

## DIVERSITY AND ROLE OF AQUATIC INSECTS AS BIOINDICATORS IN THE LEKOPANCING RIVER, MAROS DISTRICT, SOUTH SULAWESI

*Keanekaragaman dan Peranan Serangga Akuatik sebagai Bioindikator di Sungai Lekopancing, Kabupaten Maros, Sulawesi Selatan*

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### ABSTRACT

The Lekopancing River, located in Maros Regency, is a crucial source of clean water supply for the people of Makassar City and the surrounding areas. This study aims to analyze the diversity and role of insects as bioindicators of water quality based on aquatic insect families. The study was conducted in the upstream, middle, and downstream parts of the Lekopancing River, using handpicking and kick sampling for data collection. The collected aquatic insect samples were then identified and analyzed using the diversity index Shannon-Wiener ( $H'$ ) and Hilsenhoff Family Biotic Index (HFBI) methods, which were widely accepted in ecological research for assessing biodiversity and water quality. The number of aquatic insects found was 614 individuals, consisting of 13 species, 13 families, and 7 orders. The diversity index of aerial insects in the upstream and middle parts of the Lekopancing River was 1.26 and 1.72, while in the downstream part, it was 0.42. The HFBI value of 3.26 in the upstream section is still very good; in the middle section, the HFBI value of 4.84 is considered good; in the downstream section, the HFBI value of 7.00 indicates poor quality.

Keywords: Abundance; Aquatic insect; Bioindicators; Diversity

### ABSTRAK

Sungai Lekopancing yang terletak di Kabupaten Maros merupakan sumber pasokan air bersih yang sangat penting bagi masyarakat Kota Makassar dan sekitarnya. Penelitian ini bertujuan untuk menganalisis keanekaragaman dan peranan serangga sebagai bioindikator kualitas air berdasarkan famili serangga akuatik. Penelitian dilakukan di bagian hulu, tengah, dan hilir Sungai Lekopancing dengan menggunakan teknik hand picking dan kick sampling untuk pengumpulan data. Sampel serangga air yang dikumpulkan kemudian diidentifikasi dan dianalisis menggunakan indeks keanekaragaman Shannon-Wiener ( $H'$ ) dan Hilsenhoff Family Biotic Index (HFBI), yang diterima secara luas dalam penelitian ekologi untuk menilai keanekaragaman hayati dan kualitas air. Jumlah serangga akuatik yang ditemukan sebanyak 614 individu, terdiri dari 13 spesies, 13 famili, dan 7 ordo. Indeks keanekaragaman serangga udara di bagian hulu dan tengah Sungai Lekopancing masing-masing sebesar 1,26 dan 1,72, sedangkan di bagian hilir sebesar 0,42. Nilai HFBI sebesar 3,26 pada bagian hulu masih sangat baik; pada bagian tengah nilai HFBI sebesar 4,84 tergolong baik; pada bagian hilir, nilai HFBI sebesar 7,00 menunjukkan kualitas yang buruk.

Kata kunci: Kelimpahan; Serangga air; Bioindikator; Keanekaragaman

## A. INTRODUCTION

Indonesia is a country with rich biodiversity, including a vast diversity of insect species. Geographically, the biodiversity across the Indonesian archipelago is highly varied. This is supported by the tropical climate, which provides a wide range of habitats and ecosystems, contributing to the high diversity of flora and fauna. According to Toana (2023), expert interpretations indicate that there are 713,500 species or approximately 80% of the identified animal species.

Insects are a group of macroinvertebrates that are commonly found (Nuraeni *et al.* 2024). They inhabit various aquatic environments such as rivers, channels, ditches, rice fields, and lakes. Aquatic insects commonly found in water habitats belong to the orders Coleoptera, Diptera, Hemiptera, Lepidoptera, Odonata, Ephemeroptera, Plecoptera, and Trichoptera (Arumugam & Athikesavan 2021). Some aquatic insect species are highly sensitive and vulnerable to environmental pollution, making them useful as bioindicators (Parikh *et al.* 2021). A bioindicator is an organism that can be used to monitor the health of an environment or ecosystem. In water quality assessments, specific aquatic insect species can indicate the presence of pollutants or changes in water quality (Zaghloul *et al.* 2020).

Water quality and biodiversity are interconnected, meaning that water quality degradation due to pollution will disrupt aquatic life and affect biodiversity. Visually, the upstream area of the Maros Watershed (DAS) in Tompobulu District exhibits signs of environmental degradation, particularly deforestation, high levels of erosion, and frequent deforestation activities carried out by local communities. Additional damage is caused by forest conversion into plantation land (Kaenchan *et al.* 2018). This forest land conversion is driven by economic pressures and the need for clothing and shelter, such as logging for house construction, shifting cultivation, and using wood as fuel. These community activities contribute to the increasing degradation of critical forest land, leading to a decline in water discharge within the Maros Watershed (Syafri *et al.* 2020).

Data from the Maros Regency Forestry Service in 2015 reported that forest degradation in the upstream area of the Maros Watershed was estimated at approximately 7,936.76 hectares. The average annual rate of forest degradation and critical land expansion reached about 372.94 hectares per year, and it is projected that within the next 20-25 years, forests in the upstream Maros Watershed will be entirely depleted due to deforestation. The destruction of the Maros Watershed is likely to result in a decline in aquatic insect diversity (Barkey & Nursaputra 2019).

The Lekopancing River, located in the Maros Sub-Watershed, South Sulawesi Province, serves as one of the primary sources of clean water for drinking water needs in the eastern and northern areas of Makassar City. It is also an essential water source for agricultural and fisheries development in the upstream, middle, and downstream management areas. However, there are concerns regarding the availability of clean water resources. The raw water sources utilized by the local community are located near the river, where the water appears murky due to the mixing of surface water with soil. One approach to monitoring river water quality is through bioindicators (Bertrand *et al.* 2018). Bioindicators play a crucial role in demonstrating the relationship between biotic and abiotic factors within an environment (Ali *et al.* 2021). Therefore, this study aims to observe the diversity of aquatic insects and their role as environmental bioindicators in the Lekopancing River, Maros Regency.

## B. METHODS

### Site Location

This research was conducted in June-July 2022 at the Lekopancing River, Maros Regency. The sampling locations were selected from three parts of the Lekopancing River, namely the downstream (119°38'18.4776E, 5°7'44.1084S), the middle of the river (119°43'55.5276E, 5°9'20.9304S) and the upstream (119°50'15.2088E, 5°9'8.1684S). Lekopancing is one of the large rivers in the Maros Regency area. The Lekopancing River has been used as a source of raw water and clean water to meet the needs of several nearby sub-districts in Maros Regency, such as Tompobulu, Tanralili, and Moncongloe as well as to meet the needs of clean water in the Makassar City area in the north and east. The length of this river is around  $\pm$  30 km.

### Sample Collection and Identification

The samples were taken from all aquatic insects on the substrate or riverbed, starting from the adult and pre-adult phases. Sampling was carried out when the water was low. Capturing aquatic insects was done using the direct capture method (hand picking) and the kick sampling method. Sampling was conducted in three main parts of the river, namely the upstream, middle and downstream of the river. Each main part of the river is divided into three points each on the right and left sides of the river so that there are six points in each part of the river. Sampling was conducted three times, sampling was conducted three times in a row for a period of one week. Samples were identified, and the number of individuals in the laboratory was counted. Samples were identified, and the number of individuals in the laboratory was counted. Sample

identification was done using a stereo microscope and referring to insect references or determination keys (Thorp & Covich 2009).

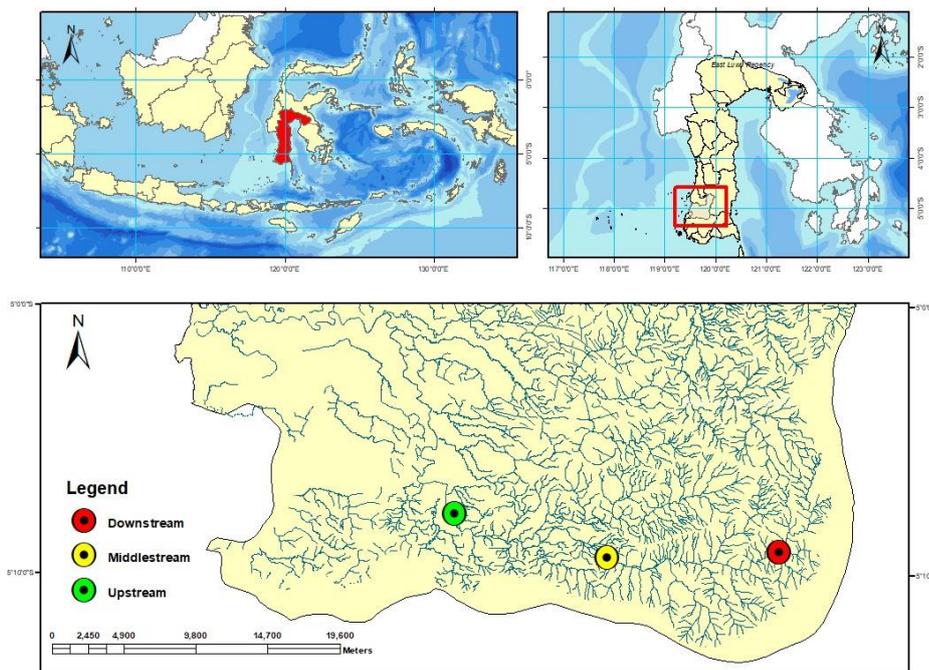


Figure 1. Map of the Lekopancing River research location

## Data Analysis

According to the Shannon-Wiener Index data analysis method, aquatic insect data were analyzed to obtain diversity index values (Yapo *et al.* 2019). To determine the aquatic insect family that can be used for biomonitoring of water quality using the Hilsenhoff family biotic index (HFBI) (Hilsenhoff 1988). The data analysis methods used were as follows:

### 1. Shannon-Wiener Species Diversity Index ( $H'$ )

The Shannon-Wiener Species Diversity Index is a mathematical measure used to quantify species diversity by considering both species richness and evenness within a community. A higher  $H'$  value indicates greater biodiversity and a more balanced ecosystem, while a lower value suggests species dominance or environmental stress. The  $H'$  formula is as follows (1):

$$H' = -\sum P_i \ln P_i \rightarrow P_i = \frac{n_i}{N} \quad (1)$$

Where  $H'$  represents the diversity index,  $p_i$  is the proportion of individuals of a species, calculated as the number of individuals of a species ( $n_i$ ) divided by the total number of individuals across all species ( $N$ ). The diversity index is categorized into three levels: a value of less than 1.5 indicates low species diversity, values ranging from 1.5 to 3.5 represent moderate species diversity, and values greater than 3.5 signify high species diversity.

### 2. Hilsenhoff Family Biotic Index

Hilsenhoff Family Biotic Index (HFBI) is an index used to assess water quality based on the tolerance of macroinvertebrate families to organic pollution. This index provides a score that reflects an organism's level of tolerance to polluted aquatic conditions, where higher values indicate greater levels of pollution and lower water quality. Categories for HFBI are divided into tolerance values (Table 1) and water quality values (Table 2). The HFBI formula is as follows (2):

$$HFBI = \frac{n \times a}{n} \quad (2)$$

Where HFBI is the Hilsenhoff family biotic index,  $n$  is the number of individuals, and  $a$  is the tolerance value.

**Table 2.** Tolerance values based on aquatic insect families

Order	Family and tolerance value
Plecoptera	Capniidae 1, Chloroperlidae 1, Leuctridae 0, Nemouridae 2, Perlidae 1, Perlodidae 2, Pteronarcyidae 0, Taeniopterygidae 2
Ephemeroptera	Baetidae 4, Baetiscidae 3, Caenidae 7, Ephemerellidae 1, Ephemeridae 4, Heptageniidae 4, Leptophlebiidae 2, Metretopodidae 2, Oligoneuriidae 2, Polymitarcyidae 2, Potomanthidae 4, Siphonuridae 7, Tricorythidae 4
Odonata	Aeshnidae 3, Calopterygidae 5, Coenagrionidae 9, Cordulegastridae 3, Corduliidae 5, Gomphidae 1, Lestidae 9, Libellulidae 9, Macromiidae 3
Trichoptera	Brachycentridae 1, Glossosomatidae 0, Helicopsychidae 3, Hydropsychidae 4, Hydroptilidae 4, Lepidostomatidae 1, Leptoceridae 4, Limnephilidae 4, Molannidae 6, Odontoceridae 0, Philopotamidae 3, Phryganeidae 4, Polycentropodidae 6, Psychomyiidae 2, Rhyacophilidae 0, Sericostomatidae 3
Megaloptera	Corydalidae 0, Sialidae 4
Lepidoptera	Pyralidae 5
Coleoptera	Dryopidae 5, Elmidae 4, Psephenidae 4
Diptera	Athericidae 2, Blephariceridae 0, Ceratopogonidae 6, Blood-red Chironomidae (Chironomini) 8, other (including pink) Chironomidae 6, Dolichopodidae 4, Empididae 6, Ephydriidae 6, Psychodidae 10, Simuliidae 6, Muscidae 6, Syrphidae 10, Tabanidae 6, Tipulidae 3
Amphipoda	Gammaridae 4, Talitridae 8
Isopoda	Asellidae 8

**Table 3.** Water quality based on HFBF

HFBF value	Water quality	Pollution level
0.00–3.75	Excellent	Not polluted by organic matter
3.76–4.25	Very good	Slightly polluted by organic matter
4.26–5.00	Good	Polluted by some organic matter
5.01–5.75	Fair	Somewhat polluted
5.76–6.50	Somewhat poor	Heavily polluted
6.51–7.25	Poor	Very heavily polluted
7.26–10.00	Very poor	Heavily polluted by organic matter

## C. RESULTS AND DISCUSSION

### Condition of Location

The upstream of the Lekopancing River is located between 119°48'56.1248 to 119°50'12.2088 E and 5°9'8.1684 to 5°9'46.188 S at an altitude of  $\pm$  583 meters above sea level, there is a waterfall in this section, the water conditions were relatively clean and clear used as a source of clean water for the clean water needs of the surrounding community (Figure 2A). In the upstream part of the Lekopancing River, the vegetation is dominated by *Bambusa vulgaris*, *Ficus benjamina*, and *Alstonia scholaris*. Besides that, some plantations and settlements were not yet dense.

**Figure 2.** Lekopancing River. Upstream (A), middlestream (B), downstream (C)

The upstream of the Lekopancing River is located between 119°43'55.5276 to 119°46'55.402 E and 5°9'20.9304 to 5°9'32.422 S at an altitude of  $\pm$  157 meters above sea level, there were rocks that were not too large and stagnant water in several places, the condition of the water is relatively clean and clear (Figure 2B). In the middle of the Lekopancing

River, there is vegetation such as *Bambusa vulgaris*, and *Werenga pinnata* on the left shoulder of the river. In contrast, on the right shoulder of the river, there is open land such as rice fields, plantations, and settlements that are not too dense.

The downstream of the Lekopancing River is located between 119°38'18.4776 to 119°39'20.272 E and 5°7'44.1084 to 5°8'33.32 S at an altitude of  $\pm 82$  meters above sea level, marked by the presence of turbid and stagnant water in several places, and the presence of rocks that can be seen clearly (Figure 2C). The downstream of the Lekopancing River has open vegetation such as rice fields, plantations, sand mines, and dense settlements. In this downstream section, some people use it to channel water in the rice field irrigation system, for daily needs, and bathing livestock.

### Diversity of Insects in the Lekopancing River

The number of individuals collected was 277 in the upper reaches of the river, 263 in the middle reaches and 74 in the lower reaches of the river (Table 3). The number of individuals from upstream to downstream tends to decrease. This is in line with the research of Maneechan & Prommi (2015), in the upper reaches of rivers in Thailand the abundance of species is higher in the upper reaches. There are 13 species of aquatic insects found in the Lekopancing River with the highest abundance being *G. remigis* (296 individuals; 48.21% of the total abundance). The species that are only found in the lower reaches are *Catascopus* sp., while *M. ornata* (Order Odonata) and *Euborellia* sp. (Order Dermaptera) are found in the middle reaches of the river and *Psephenis* sp. (Order Coleoptera) and *C. caprotina* (Order Trichoptera) in the upper reaches of the river. The difference in the number of individuals and their abundance is thought to be due to differences in conditions around the river body. In the upstream and middle areas, vegetation still covers the right and left sides of the river, except in the downstream area where the conditions are open and have changed into rice fields. Changes in surrounding land use significantly influence aquatic insect composition and abundance (Fierro *et al.* 2017).

**Table 3.** Data on aquatic insects found in the Lekopancing River

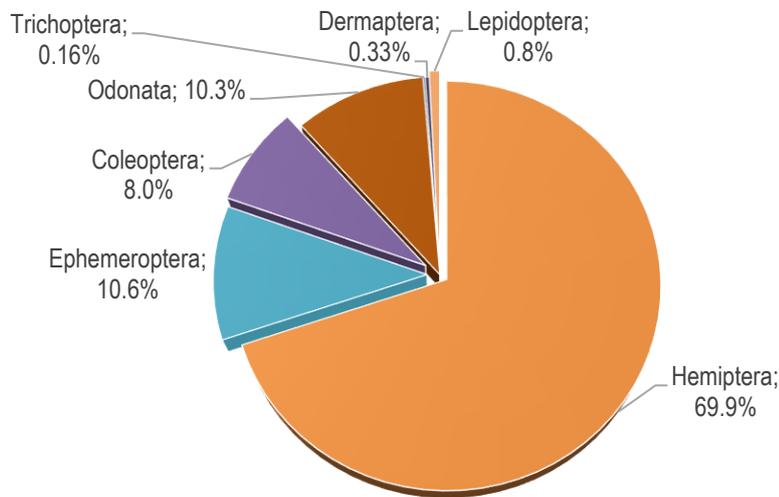
Order	Family	Species	Abundance of species			Abundance
			A	B	C	
Hemiptera	Gerridae	<i>Gerris remigis</i>	86	143	67	296
	Veliidae	<i>Ragovelia</i> sp.	78	55	-	133
Coleoptera	Psephenidae	<i>Psephenis</i> sp.	2	-	-	2
	Gyrinidae	<i>Dineutus</i> sp.	45	-	-	45
	Carabidae	<i>Catascopus</i> sp.	-	-	2	2
Odonata	Gomphidae	<i>Gomphidia</i> sp.	16	-	-	16
	Coenagrionidae	<i>Crocothemis</i> sp.	3	9	3	15
	Pseudostigmatidae	<i>Mecistogaster ornata</i>	-	3	-	3
	Chlorocyphidae	<i>Libellago</i> sp.	26	3	-	29
Trichoptera	Hydropsychidae	<i>Cheumatopsyche caprotina</i>	1	-	-	1
Dermaptera	Dermaptera	<i>Euborellia</i> sp.	-	2	-	2
Ephemeroptera	Baetidae	<i>Ecdyonurus</i> sp.	18	45	2	65
Lepidoptera	Pyralidae	<i>Aulocodes</i> sp.	2	3	-	5
Total			277	263	74	614

Note: River section. (A) upstream, (B) middlestram, (C) downstream.

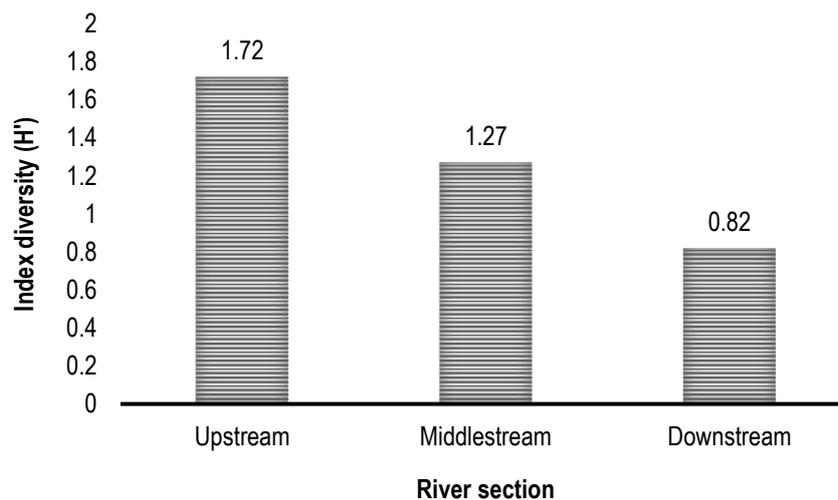
Hemiptera (429 individuals; 69.9% of total abundance), which has the most individuals as the dominant order in all three parts of the Lekopancing River. This is followed by Ephemeroptera (65 individuals; 10.6% of total abundance), Odonata (63 individuals; 10.3% of total abundance), Coleoptera (49 individuals; 8% of total abundance), Lepidoptera (5 individuals; 0.8% of total abundance), Dermaptera (2 individuals; 0.33% of total abundance) and Trichoptera (1 individual; 0.16% of total abundance) (Figure 3, Table 3). Hemiptera are often found in abundant numbers with several species found on the surface to the bottom of the river (Suhanda *et al.* 2025). Hemiptera are also found in many other rivers in Maros Regency (Nuraeni *et al.* 2019).

The diversity index value of the species in the upstream section is 1.72 (Figure 4). In the middle of the river it is 1.27 with the diversity index value category included in the moderate diversity according to the Shannon-Wiener classification because it shows a value  $> 1$ , while in the downstream section it is 0.82 with the index value category included in the low category because it shows a value  $< 1$ . Environmental conditions in the upstream and middle of the Lekopancing River still maintain vegetation but the insect diversity index is in the moderate category due to the uneven distribution of individuals between species in one observation location. It is clarified by Gilbert & Levine (2017), that species diversity is influenced by the distribution of individuals in each species in one habitat, although there are many species, the distribution

of individuals is uneven so that the diversity is low. The results of the same study by Maneechan & Prommi (2015), the diversity value of aquatic insect species in the upstream section of the river is included in the moderate category. High diversity occurs if almost all individuals come from different genera or species, conversely low diversity if almost all individuals are from the same species (Jihanlillah 2024).



**Figure 3.** Order composition of the Lelopancing River



**Figure 4.** Aquatic insect diversity index in the Lelopancing River

### Application of the Hilsenhoff Family Biotic Index scale

The Lelopancing River, located in Maros Regency, plays a crucial role as a source of clean water for Makassar City and its surrounding areas. The diversity and ecological functions of aquatic insects as bioindicators of water quality provide highly relevant information to support sustainable water resource management. Based on  $H'$  and HFBI analyses, a significant decline in water quality was observed from the upstream to the downstream sections of the river. This decline aligns with the findings of previous studies, such as those conducted by Dubois *et al.* (2018), which demonstrated the correlation between human activities and aquatic ecosystem degradation in downstream areas.

The sampling techniques employed, including manual collection and kick-sampling, effectively represented the ecosystem conditions across the three river zones. Identification results revealed that the upstream section of the Lelopancing River supports a higher diversity of aquatic insects, with a moderate diversity index ( $H' = 1.26$ ). In comparison, the midstream and downstream sections exhibited  $H'$  values of 1.72 (moderate category) and 0.42 (low category), respectively. The decline in diversity in the downstream section indicates that habitat degradation due to organic pollution has reduced the presence of species more sensitive to water quality changes (Kim *et al.* 2019), such as those belonging to the orders Ephemeroptera and Trichoptera.

Based on the HFBI values (Table 6), the water quality in the upstream section remains in the very good category (HFBI = 3.26), reflecting a relatively undisturbed ecosystem. The midstream section has an HFBI value of 4.48, which falls

into the good category but indicates signs of organic pollution originating from human activities around the river. Meanwhile, the downstream section, with an HFBI value of 7.00, exhibits poor water quality with a very high level of organic pollution. Intensive human activities in the downstream area have contributed to the increase in HFBI values, reflecting significant ecosystem degradation (Adnan *et al.* 2024).

**Table 6.** Insect bioindicators in the Lekopancing River

Order	Family	Tolerance value	Number of species			HFBI value		
			A	B	C	A	B	C
Ephemeroptera	Baetidae	4	18	45	2	72	180	8
Trichoptera	Hydropsychidae	4	1	0	0	4	0	0
Odonata	Coenagrionidae	9	3	9	3	27	81	27
	Gomphidae	1	16	0	0	16	0	0
Coleoptera	Psephenidae	4	2	0	0	8	0	0
Lepidoptera	Pyralidae	5	2	3	0	10	15	0
Total			42	57	5	137	276	35

Note: River section. (A) upstream, (B) middle, (C) downstream.

Furthermore, bioindicator analysis using aquatic insect families (Table 7), such as Baetidae, Coenagrionidae, and Pyralidae, provides valuable insights into the sensitivity of various species to pollution levels. The dominance of the Baetidae family in the upstream and midstream sections reflects a healthier ecosystem. In contrast, the dominance of the Pyralidae family in the downstream section indicates an adaptive response to polluted environmental conditions. Bioindicator analysis based on the HFBI is effective not only for monitoring water quality but also for understanding the dynamics of aquatic biota communities (Assefa *et al.* 2020).

The decline in water quality in the Lekopancing River, particularly in the downstream section, is attributed to runoff from domestic waste, agricultural waste, and residential activities near the river. Anthropogenic impacts in the downstream area align with findings that such activities contribute to increased HFBI values (Asadisharif *et al.* 2024). Therefore, this study highlights the importance of sustainable waste management, particularly in the downstream region, to protect the river ecosystem and ensure the sustainability of clean water supply.

**Table 7.** HFBI value of water quality and pollution in the Lekopancing River

River section	HFBI value	Water quality	Pollution level
Upstream	3.26	Very good	Not polluted by organic matter
Middle	4.48	Good	Polluted by some organic matter
Downstream	7.00	Poor	Very heavily polluted

The combination of the Shannon-Wiener index and HFBI provides a comprehensive overview of the aquatic ecosystem quality in the Lekopancing River. While the diversity index indicates species richness and distribution, HFBI specifically reflects the level of organic pollution (Gholizadeh & Zibaei 2021). The integration of these two methods offers a strong scientific foundation for designing ecosystem-based river management strategies, including habitat restoration and pollution source control. This study serves as a scientific basis for better policymaking in the management of the Lekopancing River. Given the importance of clean water as a vital resource, an integrated approach is required to mitigate the impacts of pollution, particularly in the downstream areas. Efforts such as domestic and agricultural waste treatment, community involvement in conservation, and regular water quality monitoring can help ensure the sustainability of the Lekopancing River as a crucial resource for the communities of Maros and Makassar.

## D. CONCLUSION

Based on the results of the study of aquatic insect diversity in the Lekopancing River, Maros Regency, the total number of insects found was 614 individuals consisting of 13 species, 13 families, and 7 orders found in the upstream part of the river 277 individuals, in the middle part of the river 263 individuals and the downstream part of the river 74 individuals were found. The highest number of individuals was 429 or 69.9% of the total abundance of the Hemiptera order. The diversity index in the upstream and middle parts of the river is categorized as Medium, while the downstream part is categorized as low. The role of aquatic insects as bioindicators based on the Hilsenhoff Family Biotic Index value in the

upstream part is 3.26, indicating that the water quality is very good. In the middle part is 4.84 indicating good water quality and in the downstream part the HFBI value is 7.00 or is categorized as poor.

## AUTHOR'S DECLARATION

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours.
- No animal studies are present in the manuscript.
- No human studies are present in the manuscript.
- No potentially identified images or data are present in the manuscript.

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