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BIOLOGY 262- FRESHWATER ECOLOGY
BENTHIC MACROINVERTEBRATES AS BIOINDICATOR OF WATER QUALITY IN SAPANG BALEN RIVER, MABALACAT CITY, PAMPANGA

Abstract

The study was conducted to evaluate benthic macroinvertebrate communities as bioindicators of water quality in Sapang Balen River, Mabalacat City, Pampanga. Two sampling sites in the river were chosen based on their accessibility and land use (Clark Freeport Zone and Residential). Seven taxa of aquatic insects were identified, with the prevalence of pollution-tolerant Chironomidae (43.91%) and mildly tolerant Caenidae (37.91%). Meanwhile, analysis of the physical characteristics of the riverine water revealed that the majority of the parameters conformed with the DENR Class C Waters Qualification. Using the Hilsenhoff Family Biotic index (HFBI; x=12.49), and biological monitoring working party ($BMWP^{Thai}$; x=31) and Average Score per Taxon ($ASTP^{Thai}$; x=31), the Sapang Balen river water was confirmed to have poor quality.

Background of the study

Benthic macroinvertebrates have gained significant recognition as a valuable ecological indicator for assessing the condition of aquatic ecosystems, owing to their widespread use and inherent characteristics such as abundance, richness, and their well-documented ability to tolerate different environmental conditions (Rosenberg and Resh, 1993; Hering et al., 2006; Birk et al., 2012).

Moreover, distinct disturbances along gradients also impact aquatic insects (Hughes et al., 1998; Pont et al., 2009). Natural waterways in pristine forested areas exhibit higher macroinvertebrate diversity and taxa richness, whereas those affected by human disturbances often exhibit altered communities dominated by specific pollution-tolerant taxa groups (Brand and Miserendino, 2015).

In the past ten decades, the development of bioindices for Benthic Macroinvertebrates has expanded the range of measures, enabling a more comprehensive assessment. (Fierro et al. 2017). Many macroinvertebrate based bioassessment programs use univariate metrics to represent an assemblage like BMWP-type indices (Armitage et al., 1983), richness metrics and diversity indices. On the other hand, the widely adopted Hilsenhoff Biotic Index (HBI; Hilsenhoff, 1988) considers the presence and abundance of pollution-tolerant macroinvertebrates at different sampling locations.

Mabalacat City is a land-locked component city within the province of Pampanga. The city naturally channels surface water through its three main waterways: Sapang Balen river, Sacobia river and Quitangil river [12].

Sapang Balen river is identified as a component of the Pampanga River Basin. Prior to the eruption of Mt. Pinatubo in 1991, a portion of the Sacobia river flowed into the Sapang Balen river. Nevertheless, due to the incomplete lateral dikes project in 1994, the Sapang Balen river experienced siltation and flooding resulting in a breach between the two waterways. [19]

Although rivers are present in Mabalacat City, the primary source of water supply for all constituent districts is groundwater, accounting for approximately 47.05% of the total water supply. In contrast, a negligible percentage (0.01%) of households still rely on water obtained from dug wells, lakes, rivers, and rainfall. [12]

Mabalacat City encompasses a total land area of 16,692 hectares, which is predominantly utilized for residential, agricultural, special economic zone, and ancestral domain purposes. As of 2020, its population reached 293,244 individuals, making it the second most populous city in the province, trailing behind the City of San Fernando. [15]

Water quality is one of the growing environmental concerns observed on a global and local scale (Gadzała-Kopciuch et al., 2004). Similarly, pollution of rivers and other bodies of water poses a significant environmental issue throughout Mabalacat City. As stated in the city's Comprehensive Land Use Plan of 2014, water and solid waste are being disposed of in rivers, most likely by informal settlers residing along the riverbanks.

In a 2011 report from Japan International Cooperation Agency (JICA), Sapang Balen river and Quitangil river are among the most problematic receiving water bodies of industrial and livestock pollution in the Pampanga River Basin. Specific areas on the stream are also hotspots of waste dumping incidents, except for the areas located in Clark Freeport and Special Economic Zone (CFEZ). [14]

In 2018, the water quality assessment of Sapang Balen indicated that sixteen out of the total water parameters examined complied with DENR Class C guidelines for Fresh Surface Waters. However, there were five parameters that did not meet the specified guidelines. These nonconforming parameters included temperature (31.70°C), biochemical oxygen demand (BOD, 10 mg/L), fecal coliform levels (350 MPN/100 ml), accompanied by total coliform levels (920 MPN/100 ml), phosphate-phosphorus (PO4-P, 0.516 mg/L), and copper (Cu, 0.0343 mg/L). [4]

This pollution problem demands attention and mitigation measures to safeguard the city's water resources and preserve the overall environmental quality. However, the limited

baseline information on the physical, chemical, and biological characteristics of the Sapang Balen river is a significant concern.

This study aims to assess the water quality of Sapang Balen River, Mabalacat City, Pampanga with the identification of the following metrics: (1) Physical and Habitat parameters and (2) Aquatic macroinvertebrate assemblages.

II. MATERIALS AND METHODS

2.1. Study Site

Sapang Balen river, also known as Mabalacat River, is one of the main waterways that flows through Mabalacat City, Pampanga. It passes through several barangays, including Sapang Balen, Paralayunan, Atlu Bola, Mangalit, Mamatitang, Poblacion, Sta. Ines, San Francisco, and Marcos Village [12]. Situated between Sacobia River and Quitangil River, these three rivers collectively cover approximately 485.20 hectares of the city's area (Figure1).

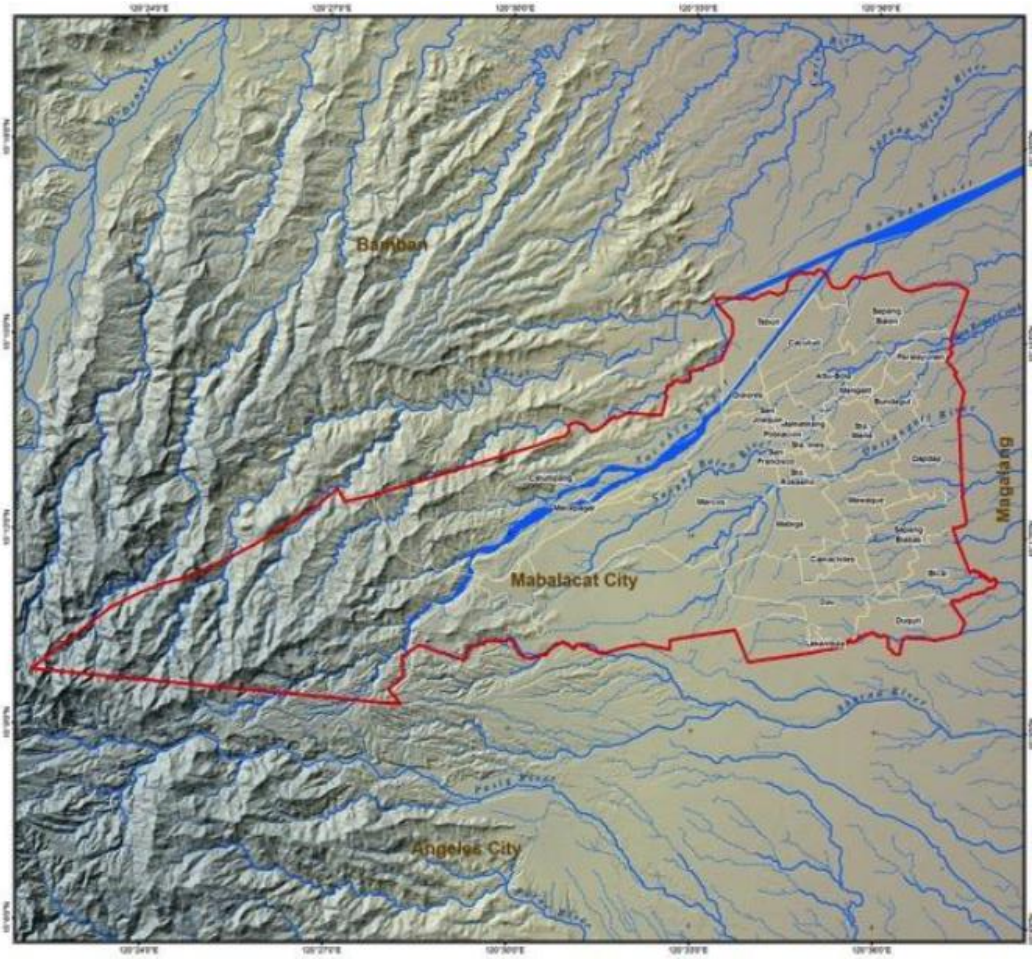

Figure 1. River Map of Mabalacat City, Pampanga.

Mabalacat City exhibits a relatively higher elevation compared to other regions within the province, with elevations ranging from 32.83 to 1,119.08 masl [12]. Climate in the area is categorized as tropical monsoonal with a distinct dry season from November to April and a wet season from May to October due to the presence of natural mounds on the west and east peripheries of the city (Figure 2).

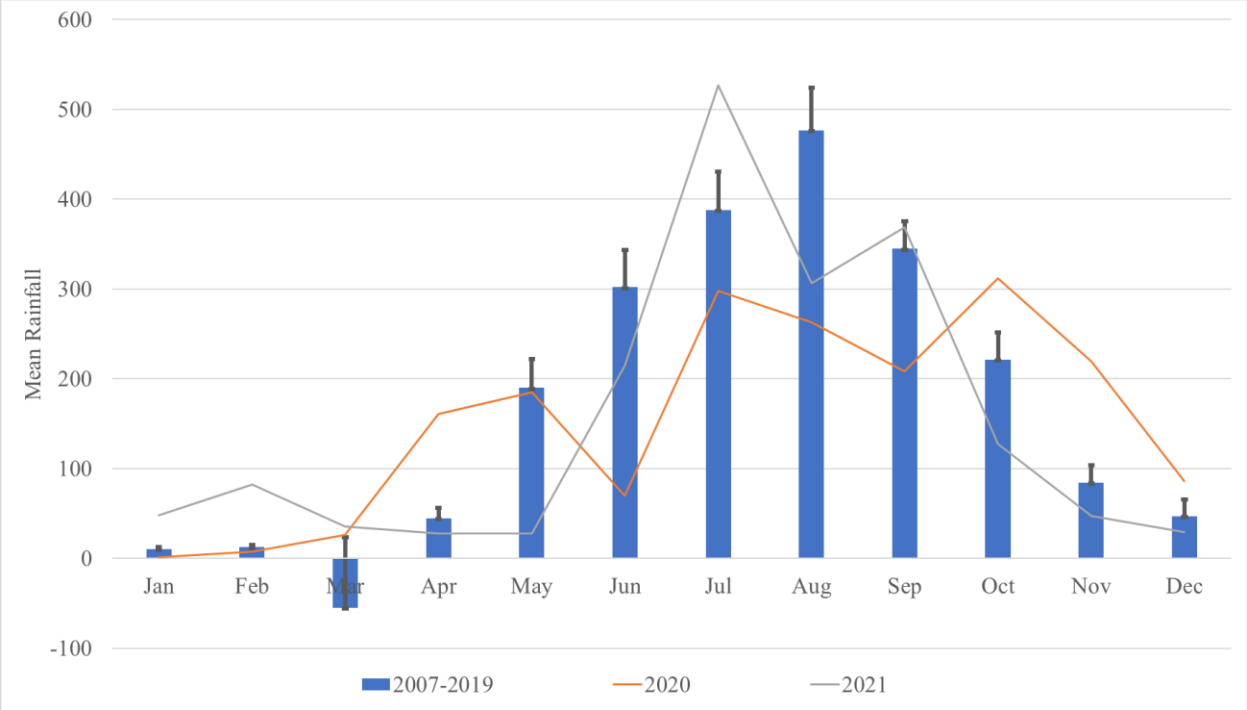

Figure 2. Mean rainfall (± standard error) values in Clark Airport, Pampanga for the period 2007-2019, and for years, 2020 and 2021. Data retrieved from the Climatology and Agrometeorology Division of the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA). 2022 climate data are still under quality control and not available for use.

Two sampling sites were selected on the basis of their land use category (Figure 3) namely: Clark Special Economic Zone (Site 1, Clark), and Residential (Site 2, Sta Ines). The sampling occurred during the wet season, specifically on May 14 and May 20, 2023.

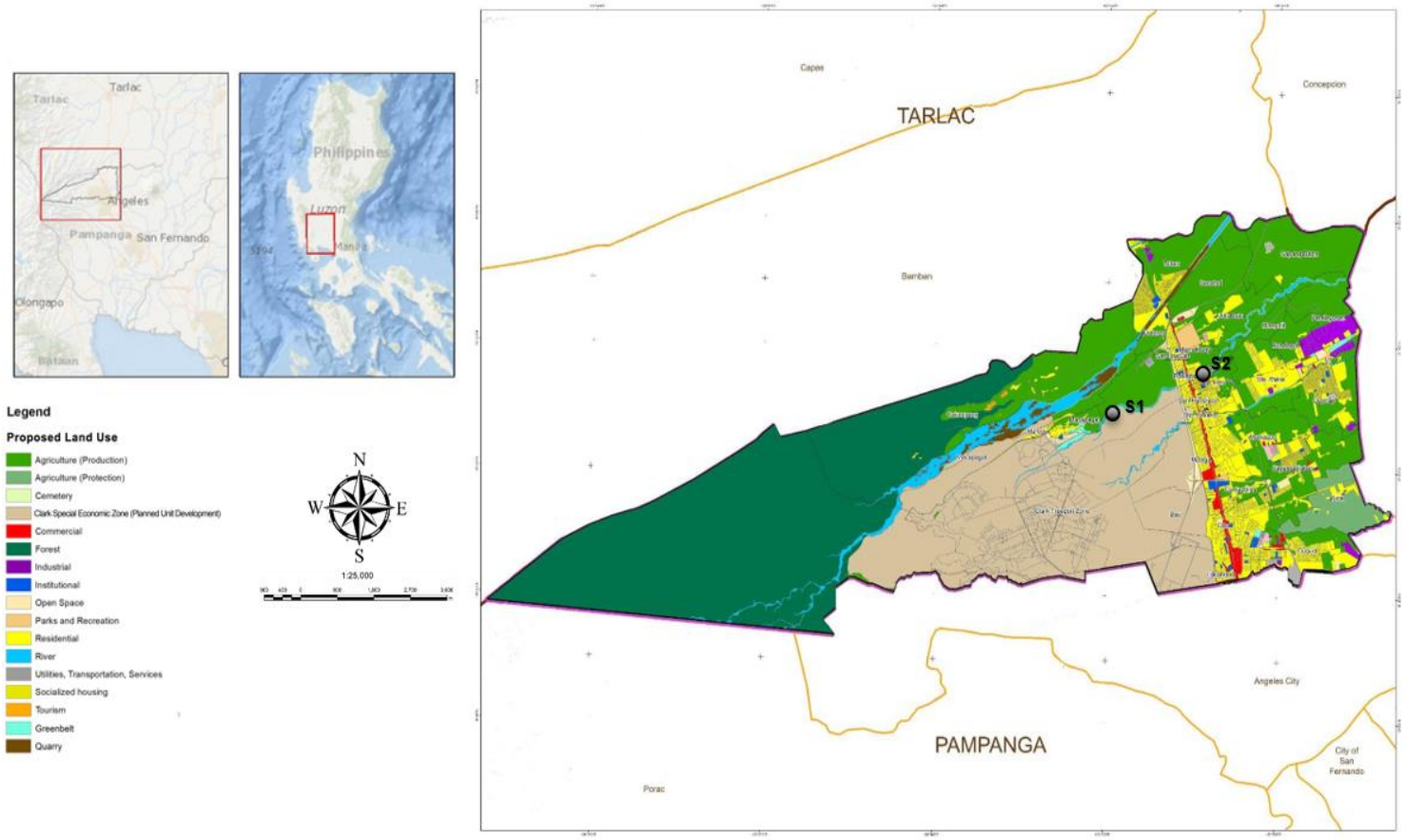

Figure 3. Map of Mabalacat City, Pampanga showing land uses and the geographic location of sampling sites. S1= Clark Freeport Zone, S2= Sta Ines (Residential)

2.2. Water Physical and Habitat Parameters

At the two designated sampling locations within the 50-meter stretch, various variables were assessed using a handheld meter (Hanna HI9811-5 pH/EC/TDS/Temperature meter). These variables included water temperature (°C), conductivity (µS/cm), and total dissolved solids (TDS; mg L-1). Additionally, measurements were taken for stream width (m), depth (cm), flow rate (m s-1), and water discharge (m3 s-1) in each designated area. These measurements were conducted prior to the collection of macroinvertebrates to minimize any disturbance.

Following this, the researcher employed the modified stream visual assessment protocol (Magbanua et al. 2013) to evaluate the riparian zones and instream habitats of the Sapang Balen river. This protocol encompasses a comprehensive set of 15 criteria that

assess the environmental condition of a stream, considering factors such as channel flow, depth patterns, bank stability, vegetative protection and zone, canopy cover, water appearance, nutrient enrichment, streambed characteristics (such as sediment deposition, habitats, habitat complexity, and barriers to movement), as well as the community of aquatic macroinvertebrates.

2.3. Benthic Macroinvertebrates

The abundance and distribution of benthic macroinvertebrates are considered to be influenced by the measured physicochemical parameters (Fetsing et al, (2022). To collect the macroinvertebrates, the researcher utilized a Surber sample and an improvised D-net to manually collect specimens from three major habitats: margin vegetation, pools, and riffles. The collection process lasted for 3 minutes per present habitat (Bis and Mikulec, 2013).

After collection, the samples were preserved in 50 mL centrifuge tubes containing 95% ethanol for subsequent sorting and identification in the laboratory (Wetland and linked Aquatic-Terrestrial Ecosystems Research Laboratory). Then, samples were washed and elutriated using a 250-µm sieve to separate macroinvertebrates from plants, sediment, and other inorganic materials (Magbanua et al. 2019)

The relatively large benthic macroinvertebrates were initially sorted based on their morphology using an illuminated magnifier, while the relatively small individuals were grouped using a stereomicroscope. Morphologically-similar organisms were then placed in appropriately labeled 50-mL centrifuge tubes with 95% ethanol. The taxonomic family level of the macroinvertebrates was identified using the keys provided by Yong and Yule (2004) and the Mekong River Commission (2006).

Using the collected macroinvertebrate data, several biological metrics were calculated, including: (i) total invertebrate density, (ii) richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) insect orders, and (iii) Simpson's Index of Diversity and Evenness.

III. STATISTICAL ANALYSIS

Independent T-tests were made to assess the difference of the values of each water and habitat parameter between the two sites as the samples have related conditions. A p-value less than 0.05 is commonly used as a threshold for statistical significance.

IV. RESULTS AND DISCUSSION

4.1. Water Physical and Habitat Parameters

The Department of Environment and Natural Resources, Philippine standards, classified Sapang Balen River as Class C Water (DENR 2006). In this study, temperature (30.80ºC),

pH level (7.20 pH) and total suspended solids (11.40mg/L) conformed to the Class C standards, compared with the noncompliant temperature (31.70ºC) in 2014.

The results also showed that among the physical water parameters Flow Rate, Conductivity, pH level, and TSS had significant differences between Clark and Sta Ines Sites *(P ≤ 0.01 in all cases, Table 1)*

Meanwhile, among measured riparian and in-stream habitat parameters, only Channel Flow, Pool Variability, Canopy Cover, Nutrient Enrichment, Pool Substrate Characterization, and Aquatic Invertebrate Habitat did not differ from the two sites (P ≥ 0.057 in all cases; Table 1)

Parameter		Sapang Balen River			
		Site 1 (Clark)	Site 2 (Sta Ines)	Mean	P-value
Water Physical Parameters	Stream Width (m)	7.46	6.46	6.96	0.749
	Water Depth (cm)	20.35	22.78	21.57	0.586
	Flow Rate (s)	6.74	1.89	4.32	0.008
	Temperature (ºC)	30.83	30.67	30.75	0.627
	Conductivity (uS cm-1)	566.67	690.00	628.34	<0.001
	pH level	6.83	7.50	7.17	0.010
	TDS (mg L-1)	278.33	340.00	309.17	<0.001
	TSS (ntu)	1.67	6.00	3.84	0.008
	Turbidity	0.48	0.77	0.63	0.181
Riparian and Instream Habitat	Channel Flow	8.50	10.00	9.25	0.609
	Channel Alteration	15.00	2.50	8.75	0.002
	Pool Variability	7.50	3.00	5.25	0.057
	Bank Stability	6.50	1.50	4.00	0.087
	Bank Vegetation Protection	19.00	7.50	13.25	0.009
	Riparian Vegetation Zone Width	18.50	3.00	10.75	0.005
	Canopy Cover	0.50	0.00	0.25	0.423
	Water Appearance	11.00	3.00	7.00	0.015
	Nutrient Enrichment	7.50	4.00	5.75	0.192
	Sediment Deposition	13.50	4.50	9.00	0.030
	Pool Substrate Characterization	9.50	5.50	7.50	0.127
	Barriers to Species Movement	18.50	14.50	16.50	0.030
	Fish Habitat Complexity	9.00	3.50	6.25	0.008
	Aquatic Invertebrate Habitat	6.50	6.00	6.25	0.423
	Macroinvertebrate Community	9.50	3.50	6.50	0.014
	Overall habitat score	10.80	4.83	7.82	0.004

Table 1. Mean (x) stream physical and habitat parameter values of selected parts of Sapang Balen River, Mabalacat City, Pampanga.

4.2. Benthic Macroinvertebrates

Classes Insecta and Gastropoda were recorded on the Sapang Balen river. A total of 583 belonging to 8 families were collected on the two 50-m sampling sites. Accordingly, 43.91% of the samples collected belong to pollution-tolerant Chironomidae and 39.79% from mildly tolerant Caenidae, citing the prevalence of pollution in the Sapang Balen River. (Table 1)

The dominant macroinvertebrates are known for their adaptability to various environmental conditions, including low dissolved oxygen concentration and high levels of dissolved solids. This wide tolerance enables them to flourish in diverse habitats, spanning from pristine streams to those severely impacted by degradation (Rosa et al., 2014, Shimano and Juen, 2013).

MACROINVERTEBRATES			SAPANG BALEN RIVER			
			number of organisms		number of organisms	
CLASS	**ORDER**	**FAMILY**	**Site 1 (Clark)**	**%Richness**	**Site 2 (Sta. Ines)**	**%Richness**
INSECTA	EPHEMEROPTERA	BAETIDAE	15	4.45	9	3.66
		CAENIDAE	139	41.25	93	37.80
	TRICHOPTERA	HYDROPSYCHIDAE	9	2.67	0	0.00
	ODONATA	CHLOROCYPHIDAE	11	3.26	8	3.25
	HEMIPTERA	GERRIDAE	1	0.30	0	0.00
	DIPTERA	CHIRONOMIDAE	138	40.95	118	47.97
		CULICINAE	1	0.30	0	0.00
GASTROPODA	BASOMMATOPHORA	LYMNAEIDAE	23	6.82	18	7.32
Total no. of individuals (by sampling site)			**337**	100.00	**246**	100.00
Over-all Total (by river)			**583**			

Table 2. Macroinvertebrate composition and abundance in Sapang Balen River, Mabalacat City, Pampanga by sampling site.

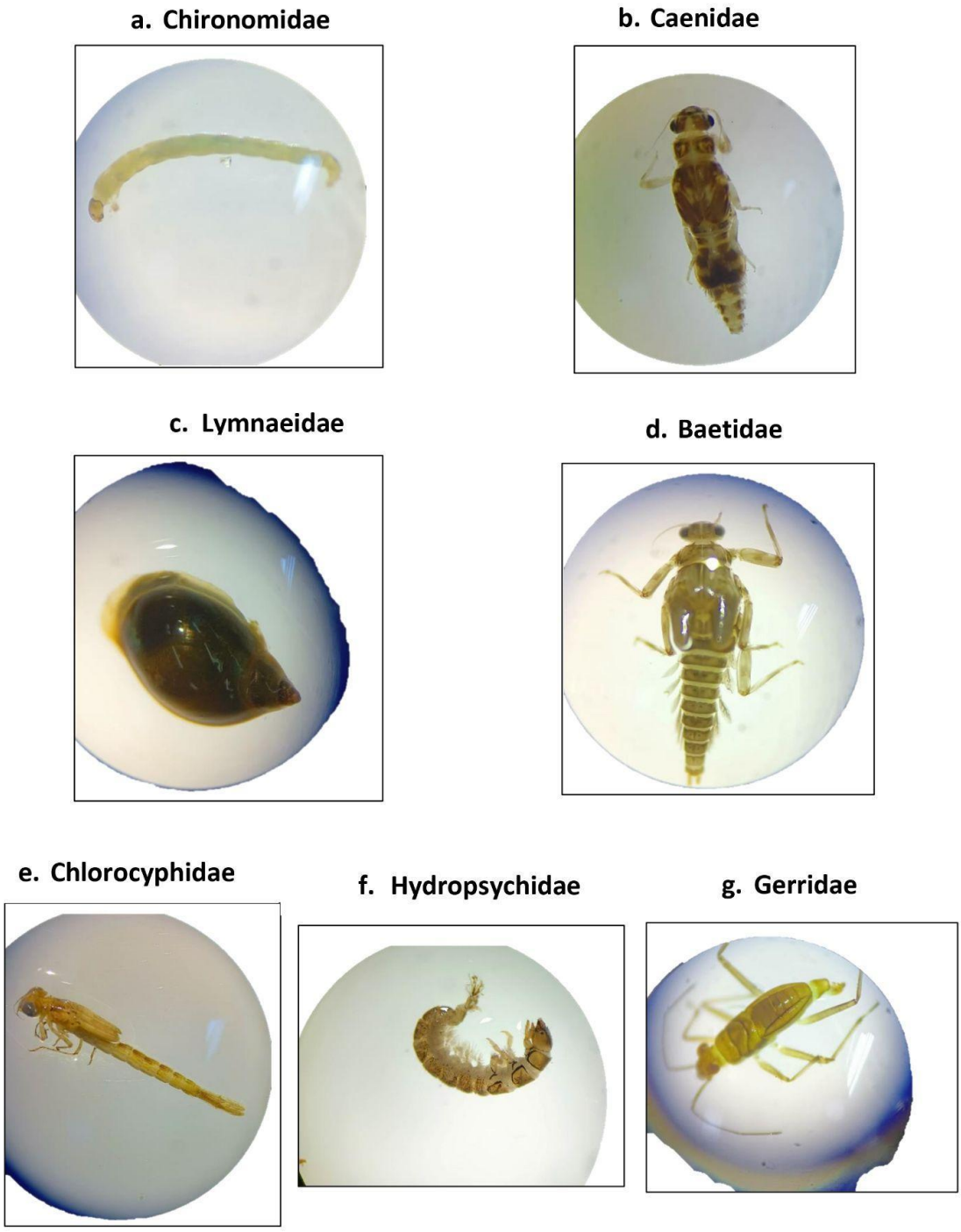

Figure 4. Macroinvertebrates across sampling sites in Sapang Balen River, Mabalacat City, Pampanga listed according to their abundance.

4.3. Biological Response Variables Among Sampling Sites

Two of the employed biological metrics, specifically the total density of benthic macroinvertebrates *(P=0.34)* and Simpson's Diversity Index *(P=0.94)*, exhibit no significant differences between the Clark and Sta. Ines sites. (Figure 4 and 5). The utilization of diversity indices is widespread in the assessment of freshwater stream health, as it enables the quantification of the diversity of benthic macroinvertebrates within a particular site. Consequently, it provides an evaluation of the overall condition of the streams (Linke et al., 1999). In this study, Simpson's Diversity Index was employed to determine the number of distinct taxa present across the sites and to assess the evenness of their distribution (Bailey et al., 1998).

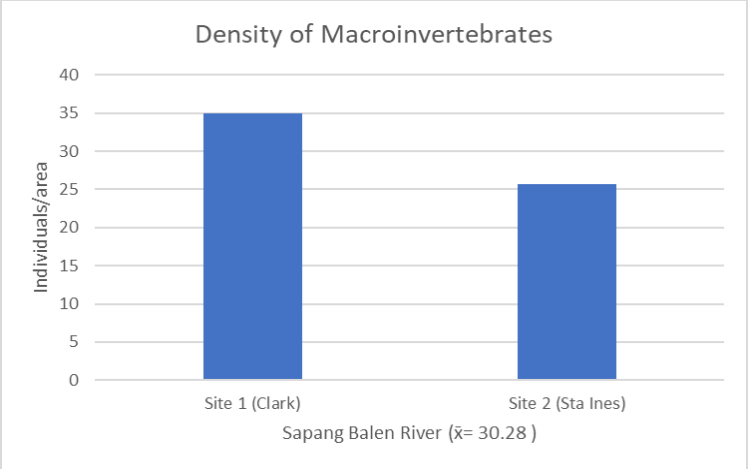

Figure 5. Density of macroinvertebrates across sampling sites in Sapang Balen River, Mabalacat City, Pampanga.

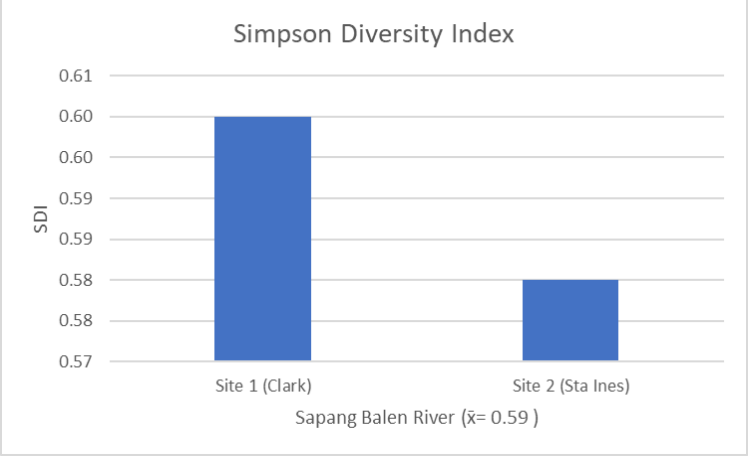

Figure 6. Simpson Diversity Index of macroinvertebrates across sampling sites in Sapang Balen River, Mabalacat City, Pampanga.

4.4. Stream Condition Based on Macroinvertebrate Biotic Indices

The high pollution tolerance score of collected and identified invertebrates in the Sapang Balen river led to poor stream condition ratings in all biotic indices, underscoring the polluted water quality condition of the waterway, regardless of land use.

site 1 and 2 exhibited relatively substantial pollution levels, as indicated by the Hilsenhoff Family Biotic Index (HFBI) values of 6.26 and 6.23 respectively. Additionally, the Biological Monitoring Working Party (BMWPThai) assigned a poor/polluted condition score of 31 to both sites. Furthermore, the Average Score per Taxon (ASTPthai) indicated moderately poor water quality of 4.43.

Parameter		Sapang Balen River			
		Site 1 (Clark)	Site 2 (Sta Ines)	Mean	Condition Score
Biotic Indices	HFBI	6.26	6.23	6.25	Fairly signifant organic pollution
	$BMWP^{Thai}$	31	31	31	Poor/polluted
	$ASTP^{Thai}$	4.43	4.43	4.43	Moderately poor water quality

Table 4. Biological Response Metric and Biotic Indices of Macroinvertebrates in Sapang Balen River, Mabalacat City, Pampanga by sampling site.

V. Conclusion and Recommendation

Pollution of freshwater rivers has become a pressing environmental issue in the country, with detrimental consequences for both aquatic ecosystems and human well-being. Thus, understanding the extent, sources, and ecological impacts of pollution in these rivers is essential for effective management and conservation strategies.

The results of this study revealed the general poor condition of Sapang Balen River. Accordingly, water quality based on considered variables indicated poor quality, which is consistent with the stream biota dominated by pollution-tolerant taxa.

The study reflected the previous results from the 2011 and 2014 studies on the waterway, highlighting the need for restoration efforts from the local government, underscoring the importance of continued monitoring and conservation efforts in the Sapang Balen river. Addressing pollution sources and implementing effective management strategies are crucial for the restoration and preservation of this ecosystem. Furthermore, the development of localized biotic indices tailored to the region would provide more accurate assessments of stream health and guide targeted conservation actions.

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