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Freshwater Fish Assemblages and Water Quality Parameters in Seven Lakes of San Pablo, Laguna, Philippines

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ABSTRACT

An ichthyofaunal survey was conducted to characterize the diversity and abundance of freshwater fish assemblages in Seven Lakes of San Pablo, Laguna, Luzon Island, Philippines. This two-year study collected 5,166 fish samples, belonging to ten species and six families. Out of ten fish species, three were classified as native (*Leiopotherapon plumbeus*, *Glossogobius* sp., and *Giuris* *margaritacea*). Nile tilapia (*Oreochromis niloticus*) and silver therapon (*L. plumbeus*) were the two most abundant fish species which comprised about 75% of the total fish collected. Overall, native fish species comprised about 41% of the total abundance. Shannon-Weiner's diversity varied from 0.82–1.64, indicating fairly low diversity. Bray-Curtis similarity recorded high resemblance rate (>56%) among the studied lakes. Various water quality parameters including dissolved oxygen, water surface temperature, and pH were within the ideal level for the growth and survival of tropical fishes, albeit high turbidity readings based on Secchi disc visibility depth were observed. The lakes were found to have a low number of freshwater fish species, albeit largely composed of non-native fish species, principally *O. niloticus*. The baseline information from this study can be useful for future conservation and rehabilitation efforts for the lakes.

Keywords: diversity, freshwater fish, *Leiopotherapon plumbeus*, Pandin, Seven Lakes

INTRODUCTION

The Seven Lakes of San Pablo City are classified as maars or low-relief volcanic craters. They were formed as result of phreatomagmatic eruptions, wherein steam-heated explosive reaction occurred when the groundwater made contact with shallow magma from Mount San Cristobal, causing crater-like depressions (Claveria et al. 2007). The lakes are water-fed mainly from rainfall, surface runoff, and surrounding-underwater springs. They are found along the rift zone between Mount Banahaw and San Cristobal, and Mount Makiling, which is a part of Southwestern Luzon Volcanic Field. Currently, the Seven Lakes namely, Bunot, Calibato, Mohicap, Palakpakin, Pandin, Sampaloc, and Yambo are one of the major sources of tourism and agro-fisheries growth, contributing to the overall socio-economic development of San Pablo City, Laguna (LLDA 2009).

Despite increasing studies on natural sciences of Philippine lakes (Papa and Mamaril 2011; Brillo 2015), majority of the recent biodiversity and ichthyofaunal studies is largely focused on major lakes such as Laguna de Bay (Cuvin-Aralar 2014), Lake Lanao (Ismail et al. 2014), Lake Taal (Papa and Mamaril 2011), and Lake Bato and Lake Buhi (Corpuz et al. 2015b). Few researches have been conducted for Philippine Seven Lakes, but generally in the form of technical reports and grey literature. Scientific papers available in peer-reviewed journals have tackled issues on a socio-economic and developmental plan for Mohicap

(Brillo 2015, 2016) and an assessment of fish diversity and trophic interaction of Sampaloc (Briones et al. 2016).

The study is significant considering the fact that small lakes are delicate and vulnerable to ecological degradation as their absorptive efficiency to buffer contaminants is reduced due to their sizes and morphometry (Brillo 2016). Similarly, the biodiversity of lakes is currently threatened by human disturbances such as the intensification of floating fish cages and effluents from lake dwellers occupying the shorelines. Because of these various anthropogenic-induced degradations, the seven lakes were chosen as the "Threatened Lakes of the Year 2014" by Global Nature Fund (Germany) (Cinco 2014).

OBJECTIVES OF THE STUDY

To address the paucity of scholarly output for small Philippine lakes, this ichthyofaunal study was conducted to characterize the diversity and abundance of freshwater fishes of the Seven Lakes, with some notes of lakes' water quality parameters.

MATERIALS AND METHODS

Study Areas

Sampling sites were defined in the Seven Lakes of San Pablo, Laguna, Philippines (Fig. 1). The geographic coordinates, areas, depth, general features, as well as anthropogenic activities in the lakes were presented in Table 1.

Fish Collection

The duration of the sampling was from February 2013 to January 2014 for Year 1, and April 2014 to March 2015 for Year 2. Samples of wild fish species per lake were randomly collected every month using scoop nets and gill nets by local fisherfolks in the Seven Lakes, San Pablo Laguna. Individual sampling lasted approximately 40 min and was done during the daytime. Gravid and juvenile fishes were released after identification. Total length (cm) and wet weight (g) of the fish samples were also determined. Dead and moribund fish samples were placed in an ice chest with local lake water and immediately transferred to the Animal Biology Research Laboratory of University of the Philippines Los Baños for further identification. Fish samples were identified using several fish identification materials (Herre 1927-1953;Vidthayanon 2007; Froese and Pauly

2012). Additional references were accessed for the taxonomic identification of flowerhorn cichlid (McMahan et al. 2010) and Red Nile tilapia (Fitzgerald 1979; Garcia and Sedjro 1987 as reported by Wattanabe 1987; Behrends et al. 1982; Wu et al. 1983; Herder et al. 2012).

Water Quality Parameters

Species richness was determined by the number of fish species present in each lake. The relative abundance of native and introduced fish population for every lake was also computed. The relative abundance of each species was calculated as:

$$\text{Relative abundance} = \left(\frac{ai}{A}\right) 100\%$$

where: ai is the number of individuals collected in the ith species and A is the total number of species collected in one sampling area during. Diversity index was computed following Shannon-Weiner diversity index (H') (Shannon and Weaver 1949):

$$H' = -\sum_{i=1}^{s} pi \ln pi$$

where: s is the number of species; p is the proportion of individuals found in the ith species, and ln is the natural logarithm. Evenness (J') was computed following Shannon's diversity index:

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

where: S is the total number of species. Species dominance was computed using the Simpson's index formula (λ) (Simpson 1949):

$$\lambda = \sum_{i=1}^{s} \frac{ni\ (ni-1)}{N\ (N-1)}$$

where: s is the number of species, ni is the number of individuals in the ith species, and N is the total number of individuals. Simpson's diversity index was also estimated for each lake using Reciprocal λ = 1/ λ.

Bray-curtis similarity was used to determine the similarity among lakes and the unweighted pair group average method was used to cluster similar groups (lakes) based on richness, and fish log (x+1) transformed abundance data. The data were also subjected to Correspondence analysis (CA) to examine the relative species abundance among the studied lakes. Statistical analyses were performed using Paleontological Statistics v 2.17 (Hammer et al. 2001).

RESULTS AND DISCUSSION

Fish Composition and Abundance

A two-year ichthyofaunal survey in seven lakes inventoried a total of 5,166 individuals, belonging to ten species and six families (Table 1 and 2; Plate 1). These families were Channidae, Cichlidae, Cyprinidae, Eleotridae, Gobiidae, and Terapontidae. Three indigenous or native fish species including *L. plumbeus*, *Glossogobius* sp., and *Giuris margaritacea* were identified, whereas the remaining seven were non-native or introduced fish species. The proportion of abundance of native and introduced fish species in each lake was summarized in Fig. 3. Among the seven lakes, only Yambo (64%) and Mohicap (66%) had a higher relative abundance of native fish population than the introduced population, with *L. plumbeus* being the most abundant in the native fish community. In general, 41% of the total fish abundance was composed of native fish species. In terms of spatial abundance, Mohicap had the highest collected fish individuals, contributing to almost 25% of the total fish catch. It was followed by Yambo with the total fish contribution of about 18%. Despite Yambo's low species richness (species = 3), it still had the second highest fish abundance among other lakes. In contrary, Calibato had the lowest fish abundance contribution (8.7%) and lowest relative abundance of native fishes (15%) (Fig. 3). Although it is not conclusive, this finding indicates that high total fish abundance or catch per unit effort is associated to high relative abundance of native fish assemblages. Theoretically, because of the small number of non-invasive native species present in small lakes, available niches are optimized, facilitating their survival and high recruitment success. In the case of other lakes, introduced fishes may have established feral populations resulting to considerable decline of native fish populations. Although our findings are not species-specific, it also conforms to the observations of Guerrero III (2014) in regards to the impacts of introduced fishes in various Philippine major lakes.

Nile tilapia (*O. niloticus*) and silver therapon (*L. plumbeus*) were the two most abundant fish species (in order of importance), which constituted about 75% of the total fish individuals. Similarly, these two fish species were also found at all the sampling sites (Table 2). *O. niloticus*, a native cichlid from Africa, was introduced in 1972 in the Philippines, and currently being cultured in different lakes and reservoirs (Guerrero III 2014). It has become the second most important finfish for aquaculture and clearly improved the fisheries in various Philippine water bodies with no profound evidence of direct adverse impact on the indigenous aquatic fauna (Guerrero III 1999). It is currently the most important cultured fish species of the lakes and largely supports the local fisheries industry of the city. On the other hand, *L. plumbeus*, which is known as endemic in Laguna de Bay was translocated in the late 1950s and has successfully established specifically in Sampaloc (Quilang et al. 2007). The current study revealed that their populations have been proliferated in all studied lakes.

A native species of goby (*Glossogobius* sp.) was collected in Mohicap, whereas another native species, snakehead gudgeon (*Giuris margaritacea*) was collected at all the sampling sites except in Calibato and Mohicap. Introduced species including prussian carp (*Carassius gibelio*), and jaguar guapote (*Parachromis managuensis*) were found in Bunot, and Sampaloc, respectively. An introduced species, common carp (*Cyprinus carpio*) was collected in Calibato and Mohicap; snakehead murrel (*Channa striata*) was found in Bunot, Palakpakin, and Pandin; red tilapia was found in Bunot, Mohicap, and Pandin; wild flowerhorn was present in Bunot, Calibato, Mohicap and Palakpakin (Table 2; Plate 1). The occurrence of cultured fishes such as Nile tilapia, common carp, flowerhorn, and red tilapia is one of the evidence of the effect of fisheries activities in natural lakes since their proliferation is linked to escapement from culture compartments (Cuvin-Aralar 2014; Corpuz et al. 2015b). It is also noteworthy to mention that this is the first time that a wild flowerhorn, an aquarium cichlid fish was documented in this study. However, the mechanism of their introduction in the lake is still unknown.

Biodiversity Indices

Different biological indices in each representative site were summarized in Table 3. Highest number of collected fish samples was observed in Mohicap (n = 1,264) and Yambo (n = 966) and was largely represented by *L. plumbeus* (>52% of the total abundance). Shannon-Weiner index was found to be relatively high in Palakpakin (1.64; species = 6) and Bunot (1.43; species = 7), which was attributed to the number of fish taxa present and proportion of individuals for each species. Overall, Shannon-Weiner index was fairly low, ranging from

0.82–1.64 (species =10). These values were lower than in Tikub lake (1.87) of Quezon Province (Labatos and Briones 2014), and in Lake Bato (2.06) and Baao (2.07) in Bato, Camarines Sur (Corpuz et al. 2015b). It was comparable to small crater lakes in Buhi, Camarines Sur including Lake Katugday (1.36–1.50, species = 6) and Manapao (1.15–1.18, species = 7) (Paller et al. unpubl data). Values of the Shannon diversity index for real communities typically fall between 1.5 and 3.5 (Kemp et al. 1993). Evenness *J'* values were fairly high to very high, varying from 0.59–0.91 (maximum value = 1.0), with lowest and highest *J'* values observed in Calibato, and Palakpakin, respectively. Simpson's dominance values were slightly low and measured from 0.21–0.57. The species dominance weighted towards the most dominant species among each representative lake and was inversely proportional to diversity index. As it was previously mentioned, the most dominant fish species from all the sampled lakes was *O. niloticus* and closely followed by *L. plumbeus*. Despite their abundance, high evenness values were still estimated signifying equitable allocation of niche space for dominant and non-dominant fish species (Ramsundar 2004; Corpuz et al. 2016).

Similarity Analysis

Bray-Curtis cluster analysis on spatial similarity produced four clusters (Fig. 4). The first cluster was composed of Pandin and Bunot having 82% level of similarity. This group was deviated from Sampalok-Yambo group (82% similarity) at about 65% level of similarity. The Sampalok-Yambo group registered a 60% similarity with Calibato-Palakpakin group (74% resemblance) and deviated from Mohicap at about 56% similarity level. The CA ordination also displayed this homogeneity ($P>0.05$) as well as the fish species that were maximally correlated with the sampling lakes ordination (Fig. 5). It was also discernible in the plot the fish species that were restricted in a particular lake (peripheral region of the plot) and those that are ubiquitous in all studied areas (center of the plot).

The observed similarities on fish assemblages may have something to do with the hydrological connection of lakes and/or due to the recognized effect of a lake-based aquaculture operation. Several lakes were proliferated by similar fish species, and their occurrence is often associated to escapement from cultured cages and by accidental or intentional re-introduction during stocking by fish farmers. The influence of the aforementioned factors on the occurrence and distribution of freshwater fishes in the seven lakes is open for further study. Since a high degree of resemblance was observed in fish assemblages, development strategies and interventions necessary for addressing management-conservation concerns can be standardized among the seven lakes.

Hydrological Parameters

Physico-chemical properties of the studied lakes were presented in Fig. 2. Mean surface DO level (dry season= 7.82 ± 0.81 mg L-1; wet season= 7.27 ± 0.25 mg L-1) fluctuated from 6.80–9.63 mg L-1. Mean DO levels in all sites were still within the desirable level of 5 mg L-1. Surface water temperature varied between seasons (dry season= 28.17 ± 1.80°C; wet season= 27.34 ± 2.42°C) and ranged from 22.00–32.00°C. In the present study, mean temperature readings in all sites did not exceed the tolerable limit of >32°C (Fig 2A). Mean pH levels were slightly basic and fairly similar between seasons (dry season = 7.69 ± 0.63; wet season = 7.91 ± 0.69). Mean pH levels recorded in seven lakes ranged from 7.13–8.52. The pH readings were still in ideal range (6.5–9.0) for the growth of most fishes (Tarazona and Munoz 1995; Boyd 1998), and considerably comparable to pH levels recorded by Laguna Lake Development Authority (LLDA 2009). Secchi disk visibility depth (SDVD) ranged from 12.20–35.00 cm, with the variation being observed between sampling seasons (dry season= 18.86 ± 5.31 cm; wet season= 22.27 ± 6.41 cm). Pandin was the least turbid lake (mean = 25 cm) in both seasons, while the most turbid for the dry and wet season was Mohicap (13.34 cm) and Palakpakin (17.37 cm), respectively. In reference to ideal SDVD of 25–45 cm in biological turbidity, those observed readings can be classified as eutrophic to hypereutrophic (Almazan and Boyd 1978; Carlson and Simpson 1996). The observed high turbidity of waters is attributed to high nutrient organic load an issue on surface run-off (LLDA 2009). For the whole duration of the research, these basic water quality parameters appeared to be in acceptable ranges, except in some turbidity readings. Further quantitative community study can be carried-out focusing on the ordination analysis of various environmental and habitat variables with the fish assemblages (Corpuz et al. 2015a).

CONCLUSION

The lakes harbored fairly low number of freshwater fish species, which was mainly represented by introduced fish species, specifically by *O. niloticus*. A translocated *L. plumbeus* was the most abundant indigenous fish species. The current fish assemblages in the lakes are the clear repercussion of aquaculture intensification and stock translocation in the lakes. Introduced fish species appeared to establish feral populations in some lakes which resulted to the decrease in the relative abundances of native fish species. Total catch was observed to be comparatively higher in lakes with high relative abundance of native fish species. This study also provides the preliminary report on the occurrence of wild flowerhorn in Bunot, Calibato, Mohicap, and Palakpakin. The current study also provide a baseline dataset of Seven Lakes' fish assemblages which is hoped to supply indispensible information for future fish monitoring and for improved ecological and economic management-development actions.

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APPENDICES

Table 1. Geographical coordinates, area, depth, general features, and anthropogenic activities in the seven studied lakes.

Lake (Geographical Coordinates)	Area (m^2)*	Depth (m)*	General Feature*	Anthropogenic Activities*
Bunot (14°08' N; 121°34' E)	305,000	23	circular in shape	In 2006, there are 183 fish pen and fish cage operators recorded occupying an area of 93,433 m^2, which was equivalent to 30.6 % of the lake area
Calibato (14°10'N; 121°38' E)	430,000	156	deepest among the seven lakes	The lake is under two jurisdictional areas; lake-based aquaculture is the main source of livelihood of the coastal community.
Mohicap (14°13' N; 121°33' E)	228,900	30	smallest among the seven crater lakes	It is one of the main suppliers of water resources for San Pablo City; a major source of tilapia in Metro Manila and adjacent towns
Pandin (14°12' N; 121°37' E)	240,000	61.75	a semi-pristine lake; deep clear lakes with low nutrient supplies, high dissolved oxygen level and containing little organic matter	In 2007, only 5,800 m^2 was occupied by aquaculture structures. One of the major recreational and tourist sites in San Pablo City
Palakpakin (14°11'N; 121.34'E)	479,800	7.7	Shallowest among the seven crater lakes; inlet is connected with the outlet of Calibato and Pandin	In 2008, the area occupied by aquaculture is about 85,000 m^2, which is equivalent to 18% of the total surface area
Sampaloc (14°08' N; 121°33' E)	1,040,000	27	85% of its volume is of uniform depth	At present, the lake has fishpens along its shallow periphery and floating cages in its deeper portions.
Yambo (14°12' N; 121°36' E)	305,000	28	Oligotrophic lake and adjacent to Pandin	Some areas are developed for swimming, outings and picnics.

* LLDA 2009

Table 2. Distribution of freshwater fish species recorded from the seven study sites. (-) absent, (+) present.

Fishes	Common Name	Status	Length (cm) Mean ± SD	Bunot	Calibato	Mohicap	Palakpakin	Pandin	Sampalok	Yambo
Gobiidae										
Glossogobius sp.	goby	Native	7.83 ± 1.12	-	-	+	-	-	-	-
Eleotridae										
Giuris margaritacea (Valenciennes, 1837)	Snakehead gudgeon	Native	6.60 ± 0.51	+	-	-	+	+	+	+
Terapontidae										
Leiopotherapon plumbeus (Kner, 1864)	Silver therapon	Endemic	9.07 ± 1.31	+	+	+	+	+	+	+
Cyprinidae										
Carassius gibelio (Bloch, 1782)	Prussian carp	Non-native	13.35 ± 6.34	+	-	-	-	-	-	-
Cyprinus carpio (Linnaeus, 1758)	Common carp	Non-native	15.51 ± 2.34	-	+	-	+	-	-	-
Channidae										
Channa striata (Bloch, 1793)	Snakehead murrel	Non-native	22.32 ± 14.51	+	-	-	+	+	-	-
Cichlidae and Hybrids										
Oreochromis niloticus (Linnaeus, 1758)	Nile tilapia	Non-native	19.54 ± 2.38	+	+	+	+	+	+	+
Parachromis managuensis (Gunther, 1867)	Jaguar guapote	Non-native	15.74 ± 4.65	-	-	-	-	-	+	-
Oreochromis mossambicus x *O. hornorum* hybrid[1]	Red tilapia	Non-native	16.46 ± 2.15	+	-	+	-	+	-	-
Cichlosoma x *Amphilopus* x *Paraneetroplus*[2]	Flowerhorn	Non-native	15.59 ± 2.33	+	+	+	+	-	-	-

[1] Source: Garcia and Sedjro 1987 as cited in Watanabe et al. 1993
[2] Source: McMahan et al. 2010

Table 3. Biological indices of the seven lakes of Laguna, Philippines.
H'= Shannon-Weiner diversity index; *J'* = Shannon Evenness Index; λ = Simpson's species dominance index.

Biodiversity Indices	Bunot	Calibato	Mohicap	Palakpakin	Pandin	Sampalok	Yambo	Overall
Taxa	7	4	5	6	5	4	3	10
H'	1.43	0.82	1.13	1.64	1.25	1.14	0.95	1.56
J'	0.74	0.59	0.70	0.91	0.77	0.82	0.87	0.68
λ	0.34	0.57	0.38	0.21	0.38	0.39	0.42	0.30
Reciprocal λ	2.94	1.75	2.63	4.76	2.63	2.56	2.38	3.33

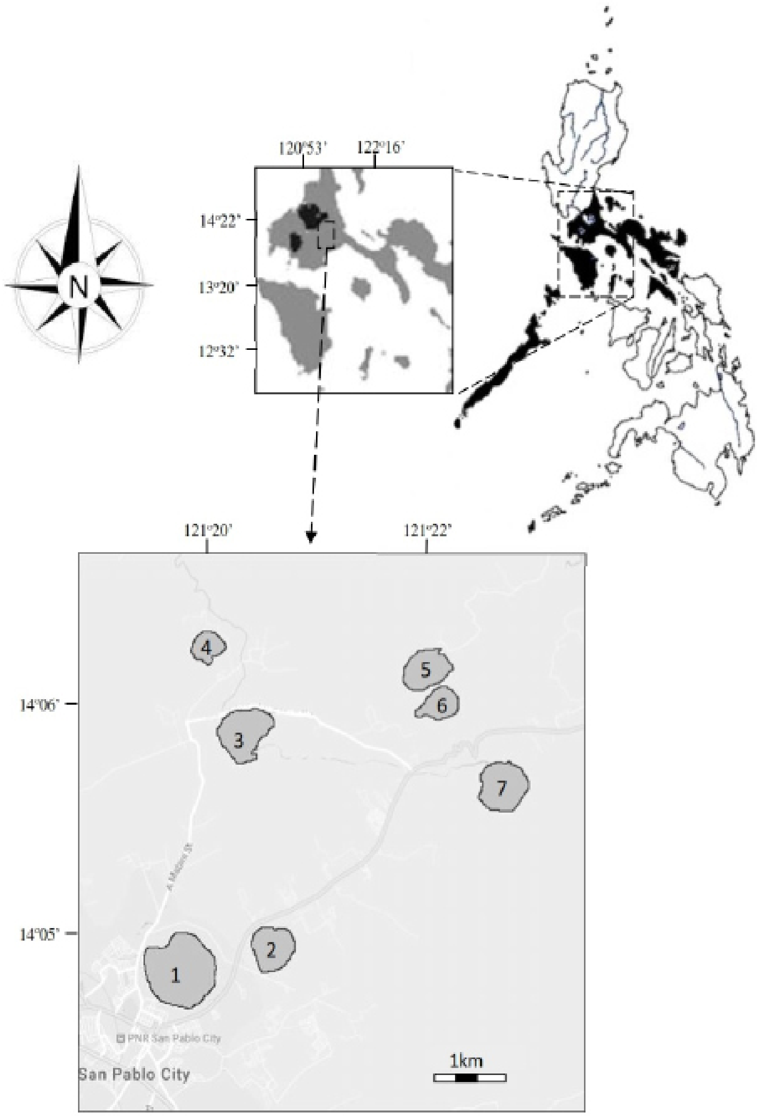

Fig. 1. Map of southern Luzon, Philippines showing the seven lakes of San Pablo, Laguna. (1) Sampalok, (2) Bunot, (3) Palakpakin, (4) Mohicap, (5) Yambo, (6) Pandin, and (7) Calibato.

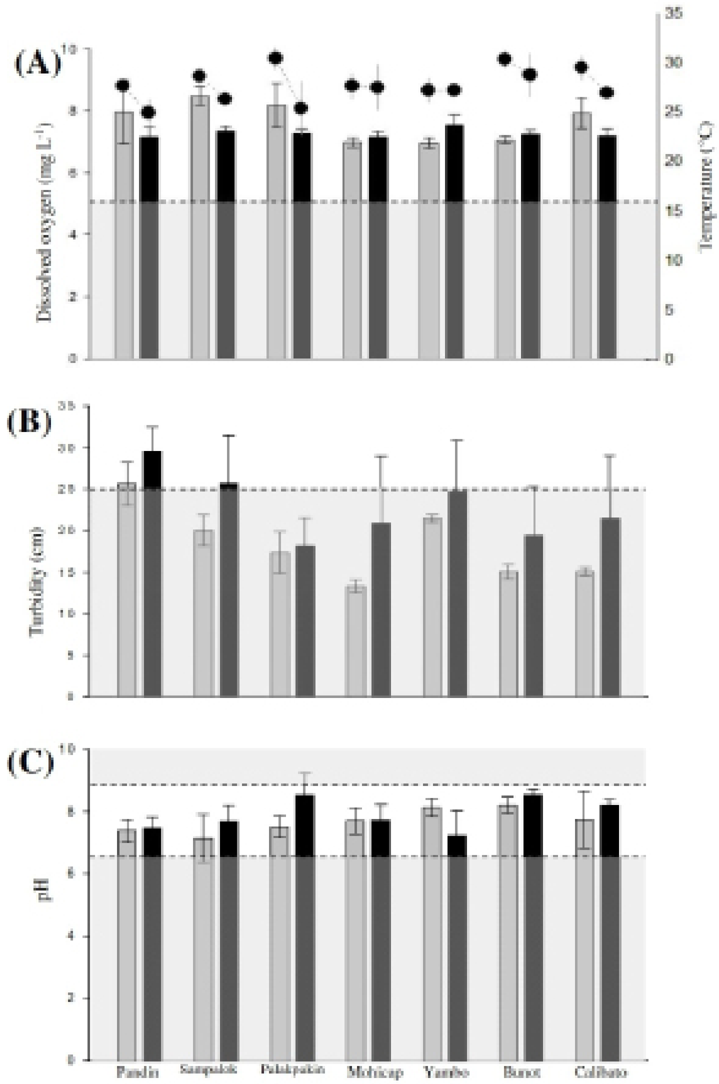

Fig 2. Water quality parameters (mean ± SD) in seven lakes during dry (gray bars) and wet season (black bars). (A) DO concentration and temperature (closed circle). (B) Turbidity. (C) pH. White areas in DO, turbidity, and pH indicate ideal ranges for the optimum growth of most tropical fishes (Boyd 1998).

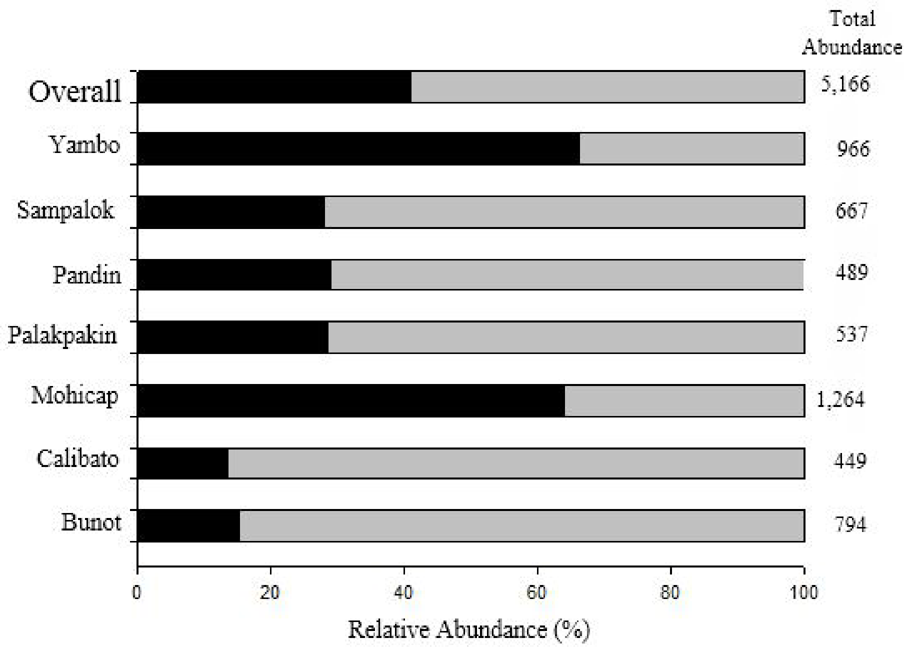

Fig 3. Stacked bar of percent representation in abundances of native (black bars) and introduced (gray bars) from the seven studied lakes.

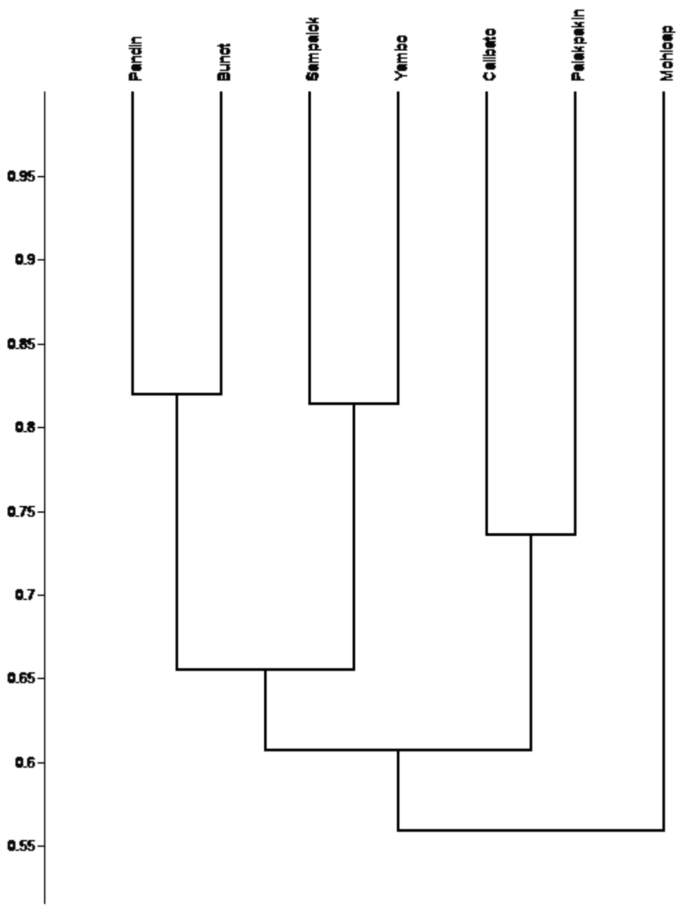

Fig. 4. A dendrogram from unweighted pair group method with arithmetic mean showing the relationship of seven lakes based on standardized fish abundance data.

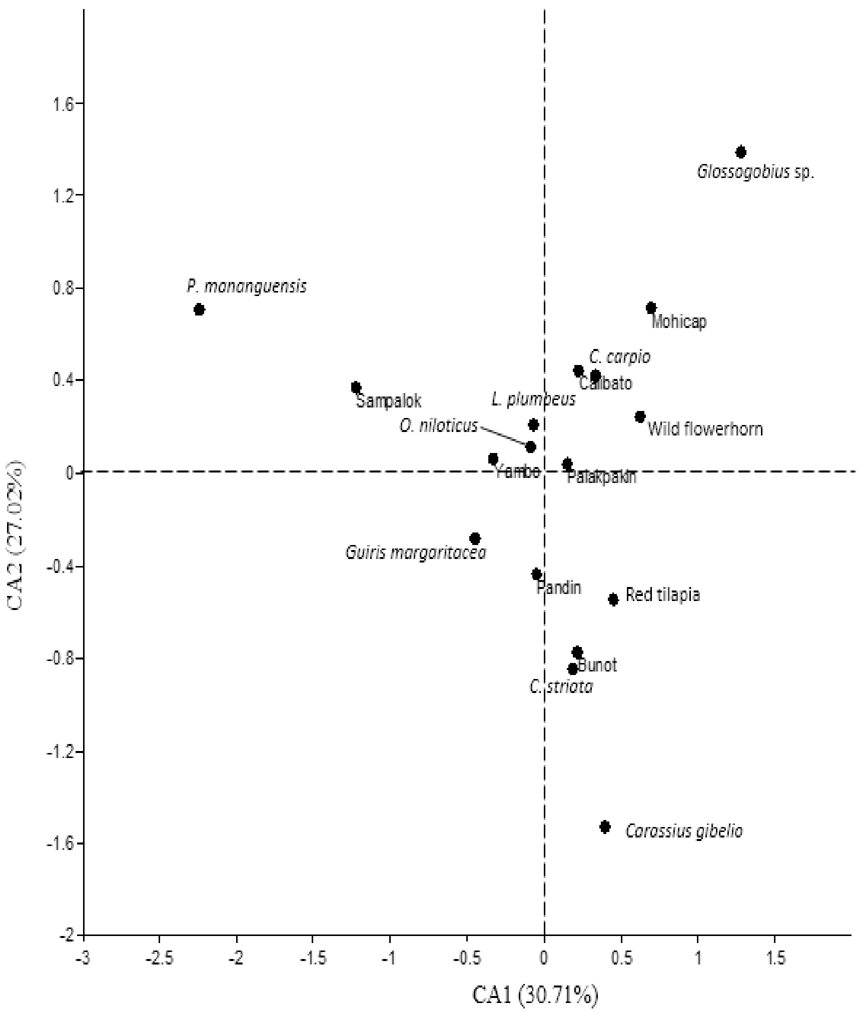

Fig. 5. Plot for CA scores of freshwater fishes and the Seven Lakes of San Pablo.

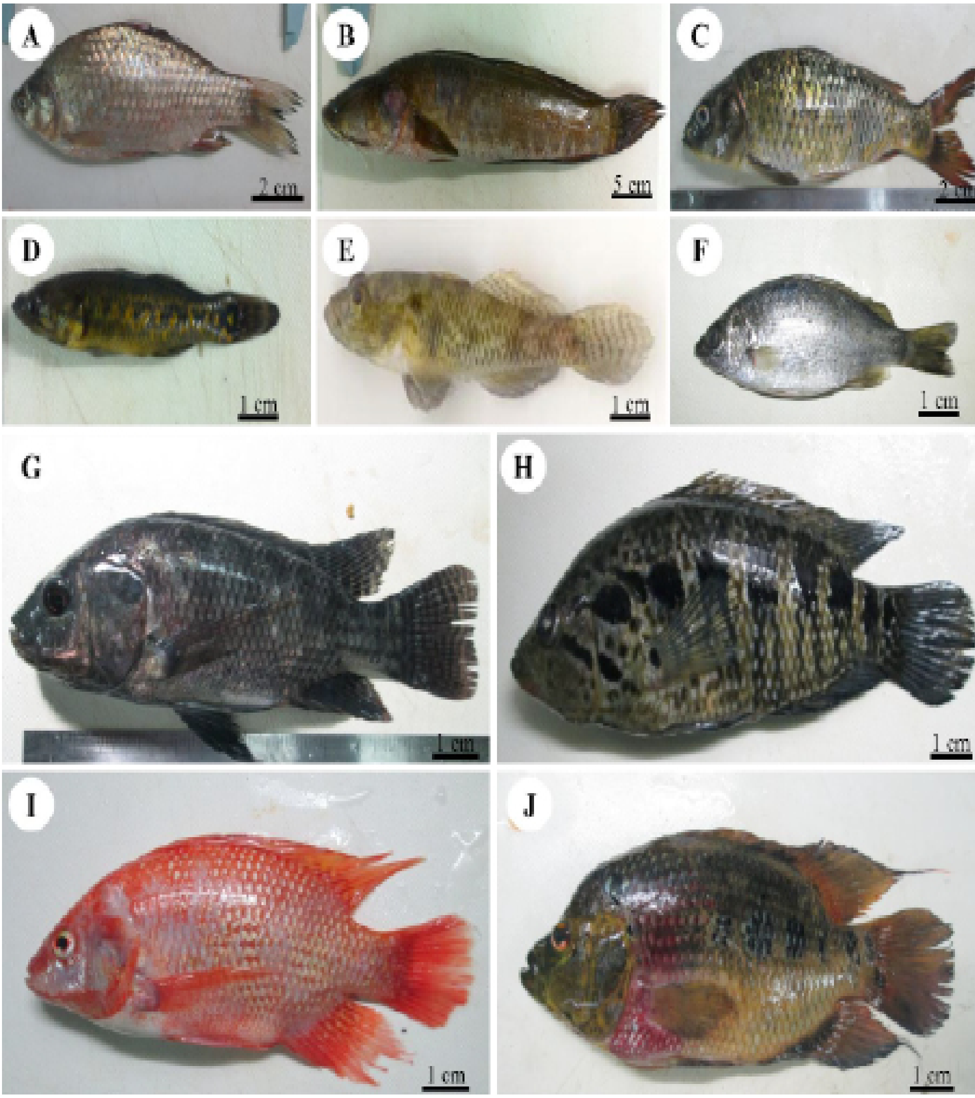

Plate 1. Photographs of fish samples collected from Seven Lakes, San Pablo Laguna. (A) *Carassius gibelio*, (B) *Channa striata*, (C) *Cyprinus carpio*, (D) *Giuris margaritacea*, (E) *Glossogobius* sp., (F) *Leiopotherapon plumbeus*, (G) *Oreochromis niloticus*, (H) *Parachromis managuensis*, (I) Red Nile Tilapia, (J) Wild flowerhorn.