AMERICAN JOURNAL OF INTERDISCIPLINARY RESEARCH AND INNOVATION (AJIRI)

ISSN: 2833-2237 (ONLINE)

VOLUME 2 ISSUE 4 (2023)

PUBLISHED BY

E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Interdisciplinary Research and Innovation (AJIRI)

Volume 2 Issue 4, Year 2023
ISSN: 2833-2237 (Online)
DOI: https://doi.org/10.54536/ajiri.v2i4.2100
https://journals.e-palli.com/home/index.php/ajiri

A Multifaceted Study of Wawa River, Esperanza, Agusan Del Sur, Philippines: Aquatic Macroinvertebrates, Water Quality, and Soil Particle Size Analysis

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Article Information

Received: September 15, 2023

Accepted: October 18, 2023

Published: October 23, 2023

Keywords

Macro-Invertebrates, Physicochemical Parameters, Soil Particles, Wawa River

ABSTRACT

The diversity of macro-invertebrate species in specific aquatic habitats often assesses environmental stress caused by pollution. To find out interactions in various macro-invertebrates communities, different water quality parameters and soil particles of Wawa River, research was conducted on Wawa River, Esperanza Agusan del Sur. Samples of macro-invertebrates, water and soil were taken from three different river stations. A total of 13 taxa of various macro-invertebrates were identified from the area. Phylum Arthropoda constitutes 62% of the total population and 32% form Phylum Mollusca. There is a notable similarity in macroinvertebrate abundance across the three stations, but the maximum numbers were observed in downstream. Most of the water physicochemical parameters of Wawa River were within the normal range, suitable for the healthy growth of macro-invertebrates. Most of the three sampling stations have medium sand particles, indicating relatively stable sediment, suitable habitat availability, and ongoing sediment transport and deposition processes. Diversified populations of various macro-invertebrates confirm good ecological condition of the environment and water in the studied site especially ample concentration of DO in River. The documented data on macro-invertebrates in the studied site will provide a baseline for future research.

INTRODUCTION

Freshwater ecosystems play a crucial role in maintaining ecological balance, sustaining biodiversity, and providing essential ecosystem services. In safeguarding these valuable resources, conducting comprehensive studies that delve into the intricate interplay between various ecological components is imperative. Macroinvertebrates are a very sensitive collection of creatures that are thought to be bioindicators of the anthropogenic pollution of freshwater ecosystems. Globally, rising anthropogenic activity and the effects of climate change have been linked to the decline of freshwater ecosystems (Bediako et. al, 2018, Kaur & Singh, 2019 and Njiru & Masese 2018). The distribution of macro-invertebrates in aquatic habitat is significantly influenced by a variety of abiotic and biotic factors (Infante *et al.*, 2019). The abundance and distribution of macro-invertebrates can change for a variety of physical and biological reasons (Sharma *et al.*, 2013). Their ability to survive in any environment is mostly influenced by temperature, pH, and dissolved oxygen. Food amount and quality are also very important. As a result, patterns of their distribution can be significantly influenced by changes in water body features, habitat, and environmental resources (Buss *et al.* 2012).

The natural habitats and nutrients of macroinvertebrates are negatively impacted by pollution and other human disturbances, leading to a fall in their quantity and diversity in many rivers in the Philippines (Rasifudi *et al.* 2018). Additionally, variations in precipitation and high temperatures can significantly impact the hydrologic regime and geomorphology in stream habitats, which in turn can impact the variety and quantity of macro-invertebrates (Dudgeon, 2020). These have the potential to alter the macro-invertebrate life cycle.

Due to their varying susceptibility to various perturbations, many studies have used macroinvertebrate abundance and richness to detect environmental responses (Rasifudi *et al.* 2018). Therefore, changes in the composition of macroinvertebrates and community structures can be utilized to detect environmental changes in rivers. One technique for determining how anthropogenic activities affect water quality is biological monitoring. It is regarded as a useful instrument for assessing water quality and learning about river ecology (Merritt *et al.*, 2017).

According to studies, increased pollution brought on by industrialization, urbanization, afforestation, mining, and agriculture is to blame for the diminishing water quality and quantity. Although it is well recognized that the Wawa River in Esperanza Agusan del Sur provides residents with high-quality water, the growing number of human activities, including farming, sand mining, and human settlements along its midstream and downstream, is having a negative impact on the stream's water quality. The stream provides certain settlements in the area with water for drinking, domestic needs, and irrigation of agricultural land. There hasn't been any scientific study done to far on the effects of stream pollution from different human activities on aquatic life.

In this study, the water quality status including soil particles of Wawa River will be evaluated along with how it affects the abundance, diversity, and distribution of macroinvertebrates at different sampling stations. The

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study's findings could be used as a crucial reference for assessing future changes in water quality and for offering advice on how to safeguard the stream and its biodiversity.

MATERIALS AND METHODS

Study Area

The study was carried out in Esperanza, in the province of Agusan del Sur, Philippines, along the chosen Wawa River areas with its geographical coordinates 8° 55' N, 125° 39' E. Wawa River located in Poblacion Esperanza, Agusan del Sur, which is a tributary of the larger Agusan River. The river bank is rich in vegetation with shrubs, grasses, and some trees. The headwaters of the Wawa River traverse the municipality of Sibagat, Bayugan, and Esperanza, all of the province of Agusan del Sur. The Wawa River is 52 km long and has a basin size of 24 km2. The river is a body of running water moving to a lower level in a channel on land. Below illustrates the map of the study areas (Figure 1).

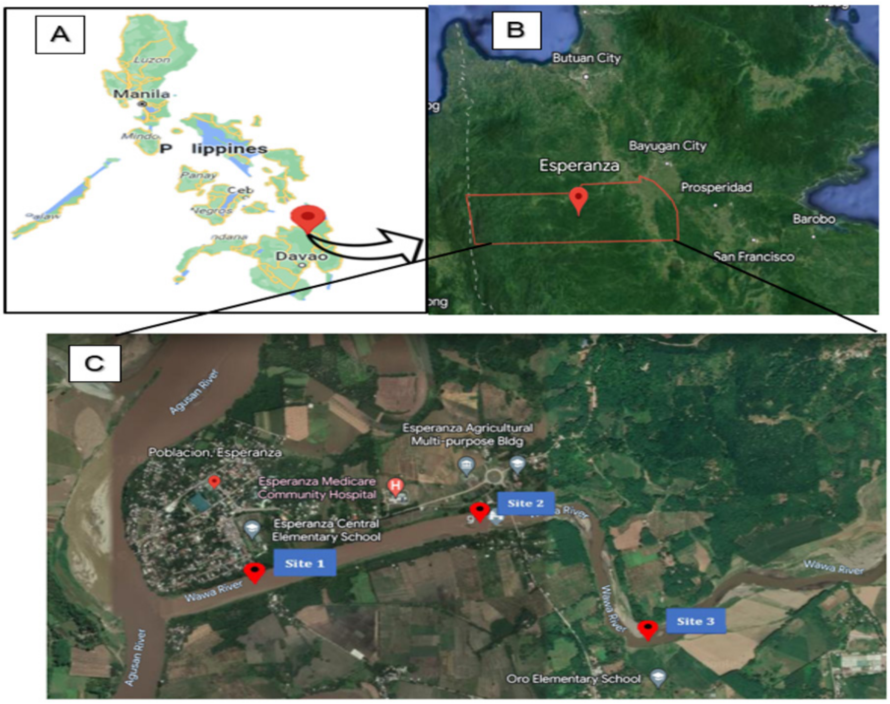


Figure 1: Map of the sampling sites showing the Philippine map (A), Esperanza, Agusan del Sur (B) and sampling area in Wawa River, Esperanza, Agusan del Sur (C) (http://maps.google.com;http://googleearth.com)

Establishment of Sampling Station

Three sampling stations were established along the Wawa River. Station 1 was the downstream of the river, Station 2 was the midstream and Station 3 was the upstream. The stations were established based on land settings, in every sampling station, 3 substations or replicates were made with approximately 50-100 meters from each substation which were altered from left to right position along the river. Each substation was measured at a length of 100 meters where three 5x10 meter quadrat were randomly established. Each sampling station had an interval of approximately 500 meters. Station 1 was established in the downstream, situated in proximity to the Larger Agusan River, adjacent to a vibrant community and a picturesque park with the coordinate of 8° 40' 29" N 125° 39' 03" E (Q1 of ST1-A) with a length of 500 m. Station 2 was established midstream of the river on the agricultural area with the coordinates of 8° 40' 38" N 125° 39' 33" (Q1 of ST2-A), where the primary agriculture crops in the site are Rice, corn and other vegetables. Station 3 was established in the upstream of the river, in the forested area with the coordinates of 8° 40' 17" N 125° 39' 56" E (Q1 of ST3-A) where thick vegetation and tons of trees are present in the location. Different activities like washing clothes and bathing are also common in the 3 sampling stations.

Determination of Physical and Chemical Properties of Habitats

Water Parameters

Measure key water quality parameters, including temperature, dissolved oxygen (D.O), pH, salinity, total dissolved solids (TDS), conductivity and resistivity of the water were analyzed using a portable multimeter instrument (Hanna H1- 98194). Readings of physical and chemical water properties will be carried out three (3) times per transect line to report the mean and the standard error of the mean (SEM±) among sampling stations.

Soil Sampling

For the soil particle size analysis, Soil samples (approximately 500 grams) were randomly collected at each substation across the three sampling stations. All the gathered samples from each station were mixed in a sterile bag to represent only one sediment sample per sampling station. The sediment samples were air-dried for three days and then subjected to particle size analysis in the laboratory to classify sediment types according to their Wentworth size class. Each sample was replicated three times, with each replicate weighing 100 grams. Each replicate was then subjected to sieving using a sieving machine with seven levels of sieve mesh sizes. The soil samples taken from each level of sieve mesh size were weighed using an electronic balance beam. The total weight among the levels of the sieve mesh size was obtained for the three replicates of each soil sample from the sampling stations.

Macroinvertebrate Collection and Identification

To collect macroinvertebrate samples, three sampling stations were established in Wawa River. A standard D-framed dip net with a mesh size of 0.5mm was used to collect samples, starting from the downstream and progressing to the upstream to minimize disturbance to the macroinvertebrate communities. The net was placed firmly against the stream bottom with the opening facing into the current at each quadrat of the sampling station. Kick sessions were done ten times in each quadrat, and the net was then lifted together with the samples. Visible species around the quadrat were also collected. Each specimen was picked out and placed in a vial with a 70% solution of ethyl alcohol for preservation. The preserved macroinvertebrates were then taken out from the alcohol solution and placed in a petri dish. The morphological features of macroinvertebrates were examined using a cellular phone camera. All gathered specimens were identified using taxonomic keys, published journals, and consultation from experts. Samples were classified according to their phyla down to the family level, and their corresponding scientific names and common names were recorded in a data sheet along with the number of individuals present in each station.

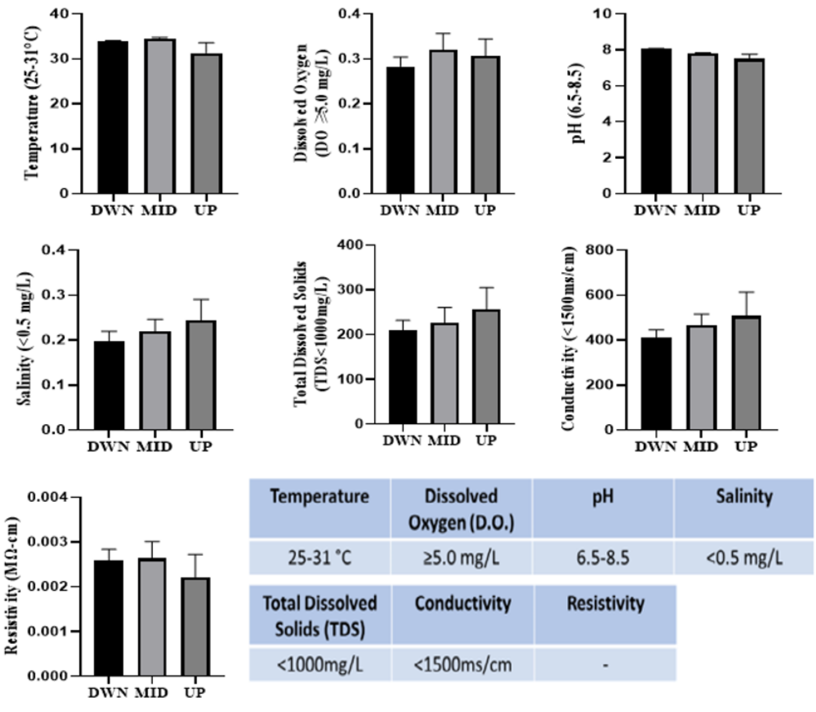
Data Analysis

The mean values of water physicochemical parameters and soil particle size were tested in Mann-Whitney U-test using GraphPad Prism v7. Paleontological Statistics (PAST ver. 3.19) was used to calculate the species diversity, dominance, richness, and evenness across sampling stations. IBM SPSS Statistics Software (ver.20) was used for comparing and correlating macroinvertebrates abundance in response to selected soil and water environmental parameters. The statistical results were set at a significant p value less than or equal to 0.05.

RESULTS AND DISCUSSION

Water Quality Parameters

The water quality parameters of each substation are summarized as the mean value of every station given in Figure 2. Generally, the pH, salinity, total dissolved solids (TDS) and conductivity levels of most of the physicochemical parameters were within the standard guideline values except for the temperature and dissolved oxygen (DO). The highest average temperature is in midstream with 34.36°C, followed by 33.88°C in downstream, and the lowest in upstream with 31.31°C. The higher temperatures in midstream might indicate a localized heat source or warmer conditions. Temperature variations can influence aquatic life, metabolic rates, and oxygen solubility (Mugwanya *et al.*, 2022). For the dissolved oxygen (DO) levels, midstream has the highest average D.O with 0.32 mg/L. This might suggest better



Temperature	Dissolved Oxygen (D.O.)	pH	Salinity
25-31 °C	≥5.0 mg/L	6.5-8.5	<0.5 mg/L

Total Dissolved Solids (TDS)	Conductivity	Resistivity
<1000mg/L	<1500ms/cm	-

Figure 2: Water physicochemical parameters (M±SEM) across three sampling stations in Wawa River, Esperanza Agusan del Sur

aeration or less organic matter decay. Adequate D.O is crucial for aquatic organisms' survival and indicates water quality. Moreover, the areas with notable low dissolved oxygen concentrations were the areas with high organic matter content, mainly from tributaries (Copper, 1993). The decreasing concentration of DO might be due to the anthropogenic activities in the area, decaying organic matter from aquatic plants and algae, weather changes and aquatic life is put under stress. A reduced concentration of dissolved oxygen in water serves as an indicator of pollution and plays a crucial role in assessing water quality, managing pollution, and guiding treatment procedures (Omid, 2021).

Soil Particle Size

In the figure 3 shown are the different types of sediments, it reveals significant variations in the percentage of particles sizes across the three locations (Downstream, Midstream, and Upstream). This suggests that the soil composition and sediment characteristics differ markedly in these areas, indicating potential spatial heterogeneity in factors such as erosion, sediment transport, and deposition (Shen *et al*., 2020).

The majority of the three stations is the medium sand particles which can impact sediment stability, habitat availability, and water movement. The higher medium sand content might influence the substrate structure and hydrodynamics of that area. Higher percentages of medium sand particles downstream could be indicative of sediment transport and deposition processes as water flows downstream. According to a review article on river sand mining (Rentier & Cammeraat, 2022), sand mining can alter the river bed morphology and sediment transport, leading to changes in the river's hydrology, water quality, and ecological health. The article notes that sand mining can increase the sediment load and turbidity of the river, which can negatively impact aquatic plants and animals.

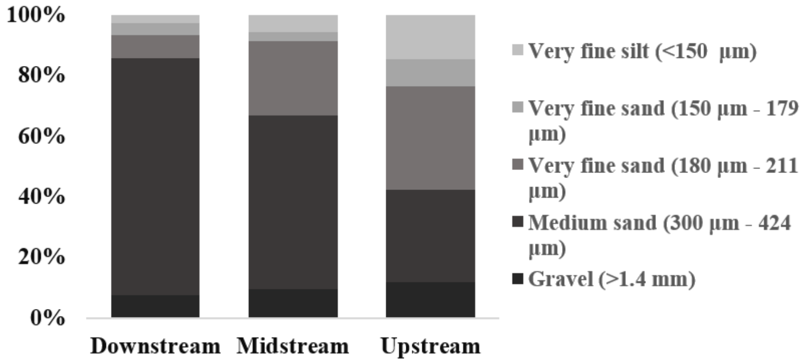


Figure 3: Soil particle size analysis across sampling stations in Wawa River, Esperanza Agusan del Sur

Comparison of the Water and Soil Parameters

The results of the statistics across the all-sampling stations in table 1, in general the physico-chemical properties of water show no variations ($p < 0.05$) across all-sampling stations. Even though the differences are not statistically significant, there may still be areas of the water resources that are more vulnerable to pollution or other environmental stressors. Identifying these areas can help to prioritize management efforts and resources. For example, a study by Laranjo *et al.* (2023) emphasized the importance of monitoring and data collection in the evaluation of the physicochemical parameters on the water quality of the major rivers of Zamboanga del Norte, Philippines. Similarly, a study by Vinueza *et al.* (2021) highlighted the importance of routine monitoring of water quality parameters to identify variations caused by climate change.

Table 1: Comparison of physico-chemical properties in water across downstream, midstream, and upstream in Wawa River, Esperanza Agusan del Sur

Streams		Temp	DO	pH	Salinity	TDS	Conductivity	Resistivity
		P value						
Downstream	Midstream	.800	.407	.126	.694	.825	.634	.990
	Upstream	.121	.672	.008*	.287	.324	.297	.502
Midstream	Upstream	.053	.873	.131	.694	.616	.770	.436

**Significant at $p \leq 0.05$ (5% level of significance), Tested in Mann-Whitney U-test*

For table 2, the soil particle size ranges with statistically significant variations ($p \leq 0.05$) across downstream, midstream, and upstream in Wawa River, Esperanza Agusan del Sur, are as follows; Particle size range: 300-424um (midstream), 180-211um (upstream) and 150-179um (midstream and upstream). Variations in particle size suggest differences in sediment transport and deposition mechanisms. Particle sizes in midstream may indicate optimal conditions for sediment transport within the river. Additionally, upstream variations could reflect specific sources of sediment or transport pathways. Moreover, particle size changes can impact substrate stability and habitat availability for aquatic organisms. Medium-sized particles (300-424um) could provide suitable habitats, while smaller particles might limit habitat diversity. The particle size distribution of soil particles can also influence the availability of nutrients and other chemical constituents in the water column. Related studies have also reported similar results. For example, a study by Belayneh *et al.* (2019) found that soil and water conservation practices have resulted in a statistically significant higher mean values of total nitrogen, exchangeable Na+ and Mg2+, soil organic carbon, and organic matter in the watershed. Another study by Xia *et al.* (2018) found that there is lateral heterogeneity of soil physicochemical properties in riparian zones, which can influence the availability of nutrients and other chemical constituents in the water column. This lateral heterogeneity underscores the intricate interplay between riparian soil characteristics and water quality, emphasizing the need for holistic watershed management approaches that consider both terrestrial and aquatic ecosystems.

Table 2: Comparison of the soil particle sizes across downstream, midstream, and upstream in Wawa River, Esperanza Agusan del Sur

Streams		>1.4mm	300-424um	180-211um	150-179um	<150um
		P value				
Downstream	Midstream	.551	.000*	.001*	.819	.165
	Upstream	.151	.000*	.000*	.050*	.000*
Midstream	Upstream	.551	.000*	.024*	.024*	.002*

**Significant at p ≤ 0.05 (5% level of significance), Tested in Mann-Whitney U-test*

Macroinvertebrate Assessment

A total of 230 macroinvertebrate individuals, 13 species belonging to the 12 families were collected. Figure 4 shows the Phylum Arthropoda had the greatest number of representative species (62%) followed by phylum Mollusca (38%). Figure 5 presented shows the abundance of different aquatic macroinvertebrates across downstream, midstream, and upstream areas of the streams. The results indicate that the abundance of different macroinvertebrates varies across the sampling areas.

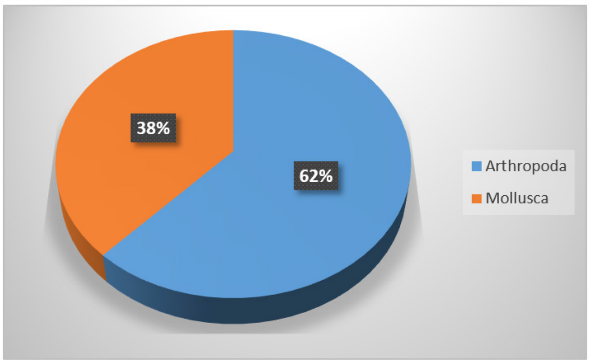


Figure 4: Percent composition & abundance of macroinvertebrates across sampling stations

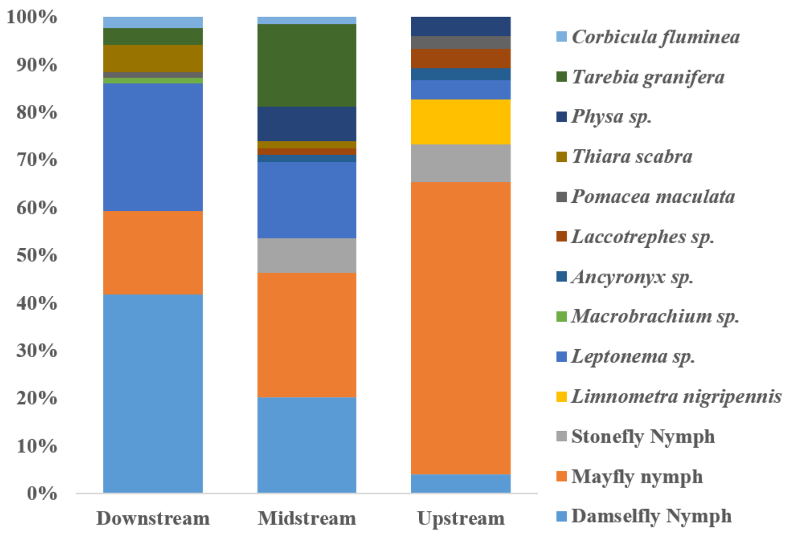


Figure 5: Relative abundance of macroinvertebrates collected in Wawa River, Esperanza Agusan del Sur

Table 3: Comparison of macroinvertebrate abundance across downstream, midstream, and upstream in Wawa River, Esperanza, Agusan del Sur

Invertebrate Taxa	Downstream and Midstream	Downstream and Upstream	Midstream and Upstream
	P value		
Damselfly Nymph	.127	.046	.178
Mayfly nymph	.658	.050	.077
Stonefly Nymph	.317	.317	.796
Limnometra nigripennis	1.000	.121	.121
Leptonema sp.	.376	.376	.376
Macrobrachium sp.	.317	.317	1.000
Ancyronyx sp.	.317	.317	.796
Laccotrephes sp.	.317	.317	.796
Pomacea maculata	.317	.796	.317
Thiara scabra	.346	.121	.317
Physa sp.	.034	.317	.361
Tarebia granifera	.261	.317	.034
Corbicula fluminea	.796	.317	.317

**Significant at $p \leq 0.05$ (5% level of significance), Tested in Mann-Whitney U test*

In downstream areas it has a higher abundance of damselfly nymphs and mayfly nymphs, while midstream areas have higher abundance of *Physa sp.* and *Tarebia granifera*. The abundance of damselfly nymphs is highest in the downstream area, indicating that this area may provide suitable habitat conditions for this species. Damselfly nymphs are often found in clean, well-oxygenated water bodies and their presence suggests good water quality (Rađa & Puljas, 2010 and Sarker & Hossain 2017). The higher abundance of damselfly nymphs in the downstream area may be due to favorable environmental conditions, such as higher dissolved oxygen levels and suitable substrate for their attachment. *Mayfly nymph*s and Stonefly also show a higher abundance in the midstream and upstream areas compared to the downstream area. Mayflies and Stoneflies are known to be sensitive to pollution and are often used as indicators of water quality (Chapter 4 Macroinvertebrates and Habitat | Monitoring & Assessment | US EPA, 2012). The higher abundance of macroinvertebrates in the midstream and upstream areas suggests better water quality in those locations. *Limnometra nigripennis* show a higher abundance in the upstream area. *Limnometra nigripennis* is a type of water bug that is often found in freshwater habitats (Nsor *et al.*, 2020). Their abundance in the upstream area may be due to specific habitat preferences or environmental conditions that are more suitable for this species. *Leptonema sp.* shows a relatively higher abundance in all three areas, with slightly higher numbers in the downstream and midstream areas. *Leptonema sp.* is a type of caddisfly larvae that are commonly found in freshwater habitats (Yaagoubi *et al.*, 2023). The presence of *Leptonema sp.* in all areas suggests that they can tolerate a range of environmental conditions. *Ancyronyx sp.* is a type of riffle beetle that is often found in fast-flowing streams and rivers and *Laccotrephes sp.* is a type of water scorpion that is also commonly found in freshwater habitats (Nsor *et al.*, 2020). The higher abundance in the midstream and upstream areas suggests that these areas may have suitable habitat conditions for this species, such as rocky substrates and fast-flowing water. *Thiara scabra* is a species of freshwater snail. The higher abundance in the downstream area suggests that this species may be more adapted to the conditions found in that area, such as slower water flow or specific substrate preferences. *Physa sp.* is a genus of freshwater snails and *Tarebia granifera* is a species of freshwater snail. Their higher abundance in the midstream area suggests that this area may provide suitable habitat conditions for this species. However, *Macrobrachium sp.* is a genus of freshwater prawns while *Pomacea maculata* is a species of apple snail and *Corbicula fluminea* is a species of freshwater clam. They show low abundance in the dataset suggesting that they may not be as prevalent in the sampled areas. The specific reasons for their low abundance in this study are not clear and may require further investigation.

The results of the comparison of macroinvertebrate abundance across different sampling stations (table 3) with a level of significance less than 0.05 suggest that the abundance of *Damselfly Nymph*, *Mayfly nymph*, *Thiara scabra*, *Physa sp.*, and *Tarebia granifera* is significantly different across the sampling stations. A study by McDevitt-Galles *et al.* (2018) found that host body size can increase the abundance of parasites in nymphal damselflies and dragonflies. Therefore, the significant differences in the abundance of *Damselfly Nymph* and *Mayfly nymph* across the sampling stations may have implications for the abundance of parasites in these macroinvertebrates. Macroinvertebrate metrics are helpful tools for the

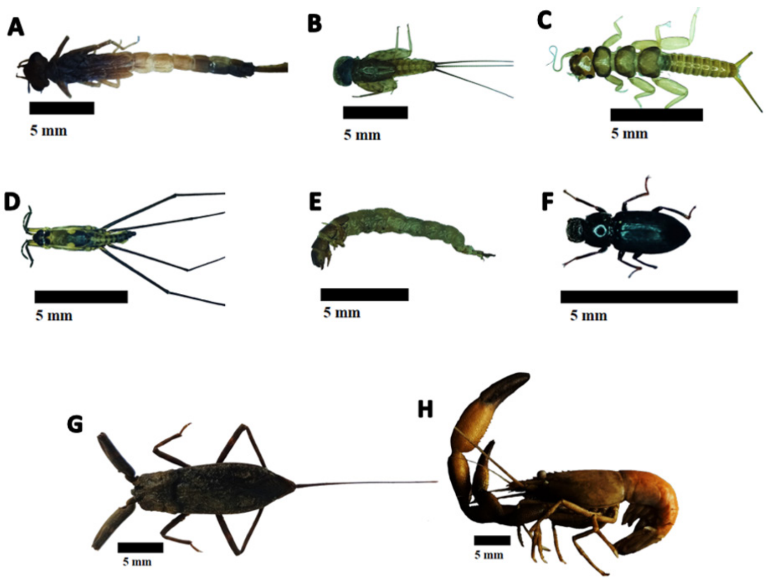


Figure 6: Macroinvertebrates collected under the phylum Arthropoda. (A) *Damselfly Nymph*, (B) *Mayfly nymph* (C) *Stonefly Nymph*, (D) *Limnometra nigripennis*, (E) *Leptonema sp.*, (F) *Ancyronyx sp.* (G) *Laccotrephes sp.*, (H) Macrobrachium sp

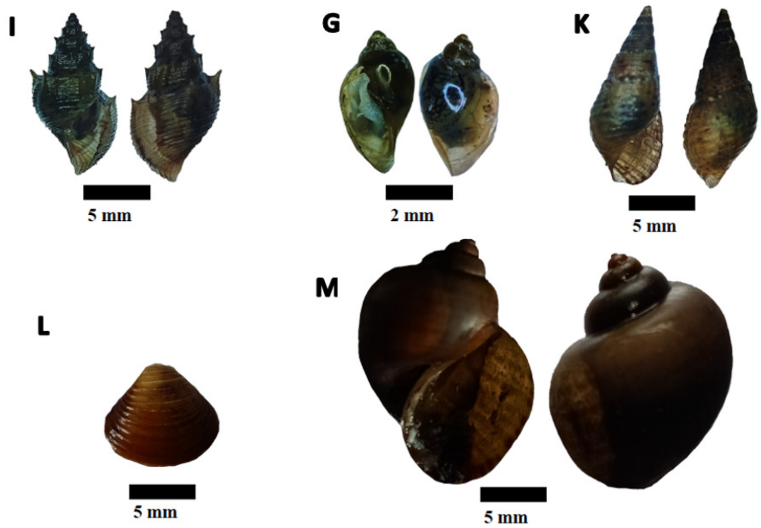


Figure 7: Macroinvertebrates collected under phylum Mollusca. (I) *Thiara scabra*, (J) *Physa sp.* (K) *Tarebia granifera*, (L) *Corbicula fluminea*, (M) *Pomacea maculata*

Table 4: Classifications and feeding habits of the collected macroinvertebrates across sampling stations

Phylum	Class	Order	Family	Common Names/ Local Names	Scientific Names	Feeding Habit	Total
Arthropoda	Insecta	Odonata	Calopterygidae	*Damselfly Nymph*	*Damselfly Nymph*	Grazers/ Scrapers	53
Arthropoda	Insecta	Ephemeroptera	Lephtophlebiidae	*Mayfly nymph*	*Mayfly nymph*	Grazers/Scrapers	79

Arthropoda	Insecta	Plecoptera	Eustheniidae	*Stonefly Nymph*	*Stonefly Nymph*	Shredder	11
Arthropoda	Insecta	Hemiptera	Gerridae	Water Strider	*Limnometra nigripennis*	Collectors	7
Arthropoda	Insecta	Trichoptera	Hydrobiosidae	caddisfly larvae	*Leptonema sp.*	Grazers/ Scrapers	37
Arthropoda	Malacostraca	Decapoda	Palaemonidae	freshwater prawns	*Macrobrachium sp.*	Collectors	3
Arthropoda	Insecta	Coleoptera	Elmidae	riffle beetle	*Ancyronyx sp.*	Grazers/ Scrapers	4
Arthropoda	Insecta	Hemiptera	Nepidae	water scorpion/ bugs	*Laccotrephes sp.*	Predator	1
Mollusca	Gastropoda		Ampullariidae	apple snail	*Pomacea maculata*	Grazers/ Scrapers	6
Mollusca	Gastropoda		Thiaridae	freshwater snail	*Thiara scabra*	Grazers/ Scrapers	8
Mollusca	Gastropoda	Hygrophila	Physidae	freshwater snail	*Physa sp.*	Grazers/ Scrapers	15
Mollusca	Gastropoda		Thiaridae	Quilted melania	*Tarebia granifera*	Grazers/ Scrapers	3
Mollusca	Bivalvia	Venerida	Cyrenidae	freshwater clam	*Corbicula fluminea*	Collectors	3

assessment of water quality and overall aquatic ecosystem health (Tampo *et al.*, 2021). The significant differences in the abundance of *Thiara scabra*, *Physa sp.*, and *Tarebia granifera* across the sampling stations may indicate differences in water quality and human disturbances in the tropical river.

It was shown in table 4 the classifications of macroinvertebrates collected from different sampling stations. These organisms belong to various phyla, classes, orders, and families, and they exhibit a range of feeding habits. Macroinvertebrates have a wide variety of shapes, appearance, and mouthparts and this diversity reflects a diversity of feeding habits as well, find food and they depend on the surrounding. Insect larvae are herbivores, they eat plants that deposited in the river and algae that stick on rocks, as well as gastropods, and they stick on stones with algae to eat food. Furthermore, water striders collect materials on the surface that can be eaten. Most insect larvae and nymphs like the mayfly larva, damselfly nymph, caddisfly and beetle scrape and feed on algae and plants. Water strider and scorpion/bug collect food and somehow act as predators. Freshwater snail and the quilted melania also feed on plants and algae that stick on the rocks and the freshwater clam feed by filtering the water.

Diversity and Abundance of Macroinvertebrates

The table provided shows the diversity of macroinvertebrates collected in the downstream, midstream, and upstream areas of the stream. The table includes several parameters that describe the diversity and abundance of macroinvertebrates, including dominance, evenness, Simpson's index, Shannon's index, and Margalef's index.

The dominance of macroinvertebrates is highest in the upstream area (0.3991) and lowest in the midstream area (0.1762). The higher dominance in the upstream area may be due to the presence of a few dominant species that make up a large proportion of the total abundance.

Table 5: Diversity of macroinvertebrates collected in Wawa River, Esperanza Agusan del Sur

	Downstream	Midstream	Upstream	Total
Taxa	8	10	9	13
Individuals	86	69	75	230
Dominance	0.2826	0.1762	0.3991	0.2071
Evenness	0.5576	0.6666	0.465	0.5168
Simpson	0.7174	0.8238	0.6009	0.7929
Shannon (H')	1.495	1.897	1.432	1.905
Margalef	1.571	2.126	1.853	2.207

The evenness of macroinvertebrates is highest in the midstream area (0.6666) and lowest in the upstream area (0.465). It suggests that the abundance of different species is more evenly distributed compared to the other areas. Simpson's index is highest in the midstream area (0.8238) and lowest in the upstream area (0.6009). Simpson's index measures the probability that two individuals randomly selected from a sample belong to the same species. The higher Simpson's index in the downstream area suggests that there is a higher probability of selecting two individuals from the same species in that area (Magurran, A.E., 2004). Shannon's index is highest in the midstream area (1.897) and lowest in the upstream area (1.432).

Shannon's index measures the diversity of species in a sample. The higher Shannon's index in the midstream area suggests that this area has a higher diversity of macroinvertebrates compared to the other areas. Margalef's index is highest in the midstream (2.126) and lowest in the downstream area (1.571).

Margalef's index measures the richness of species in a sample. The higher Margalef's index in the midstream suggests that there is a higher richness of macroinvertebrates in the studied stream (Ecology Center, 2023). These findings can be valuable for assessing the ecological integrity of the stream and guiding management strategies for the conservation and restoration of aquatic ecosystems.

Association of Collected Macroinvertebrates to the Water and Soil Physicochemical Parameters

Canonical correspondence analysis (Figure 8) revealed the association of collected macroinvertebrates abundance in response to the selected water and soil physicochemical parameters. It shows that the dissolved oxygen (DO) levels in the water show a significant influence with the abundance of *Physa sp.* Higher DO levels are generally associated with better water quality and can support the presence of oxygen-dependent species like *Physa sp.* (Yazdian *et al.*, 2014). There is a positive influence between salinity levels in the water and the abundance of *Ancyronyx sp.* This species is known to be adapted to brackish water or environments with higher salinity levels, while there is a negative influence between salinity levels in the water and the abundance of *Corbicula fluminea*. The said species is known to be more abundant in freshwater environments and is sensitive to higher salinity levels (Wang *et al.*, 2020). The Total dissolved solids (TDS) in the water show a significant influence with the abundance of *Laccotrephes sp.* This species may have specific habitat preferences related to TDS levels, and its abundance can be influenced by variations in TDS levels (Azis & Abas, 2021). And there is a negative influence between

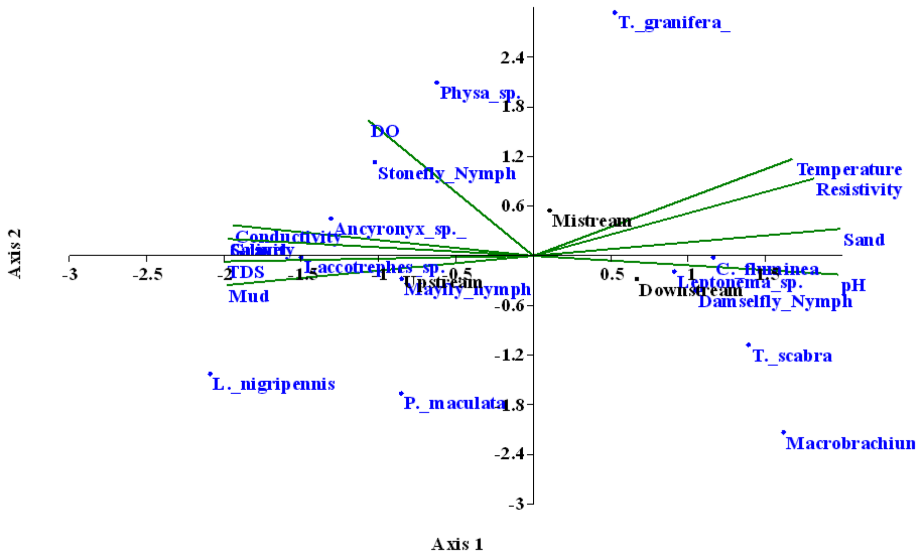


Figure 8: Canonical correspondence analysis of water physicochemical parameters and soil type to the abundance of macroinvertebrates across sampling stations

conductivity levels in the water and the abundance of *Leptonema sp.* Leptonemmay bebe more abundant in environments with lower conductivity levels, indicating a preference for less conductive water. Additionally, the resistivity of the water shows a significant influence with the abundance of *Limnometra nigripennis*. This type of species may have specific habitat preferences related to resistivity levels, and its abundance can be influenced by variations in resistivity (Azis & Abas, 2021).

The abundance and distribution of macroinvertebrates can be influenced by various environmental factors, including water quality, temperature, and substrate type (Abong'o *et al.*, 2015). Taxonomic resolution and the level of detail in species identification can also affect the accuracy and reliability of macroinvertebrate assessments (Jones, 2008). Therefore, it is important to consider multiple factors and use appropriate methods when assessing the ecological integrity of aquatic ecosystems and guiding management strategies for their conservation and restoration.

CONCLUSION

In summary, the study's results suggest that the water quality in the examined stream locations generally adheres to established standards, indicating a conducive environment for aquatic organisms. The presence of medium-sized sand particles signifies stable sediment and suitable habitat conditions, necessitating continuous monitoring of physicochemical parameters to maintain this equilibrium and implement targeted interventions when required.

The discovery of pollution-sensitive macroinvertebrates like Damselfly, Mayfly, and Stonefly further validates the stream's good water quality. For a more comprehensive evaluation of ecosystem health, it is advisable to broaden the scope of the study to include additional factors such as fish populations and nutrient cycling.

The examination of macroinvertebrate dominance, evenness, diversity, and richness underscores the variations in ecological attributes among different segments of the stream. The upstream sector displays high dominance, primarily due to a limited number of dominant species, whereas the midstream area exhibits a more balanced distribution. These patterns are intricately tied to environmental factors such as water quality, temperature, and substrate type, influencing the distribution of macroinvertebrates.

The association between macroinvertebrate abundance and environmental parameters emphasizes the necessity for continuous monitoring in the management of aquatic ecosystems. A comprehensive monitoring approach, encompassing both physicochemical parameters and species composition, offers valuable insights for customized conservation and restoration efforts. Regular assessments and ongoing monitoring are imperative to evaluate the effectiveness of conservation initiatives and ensure the long-term ecological health of the stream.

Acknowledgement

The researcher would like to extend her gratitude to the local government of Esperanza Agusan del Sur for the permission and all the people who helped in conducting and analyzing the study, especially Mr. Jesiel Cris C. Paylangco for his expertise in identification of animals.

Statement of Conflict of Interest

There are no conflicts of interest that the author can disclose with regards to this paper's publication.

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