Assessment of Macroinvertebrates as Bioindicators of Water Quality in the Littoral Zone of Lake Mainit, Philippines

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ABSTRACT

Water quality in the lake littoral zone influence habitat complexity. This study determined the relationships of macroinvertebrates in response to water physicochemical parameters in ten littoral zone stations across four municipalities of Lake Mainit Philippines. Macroinvertebrates were collected following the standard protocol for littoral areas with modifications and taxa groupings were assigned based on sensitivity to pollution. Water Quality Index (WQI) from the identified bioindicator species was computed. Results revealed that all physicochemical parameters of the ten sampling stations passed the water quality standard set by DAO 2016, except for the pH and temperature readings of Mansayao and Tagbuyawan. Out of 20, 924 macroinvertebrates collected, 16 species were identified from 13 families. Station Mansayao exhibited higher species diversity (H'=1.98). No EPT (Ephemeroptera, Plecoptera, Trichoptera) species were observed across stations. Most of the macroinvertebrates collected were under Taxa 2 (50%) and Taxa 3 (50%), the presence of which, indicates moderate to poor water quality. The WQIs range from 3.1-3.7, which means the stations have "rather dirty to average" and "dirty water", except for the San Roque station (WQI=2.5), which showed a polluted water quality. Of the 16 species of macroinvertebrates collected, only ten species showed moderate positive association to pH, dissolve oxygen, temperature and Total Dissolved Solids. Littoral zones of the Lake Mainit still support and harbor a variety of aquatic macroinvertebrates. However, the abundance of pollution-tolerant species indicates a declining water quality due to the influence of anthropogenic activities surrounding the lake.

Key words: Bioindicators, Lake littoral zone, Macroinvertebrates, Water quality, Diversity, Taxa groupings.

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INTRODUCTION

There are more than 100 freshwater lakes in the Philippines that originated either tectonic, kettle, or maare in type.[1] Lake Mainit is a unique biodiversity area characterized by having various biodiversity resources.[2] The lake is primarily used for several commercial fisheries as a source of livelihood.[3] The lake is currently facing threats from several anthropogenic activities such as mining, unsustainable fishing practices, the use of agrochemicals and the increase of human settlements that might worsen the problem.[4] Some sections of the lake were reported exceed safe limits for lead (Pb) and total mercury (tHg) in the sediments.[5] However, several protecting agencies (e.g., DENR, BFAR, LMDA) already implemented a mechanism or plans towards management and conservation of the lake and the surrounding ecosystems.[6] Still, the practical efforts were not enough and need more capacity-building since

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some problems were not being addressed, such as the point and non-point source of pollutions that are still present in the vicinity.

Monitoring the status of freshwater quality and its biodiversity-ecosystem can be performed with the use of bioindicator species living in it.[7,8] Aquatic macroinvertebrates are biological indicators used to evaluate specific pollutants in the aquatic environment because of their slow mobilization, extended life period and sensitivity to environmental changes, tolerance and contamination.[9,10] Several contaminants include nutrient inflows and household waste products that have led to lake eutrophication, algal blooms and the increment of pollution tolerant organisms that affect other organisms and ecological imbalances, particularly in littoral zone areas.[11] The use of aquatic macroinvertebrates for aquatic ecological assessments gives a short, easy approach and less expensive compared to other methods.[12,13]

There were several limnological studies concerning the aquatic management and conservation status of the Lake Mainit as one of the key biodiversity areas in Mindanao.[14,15] Consequently, monitoring the lake's water quality must be updated to address problems concerning the provision of suitable habitat of many dependent aquatic organisms; hence, mitigating measures will be implemented to help alleviate the current issues. This study is the first comprehensive assessment of macroinvertebrates assemblages in Lake Mainit and the data collected could serve as baseline information for future monitoring purposes.

MATERIALS AND METHODS

Study Area and Sampling Design

The study was conducted in selected ten littoral zones of Lake Mainit, in the provinces of Agusan del Norte and Surigao del Norte, specifically in areas of Asinda, Mansayao, Alipao, Roxas, Tabuyawan, Bunga, Dinarawan, Kitcharao, San Roque and Jabonga, respectively (Figure 1). These sampling areas were selected randomly regardless of the terrestrial habitat types such as the distance from human settlements, presence or absence of farmlands, grassland, shrubland,

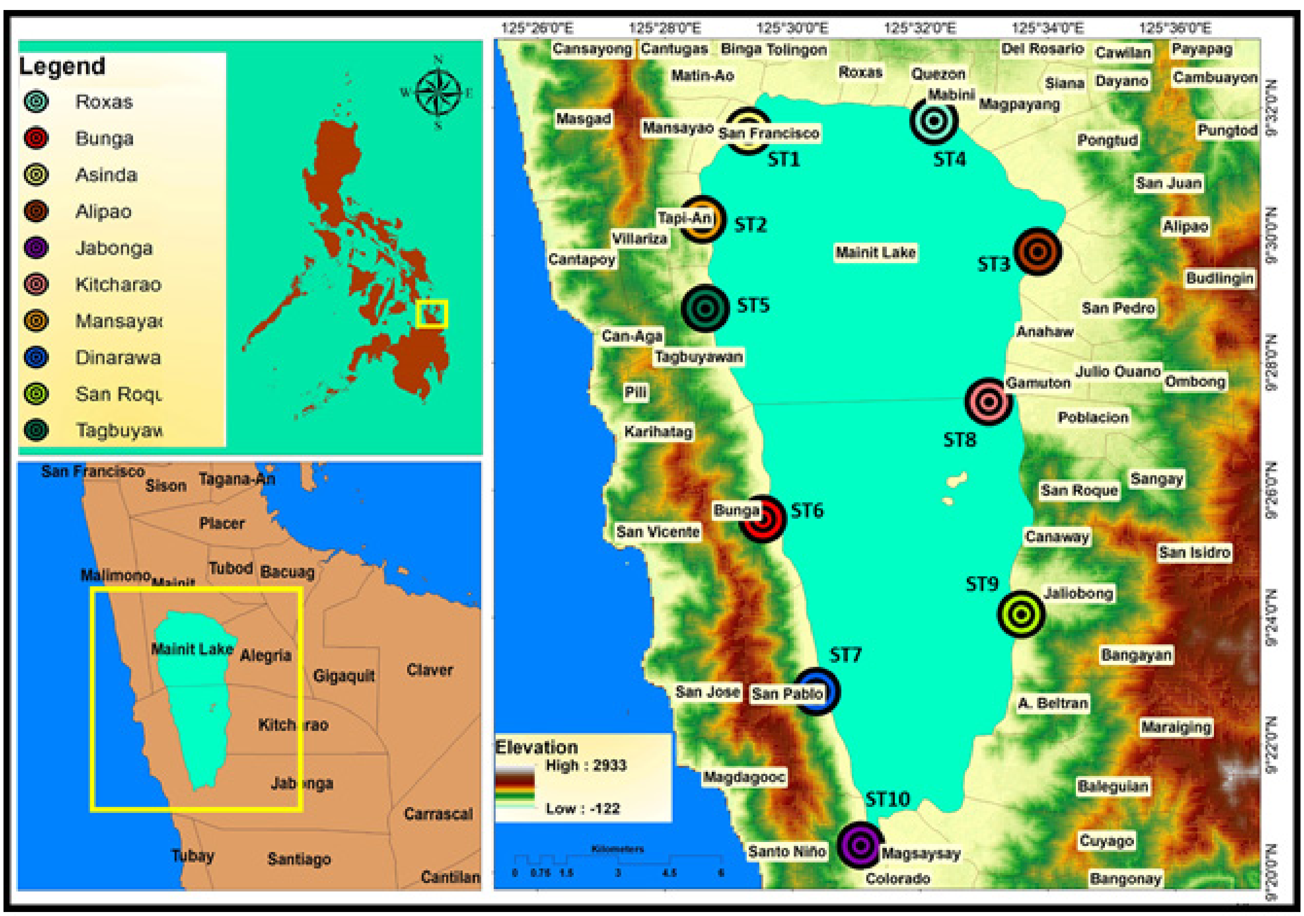


Figure 1: Map of Lake Mainit, Philippines showing the ten sampling stations in the provinces of Agusan del Norte and Surigao del Norte, Philippines.

bushes or whether it is near or far from river tributaries. Triplicate 100 m belt transects were established in the ten sampling stations. Each transect utilized 5 x 10 m quadrat for macroinvertebrate collection and measurement of water physicochemical parameters. Sampling was done in September to October 2017 and February 2018.

Determination of Physical and Chemical Water Properties

Water

The temperature, pH, dissolved oxygen (D.O), total dissolved solids (TDS), conductivity, resistivity and salinity of the water were analysed using a portable multi-meter instrument (Hach HQ40d). Secchi disc was used to measure water turbidity and echo-sounder/ fish finder (Lucky Fish Finder FF1108-1) to measure water depth. Readings of physical and chemical water properties were carried out nine (9) times per transect line to report the mean and the standard error of the mean (SEM±) among sampling stations. Physicochemical testing was done before the collection of macroinvertebrates to avoid water disturbance.

Macroinvertebrates Assessment

Sample Collection and processing

A standard method collection for littoral areas was adapted with modifications.[16] Three minutes was allocated to perform sweeps /jabs in the water and bottom sediments using a D-framed dip net for each transect and an additional 1 min for hand-picking of highly mobile macroinvertebrates. The collected samples were segregated and composited for each of the triplicate 100m transects for each station. Large specimens were placed in labeled zip-locks while smaller macroinvertebrates were placed in vials and then transported to the laboratory for sorting, documentation and identification. For more extended storage, some of the collected macroinvertebrates samples were preserved in 95% ethanol or 4% formalin depending on animal types.

Identification, Classification and Taxa groupings

Collected macroinvertebrates were sorted and identified based on Taxa groupings: Taxa 1 (pollution sensitive), Taxa 2 (wide range tolerant), Taxa 3 (pollution tolerant).[17] Digital Camera (Canon®) was used to document larger specimens, while Stereomicroscope (Lazes®) for smaller samples. The identification o macroinvertebrate species was done using online published journals[7,16,17] and consultation of experts.

Water Quality Index (WQI) Scoring

Macroinvertebrates collected were scored based on their tolerance and sensitivity to pollution.[18] The following WQI index were as follows, "very clean water= 7.7-10; rather clean to clean water = 5.1-7.5; rather dirty to average dirty water = 2.6-5.0; dirty water= 1.0-2.5; and very dirty water (no life at all) = 0".

Data Analyses

The mean values of physicochemical parameters were calculated using GraphPad Prism 7. Paleontological Statistics (PAST ver. 3.19) was used to calculate diversity, abundance, dominance and evenness of macroinvertebrates. To compare the means of macroinvertebrates abundance and water physicochemical parameters, a Kruskal-Wallis H test was used. Moreover, Spearman rank's correlation was used to analyze the association of the physicochemical properties in water to the macroinvertebrates abundance. The statistical results were set at significant p value is equal or less than 0.05. The analysis was done using IBM SPSS Statistics software (ver.20).

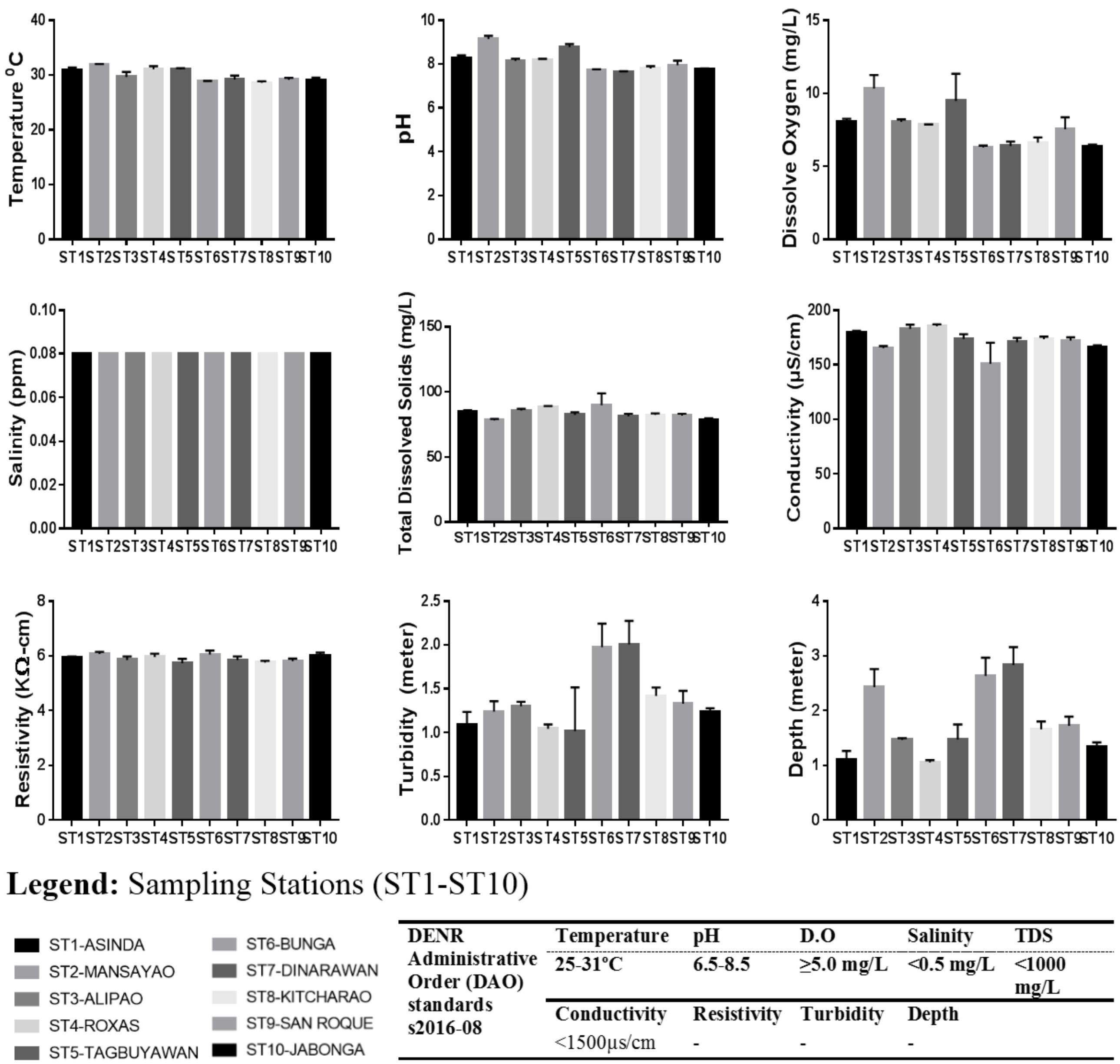
RESULTS

Water Physicochemical Assessment

The study revealed that all water physical and chemical test parameters passed the DAO series of 2016-08 water quality standards,[19] except for the temperature and pH readings of Mansayao and pH readings of Tagbuyawan (Figure 2). Temperature, resistivity, conductivity and total dissolved solids have very similar readings and salinity was consistent across sampling stations. Results showed a significant difference in temperature (p=0.001), pH (p=0.001), DO (p=0.020), conductivity (p=0.015) and depth (p=0.001) across sampling stations however, no significant difference were observed in TDS (p=0.173), resistivity (p=0.433) and turbidity (p=0.091) (Table 1).

Macroinvertebrates Assessment

A total of 20,924 macroinvertebrate individuals, belonging to 16 species and 13 families were collected. Phylum Mollusca had the most number of representative species (63%) followed by phylum Arthropoda (36%) and phylum Annelida (1%). Certain species such as *Caridina* sp., *Melanoides tuberculata*, *Corbicula fluminea* and *Vivipara angularis* were commonly observed and display dominance with regards to the number of individuals (Figure 3). Areas of Asinda, Mansayao, Alipao and Jabonga have the highest number of taxa collected, while Kitcharao has the highest number of individuals. Higher species diversity was observed in the areas of Mansayao



DENR Administrative Order (DAO) standards s2016-08	Temperature	pH	D.O	Salinity	TDS
	25-31°C	6.5-8.5	≥5.0 mg/L	<0.5 mg/L	<1000 mg/L
	Conductivity	**Resistivity**	**Turbidity**	**Depth**	
	<1500µs/cm	-	-	-	

Figure 2: Physicochemical properties of water (M±SEM) in selected sampling stations in Lake Mainit, Philippines.

(H'=1.98), Tagbuyawan (H'=1.93) and Alipao (H'=1.91). Furthermore, among the 16 species collected, only the species of *Melanoides tuberculata, Anodonta woodiana* and aquatic worm showed no significant difference at $p \leq 0.05$ (Table 2).

Taxa Groupings and Water Quality Index (WQI)

Seven gastropods and one annelid species were grouped under Taxa 3. Two bivalves (*A. woodiana* and *C. fluminea* and six arthropod species were identified under Taxa 2 (Table 3). No EPT (Ephemeroptera, Plecoptera, Trichoptera) or a pollution sensitive species under Taxa 1 collected throughout sampling stations. Taxa 3 representatives are generally tolerant to poor water quality conditions while Taxa 2 members most often thrive under a wide range to moderate water quality conditions.[17] Areas of Bunga, Dinarawan, Roxas and Tagbuyawan displayed the abundance of Taxa 3 representatives. Based on the macroinvertebrates collected, average WQI score from the ten littoral zones (3.6) indicates a "rather dirty - average dirty" water condition.

Association between Macroinvertebrate Abundance and Water Physicochemical Parameters

Among 16 macroinvertebrates collected, 10 species showed a significant association with the water physicochemical properties (Table 4). Certain species of gastropods and bivalves are greatly affected by the

Table 1: Comparison of water physicochemical properties between 10 selected sampling stations Lake Mainit, Philippines.

Physico-chemical Parameters in Water	Mean±SEM	*P*-value	Remarks
ATemperature	29.92±1.34	0.001	Significant
ApH	8.12±0.50	0.001	Significant
BDissolved Oxygen	7.69±1.69	0.020	Significant
ATotal Dissolved Solids	83.37±5.88	0.173	Not Significant
BConductivity	172.03±13.56	0.015	Significant
AResistivity	5.90±0.20	0.433	Not Significant
ATurbidity	1.37±0.46	0.091	Not Significant
ADepth	1.77±0.69	0.001	Significant

Significant at $p \leq 0.05$; ATested in ANOVA; BTested in Kruskal Wallis

influence on water quality. The association to water physicochemical parameters also vary from species to species. Moreover, only a few arthropods showed a significant association with the type of water quality in the sampling area. Water temperature, pH and dissolved oxygen showed a significant role in the abundance of species in the littoral zone areas of Lake Mainit.

Table 2: Comparison of macroinvertebrate abundance from littoral zones in selected sampling stations in Lake Mainit, Philippines.

Macro-invertebrate Taxa	Mean±SEM	AP-value
Pomacea maculata	12.50±12.57	0.007*
Vivipara angularis	153.17±361.85	0.004*
Thiara scabra	21.07±23.83	0.007*
Tarebia granifera	23.30±14.13	0.036*
Melanoides tuberculata	156.43±206.22	0.067
Radix rubiginosa	0.80±1.95	0.003*
Lymnaea natalensis	1.30±2.44	0.002*
Anodonta woodiana	5.60±7.69	0.070
Corbicula sp.	68.17±95.19	0.034*
Sundathelphusa philippina	3.30±6.61	0.010*
Limnopilos sp.	4.23±7.00	0.013*
Dragonfly nymph	0.73±1.66	0.015*
Aquarius remigis	3.60±4.52	0.023*
Penaeus monodon	237.77±703.08	0.008*
Ranatra linearis	0.07±0.25	0.028*
Aquatic worm	5.43±4.71	0.063

*Significant at p value ≤ 0.05 ATested in Kruskal Wallis Test

Table 3: Collected macroinvertebrates and Taxa classification found in in selected sampling stations in Lake Mainit, Philippines.

Phylum	Order	Taxa No.	Family	Scientific Names	No. of Individuals	WQI score
Mollusca	Architaenioglossa	3	Ampullariidae	*P. maculata*	375	3
		3	Viviparidae	*V. angularis*	4595	3
	Sorbeoconcha	3	Thiaridae	*T. scabra*	632	3
		3		*T. granifera*	699	3
		3		*M. tuberculata*	4693	3
	Hygrophila	3	Lymnaeidae	*R. rubiginosa*	24	3
		3		*L. natalensis*	39	3
	Unionoida	2	Unionidae	*A. woodiana*	168	6
	Veneroida	2	Curbiculidae	*C. fluminea*	2045	-
Arthropoda	Decapoda	2	Gecarcinucidae	*S. philippina*	99	3
		2	Hymenosomatidae	*L. naiyanetri*	127	3
		2	Palaemonidae	*Macrobrachium* sp.	22	4
	Odonata	2	Corduliidae	Dragonfly nymph	108	6
	Hemiptera	2	Gerridae	*A. remigis*	7133	5
		2	Nepidae	*R. linearis*	2	5
Annelida	Lumbriculida	3	Lumbriculidae	Aquatic worm	163	1
		Total Score			20,954	54
		Number of animal types scored				15
		WQI Score				3.6

Taxa 1. Pollution sensitive organism found in good water quality.
Taxa 2. Can exist in a wide range of water quality conditions; generally moderate water quality.
Taxa 3. Can exist in a wide range of water quality conditions; generally tolerant to poor water quality.

Table 4: Association between macroinvertebrate abundance and physicochemical properties of water in selected sampling stations in Lake Mainit, Philippines.

Species	Physico-chemical Properties of Water (Correlation Coefficient)							
	Temperature	pH	DO	TDS	Conductivity	Turbidity	Depth	
P. maculata	0.227	0.500*	0.388*	0.110	0.274	-0.401*	-0.422*	
V. angularis	0.034	-0.187	-0.293	-0.213	-0.438*	0.364*	0.369*	
T. scabra	0.576*	0.741*	0.715*	0.336	0.511*	-0.689*	-0.616*	
T. granifera	0.506*	0.486*	0.329	0.268	0.228	-0.397*	-0.351	
M. tuberculata	0.552*	0.452*	0.433*	0.409*	0.279	-0.585*	-0.350	
R. rubiginosa	0.177	0.321	0.402*	0.246	0.358	-0.234	-0.208	
Corbicula sp.	0.274	0.473*	0.571*	0.129	0.242	-0.568*	-0.453*	
S. philippina	0.460*	0.508*	0.465*	-0.180	-0.066	-0.061	0.105	
Limnopilos sp.	0.435*	0.630*	0.572*	-0.145	-0.021	-0.490*	-0.193	
A. remigis	0.374*	0.472*	0.364*	-0.028	0.112	-0.338	-0.378*	

*Significant at $p \leq 0.05$

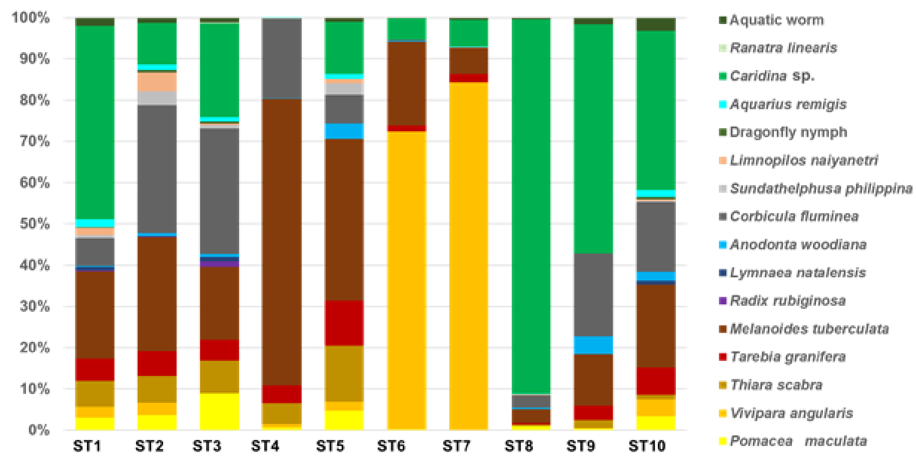


Figure 3: Macroinvertebrates species composition and abundance in selected sampling stations in Lake Mainit, Philippines.

DISCUSSION

Water Physicochemical Assessment

The littoral zones of Lake Mainit vary greatly on physical, chemical and biological components that contribute mainly to maintaining the ecological balance of both aquatic flora and fauna community. Variation of temperature and pH readings in the area of Mansayao and pH readings for Tagbuyawan was due to a time constraint. The said stations were sampled around 10:00 am to 3:00 pm where the temperature was notably high. Time and landscape variation could be factors why the two sampling stations' pH levels were higher compared to standards. In this study, water temperature, pH, dissolved oxygen and depth play a significant role in the growth, distribution and abundance of aquatic macroinvertebrates. The temperature is one of the survival factors of some aquatic organisms and it also alters the habitat availability of many aquatic organisms.[20] Moreover, the observed higher pH levels might be due to the varied landscape, vegetation type and anthropogenic activities in these stations. This might be why certain species such as *Caridina* sp., *V. angularis* and *M. tuberculata* show dominance and abundance, as observed in the sampling stations regardless of habitat type variations. Water composition flowing through the rocks and soils from the terrestrial environment contributes to phosphates primary sources to increase water alkalinity.[21] Water nitrate and sulfate removal via assimilation and dissimilatory reduction contributes to total lake alkalinity generation, resulting in increased water pH.[22] The high pH alkalinity of water also supports species richness.[23] The areas with notable low dissolved oxygen concentrations were the areas with high organic matter content, mainly from tributaries.[24]

Macroinvertebrates Assessment

Macroinvertebrates distribution and abundance are greatly influenced by the type of habitat and water quality status. The species that show abundance to every sampling station were observed to have different habitat types. Thus, their distribution is much likely influenced by their environmental conditions in which they can thrive according to their tolerance level. *Caridina* sp. were found abundant in areas near agricultural areas with sandy type of soil. The soil substrate and type of riparian vegetation serve as an indicator of crustacean distribution.[25] In contrast, mollusks that are abundant in some sampling areas such as *M. tuberculata*, *C. fluminea* and *V. angularis* also requires a sandy substrate and generate zonation patterns. The abundance of some mollusk species is carried by substrate type with a mixture of boulders, stones and sand as deep as 3-4 meters. However, as the depth increases, the number of individuals also decreases.[26] Gastropods have a file-like radula that mainly feeds on periphyton coverings found on rocks and plants.[27]

Taxa Groupings and Water Quality Index (WQI)

The equal occurrence of both Taxa 3 and Taxa 2 representatives may indicate that declining water quality. In contrast, Taxa 2 has 50% of a total species collected and suggest that the water quality is still in moderate condition. Moreover, water physicochemical testing parameters are within the acceptable range. Factors influence gastropods abundance includes water pH, salinity and desiccation tolerance.[28] The abundance of gastropods is greatly affected by the application of herbicide from agricultural lands.[29] Sampling areas of Bunga, Dinarawan, Roxas and Tagbuyawan have very similar environments, such as soil type (sandy-rocky), macrophytes, distance from the community and agricultural areas. Functional feeding groups of aquatic snails belonging to grazers and scrapers. Aquatic snails were suitable to grow in the four sampling areas mentioned because they have radula that enables them to scrape algae from the surface of the rocks.[30]

Association between Macroinvertebrate Abundance and the Physicochemical

Water physicochemical properties are the determining factors in the occurrence and abundance of aquatic macroinvertebrates. The current study shows certain macroinvertebrates taxa are associated with some water physicochemical conditions. Mollusks such as *P. maculata*, *T. scabra*, *T. granifera*, *M. tuberculata*, *R. rubiginosa* and *Corbicula* sp. may be affected when the pH and DO and even depth were beyond its tolerance level. Some Taxa 2 species, such as S. philippina, L. naiyanetri and A. remiges, may be affected by the changes in water temperature, pH and DO. Neutral pH contributed to the survival, growth, reproduction and dispersal of mollusk species.[28,31] Feeding activity of *P. maculata* is influenced by increase in water temperature, which also associated with the decreasing level of dissolved oxygen.[32] Moreover, sewage waste has been reported to decrease the level of DO and affecting the growth, survival and density of some bivalve species.[33]

CONCLUSION

This study is the first to report a comprehensive assessment of aquatic macroinvertebrates and water physicochemical analysis in the ten littoral zones of Lake Mainit. Water physicochemical parameters are within the acceptable range. The occurrence of Taxa 2 and Taxa 3 macroinvertebrates relative to their density and distribution pattern were affected by the type of water quality, serious ecological problems, anthropogenic disturbance and the influx of non-point source pollution. The use of macroinvertebrates as an indirect method for water quality monitoring suggests declining and poor water quality in Lake Mainit. Constant monitoring should be implemented to help alleviate and mitigate the current issue of water quality status.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

ABBREVIATIONS

D.O: Dissolve Oxygen; **pH:** power of hydrogen ions; **WQI:** water quality index; **T.D.S:** Total dissolved solids; **SEM:** standard error of the mean.

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