	0.910	0.721	1.674	2.908
Equitability_J	0.918	0.811	0.896	0.837

DISCUSSION

Cladocerans are believed to be good indicators of their ambient environment. This is because of their ability to respond rapidly to changes in their habitat (Omoigberale, Oronsaye, 2011; Zawisza et al., 2016). The spatial distribution of Cladocera is based on the water chemistry and the seasonal condition of the environment (Choedchim et al., 2017).

A total of 75 individuals of Cladocera (Daphniidae, Chydoridae, Bosminidae, Macrothricidae, Sididae, and Moinidae) were encountered in this study. These were made up of two species of Daphniidae, six species of Chydoridae, one species of Bosminidae, one species of Macrothricidae, three species of Sididae, and one species of Moinidae. This study is similar to the research carried out in a different region of the Okhuaihe River by Omoigberale and Oronsaye (2011), which recorded four species of Chydoridae, one species of Bosminidae, one species of Sididae, and one species of Moinidae. Similar reports were also found in studies done on the River Ossiomo by Ikhuoriah et al. (2015), which encountered two species of Daphniidae, four species of Chydoridae, one species of Bosminidae, one species of Macrothricidae, one species of Sididae, and one species of Moinidae. Also, studies on tropical coastal estuary by Abdul et al. (2016) revealed three species of Daphniidae, one species of Chydoridae, one species of Bosminidae, one species of Macrothricidae, and one species of Moinidae.

The family Chydoridae was the most abundant of the encountered Cladocera, accounting for 33.33% of the total number of individuals, followed by Sididae 26.67%, Moinidae 16.00%, Daphniidae 14.67%, Bosminidae 8.00%, and Macrothricidae 1.33%. This is similar to the study carried out by Imoobe et al. (2008), with Chydoridae accounting for 10% followed by Macrothricidae 6.1%, Bosminidae 5.2%, Moinidae 3.3%, and Sididae 2.5%. In contrast to this is the study by Adeniyi et al. (2020), which recorded Chydoridae with the lowest relative abundance of 0.13%, the highest being Bosminidae 6.33%, followed by Sididae 3.85%, Moinidae 2.63%, and Daphniidae 0.54%.

The overall distribution, diversity, composition, abundance and dominance of the Cladocera species varied spatially at the study stations. Station 4 recorded the highest abundance of Cladocera species, while the lowest value was recorded at station 1. The low abundance of the Cladocera species in station 1 may be due to the common anthropogenic activities (Ikhuoriah et al., 2015) at the station, such as swimming, laundry, timber and lumber production, fishing, palm wine and local gin (ogogoro) production, and spiritual activities.

The density of Cladocera recorded from August 2021 to January 2022 coincides with wet and dry seasons. During the wet season, nutrients become significantly higher due to increased surface runoff (Kitheka et al., 1999); these nutrients in the water body initiate food production, i.e., phytoplankton, thus enabling the water body to support the high abundance of Cladocera species present (Manickam et al., 2017; 2018). This explains the peaks of Cladocera species in the rainy months of September and October. This was in agreement with the studies carried out in the Ogbei Stream by Ibemenuga (2020) and in Kenyir Reservoir, Malaysia, by Yusoff et al. (2002), which observed an increase in zooplankton abundance during the rainy season. This is in contrast with studies carried out by Omoboye et al. (2022) and Anyanwu et al. (2022), which recorded an increase in zooplankton abundance reported during the dry season. However, the abundance of Cladocera was low in August 2021, despite it being part of the rainy season. This was due to the short dry period known as 'August break', which is generally observed 2–3 weeks in late July and early August in most of southern Nigeria (Chineke et al., 2010; Asadu, 2002; Adejuwon, Odekunle, 2006).

The calculated diversity indices using Shannon's index revealed that station 4 (2.147) had high diversity followed by Margalef's richness index at station 3 (1.242), which take into consideration the relationship between the number of species 'S' and the total number of individuals observed 'N' indicated that station 4 (2.908) was higher in species richness followed by station 3 (1.674). Simpson's index, which considers both richness and diversity, showed that station 4 (0.851) had the greatest diversity followed by station 3 (0.667), and the study station with the lowest diversity was at station 2 (0.375). The high values of Shannon's index, Margalef's index, and Simpsons' index recorded during the course of this study indicate high diversity and the nutrient-rich status of the station; this may be because station 4 has the lowest flow velocity and less anthropogenic activities compared to the other stations on the Okhuaihe River. This is in agreement with the study by Imoobe (2011), which suggested that the Okhuo River was not under pollution threat due to the high diversity of organisms present in it.

CONCLUSIONS

The diversity of the Cladocera community in Okhuaihe River was quite low and did not reflect the prevailing physicochemical conditions. In this study, the cladocerans encountered are characteristic of a typical freshwater habitat. Continuous monitoring should be carried out periodically on the river so that a deviation in the quality of the water can be detected timely as increased anthropogenic activities in the river would impair the water quality which would, in turn, affect the abundance, richness and diversity of the species in years to come.

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CLADOCERA ZOOPLANKTONO OKHUAIHE UPĖJE (IKPAS, BENINO MIESTAS, EDO VALSTIJA, NIGERIJA) KAITA ERDVĖJE IR LAIKE PAGAL RŪŠINĘ SUDĖTĮ, GAUSĄ, PASISKIRSTYMĄ IR ĮVAIROVĘ

Santrauka

Cladocera mikrovėžiagyviai yra biologiniai vandens kokybės rodikliai. Tyrimo metu buvo stebima Cladocera rūšių sudėties, gausos, paplitimo ir įvairovės kaita erdvėje ir laike Okhuaihe upėje, Ikpe, Benino mieste (Nigerija) nuo 2021 m. rugpjūčio iki 2022 m. sausio mėnesio. Standartiniais metodais buvo užfiksuotos šešios šeimos, apimančios 75 individus. 4-oje stotyje užfiksuota didžiausia gausa (64 individai), o 1-oje – mažiausia (3 individai). Pasiskirstymas pagal gausą: Chydoridae (33,33 %), Sididae (26,67 %), Moinidae (16,00 %), Daphniidae (14,67 %), Bosminidae (8,00 %) ir Macrothricidae (1,33 %). Didžiausia rūšių gausa ir įvairovė nustatyta 4-oje stotyje, o mažiausia – 2-oje stotyje. Didžiausias tolygumas užfiksuotas 1-oje stotyje, o dominavimas – 2-oje stotyje. Daphniidae šeima teigiamai koreliavo su drumstumu, o Macrothricidae – su sulfatais ir drumstumu. Tyrimas rodo, kad Okhuaihe upės vandens kokybė yra gera, o Cladocera bendrija atitinka tropinių gėlavandenių buveinių charakteristikas, tačiau nedidelė jos įvairovė nevisiškai atspindėjo fizikines ir chemines sąlygas. Siekiant anksti nustatyti vandens kokybės pokyčius, rekomenduojama tęsti stebėseną, nes didelis antropogeninis poveikis gali neigiamai paveikti rūšių gausą, turtingumą ir įvairovę.

Raktažodžiai: Cladocera, fizikiniai ir cheminiai parametrai, įvairovė, gausa, stebėsena