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Evaluation of Organic Pollution Using Algal Diversity in Rivers of Cotabato City, Bangsamoro Autonomous Region in Muslim Mindanao (BARMM), Mindanao Island, Philippines

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ABSTRACT

This study investigated the water quality and the organic pollution level of rivers in Cotabato City, specifically the Rio Grande de Mindanao, Matampay, Esteros, and Tamontaka rivers. The physicochemical characteristics of water in these rivers were determined in the laboratory, and the level of organic pollution was determined using Palmer's algal pollution index. Water quality assessment showed that the dissolved oxygen (DO) in Matampay River and the biological oxygen demand (BOD) in Esteros River exceed the minimum standard set by the Department of Environment and Natural Resources (DENR) for water quality in class C rivers. Results also showed that there were thirty (30) algal genera belonging to twelve (12) classes were observed in Cotabato City rivers. Algal genera belonging to *Chlorophyceae* and *Bacillariophyceae* were found to be the most abundant in these rivers. Using Palmer's algal pollution index, the Rio Grande de Mindanao showed a probability of high organic pollution, while the rest of the rivers indicated a lack of organic pollution. For a more thorough assessment of the Cotabato City rivers, it is advisable to consider more comprehensive measures, such as extending the sampling duration and expanding the number of sampling stations.

INTRODUCTION

Among the freshwater ecosystems, rivers are among the most productive and diverse ecosystems, representing below a percent of the Earth's surface (Opperman et al. 2015). This ecosystem has been utilized for domestic and personal purposes (Tickner et al. 2017). However, rivers that are situated near urban areas have been negatively affected by anthropogenic activities such as sewage discharge and industrialization (Khatri & Tyagi 2015). This leads to the degradation of rivers, worsening their water quality and adversely affecting the living organisms that depend on them (Bassem 2020).

Algae has an important role in a freshwater environment. It yields oxygen, consumes carbon dioxide, and serves as the foundation of the aquatic food chain (Stevenson 2014). These organisms are recognized as excellent reflectors of water quality due to their rapid life cycle and fast response to a wide range of pollutants. Nowadays, eutrophication and freshwater quality are assessed using microalgae as bioindicators and standards (Parmar et al. 2016). The nutrient condition of water bodies, such as eutrophication, is reflected by the increasing number of blue-green algae.

In contrast, oligotrophic conditions are highlighted by the abundance of diatoms and green algae (El-Serehy et al. 2018). This makes the algae population reliable bioindicators of freshwater environments such as streams and rivers since they represent the status of an ecosystem through their distribution and type. Furthermore, freshwater monitoring is much easier using algae as bioindicators due to the ease of sample collection, and most species are easy to identify (Omar 2010).

The growth and responses of freshwater algae have a positive response to variations in water quality. The abundance of organic nutrients in a freshwater body could lead to a sudden increase in the algal population and has been considered a detrimental environmental problem (Paerl et al. 2018). Several studies evaluated the level of organic pollution in freshwater bodies using algae in rivers (Bhatnagar & Bhardwaj 2013, Noel & Rajan 2015, Salem et al. 2017). Algal communities can serve as biological indicators of environmental changes in freshwater ecosystems, such as in rivers (Omar 2010). Palmer's algal pollution index is a tool that has been used to provide descriptive characteristics of the level of organic pollution in freshwater bodies using algal communities (Palmer 1969). Several studies have used the index in determining the water quality of various freshwater bodies, particularly in rivers. Shahare (2017) used this index in assessing the organic pollution level of the Chudband River in Gondia District, India. Results showed the different physicochemical parameters of a water sample have a direct relationship with pollution-tolerant algal genera. Salem et al. (2017) also utilized Palmer's algal pollution index in evaluating the surface water quality of the middle Nile Delta in Egypt. The results of their study showed that the index is a reliable and convenient method for detecting organic pollution. In the Philippines, an assessment of water quality in rivers using Palmer's algal pollution index has also been conducted (Lacdan et al. 2014, Galinato & Evangelio 2016, Martinez 2017, Seriñio & Belonias 2020).

Cotabato City is an urban area situated in the Bangsamoro Autonomous Region in Muslim Mindanao (BARMM) that is located between the Rio de Grande de Mindanao and Tamontaka River, making it a catch basin of floodwater from the Ligawasan marshland in Maguindanao. The study of Corcoro et al. (2012) pointed out that these rivers are very important to residents aboding along these rivers as they provide a wide range of services such as irrigation, source of drinking water, and domestic purposes. To date, hydrological and biological studies in these urban rivers are very little to none. Hence, this study aims to determine the organic pollution in select areas of rivers in Cotabato City using different algal genera.

To our knowledge, there was no assessment regarding the determination of the probability of organic pollution based on algal diversity conducted in the rivers in Cotabato City. The data from this study will provide a valuable contribution to the knowledge about the diversity of algal diversity in rivers within an urban area in the country. Moreover, data on algal diversity indicating organic pollution may be utilized by policymakers and the community to come up with plans and programs that may help protect and conserve the rivers in Cotabato City.

MATERIALS AND METHODS

Study Sites

For this study, water samples were collected from three (3) sampling stations within the Rio de Grande Mindanao, Matampay, Esteros, and Tamontaka rivers in Cotabato City (Fig. 1) last August 2022. These rivers were classified as class C based on the classification set by the Department of Environment and Natural Resources (DENR). Class C rivers are intended to be used only for fish growth and propagation, recreational and agricultural purposes, and are not recommended for public water supply (DENR 2016). Sampling stations were established 10-15 meters from the river banks of each river and were at least 500 meters from each other. Proximity to the nearest household areas and access roads were the bases for establishing the sampling stations in each river. The abundance of *Eichornia crassipes* is highly notable in these rivers.

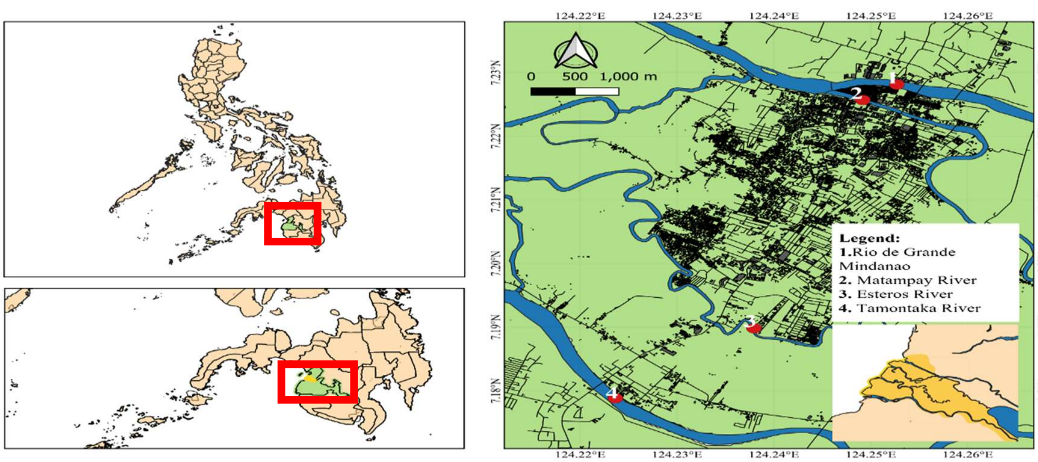

Fig. 1: Map showing the rivers in Cotabato City, BARMM, Philippines. (QGIS v3.24.1, PJdeVera).

Water Sampling

The physicochemical parameters of the water in the rivers, such as pH, dissolved oxygen (DO), biological oxygen demand (BOD), total dissolved solids (TDS), and nitrates, were determined in the laboratory. The temperature of the three (3) sampling stations in each river was determined on-site. Sampling stations were at least 500 meters from each other. Water samples were collected and placed in empty plastic bottles (labeled with river and station numbers). The empty plastic bottles were rinsed three times with the river water before collection. All water samples were taken at an average depth of at least twelve (12) inches from the surface water and were collected on the same schedule as the collection of algal samples. The samples were placed in a styrofoam box with ice and were brought to a third party for analysis. The temperature was determined using a mercury-filled thermometer *in situ*. The pH was determined through the electrometric method. DO was determined using the glass electrode. The BOD was determined through the respirometric method. TDS was evaluated through the gravimetric method. Nitrates were determined through a closed reflux cell test. All physicochemical parameters were determined following the standard methods for the examination of water and wastewater (WEF 2022).

Algal Collection and Identification

Algal samples were collected from the water surface of the same sampling stations where the water samples were taken. A plankton net was used to collect 250 mL of water from each river. Water samples were fixed using Lugol's solution and were brought to Notre Dame University, Cotabato City - Biology laboratory for identification of algal genera. All water samples were allowed to settle for 24 h in the Biology laboratory, and the supernatant was decanted until 20 mL of the liquid was left. One (1) mL of decanted water samples was placed in a Segdwick-Rafter counting chamber (Suther et al. 2009) and was examined under the microscope at higher magnification using an Olympus microscope cx23. Three replicates of 1 mL aliquot in each sampling station were used for the identification of algal genera. Only algal genera that are present at a density of more than fifty (50) cells in a one-ml sample were recorded for this study (Salem et al. 2017). Identification of algae down to the genus level was done using references by Palmer (1979) and Bellinger and Sigee (2005). The online database AlgaeBase (Guiry & Guiry 2018) was also consulted.

Level of Organic Pollution Using Palmer's Algal Pollution Index

The organic pollution level of the study areas was determined using Palmer's algal pollution index (Palmer 1969) (Table 1). Only algal genera that are present at a density of more than fifty (50) cells in a one-ml sample will be recorded and included in the index (Salem et al. 2017). All the algal genera identified and used for the analysis in this study were present in all three sampling stations established in each river. The recorded algal genera were compared with the list of pollution-tolerant genera listed in Palmer's algal pollution index. Index scores designated in each algal pollution-tolerant genera were added to obtain each river's total pollution index score. A score lower than 15 means that the river lacks moderate organic pollution; 15-19 indicates a high probability of organic pollution in the river, and 20 or more signifies high pollution in the river.

Data Analysis

Data collected from the physicochemical parameters were analyzed using the SPSS (version 26). One-way analysis of variance (ANOVA) was used to determine if there were significant differences ($p < 0.05$) among the rivers in Cotabato City. Tukey post hoc test was used to differentiate between means.

RESULTS AND DISCUSSION

Physicochemical Characteristics of Water Samples From Cotabato City Rivers

The mean values of the physicochemical parameters of water in rivers where water samples were taken are shown in Table 2. All the rivers assessed in this study were designated as class C based on the classification of water bodies by the Department of Environment and Natural Resources (DENR), Philippines. Results showed that these rivers had passed the minimum standard of water quality set by the DENR except for the dissolved oxygen (DO) in Matampay River and the

Table 1: Pollution-tolerant algal genera as listed in Palmer's algal pollution index.

Genus	Index Score	Genus	Index Score
Anacystis	1	*Micractinium*	1
Ankistrodesmus	2	*Navicula*	3
Chlamydomonas	4	*Nitzchia*	3
Chlorella	3	*Oscillatoria*	5
Closterium	1	*Pandorina*	1
Cyclotella	1	*Phacus*	2
Euglena	5	*Phormidium*	1
Gomphonema	1	*Scenedesmus*	4
Lepocinclis	1	*Stigeoclonium*	2
Melosira	1	*Synedra*	2

biological oxygen demand (BOD) in Esteros River. Data analysis showed that there is no significant difference in the DO in the Matampay River compared to other rivers such as Rio de Grande Mindanao and Tamontaka Rivers. However, the BOD in the Esteros River is significantly different from other rivers being studied (Table 2). High BOD levels were also observed in other class C rivers within an urban area in the country, such as the Carangan Estero in Ozamiz City (Enguito et al. 2013), Meycauayan River in Bulacan (Pleto et al. 2020) and the Guadalupe River in Metro Cebu (Claudio et al. 2019). High BOD may indicate high domestic discharges in the river system (Aniyikaye et al. 2019). However, this study is only limited to one sampling season. Thus, it is suggested that further monitoring of the water quality of Cotabato City rivers in different seasons shall be conducted to assess further the status of these freshwater bodies.

Algal Genera Present in the Rivers

A total of thirty (30) algal genera represented by twelve (12) classes were observed in the rivers in Cotabato City (Table 3). Algal genera observed in this study, such as *Asterionella*, *Cocconies*, *Eunotia*, *Gomphonema*, *Navicula*, *Nitzchia*, *Synedra*, *Ankistrodesmus*, *Oedegonium*, *Synura*, *Cryptomonas*, *Kumanoa*, *Ulothrix*, and *Spirogyra* were also found in other rivers in the country (Galinato & Evangelio 2016, Martinez 2017, Seriño & Belonias 2020, Arguelles & Monsalud 2021). However, the algal genera observed in this study are slightly lower compared to the algal genera noted in the Banahao (39 against 30 genera) and Biasong (32 against 30 genera) rivers in Leyte (Galinato & Evangelio 2016) and Pagbanganan river (39 against 30 genera) in Baybay City, Leyte (Seriño & Belonias 2020).

Algal genera belonging to *Chlorophyceae* and *Bacillariophyceae* were found to be the most abundant Cotabato City rivers. A high number of genera from *Chlorophyceae* and *Bacillariophyceae* in these rivers can be attributed to the vast number of genera under these classes (John et al. 2011). Moreover, the genera of *Bacillariophyceae* noted in this study were also present in the Banahao-Palhi rivers in Leyte (Galinato & Evangelio 2016). Among the six (6) genera included in Chlorophyceae, only the *Rhizoclonium* was present in all rivers. This may suggest that species from these genera were likely to be well-distributed in freshwater ecosystems.

Level of Organic Pollution in the Rivers

Among the twenty (20) pollution genera in Palmer's algal pollution index, there were ten (10) genera documented in this study. The number of pollution genera detected was similar to the number of pollution genera encountered in the Pagbanganan River in Baybay City, Leyte (Seriño & Belonias 2020). Moreover, the pollution genera observed in this study were slightly higher compared to algal pollution genera observed in the Banahao-Palhi River (9 against 10 genera) in Leyte (Galinato & Evangelio 2016) and in Ylang-Ylang River (4 against 10 genera) in Cavite (Martinez 2017).

Using Palmer's algal pollution index, all water samples collected from rivers in Cotabato City indicated a lack of organic pollution except in Rio Grande de Mindanao (Table 4). Out of the twenty (20) genera listed as indicators of possible organic water pollution, six (6) genera were documented in Rio Grande de Mindanao, namely *Anacystis, Synedra, Navicula, Nitzchia, Oscillatoria,* and *Euglena*. Based on Palmer's pollution index, this river yields a score of eighteen (18), which is interpreted as having a high probability of organic pollution.

The algal genus *Nitzchia* is common in all rivers except the Tamontaka River. It is considered an organic tolerant diatom that serves as a good indicator of organic pollution in both marine and freshwater ecosystems (Xia et al. 2020). This algal pollution genus was also observed in other rivers in the country (Galinato & Evangelio 2016, Martinez 2017, Seriño & Belonias 2020, Arguelles & Monsalud 2021). The presence of nutrients and organic substrates in freshwater regulates the relative abundance of these diatoms (Kim et al. 2019). This

Table 2: Physicochemical characteristics of rivers in Cotabato City.

Physicochemical Parameters (unit)	Water Quality Standard	Rivers Surrounding Cotabato City			
		Rio Grande de Mindanao	Matampay	Esteros	Tamontaka
Temperature [°C]	25-31	28.77 ± 0.59	28.6 ± 0.61	28.75 ± 0.67	28.87 ± 0.59
pH	6.5-9.0	7.78 ± 0.07^{a}	7.73 ± 0.03^{a}	7.48 ± 0.06^{b}	7.75 ± 0.05^{a}
Dissolved Oxygen - DO [$mg.L^{-1}$]	5	4.83 ± 0.32^{a}	5.03 ± 0.15^{a}	2.78 ± 0.06^{b}	4.63 ± 0.12^{a}
Biological Oxygen Demand – BOD [$mg.L^{-1}$]	7	3.1 ± 0.80^{a}	2.2 ± 0.61^{a}	9 ± 2.78^{b}	1.97 ± 0.96^{a}
Total Dissolved Solid – TDS [$mg.L^{-1}$]	500	114 ± 4.0^{a}	118.33 ± 1.53^{a}	123.33 ± 4.16^{a}	125.33 ± 4.73^{b}
Nitrates [$mg.L^{-1}$]	45	0.94 ± 0.09^{a}	0.57 ± 0.04^{b}	0.66 ± 0.04^{b}	1.17 ± 0.15^{a}

Values are expressed as mean ± standard deviation (n = 3). Means having identical superscript in the same row are not statistically significant ($p < 0.05$). Water quality standards were based on the Department of Environment and Natural Resources (DENR) – Philippines Water Quality Guidelines of 2016.

Table 3: Distribution of algal genera in Cotabato City rivers.

Algal Classes	Algal Genera	Rivers in Cotabato City			
		Rio Grande de Mindanao	Matampay	Esteros	Tamontaka
Bacillariophyceae	*Asterionella*	+	-	-	-
	Cocconeis	-	+	-	-
	Eunotia	-	-	-	+
	Gomphonema	-	-	+	-
	Navicula	+	-	-	-
	Nitzchia	+	+	+	-
	Synedra	+	-	-	-
Chlorophyceae	*Ankistrodesmus*	-	-	-	+
	Carteria	-	+	-	-
	Chlamydomonas	-	-	+	-
	Chlorogonium	-	-	-	+
	Crucigenia	-	-	+	+
	Oedogonium	+	+	-	+
Chrysophyceae	*Dinobryon*	-	+	-	-
	Synura	-	+	-	-
Conjugatophyceae	*Cosmocladium*	-	-	+	-
	Zygnema	-	+	-	-
Cryptophyceae	*Cryptomonas*	-	-	+	+
Cyanophyceae	*Oscillatoria*	+	-	-	-
Dinophyceae	*Ceratium*	-	+	-	-
Euglenophyceae	*Euglena*	+	+	-	+
Florideophyceae	*Bostrychia*	-	+	-	+
	Kumanoa	-	+	-	+
	Polysiphonia	+	-	+	-
	Sterrocladia	-	-	-	+
Ulvophyceae	*Rhizoclonium*	+	+	+	+
	Ulothrix	+	-	-	-
	Ulva	-	-	+	+
Xanthophyceae	*Excentrochloris*	-	-	+	-
Zygnematophyceae	*Spirogyra*	+	-	-	-

diatom can be used as a pollution index in rivers for assessing pesticide contamination (Rimet & Bouchez 2011). In the study conducted by Xia et al. (2020), *Nitzchia* indicated the high presence of organic pollutants and pesticides in the river, which may exacerbate if not controlled.

This study also noted the presence of *Navicula* and *Synedra* in the Rio de Grande de Mindanao, which were also present in the Ylang-Ylang River in Cavite (Martinez 2017), and in Pagbanganan River in Baybay City, Leyte (Seriño & Belonias 2020). These genera were noted as two of the most abundant genera in the Pagbanganan River (Labonite & Belonias 2013). The genus *Euglena* is another algal bioindicator recorded in the Rio Grande de Mindanao, Tamontaka, and Matampay rivers. This genus was also noted in the Ylang-Ylang River (Martinez 2017) and was used to calculate the organic pollution of the river based on Palmer's algal pollution index. Rastogi et al. (2015) stated that *Euglena* is a highly pollution-tolerant genus that can be used to detect eutrophication. However, the current study only accounted for the presence of the algal genera and not the frequency. Thus, continuous monitoring of algal diversity, as well as the frequency of the pollution-tolerant genera in the rivers of Cotabato City, is recommended to be conducted in future studies.

CONCLUSION

Among the rivers in Cotabato City, the Rio Grande de

Table 4: Palmer's pollution index values in rivers surrounding Cotabato City

Genera	Index Value	Esteros	Tamontaka	Matampay	Rio Grande de Mindanao
Anacystis	1	-	-	1	1
Ankistrodesmus	2	-	2	-	-
Chlamydomonas	4	4	-	-	-
Chlorella	3	-	-	-	-
Closterium	1	-	-	-	-
Cyclotella	1	-	-	-	-
Euglena	5	-	5	5	5
Gomphonema	1	1	-	-	-
Lepocinclis	1	-	-	-	
Melosira	1	1	1	-	-
Micratinium	1	-	-	-	-
Navicula	3	-	-	-	3
Nitzchia	3	3	-	3	3
Oscillatoria	4	-	-	-	4
Pandorina	1	-	-	-	-
Phacus	2	-	-	-	-
Phormidium	1	-	-	-	-
Scenedesmus	4	-	-	-	-
Stigeoclonium	2	-	-	-	-
Synedra	2	-	-	-	2
Total		8	8	9	18

Mindanao, particularly in Cotabato City, exhibited a high probability of organic pollution. At the same time, the Esteros, Tamontaka, and Matampay Rivers indicated a lack of organic pollution. The results of this study show that Palmer's algal pollution index can be utilized in detecting the levels of organic pollutants. Moreover, this index can be used as part of monitoring the health of the rivers along with the physicochemical characterization of the rivers. For further research, it is recommended to increase the sampling duration, both wet and dry seasons, in assessing the levels of organic pollution using algal diversity in Cotabato City rivers. The number of sampling stations in each river should be increased to capture the entire algal diversity in Cotabato City rivers.

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