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MORALITY BEFORE KNOWLEDGE

Assessment of macrozoobenthic community dynamics in the Ijuk River: Implications for freshwater ecosystem health and conservation management

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ABSTRACT
Background: Nestled within the Isau-Isau Wildlife Reserve, the Ijuk River stretches approximately three kilometers, serving as a vital conservation area. Its upstream region plays multiple ecological roles, including watershed management, hydrological regulation, microclimate control, soil fertility maintenance, microbial habitat provision, air quality regulation, and carbon sequestration. However, escalating human activities, particularly changes in land use, pose significant threats to its ecological balance. The particular concern is the conversion of forested areas into agricultural lands, primarily for coffee cultivation and mixed gardens, encroaching dangerously close to the riverbanks. This encroachment necessitates a critical reevaluation of the river's water quality, given its crucial role in supporting biodiversity and ecological equilibrium. Benthic insects dwelling in the riverbed serve as invaluable bioindicators, offering insights into the overall health of aquatic ecosystems. **Methods:** Conducted between January and July 2022 in the Isau-Isau Wildlife Refuge, Lawang Agung Village, Mulak Ulu District, Lahat Regency, the study aimed to assess the macrozoobenthic community structure across three river segments: upstream, midstream, and downstream. Employing field sampling, observational surveys, taxonomic identification, and data analysis, the research aimed to unravel the river's ecological dynamics. **Findings:** Through meticulous examination of benthic insect communities, the study revealed relatively favorable water quality in the Ijuk River. However, discernible declines in various ecological parameters, as evidenced by evaluation results, highlight the urgency of conservation efforts and proactive management strategies to mitigate further degradation and preserve the river's ecological integrity. **Conclusion:** Such endeavors are crucial for safeguarding the biodiversity and sustainability of this vital freshwater ecosystem. **Novelty/Originality of this Study:** The study uniquely assesses the macrozoobenthic community dynamics in the Ijuk River, revealing significant changes over two decades that highlight the river's ecological health and underscore the urgent need for conservation efforts. It offers a comprehensive, updated evaluation of the macrozoobenthic community structure, providing critical insights into the impacts of land use changes and human activities on freshwater ecosystems.

KEYWORDS: freshwater ecosystem; Ijuk River; macrozoobenthic community.

1. Introduction

The Isau-isau wildlife sanctuary is a designated natural reserve aimed at safeguarding its indigenous flora and fauna. Geographically situated between 103°35' – 103°43' East Longitude and 03°52' – 04°02' South Latitude, it spans an area of 16,742.92 hectares, administratively falling within the jurisdictions of Lahat and Muara Enim Regencies. Its topography comprises highlands, undulating terrain, and hills, with elevations ranging

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from 600 to 1400 meters above sea level. Despite maintaining a predominantly natural ecosystem, encroachment from agricultural activities, notably the expansion of coffee plantations and mixed gardens, has begun to disrupt some areas surrounding it. The sanctuary features several small rivers, including the prominent tributary, Ijuk River, which extends approximately 3 kilometers and serves vital roles in water infiltration and hydrological protection. The aforementioned conditions are crucial for the survival of organisms inhabiting them, including aquatic insects that dwell in the riverbed (Salmin, 2005).

The microhabitats of aquatic insects in Ijuk River significantly influence their existence, and disturbances to these microhabitats can diminish water quality and disrupt aquatic insect populations. River degradation commonly stems from land use changes, population growth, and insufficient community awareness of river conservation. This study selects aquatic insects as indicators of river condition changes due to their sensitivity to pollution (Popoola and Otalekor, 2011). Previous research in the same area documented various species of aquatic insects, but there is a lack of recent scientific information after 20 years, emphasizing the need for updated research. Therefore, this study aims to evaluate changes in river conditions and aquatic insect populations in Ijuk River. The primary objective of this study is to describe and evaluate the community of aquatic insects in the ecosystem of Ijuk River, encompassing composition, density, and diversity regarding changes over a period of 20 years. The escalating human activities in the vicinity of the river and the construction of dams in proximity to river bodies have the potential to influence the aquatic ecosystem's environmental dynamics. Agricultural practices conducted by the local community near the downstream section of the river may exert pressure on the aquatic insect community. Hence, there is a need to conduct an assessment of the changes in river environmental conditions over the past two decades.

1.1 Freshwater ecosystem and river

Freshwater ecosystems comprise habitats abundant in freshwater, rich in minerals, with a pH of approximately 6. Surface water conditions are not always stable; there are fluctuating phases, and at times, freshwater bodies may dry up due to unpredictable weather conditions. Freshwater ecosystems can be broadly classified into two main categories: lotic ecosystems, characterized by flowing water, and lentic ecosystems, comprising stagnant water bodies. Lotic ecosystems encompass springs, streams, and rivers, while lentic ecosystems include lakes, ponds, marshes, reservoirs, and dams (Odum, 1993). According to Odum (1996), lotic freshwater ecosystems consist of two primary zones: 1) The fast-flowing zone is characterized by shallow areas with high water velocity, resulting in clean water bottoms with hard substrates. This zone is inhabited by benthic organisms adapted to this specific habitat. 2) The slow-flowing zone, comprising deeper water with reduced water velocity, allows sediment such as mud or other loose material to settle in this area.

A watercourse primarily sourced from natural origins and flowing from higher to lower elevations or distances is referred to as a river. River streams ultimately converge into larger bodies of water such as lakes, seas, or other rivers. Rivers are defined as lotic ecosystems or flowing water bodies that serve as habitats for various organisms. River waters are divided into three sections: the upper reaches known as the headwaters, the middle section called the river body, which extends longitudinally, and the lower section known as the downstream. The distinction between waters in the upstream and downstream regions lies in the fact that upstream waters are freshwater originating from springs, whereas downstream areas contain brackish water due to the mixing of freshwater with seawater. Condition of the upstream section of Ijuk River, Isau-Isau can be seen in Figure 1.

Fig 1. Condition of the upstream section of Ijuk River, Isau-Isau

1.2 Aquatic bottom insects

The aquatic bottom insects, classified within the Insecta class, predominantly inhabit the underwater environment throughout their life cycle, serving as reliable indicators of water quality (Ward, 1992). While approximately 3% of global insect species are aquatic, nearly 95% constitute macroinvertebrates in freshwater habitats, including various orders such as Diptera, Ephemeroptera, Hemiptera, Megaloptera, Odonata, Plecoptera, and Trichoptera (Ward, 1992). These insects exhibit sensitivity to pollution, although some can adapt and proliferate in polluted conditions, their existence heavily reliant on the availability of energy and food sources like organic matter, contributing significantly to nutrient cycling within aquatic ecosystems (Popoola and Otalekor, 2011).

The distribution of aquatic bottom insects predominantly spans freshwater environments, with only a small fraction inhabiting marine waters (HBN, 1970). Their distribution is influenced by various factors including flow velocity, temperature, substrate type, vegetation cover, dissolved substances, food availability, interspecies competition, turbidity, and zoogeography (HBN, 1970). Typically, benthic invertebrates exhibit the highest densities in fast-flowing water communities, distributing across substrates such as rocks, gravel, detritus, sand, and mud in rivers, and encompassing different zones in lakes, including littoral, limnetic, and profundal zones (Odum, 1993).

The habitat of aquatic bottom insects is classified based on primary physical and chemical environmental factors, resulting in three major categories: natural or permanent, temporary, and anthropogenic habitats (Merrit and Cummins, 1996). These insects can be found in various habitats such as rivers, which offer microhabitats like detritus, rocky, gravelly, sandy, and muddy substrates, and lakes, which include areas distant from the shoreline, areas devoid of sunlight penetration, as well as ponds and marshes (Merrit and Cummins, 1996).

1.3 Factors affecting the life of aquatic bottom insects and diversity index

The condition of a riverine ecosystem can be influenced by environmental factors. The environmental factors affecting the presence of aquatic bottom insects in a water area include physical-chemical factors such as temperature, flow velocity, water pH, and substrate composition. Flow velocity is determined by slope, roughness, depth, and substrate moisture. Organisms inhabiting both swift and calm waters have well-developed adaptive systems to maintain their position in flowing water. Flow is a limiting factor for community life in rivers because swift currents can sweep away and dislodge organisms. Rivers generally exhibit five types of flow velocities: very fast flow > 100 cm/sec, fast flow 50-100 cm/sec, moderate flow 25-50 cm/sec, slow flow 10-25 cm/sec, and very slow flow <10 cm/sec (Harahap, 1991, as cited in Helmi and Anita, 2013).

Diversity is a unique characteristic at the community level that reflects the community structure. Based on community properties, diversity is determined by the number of species and the evenness of individual abundance of each species obtained. The greater the value of diversity, the more species are present, and this value depends greatly on the total value of individuals of each species or genus. Diversity (H') has the highest value when all individuals come from different genera or species, whereas the lowest value is when all individuals come from only one genus or one species. Species are defined as individuals of the same kind that can reproduce and produce fertile offspring. Meanwhile, a population is a collection of similar individuals found in the same place for a certain period. If a community is defined as a collection of several populations from different places (Kusnadi, 2016).

2. Methods

2.1 Research location

This research was conducted from January 2022 to July 2022 at SM Isau-Isau, Lawang Agung Village, Mulak Ulu Subdistrict, Lahat Regency (Figures 2 and 3). The process of observing and identifying samples of benthic aquatic insects was carried out at the Ecology Laboratory, Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Sriwijaya. Measurement of physicochemical parameters was conducted directly during sample collection in the field, and testing of phosphate and nitrate content was performed at the Environmental Laboratory of the Environmental and Sanitation Agency of Palembang City.

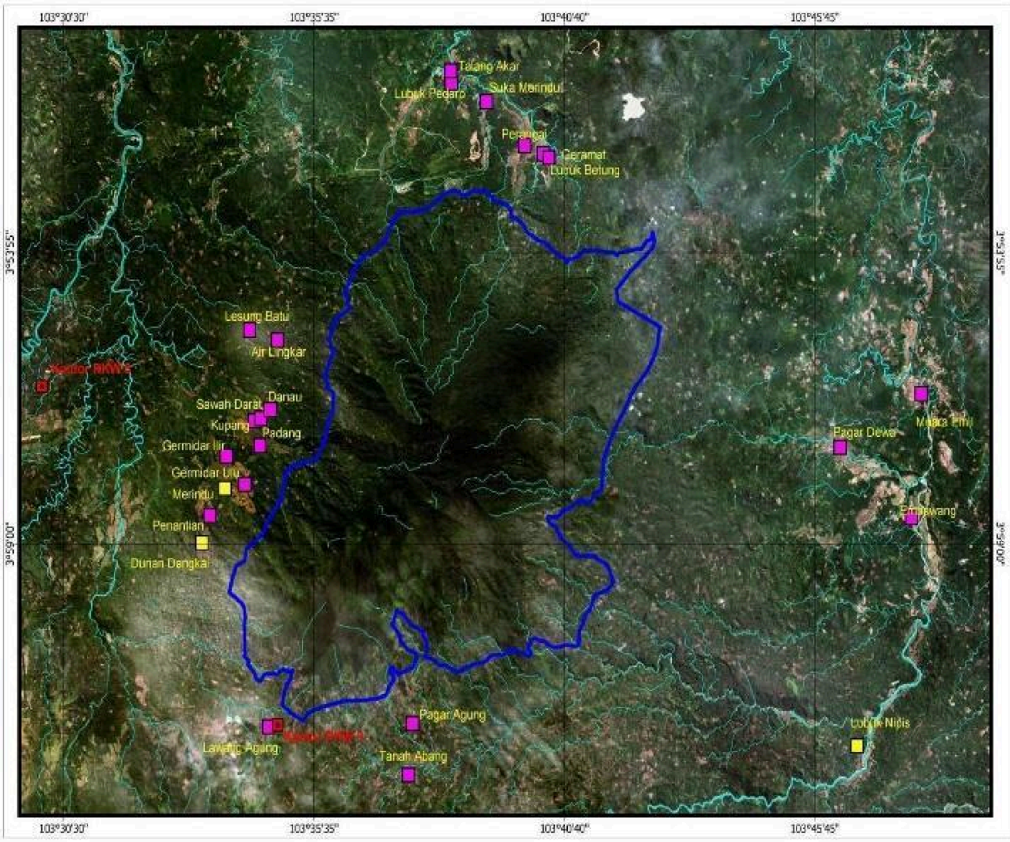

Fig 2. Map of the Isau-Isau wildlife sanctuary area, South Sumatra

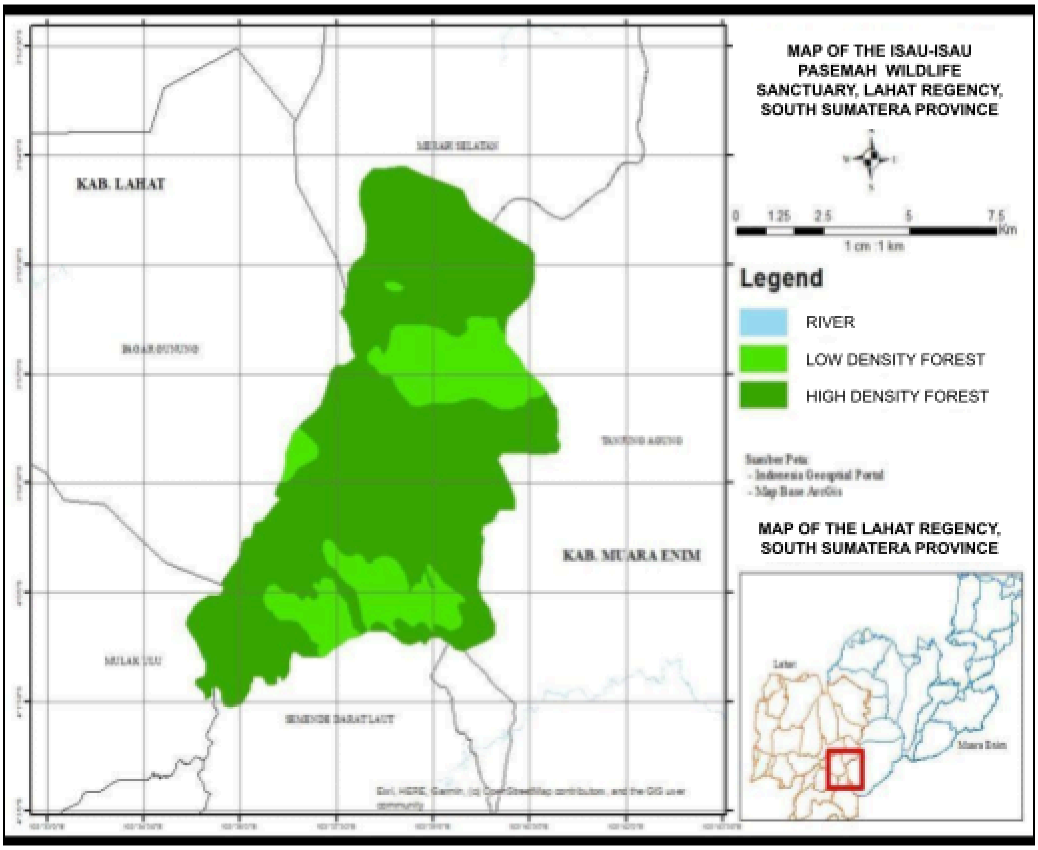

Fig 3. Map of the planned research location in Isau-Isau wildlife sanctuary, Pasemah, Lahat Regency

2.2 Benthic aquatic insect sampling and field research procedure

The research methodology involved direct survey methods conducted at the research site with a quantitative descriptive approach. The survey results in the Ijuk River waters were based on environmental conditions, with sampling locations selected purposively to represent each station corresponding to its environmental conditions. Sampling was done using a surber net, with each of the three sampling stations having four different microhabitat types: rocky, sandy, gravelly, and leaf litter. Each microhabitat was sampled twice, resulting in a total of 24 research samples for identification. Samples collected were sorted, preserved in formalin and distilled water, and then identified under a microscope to assess the river water quality changes over a 20-year period due to coffee plantation expansion and dam construction.

Benthic aquatic insect samples were collected using a surber net, which was placed on the riverbed against the current. After waiting for three minutes, the net was lifted, and the collected material was poured onto a sieve, allowing benthic insects to pass through while retaining other materials. This process was repeated twice for each substrate type. Stones from the riverbed, which serve as habitats for benthic aquatic insects, were collected, cleaned, and brushed to remove attached insects. The resulting mixture was filtered through a 0.5 mm sieve, and the collected sample was preserved in bottles containing 10% formalin.

2.3 Environmental parameters data collection and laboratorium research method

The measured environmental parameters included temperature, water depth, flow velocity, and substrate type. Water quality assessment involved measuring dissolved oxygen, phosphate, and nitrate levels. Temperature was measured using a thermometer, flow velocity using a Current Velocity Meter. Analysis conducted at the Environmental Laboratory of the Environmental and Sanitation Agency of Palembang City.

Samples collected from the field were sieved again using a 0.5 mm mesh sieve to remove formalin, then transferred to sample bottles filled with 70% alcohol for long-term preservation. Larval insect specimens, particularly small ones like Chironomidae, were boiled in a 10% KOH solution to dissolve muscle tissue, making identification easier. Samples were then placed on glass slides for identification using various reference books. Environmental parameter measurements were conducted directly in the field, while water sample testing was done at the Environmental Laboratory of the Environmental and Sanitation Agency of Palembang City.

2.5 Data analysis

2.5.1 Macrozoobenthos density, diversity index, amd evenness index

The quantitative descriptive method was employed in this research, utilizing the Shannon-Wiener, Simpson, and Sorensen indices to analyze macrozoobenthos density (Equation 1). Where D is density (ind./m^2); N is the number of individual species; and A is area of observation (m^2).

$$D = N/A \quad \text{(Eq. 1)}$$

To analyze data regarding the diversity of bottom water insects, the Shannon-Wiener diversity index formula is used (Odum, 1993):

$$H' = \sum\left[\frac{ni}{N}\right] ln\left[\frac{ni}{N}\right] atau \sum Pi\ lnPi \quad \text{(Eq. 2)}$$

Where H' is Shannon diversity index; Pi is probability of finding an individual of species ii = niNNni; ni is number of individuals of species ii; and N is the total number of individuals (Equation 2).

The stability of biotic communities is assessed through the Shannon Diversity Index (H'), which categorizes stability into three ranges: If H' < 1, the biotic community is considered unstable. If H' ranges between 1-3, the stability of the biotic community is moderate. Conversely, if H' > 3, it indicates that the stability of the respective biotic community is in an optimal or stable condition.

The maximum value of H' occurs when encountered in an environment where all species are abundant. Meanwhile, the value of E ranges between 0 and 1, where the value depicts a state in which all species are sufficiently abundant (Fachrul, 2007). Where s is total number of species; and $H'max$ is maximum diversity (Equation 3).

$$E = \frac{H'}{H'max} \quad \text{(Eq. 3)}$$

3. Results and Discussion

3.1 Composition and relative density of aquatic benthic insects

The results of the conducted research on the Evaluation of Aquatic Benthic Insect Communities in the Ijuk River Wildlife Sanctuary of Isau-Isau, South Sumatra, yielded the following findings (Table 1).

Table 1. Composition and average density (ind/m^2) of aquatic benthic insects in the Ijuk River wildlife sanctuary of Isau-Isau, South Sumatra

Taxonomic Group	Station														
	I					II					III				
	B	K	P	S	X	B	K	P	S	X	B	K	P	S	X
ARTHROPODA															
INSECTA															
COLEOPTERA															
Elmidae															
Stenelmis sp.				28	28	17				17					
Hydrophilidae															
Berosus sp.				78	78										
Diboloceus sp.									56	56					
Helophorus sp.				11	11			17		17			6		6
Leiodidae															
Prionochaeta sp.		22	17	117	52		6			6	144				144
Psephenidae															
Acneus sp.				11	11										
Ectopria															
Ectopria sp.				6	6										
Psephenus sp		6		39	23										
ODONATA															
Aeshnidae															
Gynacantha															
Gynacantha sp.				11	11										
Calopterygidae															
Hetaerina sp.									61	61					
Coenagrionidae															
Argia															
Argia sp.									22	22					
Ischnura sp.														6	6
Cordulegastridae															
Cordulegaster sp.				6	6										
Euphaeidae															
Euphaea						11				11					

Euphaea sp.															
Ghompidae															
Epigomphus sp.	6			6	6										
Ghompus sp.	28		6		17										
Libellulidae															
Libellula															
Libellula sp.				6	6										
Platycnemididae															
Coeliccia															
Coeliccia sp.	44				44										
DIPTERA															
Chironomidae															
Polypedilum sp.		50	44	600	231			28	28	28					
Ablabesmyia sp.	11		11		11	28		78		53	11	78	11		50
Orthocladius sp.				6	6										
Simuliidae															
Simulium sp.	6				6										
Tipulidae															
Angarotipula															
Angarotipula sp.															
Anthoca sp.							6			6					
Tipula sp.				261	261				11	11					
EPHEMEROPTERA															
Baetidae															
Acentrella sp.				11	11				17	17					
Baetis sp.		22		6	14	61	6	39		35	44				44
Procleon sp.		11			11										
Leptophlebiidae															
Paraleptophlebia sp.		11			11										
Heptageniidae															
Ecdyonurus sp.		22			22	28		50	17	32	17			11	14
Heptagenia sp.	6			6											
PLECOPTERA															
Chloroperlidae															

Hastaperla sp.				17	17	6	6		100	37	89	11	6	17	31
Perlodidae															
Isoperla sp.	50	17		89	52	22	6		67	32	6				6
TRICHOPTERA															
Hydropsychidae															
Hydropsyche sp.	50	17		106	58	33	6	11	117	42	433				433
Rhyacophilidae															
Ceraclea sp.				22	22										
ORTHOPTERA															
Orthoptera sp. I				11	11				22	22				33	33
Number of Species	7	10	4	21	*29	8	6	6	11	*18	7	2	3	5	*11
Total Individuals per Square Meter (Ind./m^2)	195	184	78	1448	*1049	206	36	223	518	*505	744	89	23	78	*767
Diversity Index	1.49	2.12	0.84	2.05		1.79	1.79	1.66	2.32		1.46	1.42	1.80	1.64	
Dominance Index	0,26	0,12	0,50	0,22		0,20	0,17	0,20	0,12		0,32	0,08	0,20	0,22	

The identification results of all samples of aquatic benthic insects conducted at three observation stations revealed the presence of 7 orders, namely Coleoptera, Diptera, Ephemeroptera, Odonata, Orthoptera, Plecoptera, and Trichoptera, encompassing 22 families and 36 genera. Different compositions were observed among rocky, leaf litter, and gravel substrates compared to sandy substrates, which exhibited fewer compositions, and not all types of aquatic benthic insects could survive and adapt to such substrates. Sandy substrates are considered poor substrates due to their unstable position, and the flow passing through them is less vigorous (Siahaan et al., 2011). Substrate type in river waters determines the diversity of orders present in the river.

Aquatic benthic insects exhibit varying levels of adaptation to the types and organic content of the substrate. Insects from the class Insecta can inhabit various habitats with different conditions, whether in flowing or stagnant waters. Insecta class has the ability to survive in fast-flowing waters. The rapid flow of rivers and natural conditions affect the diversity of insects in rivers significantly.

The Ijuk River waters have various types of microhabitats, generally inhabited by aquatic insects ranging from rocky, gravel, sandy, to leaf litter substrates. Aquatic organisms have a better chance of reproducing and surviving on rocky and gravel substrates due to their relatively stable nature and resistance to movement even in strong currents. Rocky and gravel substrates provide cavities for aquatic benthic insects to dwell and hide from predators, and these cavities are useful for providing sufficient oxygen for the organisms (Hanafiah and Harmida, 2001).

The water quality of the river can be monitored using biotic methods that use bioindicators, divided into 2 groups, EPT and non-EPT. The orders Ephemeroptera, Plecoptera, and Trichoptera (EPT) are the most sensitive group of insects to changes in river water quality. Non-EPT groups consist of aquatic benthic insects resistant to unhealthy or polluted river flows. The EPT group is highly sensitive to environmental changes in water bodies and is considered an environmental quality indicator. The differentiation within this group can provide guidance on the quality of river water in a short period (Chandra et al., 2014).

In the Ijuk River waters, the order Ephemeroptera was found to have 6 species, with Baetis sp., Ecdyonurus sp., and Acentrella sp. being the most abundant. This order possesses shredder feeding habits, making it capable of surviving in fast-flowing waters by utilizing its body structure and hiding under the substrate (Mar'i, 2018).

The Plecoptera order found in the Ijuk River waters consists of two genera, namely Hastaperla sp., and Isoperla sp. Plecoptera are rarely found in sandy substrates in the Ijuk River waters but thrive in rocky substrates, earning them the nickname "stoneflies." They generally inhabit clean freshwater with temperatures below 25°C and sufficient oxygen levels, being unable to withstand pollution. Plecoptera have a life cycle that can adapt to depths of up to 70 meters. They are rarely found in calm waters such as lake edges with water wave movement for oxygen enrichment.

The Trichoptera order prefers shallow waters with flowing water over rock surfaces. Trichoptera can be found in waters ranging from unpolluted to heavily polluted. Throughout the river, Trichoptera is predominantly found in the downstream area, as the presence of aquatic benthic insects tends to increase in downstream areas when water quality improves (Sudarso, 2009).

3.2 The composition of aquatic benthic insect species

The bar chart depicting the total composition of aquatic benthic insect species in the Ijuk River shows fluctuations, both increases and decreases, across each station and substrate type (Figure 4).

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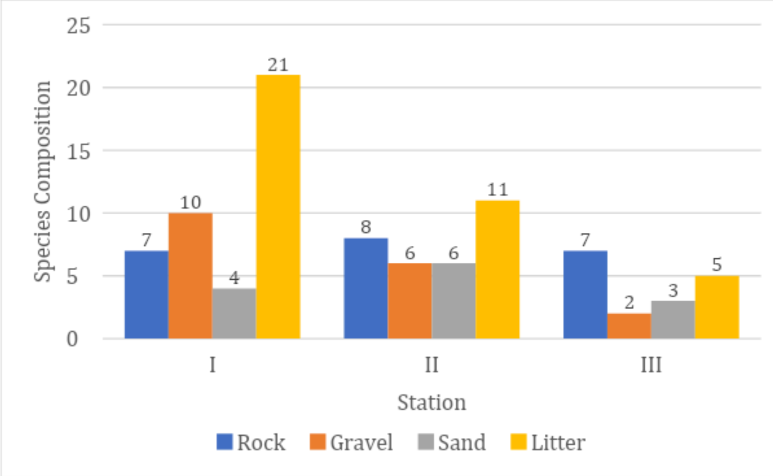

Fig. 4. The total composition of aquatic benthic insect species across three stations in the Ijuk River wildlife sanctuary, Isau-Isau, Lahat Regency, is depicted in the bar graph

At Station I, a total of 7 species were found on rocky substrates, consisting of 4 orders: Diptera, Odonata, Plecoptera, and Trichoptera. On gravel substrates, 10 species were identified, encompassing 6 orders: Coleoptera, Odonata, Diptera, Ephemeroptera, Plecoptera, and Trichoptera. Sandy substrates revealed 4 species across 3 orders: Coleoptera, Odonata, and Diptera. Leaf litter substrates harbored 21 species from 7 orders: Coleoptera, Odonata, Diptera, Ephemeroptera, Plecoptera, Trichoptera, and Orthoptera.

At Station II, the highest species composition was found on leaf litter substrates, consisting of 7 orders: Coleoptera, Odonata, Diptera, Ephemeroptera, Plecoptera, Trichoptera, and Orthoptera. Eight species were identified on rocky substrates, spread across 6 orders: Coleoptera, Odonata, Diptera, Ephemeroptera, Plecoptera, Trichoptera. Gravel substrates at Station II revealed the fewest species, with 6 species distributed among 5 orders: Coleoptera, Diptera, Ephemeroptera, Plecoptera, and Trichoptera. Sandy substrates contained 6 species distributed across 4 orders: Coleoptera, Diptera, Ephemeroptera, and Trichoptera.

At Station III, rocky substrates harbored the highest species composition, with 7 species, while gravel substrates had the lowest, with only 2 species. Rocky substrates comprised 5 orders: Coleoptera, Diptera, Ephemeroptera, Plecoptera, and Trichoptera. Gravel substrates were distributed across 2 orders: Diptera and Plecoptera. According to Sinulingga et al., (2017), the substrate type influences the distribution of aquatic benthic insects as it provides attachment points, pathways, and food sources.

The most abundant composition of aquatic benthic insect species across all stations was found on leaf litter substrates at Station I. This is attributed to leaf litter substrates serving as a food source for aquatic benthic insects. However, the condition of leaf litter substrates at Station II decreased due to the more open environmental conditions, and the accumulation of leaf litter substrates at Station II was carried away by the river current towards the dam and Station III. According to Rachman et al., (2016), rocky substrates in river headwaters typically have the highest productivity and diversity of aquatic benthic insects.

The least abundant composition of aquatic benthic insect species from all three stations was found on sandy substrates, with only 4 and 3 species respectively, across 3 orders. Sandy substrates are impoverished in organisms due to their unstable nature and lack of adaptability for all species (Brusven and Prather, 1974). The substrate bottom is influenced by flow velocity, where high flow velocity indicates rocky riverbed conditions, while low flow velocity indicates sandy substrate conditions. Rocky riverbeds exhibit higher biodiversity compared to sandy riverbeds, which are unstable in position. Therefore, the EPT group of insects is predominantly found at Station I.

The EPT group represents aquatic biota highly sensitive to pollution. The higher the pollution level, the more difficult it is to find EPT groups, as they are intolerant of polluted

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water. Utilizing the EPT group as water bioindicators can provide early warning signals for changes in water quality in the Ijuk River.

3.3 Composition of aquatic benthic insect species

The bar graph depicting the total composition of aquatic benthic insect species in the Ijuk River indicates fluctuations, with both increases and decreases observed at each station across different substrate types (Figure 5). Station I exhibited the highest diversity of benthic insect species, with 7 species identified on rocky substrates and 10 species on gravel substrates. The species were distributed among 4 orders on rocky substrates (Diptera, Odonata, Plecoptera, and Trichoptera) and 6 orders on gravel substrates (Coleoptera, Odonata, Diptera, Ephemeroptera, Plecoptera, and Trichoptera). Sandy substrates supported 4 species from 3 orders (Coleoptera, Odonata, and Diptera), while leaf litter substrates harbored the highest diversity, with 21 species from 7 orders (Coleoptera, Odonata, Diptera, Ephemeroptera, Plecoptera, Trichoptera, and Orthoptera).

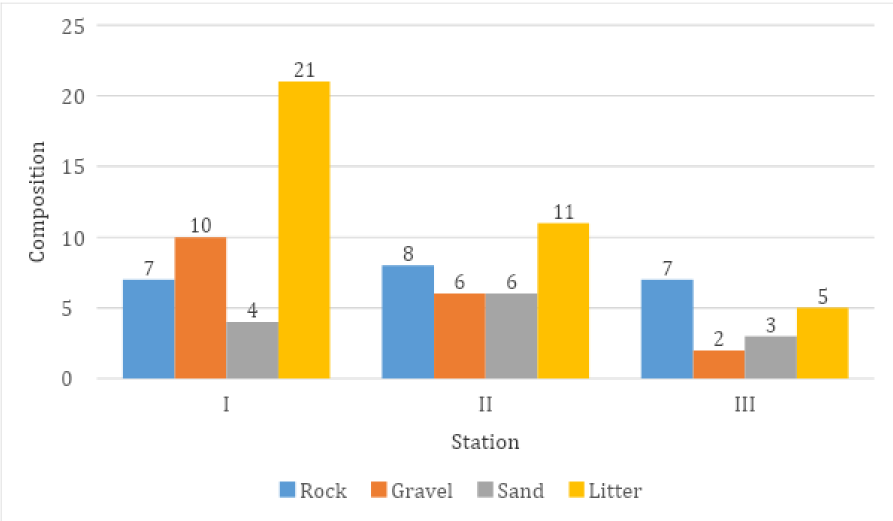

Fig. 5. The total composition of aquatic benthic insect species at 3 stations in the Ijuk River wildlife sanctuary, Isau-Isau, Lahat Regency

Station II displayed a decline in species diversity on leaf litter substrates due to environmental openness and the accumulation of leaf litter substrates carried away by the river current towards the dam and Station III. Rocky substrates at Station II exhibited the highest species diversity, with 8 species from 6 orders, while gravel substrates had the lowest diversity, with 6 species from 5 orders. Sandy substrates supported 6 species from 4 orders.

At Station III, rocky substrates showed the highest species diversity, with 7 species from 5 orders, whereas gravel substrates had the lowest diversity, with only 2 species from 2 orders. The influence of substrate type on benthic insect distribution was highlighted, with rocky substrates supporting diverse insect communities due to their stability and suitability as habitats. In contrast, sandy substrates exhibited lower species diversity due to their unstable nature and limited adaptability for many insect species.

The presence of Environmental Protection Technology (EPT) group insects, which are highly sensitive to pollution, was observed predominantly at Station I, indicating the potential use of EPT as bioindicators for water quality monitoring in the Ijuk River. The utilization of EPT as bioindicators can provide early warning signals for changes in water quality, benefiting local communities (Sinulingga et al., 2017; Rachman et al., 2016; Brusven and Prather, 1974).

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3.4 Relative composition percentage of aquatic benthic insects

The percentage composition of aquatic benthic insects varies across Station I to Station III, indicating differences in relative abundance and distribution among the stations.

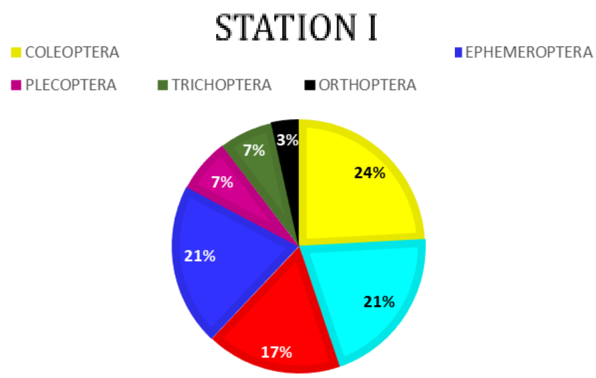

Fig. 6. Relative composition percentage of aquatic benthic insects at station I in the Ijuk River wildlife sanctuary, Isau-Isau, Lahat Regency

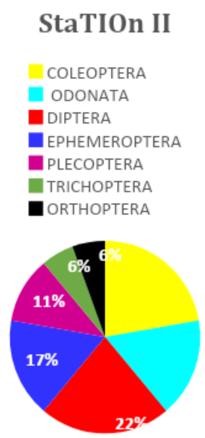

Fig. 7. Pie chart of relative composition percentage of aquatic benthic insects at station II in the Ijuk River wildlife sanctuary, Isau-Isau, Lahat Regency

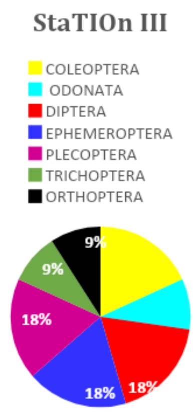

Fig. 8. Pie chart of relative composition percentage of aquatic benthic insects at station III in the Ijuk River wildlife sanctuary, Isau-Isau, Lahat Regency

The bar graph above indicates the diversity index values for leaf litter substrates across the three stations. Station II recorded the highest value at 2.32, followed by Station I at 2.12, and Station III at 1.80, suggesting a moderate level of biotic community diversity (Figure 6 - 8). According to Odum (1998), species diversity is influenced by the distribution

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of individuals within each species. Even if a community has many species, if the distribution of individuals is uneven, the species diversity may be classified as low. Leaf litter substrates provide a comfortable habitat for benthic insects to seek shelter among the fallen leaves, preventing them from being swept away by the strong river currents.

The gravel substrates at each station exhibited varying diversity index values. Station I recorded a value of 0.84, categorized as unstable, while Station II recorded 1.66, indicating a moderate level, and Station III recorded 1.42, also categorized as moderate. The index values decreased from upstream to downstream. Rauf (2019) suggests that human activities resulting in waste production lead to a decline in water quality, which in turn affects the quality of the habitat substrate and subsequently impacts diversity. Diversity is a characteristic involving the level of diversity of existing organism species.

The diversity index values for rocky substrates at Station I, II, and III were 1.49, 1.79, and 1.46, respectively, all categorized as moderate. Pelealu et al. (2018) add that a community composed of species with similar or nearly similar densities exhibits high diversity. For sandy substrates, Station I recorded an index value of 0.84, indicating an unstable category, while Stations II and III showed values of 1.80, both categorized as moderate. Izmiarti (2021) explains that the height of the diversity index is determined by the number of species and the evenness of the population within the community. If there are many species and the population is evenly distributed, it will result in a high diversity index. However, if the population is uneven or dominated by certain species, despite having many species, it will lead to a low diversity index.

3.5 Evenness index of aquatic benthic insects

The high or low value of the similarity index is influenced by the uneven distribution of individuals within the community. The results of the above graph indicate uneven distribution, particularly evident at Station 1 with a substrate of sand, showing the lowest evenness index value of 0.25 (Figure 9). Conversely, the highest evenness index value occurred at Station II, specifically on leaf litter substrate. The high value of the evenness index at this station is attributed to the evenly distributed abundance of individuals. Across all stations, based on their substrate types, some exhibit evenness in their evenness index values, while others show uneven distribution.

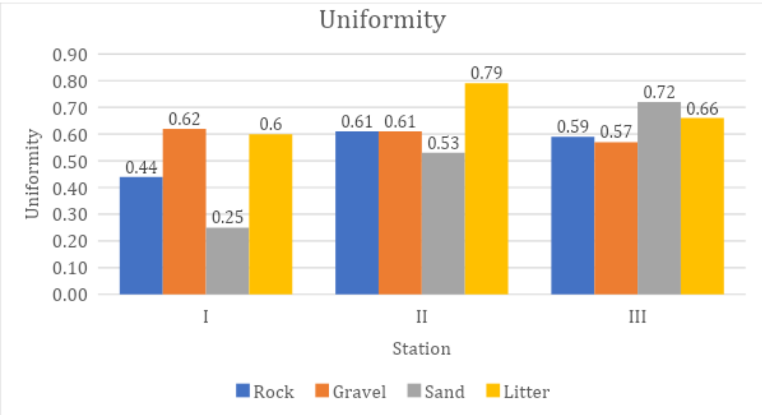

Fig. 9. Bar chart of evenness index of aquatic insects based on substrate at 3 stations in the Ijuk River wildlife sanctuary, Isau-Isau, Lahat Regency

An evenness index value approaching 1 signifies a uniformly distributed community of aquatic organisms. According to Krebs (1985), the evenness index ranges from 0 to 1. A value close to 0 indicates low evenness due to dominance by certain species, while a value approaching 1 indicates high evenness, with no dominant species and a uniform distribution of individuals across species.

The rocky substrate shows an increase in evenness index values from Station I to Station III. Odum (1993) suggests that the evenness of benthic animals in a water body can

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be determined by their evenness index. A smaller evenness index value (E) indicates lower species evenness within a community, suggesting that the distribution of individual counts is not uniform and may be dominated by certain species. A community where each species has a sufficiently large number of individuals indicates that the ecosystem has integrity.

3.6 Evaluation and trend of benthic insect community in Ijuk River over a 20-year period

Based on the research data collected in 2001 and 2022, a comparison of the benthic insect community in Sungai Ijuk can be observed in Table 2. The components of the community structure are outlined below.

Table 2. Comparison of benthic insect community structure components in Ijuk River

Community structure components	2001	2022
Overall species composition	9 Ordo, 30 Famili, 62 Genera.	7 Ordo, 22 Famili, 36 Genera.
Density	Density was not calculated per station, but overall and randomly. Highest density was observed on rocky substrate	Station I had the highest density on leaf litter substrate. Station II had the highest density on leaf litter substrate. Station III had the highest density on rocky substrate
Evenness index		Evenness is nearly uniform
Diversity index	Rocky: 3.1 Sandy: 2.3 (No data for stations)	The diversity index across all stations indicates moderate diversity, except for the sandy substrate in station I, which shows low diversity

The results in the table above indicate that the community structure components observed from 2001 to 2022 have undergone significant changes. The evaluated components of the benthic insect community structure in this study include overall species composition, benthic insect density, diversity index, and evenness index. Changes in the community structure of benthic insects in a river can be observed through the existing components.

The overall species composition in 2001 recorded 9 orders, 30 families, and 62 species, which experienced a decrease in the number of species by 2022, with 7 orders, 22 families, and 36 genera recorded. This decrease in composition is approximately 50%. According to Setiawan (2009), differences in the number of taxonomic compositions can be attributed to variations in substrates resulting from anthropogenic activities, which may exert pressure on certain benthic insect species. Anthropogenic factors may include pollution or the influx of waste from industrial, mining, or other human activities.

Benthic insect density in 2022 experienced a lower change compared to 20 years ago. Density is calculated by observing the number of individuals present at each station. The highest density value in 2000 was recorded at 1696 ind/m^2, whereas in 2022, the highest density value was 1448 ind/m^2 at station I on leaf litter substrate. Benthic insect density is also calculated based on the orders found, and it is related to the supporting factors for life of each order.

The diversity index is often used to assess the environmental condition of aquatic ecosystems and the stability of communities based on biological components. The diversity index values observed in 2001 and 2022 differed. The highest value in 2001 was recorded on rocky substrates, while in 2022, the highest index value occurred on leaf litter substrate at station I. According to Fikriyati (2009), the environmental condition of a water body can be considered good or stable if there are high diversity and evenness indices and low dominance index.

The computed values reveal an evenness index ranging from 0.246 to 0.787 for the year 2022, suggesting a heterogeneous distribution pattern within the benthic insect community inhabiting the river. The observed non-uniformity becomes evident upon scrutinizing the species abundance across each station; a lower evenness index at a given station implies the prevalence of particular organisms within that specific ecological niche.

4. Conclusions

The investigation into the Evaluation of Benthic Insect Community in the Ijuk River, situated within the Isau-Isau Wildlife sanctuaryin Lahat Regency, provides insightful observations regarding the environmental dynamics along the river's gradient, spanning from its headwaters to its downstream reaches. These observations illuminate notable shifts in ecological conditions over the course of two decades. As elucidated by Ika Agustina's seminal study in 2000, the initial assessment revealed a diverse benthic insect community characterized by the presence of 9 taxonomic orders, encompassing 30 families and 62 genera. However, upon revisiting the study area, the subsequent evaluation unveiled a discernible decline in taxonomic richness, with the benthic insect community exhibiting a reduction to 7 orders, 22 families, and 36 genera.

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Author Contribution
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