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Ichthyofaunal Survey in Selected Freshwater Habitats in Camarines Sur, Philippines

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ABSTRACT

Ichthyofaunal surveys were conducted in five aquatic habitats (Lake Bato, Agos River, Bagacay Falls, Lake Baao-Bula, and Pawili River) in Camarines Sur, Philippines to evaluate the diversity and distribution of freshwater fish assemblages. The study collected a total of 8,184 individuals comprising 29 species, 22 genera, and belonging to 14 families. The three most abundant groups, in order of importance were cichlids, cyprinids, and poeciliids. Overall, four fish species comprised 52% of the total abundance. These were *Oreochromis niloticus*

(Cichlidae), *Glossogobius giuris* (Gobiidae), *Poecilia sphenops* (Poeciliidae), and *P. reticulata* (Poeciliidae). In terms of richness, Gobiidae are the most dominant fish group (8 species). Except in Bagacay, Shannon-Weiner diversity indices ranged from 2.04 to 2.07. Relatively high evenness indices and low dominance values were computed in the four sites. Fish densities were significantly different among the five studied areas (Friedman test: χ^2 = 43.06, P< 0.01). Bray-Curtis similarity analysis on abundance data clearly showed two clusters. Fairly high levels of similarity (49.61%— 62.81%) were observed in Baao, Bato, Pawili, and Agos, whereas Bagacay was apparently deviated from the rest. Environmental variables are fluctuating but still within the tolerable level. The survey revealed the established feral populations of introduced fish species in the four representative sites. Aquaculture operations and domestic effluents were observed to be the main key drivers of fish faunal change in the lake and stream habitats.

Keywords: Bato, Camarines Sur, diversity, fish survey, Gobiidae, native species

INTRODUCTION

There are few fish surveys conducted in the Philippines after the monumental works of Herre (1924, 1927, 1953), mainly due to the limited ichthyofaunal surveys after the post-war period. Much of the research done had been focused only on evaluating the biodiversity of most marine species as well as commercially important freshwater fishes in the Philippines. A number of studies on freshwater fish species, however, were taxonomical in nature that described several newly discovered Philippine fish species (Larson 2005; Cervancia and Kottelat 2007; Watanabe et al. 2009). Nevertheless, few ecological studies have been done for diminutive freshwater fishes due to the deficiency in current conservation status and data on many native/endemic taxa (IUCN 1999; BAS 2013). The implications of valuable native freshwater ichthyofaunas with no commercial value are not fully well-documented (Santiago et al. 2001; Paller et al. 2011).

Current conservation status of freshwater fish assemblage in major aquatic habitats in western part of Camarines Sur (CamSur), Philippines is poorly evaluated. Despite of the conservation and mitigation efforts for CamSur, the lake and stream ecology remains under the continued threats from different degree of anthropogenic pressures and habitat degradation. It is also worsen by lack of local awareness, and participatory protection on freshwater native fish assemblages. To the best of our knowledge, much of scientific and research endeavors in CamSur are bias towards commercially important fish species such as *Mistichthys luzonensis* (Soliman et al. 1998; Soliman and Sergio 2001), and *Oreochromis niloticus* (Cuvin-Aralar et al. 2012), whilst conservation studies for other indigenous diminutive freshwater fish species are apparently overlooked.

Fish assemblage structure is commonly used key bioindicator and descriptor of fisheries stability (Welcomme 1995), invasive alien species (Guerrero 2014), and ecological integrity of aquatic habitats at spatial and temporal scales (Zampella and Bunnell 1998; Uy 2008). Furthermore, several synthetic biological indices are commonly applied for the study of diversity and distribution of fish assemblages, mainly to evaluate the ecological health condition of aquatic habitats (Begon et al. 1996; Kwak and Peterson 2007; Paller et al. 2011, 2013).

Little is known on the current status and distribution of freshwater fish assemblages in CamSur, Philippines, particularly those thriving in Lake Bato, Lake Baao-Bula, Pawili River, Agos River, and Bagacay Falls. This study aimed to describe the spatial variation of freshwater fish assemblages, and to compare the diversity indices and environmental variables among the aforementioned aquatic habitats.

MATERIALS AND METHODS

Studied Areas

Fish species were inventoried in the five studied sites in western part of CamSur, Philippines representing two lakes, two streams, and one cataract (Fig. 1). (1) Lake Bato (13°19'N, 123°21'E near the center) is the seventh major lake in the country. It is a shallow eutrophic lake that recognized as the biggest, and one of the most important lakes in Bicol Region, Philippines in terms of size and economic benefits. It has a surface area that varies from 25 km^2 to 60 km^2 on dry and wet season, respectively. Its average depth is around 8 m. (2) Agos River is a 4.3 km-long stream (13° 20N, 123° 24'E) that fed Bato with water mainly coming from the eastern part of CamSur. (3) Lake Baao-Bula (13°27'N; 123°18'E near the center) (hereafter denoted Baao) is also a shallow eutrophic freshwater lake, and known as phantom lake since it usually dries up during the dry months. It has an estimated surface area of (1.77 km^2) and an average of only 1 meter deep. Pawili River (13° 31'N, 123° 17'E) is a 4.7-km long river that drains from urbanized Naga City and empties into the Baao. These four studied sites provide livelihood to the communities through aquaculture, fishing, irrigation, and tourism. Bagacay Falls is a semi-pristine cataract which has highly steep walls (about 6 m) surrounded mostly by pristine portion of deciduous and riparian forest, and epiphytes. The presence of calcified marine biota remnants such as shells, bryozoans, and sponges suggest marine origin of the areas. The site offers eco-tourism.

Sampling and Data Collection

Sixteen sampling stations were selected in littoral zone of the two lakes, whilst twelve stations were sampled in the two streams. Unit area sampled in each station was approximately 80–100 m^2. Three stations each having 60–80 m^2 were selected in the pool zone, and riffle zone of Bacagay. Seine netting (dimension = 8.0 m x 1.0 m, mesh size = 1.2 mm x 1.2 mm) was used in lakes and rivers with fine substrate, whereas 12-v backpack electrofishing gear was used in sites areas having rocky substrate. Seine nets and hand-nets were also used as traps during electro-fishing, wherein they were placed at the end of the transect lines to catch the fishes that goes with the water flow. Individual sampling run lasted ca. 40 min, and were done during day time (700–1500 hrs). Three-day sampling was carried out in February-March, and in July 2010. All species caught regardless of collection method used were initially counted, and identified at lowest possible taxon. Most of the captured fish were released alive back into the water. Captured fish were immediately counted and identified at lowest possible taxon. Specimens were either housed in laboratory as live specimens or preserved in 10% buffered formaldehyde for further documentation and identification. Specimens were identified using several fish identification materials (Herre 1924, 1927, 1953; Conlu 1986; Vidthayanon 2007; Froese and Pauly 2012).

Before collection, dissolved oxygen (DO, mgl^{-1}, Hanna HI 3810), water temperature (^oC), pH (Oakton pH tester 30), and salinity (mg L^{-1}, Atago hand refractometer) were recorded in each site. Geographic position was also recorded for each sampling station using a GPS device (CarNAVi Pro 400). Transparency (cm) was measured using a Secchi disc in each sampling station. Mean depth (m) was measured using a Secchi disc for depth more than 1 m, and a wooden ruler for depth less than 1 m at three points at each sampling station. Stream flow (m s^{-1}) was measured using a simple float. Dominant bottom type was recorded and categorized as organic detritus, silt, mud, sand (0.02—2.0 mm), gravel (2—64 mm), cobble (64—256 mm), and boulder (>256 mm) (May & Brown 2000). Visual estimation of vegetation cover (%) was determined by the relative amount of submerged and floating hydrophytes to sampling path as well as those occupying both sides of the riverbanks at time of sampling. Land use pattern is categorized based on the characteristic of landscape surrounding the riparian zone.

Data Analyses.

Species richness was determined by the number of species present in a community. The relative abundance for each species was calculated as:

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

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

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

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 the Shannon's diversity index:

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

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, n_i is the number of individuals in the ith species and *N* is the total number of individuals. Fish densities (number of individuals collected in one species /10 m^2) were computed for each site. Cumulative fish density data did not follow the normality assumptions (Shapiro-Wilk test), and with that, Friedman test and Wilcoxon test (pairwise comparison) were employed to determine the median variation of pooled density among the studied sites ($P<$ 0.05).

Abundance data were $\log_{10}$ (x+1) transformed to linearize the relationship.

Descriptive statistics of environmental variables were also computed. All variables did not meet the parametric assumptions and were subjected to univariate nonparametric tests (Kruskal-Wallis *H*-test, and Mann-Whitney *U*-test, $P < 0.05$). Bray-Curtis Index (Bray and Curtis 1957) was used to measure the similarity between habitats and the unweight pair group method with arithmetic mean was used to classify the groups according to log-transformed abundance data. All statistical analyses were performed using Paleontological Statistic version 3.0 and Statistica version 7.0.

RESULTS AND DISCUSSION

Environmental Data

Environmental characteristics of the five studied sites are presented in Table 1. Significant spatial differences were recorded in DO levels ($P< 0.05$), with the highest, and lowest DO concentrations were recorded in Bagacay, and Baao, respectively. Levels of pH (7.74-8.47) were statistically varied among sites ($P< 0.01$). Temperature was significantly comparable between Bato, Agos, Baao-Bula, and Pawili, but the temperatures of such were statistically different in Bagacay ($P< 0.01$). Surface water current was statistically similar between the two streams ($P< 0.01$), albeit considerably stronger current was measured in Bagacay. Freshwater conditions (≤ 0.05 ppt) were recorded in all sites.

The observed fluctuation of water parameters can be attributed to the variation between habitat types (lacustrine vs. riverine environment). Likewise, physico-chemical parameters (particularly temperature) in each site varied only according to the time of the sampling day when the parameters were recorded. Increased aeration brought by the water current could be the contributory factor in the higher measured DO levels in studied streams and cataract. Although slightly variable, conditions of pH are fairly neutral to basic. Spatial variation on temperatures was likewise observed, with higher temperatures measured in lacustrine habitats as compared to representative streams and cataract. Nevertheless, the parameters are still within the tolerable range for the survival of tropical fishes (Boyd 1982).

Abundance and Fish Composition

Overall,the completed ichthyofaunal survey inventoried a total of 8,184 specimens belonging to 29 species, 22 genera, and 14 families (Table 2). Bato had the highest fish abundance (n = 2,633) followed by Agos (n = 2,182), Baao-Bula (*n* = 1,412), Pawili (*n* = 1,400), and Bagacay (*n* = 557). Baao and an adjacent river Pawili had equal number of collected fish species (12 species). Bato had 20 species and its tributary Agos had 18 species. The isolated Bagacay had two enigmatic gobiids (Table 2). In terms of richness, gobiids (8 species), cyprinids (3 species), and poeciliids (3 species) are the most dominant fish species recorded in all sites. Gobiid was the most dominant fish group in Agos (5 species), Pawili (4 species), Bagacay (2 species), and Bato (jointly shared by cyprinids with 3 species each family), whereas cyprinids (3 species) are the most common fish group in Baao.

In general, four fish species comprised ca. 52% of the total abundance collected from the five studied sites. These were *Oreochromis niloticus* (Cichlidae), with relative abundance of 18.64%, *Glossogobius giuris* (Gobiidae) 13.28%, *Poecilia sphenops* (Poeciliidae) 10.82%, and *P. reticulata* (Poeciliidae) 10.31%. Two fish species comprised the 55.34% of the total abundance collected from Bato. These were *O. niloticus*, with relative abundance of 30.12%, and *G. giuris* 25.22%. The most abundant fish species in Agos were *P. reticulata* and *P. sphenops* (50.87% of the cumulative relative abundance and in order of importance). Three fish species namely, *Borbodes gonionotus* (Cyprinidae), *Leiopotherapon plumbeus* (Terapontidae),and *Cyprinus carpio* (Cyprinidae) were the most abundant catch in Baao (57.36%), whereas *O. niloticus, C. carpio,* and *G. giuris* in Pawili (55.36%). In Bagacay, a single fish species *Redigobius rivalis* (Gobiidae) (99.38%) dominated the total number of fish collected

The survey revealed that the introduced species mostly consisting of cichlids, cyprinids, and poeciliids are establishing feral populations in four representative sites. Introduced species documented in the current study are known to be habitat generalists, highly prolific, and can reduce fish diversity through competition with natives (Cagauan 2007, Guerrero III 2014). As suggested by Humpl and Pivnicka (2006), the abundance of introduced fish species is often attributed by their escaping from fish cages, and or by regular stocking by fish farmers.

Escapement of introduced cultured fish species and their potential to become invasive are considered to be the most detrimental effect of aquaculture on biodiversity loss (Diana 2009). It is widely known that their establishment and invasion success are mainly attributed for being highly adaptive to wide range of conditions and efficient resource acquisition in the environment (Burnett et al. 2006). In Bato, around 14,000 fish cages (mostly tilapia farming) are said to be operating in the lake, and the presence of these may negatively influence the lake and stream fish assemblages. One damaging impact of such is the recognized depletion of stock of the esteemed smallest commercial fish, *M. luzonensis* (Gobiidae) due to predation. Continuous agricultural run-offs and residential effluents also pose threats to the stability of more vulnerable native fish faunas. (Pili, Municipal Agriculturist of Bato, pers. comm.). A similar plight was also recognized in Baao. Although unlike in Bato, the local communities seem to be satisfied in the existing ichthyofaunal condition of the lake as the fisher folks otherwise desire the introduced species as the major components of their fish catch (Joven, Agricultural Officer of Baao, pers. comm.).

Fish Diversity and Densities

Biological indices and fish densities for each representative site were summarized in Table 3. Four studied sites namely, Bato, Agos, Baao, and Pawili exhibited relatively high diversity indices (2.04—2.07), while Bagacay was least diverse (0.04, $P< 0.01$). Shannon's Evenness for the aforementioned sites also showed relatively high values (0.68—0.82), albeit the equitability indices of Bato and Agos were statistically different from those computed in Baao and Pawili ($P< 0.05$). Bagacay had significantly lowest evenness value (0.07, $P< 0.01$).

Bagacay had a very high Simpson's dominance value (0.99), which was statistically different from the low dominance values (0.15—0.18) of other four sites ($P< 0.01$). Pooled fish densities were significantly different among the five studied areas (Friedman test: $\chi^2 = 43.06$, $P< 0.01$). Pairwise comparison revealed significant spatial differences except to fish densities recorded in Bato vs Bagacay (Wilcoxon test: $Z = 1.63$, $P> 0.05$), and Baao vs Pawili (Wilcoxon test: $Z = 1.73$, $P> 0.05$).

In comparison, estimated H' (except Bagacay) was higher than any of those in the mountain streams in Mt. Makiling Forest Reserve in Laguna (mean richness = 12, mean H'= 1.16) (Paller et al. 2011), and in Tayabas-Iyam streams of Mt. Banahaw Protected Lanscape in Quezon (mean richness = 13, mean H' = 1.55) (Paller et al. 2013). Our computed H', however, was comparatively lower than any of those measured in the streams in Sorsogon (richness = 16, mean H' = 2.41), and Pansipit River in Batangas (richness = 21, mean H'= 3.05) (Corpuz et al. 2010, 2011). According to Namin and Spurny's (2004) method of categorizing the estimated H' values based on the impact of anthropogenic disturbances, the computed H' in Bato's lakes and streams are considered moderately impacted. The species distribution exhibited low dominance and relatively high evenness signifying that the allocation of niche space is distributed equitably for dominant and non-dominant fish species (Begon et al.1996), albeit a very high dominance of a single species was determined in Bagacay.

Similarity

Bray-Curtis similarity analysis for fish composition and log-transformed abundance data revealed the clustering of the five sites (Fig. 2). Bagacay registered nearly 0.00% level of similarity, which was clearly deviated from the other sites. Interestingly, relatively high levels of similarity were observed between Baao, Bato, Pawili, and Agos (in order of similarity) having a range of 49.61%— 62.81%. The overall ichthyofaunal resemblances among watersheds (except Bacagay) are relatively high as inferred by the occurrence of various introduced fish species *O. niloticus, C. carpio, Trichopodus pectoralis,T. trichopterus, P. sphenops, P. reticulata*, and a native species, *G. celebius*. Such fish species are the most common and widely distributed in the studied sites of CamSur. These similarities are associated to hydro-spatial connection of the four sites, dispersal mechanism of the fish, and or due to translocation and re-introduction during stocking of cultured species. Native fish species, however, had relatively low similarity (23.24%), indicating the exclusivity of some species in a particular site (*e.g. Anguilla marmorata,M. luzonensis, R. bikolanus, Leiognathus equulus,* and *Crenimugil heterocheilos* in Bato, *Gulaphallus bikolanus*, and *Dermogenys pusilla* in Pawili). Interestingly, the pristine Bagacay served as sanctuary for only two gobiids, a riffle-dwelling *R. rivalis* and a pool-dwelling *Stiphodon elegans*. For this study, 6 out of 20 species were considered exclusive to Bato; 4 out of 18 species were exclusive to Agos; whereas fish species in Baao and Pawili are common inhabitants in Bato and Agos.

CONCLUSIONS

The four aquatic habitats namely: Bato, Agos, Baao, and Pawili had relatively diverse freshwater fishes, with true gobies (Gobiidae) being the most dominant group in terms of richness, albeit the fish abundance is numerically dominated by introduced or exotic fish species (cichlids, cyprinids, and poeciliids). The presence of introduced species, specifically, *O. niloticus* is attributed to escapement from fish pens and cages, and or introduction for aquaculture. In general, the areas are classified moderately impacted by anthropogenic pressures. Despite having a low diversity, the isolated and semi-pristine Bacagay provides haven for two enigmatic gobies. This study updated the list of freshwater fishes in CamSur, and provide essential baseline information for future fish survey and further conservation strategies for the studied areas.

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Table 1. Abiotic (mean ± SE) and habitat characteristics of five studied sites in Bato, Camarines Sur, Philippines

Abiotic and Habitat Characters	**Bato**	**Agos**	**Bagacay**	**Baao**	**Pawili**	***H*-values**
Dissolved Oxygen (mg L^{-1})	5.66 ± 1.02^{ab}	6.38 ± 1.54^{abc}	7.41 ± 0.37^{c}	5.22 ± 0.57^{a}	6.15 ± 0.15^{b}	9.91*
pH	8.47 ± 0.22^{a}	7.82 ± 0.26^{b}	8.1 ± 0.36^{a}	7.74 ± 0.55^{b}	7.75 ± 0.18^{b}	16.76**
Water Temperature (°C)	29.28 ± 0.85^{a}	28.56 ± 1.73^{a}	25.53 ± 0.15^{b}	29.59 ± 1.28^{a}	27.93 ± 1.10^{a}	15.39**
Surface Velocity (m s^{-1})	-	0.49 ± 0.09^{a}	0.98 ± 0.13^{b}	-	0.47 ± 0.07^{a}	12.52**
Transparency (cm)	28.78 ± 0.74^{ab}	30.56 ± 0.97^{b}	43 ± 0.84^{c}	26.89 ± 0.86^{a}	29.67 ± 0.83^{b}	18.25**
Depth (m)	0.97 ± 0.07^{a}	0.56 ± 0.04^{c}	0.52 ± 0.08^{c}	0.72 ± 0.04^{b}	0.56 ± 0.03^{c}	26.17**
Salinity (mg L^{-1})	0.01	0.0	0.0	0.0	0.0	-
Substrata	muddy + sandy	Sandy	Boulder + Cobble + Sandy	Muddy	Sandy + cobble	-
Dominant vegetation	*Eichhornia crassipes,* riparian macrophytes	riparian macrophytes	bryophytes, epiphytes, algae	*Oryza sativa,* riparian macrophytes, algae	riparian macrophytes	-
Land use	residential, agriculture	grassland, agriculture, residential	forest	agriculture	grassland, agriculture	-

**significant at 1% level of confidence; *significant at 5% level of confidence; for each abiotic variable, means with same superscript letter are not significantly different at 5% level of confidence

Table 2. Distribution of freshwater fish species recorded from the five studied sites in Bato, CamSur, Philippines

Fishes	Bato	Agos	Bagacay	Baao	Pawili
Anguilidae (freshwater eels)					
Anguilla marmorata	+	-	-	-	-
Gobiidae (true gobies)					
Glossogobius celebius	+	+	-	-	+
Glossogobius giuris	+	-	-	+	+
Mistichthys luzonensis	+	-	-	-	-
Redigobius bikolanus	-	+	-	-	-
Redigobius dispar	-	+	-	-	+
Redigobius rivalis	-	-	+	-	-
Rhinogobius sp.	-	+	-	-	+
Stiphodon sp.	-	+	+	-	-
Hemiramphidae (halfbeaks)					
Dermogenys pusilla	-	+	-	-	-
Zenarchopterus sp.	+	-	-	-	+
Leiognathidae (slipmouths)					
Leiognathus equulus	+	-	-	-	-
Mugiliidae (mullets)					
Crenimugil heterocheilos	+	-	-	-	-
Phallosthetidae (priapium fishes)					
Gulaphallus bikolanus	-	+	-	-	-
Terapontidae (grunters)					
Leiopotherapon plumbeus	+	+	-	+	+
Anabantidae (climbing gouramis)					
Anabas testudineus	+	-	-	-	-
Channidae (murrels)					
Channa striata	+	+	-	+	-
Cichlidae (cichlids)					
Oreochromis niloticus	+	+	-	+	+
Tilapia zillii	+	-	-	-	-

Clariidae (freshwater catfishes)					
Clarias batrachus	+	+	-	+	+
Clarias gariepinus	-	+	-	+	-
Cyprinidae (cyprinids and minnows)					
Ctenopharyngodon idella	+	-	-	+	-
Borbodes gonionotus	+	-	-	+	+
Cyprinus carpio	+	+	-	+	+
Osphronemidae (gouramis)					
Trichopodus pectoralis	+	+	-	+	-
Trichopodus trichopterus	+	+	-	+	-
Poecilidae (livebearers)					
Xiphophorus hellerii	-	+	-	-	-
Poecilia reticulata	+	+	-	-	+
Poecilia sphenops	+	+	-	+	+
Abundance	2,633	2,182	557	1,412	1,400

Table 3. Number of taxa, and diversity indices recorded from five studied sites in Camarines Sur, Philippines. H'= Shannon-Weiner diversity index; J'= Shannon evenness Index; λ= Simpson's species dominance index; *d* = fish density (fish/10m^2).

Biological indices	Bato	Agos	Bagacay	Baao	Pawili
Taxa	20	18	2	12	12
H'	2.06^a	2.05^a	0.04^b	2.07^a	2.04^a
J'	0.68^a	0.72^a	0.07^c	0.83^b	0.82^b
λ	0.18^a	0.17^a	0.99^b	0.15^a	0.15^a
d	12	16—17	12—13	8	7—8

In a row, means with same superscript letter are not significantly different (*P*> 0.05)

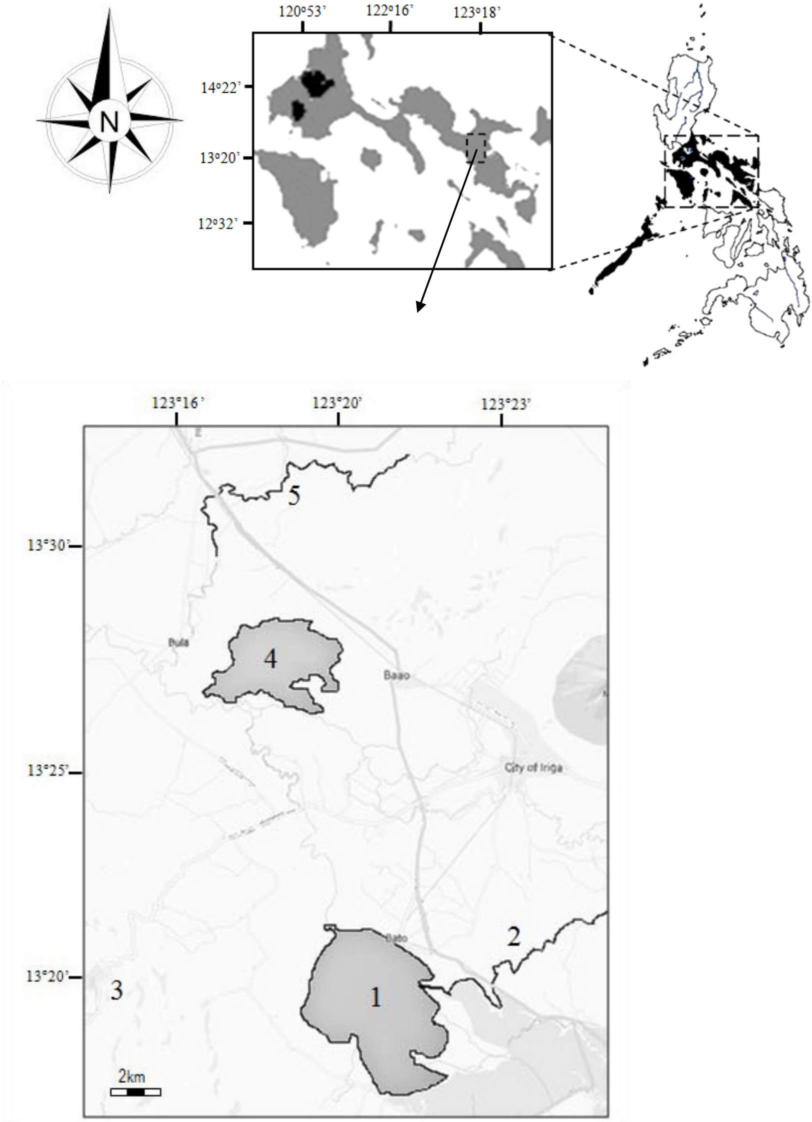

Fig. 1. Map of southern Luzon, Philippines showing the five studied sites. (1) Lake Bato, (2) Agos River, (3) Bagacay Falls, (4) Lake Baao-Bula, and (5) Pawili River.

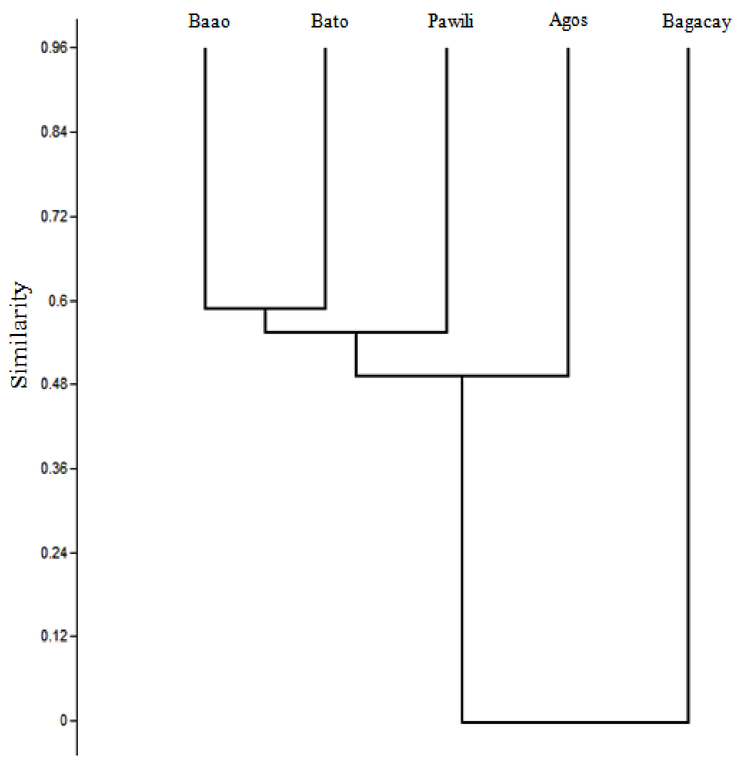

Fig. 2. A dendrogram from unweighted pair group method with arithmetic mean showing the relationship of five studied sites based on species composition and log-transformed abundance data.

Plate 3. Photos, scientific names, and common names of freshwater fishes recorded from the five studied sites in Bato, CamSur, Philippines.