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Zooplankton Community Structure and its Relationship to Physico-Chemical Parameters in the Swamp Ecosystem of Rawa Bento, Kerinci

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Abstract

This study aims to analyze the diversity, abundance, and community structure of zooplankton and its relationship with the physico-chemical parameters of the waters in Rawa Bento, Kerinci Regency, Jambi Province. The Bento Swamp Ecosystem is a highland swamp that has an important ecological function as a buffer for water systems, carbon storage, and habitat for various aquatic biota. The research was carried out in February-May 2023 using a quantitative descriptive approach through field survey methods at three stations representing differences in anthropogenic activity levels. Zooplankton samples were taken with a plankton net measuring 64 µm and identified using a binocular microscope. The physico-chemical parameters measured include temperature, pH, brightness, flow velocity, dissolved oxygen (DO), biochemical oxygen requirement (BOD_5), and total suspended solids (TSS). The identification results found 9 species of zooplankton classified into four classes and three phyla (Rotifera, Protozoa, and Ciliophora), with the dominance of Rotifera (Eurotatoria and Monogononta) contributing about 80% to the total community. The diversity index (H') value ranged from 2.058–2.093 (medium category), the equality index (E) was high (0.936–0.953), and the dominance (C) was low (0.132–0.140), indicating a stable community. Correlation analysis showed that pH and TSS were positively correlated very strongly with zooplankton abundance, while temperature and BOD_5 were negatively correlated very strongly. These results indicate that the water conditions of Rawa Bento still support zooplankton life, despite light anthropogenic pressures. These findings are expected to be basic data for ecological monitoring and sustainable management of highland swamp conservation

Keywords: Water Quality; Rawa Bento; Community Structure; Zooplankton

Cite This Article

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INTRODUCTION

Swamp ecosystems are a form of inland waters that have important ecological and social functions, both as a buffer for water systems, carbon storage, and habitats for various aquatic organisms [1]. Organisms that play an important role in maintaining the balance of swamp ecosystems are plankton, which are microscopic organisms that float in water and their movement depends on currents. Plankton is divided into two main categories, namely phytoplankton, which are primary producers through photosynthesis, and zooplankton, which act as primary and secondary consumers in aquatic food webs [2]. In the aquatic food chain, zooplankton act as a link between primary producers and higher-level trophic organisms such as fish, so their existence can reflect the ecological balance of a body of water [3,4]. This central role makes zooplankton an important indicator in assessing the quality of the aquatic environment and the health of the ecosystem as a whole [5]. These aquatic organisms are particularly sensitive to changes in water quality due to their small body size, simple cell structure, short life cycles, and rapid reproductive rates [6]. Fluctuations in zooplankton abundance and diversity often indicate the trophic conditions and pollution levels of a watershed, making them effective bioindicators [7,8].

The diversity and abundance of zooplankton is greatly influenced by aquatic physical and chemical factors such as temperature, pH, brightness, dissolved oxygen (DO), as well as suspended solids concentration (TSS) and biochemical oxygen requirements (BOD_5) [8]. Changes in community composition and plankton abundance structure indirectly reflect the overall health conditions of the aquatic environment [6]. Therefore, the study of zooplankton diversity and abundance is crucial to understand the ecological relationship between biotic components and the environment in wetlands [9].

Rawa Bento is the highest swamp on the island of Sumatra which is located in Jernih Jaya Village, Gunung Tujuh District, Kerinci Regency, Jambi Province, at an altitude of about 1,950 meters above sea level with an area of ±150 hectares. This swamp is included in the Kerinci Seblat National Park area [10]. The ecosystem consists of peat swamps, swamp grasses, and puddles that are the habitat of various aquatic plants, birds, and microbiota, as well as being used by the community for natural tourism, birdwatching, and fishing [1]. Previous research [11] found 48 types of phytoplankton from 8 classes with a predominance of Bacillariophyceae such as Cocconeis sp., Melosira varians, and Fragilaria capucina, as well as a diversity value (H') between 2,664 and 3,348 indicating unpolluted and ecologically productive water conditions. The findings show that the waters of the Bento Swamp support high primary productivity. Based on these results, this study continues the study at the next trophic level, namely zooplankton as primary consumers which play an important role in connecting primary producers with higher-level organisms. The study of the structure and abundance of zooplankton is expected to strengthen understanding of ecosystem balance and trophic linkages in the highland swamp water system of Rawa Bento.

However, in the midst of these relatively good ecological conditions, there are various anthropogenic activities in the Bento Swamp area. These activities include the release of buffalo in the swamp, the conversion of agricultural land around the area, and water tourism activities. These activities have the potential to cause ecological pressure on the waters. Increased input of organic and inorganic matter into water bodies can trigger eutrophication processes and massive growth of invasive plants such as Eichhornia crassipes (water hyacinths), which cover the surface of swamps and decrease the penetration of sunlight into

the water column [12,13]. These conditions can disrupt phytoplankton productivity and affect zooplankton abundance, potentially altering the ecological balance of Bento Swamp.

Research on the structure of zooplankton communities in Rawa Bento is still very limited, although this information is important for assessing the ecological conditions and fertility levels of tropical mountain swamp waters. Based on this urgency, this study was conducted to analyze the diversity, abundance, and structure of zooplankton communities in Rawa Bento, Kerinci Regency, as well as to determine the relationship between zooplankton abundance and aquatic physico-chemical parameters. The results of this study are expected to provide basic data that is useful in ecological monitoring, as well as a reference for the sustainable management and conservation of swamp areas in Kerinci Seblat National Park.

METHODS

Research Design

This study uses a quantitative descriptive approach with field survey methods to describe and analyze the diversity and abundance of zooplankton in Bento Swamp and its relationship with aquatic physico-chemical parameters. The research was carried out from February to May 2023 in Rawa Bento, Jernih Jaya Village, Gunung Tujuh District, Kerinci Regency, Jambi Province. Laboratory analysis was carried out at the Laboratory of Agroindustry, Medicinal Plants, and Biotechnology, Faculty of Science and Technology, University of Jambi and the Environmental Laboratory of the Jambi Provincial Environmental Office.

Research Target/Subject

This study examines zooplankton communities living in the waters of Rawa Bento. Zooplankton sampling was carried out at three observation stations determined by purposive sampling, considering differences in anthropogenic activity around the swamp. Station I is in the downstream part of the swamp, adjacent to the tourist pier and receives household waste flows and runoff from the surrounding community's agricultural land, so it has the potential to experience quite high environmental pressure. Station II is in the middle of the swamp which is used as a soaking and hollow buffalo activity area, this condition causes an increase in organic matter and water turbidity due to the input of animal manure and the growth of water hyacinths that are quite dense. Meanwhile, Station III is in the upstream part of the swamp which is relatively more natural and is used for natural tourism activities such as camping, water tourism, and as a fishing location by the community. The selection of these three stations was based on the consideration that each site represents a different level of anthropogenic pressure, thus providing a comprehensive picture of the variation in zooplankton community structure and the overall environmental conditions of the waters of the Bento Swamp.

Research Procedure

Zooplankton sampling was carried out in the morning (07.00–09.00 WIB) and afternoon (16.00–18.00 WIB) for three consecutive days at each station. 100 liters of water was filtered using plankton net No. 25 (mesh size 64 μm) with a 50 mL collection tube, then preserved using 4% formalin (1:9 to the volume of water) and stored in an ice box [14]. Samples were observed using a binocular microscope in the Sedgwick-Rafter counting chamber, and were identified based on the Practical Guide to Identifying Freshwater Crustacean Zooplankton [15] and the Identification Handbook of Freshwater Zooplankton of the Mekong River and Its Tributaries [16].

Instruments, and Data Collection Techniques

The research instruments used include:

1. Field equipment: plankton net, 10-liter bucket, sample bottle, Secchi plate, pH meter, thermometer, DO meter, table tennis ball, rope, stopwatch, GPS, meter, and ice box.
2. Laboratory equipment: trinocular microscope, Sedgwick-Rafter cell, dropper pipette, object glass, cover glass, and identification aids.

The data collected includes:

1. Biotic data – the number of individuals and types of zooplankton from each station, calculated as abundance (individuals/liters).
2. Abiotic data – temperature, pH, brightness, flow rate, DO, TSS, and BOD_5 values.

Data analysis technique

1. Analysis of Zooplankton Community Structure with Shannon–Wiener Diversity Index (H')

$$H' = -\sum(p_i \ln p_i)$$
$$with\ p_i = n_i/N.$$

2. Evenness index (E)

$$E = H'/\ln S$$

3. Simpson's Dominance Index (C)

$$C = \sum(n_i/N)^2$$

4. Environmental and Biotic Relationship Analysis

The relationship between zooplankton abundance and environmental parameters was analyzed using Pearson correlation with PAST software version 5.3.

RESULTS AND DISCUSSION

Composition and Abundance of Zooplankton

The identification results showed that there were 9 types of zooplankton classified into 3 phyla and 4 classes from all stations (Table 1). The phylum Rotifera dominates with eight species, namely *Asplanchna priodonta*, *Proales* sp., *Anuraeopsis fissa*, *Trichocerca* sp., *Rotaria* sp., *Lecane* sp., *Monostyla* sp., and *Arcella arthrocea* (Protozoa), as well as *Paramecium bursaria* (Ciliophora).

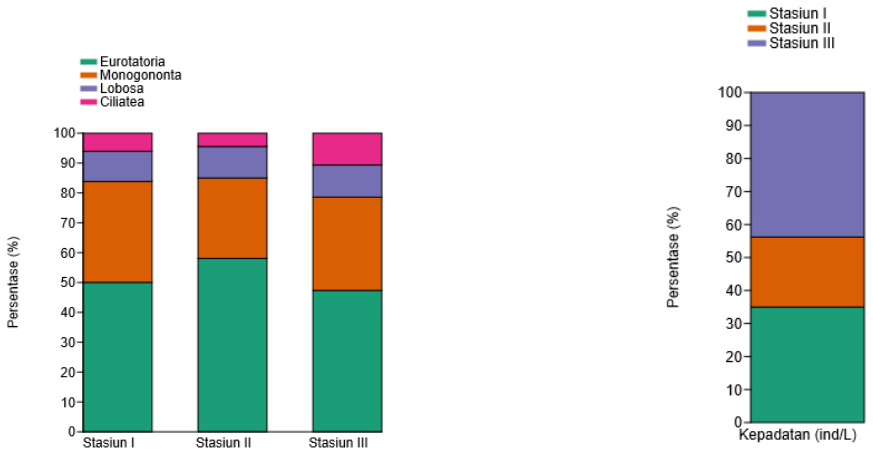
Table 1. Composition of Zooplankton Types and Abundance in Rawa Bento

No	Filum	Zooplankton Classes and Species	Stasiun I (Ind/L)	Stasiun II (Ind/L)	Stasiun III (Ind/L)
1	**Rotifera**	**Eurotatoria**			
		Asplanchna priodonta	9.36	5.7	10.02
		Proales sp.	7.45	5	10.8
		Anuraeopsis fissa	2	4	2.95
		Trichocerca sp.	3.5	1	2.67
		Monogononta			
		Rotaria sp.	6.02	3.4	7.4
		Lecane sp.	5.83	1.72	7.43
		Monostyla sp.	3.21	2.16	2.6
2	**Protozoa**	**Lobosa**			
		Arcella arthrocea	4.5	2.86	6

No	Filum	Zooplankton Classes and Species	Stasiun I (Ind/L)	Stasiun II (Ind/L)	Stasiun III (Ind/L)
3	**Ciliophora**	**Ciliatea**			
		Paramecium bursaria	2.7	1.2	5.95
TOTAL			**44.57**	**27.04**	**55.82**

The relative composition of zooplankton at each observation station in Bento Swamp shows less marked variation but shows a consistent tendency of dominance by the phylum Rotifera, particularly the classes Eurotatoria and Monogononta, with contributions reaching about 80% of the total community (Figure 2a). This pattern suggests that the zooplankton community structure at all three stations is relatively stable, with Rotifera being the dominant group across the study area. Small differences between locations are mainly present in minor classes such as Lobosa and Ciliatea, which tend to fluctuate more with respect to local environmental conditions. The existence of these two groups still shows the existence of a fairly balanced zooplankton taxonomic diversity in this highland swamp ecosystem.

In addition, the total density of zooplankton in Bento Rawa also shows variation between stations (Figure 2b). Station III had the highest contribution to the total density, which was about 45–50% of the total individuals found, followed by Station I with a proportion of about 35–40%, while Station II showed the lowest value, only about 20–25% of the total zooplankton density. This pattern suggests that more natural water conditions and low anthropogenic pressures, such as at Station III, tend to support higher zooplankton abundance than locations with greater levels of disturbance.



a) b)

Figure 1. The relative composition of zooplankton in Bento Swamp: a) the proportion of each class at the three observation stations, and b) the percentage contribution of the total zooplankton density per station

Water Physics and Chemistry Parameters

The results of the water quality measurement showed a brightness value range of 0.368–0.606 m, current speed of 0.09–0.13 m/s, pH 6.98–7.30, temperature 19.5–19.83°C,

dissolved oxygen (DO) 5.5–6 mg/L, BOD_5 1.3–1.7 mg/L, and TSS 10–30 mg/L. In general, these values are still within the optimal range for aquatic organism life.

Table 2. Physical-Chemical Parameters at Each Research Station

Location	Physical-chemical Parameters of Waters						
	Brightness (m)	Current speed (m/s)	pH	Temperature (°C)	DO (mg/L)	BOD5 (mg/L)	TSS (mg/L)
Station I	0.61	0.13	7.15	19.83	5.50	1.70	16.00
Station II	0.41	0.09	6.98	19.83	6.00	1.70	10.00
Station III	0.37	0.10	7.30	19.50	5.80	1.30	30.00

Diversity, Equity, and Dominance Index

The values of the Shannon-Wiener (H') diversity index of zooplankton in the three stations ranged from 2.058–2.093 (medium category), the evenness index (E) 0.936–0.953 (high), and the dominance index (C) 0.132–0.140 (low). The highest H' values were found at station I, while high evenness values at all stations indicated that the distribution of individuals between species was relatively even and that the community was in stable conditions (Table 3).

Table 3. Diversity, Equity, and Dominance Index

Location	Diversity Index (H')	Evenness Index (E)	Dominance Index (C)
Station I	2.093	0.953	0.134
Station II	2.058	0.936	0.14
Station III	2.084	0.948	0.135

The Relationship of Environmental Parameters to Zooplankton Abundance

Spearman's correlation analysis between environmental parameters and zooplankton groups shows different variations in relationships on each parameter (Table 4). The value of the correlation coefficient (rs) between brightness and the rest of the zooplankton group was at –0.5, indicating a moderate negative relationship direction. The current velocity had a moderate positive correlation (rs = 0.5) with Eurotatoria, Monogononta, Lobosa, and Ciliatea. The pH and TSS parameters showed a very strong positive correlation (rs = 1.0) with the entire zooplankton group. In contrast, temperature and BOD_5 showed a very strong negative correlation (rs = –0.866), while DO show a moderate negative correlation (rs = –0.5) with all observed zooplankton groups.

Table 4. Spearman correlation coefficient (rs) values between environmental parameters and zooplankton groups at three observation stations

Environmental Parameters	Eurotatoria	Monogononta	Lobosa	Ciliatea
Light penetration (m)	-0.5	-0.5	-0.5	-0.5
Current speed (m/s)	0.5	0.5	0.5	0.5
pH	1	1	1	1
Temperature (°C)	-0.86603	-0.86603	-0.86603	-0.86603
DO (mg/L)	-0.5	-0.5	-0.5	-0.5
BOD_5 (mg/L)	-0.86603	-0.86603	-0.86603	-0.86603
TSS (mg/L)	1	1	1	1

The identification results from Rawa Bento showed that there were nine zooplankton species belonging to three phyla and four classes, with a very strong dominance of the phylum Rotifera, which accounted for seven of the nine species and contributed approximately 80% of the average abundance. A high dominance of Rotifera has also been reported in various tropical and subtropical waters in Asia, including dams or reservoirs [17], shallow wetlands [18,19], and tropical lakes with varying trophic levels [20,21]. The groups Eurotatoria and Monogononta consistently constitute the main components of rotifer communities in waters with relatively low to moderate temperatures and near-neutral pH, as observed in Rawa Bento, where the temperature ranged from 19.5 to 19.83°C and the pH ranged from 6.98 to 7.30.

The presence of *Asplanchna priodonta* as one of the species identified in Rawa Bento is consistent with the findings of [18] in a shallow wetland in South Korea. This species is known to be omnivorous-raptorial, capable of preying on other rotifers, including Keratella and Polyarthra, as well as protozoa and phytoplankton, and shows a strong preference for open-water zones free from macrophytes [18]. The occurrence of A. priodonta at low to moderate densities indicates the presence of predator-prey interactions within the rotifer community and suggests that food-web complexity is still maintained, despite the relatively low total abundance of zooplankton [20].

The pattern of high Rotifera dominance is also consistent with findings from other tropical lakes in Southeast Asia. In Lake Sembrong, which is hypereutrophic, and Lake Putrajaya, which is meso-eutrophic, rotifers contributed more than 70–80% of the total zooplankton abundance, with species such as Brachionus, Keratella, and Trichocerca frequently dominating [21]. In the Shanghai wetland, Polyarthra trigla was the most common species throughout the year, whereas in Telaga Tunjung Reservoir, Bali, Polyarthra vulgaris and Anuraeopsis coelata were among the most abundant species [17,19]. These conditions further support the view that Rotifera dominance is a characteristic feature of tropical and subtropical waters that remain within the oligotrophic to slightly mesotrophic range, as reflected in Rawa Bento.

The highest zooplankton abundance at Station III, located upstream and relatively natural, and the lowest abundance at Station II, the buffalo wallowing area, indicate a clear gradient of anthropogenic pressure. Buffalo grazing activities increase total suspended solids (TSS) and nutrient input through feces and sediment resuspension, which may disrupt the stability of the zooplankton community. This decline in stability is further exacerbated by the invasion of water hyacinth, which reduces sunlight penetration to the swamp bottom and consequently affects phytoplankton availability as the main food source for zooplankton [11,22]. A similar finding was reported by Mohammed et al. [24] in a tropical high-altitude lake, where an increase in TSS of more than 25 mg/L caused a 40–60% reduction in Rotifera abundance due to reduced visibility and mechanical interference with the food-collecting apparatus, namely the corona. In contrast, Station III, which remains covered by natural vegetation and experiences minimal disturbance, showed the highest abundance, indicating that riparian vegetation protection and low sediment input are important factors in maintaining zooplankton populations in mountain swamps [23].

The Shannon-Wiener diversity index values (H') of 2.058–2.093, categorized as moderate, high evenness values ($E > 0.9$), and low dominance values ($C < 0.15$) indicate that the zooplankton community in Rawa Bento remains in a stable condition and has not yet experienced severe ecological pressure. Similar H' values have been reported in a highland

reservoir in Ethiopia [25] and Lake Lindu in Sulawesi [26], both of which were categorized as waters with low to moderate pollution levels. High evenness reflects the absence of any species that dominates extremely, a condition generally associated with ecosystems that still maintain good ecological function.

Spearman correlation analysis showed highly consistent relationships between environmental parameters and the abundance of four zooplankton classes, namely Eurotatoria, Monogononta, Lobosa, and Ciliatea, in Rawa Bento (Table 4). Water temperature and BOD_5 showed a very strong negative correlation ($r_s = -0.86603$; $p < 0.05$) with the abundance of all zooplankton groups. The stable low temperature of 19.5–19.8°C at an elevation of approximately 1,950 meters above sea level reflects the typical condition of tropical high-altitude waters that support the dominance of psychrophilic Rotifera [22,24]. Although the measured BOD_5 values were relatively low, ranging from 1.3 to 1.7 mg/L, they still exerted negative pressure because they indicate additional organic matter input that could potentially reduce dissolved oxygen at night and disturb sensitive zooplankton [6,27].

In contrast, TSS showed a perfect positive correlation ($r_s = 1.0$) with the abundance of all zooplankton groups. The low to moderate TSS values recorded in Rawa Bento, ranging from 10 to 30 mg/L, appear to enhance the availability of organic detrital particles as an additional food source for filter-feeding Rotifera and Ciliatea [20,21]. A similar phenomenon has been reported in shallow tropical lakes, where moderate TSS was positively correlated with Rotifera abundance because it provided organic food substrates [19]. Current velocity showed a moderate positive correlation ($r_s = 0.5$) with Eurotatoria, Monogononta, Lobosa, and Ciliatea. Mild to moderate water currents in mountain swamps help prevent the sedimentation of food particles and distribute zooplankton more evenly, thereby supporting higher abundance.

Dissolved oxygen (DO) and water transparency showed moderate negative correlations ($r_s = -0.5$). This negative relationship is indirect: stations with high zooplankton abundance tend to experience decreased DO and water transparency due to intense respiratory activity and increased organic particles originating from the zooplankton themselves during the night to early morning period [6,22]. Overall, zooplankton abundance in Rawa Bento remains within optimal conditions due to the combination of naturally low temperature, moderate TSS that serves as a beneficial food source, and BOD_5 pressure and anthropogenic disturbance that have not yet exceeded the tolerance threshold of the community [22–24,28].

CONCLUSIONS

This study identified 9 types of zooplankton (3 phylum, 4 classes) in Bento Swamp with the dominance of Rotifera (7 species, about 80% abundance). The highest abundance occurs in relatively natural upstream stations, while the lowest in stations with buffalo herding activities. The Shannon-Wiener index (H') of 2.058–2.093 (moderate), the evenness (E) 0.936–0.953 (high), and the dominance (C) of 0.132–0.140 (low) indicate that zooplankton communities are still stable and the waters are in a mild oligotrophic–mesotrophic status.

Spearman's correlation analysis revealed that pH and TSS were strongly positively correlated ($r_s = 1.0$), temperature and BOD_5 were strongly negatively correlated ($r_s = -0.866$), and moderate negative DO ($r_s = -0.5$) to zooplankton abundance. These results indicate that natural low temperatures and low–moderate TSS still support Rotifera dominance, while increased BOD_5 due to anthropogenic activity is the main limiting factor.

Bento Swamp as a whole still has good ecological quality with stable zooplankton communities as primary–secondary trophic links. However, there is a gradation of quality from upstream to downstream that needs to be watched out. This data is an important baseline for the monitoring and sustainable management of the highest mountainous swamp area in Sumatra within the Kerinci Seblat National Park.

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