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Physicochemical Characteristics and Fish Fauna Composition of Lake Duminagat, Mt. Malindang Range Natural Park, Philippines

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Abstract

Study on physicochemical properties and freshwater fish was conducted in Lake Duminagat, a lone small crater lake of Mount Malindang Natural Park with a total area of 8.04 hectares. Temperature, pH, oxidation reduction potential (ORP), electrical conductivity, turbidity, dissolved oxygen (DO), and total dissolved solids of (TDS) were the water parameters analyzed. The survey was undertaken in May 2013. The pH, turbidity, and DO in Lake Duminagat fall within the permissible limit for Class AA water body classification intended primarily for waters having watersheds that are declared as protected areas, whereas temperature and TDS were below the standards. Not all of the water parameters analyzed showed significant relationship with water depth. A total of six species of freshwater fish belonging to three families was collected. Diversity Index was found to be high (1.63). The most abundant species in the lake are the native *Barbodes binotatus* (34.43%) and the exotic *Xiphophorus helleri* (21.31%), whereas the native *Anguilla marmorata* (4.92%) was found to be the least abundant. Interestingly, three new exotic freshwater fish species were recorded, the *Xiphophorus helleri*, *Xiphophorus maculatus,* and *Poecilia reticulata*. This study provides an important update of the status of Lake Duminagat.

Keywords: diversity, freshwater, species, temperature, turbidity

Introduction

Lake Duminagat is the only established lake site of the Long-Term Ecological Research (LTER) in Mindanao spearheaded by the Center for Biodiversity Research and Extension in Mindanao (CEBREM) of Central Mindanao University. It is considered as an upland small crater lake with a total area of 8.04 ha (Hansel et al., 2005) nestled adjacent in the north peak of Mount Malindang Range Natural Park (MMRNP). The MMRNP is among the declared Protected Areas of the Philippines and serves as the only remaining representative natural forest of the Zamboanga Peninsula Biogeographic Zone (Myers, 1988). The lake is biologically significant which plays a vital role as water source for drinking and domestic purposes by the villagers (Hansel et al., 2004). However, the lake is also threatened by illegal logging, intrusion and tourism development like any other lake ecosystems in the country [Department of Environment and Natural Resources (DENR)–National Integrated Protected Areas Programme, 2000].

Being a natural park and a protected area, several research works have been undertaken on the rich flora and fauna, yet only little attention has been given to the freshwater fishes of MMNRP. The lone and first generation limnological research study in the lake was done by Hansel et al. (2004) under the Philippines-Netherlands Biodiversity Research Programme (BRP) for Development in Mindanao. That study focused on the participatory biodiversity inventory and assessment of Lake Duminagat providing important baseline data on lake's hydroecology and biodiversity. The study also showed the low productivity of the lake resulting to low account of fish species population. Some of the few freshwater fishes recorded were native and commercially introduced species. No other limnological research studies were conducted in the lake after the monumental work of Hansel et al. (2004).

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Lake Duminagat has no visible inlet streams with only one small outlet stream located at the southwestern part of the lakeshore that drains towards the Kalilangan River and eventually joins to Dapitan River (Arances et al., 2004). The small stream, however, only passes if there is a shallow depression from the lake's rim (Hansel et al., 2005). The lake is considered as a mystery and sacred place for the Subanen villagers because they believe that the water of the lake has a "healing power" that could wash off sins. Thus, this lake attracts many tourists during the Holy Week. Hansel et al. (2004) reported that the middle of the lake is potable enough as a source of drinking water for the villagers. Fishing is, however, discouraged because of their belief that the lake is a dwelling place of spirits. In 2013, during the conduct of this study, the residents living around the lake perimeter were observed fetching water in the middle of the lake for drinking purposes. Aside from drinking, domestic and "healing" use of the lake, Hansel et al. (2004) reported that the municipal government of Don Victoriano, Misamis Occidental planned to utilize the lake for fisheries and as a source of hydroelectric power. However, based on their findings of the lake's productivity and hydroecology, the proposed plan to tap water from the lake for a hydroelectric power plant is not feasible.

The lake is oligotrophic with at least five fish species on record (Hansel et al., 2004). Thus, this research primarily aimed to assess some physicochemical characteristics of the lake and update the list of freshwater fishes that would serve as additional baseline data for the lake's management. Specifically, this study determined the temperature, pH, oxidation reduction potential (ORP), electric conductivity (EC), turbidity, dissolved oxygen (DO), total dissolved solids (TDS), and the fish species composition of the lake highlighting those most in need of conservation interventions. The physicochemical properties were also correlated with water depth. Moreover, this study examined the association between the physicochemical properties of the lake and the freshwater fish diversity. The data provide an important update of the status of Lake Duminagat.

Materials and Methods

Study area and duration of the study

The study was conducted in the month of May 2013 in Lake Duminagat, MMRNP, Misamis Occidental with coordinates of 8°18'N and 123°37'E at the water's edge and elevation of approximately 1560 meters above sea level (Figure 1). The lake is considered as crater lake based on its geologic history (Dickerson, 1928) and basin's topography (Hansel et al., 2004). Despite being a known lake within the MMRNP, it was not included among the lakes of the Philippines reported by Pratt (1916) and Woltereck (1941) and was not in the list of Philippine Lakes compiled by the DENR-National Mapping and Resource Information Authority (1989).

The only outflow stream located in the southwestern shore of the lake was also sampled during the conduct of this study. Five households were notably observed, three of these were actively living around the lake. Fishing was not observed. Residents were observed bathing along the side and fetching water in the middle of the lake.

Physicochemical properties

A multi-parameter (Horiba U-52G) was used in measuring the physicochemical parameters of the lake, namely: water temperature, pH, ORP, EC, turbidity, DO, and TDS. The probe was submerged at various depths at one-meter intervals until it reached the bottom (23 m). A total of nine sampling points were randomly selected for the reading of the physicochemical data, three points in every west, east, and middle portion of the lake. The physicochemical parameters were not measured in the outlet stream. The DENR Administrative Order (DAO) No. 2016-08, DAO No. 34 (Series of 1990) and the Philippine National Standards for Drinking Water (2007) set by the Department of Health (DOH) were the references used to determine the water quality of the lake.

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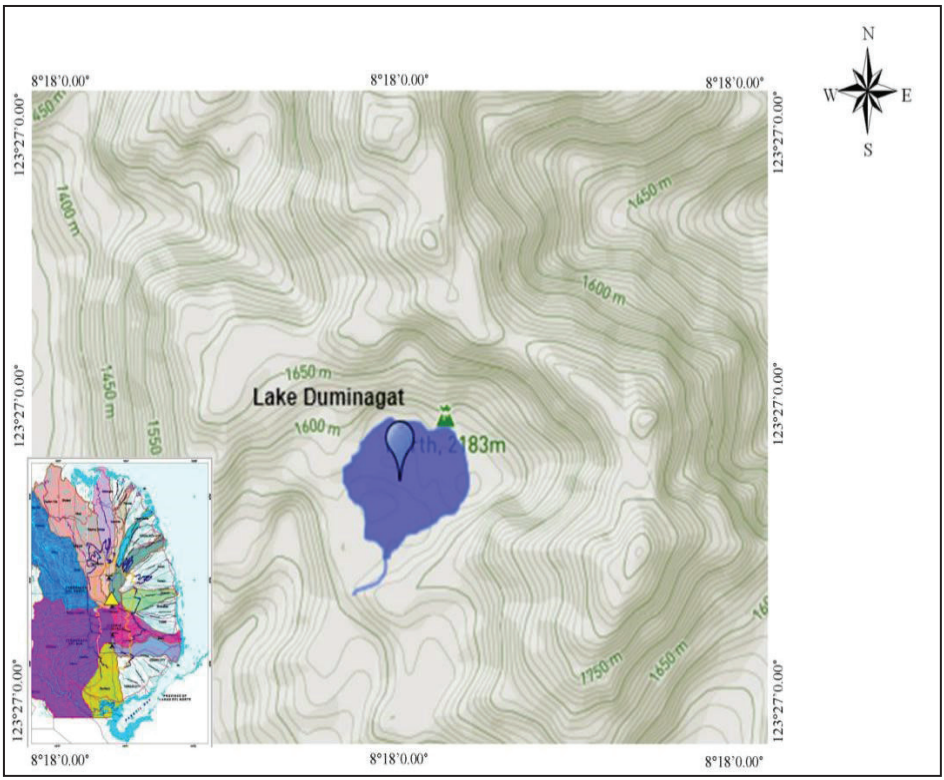

Figure 1. Study location map of Lake Duminagat, Mount Malindang Range Natural Park, Philippines (Modified satellite image Google Earth map).

Sampling of fish

With respect to the tradition of the villagers, a ritual session headed by tribe leaders was done prior to the conduct of the study in the lake. Formal informed consent was also secured from the villagers of Barangay Lake Duminagat. Fish collection was done within the lake and in the outlet stream. The outlet stream is located in the southwestern shore of the lake. Various materials were used for fish collection such as the seine and gill net (with approximately 1.2mm x 1.2mm mesh size), hook-and-line, and low voltage (10V) backpack electrofishing

gear used for specific species of interest where passive gears are not applicable. The gratuitous permit to conduct the study was secured with all the methods for fish species collection including the use of electrofishing being approved.

Gill net (1.2mm x 1.2mm) was placed near the shore and left for 24 hours. Hook-and-line was placed along the shoreline and occasionally checked for any fish capture. The backpack electrofishing gear was used only in the outflow stream of the lake. All fishes caught were counted, photographed immediately, and initially identified in the field at their lowest possible taxa. Only five samples of each fish species were brought to the station for preservation (10% formalin solution) and further identification. Other samples were returned alive, more specifically those stunned by the electrofishing gear. Samples were identified and assessed in their current systematic status using the FishBase website (Froese & Pauly, 2018).

Data analysis

The Shannon-Weiner Diversity Index was used to analyze the quantitative composition of the fish fauna collected in the lake with the BioDiversity Professional software (version 2.0). Species richness was used to determine the total number of species present in the lake. Correlation between water quality parameter data and fish species abundance in the lake was examined using the principal correspondence analysis (PCA) with XLSTAT software. The Pearson correlation coefficient was used to measure the relationship between the physicochemical variables and water depth.

Results and Discussion

Physicochemical analysis

Data on water quality parameters are summarized in Table 1. The results were compared to the standard level set by the DENR (1990 & 2016) and DOH (2007). Temperature and TDS were below the standard level.

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Table 1. Physicochemical parameters of Lake Duminagat compared to the standard level set by DENR for Class AA water body classification and DOH for drinking water (May 2013).

Parameters	Unit	Standard level set by DENR (2016) for Class AA water body classification of freshwater	**PNSDW Standards (DOH, 2007)	Min. value	Max. value	Mean	Interpretation of Data
Temperature	°C	26-30	-	19.59	21.32	20.20	Below the standard
pH	-	6.5-8.5	6.5-8.5	6.27	10.31	8.45	Within the standard
ORP	mV	-	-	31.0	208.7	138.46	
EC	mS	-	-	0.01	0.03	0.01	
Turbidity	NTU	-	5	2.17	2.90	2.36	Within the standard
DO	mg/L	5.0 (minimum)	5.0	4.47	11.39	6.80	Within the standard
TDS	mg/L	*500	500	0.01	0.01	0.01	Below the standard

*Based on DAO No. 34 (Series of 1990)
**Philippine National Standards for Drinking Water (2007)

A. Water temperature

The water temperature of the lake did not fall within the standard range (26-30°C) set by the DENR and DOH. It can be seen that the water temperature decreases as the depth increases (Figure 2). Similar trend was recorded in the study of Hansel et al. (2004). The decreasing pattern of water temperature with the increasing depth was mainly influenced by the small emission of sunlight that could not penetrate the deeper part of the lake. Another factor could be the dense amount of submerged dead logs in the water surface area that block the passage of the sunlight. The trend shows the thermal stratification of the lake and signifies the findings of Hansel et al. (2004).

B. pH

The pH mean value (8.45) of Lake Duminagat falls within the standard set by DENR and DOH. Almost the same range of pH was also observed in the study of Martinez and Galera (2011) in Taal Lake. They noted that the average level of pH is extremely significant to the health of aquatic life. In this study, the pH level in the surface water of the lake was slightly acidic and gradually became alkaline in the middle water column and declined slightly at the bottom. The observed decline in the acidity level of the water in the middle to bottom column of the lake is partly due to the hydrogen ion exchange with cations from the organic materials submerged in the lake.

C. Oxidation Reduction Potential (ORP)

As shown above, the oxidation reduction potential (ORP) was highest at the surface and tend to decline as the depth approaches <15 m and increased slightly at the bottom. The subjected states of flux of ORP are the chemical processes involving atoms, ions, molecules and compounds on the lake. A positive ORP means the water is in oxidizing condition while a negative ORP suggests that the water is in reducing condition (Reyneke, 2014). Since oxygen is an oxidizing agent, the exchange of oxygen with the atmosphere also governs the variation of ORP with depth in which higher dissolved oxygen is present

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near the surface. At the bottom, the anaerobic decomposition of organic matter produces methane and carbon dioxide in which the latter is an oxidizing agent.

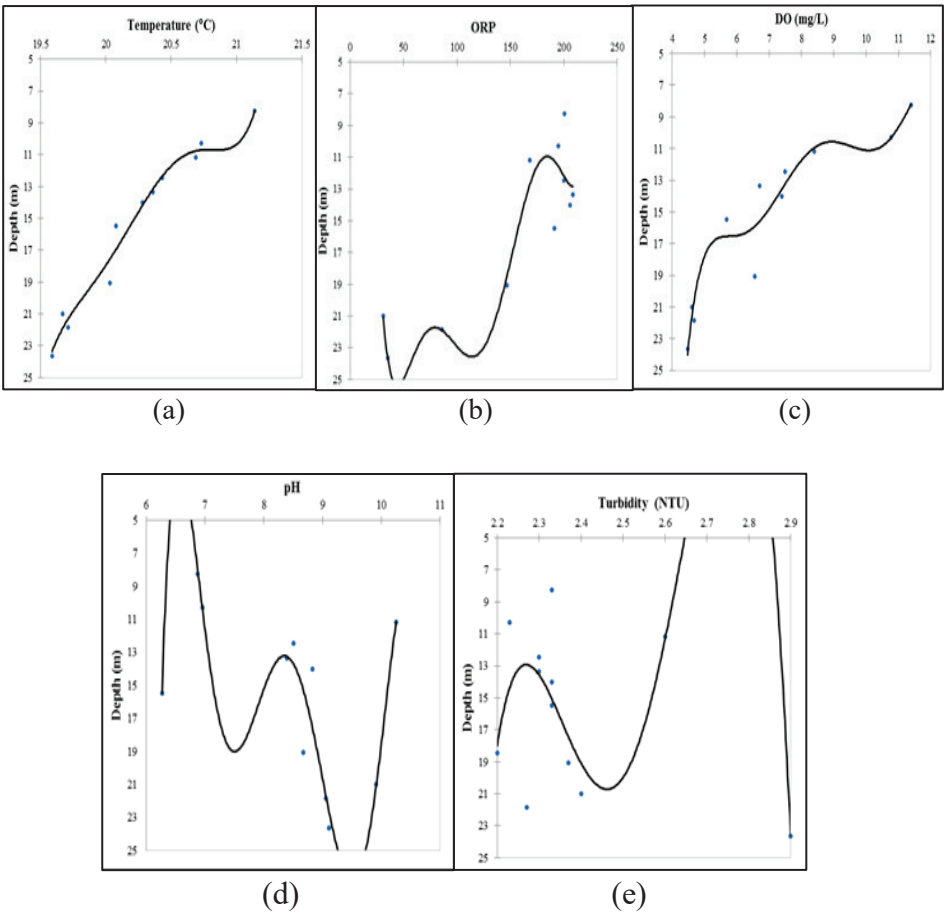

Figure 2. Water depth (a) temperature, (b) oxidation reduction potential, (c) dissolved oxygen, (d) pH, and (e) turbidity profile distribution in Lake Duminagat, MMRNP (May, 2013).

D. Electrical conductivity

The electrical conductivity reflects the mineral salt content of the water and its ability to conduct electricity. In the case of Lake Duminagat, EC level showed increasing trend from the surface to the bottom of the lake. The EC ranges from 0.01-0.03 µs/cm. The value of electrical conductivity usually varies according to season. The low record of electrical conductivity in the lake could be attributed to precipitation during May 2013. This conforms to the work of Lawal and Ahmed (2014) having a result of 0.02 µs/cm in May (wet season).

E. Turbidity

The water clarity of the lake varies from 2.17 - 2.90 NTU. The clarity of the surface water (8-10 m) was higher compared to the bottom of the lake. The result in turbidity within the surface of the lake meets the standards set by the DOH (2007) for drinking water. The turbdity readings indicate that the water in Lake Duminagat is clear and would qualify as a source of drinking water and other domestic use. The higher turbidity (2.90 NTU) in the bottom of the lake could be attributed to the organic sludges which create a layer of soft peat or muck deposits. The same high value of this parameter in the lake was noted by Hansel et al. (2004). The turbidity value of Lake Duminagat is quite high compared to the findings of Tumanda et al. (2003) in Lake Mainit.

F. Dissolved oxygen

The DO is one of the important regulators of chemical processes and biological activity in the lake and the most essential parameter for all aerobic organisms (Tumanda et al., 2003). The measured DO of Lake Duminagat varied from greater than 10 mg/L at the surface to almost 4 mg/L at the bottom of the lake. This variation of DO is typical for deep lakes with depth of greater than 10 m. The decline of DO level with depth may be due to the stratification of the lake, and the biological activities at the bottom of the lake which utilize oxygen for decomposition.

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The exchange of oxygen with the atmosphere also governs the variation of DO with depth and expected to increase at the surface with high temperature and decrease at the bottom with low temperature. The rapid decrease of DO level from 14 m to the bottom of the lake is in accordance with the report of Hansel et al. (2004). Overall, the DO concentration of the lake is satisfactory for freshwater fishes in the lake.

G. Total Dissolved Solids

The amount of total dissolved solids in the lake was very low (0.01 mg/L) and did not fall within the standards set by DENR. The maximum value of total dissolved solids is 400 mg/L which is permissible for diverse fish population in a water ecosystem (Ali et al., 2000; Boyd & Tucker, 2012). The result of this study indicates that the aquatic biodiversity of the lake is expected to be low. The absence of rain during the field sampling may have resulted to very low TDS level since soil particles were not washed into the lake from run-off.

Table 2 shows the correlation between the physicochemical parameters data of Lake Dumnagat last May 2013 and water depth. The water temperature and DO showed high significant differences from the surface to deeper layer of the lake with values of ($p=0$ and $p=<0.0001$), respectively. High significant differences in the DO were also observed in the water depth of Lake Lakewood in Zamboanga del Sur (Superales et al.,2013) and Lake Lanao in Lanao del Sur province (Angagao et al., 2017). Other parameters like pH ($p=0.02$) and ORP ($p=0.00$) of Lake Duminagat showed significant differences, whereas, no significant differences were observed in conductivity and turbidity with p-value of 0.06 and 0.38, respectively.

Table 2. Pearson's correlation coefficient of the physicochemical parameters of Lake Duminagat with water depth (May 2013).

Parameters	Mean	Std. Error	Std. Dev	Correlation coeff.	p-values	Remarks
Temperature	20.20	.127	.522	1	0	Highly significant
pH	8.45	.308	1.27	-0.548*	0.02	Significant
ORP	138.46	16.73	68.97	0.792**	0.00	Significant
EC	.011	.001	.005	0.463	0.06	Not significant
Turbidity	2.36	.045	.187	-0.178	0.38	Not significant
DO	6.80	.572	2.36	0.967**	<0.0001	Highly Significant
TDS	.010	.000	.000	c	-	

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is highly significant at the 0.01 level (2-tailed).
[c] Cannot be computed because at least one of the variables is constant.

Fish species composition

Six species from three families: Cyprinidae, Anguillidae and Poeciliidae (Figure 3 & Table 3) were collected and identified. This number is higher compared to the five species reported by Hansel et al. (2004) in their first fish fauna research study in the lake. Two (33.3%) native freshwater fish species: *Anguilla marmorata* and *Barbodes binotatus* and four (66.7%) exotic species: *Cyprinus carpio carpio*, *Xiphophorus helleri*, *Xiphophorus maculatus,* and *Poecilia reticulata* were recorded during the conduct of this study. Members of family Poeciliidae presented the highest species richness. All of the species of family Poeciliidae are new records. They were not collected during the first generation limnological research in 2002.

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Figure 3. Freshwater fish species collected in Lake Duminagat, Mount Malindang Range Natural Park (May 2013). A) *A. marmorata*; B) *B. binotatus*; C) *C. carpio carpio*; D) *X. maculatus*; E) *P. reticulata*; F-H) *X. hellerii* variety (male and female).

Table 3. List of fish species in Lake Duminagat, Mount Malindang Range Natural Park (May 2013).

Family	Species	*RA (%)	Common Name	Occurrence	**Current Status
Anguillidae	*Anguilla marmorata* (Quoy & Gaimard, 1824)	4.92	Giant Mottled eel	Native	Least concern
Cyprinidae	*Cyprinus carpio carpio* (Linnaeus, 1758)	18.03	Common carp	Exotic/Non-indigenous	Vulnerable
	Barbodes binotatus (Valenciennes, 1842)	34.43	Common barb	Native	Least concern
Poeciliidae	*Xiphophorus helleri* (Heckel, 1848)	21.31	Swordtail fish	Exotic/Non-indigenous	Not evaluated
	Xiphophorus maculatus (Günther, 1866)	13.11	Southern platyfish	Exotic/Non-indigenous	Not evaluated
	Poecilia reticulata (Peters, 1859)	8.20	Guppy	Exotic/on-indigenous	Not evaluated

*Relative abundance
**Based on IUCN Red List of Threatened Species (IUCN, 2018)

Comparison of ichthyofauna in the lake from the first generation research and this study is shown in Table 4. The Shannon-Weiner Diversity Index (*H'*) showed that Lake Duminagat supports high diversity of ichthyofauna species (1.63). However, the low count of species in the lake is expected because the lake is an oligotrophic type (Hansel et al., 2004) indicating that the productivity of the lake is quite low. In terms of abundance, *B. binotatus* is the commonly collected freshwater species (34.43%) in the lake. *Barbodes binotatus* or the common barb is commonly distributed in the freshwater tributaries of MMRNP even before the denudation of the forest cover particularly in the areas of Don Victoriano and Conception (Hansel et al., 2005). Overall, in terms of species dominance, exotic or non-indigenous freshwater fish species were found in higher percentage than the native species. Further, it was observed that *X. helleri* and *X. maculatus* were isolated only in the outlet stream of the lake.

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Table 4. Comparison of ichthyofauna in Lake Duminagat from the first generation limnological research (Hansel et al., 2004) and this study (2013).

Family	Species	Common Name	Occurrence	Hansel et al. (2004)	Current study
Anguillidae	*Anguilla marmorata* (Quoy & Gaimard, 1824)	Giant Mottled eel	Native	+*	+
Cyprinidae	*Cyprinus carpio carpio* (Linnaeus, 1758)	Common carp	Exotic/Non-indigenous	+	+
	Barbodes binotatus (Valenciennes, 1842)	Common barb	Native	+	+
Poeciliidae	*Xiphophorus helleri* (Heckel, 1848)	Swordtail fish	Exotic/Non-indigenous	-	++
	Xiphophorus maculatus (Günther, 1866)	Southern platyfish	Exotic/Non-indigenous	-	++
	Poecilia reticulata (Peters, 1859)	Guppy	Exotic/Non-indigenous	-	++
Cichlidae	*Oreochromis niloticus* (Linnaeus, 1758)	Nile tilapia	Introduced	+*	-
---	----	Pargo		+	-
Total Number of Species:				**5**	**6**

Note: (+) collected, (++) new record of freshwater fish species in the lake, (+*) reported freshwater fish species in the lake by the locals, (-) absent

Two recorded freshwater fishes (*A. marmorata* and *C. carpio carpio*) were also reported in the work of Superales et al. (2013) in Lake Lakewood located in Lakewood, Zamboanga del Sur which is classified as an ultra-oligotrophic lake. Three exotic or non-indigenous freshwater fish species (*X. helleri*, *X. maculatus, P. reticulata)* recorded in this study were not reported in the earlier limnological work of Hansel et al. (2004). The intentional release of these three species in the riverine system of MMRNP according to the local people in the area could

explain these new records. However, the purpose of introducing these species in the lake was not clearly assessed. Among the freshwater fish species recorded in Lake Duminagat, *C. carpio carpio* or the common carp and *A. marmorata* or the giant mottled eel are economically important in aquaculture industry in the country.

The various techniques used in fish collection in the earlier research of Hansel et al. (2004) and in this study might influence the total abundance of collected fish species in the lake. The earlier work was able to collect five species with the aid of two kinds of passive fishing gear: hook-and-line and installation of bamboo traps. Whereas, this study used one active fishing gear (electricfishing) and two passive gear (seining and hook-and-line method). Electricfishing was used for specific species of interest where passive gears are not applicable to use.

Non-indigenous/exotic freshwater fishes and their implications

Shafland and Lewis (1984) defined exotic fishes as non-indigenous species whose entire range is outside the country to which they are introduced. As shown in Table 5, four freshwater fishes are listed as exotic species in the Philippines. These species, excluding the *C. carpio carpio* have proven ecological negative impact in aquatic ecosystem.

Table 5. Exotic/non-indigenous freshwater fish species in Lake Duminagat and their point of introduction.

Family	Species	Common name	Point of introduction
Cyprinidae	*Cyprinus carpio carpio* (Linnaeus, 1758)	Common carp	Sportfish & Aquaculture
Poeciliidae	*Xiphophorus helleri* (Heckel, 1848)	Swordtail fish	Aquarium
	Xiphophorus maculatus (Günther, 1866)	Southern platyfish	Aquarium
	Poecilia reticulata (Peters, 1859)	Guppy	Aquarium

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The *X. helleri,* commonly known as swordtail fish, has been implicated in the decline of the utah sucker (*Catostomus ardens*) which is a native freshwater fish in Wyoming (Courtenay et al., 1987). The guppy (*P. reticulata*) is considered as a threat to native cyprinids and killifishes in United States (Sigler & Sigler, 1987) and a known carrier of trematode parasites, which may affect native fish populations (Nico & Martin, 2001). It eats the eggs of native fish species and acts as a host for the parasitic nematode in Hawaii (Eldredge, 2000).

The presence of of *P. reticulata* and *X. helleri* may contribute to the possible decline of native freshwater fishes in the lake in the future. Study showed that hybrids between *P. reticulata* and *X. helleri*are shown to threaten a native fish species in the western USA (Courtenay & Meffe, 1989). In particular, fish populations are highly dependent upon the variations of physicochemical characteristics of their aquatic habitat that support their biological functions (Mushahida-Al-Noor & Kamruzzaman, 2013).

Conclusions and Recommendations

The pH, turbidity, and DO in Lake Duminagat fall within the permissible limit for Class AA water body classification intended primarily for waters having watersheds that are declared as protected areas, whereas temperature and TDS were below the standards. Not all of the water parameters analyzed showed significant relationship with water depth. Lake Duminagat supports diverse ichthyofauna comprising of two native and four non-indigenous freshwater fish species. Fish abundance, however, is quite low per species. Very low amount of TDS and oligotrophy of the lake could have influenced the total abundance of the freshwater fishes. Additionally, the low abundance of native *B. binotatus* could be attributed to the high percentage of non-indigenous freshwater fishes present in the lake. This study indicates high species richness of the lake compared to the previous research because of the presence of the members from family Poecilidae that were intentionally released in the lake.

It is important to address the high percentage of the non-indigenous freshwater fishes, specifically the species from the family Poecillidae because they are detrimental to the native freshwater hearings of the lake. Monitoring program and community awareness regarding the implications of non-indigenous freshwater fishes to native species should be implemented in Lake Duminagat.

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