Malaysian Journal of Microscopy 2024 20(2) 86-98

MALAYSIAN JOURNAL OF MICROSCOPY

Journal homepage: https://malaysianjournalofmicroscopy.org

RESEARCH ARTICLE

ZOOPLANKTON DIVERSITY AS A RELIABLE INDICATOR OF WATER QUALITY IN DERHAKA RIVER

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Abstract. A study on the zooplankton community was conducted in Derhaka River, Seberang Jaya, Pulau Pinang, from November 2023 to January 2024. Zooplankton samples were collected from three stations, with three replicates taken at each station. These samples were then analyzed under a microscope at various magnifications. Fifty-four zooplankton taxa were identified in the Derhaka River, comprising three main groups: Rotifera, Cladocera, and Copepoda. Rotifera was the dominant group, with 46 taxa recorded. In terms of zooplankton abundance, Station 2 had the highest numbers, with 38,611 ± 4.28 ind/m³ in November, 150,000 ± 36.48 ind/m³ in December, and 104,444 ± 23.89 ind/m³ in January. Various physicochemical parameters were measured *in-situ*, including temperature, conductivity, total dissolved solids (TDS), dissolved oxygen (DO), pH, and transparency. Pearson correlation results indicated that zooplankton abundance had a strong positive correlation with species number ($r = 0.804$) and a strong negative correlation with DO ($r = -0.493$). Additionally, there was a significant difference in zooplankton abundance with the sampling stations ($p<0.05$). The study concludes that human activities or other environmental factors may influence the zooplankton community in the study area. Monitoring human activities that impact the river, along with agricultural practices, is crucial to protect the health and biodiversity of this ecosystem.

Keywords: Cladocera, Copepoda, Rotifera, zooplankton.

Article Info

Received 28 August 2024
Accepted 20 November 2024
Published 6 December 2024

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ISSN: 1823-7010, eISSN: 2600-7444

1. INTRODUCTION

Within the vast expanse of freshwater ecosystems, tiny aquatic organisms like zooplankton typically drift within the water currents. Zooplankton are more accurate indicators of trophic conditions than phytoplankton due to their larger size, facilitating easier identification. Moreover, zooplankton demonstrate a stronger correlation with environmental variables and exhibit more rapid responses to environmental fluctuations than fish. Consequently, they hold substantial promise as reliable water quality indicators [1].

As a fundamental food source for fish and other aquatic life, freshwater zooplankton are vital in the freshwater food chain. Additionally, since zooplankton primarily feeds on phytoplankton, they regulate phytoplankton populations, helping prevent algal blooms [2]. The major groups of freshwater zooplankton are copepods, rotifers, protozoa, ostracods, and cladocerans. Zooplankton are sensitive organisms that react quickly to changes in water quality, making them valuable indicators for assessing water quality and biodiversity [3].

Species abundance and diversity are essential characteristics of an aquatic environment [4]. Therefore, this study was conducted in Derhaka River, Pulau Pinang, focusing on analyzing the river's influence on the dynamics of the zooplankton community. While previous research [5-7] has primarily focused on specific areas and habitats, comprehensive data on zooplankton in freshwater ecosystems nationwide are still lacking. Thus, further research is needed to understand how human activities affect zooplankton diversity and abundance in Malaysia.

Derhaka River is a domestic river located in Seberang Jaya, Pulau Pinang, Malaysia, and provides a habitat for various aquatic organisms, including zooplankton species. This river attracts many people, especially on weekends. Because the Derhaka River connects to Perai River, it plays a crucial role as a water basin during the monsoon season. It regulates water flow, reduces flood risks, and replenishes groundwater, adding to its ecological and conservation significance. However, it lacks a proper sanitary treatment system, resulting in significant amounts of agricultural and domestic wastewater being discharged into the river. These anthropogenic activities can disrupt the structure and abundance of zooplankton communities [8-9]. Despite this, no studies have been conducted on the zooplankton communities in Derhaka River. Therefore, this study aims to determine the dominant species abundance of freshwater zooplankton communities in Derhaka River and to examine how the physicochemical parameters correspond to zooplankton abundance as a reliable indicator of water quality in the river.

2. MATERIALS AND METHODS

Derhaka River is located in the northern part of Seberang Perai, Pulau Pinang. Three different sampling points were chosen for zooplankton sample collection along the riverbank: Station 1, the downstream site near the Perai River estuary; Station 2, midstream, placed near a park with a jogging track in Tunku Park; and Station 3, representing upstream, near a restaurant and housing areas (Figure 1). The sampling sites were chosen based on the area's physical characteristics to resemble the zooplankton habitat's varying physical conditions.

Quantitative sampling methods were used to collect zooplankton specimens. Sampling was conducted over three months, from November 2023 to January 2024. For each sample, quantitative sampling was done by filtering 40 L of river water using a Wisconsin plankton net with a mesh size of 35 µm. Three sample replicates were gathered at each sampling station. The filtrate was then moved into 120 ml sample bottles, and 70% ethanol was used to preserve it.

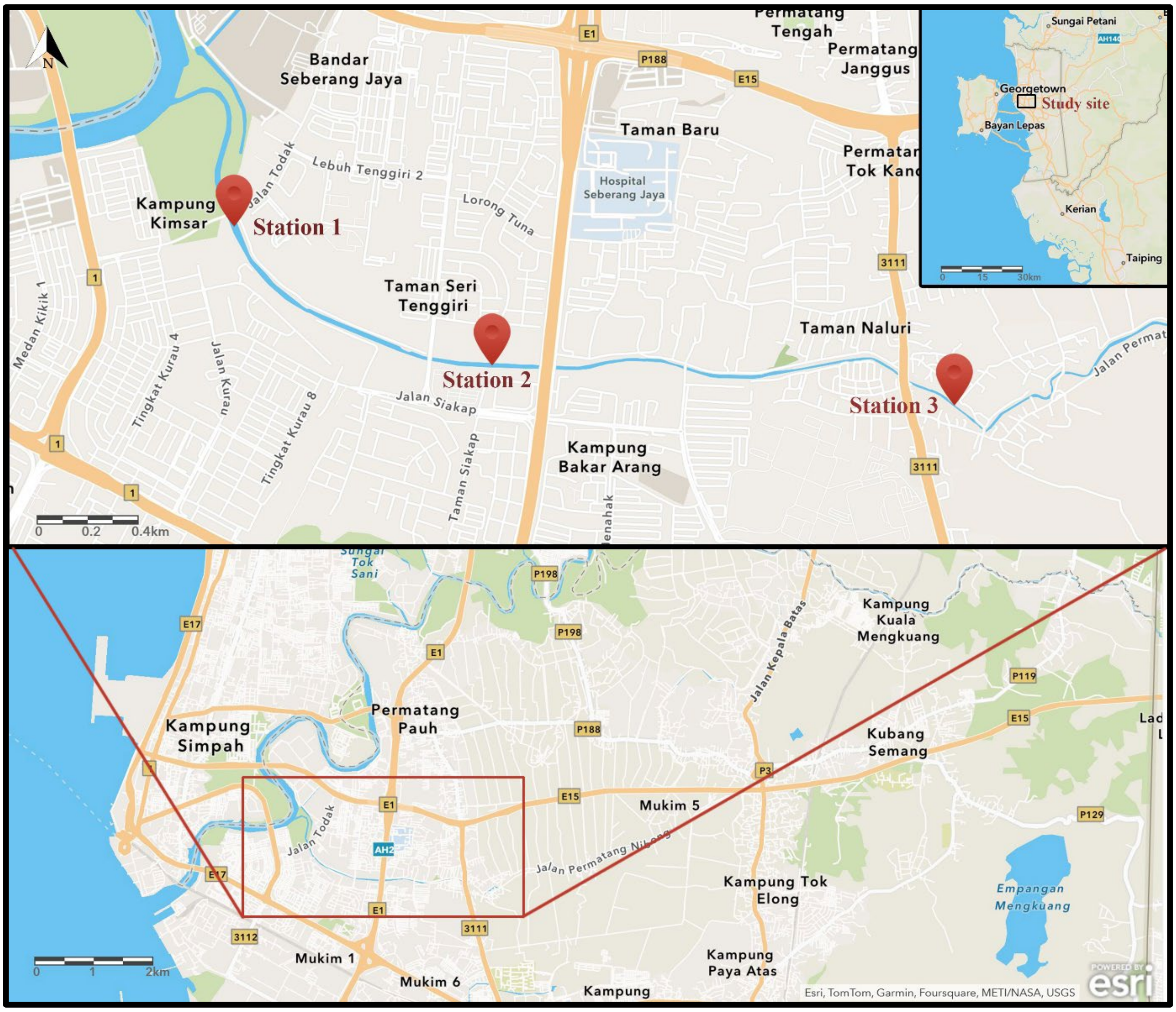

Figure 1: Map of Derhaka River with the three sampling stations (Station 1, the downstream site, near the Perai River estuary; Station 2, midstream, near Tunku Park; and Station 3, upstream, near restaurant and housing areas. Source: ArcGIS, 2024)

With the aid of the YSI Multiparameter (Model 556 MPS), the following parameters were measured *in-situ*, which are water temperature, conductivity, pH, dissolved oxygen (DO), and total dissolved solid (TDS). A pH water was recorded using a HACH sensION1 portable pH meter, while the Secchi disc and measuring tape were used to calculate the water's transparency. Each sampling station's precise location was recorded using a Garmin GPS unit, and the Vernier LabQuest® 2 was utilized with a Turbidity Sensor (TRB-BTA) to collect the turbidity data.

Zooplankton was identified using a compound microscope (Olympus BX41) connected to a computer and an imaging camera. After gently shaking, 1 ml of the sub-sample was randomly extracted from the sample vial using an adjustable volume pipette. With care, a coverslip was placed over the sub-sample in a Sedgewick Rafter counting cell to prevent air bubbles from forming in the slide.

The sample was examined under a microscope at 20X, 40X and 100X magnifications, and each specimen was placed on a slide for a close inspection. The taxonomic keys and illustrations found in the earlier publications [10-11] were then used to identify each specimen.

The zooplankton community's richness and diversity were analyzed using the ecological indices: Simpson Diversity Index (D), Shannon-Wiener Index (H'), Margalef Index and Pielou's Index

(J'). Zooplankton abundance was calculated following [12]. Pearson correlation was used to evaluate the relationship between physicochemical parameters and zooplankton abundance. The correlation aimed to determine whether the abundance of zooplankton and the physicochemical parameters, including pH, dissolved oxygen, total dissolved solids, conductivity and temperature, were correlated. A two-way ANOVA was run to determine whether the amounts of zooplankton varied significantly between sampling stations ($p < 0.05$) and sampling months ($p < 0.05$).

The present study faces several limitations, including time constraints, particularly during sampling. The zooplankton samples are time-consuming, involving multiple steps like collection, preservation, identification, and counting. This can delay data analysis, especially when large datasets or frequent sampling are needed. Additionally, adequate manpower is often unavailable, leading to longer sampling times. Technical issues like equipment malfunctions, calibration errors, and sample contamination can also compromise data quality. These limitations can reduce the reliability of assessments and the ability to make timely management decisions. Overall, the three-month sampling period was chosen to optimize the study's feasibility and quality, considering the constraints related to time, laboratory processing, and climatic factors.

3. RESULTS AND DISCUSSION

In limnological research, Rotifera, Cladocera, and Copepoda constitute the main groups of freshwater zooplankton [13]. In this current study, 54 zooplankton taxa were recorded between November 2023 and January 2024. Among these, 46 taxa were Rotifera, six were Cladocera and two were Copepoda (Table 1). Figure 2 shows some of the specimen images at different magnifications. According to Rivas et al. [13], zooplankton species are more numerous in the littoral zone than in other zones. In this study, Stations 2 and 3 were situated in the littoral zone. This is relevant because Station 2 exhibited the highest zooplankton abundance. However, Station 3 had a lower zooplankton abundance, probably due to water movement. Wastewater from a nearby restaurant and housing areas entered the river via pipes near Station 3, creating ongoing water movement. According to Nguyen et al. [14], 137 distinct taxa were found throughout their study, a large case assessment compared to the current study. This variation is attributed to the different sampling zones and durations used in the study.

Rotifera was the most dominant group of zooplankton recorded in Derhaka River during the sampling periods. With a total of 48 species, it comprised the highest percentage of species at 82.76%. The Brachionus family was the most diverse within Rotifera, containing 15 zooplankton species. Wallace et al. [15] noted that most rotifers thrive in freshwater environments due to their generalized feeding habits, high reproductive rates, and rapid growth, which enable them to survive effectively. However, Feike and Heerkloss [16] observed that predation by copepods has a stronger impact on rotifer suppression than exploitative resource competition. This observation is supported by Liu et al. [17], who found that the copepods, along with predatory rotifer *Asplanchna* [18], are effective predators of rotifers, frequently leading to seasonal declines and species replacements in rotifer populations. Thus, predation is more closely associated with rotifer suppression by copepods than resource competition. Therefore, the thriving population of rotifers in Derhaka River can be attributed to the lack of copepod species in the sampling ecosystem.

Table 1: Zooplankton taxa and abundance in Derhaka River from November 2023 until January 2024 (ind/m³)

			November			December			January		
Group	**Order**	**Species**	**ST.1**	**ST.2**	**ST.3**	**ST.1**	**ST.2**	**ST.3**	**ST.1**	**ST.2**	**ST.3**
Rotifera	Bdelloidea		278	6389	2222	278	3611	1944	0	13889	2500
		Rotaria sp.	0	0	0	0	556	0	0	278	0
		Rotaria neptunia	2222	2222	278	0	5000	278	0	4444	278
	Flosculariaceae	*Conochilus* sp.	0	0	0	556	0	0	0	0	0
		Filinia sp.	833	1111	278	4722	12500	1389	278	11667	1389
		Testudinella sp.	1111	0	0	3056	278	0	0	0	833
		Testudinella patina	833	1667	278	0	0	0	0	0	0
		Ptygura sp.	0	0	0	0	0	0	0	0	278
	Ploima	*Ascomorpha* sp.	0	0	0	0	0	0	0	556	0
		Asplanchna sp.	0	278	0	278	556	556	0	0	0
		Asplanchna priodonta	0	1111	556	1111	1111	0	0	833	0
		Asplanchnopus sp.	0	278	0	0	0	0	0	0	0
		Anuraeopsis sp.	0	0	0	0	278	0	0	0	0
		Anuraeopsis fissa	2222	4444	2500	9722	3611	3056	833	3333	2222
		Brachionus sp.	278	556	0	8889	5556	1111	1111	7500	556
		Brachionus angularis	278	0	556	23333	19722	2778	3889	18611	3056
		Brachionus bidentatus	0	0	0	0	0	0	3611	556	0
		Brachionus budapestinensis	0	0	0	278	0	0	0	0	0
		Brachionus calyciflorus	0	0	0	833	278	278	1389	4444	278
		Brachionus calyciflorus amphiceros	0	0	0	0	278	0	0	0	0
		Brachionus caudatus	0	0	0	0	0	0	0	3056	0
		Brachionus falcatus	0	0	0	278	0	0	278	278	0
		Brachionus leydigi	0	0	0	0	0	0	0	833	0
		Brachionus nilsoni	278	278	0	278	0	0	0	0	0
		Brachionus plicatilis	0	0	0	0	0	0	0	2222	0
		Brachionus quadridentatus	0	0	0	0	278	0	0	0	0

		Lecane sp.	0	278	0	556	0	0	0	278	0
		Lecane bulla	0	0	556	0	556	278	0	0	0
		Lecane cf. *signifera*	278	0	0	0	0	0	0	0	0
		Lecane curvicornis	0	278	0	0	0	0	0	0	0
		Lecane hamata	278	0	278	833	0	0	0	0	0
		Lecane papuana	0	556	0	0	0	556	0	0	833
		Lecane pyriformis	0	0	0	278	0	0	0	0	0
		Lepadella sp.	0	0	0	278	278	0	0	278	0
		Keratella valga	0	0	0	278	278	0	0	0	0
		Eosphora najas	0	0	0	0	278	0	0	0	0
		Cephalodella sp.	0	0	0	0	278	278	0	278	0
		Hexathra sp.	0	0	0	0	0	0	0	833	0
		Mytilina bisulcata	0	0	0	0	0	0	0	6389	833
		Mytilina sp.	278	0	0	0	0	0	0	0	0
		Notommata sp.	0	3889	0	833	556	278	0	833	556
		Plationus patulus	0	1389	278	0	0	0	0	0	0
		Polyarthra sp.	3056	556	0	0	0	0	0	556	0
		Proalides sp.	0	556	0	0	0	278	0	278	556
	Collothecaceae	*Collotheca* sp.	278	278	0	1667	1667	556	0	556	278
		Collotheca pelagica	0	0	0	278	0	0	0	0	0
Copepoda	Calanoida		0	0	0	0	0	0	0	278	0
	Harpacticoida		0	0	0	0	278	0	0	0	0
Cladocera	Anomopoda	*Ceriodaphnia cornuta*	0	556	0	0	0	0	0	0	0
		Daphnia galeata	0	0	0	278	0	0	0	0	0
		Moina sp.	0	0	0	0	16667	0	0	0	0
		Moina macrocopa	0	0	0	0	38611	4444	0	5833	3333
		Moina micrura	278	0	0	5000	26389	3333	2778	1111	3333
	Ctenopoda	*Diaphanosoma* sp.	0	556	0	0	0	0	0	0	0

Abbreviation: ST., Station

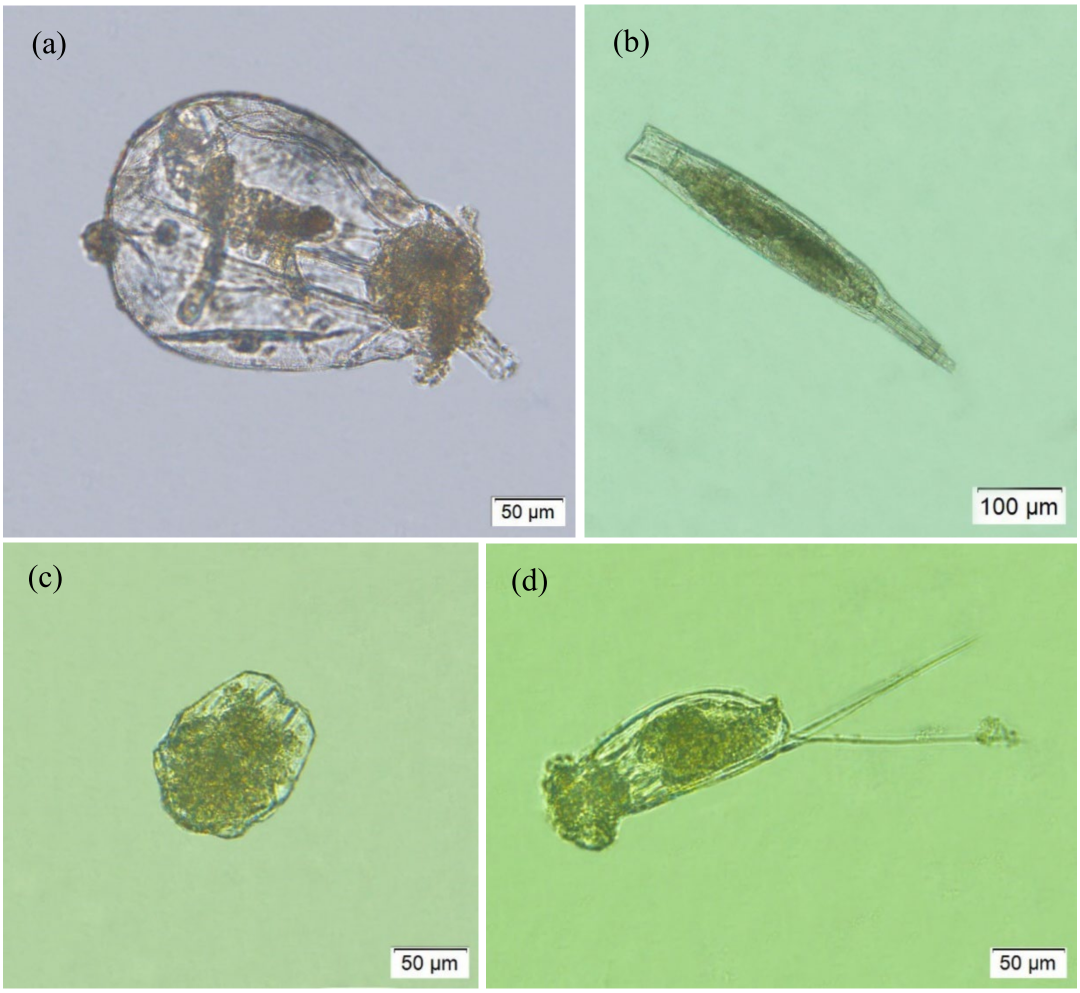

Figure 2: Some of the specimen images at different magnifications (a) *Asplanchna priodonta*, (b) *Rotaria neptunia*, (c) *Brachionus angularis* and (d) *Filinia* sp.

Cladocera and Copepoda exhibited lower species richness and abundance across all sampling sites in this study. Only two Cladocera families and two Copepoda orders were identified in the present study. Medeiros and Arthington [19] suggest that this could be attributed to changes in water's chemical properties, rendering the habitat unsuitable for these species of copepod and cladoceran.

The variability in zooplankton abundance observed in the current study suggests inconsistency. Station 2 recorded the highest mean abundances over three months (November, December, January), with values of 38,611 ind/m³, 150,000 ind/m³, and 104,444 ind/m³, respectively, while Station 3 consistently exhibited the lowest abundances during the sampling periods, with values of 13,056 ind/m³, 26,944 ind/m³, and 23,889 ind/m³, respectively. This fluctuation could be attributed to prey-predator interactions and fluctuations in physicochemical parameters, which influence zooplankton abundance. The decrease in cladoceran species numbers may be linked to the higher presence of rotifer, which can also prey on cladoceran [20]. Additionally, Shah et al. [21] propose that the higher number of copepods compared to cladocerans may be due to the latter serving as prey for copepods, potentially contributing to the decline in cladoceran species. The limited number of Cladocera species in the current study could also result from increased predation pressure, leading to the dominance of Rotifera species in the Derhaka River ecosystem. Therefore, the inconsistent abundance of zooplankton in Derhaka River may result from complex prey-predator dynamics.

Zooplankton are also potential bioindicators of health in freshwater ecosystems because their community composition and abundance quickly respond to changes in environmental conditions. Table 2 shows the mean values of physicochemical parameters across three sampling stations in Derhaka River during the study periods. The water's chemical properties greatly influence the number and types of zooplankton in water. Bari et al. [22] suggested that changes in zooplankton populations are closely linked to how these tiny animals interact with their environment's physical and chemical aspects. Hence the current study inquired into the relationship between the three sampling stations' physicochemical parameters and the diversity and abundance of zooplankton.

Dissolved oxygen (DO) is crucial for the survival and health of aquatic life, serving as a key indicator of water quality. DO levels fluctuate due to biotic and abiotic factors such as respiration, photosynthesis, organic waste decomposition, temperature, atmospheric pressure, and human activities, which often contribute to variations in DO levels [23]. The present study recorded the highest dissolved oxygen reading in Station 3, showing the lowest abundance of zooplankton for all stations. The study by Imant & Novoselov [24] is consistent with the present study, as dissolved oxygen has an inverse relationship with zooplankton abundance.

pH is one of the parameters that could influence the distribution and abundance of zooplankton species [25]. In the current study, the pH value in December was higher than in November and January. Low pH values indicate fewer zooplankton species [25]. Hence, zooplankton abundance in December was the highest compared to zooplankton abundance in November and January.

Water transparency measures the depth to which light can penetrate the water column. Higher water transparency indicates greater light penetration into deeper layers of the water bodies [26]. High transparency favours phytoplankton abundance as it depends on light to perform photosynthesis [27]. Zooplankton depends on phytoplankton as one of its food sources.

With lower water transparency, lower abundance of phytoplankton, and lower abundance of zooplankton. However, in this study, Station 3 indicated high transparency but lower abundance of zooplankton. This is probably due to prey-predator interaction in the water ecosystem and other factors, including nutrient availability [28].

In this study, the ecological indices including the diversity, evenness and richness indices were calculated (Table 3). According to Gregorius and Gillet [29], the Shannon-Wiener Index value increases as diversity increases. Thus, it has been considered a better index than Simpson's. A higher index value indicates a greater probability of selecting individuals representing different species. Heip, Herman and Soetaert [30] show that diversity indices are separated into three categories, which are ($H' < 1$) for low diversity, ($1 < H' < 3$) for moderate diversity and ($H' > 3$) means great species diversity. Therefore, according to the categorization, zooplankton in Derhaka River have a moderate species diversity with a range of 1.64 (the lowest value) to 2.48 (the highest value) in the Shannon-Wiener Index.

For the Pielou Index, the index is used to calculate the evenness of the abundance in the community [31]. The value of near 1 indicates that the zooplankton species were distributed evenly. Based on the study, Station 1 and Station 3 were evenly distributed in three months; however, Station 2 was not evenly distributed. Thus, it can be concluded that the zooplankton was not evenly distributed at the sampling site. Gamito [32] points out that for the Margalef Index, higher diversity values indicate the quality of the environment for the organism and a strong food chain, a robust food web, plus a more stable community. Therefore, Station 2 in November and January have the highest values of the Margalef Index, possibly meaning that those stations have a stable community.

Table 2: Mean values of physicochemical parameters at three sampling stations from November 2023 until January 2024

Month	Station	Temperature (°C)	Conductivity (µS/cm)	Total dissolved solid (g/L)	Dissolved oxygen (mg/L)	pH	Transparency (cm)
November	1	27.95 ± 0.03	1052.67 ± 70.14	0.65 ± 0.04	1.07 ± 0.19	6.40 ± 0.09	7.33 ± 0.88
	2	26.83 ± 0.08	133.33 ± 4.10	0.09 ± 0.00	1.51 ± 0.09	5.67 ± 0.03	6.33 ± 0.88
	3	26.67 ± 0.02	91.00 ± 1.00	0.06 ± 0.00	3.55 ±0.06	5.64 ± 0.12	5.33 ± 0.33
December	1	28.55 ± 0.65	2009.67 ± 35.88	1.21 ± 0.02	1.25 ± 0.03	6.76 ± 0.13	13.00 ± 0.58
	2	29.38 ± 0.05	594.33 ± 3.48	0.36 ± 0.00	1.39 ± 0.31	6.21 ± 0.02	17.17 ± 1.09
	3	27.42 ± 0.03	111.67 ± 0.67	0.07 ± 0.00	2.92 ± 0.10	5.98 ± 0.10	20.33 ± 0.33
January	1	28.62 ± 0.03	5171. 67 ± 14.77	3.15 ± 0.01	3.90 ± 0.15	6.82 ± 0.04	25.67 ± 0.33
	2	28.56 ± 0.08	1013.00 ± 5.57	0.62 ± 0.00	1.77 ± 0.10	6.13 ± 0.05	33.97 ± 2.11
	3	28.75 ± 0.03	122.00 ± 1.15	0.07 ± 0.00	4.59 ± 0.12	5.71 ± 0.07	28.00 ± 0.58

Table 3: Ecological indices of zooplankton at three sampling stations from November 2023 until January 2024

Month	Station	Indices		
		Diversity	**Evenness**	**Richness**
		Shannon-Wiener Index (H')	**Pielou Index (J')**	**Margalef Index (R)**
November	Station 1	1.64	0.71	2.86
	Station 2	2.36	0.87	3.97
	Station 3	1.59	0.83	2.36
December	Station 1	2.25	0.84	3.36
	Station 2	2.16	0.77	3.22
	Station 3	2.27	0.88	3.71
January	Station 1	1.81	0.91	2.16
	Station 2	2.48	0.85	3.85
	Station 3	2.12	0.91	3.01

The findings on zooplankton biodiversity in the Derhaka River have important implications for freshwater conservation. As a potential bioindicator that reflects the health and quality of the aquatic ecosystem, high biodiversity indicates a balanced and healthy ecosystem, while low diversity or shifts in community composition can signal water quality issues, such as pollution or nutrient imbalances. The total number of zooplankton taxa in the present study is greater than that in the Pinang River [7], which is experiencing pollution and significant threats to water quality due to anthropogenic activities. This finding highlights the importance of maintaining and enhancing biodiversity to ensure the long-term health of the Derhaka River and its ecosystem.

4. CONCLUSIONS

In conclusion, this study has recorded 54 zooplankton taxa in the Derhaka River, Pulau Pinang, from November 2023 to January 2024. The primary objective is to determine the abundance of dominant zooplankton species at the three sampling stations. Five dominant zooplankton that have been recorded in the study site with their abundance are *Brachionus angularis* (72, 223 ind/m^3), *Moina macrocopa* (52, 221 ind/m^3), *Moina micrura* (42, 222 ind/m^3), *Filinia* sp. (34, 167 ind/m^3) and *Anuraeopsis fissa* (31, 943 ind/m^3). Kruskal-Wallis test revealed a significant difference in zooplankton abundance among the sampling stations ($p < 0.05$) and across months. Therefore, it indicated that zooplankton abundance varies across stations and months. In the current study, zooplankton abundance is influenced by certain physicochemical parameters, especially pH and water transparency. These parameters consistently correlate with disturbances caused by anthropogenic factors, such as human activities or natural calamities. Moreover, the Derhaka River serves as a fishing spot for local communities, indicating high primary productivity and a healthy zooplankton community. The availability of food, specifically phytoplankton and nutrient abundance, also plays a crucial role in determining zooplankton populations in the ecosystem. The interactions among the three main groups of zooplankton and their effects on each other are important factors in their distribution. Furthermore, future research should prioritize long-term monitoring of zooplankton communities to evaluate the impacts of anthropogenic activities on biodiversity and water quality. Monitoring human activities that affect the river, as well as agricultural practices, is essential. Local water quality monitoring agencies could incorporate regular zooplankton assessments to track ecosystem health over time. Further studies should investigate the relationship between zooplankton diversity and specific water quality parameters, such as nutrient levels and pollutants. This information can guide the development of conservation strategies and management approaches to preserve the Derhaka River's ecosystem health and promote its sustainability for future generations.

Acknowledgements

The authors express their sincere gratitude to Zalin Nazatul Akmal Zainal, Naaga Leechume, Auni Izzati Kamarudin, Sahwanti Dulamit, and Tang Wei Li for their invaluable assistance during the field sampling.

Author Contributions

All authors contributed toward data analysis, drafting and critically revising the paper and agree to be accountable for all aspects of the work.

Disclosure of Conflict of Interest

The authors have no disclosures to declare

Compliance with Ethical Standards

The work is compliant with ethical standards

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