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Macroinvertebrate Community as Bioindicator of Water Quality of Tambis River, Palompon, Leyte, Philippines

ABSTRACT

Macroinvertebrates have been used globally as bioindicators of water quality of rivers due to their varying tolerance to pollution. The water quality of Tambis River in Palompon, Leyte, Philippines was determined using macroinvertebrates and selected physico-chemical and ecological assessments. Employing kick-sampling method, three sampling stations were established based on the surrounding land use (forested, agricultural, and near residential). Twenty-seven macroinvertebrate families were identified. Permutational multivariate analysis of variance (PERMANOVA) revealed a significant difference in the benthic macroinvertebrate families across three stations (p=0.001). There was a decrease in the abundance of pollution-sensitive families from the forested station towards the downstream, closest to the residential area. Sensitive Ephemerellidae and tolerant Thiaridae were the most abundant in the forested and downstream area respectively. The highest diversity and evenness were observed from the agricultural area. Stream Invertebrate Grade Number - Average Level (SIGNAL 2) scores were plotted declined in all quadrants, suggesting good water quality to moderately polluted. Water temperature, pH, and velocity were the most influencing environmental variables to the macroinvertebrate assemblage as revealed by the Canonical Correspondence Analysis (CCA). Overall, the water quality of Tambis River ranged from being of good quality to moderately polluted. The data obtained in this study could serve as a baseline in providing information to formulate and implement scientific-based regulatory measures towards the conservation of Tambis River.

Keywords: *land use, conservation, diversity, Palompon Watershed Forest Reserve*

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INTRODUCTION

River ecosystems were the lifeblood of ancient civilizations, where the abundant water was utilized by large-concentrated populations, for agriculture, and for transportation (*Hellawell 1986; Gill 2020*). Humans, as well as other forms of life depend on these ecosystems. River ecosystems are facing serious threats due to the increasing impacts of anthropogenic activities (*Kullasoot et al. 2017*). Intense urbanization and agricultural activities are the primary contributors to the degradation of river ecosystems, altering not only their physical and chemical characteristics, but also their biotic composition (*Hepp et al. 2010*). Consequently, the future supply and quality of water are affected (*Camacho and Taniegra 2019*). Therefore, quality assessment and monitoring of rivers are very important for their management and conservation.

Among many organisms, macroinvertebrates are the most utilized in assessing freshwater ecosystemsin many parts of the world (*Fajardo et al. 2015; Clemente et al. 2019; Calabrese et al. 2020*). Aquatic macroinvertebrates are good indicators of water quality because they are abundant, easily sampled and identified, easily affected by the physical, chemical and biological conditions of the river, and are a critical part of the aquatic food web (*Waterwatch Australia Steering Committee 2004a*). They can show the cumulative impacts of pollution, following the basic principle that some macroinvertebrates are either more sensitive or tolerant to pollution than others (*USEPA 1997*). However, aquatic macroinvertebrates are underutilized in tropical freshwater assessments in contrast to temperate regions (*Deborde et al. 2016*) due to generally limited data (*Forio et al. 2017*). The Philippines lag behind other Asian countries in the use of biological communities in the assessment of freshwater ecosystems, and with most studies centered around Luzon (*Magbanua et al. 2017*). Hence, the need for studies in the Visayas and Mindanao regions.

In Palompon, Leyte, Philippines, freshwater assessments and studies using macroinvertebrates are not yet explored. The Tambis River, one of the rivers connected to the Palompon Watershed Forest Reserve, is a major water resource for the residents of Barangay Tambis and Barangay Rizal. They rely on this river for agricultural use, household activities, and contact recreation. Unfortunately, there has been no known documentation or studies on the river's biodiversity and its water quality yet. Assessing its water quality using an inexpensive tool such as benthic macroinvertebrates will be beneficial for the protection of this very important water resource. This is also a key step towards conducting future biodiversity studies.

This study investigated the water quality of Tambis River using benthic macroinvertebrates as bioindicators. Specifically, it aimed to determine and compare the composition, occurrence, abundance, and community structure of macroinvertebrates in the different portions of Tambis River, from the downstream towards the upstream; determine the effect of different land uses and associated anthropogenic disturbances in the study site; and assess select physico-chemical parameters of the river and identify relationships and patterns to the distribution of macroinvertebrates. This will provide valuable insights to prompt policy-driven strategies in the local community for the proper conservation and management of the Tambis River.

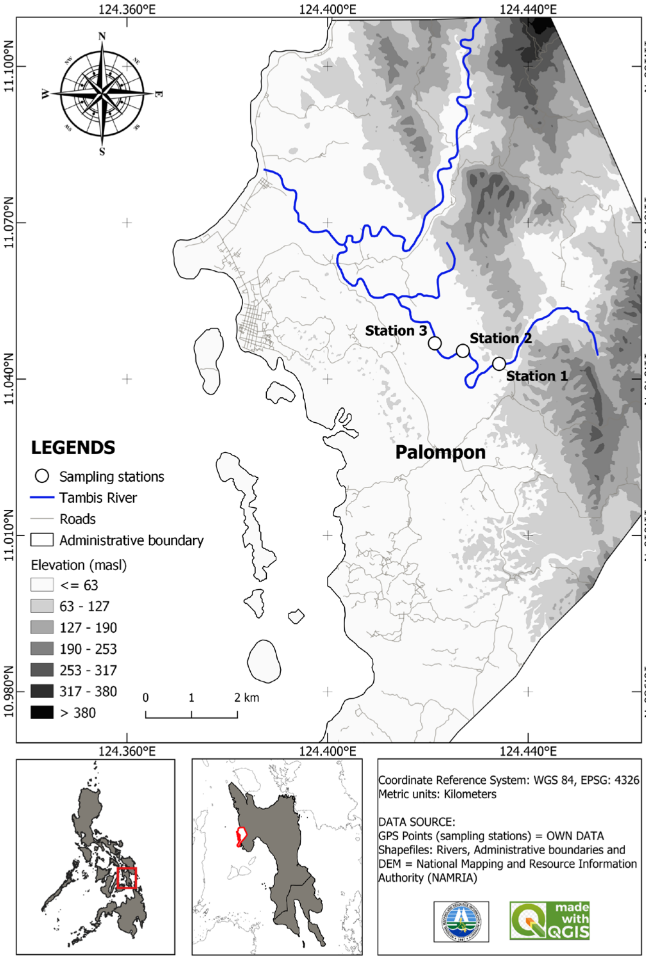

Figure 1. Map showing the three sampling stations in the forested (Station 1), agricultural (Station 2), and near residential (Station 3) portions of Tambis River, Palompon, Leyte, Philippines.

MATERIALS AND METHODS

Study site

This study was conducted in Tambis River in Palompon, Leyte, Philippines, whose source originates from the Palompon Watershed Forest Reserve. Due to accessibility and safety concerns, especially during the height of the pandemic, three sampling stations were established only within the jurisdiction of Barangay Tambis. These stations were chosen based on land use observed from the preliminary survey conducted in October 2021.

Station 1 was a forested part of the river located upstream where the river channel narrows. It had a rocky substrate and intact riparian vegetation with less disturbance (**Figure 1**). Station 2 is situated on the midstream of the study area where one side is open towards a grassland and where farming carabaos were bathing nearby. This station was also adjacent to an agricultural area. Station 3 is established going downstream and close to a residential area. Slash-and-burn areas, logging and household activities such as laundry were also observed in the vicinity of this station.

Macroinvertebrates sampling and identification

Benthic macroinvertebrate samples were collected in March 2022. At each of the three sampling station, 5 replicates were obtained, hence a total of 15 samples were collected from the study site. The kick-sampling method (C*urry et al. 2012; Corpuz et al. 2016)* was employed using a triangular-framed net (29 x 39 x 29 cm; 0.1 mm mesh). Facing downstream, the net was held in front of the collector while its opening was facing upstream. The streambed where the collector was standing had been disturbed for three minutes by vigorous shuffling and kicking, which directed the current to sweep the dislodged macroinvertebrates into the net. Collected samples were preserved with 70% ethyl alcohol and then viewed under a portable digital zoom microscope. The KKmoon Digital Zoom Microscope was used which supports a USB interface to connect to a computer or laptop to view samples. The macroinvertebrates was identified at the family level using references from the internet such as macroinvertebrates.org and bugguide.net, and identification guides by *Jessup et al.* (*2002*) and *Thorp and Rogers* (*2010*).

Physico-chemical parameters

Adopting the protocols from *Waterwatch Australia Steering Committee* (*2004b*), the selected physico-chemical parameters were measured *in situ* at each point where benthic macroinvertebrate samples were collected. These were temperature (˚C), pH, total dissolved solids (ppm), cross-sectional area of the river channel (m^2), water velocity (m/s), and discharge ($m^3 s^{-1}$). The YIERYI Digital TDS Meter, was used to assess the TDS and temperature, while paper test strips were used to determine the water pH. The data collected were also compared to the accepted water quality guidelines and standards established by the Department of Environment and Natural Resources (*DENR 2016*). The weather condition and substrate type were also noted by visual observation.

Data analysis

The diversity of the macroinvertebrates was determined and analyzed using other ecological measures such as the Shannon-Weiner Diversity Index, Jaccard Similarity Index and Pielou's Evenness Index. The Kruskal-Wallis test was performed to determine if the physico-chemical characteristics and diversity differ across stations, followed by the Dunn post-hoc test to determine if the difference is significant.

The Stream Invertebrate Grade Number-Average Level (SIGNAL 2) scoring system was used to assess the macroinvertebrates as indicator of the water quality. Ranging from 1-10, a low-grade number means that the macroinvertebrate is tolerant of water pollution and vice versa (*Waterwatch Australia Steering Committee 2004a*). The grade number for each family was multiplied by the corresponding weight factor. Next, the sum of the weight factors for all families, and the sum of the products of grade numbers and weight factors were calculated. To get the SIGNAL score, the latter was divided by the former.

To determine the possible associations between the macroinvertebrates and environmental variables and to identify corresponding patterns in the composition of the macroinvertebrates, the Canonical Correspondence Analysis (CCA) was performed using the Paleontological Statistics (PAST ver 4.03) software. In addition, R software (ver 4.4.0) was used to perform Non-Metric Dimensional Scaling (NMDS) and one-way Permutational Multivariate Analysis (PERMANOVA) to test the difference in the taxonomic composition of macroinvertebrates across sampling stations. Any significant difference was subjected to a pair-wise comparison using the Bray-Curtis Similarity Test.

RESULTS AND DISCUSSION

Physico-chemical Parameters

In the physico-chemical characteristics of the river (**Table 1**), five of the eight parameters- water temperature, pH, channel width, depth, and cross-sectional area- showed a significant difference across sampling stations.

Water temperature significantly increased from Station 1 to Station 3. Although sampled the earliest in the morning, around 7:00 am, station 3 had the highest temperature (29.2˚C). The lowest temperature was at Station 1 (25.48˚C) despite being sampled early in the afternoon. Water pH also significantly varied, yet all sampling stations were within neutral range- 7.6 (Station 1), 6.8 (Station 2), and 7.5 (Station 3). Hence, no station was too acidic or too basic. The water pH values were within the range for river ecosystems by the DENR, which is 6.5-8.5.

For the cross-sectional area, the widest was in

Table 1. Mean Physico-chemical characteristics of sampling stations in Tambis River, Palompon, Leyte Philippines.

Parameters	Station 1	Station 2	Station 3	Mean	p-value
Temperature (˚C)	25.5	28.4	29.2	27.7	0.021*
pH	7.6	6.8	7.5	7.3	0.004*
Total dissolved solids (ppm)	21.3	23.7	24.2	23.1	0.181
Channel width (m)	8.64	12.78	11.36	10.93	0.012*
Channel depth (m)	0.20	0.23	0.25	0.23	0.024*
Cross-sectional area (m^2)	1.75	2.93	2.79	2.49	0.009*
Water velocity ($m\ s^{-1}$)	0.35	0.28	0.32	0.32	0.632
Water discharge ($m^3 s^{-1}$)	0.60	0.84	0.86	0.77	0.401

*significant ($p<0.05$)
DENR DAO No. 2016 water quality guidelines: Temperature (˚C): 26-30; pH: 6.5-8.5; and TDS: 500.

Station 2 (2.93 m^2), followed by Station 3 (2.79 m^2), Station 1 was the narrowest (1.75 m^2). According to *Leece* (*2013*), adjustments of the channel cross section depend on erosion and depostion. The author emphasized that as water flows downstream, potential energy is converted to kinetic energy, resulting to a geomorphic work in the form of erosion and sediment transport. Thus, creating a wider and deeper river channel in the downstream as compared to the upstream.

Although TDS estimates were not significantly different across stations, readings were very low at 21.3-24.2 ppm, as compared to the WHO and DENR standard which is 500 ppm (*Kadhem 2013; Martin et al. 2018*). They attributed this to the prevailing rains during the week and even the night before the sampling which caused significant dilution.

Macroinvertebrate composition, occurrence and abundance

A total of 755 individuals of benthic macro-invertebrates were obtained from the three sampling stations in Tambis River, Palompon, Leyte. These were under 27 families representing 11 orders– Basommatophora, Cerithimorpha, Coleoptera, Decapoda, Diptera, Ephemeroptera, Hemiptera, Odonata, Pholadomyoida, Sorbeoconcha and Trichoptera. There were four classes represented– Bivalvia, Gastropoda, Hexapoda and Malacostraca (**Table 2**). Orders Coleoptera, Ephemeroptera and Trichoptera were the most represented groups each comprising no fewer than five families.

Station 1 had the highest mean abundance of collected individuals at 60, followed by Station 2 with 49, and Station 3 with 42. Despite these differences, a Kruskal Wallis Test indicated non-significant variation (p=0.141). However, the PERMANOVA test revealed that the macroinvertebrate families significantly differed across stations (**Table 3**). This is followed by a pair-wise comparison showing that each station are significantly different to each other (**Table 4**).

Ephemerellidae (super crawler mayflies) was the most abundant in Station 1 and constituted 41% of the relative abundance (**Figure 2A**). Other top families found at this station were Hydropyschidae (17%), Philopotamidae (12%), Leptophlebidae (7%) and Baetidae (5%). In the studies of *Labajo-Villantes and Nuñeza* (*2015*) in Labo and Clarin Rivers in Bohol, Philippines and *Jolejole et al.* (*2021*) in San Cristobal River, Laguna, Philippines, similar orders were observed as the most abundant taxa in their upstream or forested sites. In the Tambis River, a high abundance of Ephemereptorans may also be attributed to the most common microhabitat in the upstream sampling stations, which were riffles. They are most common and abundant in this microhabitat because most of their life is spent in the water as larvae (*Dacayana et al. 2013*). Most Ephemroptera nymphs are herbivores or detrivores and thus often found in riffles, burrowing and clinging onto the underside rocks, woody debris or within leaf packs (*Thorp and Rogers 2011*).

In Station 2, orders Ephemeroptera and Trichoptera were well represented (**Figure 2B**). Hydropsychidae (28%), Ephemerellidae (21%), Baetidae (14%) and Philopotamidae (6%) were the most frequently observed families. Hydropsychidae (net-making caddisflies) is most commonly collected from areas with cobble or bedrock substrate where solid structures are available to attach their nets (*Bouchard 2004*). Furthermore, this taxon exhibited high densities in agricultural sites as observed in the study by *Deborde et al.* (*2016*) in the selected rivers of Silago, Southern Leyte, Philippines. An increase in density in areas were influenced by farm-related activities. According to the authors, Hydropsychidae are typically filtering-collectors and, depending on their density, may considerably influence the quality of suspended organic particles. Families under order Coleoptera, including Coenagrionidae (3%), Dytiscidae (3%), Elmidae (2%) and Gyrinidae (2%), and order Diptera such as Chironomidae (2%) were also identified. Additionaly, non-insect families including Palaemonidae (4%), Thiaridae (3%) and Gecarcinucidae (0.4%) were present. These families exhibit a range of tolerance level to water pollution, spanning from moderate to high tolerance (*Chessman 2001*). The presence of both pollution-sensitive and tolerant macroinvertebrates in the midstream portion was also reported in the study of *Baclayon et al.* (*2017*). The authors concluded that this coexistence suggests relatively good water quality, yet pollution threats are at the forefront.

In contrast to Station 1, non-aquatic insects were dominant in Station 3, particularly the family Thiaridae (51%), which belongs to the class Gastropoda (**Figure 2C**).

This was followed by the family Corbiculidae (19%) under the class Bivalvia. Thiaridae (trumpet snails) are filter- and deposit-feeder invertebrates and are very abundant in waters affected by agricultural wastes, which makes the sediment richer in organic matter (*Patang et al. 2018; Pan et al. 2015*). Moderately tolerant families such as Elmidae (7%), Glossosomatidae (3%) and Hydropsychidae (3%) were also present. Among the pollution-sensitive groups, only family Baetidae

Table 2. Occurrence of benthic macroinvertebrates across stations in Tambis River, Palompon, Leyte, Philippines.

Phylum	Class/Order/Family	Station 1	Station 2	Station 3
Phylum Arthropoda (Insects)	Class Hexapoda			
	Order Coleoptera (Beetles)			
	Family Dytiscidae	1	1	1
	Family Elmidae	1	0	0
	Family Psephenidae	1	1	0
	Family Gyrinidae	1	1	0
	Family Lampyridae	0	1	0
	Order Diptera (True Flies)			
	Family Chironomidae	1	1	0
	Family Simuliidae	1	1	0
	Family Tipulidae	1	1	0
	Family Ephyridae	0	0	1
	Order Ephemeroptera (Mayflies)			
	Family Baetidae	1	1	1
	Family Caenidae	1	1	0
	Family Ephemerellidae	1	1	0
	Family Leptophlebiidae	1	1	0
	Family Heptageniidae	1	0	0
	Order Hemiptera (Bugs)			
	Family Hydrometridae	0	1	0
	Order Odonata (Dragonflies and Damselflies)			
	Family Coenagrionidae	1	1	0
	Order Trichoptera (Caddisflies)			
	Family Glossosomatidae	1	0	1
	Family Hydropsychidae	1	1	1
	Family Philopotamidae	1	1	0
	Family Polycentropodidae	1	1	0
Phylum Arthropoda (Non-insects)	Class Malacostraca			
	Order Decapoda (Shrimps and crabs)			
	Family Gecarcinucidae	0	1	0
	Family Palaemonidae	0	1	0
	Class Bivalvia (Clams and mussels)			
	Order Pholadomyoida			
	Family Corbiculidae	1	0	1
	Class Gastropoda (Snails)			
	Order Basommatophora			
	Family Ancylidae	0	0	1
	Family Physidae	0	0	1
	Order Cerithimorpha			
	Family Thiaridae	0	1	1
	Order Sorbeoconcha			
	Family Pachychilidae	0	0	1
	TOTAL	18	19	10

Note: 1 - present; 0 - absent

Table 3. Results of PERMANOVA for the test of significant difference in the benthic macroinvertebrate families composition across three sampling stations in Tambis River, Palompon, Leyte, Philippines.

Source	Df	SS	MS	F. model	Pr(>F)
Stations	2	2.3210	1.1605	8.4772	0.001*
Residuals	12	1.6428	0.1369		
Total	14	3.9638			

*=significant (p<0.5)

Table 4. Results of post-hoc test using pair-wise comparison between stations (Bray Curtist Similarity).

Pairs	Df	SS	F. model	Pr(>F)
S1 vs S2	1	0.4358385	3.211440	0.011*
S1 vs S3	1	1.7135254	17.203082	0.007*
S2 vs S3	1	1.3321279	7.596057	0.008*

of the Order Ephemeroptera was encountered in low abundance. This family is ubiquitous and can be found in many habitats along the river gradient (*Barbosa et al. 2001*).

Diversity, Evenness and Similarity

The diversity and evenness index values of benthic macroinvertebrates across sampling stations in the Tambis River were also determined (**Table 5**). The highest diversity value was recorded from Station 2 (2.21), followed by Station 1 (1.94), then, Station 3 (1.56). In terms of evenness, Station 2 maintained the highest (0.76), while Stations 1 and 3 had the same value (0.67). The presence of the most abundant families Ephemerellidae (41%) and Thiaridae (51%) in Stations 1 and 3, respectively, might have contributed to the lower diversity of these stations. In contrast, Station 2 demonstrated 19 families with comparatively even distribution including Hydropsychidae (28%), Ephemerellidae (21%) and Baetidae (14%). Thus, the midstream section supports a variety of macroinvertebrate families with a more even distribution than the other stations. According to *Niyogi et al.* (*2006*), when native grassland catchments are converted to pasture, such as in Station 2, nutrient concentrations increase and would produce a subsidy-response – increased density and biomass of invertebrates.

Table 5. Diversity and evenness index values of benthic macroinvertebrates in Tambis River, Palompon, Leyte, Philippines.

	Station 1	Station 2	Station 3	Mean
Diversity (H')	1.94	2.21	1.53	1.90
Evenness (J)	0.67	0.76	0.67	0.67

In addition, the mid-domain effect (MDE) hypothesis offers an explanation for geographic diversity patterns. Many studies have shown that it is an important

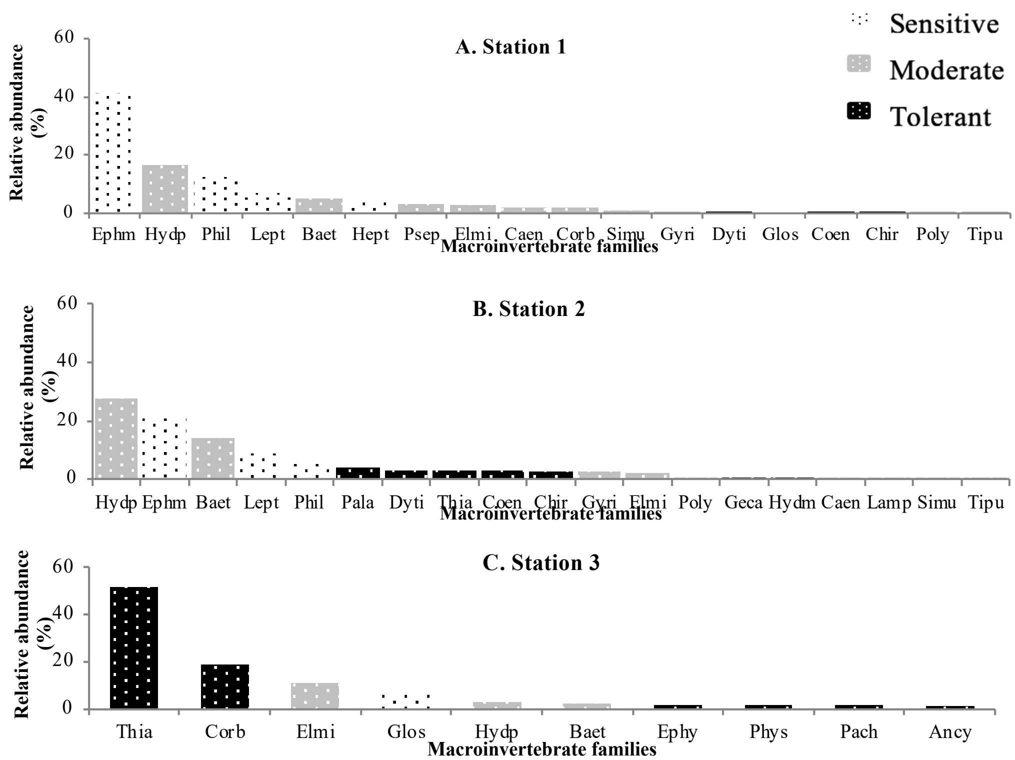

Figure 2. Relative abundance of benthic macroinvertebrates in Tambis River, Palompon, Leyte, Philippines. Sensitivity level based on *Chessman* (*2001*).

Note: Ephemerellidae (Ephm), Hydropsychidae (Hydp), Thiaridae (Thia), Baetidae (Baet), Philopotamidae (Phil), Corbiculidae (Corb), Leptophlebiidae (Lept), Elmidae (Elmi), Glossosomatidae (Glos), Heptagenidae (Hept), Palaemonidae (Pala), Psephenidae (Psep), Dytiscidae (Dyti), Gyrinidae (Gyri), Caenidae (Caen), Ephyridae (Ephy), Physidae (Phys), Simuliidae (Simu), Pachylidae (Pach), Polycentropodidae (Poly), Ancyildae (Ancy), Tipulidae (Tipu), Gecarcinucidae (Geca), Hydrometridae (Hydm), and Lampyridae (Lamp).

mechanism affecting geographic richness patterns (*Wang et al. 2009*). This suggests that under the assumption of a random distribution of ranges within a bounded domain, in general, there tends to be a higher overlap near the middle of the domain than at the edges. This would result in a peak or plateau of taxa richness toward the center as a result of environmental gradients and spatial constraints (*Prillwitz and Blasius 2020*).

However, there were no significant differences between the diversity (p=0.0652) and evenness (p=0.2808) across sampling stations. According to *Fernando* (*1998*), Shannon diversity values from 1-2.49 means low diversity. Similar to the findings of *Flores and Zafaralla* (*2012*) in the Mananga River, Cebu, Philippines the mean diversity value of the Tambis River was 1.90, suggesting state of moderate pollution (*Wilm and Dorris 1968*). Low diversity was also observed in Agusan River, Agusan del Sur, through the study of *Cuadrado and Calagui* (*2017*). They attributed this low diversity to agricultural activities, such as using the rivers as bathing places both for animals and humans and utilization of the riparian zone as pasture areas. This description fits closely with the characteristics of the study area.

The computation of the Jaccard similarity index (**Figure 3A**) revealed that Stations 1 and 2 exhibited the highest percent similarity at 61%. This suggests that more than half of the common macroinvertebrate families (particularly those with high abundance such as Ephemerillidae, Hydropsychidae, and Leptophlebiidae), were observed in both stations. In contrast, Stations 2 and 3 had the least similarity (15%). These results were supported by the Non-metric Dimensional Scaling (NMDS) (**Figure 3B**). Stations with more similarity in composition were ordinated closer together, exemplified by the proximity observed between Stations 1 and 2 (*Blakely et al. 2014*).

The results obtained may be attributed to the type of substrate present in these stations. The first and second stations had a stony and coarser substrate compared to the third one, which was mostly sand. According to *Duan et al.* (*2008*), many benthic taxa exhibit varying substrate preferences such that grain size, porosity and interstitial dimension significantly affecting macroinvertebrate assemblage.

Cluster analysis of macroinvertebrate families using the Jaccard Similarity Index was also conducted (**Figure 4**). The dendrogram reveals the formation of two major groups. All macroinvertebrates belonging to the phylum Mollusca (Thiaridae, Corbiculidae, Physidae,

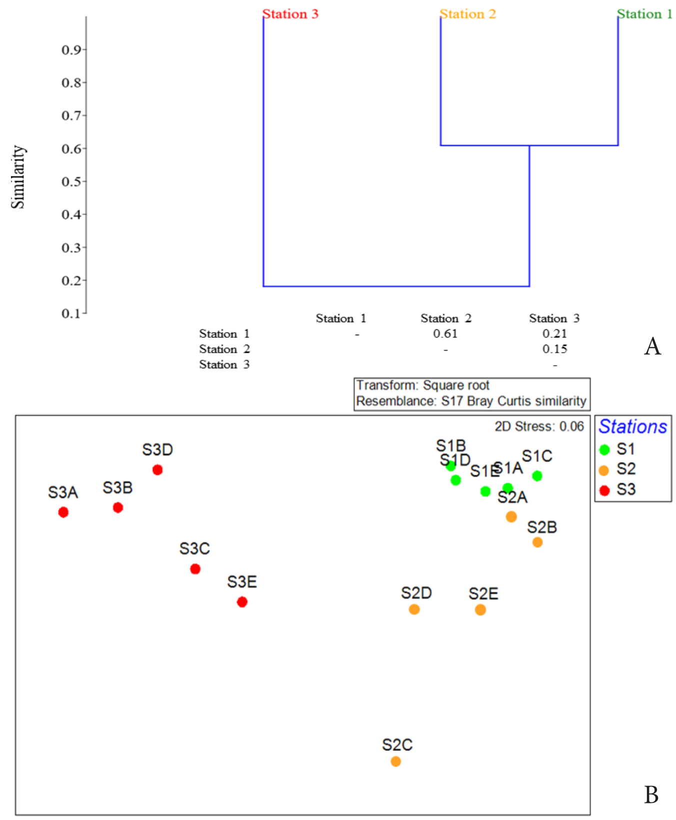

Figure 3. Hierarchical representation of the sampling stations based on similarity of the present benthic macroinvertebrates in Tambis River, Palompon, Leyte, Philippines (A) and Schematic of an NMDS plot (letters indicate replicates) (B).

Ancylidae and Pachychilidae) which were most abundant in Station 3, informing one clade. Ecologically, these organisms share similar feeding habits and are tolerant to pollution (*Thorp and Rogers 2010; Bouchard 2004*). In contrast, the other clade consists of macroinvertebrates belonging to phylum Arthropoda. Most families within this clade, such as Baetidae, Hydropsychidae, Philopotamidae, Leptophlebiidae and Epheremellidae, were highly abundant in Stations 1 and 2. These families also displayed the shortest branching length, implying that they were the most similar. Specifically, these families range from very to moderately sensitive to pollution and thus share relatively similar environmental requirements (*Chessman 2001*).

The points representing the sampling stations were scattered in all quadrants (**Figure 5**). All from Station 1, with family occurrence ranging from 9 to 11, fell within the first quadrant (Q1) and gained SIGNAL scores of 6.6-7.4. This signified a favourable habitat and good waterquality. Although the diversity of this station is relatively low, pollution-sensitive groups, such as Ephemerellidae Leptophlebiidae, Heptageniidae and Philopotaminidae

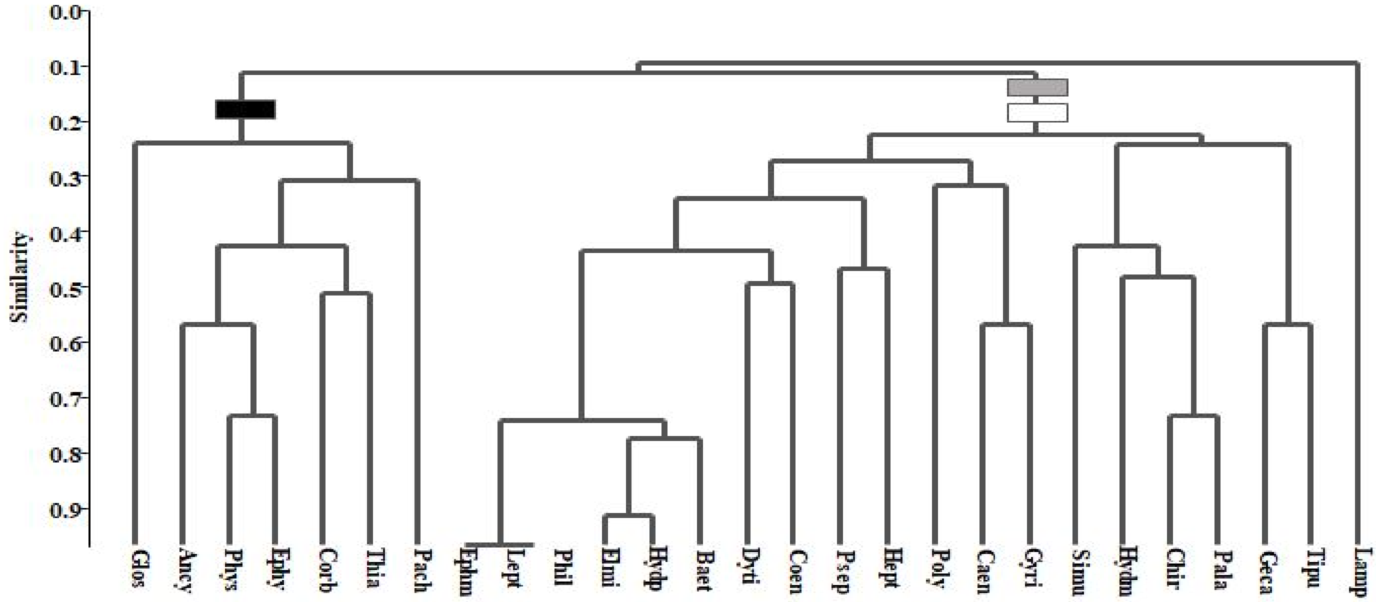

Figure 4. Cluster plot showing the similarity of benthic macroinvertebrate families across sampling stations in Tambis River, Palompon, Leyte Philippines. Tick marks represent high abundance in Station 1(white), Station 2 (gray) and Station 3 (black).

Note: Ephemerellidae (Ephm), Hydropsychidae (Hydp), Thiaridae (Thia), Baetidae (Baet), Philopotamidae (Phil), Corbiculidae (Corb), Leptophlebiidae (Lept), Elmidae (Elmi), Glossosomatidae (Glos), Heptagenidae (Hept), Palaemonidae (Pala), Psephenidae (Psep), Dytiscidae (Dyti), Gyrinidae (Gyri), Caenidae (Caen), Ephyridae (Ephy), Physidae (Phys), Simuliidae (Simu), Pachylidae (Pach), Polycentropodidae (Poly), Ancyildae (Ancy), Tipulidae (Tipu), Gecarcinucidae (Geca), Hydrometridae (Hydm), and Lampyridae (Lamp).

were rather highly abundant, contributing to a high SIGNAL score.

Station 2 obtained SIGNAL scores of 5.6-6.4 and were plotted in Q1, Q2, and Q4, with number of families present at 5 to 13. Scores at Q1 suggest that the midstream portion generally has a high diversity of macroinvertebrates and habitat conditions (*Chessman 2001*). However, scoreat Q2 and Q4 have higher turbidity, nutrient, and salinity levels (*Arevalo 2020*). Rivers near agricultural areas with benign physical conditions and without severe impacts fall into Q2 quadrant, while most sites falling into Q4 suffer from one or more forms of human impact (*Chessman 2001*). These results agree with the diversity and evenness values obtained and the abundance of very sesnsitive to moderately sensitive groups in this station.

Lastly, the SIGNAL score for Station 3 was 3.2-4.9, fell within Q3 and Q4. This represents a higher SIGNAL score but lower number of macroinvertebrate families present. In this station, the lowest number of families were recorded (4-7), and pollution-tolerant groups (Thiaridae and Corbiculidae) were highly abundant. Despite this, the presence also of other moderately sensitive families, such as Elmidae, Hydropsychide and Baetidae, mayhave contributed to the scores beyond 5. According to *Chessman* (*2003*), sites falling within Q3 and Q4 usually indicate urban, industrial or agricultural pollution, and

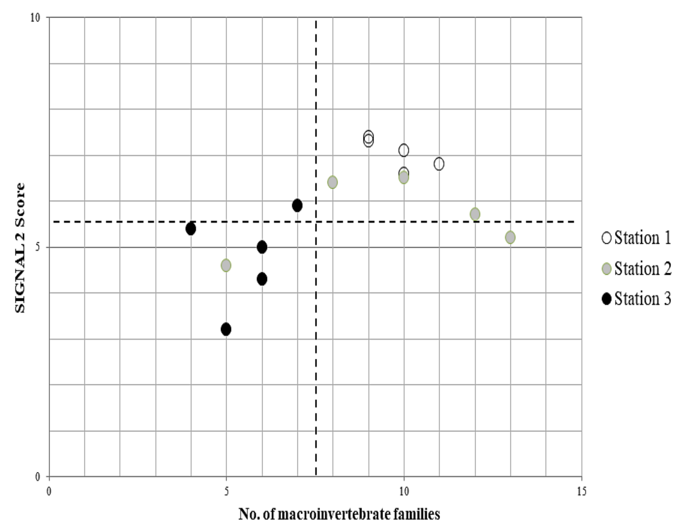

Figure 5. SIGNAL 2 scores based on the number of benthic macroinvertebrate families in Tambis River, Palompon, Leyte, Philippines.

Note: Q1 (Upper right)-favorable habitat and good water quality; Q2 (Lower right) – benign physical conditions, toxic chemicals are not present in large amounts; Q3 (Upper left) – poor habitat, presence of pollution, harsh physical conditions or inadequate sampling; and Q4 (Lower right) – polluted habitat, suffering from one or more forms of human impact (*Chessman 2001*).

high salinity or nutrient levels. Notably, anthropogenic activities observed in this station include slash-and-burn, logging and laundry.

Based on the results of SIGNAL 2, Tambis River can be characterized as having relatively good water quality to moderately polluted.

Results from CCA suggest that water temperature, pH and velocity influenced the community structure of macroinvertebrates in the Tambis River. According to the diagram (**Figure 6**), a stronger association between the environmental variable and the benthic macroinvertebrates is represented by a closer proximity to the green line.

The family Physidae or bladder snails (**Figure 7A**) exhibited the closest association with water temperature, suggesting that the abundance of this snail family has been likely influenced by this variable. Physids are hermaphrodites, and their life cycle is strongly affected by temperature (*Hammond and Burch 2000*). An experiment by *Brackenburry and Appleton* (*1991*) investigated the effect of controlled temperatures on the gametogenesis of physids. Their results showed a positive influence of increased temperature to the gametogenesis of *Physa acuta*. It accelerated the process and increased the survivorship rate. In this study, Physidae was encountered only in Station 3 which had the highest temperature reading at 29.2˚C. However, this may be confounded since temperature readings in each station were obtained at different times of the day.

Family Baetidae or small minnow mayflies (**Figure 7B**) was observed to be correlated with pH. Members of this family are acid-intolerant, thus positively correlated with pH (*Buluta et al. 2010*). *Tabak and Gibbs* (*1991*) indicated that decreasing pH also decreased successful hatching, while a high success rate was observed between pH 5.0 and 7.5. In Tambis River, the water pH levels of all sampling stations were within the neutral range (6.8-7.6) and were within the water quality standards set by Department of Environment and Natural Resources.

Both Elmidae and Leptophlebiidae families were observed to be closely associated with water velocity. Elmidae, commonly known as riffle beetles (**Figure 7C**), as their name implies are found crawling on stones and woody debris in the riffle zones of freshwater streams characterized by fast flowing waters (*Hammond 2009*). This coincides with the study of *Braun et al.* (*2014*) in the montane rivers of Southern Brazil. Similarly, Leptophlebidae (**Figure 7D**) is also a fast-flowing water dweller and was found to be closely associated with water velocity through Canonical Correspondence Analysis of other studies (*Nguyen et al. 2018; Forio et al. 2017*).

Despite showing associations, the eigenvalues in this CCA suggest that the environmental variables explained only 52.97% (axis 1) and 26.22 % (axis 2) of variations in the abundance of benthic macroinvertebrate families. In addition, p-values obtained were greater than 0.05. This implies that although associations can be derived, they were not statistically significant and do not completely reveal the real pattern in the sampling area. This could be attributed to the limitations of a one-time sampling

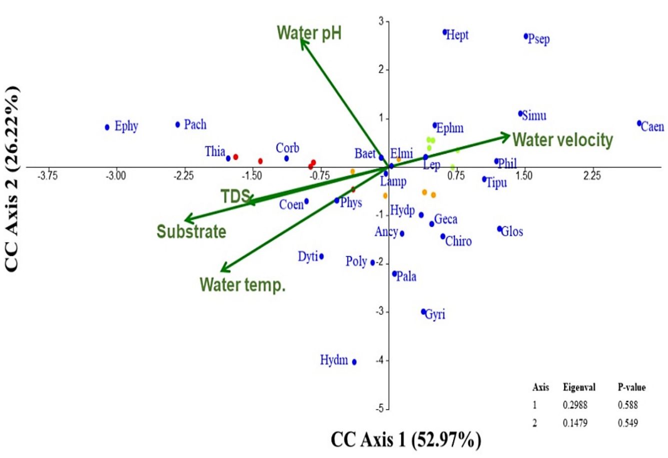

Figure 6. Canonical correspondence analysis (CCA) of macroinvertebrate families and environmental variables in Tambis River, Palompon, Leyte, Philippines. Green lines represent the environmental variables (water temperature, pH, velocity, and total suspended solids). Dots represent Station 1 (green), Station 2 (orange), Station 3 (red), and macroinvertebrate families (blue).

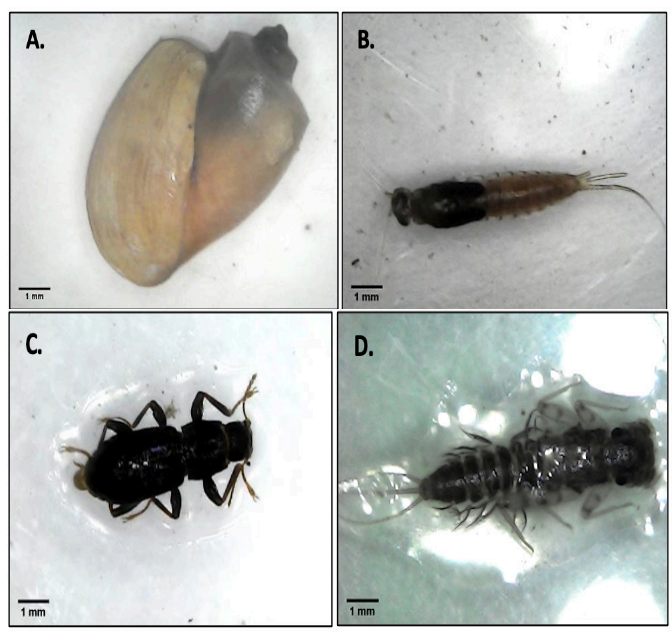

Figure 7. Representatives of families closely associated with the environmental variables. (A) Physidae, (B) Baetidae, (C) Elmidae and (D) Leptophlebidae.

design. Thus, additional sampling is recommended to enhance robustness of results.

CONCLUSIONS AND RECOMMENDATIONS

This study revealed that there was a variation in the abundance and diversity of benthic macroinvertebrates across three sampling stations in Tambis River, Palompon, Leyte, Philippines, based on land-use. There was a decrease in the abundance of pollution-sensitive families from the forested station towards the downstream area of the river. Although diversity were relatively low, Station 2 (agricultural area) had the highest diversity among the three, attributed by the coexistence of both pollution tolerant and sensitive groups. Along with the SIGNAL 2 index, it showed that Tambis River have a good water quality to moderately polluted. This conclusion should be appreciated with caution as the river may potentially deteriorate if no management and protective measures are taken.

To protect and conserve the Tambis River, this study can serve as a baseline for formulating and implementing scientific-based policies, regulating the agricultural and household activities near the area. Regardless, continuous assessment of the river as well as the monitoring on the implementation of formulated policies should be also considered.

It is recommended that more studies should be conducted in Tambis River that must include an assessment of the seasonal variations and more physico-chemical parameters, such as dissolved oxygen, elevation, and light intensity. Studies on the river systems in neighboring barangays and the whole Palompon Watershed Forest Reserve will also be beneficial for comparison.

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