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Research Article

Applying zooplanktonic biological indices for assessment of water quality in the watersheds of Ray river, Baria-Vung Tau province

Tran Ngoc Diem My*, La Duong Song Nhi

ABSTRACT

The Ray River is an important river system in Ba Ria-Vung Tau Province, Vietnam, supplying water for domestic, agricultural, and industrial purposes, thereby facilitating the province's economic development. The research was executed in 2024 across 9 watersheds, comprising 5 sites on the Ray River and 4 sites on the Ray River reservoir, throughout both the rainy and dry seasons. The findings documented 111 species of zooplankton, categorized into 50 genera, 13 orders, and 5 primary groups: Protozoa, Rotatoria, Cladocera, Copepoda, and Ostracoda. The research noted variations in zooplankton communities throughout the two seasons, suggesting saline intrusion at specific locations along the Ray River during the dry season. The Shannon-Wiener biodiversity score varied between 1.95 and 3.43, whereas the Pielou Evenness index consistently exceeded 0.8. The biological indicators of zooplankton communities indicate that most aquatic systems exhibited generally clean water quality, with only two locations demonstrating moderate pollution levels (α-mesosaprobe) during the dry season. The findings indicate that the aquatic environment in the Ray River system, encompassing both the river and reservoir, satisfies the water supply criteria for supplying domestic water and irrigation water in Ba Ria-Vung Tau Province. The study suggests utilizing zooplankton as an indicator for precise water quality scenarios, owing to their sensitivity to environmental fluctuations and brief life cycles. This would also offer a cost-effective approach for environmental monitoring and management of the river system.

Key words: zooplankton, water quality assessment, biological indices, Ray River, Ba Ria – Vung Tau province

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INTRODUCTION

The Ray River originates in Xuan Loc District (Dong Nai Province) and traverses multiple regions of Ba Ria-Vung Tau Province, spanning around 90 km and constituting a significant transportation canal. The Ray River Basin and Ray River Reservoir are vital water sources in the Ba Ria-Vung Tau region, serving crucial functions in supplying water for home, agricultural, and industrial purposes, while also safeguarding the surrounding natural environment. The Ray River supports biodiversity through a diverse array of plants and fauna. The regions next to the river encompass vital natural ecosystems that contribute to climate regulation and mitigate soil erosion.

The Ray River Reservoir, with a capacity of over 240 million m^3, was established to store and manage water for industrial, residential, and flood mitigation purposes[1]. The reservoir's water is processed to provide clean and safe drinking water to hundreds of thousands of families in Ba Ria-Vung Tau, guaranteeing daily access to potable water. Agriculture in this region is predominantly dependent on water from the Ray River. Irrigation systems extract water from rivers and reservoirs to irrigate rice fields, industrial crops (including rubber, pepper, and cashew), and fruit trees. In the dry season, the Ray River supplies essential water to maintain agricultural productivity.

The Ray River Reservoir supplies water to significant industrial zones in the region, including Phu My Industrial Zone and My Xuan Industrial Zone. The reservoir's water fulfills the operating requirements of companies and businesses in the region, hence aiding the economic advancement of Ba Ria-Vung Tau Province.

Nonetheless, human activities, including water extraction, industrial waste disposal, and routine practices, are causing the Ray River and its reservoir to confront issues like water contamination and deteriorating ecological quality. Ensuring clean water and safeguarding the aquatic ecosystem in the river and reservoir is crucial for conserving biodiversity and regulating the local climate.

Zooplankton are small organisms that drift in aquatic environments; they possess the ability to swim but are unable to navigate against the current. They are extensively distributed over freshwater, brackish, and

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marine ecosystems, including both stagnant and flowing waters. Their body dimensions exhibit considerable variation, spanning from tens of micrometers (protozoa) to several millimeters (larger zooplankton). Zooplankton serves as an essential connection between primary producers and higher trophic levels in aquatic environments[2]. Their distribution is contingent upon various parameters, like flow conditions, salinity, and nutrient availability[3]. Multiple studies underscore zooplankton as effective bioindicators, particularly in aquatic environments contaminated by organic waste and heavy metals. Zooplankton can swiftly respond to environmental alterations, effectively indicating ecosystem health, with minimal monitoring expenses[4,5].

To comprehensively and precisely evaluate the contaminants in water sources, it is essential to utilize biological markers in conjunction with physical and chemical indicators. Physical and chemical indicators provide data at the moment of measurement, but they rapidly fluctuate over time, thereby failing to accurately represent the true features of the water environment. The organism's body will preserve these characteristics, which affect it at multiple levels. Presently, monitoring programs regard it as a constraint that nearly all periodic environmental assessments predominantly emphasize physical and chemical indicators of water.

It is imperative to preserve biodiversity and regulate the local climate by ensuring the quality of water and the protection of the aquatic ecosystem in the Ray River system. This necessitates consistent environmental surveillance to promptly identify anomalous occurrences. The research aimed to evaluate the feasibility of employing zooplankton bioindicators for water quality evaluation in the Ray River basin system. This study was undertaken to establish a scientific foundation for zooplankton population structure and their potential as bioindicators within the river system.

RESEARCH METHODS

Samples were collected at 9 sites, including 5 sites on the Ray River Basin (SR1, SR2, SR3, SR4, SR5) and 4 sites on the Ray River Reservoir (HSRay1, HSRay2, HSRay3, HSRay4), during two seasons: dry season (March 2024) and the rainy season (September 2024) (Figure 1).

Sampling locations in the Ray River Basin:

SR1, SR2, SR3, SR4, and SR5: These points must be designated along the Ray River as it traverses distinct regions, commencing with Xuan Loc District in Đồng Nai Province and proceeding through numerous sites in Ba Ria-Vung Tau Province.

Sampling locations at Ray River Reservoir: HSRay1, HSRay2, HSRay3, HSRay4: These points must be situated on the Ray River Reservoir, a vital water source for nearby residences, agriculture, and business. Qualitative and quantitative zooplankton samples were obtained utilizing a Juday net featuring a mesh size of 45 μm, a mouth diameter of 0.4 m, and a net length of 0.9 m. The net was towed seven times at a velocity of 0.3 m/s, and the samples were transferred to 100-ml vials and preserved with 5% formalin. The identification of zooplankton species was based on the subsequent sources: The Rotifer Fauna of Wisconsin[6]; The Plankton of South Viet Nam: Fresh Water and Marine Plankton[7]; Rotatoria: Die Rädertiere Mitteleuropas by Max Voigt[8]; Fauna of Vietnam[9]; Freshwater Biology[10]; Free-Living Freshwater Protozoa[11]; Copepoda-Calanoida-Diaptomidae[12]; Zooplankton quantification was performed by enumerating organisms using a Sedgwick-Rafter counting chamber.

Biodiversity indicators, including the Shannon-Wiener diversity index (H') and the Pielou Evenness index (J')[13], were employed to assess the variability, similarity, and stability of zooplankton populations at each sample location in relation to pollution levels. Table 1 juxtaposes the outcomes of the biological index analysis with evaluation scales derived from Staub et al. (1970) and Pielou (1966)[14,15] (Table 2).

All water and zooplankton samples are analyzed at the Department of Ecology and Evolutionary Biology, Biology–Biotechnology Faculty, University of Sciences, Vietnam National University.

The research findings were computed and analyzed utilizing Excel 2013 and the Primer 6 software, employing a 95% confidence interval to determine biological indices. The t-test and ANOVA variance analysis were performed using SPSS with the LSD method at a 95% confidence interval.

RESULTS AND DISCUSSION

Zooplankton composition

The examination of species composition in the Ray River system over two seasons identified 111 taxa across 50 genera, 13 families, and 5 groups: the Rotatoria group represented the highest proportion with 45 species, constituting 40.54%, followed by the Protozoa group with 34 species (30.63%), the Copepoda group with 17 species (15.32%), the Cladocera group with 12 species (10.81%), and the Ostracoda group, which had the lowest representation with 3 species,

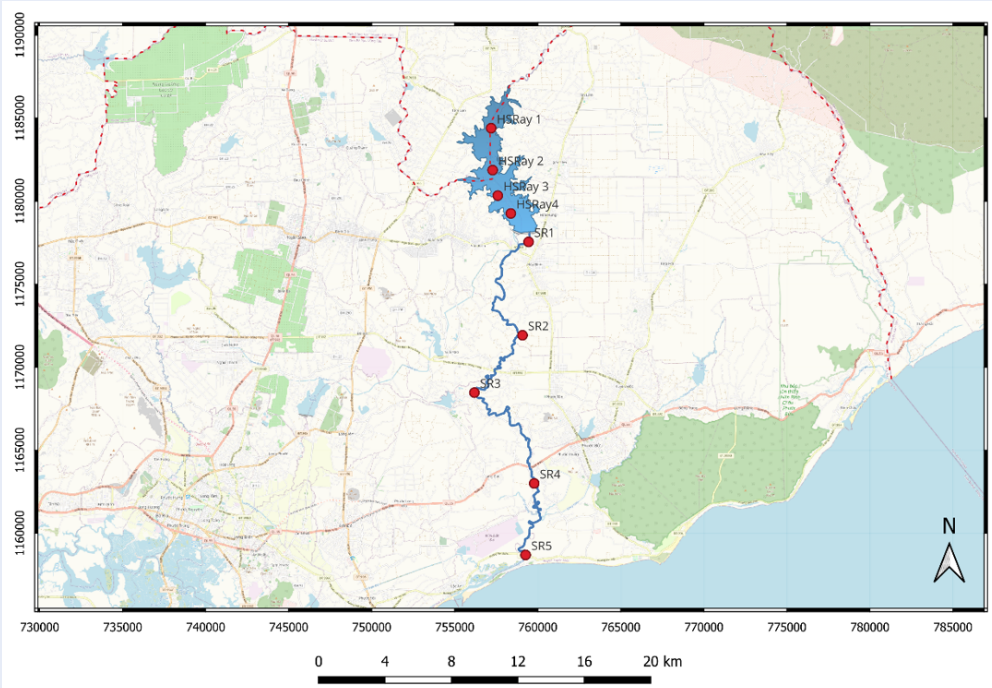

Figure 1: The map of 9 sampling sites

Table 1: Water quality assessment based on the Shannon-Wiener diversity index (H') [16]

Shannon-Wiener diversity index (H')	Water quality
< 1	High pollution (Polysaprobic)
1 - 2	Heaviest pollution (α-polysaprobic)
> 2 - 3	Moderate pollution (β-mesosaprobic)
> 3 - 4,5	Slight pollution (Oligosaprobic)
> 4-5	Pure water

Table 2: Scoring scale for assessing the sustainability of the zooplankton community corresponding to the level of pollution. [14]

Peilou index J'	Sustainable – Pollution scales
J' > 0,8	sustainable communities – oligosaprobic.
0,6 < J' < 0,8	less sustainable communities – Mesosaprobic / moderate pollution
0,4 < J' < 0,6	very less sustainable communities - Mesosaprobic α / heaviest pollution
J' < 0,4	unsustainable communities – Polysaprobic / high pollution

accounting for 2.7% (Figure 2). Of the 111 documented species, 83 species from five groups were identified during the rainy season, with a notable predominance in the Rotatoria group (44 species). During the dry season, 74 species across 5 groups were documented, with the Protozoa group exhibiting the highest diversity at 28 species. The study identified 46 species present in both seasons and detected Nauplius larvae from the Copepoda group at every sampling location in both seasons. The zooplankton findings demonstrated a notable increase relative to Nguyen Van Khoi's study[17], which discovered merely 36 species and revealed little richness, since numerous species were prevalent in coastal regions but absent in the river. The lack of common freshwater zooplankton species from the classes Cladocera, Chaetognata, Pteropoda, and Heteropoda significantly diminished the species mix. The Copepoda group comprised 73.53% of the total zooplankton species.

During the rainy season, there were more species at sample sites than during the dry season (Figure 3). This was likely because the water levels rose quickly and more nutrients from land ran off, which helped zooplankton grow ($p = 0.004$). In the rainy season, the Rotatoria group comprised more than 50% of the total species seen. During the dry season, elevated salinity promoted the survival and proliferation of the Protozoa and Copepoda groups. The Protozoa group exhibited an increase in species from 17 during the rainy season to 27 in the dry season, whereas the Copepoda group rose from 10 species to 13, including some species typical of brackish water habitats. This suggests that seasonal variables and salinity levels impact zooplankton at the sampling locations year-round. The results of this study align with those of research such as Zakaria (2007)[18], Nguyen Thi Kim Lien (2013)[19], and Nguyen Manh Hung (2003)[20], all of which observed that zooplankton exhibited seasonal variation impacted by salinity variables.

The zooplankton groups during the rainy season indicated a substantial disparity in species composition, ranked as follows: Rotatoria > Copepoda > Protozoa = Cladocera > Ostracoda ($p = 0.000$). During the dry season, a statistically significant variation in species composition was observed among the categories, classified as Protozoa = Rotatoria > Copepoda > Cladocera > Ostracoda ($p = 0.0035$). The t-test indicated significant variations in species composition between the two seasons for the Rotatoria group ($p = 0.001$), Protozoa group ($p = 0.002$), and Copepoda group ($p = 0.01$). The other groups exhibited no notable differences. The locations in the Ray River basin exhibited a significant variation in species composition between the two seasons ($p = 0.008$), whereas the sites in the Ray River reservoir displayed no significant variations in species composition.

Density of zooplankton individuals

At the sampling sites, the density of zooplankton ranged from 12,100 to 117,625 individuals/m^3. The individual density among groups also showed significant differences, ranked as Rotatoria = Copepoda > Protozoa > Cladocera = Ostracoda ($p=0.005$). Notably, the individual density in the dry season was higher than in the rainy season ($p=0.008$).

During the dry season, the total density of individuals ranged from 16,906 to 117,625 individuals/m^3, with the highest density observed at site SR5 and the lowest at site SR2. In the rainy season, the total density ranged from 12,100 to 43,196 individuals/m^3, with the highest density at site HSRay 2 and the lowest at SR1. At the sites in the Ray River basin, there was a recorded difference in the total number of zooplankton individuals between the dry and rainy seasons, with individual counts increasing by 1 to 4 times compared to the rainy season ($p<0.05$). This phenomenon is explained by the intrusion of saline water at sites SR3, SR4, and SR5, along with low water flow, which led to the dominance of certain species in these areas. Meanwhile, the total density of individuals in the Ray River reservoir showed no significant differences between the rainy and dry seasons.

The dominant species that thrive at the sampling points during the rainy season include Keratella tropica (SR1), Pompholyx complanata (SR2), Thermocyclops hyalinus (SR3), Anuraeopsis fissa (SR4), Microcyclops varicans (SR5), AT Nauplius (HSRay1, HSRay3, HSRay4), and Trichocerca pusilla (HSRay2). In the dry season, the dominant species in the water bodies include Nauplius larvae (SR1, SR3, SR4, SR5, HSRay1, HSRay2, HSRay4) and Keratella tropica (SR2, HSRay3). The density of these species in the water bodies accounts for 20–80% of the total individuals. Most of the dominant plankton species are widely distributed ecologically; they are quite common in natural water bodies and thrive while competing with other species. Research indicates that elements like pH and nutrient levels play a crucial role in the variations observed within zooplankton species groups. Species like Lepadella sp., Mesocyclops sp., Polyarthra sp., and Brachionus sp. serve as bioindicators for nutrient-rich environments[21]. Species such as Phacus caudata, Brachionus spp., Keratella cochlaeris, Moina spp., Daphnia spp., Bosmina spp., Cyclops spp., Mesocyclops spp., Chironomus larvae,

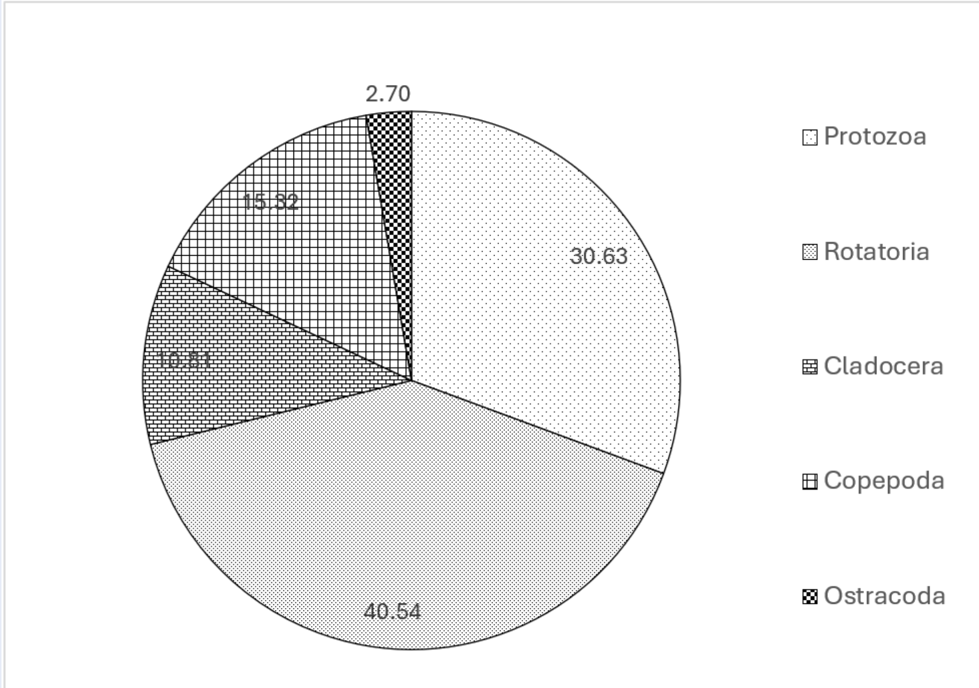

Figure 2: Structure of the zooplankton community in the sampling sites.

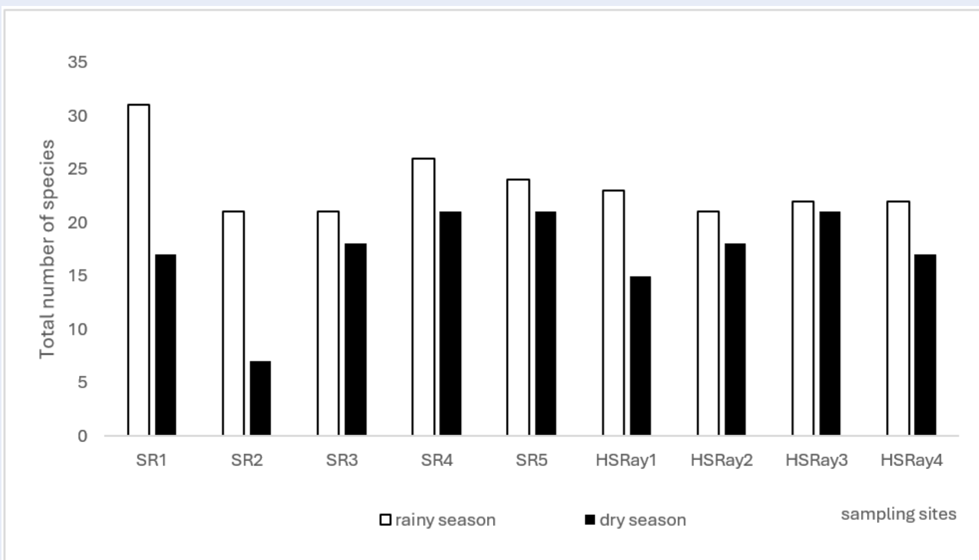

Figure 3: Total number of zooplankton species at the sampling sites during 2 seasons

Oxytricha, Eristalis tenax, and others have been documented as resilient to polluted water sources[5]. If the Rotatoria group is the dominant species in the water bodies during the rainy season, the Copepoda group shows a notable increase and dominance during the dry season, particularly in the flowing water bodies in the Ray River system. In the dry season, the increase in salinity causes the density of Copepoda plankton to be notably high because this group thrives in saline environments[22].

Different water body types have also shown variations in the structure of zooplankton communities. In the Protozoa group, the species composition in flowing water is higher than in standing water ($p = 0.028$), but the individual density in standing water is higher than in flowing water ($p = 0.008$). Meanwhile, in the Cladocera group, both species composition and density in flowing water bodies are higher than in standing water bodies ($p = 0.004$). During the rainy season, the presence of Rotatoria is high in all water bodies in the Ray River system, ranging from 40 to 90%; however, during the dry season, the Copepoda group dominates in terms of individual numbers, particularly in the flowing water bodies of the Ray River basin (Figure 5).

Notably, the study found that species of brackish water lived along the Ray River (SR3, SR4, SR5) during the dry season. These species included Acartia bispinosa, Acartia clausi, Acartia tsuensis, Clausocalanus furcatus, Paracalanus crassirostris, and Hemicyclops japonicus. This is supported by data on salinity directly measured in the water bodies. Salinity in the dry season varies from 0.1 to 13.6‰, with significant measurements at SR3 (11.2‰), SR4 (13‰), and SR5 (13.6‰) (unpublished data). The findings correspond with earlier research identifying Acartia clausi, Acartia centrura, Acartia danae, Acartiella sinensis, Paracalanus crassirostris, and Hemicyclops japonicus as zooplankton species from brackish and saline aquatic habitats[23,24]. This indicates a saline intrusion into the water bodies during the dry season, which is also an important point to consider in water resource management, as the Ray River system supplies water for agriculture and domestic use in the province.

The Shannon-Weiner diversity index (H') at the sampling locations varies from 1.95 to 3.43 (Figure 6). The H' index exhibits greater variability during the dry season compared to the rainy season. During the rainy season, environmental circumstances are more conducive to the growth and development of zooplankton, leading to increased species composition and a correspondingly elevated H' index relative to the dry season. Analysis of the H' index in conjunction with the water quality evaluation in Table 1 indicates that water quality during both seasons varies from relatively clean to moderately polluted (α - mesosaprobe). No sampling point was evaluated as significantly contaminated according to the biological indicators of zooplankton. The Pielou Evenness index (J') varies from 0 to 1, with values nearing 1 signifying a more stable zooplankton community. The findings indicate that the J' index values span from 0.8 to 0.99 (Figure 7). The Pielou index indicates that all sampling locations in the Ray River system include stable zooplankton ecosystems with a minor degree of contamination.

The study measured COD content at sampling points, which ranged from 18 to 35 mg/L. This falls within the classification from A2 (suitable for domestic water supply with necessary treatment) to B1 (appropriate for irrigation) (unpublished data). The COD data indicates that the water quality in Ray River continues to meet the established usage standards. It is essential to integrate additional indicators to achieve more precise assessment outcomes. The research conducted by Nguyen Duong DT[25] determined that the water quality was satisfactory. Certain indicators, such as pH, ranged from 6.42 to 6.75, while the dissolved oxygen (DO) concentration exceeded 10 mg/L, surpassing the minimum threshold of 5 mg/L[22]. Parameters including turbidity, total suspended solids (TSS), chemical oxygen demand (COD), and heavy metal concentrations were all within low and safe thresholds. Following preliminary treatment, the majority of water quality parameters conformed to the permissible thresholds of the Standard of Vietnam for surface water (QCVN 08-MT:2015/BTNMT) requirements (A2 level), signifying that the water is appropriate for household consumption. The water quality of the Ray River is presently evaluated as satisfactory and stable, fulfilling the criteria for household and industrial use. In the study conducted by Phan TTT[26], the water quality findings revealed a trend of pollution, especially in the aquatic systems of the Ray River Reservoir and the segment of the Ray River near the sea[17]. This highlights the importance of evaluating water quality through diverse indicators, especially biological ones, which improve accuracy by demonstrating the adaptation of aquatic organisms, regardless of sampling time or place.

The Ray River system serves as a crucial water source, necessitating prompt recognition of rapid changes for the implementation of timely management and remedial actions. The physicochemical indicators measured solely represent the environmental circumstances at the time of sampling and do not provide a

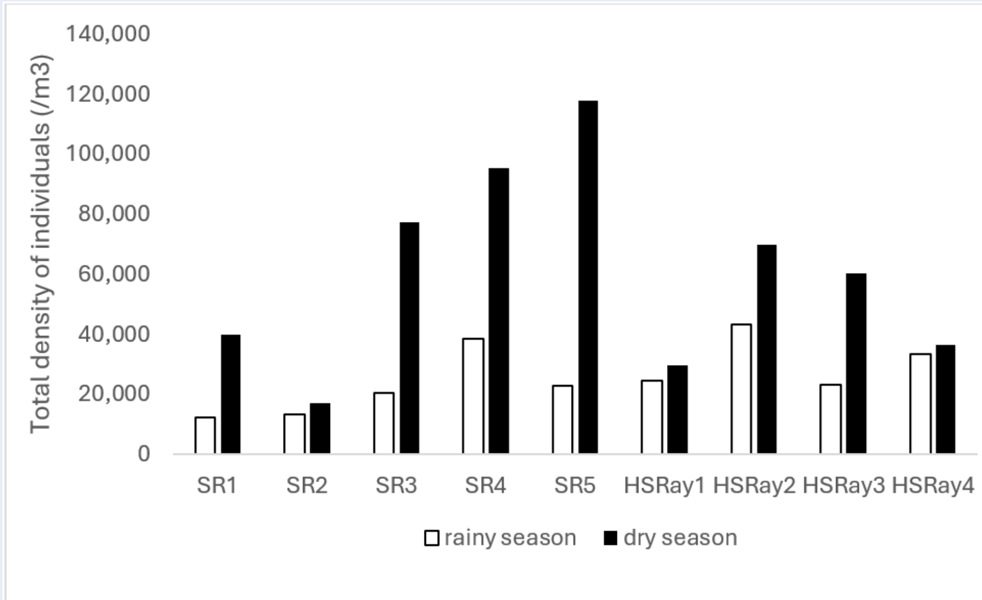

Figure 4: Total density of individuals at sampling sites during two seasons

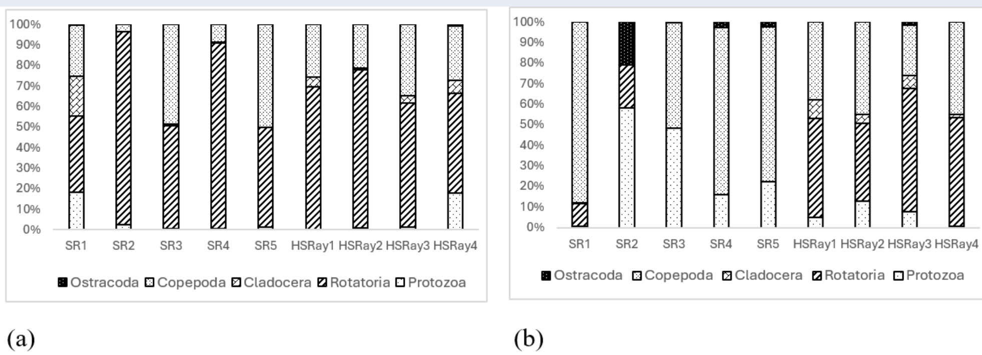

Figure 5: Varation in the structure of zooplankton communities at sampling sites based on the number of individuals (a: rainy season; b: dry season)

reliable evaluation of water quality. To improve precision, many measurements are required, which may incur significant expenses. The results show that the biological indices of zooplankton can be effectively used as a tool for monitoring water quality in the Ray River. Environmental variables will influence species inhabiting aquatic settings, yielding a more precise depiction of water quality. Consequently, a comprehensive evaluation of water quality in the examined region necessitates the integration of physicochemical analysis and biological markers.

CONCLUSION

The study recorded 111 species among five zooplankton categories, with the Rotatoria group representing the predominant portion at 40.56%. Zooplankton density demonstrates more pronounced changes in the dry season than in the wet season. The analysis of the biological indicators H' and J' indicates that the water quality of samples from both seasons shows that the aquatic environment in the Ray River system is currently stable, meeting the standards for domestic water supply, as well as for agricultural and industrial applications. The Ray River functions as the primary water source for the water treatment facility in Long Phước commune, Ba Ria - Vung Tau province,

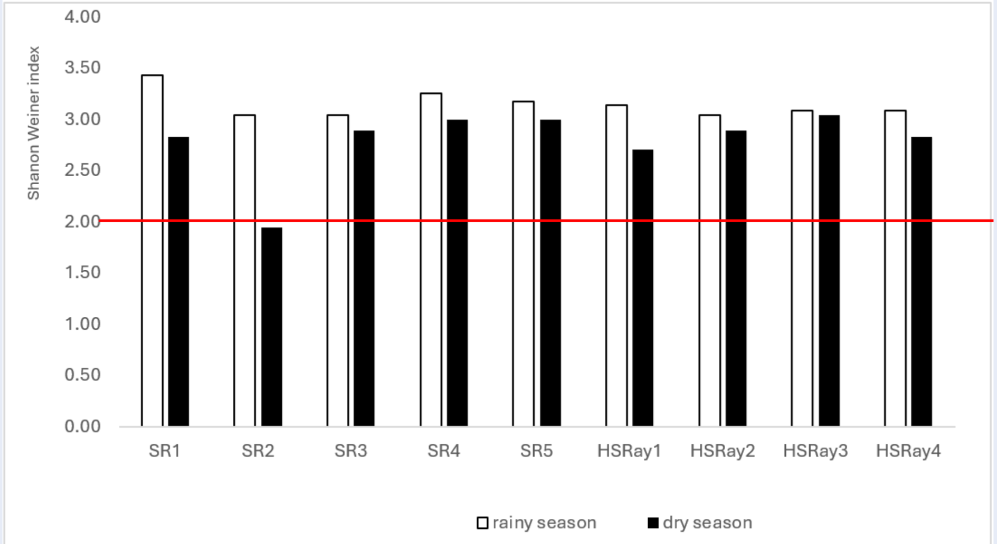

Figure 6: Shannon Weiner index at sampling sites during two seasons

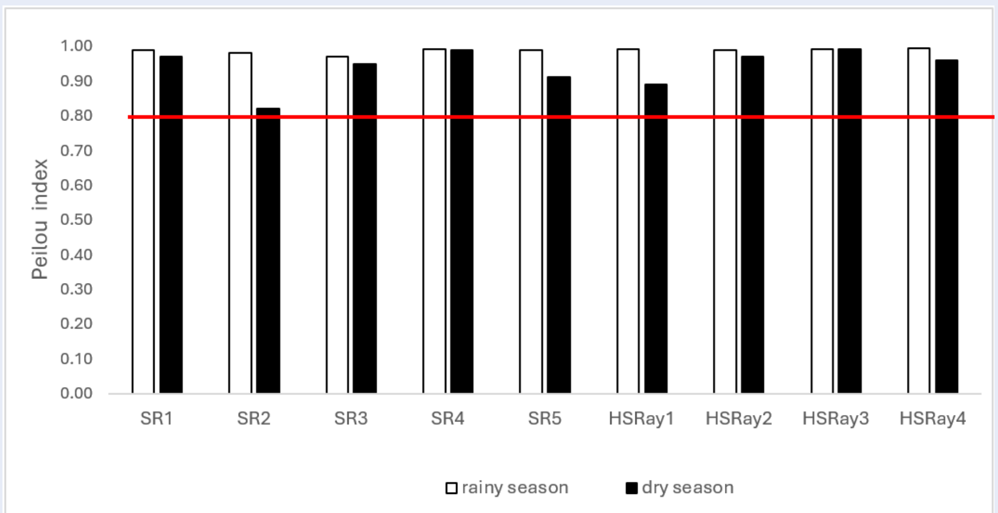

Figure 7: Peilou index at sampling sites during two seasons

demonstrating the dependability of this water supply for residential use. The results show that the biological indices of zooplankton can be effectively used as a tool for monitoring water quality in the Ray River.

However, climate change and economic development may jeopardize the stability of the water source in the future. Saline intrusion, prolonged drought, and over-extraction of groundwater may reduce the volume and quality of the Ray River. The study noted saltwater intrusion during the dry season at sampling sites along the Ray River, a problem that managers must consider when developing sustainable management techniques to protect the river system's ecosystem and alleviate potential future challenges. It is essential to incorporate additional tools for monitoring water quality to effectively identify potential rapid changes in environmental management.

ABBREVIATIONS

xxxx

ACKNOWLEDGMENTS

xxxx

AUTHOR'S CONTRIBUTIONS

xxx

FUNDING

xxxx

AVAILABILITY OF DATA AND MATERIALS

Data and materials used and/or analyzed during the current study are available from the corresponding author on reasonable request.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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