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Biomonitoring of Bedog River Water Quality Using Dragonfly Diversity as Bioindicators in Yogyakarta, Indonesia

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ABSTRACT

The quantity of contaminants being released into rivers is rising in direct correlation with the growth of the human population. Bedog River is a tributary located in the vicinity of Mount Merapi. This river flows through agricultural, residential, and cattle sectors, making it easier to detect river contamination. The objective of this study is to evaluate the water quality of the Bedog river. The research employs a methodology that evaluates water quality by considering biological indicators, specifically the existence of dragonfly species, with the analysis of other chemical and physical properties in river water. The water quality research findings indicate that the physical and chemical characteristics remain satisfactory, with the water falling into the moderately polluted category. It also meets the water quality criteria outlined in PPRI No. 82 of 2001, specifically class 2 threshold. The dragonfly variety index in the Bedog River is relatively high, with values of 2.08, 2.79, and 1.47 for the upstream, middle, and downstream sections, respectively. The Pearson correlation coefficient indicates a strong positive correlation of 0.961, while the significance level of 0.179 suggests a statistically meaningful association. The findings highlight the potential of using dragonflies as bioindicators for long-term monitoring of river health and pollution levels. This study contributes to the understanding of how water quality impacts biodiversity and provides a basis for future research and river management practices. This research fills a gap by integrating biological indicators with traditional water quality assessments in a specific regional context. It provides new insights into the relationship between water quality and dragonfly diversity, offering valuable information for environmental monitoring and conservation efforts.

Key Words	Water Quality, Bioindicators, Dragonfly Diversity, River Pollution

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INTRODUCTION

Several land use activities, including agriculture and housing development, will have an impact on the hydrological conditions in the nearest river basin (Aflizar, 2008). Converting forests into agricultural and residential land increases surface runoff, carrying along the soil layer it passes through (Agustiningsih et al., 2012). This is related to one of the river functions as a water reservoir for the surrounding area (Ali et al., 2013). The level of pollutants in the water can have an impact on aquatic organisms; it can kill certain species, or support the life of others. The increasing population is one of the factors affecting environmental pollution, including water pollution (Amneera et al., 2012). The growing population leads to an increase in the number of people competing to fulfill their needs and driving rapid development. On the other hand, the increasing population is also proportional to the increasing demand for clean water, but the availability of clean water for daily consumption is disrupted by water pollution (Anwar et al., 2016).

The decrease in water quality can reduce the usefulness, productivity, carrying capacity, and sustainability of water resources, which ultimately reduces the natural resource wealth (PPRI No. 82 of 2001). In the hydrological cycle, rivers function as a raw water source, irrigation storage, and are utilized as water catchment areas, making rivers a very important role as an aquatic ecosystem (Setiari, 2012). The amount of water supply on earth is about 0.036% derived from rivers and lakes, then the majority of it, as much as 76%, is used for household sectors (Kumar Reddy & Lee, 2012). The use of river water for various needs must be done sustainably. Rivers are very important ecosystems for humans. They also provide water for various activities such as agriculture, industry, and household needs. Therefore, river resources must be protected so that they can be well utilized by humans and other living creatures (Djaja et al., 2018). Increasing domestic, agricultural, and industrial activities can affect the quality of river water. Specifically, domestic activities contribute the largest BOD concentration to the river body (Minister of Environment Regulation 115/2003). Large companies or industries can overcome wastewater management problems because they have more capital, but it will be different for small or medium-scale industries. Small-scale industries are not yet able to overcome wastewater problems (Asmadi and Suharno, 2012).

The presence or distribution of species is closely related to the conditions of the environment in which they live (Setyawan et al., 2021; Setyawan et al., 2020). This close relationship between environmental conditions and the presence of species underpins the concept of biomonitoring. Konsep ini pernah diterapkan untuk mengevaluasi organic pollution berdasarkan diversity dari algal (Alombro et al., 2023). It is expected that using biotic methods can become a benchmark in water quality monitoring by identifying the presence of macroinvertebrates that can be used as bioindicators of changes in the quality of a water source. In identifying the presence of macroinvertebrates, the type, composition, and domination of a particular species of macroinvertebrates that inhabit the area must be considered. Macroinvertebrates are invertebrates that live on the riverbed and can be an important component in the food chain of an aquatic ecosystem. Some macroinvertebrate groups that can be used as bioindicators of water quality in a water source include worms and leeches (Annelida), flatworms (Platyhelminthes), insects (Insecta), shrimps and crabs (Decapoda), as well as snails and mussels (Mollusca). The main advantage of biotic methods over chemical and physical methods is the potential for this method to be used by the public widely, thus opening opportunities for participatory river water quality monitoring activities by the community.

The Bedog River is a tributary that traverses the Bedog River Basin, situated in Sleman Regency, Yogyakarta City, and Bantul Regency. Presently, the Bedog River serves as a primary water source for local inhabitants to fulfill their home and industrial requirements. The water sourced from Bedog River is utilized for various purposes such as domestic, industrial, and agricultural uses, among others. The assessment of water quality status is conducted by employing the Pollution Index Method. The Pollution Index is utilized to assess the comparative pollution level in relation to the authorized water quality indicators. The Pollution Index (PI) is initially established for a specific objective and subsequently extended to encompass several other objectives pertaining to the entire body of water or specific segment of a river, as outlined in Minister of Environment Decree 115/2003. The Water Quality Index (WQI) is frequently employed to evaluate the water quality in wetlands. The river water quality index, as described by Bordalo et al. (2006) and Phong et al. (2023), is a measure that can be used to determine the quality status of a river's water. Nevertheless, alterations in the plant cover inside wetlands have been observed to have an impact on Water Quality Index (WQI) values, both in a direct and indirect manner. Wetland ecosystem restoration is achieved through restoration initiatives. Improving existing ecosystems has gained significant attention (Menberu et al., 2017). Moreover, revegetation is a deliberate undertaking aimed at restoring an area (Waluyo and Nurlia, 2017).

The current study aims to fill this gap by evaluating the water quality of the Bedog River using both chemical and physical water parameters and biological indicators, specifically dragonfly diversity. The primary objectives of this study are to assess the current water quality status of the Bedog River, determine the diversity of dragonfly species in different segments of the river, and explore the correlation between water quality and dragonfly diversity. By addressing these objectives, the study seeks to provide a more integrated understanding of river health and the potential of dragonflies as bioindicators for long-term water quality monitoring.

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Moreover, this study aims to contribute to the scientific knowledge by providing new insights into the use of dragonflies as bioindicators, particularly in the context of Indonesian river systems. The authors hypothesize that there is a strong positive correlation between water quality and dragonfly diversity, with higher water quality supporting greater species richness and diversity. This research not only addresses the existing gaps in the integration of biological and physicochemical assessments but also aims to inform future river management and conservation strategies by highlighting the importance of maintaining and improving water quality to preserve aquatic biodiversity.

METHODS

1. Materials and Tools

The tools used in this research are GPS (Global Positioning System), insect nets, dragonfly identification guidebooks, Horiba Multi parameter, and digital cameras.

2. Data Analysis Method

This study was conducted by segmenting the flow of the Bedog River into three areas, namely upstream, middle, and downstream (Table 1). Chemical and physical water quality measurements were carried out using a Horiba multi-parameter instrument that can measure temperature, pH, TDS, DO, conductivity, salinity, depth, and turbidity. Meanwhile, for biological parameters, observations were made visually and records were made of the presence of dragonflies in the water. The research activities were generally divided into survey, data collection of dragonfly species and quantity, data collection of chemical and physical parameters, data processing, and analysis. Water samples were taken from the river using the grab sampling technique, which is a direct sampling technique from the observed body of water and only informs the characteristics of the water at the time the sample is taken.

Table 1. Coordinates of sample collection locations

Segmentation	Coordinat X	Coordinat Y
Upstream	-7.67987	110.3545
Middle	-7.77942	110.3278
Downstream	-7.88725	110.3112

The water quality state is assessed utilizing the Pollution Index Model by the following sequential procedures:

1) Systematic collecting of water quality data to create a time series dataset.
2) The data from each water quality parameter is compared to the quality threshold based on the water class.

This study used the Pollution Index approach [KLHK, 2001] to determine the status of river water quality. The Pollution Index equation used is as follows:

$$PIj = \sqrt{\frac{\left(\frac{Ci}{Lij}\right)M^2 + \left(\frac{Ci}{Lij}\right)R^2}{2}} \ldots\ldots\ldots(1)$$

Where :
PIj : Pollution Index for its designation (j)
Ci : Concentration of water quality parameters (i)
Lij : Concentration of water quality parameters (i) listed in the water quality standards (j)
M : Maximum
R : Average

The Pollution Index values indicate the extent of pollution in the Bedog River by comparing it to the quality standard specified in Government Regulation 82/2001 for the respective water class. By doing this, it is anticipated that significant data will be obtained to ascertain whether the water in the river is suitable for its intended uses based on its water classification. The collected data on physical and chemical parameters of water quality were examined in accordance with the water quality standard of class 2, as outlined in Government Regulation Number 82 of 2001. Based on the results of the Pollution Index calculation that has been obtained, then an assessment of the quality status of river water quality can be carried out with 4 assessment categories following Table 2 below:

Table 2. Pollution Index Category (Decree of the Minister of Environment Number 115 of 2003)

Pollution Index Score	Quality Status
$0 \leq PI \leq 1.0$	Good
$1.1 < PI \leq 5.0$	Lightly Polluted
$5.1 < PI \leq 10$	Moderately Polluted
$PI > 10$	Heavily Polluted

The obtained dragonfly data were analyzed using the Shannon-Wiener Diversity Index formula to determine the level of diversity and the evenness index to indicate the number of individuals spread across each species, obtained as follows:

$$H' = \sum(pi \, . \ln(pi)) \ldots\ldots\ldots(2)$$

$$pi = \frac{ni}{N} \ldots\ldots\ldots(3)$$

H' = diversity index
pi = proportion of individuals of species i
ni = number of individuals of species i
N = total number of individuals of all species
The criteria for species diversity are determined as follows:
H'< 1 = low diversity type

1 <H'< 3 = moderate diversity type

H' > 3 = high diversity type

The collected data is then tabulated, processed and analyzed descriptively. Data analysis includes the calculation of diversity index (Hasyim and M. Asmuni). The final analysis stage of this study is to correlate the previously known water quality values with the diversity index of dragonflies.

RESULT AND DISCUSSION

1. Bedog River water quality

Based on field measurements, several values of chemical and physical parameters were obtained, namely: temperature, pH, DO, TDS, turbidity, conductivity, salinity, and depth, which are presented in Table 3. In the table, it can be compared that there is a temperature difference in the upstream, middle, and downstream sections caused by the elevation and time of measurement. For the pH parameter, the obtained value is above the specified threshold, which is due to the potential contamination from wastewater originating from households or agricultural activities. Therefore, further research needs to be conducted on parameters that affect the pH value.

Table 3. Chemical and physical parameters of water in the Bedog River

Parameter	Unit	Upstream	Middle	Downstream
Temperature	˚C	25.74	27.81	28.71
pH		5.61	5.36	5.03
DO	mg/L O2	7.9	8.8	6.79
TDS	mg/L TDS	313	361	503
Turbidity	NTU	3.5	5.5	10.8
Conductivity	mS/cm	0.481	0.565	0.785
Salinity	mg/L	0	0	0
Depth	˚C	0.25	0.15	0.25

According to Table 3, the temperature variations in the Bedog River at the three observation stations remain rather constant, with a variation of approximately 3 degrees compared to the initial state prior to alterations in land use along the river. The temperature parameter of the Bedog River indicates that its water quality remains within the designated threshold for its intended use, since it does not deviate more than (+3) from its natural condition, which is the requirement for class II water quality. Observations of pH levels at each station indicate varying results from the upstream, middle, and downstream locations. The pH values are arranged in the following order: 5.61, 5.36, and 5.03. The pH of the Bedog River is still below the water quality threshold necessary for its authorized use, as specified by Government Regulation 82/2001 (6-9), which sets the pH range for class II water quality. The height and time of measurement result in a temperature disparity between the upstream, middle, and downstream regions. Based on the provided information, it can be inferred that the water quality of Sungai Bedog at stations 1 and 2 fulfills the required standards for the TDS parameter. However, station 3 has over the acceptable water quality limit for its intended use.

The increase in TDS values may be due to water pollution from agricultural activities and domestic waste that contain heavy metals and harmful chemicals. The salinity value at each station indicates the absence of salt content in the water, with salinity values at all stations being 0 mg/L.

Table 4. Water pollution levels in the Bedog River

Segmentation	Score	Result
Upstream	1.933504	Lightly Polluted
Middle	2.055469	Lightly Polluted
Downstream	1.635416	Lightly Polluted

The pH levels fluctuate due to the release of organic waste from domestic activities, the decomposition of plants and animals, and the garbage generated by industrial planting forests near the Bedog River. Furthermore, the proper management of inorganic waste also plays a substantial role. Nevertheless, variations in pH have minimal impact on the overall quality of the river water. Water that is suitable for sustaining life typically has a pH level between 6.5 and 7.5 [Wardhana, 2004]. Typically, unpolluted water has a pH level that is close to neutral, about pH 7, which is suitable for the majority of aquatic creatures [Sutriati, 2018]. The Bedog River is not now a suitable environment for aquatic species due to its pH level being below 6.

Dissolved oxygen (DO) serves as a reliable measure of the freshness of water. Oxygen is crucial for assessing water quality because dissolved oxygen (DO) facilitates the oxidation and reduction of both organic and inorganic substances. The oxidation and reduction processes play a crucial role in naturally reducing pollutant burdens in water. The recorded measurements of the dissolved oxygen (DO) parameter at each station shown variability in the upstream, middle, and downstream sections. Specifically, the DO levels were observed to be 7.9 mg/l at point 1, 8.8 mg/l at station 2, and 6.79 mg/l at station 3. The water quality conditions of the Bedog River at all stations have surpassed the minimal standards for their classification, as specified by PP 82/2001, with regards to the quality threshold limit for Class II water parameters for dissolved oxygen (DO) which is set at 4 mg/l. In general, our analysis discovered only a minute portion of contaminated water. As the amount of organic waste increases, the level of dissolved oxygen in the water decreases. Anthropogenic activities, such as agricultural practices and waste disposal, have led to a decline in the levels of dissolved oxygen in the environment [Anhwange, 2012].

2. Dragonfly Diversity Index

In the upstream area, 12 dragonfly species were found, with Heliocypha fenestrate being the most commonly found species with 11 individuals. Heliocypha fenestrate is an endemic Javanese dragonfly species that can be found along the Bedog River. The dragonfly species diversity index in the upstream area is 2.08, indicating that the dragonfly diversity in the upstream area is categorized as moderate. Neurobasis chinensis florida, a rare Javanese endemic dragonfly species, was also found in the upstream area.

Table 5. Dragonfly Diversity Index in the Upper Part of Bedog River

Number	Species	ni	pi ln pi	H'
1	Copera marginipes	10	-0.32927	0.329269

2	Heliocypha fenestrata	11	-0.33989	0.339889
3	Orthetrum testaceum	1	-0.08192	0.081918
4	Euphaea variegata	9	-0.31652	0.316517
5	Pseudagrion pruinosum	1	-0.08192	0.081918
6	Libellago linneata	1	-0.08192	0.081918
7	Neurothemis ramburii	2	-0.13434	0.13434
8	Macrogomphus parallelogramma	1	-0.08192	0.081918
9	Neurobasis chinensis florida	2	-0.13434	0.13434
10	Orthetrum sabina	1	-0.08192	0.081918
11	Prodasineura autumnalis	3	-0.17563	0.17563
12	Neurothemis terminata	5	-0.23837	0.238373
	N	47	index	2.08

The middle area is the region with the highest number of species and individuals compared to the other two regions. Nineteen species of dragonflies were found in this region, with a total of 59 individuals. The diversity index value for this area is almost 3, at 2.79, which categorizes this region as having moderate diversity index.

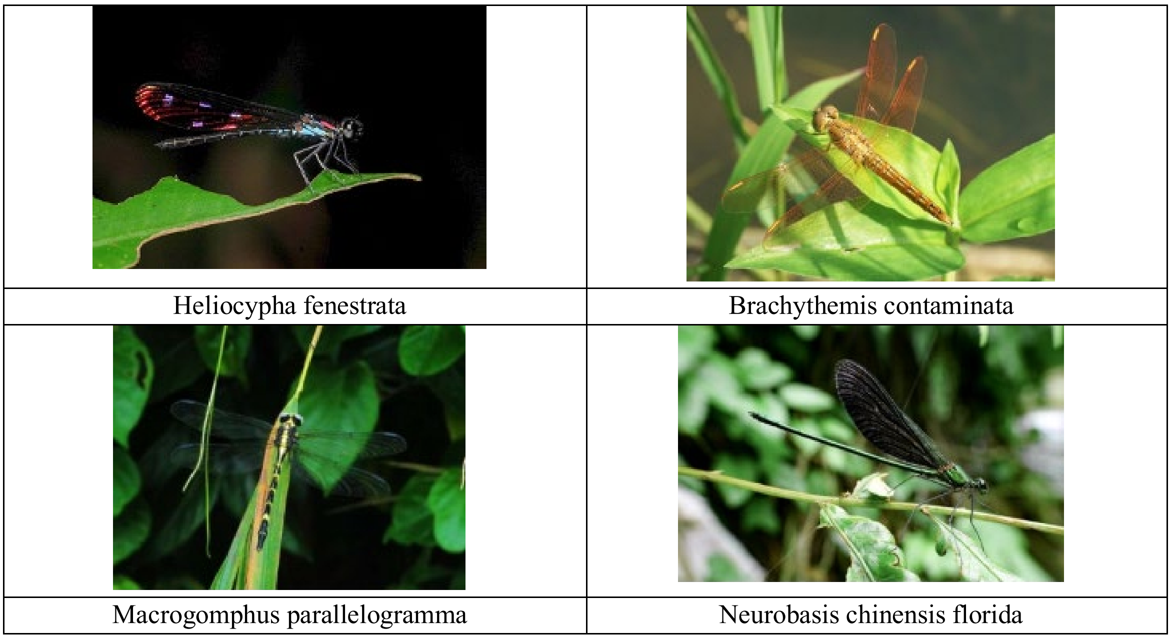
Table 6. Dragonfly Diversity Index in the Middle Part of the Bedog River

Number	Species	ni	pi ln pi	H'
1	Neurobasis chinensis florida	7	-0.2529	0.252905
2	Potamarcha congener	2	-0.11473	0.114725
3	Orthetrum testaceum	1	-0.06911	0.069111
4	Orthtetrum chrysis	3	-0.15147	0.151471
5	Neurothemis terminata	2	-0.11473	0.114725
6	Neurothemis ramburii	3	-0.15147	0.151471
7	Pseudagrion pruinosum	2	-0.11473	0.114725
8	Prodasineura autumnalis	3	-0.15147	0.151471
9	Libellago linneata	5	-0.20916	0.209161
10	Onycothemis culminicola	1	-0.06911	0.069111
11	Heliocypha fenesrata	7	-0.2529	0.252905
12	Anax guttatus	2	-0.11473	0.114725
13	Rodhothemis rufa	3	-0.15147	0.151471
14	Pseudagrion microcephallum	2	-0.11473	0.114725
15	Ictinogomphus decoratus	1	-0.06911	0.069111
16	Brachythemis contaminata	3	-0.15147	0.151471
17	Orthethrum sabina	3	-0.15147	0.151471
18	Copera marginipes	6	-0.23245	0.232452
19	Crocothemis servilla	3	-0.15147	0.151471
	N	59	index	2.79

The downstream area has the lowest diversity index compared to the two previous areas, which is 1.47, although it still falls into the moderate category. The index is obtained from the number of species found, which is 10, and the number of individuals is 103. The most commonly found species in this area is Brachythemis contaminata, with 51 individuals. As the name suggests, this species has the highest tolerance level to contaminants, making it more commonly found in the downstream area compared to other species.

Table 7. Dragonfly Diversity Index in the downstream area of Bedog River

Number	Spesies	ni	pi ln pi	H'
1	Brachythemis contaminata	51	-0.34804	0.34804
2	Pseudagrion microcephallum	22	-0.32972	0.329719
3	Orthetrum sabina	3	-0.10299	0.102994
4	Ictinoomphus decoratus	1	-0.045	0.044997
5	Heliocypha fenesrata	2	-0.07654	0.076536
6	Libellago linneata	17	-0.29734	0.297338
7	Potamarcha congener	2	-0.07654	0.076536
8	Thollymis tillarga	3	-0.10299	0.102994
9	Orthetrum testaceum	1	-0.045	0.044997
10	Zyxomma obtusum	1	-0.045	0.044997
	N	103	index	1.47
		N		



Heliocypha fenestrata | Brachythemis contaminata

Macrogomphus parallelogramma | Neurobasis chinensis florida

Figure 1. Types of dragonflies found in the Bedog River

Based on the measurements of the three areas, the overall value of the dragonfly diversity index in the Bedog River is at a moderate level. It can be concluded that ecologically, the Bedog River area has good productivity and relatively balanced ecosystem conditions. Figure 1 shows some of the dragonfly species encountered during field data collection.

3. Relationship between Water Quality and Dragonfly Diversity Index

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Table 7 displays a correlation coefficient of 0.961 between water quality and the diversity index, demonstrating a robust link. This is further reinforced by the r value lying within the range of 0.5 to 0.75. Nevertheless, the correlation coefficient (r value) of 0.179 indicates a somewhat weak relationship between water quality and diversity index, since it falls below the threshold of 0.5. This juxtaposition emphasizes the intricacy of the correlation between water quality and biodiversity indices, indicating that although there may be a broad pattern, the intensity of the connection might fluctuate depending on unique circumstances or supplementary factors.

Table 8. Correlation of water quality values and dragonfly diversity index

Correlation result	Score
Correlation	0.961
Significance	0.179

The intricacy of this matter is further clarified by studies that shows a direct relationship between the quality of water and the diversity of dragonflies. Areas with higher water quality have been found to have greater species richness and abundance of dragonflies (Jacob & Ek, 2016; Bora, 2019). Dragonfly populations in Indonesia, India, and Malaysia have been evaluated in terms of water quality using diversity indices such as Shannon-Wiener and Simpson's (Saifullah Hidayat et al., 2019; Bora, 2019; Rohman & Faradisa, 2020). According to Jacob and Ek (2016), certain species of dragonflies, such as Brachythemis contaminata and Bradinopyga geminate, have been recognized as reliable markers of contaminated and non-polluted waters, respectively. The parameters that affect the distribution of species, such as pH, conductivity, and the concentration of dissolved oxygen, also have a substantial impact (Bora, 2019). Hence, although there may be overall associations indicating a robust connection between water quality and biodiversity indices, the specific connections can be affected by various environmental and biological factors. Dragonflies serve as bioindicators, indicating water quality over an extended period rather than at a specific moment, highlighting their significance in long-term ecological monitoring. This comprehensive method affirms the concept that the variety of odonates can serve as a beneficial means of evaluating and tracking water quality in various habitats.

CONCLUSION

The main objective of this study was to assess the water quality of the Bedog River by employing a range of chemical, physical, and biological indicators, with a specific emphasis on the diversity of dragonflies. According to PPRI No. 82 of 2001, the data suggest that the water quality of the Bedog River is moderately contaminated. The water's physical and chemical properties, including temperature, pH, dissolved oxygen, and total dissolved solids, were evaluated and determined to meet the criteria for Class II water quality. However, certain parameters, such as pH and TDS, showed variations from the desired thresholds. The study found that the Bedog River has a reasonably high level of diversity in dragonflies, as shown by diversity indices of 2.08 in the upstream portion, 2.79 in the middle region, and 1.47 in the downstream section. The indices indicate a modest level of diversity in the different sections of the river, with the middle part showing the highest level of diversity. The Pearson correlation value of 0.961 indicates a robust positive association between water quality and dragonfly diversity. However, the significance level of 0.179 suggests that although the correlation is strong, it is not statistically significant.

The novel scientific findings of this study reside in the amalgamation of biological and physicochemical studies to offer a thorough evaluation of river health. Utilising dragonfly diversity as a bioindicator, in conjunction with conventional water quality measurements, addresses a crucial deficiency in river monitoring by providing a more nuanced comprehension of biological circumstances. This approach emphasises the efficacy of dragonflies as indicators of water quality and emphasises their potential for ongoing ecological monitoring. This work presents new opportunities for river management and conservation initiatives by highlighting the significance of preserving water quality to sustain a wide range of aquatic species. Furthermore, it creates opportunities for future investigations into the interaction between biological indicators and water quality, which could result in enhanced approaches for assessing river health and managing the environment.

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