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Biodiversity of Macroinvertebrate Assemblages in Pagbanganan River, Baybay City, Leyte, Philippines

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ABSTRACT

Threats to aquatic ecosystems, especially rivers, have spurred the development of biological monitoring practices to address environmental issues. This study which was conducted in the three sites of Pagbanganan River aimed to identify macroinvertebrate faunal groups, determine the macroinvertebrate biodiversity, measure the physico-chemical parameters, and evaluate the water quality of the river using the SIGNAL 2 scoring system. Macroinvertebrates were collected using the Hess sampler and a total of 29 macroinvertebrate families were identified belonging to five classes (Acarina, Bivalvia, Gastropoda, Insecta and Polychaeta) and 11 orders. The top two most abundant macroinvertebrate groups (71% combined) in the river were Orders Ephemeroptera and Trichoptera. Results showed that station 2 (Brgy. Imelda) of the Pagbanganan River had the highest diversity and evenness values but had the lowest richness and dominance values compared with the other two stations. Average water temperature, pH, and dissolved oxygen were all within the acceptable range and standards. However, total dissolved solids concentration in station 3 (Brgys. Kan-ipa and Hibunawan) had unacceptable value for drinking water but still was within the normal range for rivers which may be attributed to anthropogenic disturbances found to be more concentrated on the lower part of the river. SIGNAL 2 scoring system showed that the water quality of station 1 and 2 were affected by a pollution source or there were habitats exposed to harsh physical conditions while site 3 indicated that the water quality was affected by urban, industrial or agricultural pollution.

Keywords: macroinvertebrates, diversity, physicochemical parameters, bioassessment

INTRODUCTION

Human activities have significantly disrupted global ecosystems over the past few decades. This has placed immense strain on the physical environment, threatening the survival of many species, including humanity itself. One of the most impacted and critically affected natural resources are the rivers. Riverine

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ecosystems are vital to human existence and well-being, providing numerous benefits such as potable water, food, habitat for diverse aquatic life, irrigation for agriculture and aquaculture, and essential roles in the water cycle, nutrient cycling, navigation, waste disposal, and renewable energy generation (Allan & Flecker 1993; Baclayon 2017). Despite the exceptional uses and contributions of rivers, they are currently being subjected to many disturbances that, in one way or another, affect the natural processes and cycle of life itself. One of the most widely known disturbances affecting aquatic ecosystems are anthropogenic activities (i.e., modern farming utilizing synthetic fertilizers, pesticides, etc., and large-scale conversion and degradation of forests landscapes) that lead to the alteration of the physical habitat, biotic communities as well as ecological functions (Kripa et al 2013; Principle 2007; Srivastava & Singh 2012).

The current threats in aquatic ecosystems, specifically on rivers, have brought about various ecological methods, like biological monitoring practices, to help address environmental problems. One group of organisms that are commonly used as bioindicators in biological assessments and monitoring and serve as valuable indicators of degradation in aquatic ecosystem assessments are the macroinvertebrates. These organisms refer to the diverse, ecologically important, and virtually ubiquitous animals without a backbone. These organisms can be seen by the naked eye or are usually 1mm in size or those that can be retained by a net or sieve with a 500 µm or less, living permanently or part of their life cycle in an aquatic ecosystem. These including arthropods, mollusks, annelids, nematodes, and turbellarians that feed on microorganisms and periphyton and directly on macrophyte tissues (Benetti et al 2012; Hauer & Lamberti 2007; Waterwatch Australia National Technical Manual 2004). Different macroinvertebrate groups have various habitat preferences and levels of pollution tolerance. Thus, their presence or absence as well as their abundance will likely suggest water quality deterioration in aquatic ecosystems and mirror brief and prolonged environmental conditions (Kripa et al 2013; Stroud Water Research Center 2005; Wallace & Webster 1996). A great number of past and recent studies focusing on macroinvertebrates both locally and internationally have been reported (Albutra et al 2017; Baclayon 2017; Bode et al 1999; Hodkinson & Jackson 2005; Labajo-Villantes & Nuñeza 2015; Patang et al 2018; Paylangco et al 2020; Uherek & Gouveia 2014) but, so far, no studies were conducted in Pagbanganan River in Baybay City.

Pagbanganan River is Baybay City's largest river. It is one of the 12 major river systems in the province of Leyte (Labonite 2013) and is part of the 28 river systems of Eastern Visayas (Morales & Paringit 2017). This river, which stretches 19.77 kilometers from its source to its mouth near the city center, is situated in the western coasts of Leyte, fronting the Camotes sea. The immediate area of the river is distributed among 10 barangays (Morales & Paringit 2017). The river has been utilized for domestic purposes (e.g., food source, for washing clothes and domesticated animals, recreation and irrigation of agricultural lands). The river also served as drainage of agricultural wastes as well as domestic wastes from nearby residential areas. Moreover, sand and gravel quarrying in selected parts of the river can also be observed. These human activities have degraded the river's ecosystem, leading to pollution and potential health risks.

This study investigated the biological, physical and chemical characteristics of the Pagbanganan River through the identification of macroinvertebrate fauna present in the three selected stations (upstream, midstream, downstream) of the river, determination of the biodiversity of macroinvertebrates, measurement of the physico-chemical parameters and finally, evaluation of the water quality of the river using SIGNAL (Stream Invertebrate Grade Number – Average Level) version 2 scoring system (Chessman 2003). Furthermore, the result of this study will be used as part of the development of an ecosystem health report card for the Tropical Ecosystem Health Report Card (TrEcH Report Card) project of the Department of Biological Sciences, Visayas State University, as well as to contribute to policy advocacy of the LGU of Baybay on sustainable development of aquatic ecosystems.

MATERIALS AND METHODS

Study Site

Baybay City is the second largest city (46,050 hectares) in the province of Leyte, Eastern Visayas, Philippines and comprises a total of 92 barangays (Rupa & Portugaliza 2016). Three sampling stations were established and chosen along the 19.77 km stretch of the Pagbanganan river from the nine pre-determined study stations of the TrEcH project. This project titled: Development of Tropical Ecosystem Health Report Card (TrEcH Report Card) aims to evaluate the existing ecosystem health of the Pagbanganan River in the on-set of urbanization through the assessment of various ecosystem parameters like ecological, physicochemical, and socio-economic impacts. Station 1 (upstream) with a distance of 16 km from the city proper, was located in Brgy. Mapgap. Station 2 (midstream) was in Brgy. Imelda, eight km from the city proper and 4.30 km from Station 1 (upstream). Meanwhile, station 3 (downstream) was situated between Brgy. Can-ipa and Brgy. Hibunawan which is 3.3 km and 8.4 km from the city proper respectively and 6.26 km from station 2 (Fig. 1). Most of the local residents' livelihood located in the three stations are centered mainly on agriculture thus agricultural and livestock farms as well as vegetable and crop gardens can be observed near the riverbank.

Moreover, the river was greatly used for fishing, irrigation, and for domestic purposes such as bathing, washing of clothes, pets and domesticated animals as well as for recreational activities and even waste disposal. Residential houses were a distance away from the river in stations 1 and 2 since these were in the upstream and midstream portion of the river, respectively, with various vegetation like fruit trees and coconuts, shrubs and grasses that can be found near the river banks. Additionally, agricultural farms were present near the river in station 1. The predominant substrate in station 1 are mostly boulders, rocks and sand, while station 2 had rocky to sandy-silty substrate with sand concentrated in the river banks. Station 3, on the other hand, had more houses present near the river channel because it was located in the downstream area, nearer and accessible to the roads towards the city proper. This station was near a bridge, with river dikes flanking both sides of the river and stretching across most of the barangay. The substrate primarily consisted of mud, sand, and silt. The river banks lacked trees and shrubs, with only grasses and sedges present, resulting in no canopy cover.

Predominantly planted on the three sampling stations were coconut and banana. There were also evident sand and gravel extraction activities along the river that can be observed on all sampling stations. Sampling of benthic macroinvertebrates was conducted on April 24-25, 2023 (station 3 and 2 respectively) and May 4, 2023 (station 1).

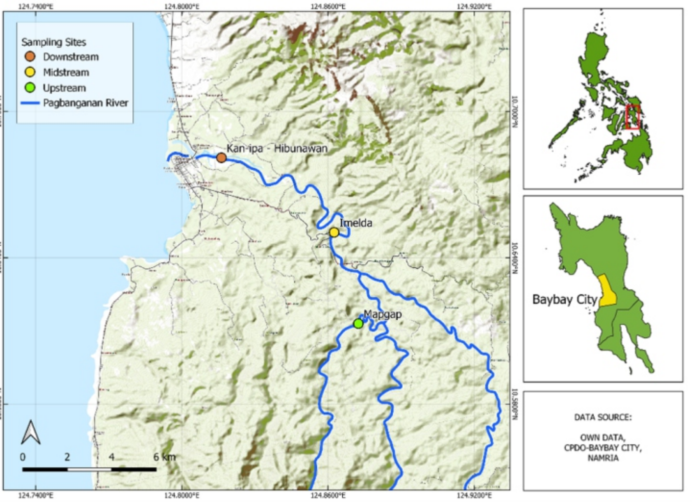

Figure 1. Map showing the three sampling stations in the Pagbanganan River, Baybay City. Source: Google Maps and https://en.wikipedia.org/wiki/Baybay

Collection and Preservation of Macroinvertebrates

In collecting macroinvertebrate samples, a sampling reach was determined (six times the channel width) as a representative of the stream throughout the area of the river (Environment Canada 2012).

A metal cylinder frame Hess sampler with a diameter of 34 cm was used. Collection of macroinvertebrates was replicated thrice per sampling station within the sampling reach. A total of nine macroinvertebrates samples were collected from the three sampling stations. This was done by placing the sampler with the screened opening and net (243 µm mesh size) securely on the river bottom facing downstream. Large rocks and/or cobbles were lifted and later removed after being scrubbed gently within the sampler, scraping off all possible attached macroinvertebrates. The remaining sediments within the sampler were then disturbed using a screwdriver for three minutes so that all organisms can flow into the Hess sampler net. The sampler's net was then dipped into the river a couple of times to rinse the sides of the net so as to direct the flow towards the detachable dolphin bucket attached to the end of the net. The dolphin bucket was unscrewed from the net and was rinsed into a bucket with water to remove its contents. Once the sediments and other detritus settle at the bottom of the bucket, the samples were then transferred to labeled sampling bottles and was added with 95% ethyl alcohol for preservation. The sampler was cleaned in stream water before collecting another set of samples (Parker 2019).

Identification of specimen

In the laboratory, collected macroinvertebrate samples were placed in a petri dish and examined under a stereomicroscope for identification. Individual samples were identified, listed and counted. Photos were taken using a mobile phone's camera for documentation and further identification. Macroinvertebrate identification was limited up to the family level with the help of Waterwatch macroinvertebrate practical guide/Waterwatch Field Manual 2010 and from reputable online identification keys (Ingram et al. 1997; Jessup et al 2002; Macroinvertebrates.org n.d.; Murray et al 2018; Stroud Research Center n.d.).

Measurement of Physico-chemical Parameters

The physico-chemical parameters were measured before the collection of macroinvertebrate samples. Water temperature (^{o}C), water pH, dissolved oxygen (mg/L) and Total Dissolved Solids (mg/L) were measured using Horiba Water Quality Monitor wherein a multi parameter probe was dipped into the water after which the readings were recorded. Flow velocity (m/sec) was measured using the float method in which a partially filled water bottle was timed using a stopwatch as it floats on a predetermined 10 m-distance parallel to the river. The velocity was computed by dividing the distance by the average time it took the water bottle to travel per second._All readings were replicated three times and the mean was determined.

Data Analysis

Once the sample specimens were identified, the SIGNAL (Stream Invertebrate Grade Number - Average Level) version 2 scoring system was used to create a site score and water quality rating for the river under study using the different pollution tolerances of various macroinvertebrates as adapted from Waterwatch Field Manual (2010) and Chessman (2003). Each type of macroinvertebrate is assigned a 'grade number' from 1-10. Low grade number means that a particular macroinvertebrate is tolerant to water pollution and a high number means the macroinvertebrate is sensitive. To do this, a weighting factor was multiplied by the grade number of each macroinvertebrate family. Then the product result was summed. The sum of the product was divided by the total number of weighting factors to get the Stream Pollution Index (SPI) value. Number of macroinvertebrate type and Stream Pollution Index (SPI) value were then classified as high or low consulting the Macroinvertebrate type and SPI rating table. Finally, site condition was determined based on the SIGNAL 2 scoring table.

Data was analyzed by some ecological parameters like relative abundance, dominance, evenness, diversity and richness indices using the following formula (Magurran 1984):

1. Relative abundance (Ai):

$$(Ai) = \frac{\text{Total no. of individual species}}{\text{Total no. of species population}}$$

2. Dominance (Simpson's Index of Dominance (D)):

$$D = \Sigma (ni/N)^2$$

where:
D = dominance
ni = abundance of each species
N =total abundance

3. Species evenness (Pielou's Evenness Index (J')):

$$J' = \frac{H}{\ln\ (S)}$$

where:
H' = Shannon-Weiner Diversity Index
S = total number of
ln = natural log

4. Diversity (Shannon-Weiner Index (H')):

$$H' = \Sigma\ [(pi) \times (\ln pi)]$$

where:
H' = Shannon-Weiner Diversity Index
Pi = proportion of total sample represented by species i.
ln = natural log

5. Richness (Menhinick's Index (R_2)):

$$R2 = \frac{S}{\sqrt{N}}$$

where:
R_2 = Menhinick's Index
S = total no. of species observed
N = total no. of individuals observed

Furthermore, data were further analyzed using One-way Analysis of Variance (ANOVA) which was implemented in testing foe significant differences of the response variables considered in this study (diversity, evenness, richness, and dominance) among the three sampling stations of the river. Pearson Correlation Analysis was used to correlate the physico-chemical parameters of the rivers with diversity of macroinvertebrates.

RESULTS AND DISCUSSION

Macroinvertebrate Composition and Occurrence

A total of 29 macroinvertebrate families belonging to five classes (Acarina, Bivalvia, Gastropoda, Insecta and Polychaeta) and 11 orders were recorded in the three sampling sites of Pagbanganan River (Table 1). Class Insecta was the most represented of all macroinvertebrate species including seven orders (Coleoptera, Diptera, Ephemeroptera, Hemiptera, Lepidoptera, Plecoptera and Trichoptera). Station 1 had the greatest number of observed macroinvertebrates (20), followed by Station 2 with 18 species and station 3 with only 8 identified macroinvertebrates. It is clear that Station 3 had a lower diversity of macroinvertebrate species compared to Stations 1 and 2. This can be attributed to the higher level of human-induced disturbances in the downstream portion of the river, such as domestic waste from nearby residences, agricultural runoff, and sand and gravel extraction activities. These observations are consistent with the findings of Erasmus's 2021 study.

There were only two species that were common in all of the three sampling sites in the Pagbanagan River, the beetles under Family Elmidae (Order Coleoptera) and the true flies under Family Chironomidae (Order Diptera). These two groups are recognized to be abundant and widespread in freshwater ecosystems (Elliot 2008; Hilsenhoff 2001; Koperski 2019). However, there were macroinvertebrates that were only observed in specific sampling stations in the river such as the beetles Hydrophilidae and Psephenidae (Coleoptera), the true bugs Naucoridae, and Valiidae (Hemiptera), and the Pyralidae species (Lepidoptera) which occurred only in station 1. The Sphaeriidae under Class Bivalvia, the true flies Dytiscidae and Simulidae (Diptera), and the hemipteran Corixidae were only observed in Station 2. Meanwhile, the beetles Hydraenidae and Staphylinidae (Coleoptera) and the true flies Athericidae and Drosophilidae (Diptera) were only observed in Station 3. The specificity of certain groups of macroinvertebrates in the different areas of the river could be due to the differences of these organisms in terms of their sensitivity and tolerances to various river conditions, level of pollution, and riparian vegetation (Zelnik & Muc 2020).

Table 1. Species composition and occurrence of macroinvertebrates on the three sampling sites of Pagbanganan River

CLASS	ORDER	FAMILY	COMMON NAME	S1	S2	S3
Acarina	Unidentified	Unidentified	Mites	1	1	0
Bivalvia	Sphaeriida	Sphaeriidae	Clams/mussels	0	1	0
Gastropoda	Neotaenioglossa	Thiaridae	Snail	1	1	0
Insecta	Coleoptera	Elmidae	Beetles	1	1	1
		Hydraenidae	Beetles	0	0	1
		Hydrophilidae	Beetles	1	0	0

Table 1 continued to next page ..

Table 1 continued ..

		Psephenidae	Beetles	1	0	0
		Staphylinidae	Beetles	0	0	1
	Diptera	Athericidae	True flies	0	0	1
		Ceratopogonidae	True flies	1	1	0
		Chironomidae	True flies	1	1	1
		Drosophilidae	True flies	0	0	1
		Dytiscidae	True flies	0	1	0
		Simuliidae	True flies	0	1	0
		Tabanidae	True flies	1	0	1
	Ephemeroptera	Baetidae	Mayflies	1	1	0
		Heptageniidae	Mayflies	1	1	0
		Leptohyphidae	Mayflies	1	1	0
		Leptophlebiidae	Mayflies	1	1	0
		Prosopistomatidae	Mayflies	1	1	0
	Hemiptera	Corixidae	True bugs	0	1	0
		Naucoridae	True bugs	1	0	0
		Valiidae	True bugs	1	0	0
	Lepidoptera	Pyralidae	Moths	1	0	0
	Plecoptera	Perlidae	Stoneflies	1	1	0
	Trichoptera	Glossosomatidae	Caddisflies	1	1	0
		Hydropsychidae	Caddisflies	1	1	0
		Philopotamidae	Caddisflies	1	1	0
Polychaeta	Phyllodocida	Phyllodocidae	Bristleworms	0	0	1
			Total	**20**	**18**	**8**

Note: 1 (present) & 0 (absent)

Relative Abundance of Macroinvertebrates

The top two most abundant macroinvertebrate groups were from the Order Ephemeroptera with 37.78% and Order Trichoptera with 33.71% under Class Insecta. The rest of the identified macroinvertebrate species in the river were under Class Insecta belonging to Order Diptera, Coleoptera, Plecoptera, Hemiptera, and Lepidoptera comprising 24.61%, Class Acarina (2.51%), Class Bivalvia (0.69%), Class Gastropoda (0.52%), and Class Polychaeta (0.17%) (Figure 2).

It was observed that mayflies (Order Ephemeroptera) and caddisflies (Order Trichoptera) were abundant. These order together with stoneflies (Order Plecoptera) are categorized as pollution-sensitive in aquatic systems and are indicators of water quality affecting their abundance with the presence of active anthropogenic activities (Hamid & Rawi 2017; Hazeful et al 2016).

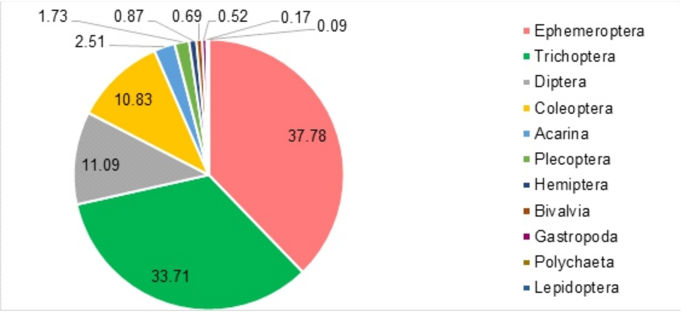

Figure 2. Relative abundance (%) of macroinvertebrates in Pagbanganan River

Macroinvertebrate Species Diversity, Evenness, Richness and Dominance

Station 2 supported the greatest number of macroinvertebrates with more equal distribution resulting in higher diversity index of H'=1.55, evenness of J'=0.70 and richness of R_2=0.53 compared to stations 1 and 3. Furthermore, this station had the lowest dominance value of D=0.27 compared with the other two stations which means that there were few species dominating on this site than the other two stations (Figure 3). High diversity and low dominance index values of macroinvertebrates could be attributed to more stable ecosystems and less disturbances (Padmanabha 2011).

On the contrary, station 3 had the lowest diversity (D=0.66) and evenness (J'=0.60) compared with station 1 and 2 but had the highest dominance value of D=0.63 which implies that species diversity was affected due to the uneven distribution of macroinvertebrate species in the area. These factors lead to increased impact from daily human activities, agricultural practices, and industrial processes. Furthermore, the decreased presence of riparian vegetation in the downstream portion of the river may negatively impact macroinvertebrate diversity and distribution, as plants play a crucial role in water pollution remediation (Suriano & Fonseca-Gessner 2013).

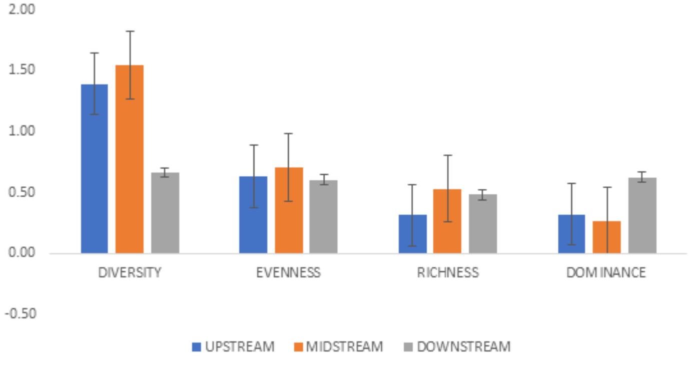

Figure 3. Diversity, Evenness, Richness and Dominance values in the three sampling sites of the Pagbanganan River

There was a significant difference (F=5.2621, p<0.05) in the diversity among the three sampling stations of the Pagbanganan River implying that the mean diversity of the upstream and midstream areas of the river was higher compared to the downstream area (Table 2). This could also explain the lesser occurrence of macroinvertebrate groups in Station 3 that could possibly be attributed to more anthropogenic disturbances in this area of the river. Meanwhile, there was no significant difference in the mean evenness, richness and dominance among the three sampling sites of the river. The results suggest that macroinvertebrate diversity is positively correlated with water quality, with higher diversity observed in less disturbed areas. (Arimoro & Keke 2017; Raphahlelo et al 2022).

Table 2. One-way analysis of variance (ANOVA) results of the biological indices of the three sampling stations of the Pagbanganan River

STATION	DIVERSITY		EVENNESS		RICHNESS		DOMINANCE	
	Mean	F_c	Mean	F_c	Mean	F_c	Mean	F_c
S1	1.3603^{a}	5.2621^{*}	0.6937^{a}	0.2909^{ns}	0.6197^{a}	0.3297^{ns}	0.3367^{a}	2.0401^{ns}
S2	1.3420^{a}		0.8060^{a}		0.7420^{a}		0.3143^{a}	
S3	0.7093^{b}		0.6783^{a}		0.8780^{a}		0.5770^{a}	

*Note: Means assigned with the same letter are not statistically different based on Tukey's HSD test at 5% level of significance; ns-Not Significant; *-Significant at 5% level*

SIGNAL 2 Scoring System

The analysis of the three sampling stations in the Pagbanganan River revealed that Stations 1 and 2 had high SPI scores of six, with only nine macroinvertebrate orders present. This suggests that the water quality of the river may be compromised by pollution sources upstream or limited habitat availability, exposing organisms to harsh physical conditions. The anthropogenic activities observed at the sampling sites, such as the disposal of domestic and agricultural waste and the extraction of sand and gravel, may have contributed to the observed degradation of water quality and the subsequent impact on the macroinvertebrate community. Station 3 exhibited a low SPI score of three and only three macroinvertebrate groups, indicating a significant decline in water quality. This degradation is likely caused by human activities such as urban, industrial, or agricultural pollution, or the downstream effects of dams, all of which were observed in the downstream area of the river. This site is nearer the city proper where there was a higher concentration of residential houses and commercial establishments as well as major roads and bridges compared to the other two stations. These factors can significantly affect the survival and diversity of organisms, such as macroinvertebrates, which play a crucial role in maintaining water quality.

Table 3. SIGNAL 2 scores of the three sampling stations of the Pagbanganan River

CLASS/ORDER	COMMON NAME	GRADE NO.	NO. OF SPECIMENS	WEIGHT FACTOR	GRADE NO. X WEIGHT FACTOR
Station 1					
Acari	Mites	6	26	5	30
Coleoptera	Beetles	5	75	5	25
Diptera	True flies	3	62	5	15
Ephemeroptera	Mayflies	9	371	5	45
Gastropoda	Snail	1	4	2	2
Hemiptera	True bugs	2	9	3	6
Lepidoptera	Moths	2	1	1	2
Plecoptera	Stoneflies	10	12	2	20
Trichoptera	Caddisflies	8	268	5	40
			828	33	185
SPI	6	high			
No. of species	9	low			
Station 2					
Acari	Mites	6	3	2	12
Bivalvia	Clams	3	8	3	9
Coleoptera	Beetles	5	43	5	25
Diptera	True flies	3	36	4	12
Ephemeroptera	Mayflies	9	65	5	45
Gastropoda	Snails	1	2	1	1
Hemiptera	True bugs	2	1	1	2
Plecoptera	Stoneflies	10	8	3	30
Trichoptera	Caddisflies	8	121	5	40
			287	29	176
SPI	6	high			
No. of species	9	low			
Station 3					
Coleoptera	Beetles	5	7	2	10
Diptera	True flies	3	30	3	9
Polychaeta	Bristleworms	1	2	1	1
			39	6	20
SPI	3	low			
No. of species	3	low			

Physico-Chemical Parameters

The average depth measured in the three sampling stations of the Pagbanganan River was 0.66 m with station 2 (0.46m) as the shallowest part of the river. Meanwhile, the average width was 70 m, while the river's average flow velocity was 0.33 m/s. Station 3 had the highest water temperature (30.68°C), likely due to the absence of canopy cover along the riverbanks. Since the sampling in this river was done during the summer months, the average water temperature recorded was 28.04°C which was within the acceptable limit of DENR (2016). According to the study conducted by Villarmino and Quevedo (2021) in this Pagbanganan river, average pH value was 7.4 which is close to the average pH recorded in the present study which is 7.3. Despite Station 3 exhibiting the lowest pH value of 6.89, all three stations maintained pH levels within the normal range of 6.5-9 for rivers, as stipulated by DENR 2016 and EPA 2023. Dissolved oxygen (DO) concentrations ranged from 6.60 mg/L in Station 3 and 8.53 mg/L in Station 1, possibly due to reaeration from differences in water depth and flow velocity (Villarmino & Quevedo 2021). However, the average DO measurement of 7.82 mg/L of the river fall within the standard range of freshwaters set by the EPA 2023 (6.5-8 mg/L) and DENR 2016 ($\geq$ 5 mg/L). Total dissolved solids (TDS) concentration in stations 1 (72 mg/L) and 2 (122 mg/L) were within the acceptable limits for rivers (100-20,000 mg/L) and drinking water (500 mg/L or less) according to EPA 2018 and LEO Envirosci Inquiry 2011. Station 3 had a TDS concentration of 1683 mg/L which is an unacceptable value for drinking water although it is still within the range of normal TDS value for rivers. This higher TDS concentration in the downstream area of the river may be due to more intense human disturbances such as daily domestic activities (e.g., washing of clothes, bathing, dumping of wastes), runoffs from agricultural fields as well as sand and gravel extraction since this site had more residential houses and structures (i.e., bridges and roads) near the river banks. These findings align with the lower species occurrence observed in Station 3, the downstream portion of the river. The elevated TDS levels in this area can negatively impact the presence and abundance of macroinvertebrate species by hindering their growth and reproduction (Halabowski &Lewin 2021).

Table 4. Physico-chemical parameters of the Pagbanganan River

PARAMETER	S1	S2	S3	Ave .	EPA (2023)	DENR (2016)	LEO (2011)
Depth (m)	0.56	0.46	0.96	0.66	-	-	-
Width (m)	30	45	135	70.00	-	-	-
Water Temp . (^{O}C)	25.74	27.69	30.68	28.04	$\leq$32	25-31	-
Flow Velocity (m/s)	0.45	0.44	0.09	0.33	-	-	-
pH	7.47	7.53	6.89	7.30	6.5-9	6.5-9	-
DO (mg/L)	8.53	8.34	6.60	7.82	6.5-8	$\geq$5	-
TDS (mg/L)	72	122	1683	625.67	$\leq$500	-	100 - 20,000

Species diversity was positively correlated with dissolved oxygen (DO) but was negatively correlated with water temperature and total dissolved solids (TDS) (Table 5). This means that as DO increases, so does diversity and vice versa. However, as water temperature and TDS increase species diversity decrease. There was also positive association between dominance and water temperature wherein an increase in water temperature also means an increase in dominance. These results show the same condition from the study conducted by Flores and Zafaralla (2012) in Cebu, Philippines as well as from the study of Silva et al (2009) conducted in Brazil where it was found out that macroinvertebrate diversity tends to be higher in areas with lower temperature and higher DO.

Table 5. Pearson's correlation analysis results of the Pagbanganan River

PHYSICOCHEMICAL FACTOR	DIVERSITY	EVENNESS	RICHNESS	DOMINANCE
	COEFFICIENT			
Water Temperature (^{O}C)	-0.8459 **	-0.2840 ns	0.1923 ns	0.7227 *
Flow Velocity (m/s)	0.5487 ns	0.1501 ns	-0.3157 ns	-0.4554 ns
Water pH	0.5215 ns	-0.1542 ns	-0.5289 ns	-0.3176 ns
Dissolved Oxygen (mg/L)	0.7663 *	0.1671 ns	-0.1627 ns	-0.5982 ns
Total Dissolved Solids (mg/L)	-0.8059 **	-0.1806 ns	0.2887 ns	0.6447 ns

*ns-Not Significant; *-Significant at 5% level; **-Significant at 1% level*

CONCLUSIONS

The study conducted revealed that there are different macroinvertebrate species present in the river that can be used as bioindicators of water quality.

Macroinvertebrate communities were observed to be more diverse and evenly distributed in station 2 of the Pagbanganan River while station 3 had the lowest diversity and evenness values with the highest dominance. The downstream area, with its concentrated residential and agricultural areas, roads, bridges, and sand and gravel extraction sites, experiences higher anthropogenic disturbance, affecting macroinvertebrate distribution. The diversity values also coincide with the results from the SIGNAL 2 scoring system suggesting that station 3 of the Pagbanganan River was affected by urban, industrial or agricultural pollution. The physico-chemical parameters measured further indicates that station 3 was more affected by anthropogenic pressures because of its slightly low pH and DO values with high TDS concentration which was an unacceptable value for drinking water.

RECOMMENDATIONS

Further studies are recommended for other barangays in the Pagbanganan River, including increased sampling frequency to compare seasonal variations. These are recommended in order to have a better and holistic view of the current environmental conditions of the river over different seasons. Additionally, it is recommended to educate Baybay City LGU and local communities on the ecological importance of macroinvertebrates and other organisms, promoting better freshwater resource management. Finally, the LGU should work hand in hand with the academe and other research institutions to evaluate and monitor the water quality of the rivers in order to come up with solutions to improve water resources management practices that promotes sustainability not just for the present but for the future generations as well.

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