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Diminutive Freshwater Fish in the Santa Cruz River System, Laguna, Philippines

ABSTRACT

Diminutive freshwater fishes are small vertebrate species, maturing at sizes equal or less than 50-100 mm. The distribution and diversity status of these fishes are poorly known because they are difficult to observe in the wild due to their small size and remote location, especially in selected crater lakes, mountain streams, and waterfalls. The study provides baseline data for the diminutive freshwater fishes in the Santa Cruz River System in Laguna, Philippines. The survey was conducted in the upstream, midstream, and downstream for three quarters in 2016-2017. A total of 1,474 individuals belonging to nine families, 12 genera and 15 species were collected. Of the nine families, Gobiidae was the most abundant (47%) followed by Poeciliidae (18%) and Eleotridae (11%). Shannon-Weiner diversity indices ranged from 0.59 to 1.73. Dominance and Evenness ranged from 0.20 -0.75 and 0.23 to 0.99 respectively. The study recommends preventive approaches over restorative actions for the conservation and protection of the diminutive fishery resource.

Keywords: *Diminutive Freshwater Fish, Diversity, Distribution, Fish assemblages, Philippines*

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INTRODUCTION

The Philippine freshwater ecosystem is one of the major zoogeographic regions of Southeast Asia where an extremely diverse ichthyofauna is recorded (*Zakaria-Ismail 1994*). It is also one of the seventeen-megadiverse countries, which together contain 70% to 80% of global biodiversity recognized by the UNEP World Conservation Monitoring Centre and at the same time a biodiversity hotspot in its entirety (*Mittermeier et al. 1997*). The monumental work of *Herre* (*1953*) recorded 2,145 Philippine fishes, 608 (28.3%) are freshwater fishes, of which 83 are endemic, 206 are native, and 44 are introduced in the country and 42 are of uncertain status (*Froese and Pauly 2022*).

The ecoregion is unique in Asia because of the large number of fish species that have evolved from a few ancestral species, including diminutive freshwater fishes which are least known because of their extremely small adult sizes. Diminutive freshwater fishes mature at 50 mm or less (*Bennet and Conway 2010*). In the Philippines, little is known about the diversity and status of these species because these are difficult to see in the wild due to their small size and remote location, especially in selected crater lakes, mountain streams, and waterfalls (*Vallejo Jr. 1986; Ng et. al. 1998*). Seven fish families of diminutive taxa are known from the Philippine freshwater, namely, Gobiidae, Cyprinidae, Eleotridae, Phallostethidae, Syngnathidae, Terapontidae, and Zenarchopteridae (*Ocampo et al. 2010*).

The decline of freshwater fishes is a generalized phenomenon noticeable on global, regional, and local scales. In the Philippines, many freshwater ecosystems are experiencing natural and anthropogenic pressures, and many were invaded by introduced species (*Dudgeon et al. 2006*). Native and endemic fishes face various threats and possible extinction even before they get discovered and described. Factors such as overexploitation of species, introduction of exotic species, pollution from urban, industrial, and agricultural areas, as well as habitat loss (*Krauss et al. 2010*), and alteration through damming and water diversion all contribute to the declining levels of aquatic biodiversity. *Harrison et al.* (*1999*), reported that habitat alteration contributed to 71% of extinction and 5% of non-native species which can compete or feed on native species. Of the 71%, 29% is from overfishing and 26% from pollution. Consequently, valuable aquatic resources are becoming increasingly susceptible to both natural and artificial environmental changes, which resulted in the declining population of fish species in the Philippines (*Bagarinao 2001*).

Surveys of the freshwater habitats can be an initial step in addressing issues related to the freshwater fish because many unique species in the Philippine freshwater ecoregion could soon become extinct. Some areas have been identified as having abundant freshwater species, but it is unknown whether these areas are special or are typical of most freshwater habitats. Additionally, these are integral components of the aquatic food web, feeding on insects and serving as prey for other fishes such as mudfish, birds, and other wildlife. With further surveys, it is possible to highlight those areas most in need of conservation. Especially that the freshwater environment is severely threatened more than those most affected terrestrial environments (*Nath et al. 2021*). Their conservation and management are critical to the interests of all humans, nations, and governments, yet this precious heritage is in crisis. If trends in human demands for water remain unaltered and species losses continue at current rates, the opportunity to conserve much of the remaining biodiversity in freshwater will vanish.

The Santa Cruz River System has two major headwaters - Liliw and Nagcarlan. They are characterized by intact forest cover, its midstream is in Magdalena which is an agricultural area, and downstream is in Santa Cruz a residential and commercial area that drains into Laguna de Bay. The study provides a baseline information on the diversity and abundance of freshwater fishes in the Santa Cruz River System.

MATERIALS AND METHODS

Study Site

The Santa Cruz River System is one of the 21 major tributary rivers contributing to about 15% of the total water in the biggest lake in the Philippines-the Laguna de Bay (*LLDA 2011*). Its headwaters are located in Mounts Banahaw-San Cristobal Protected Landscape (MBSCPL) in the Southern part of Luzon. The MBSCPL is considered one of the remaining forested areas in Southern Luzon. It supports a wide range of flora and fauna diversity and endemicity that ranges from 66-76% (*Gascon 2002*). The downstream part of the Santa Cruz river system is classified by the Environment and Management Bureau (EMB) Department of Environment and Natural Resources (DENR) as Class C (*EMB 2022*). The water quality of Class C freshwater is suitable for agriculture, irrigation, livestock watering, and industrial water supply class.

Four sampling stations were established in the Santa Cruz River System, which would represent the upstream, midstream, and downstream sections of the river. Two sampling stations were established in the upstream portion to represent the two headstreams of the river. These were located in the Municipalities of Nagcarlan and Liliw. The municipalities of Magdalena and Santa Cruz cover the midstream and downstream portions, respectively. The upstream stations were surrounded by primary and secondary forests and a small community with about 45 households. The midstream is inhabited by a community engaged in livestock raising and farming. The downstream site is in the población area of Santa Cruz where residential and commercial establishments are present.

Sampling Design

The collection of samples was done for three quarters from December 2016 to June 2017. December 2016 to June 2017. Year 2017 is the 10th hottest year in the Philippines since the 1950s. It is also the year where the annual and monthly precipitation is above normal, and a weak La Niña event during the last quarter of 2017 (*OML 2019*). The collection of samples followed

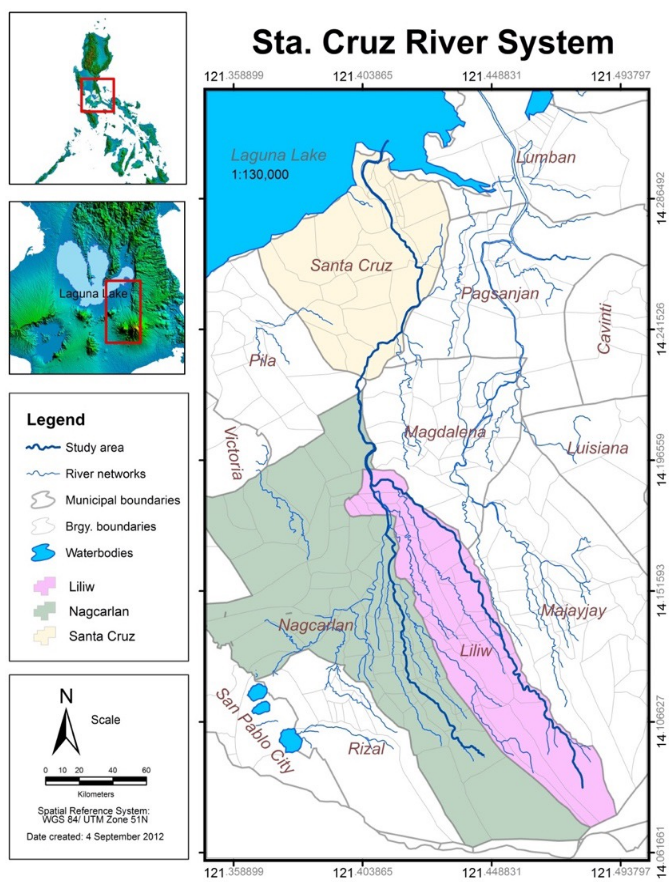

Figure 1. Map of Santa Cruz river system showing the upstream in Nagcarlan and Liliw, midstream in Magdalena, and downstream in Sta. Cruz.

that of *Paller et al.* (*2011*), where fish sampling was carried out for two days at almost the same time of the day to minimize temporal biases. Fishes were sampled and harvested using electrofishing, seine net, and gill net. Before the sampling, an electrofishing permit was secured at the Bureau of Fisheries and Aquatic Resources (BFAR) and the Local Government of Nagcarlan, Liliw, Magdalena, and Santa Cruz. The electroshocking device consists of two copper electrodes mounted on wooden handles and powered by a 10-watt portable battery, enough to stun the diminutive fishes. Hand-nets were used as traps and were placed at the end of the transect line to catch the fishes that go with the water flow. A 2.8 m wide x 8.44 m and 1.4 m long seine net with a mesh size of 1.2 x 1.2 mm was used in shallow pools. The methods used were all carefully standardized to minimize sampling variability. All species caught during the survey were counted and their initial identifications were recorded. Among the sampled fishes, diminutive species with a standard adult length of less than 100 mm were considered. Representative samples were brought to the laboratory for accurate identification while the remaining catch was released back into the water. The collected specimens were preserved in 10% buffered formalin. Identified fishes were sent to the Museum of Natural History (MNH), University of the Philippines Los Baños (UPLB) for verification.

Data Analysis

The abundance of diminutive fish was used in the construction of a matrix of species across different freshwater habitats and across the sampling period. It was further subjected to different diversity and community structure analyses. The non-metric multi-dimensional scaling (NMDS) was used to geographically represent a relationship of diminutive fish species between freshwater habitats across different sampling periods in a multidimensional space. The association among species was analyzed by species-clustering analysis (UPGMA). The Microsoft Excel and PAST software version 3.14 (*Hammer et al. 2001*) was used in the data analyses.

RESULTS AND DISCUSSION

Diversity and Distribution of Diminutive Freshwater Fish

Fifteen species of diminutive freshwater fishes belonging to nine families and 12 genera comprising the

Table 1. Diminutive freshwater fishes of the Santa Cruz river system.

Family	Species	Common name	IUCN Conservation Status	Sampling stations			Sta. Cruz
				Nagcarlan	Liliw	Calumpang	
Gobiidae (True Gobies)	*Glossogobius aureus*	Golden fathead Goby	Least Concern	38	65	18	52
	Glossogobius cf. illimis	False Celebes Goby	No data	45	47	10	15
	Gobiopterus lacustris	Lacustrine Goby	Data Deficient	-	-		413
Hemiramphidae (Halfbeaks)	*Nomorhamphus pectoralis*	Halfbeak	Least Concern	45	38	15	-
Zenarcoptiridae (Halfbeaks)	*Zenarchopterus philippinus*	Halfbeak	Least Concern	3	-	25	72
Terapontidae (Tigerperch)	*Leiopotherapon plumbeus*	Silver Perch	Vulnerable		-		13
Cyprinidae (Carps and Minnows)	*Barbodes binotatus*	Spotted Barb	Least Concern	12	-	60	1
	Dawkinsia arulius	Aruli Barb	Endangered	-	-	23	-
Syngnathidae (Pipefishes)	*Micropis brachyurus brachyurus*	Pipefish	No data	-	-	-	28
Eleotridae (Sleepers and Gudgeons)	*Giuris margaritacea*	Snakehead Gudgeon	Least Concern	-	1	-	162
Osphronemidae (Gouramies)	*Trichopodus trichopterus*	Three-spot Gourami	Least Concern	-	-	-	7
	Trichopodus pectoralis	Snakeskin Gourami	Least Concern	-	-	-	6
Poeciliidae (Livebearers)	*Poecilia reticulata*	Guppy	Least Concern	21	29	28	-
	Poecilia sphenops	Molly	Least Concern	53	33	68	10
	Xiphophorus hellerii	Green Swordtail	Least Concern	2	-	12	4

1,474 individuals were recorded from the ichthyofaunal survey conducted in the Santa Cruz River System (**Table 1**). These belong to the family: Cyprinidae, Eleotridae, Gobiidae, Hemiramphidae, Osphronemidae, Poeciliidae, Syngnathidae, Terapontidae, and Zenarcopteridae. *Giuris margaritacea*; *Micropis brachyurus brachyurus*; *Leiopotherapon plumbeus; Nomorhamphus pectoralis* and *Zenarchopterus philippinus* were the only species collected from Families Eleotridae, Syngnathidae, Terapontidae, Hemiramphidae and Zenarchopteridae, respectively.

Two species were collected from Family Cyprinidae, namely: *Barbodes binotatus* and *Dawkinsia arulius*. The Gobiidae family had *Glossogobius aureus, Glossogobius cf. illimis*, and *Gobiopterus lacustris*.

Among the fish as collected, the Gobiidae family dominated the number of individuals at 48%, followed by Poeciliidae at 17% and Eleotridae at 11% (**Figure 2**).

Poecilia reticulata (guppy), *Poecilia sphenops* (molly), and *Xiphophorus hellerii* (green swordtail) were the three species identified belonging to Family Poeciliidae. Two species of Family Osphronemidae were *Trichopodus trichopterus* (three spot gourami) and *Trichopodus pectoralis* (snakeskin gourami). *Dawkinsia arulius* (aruli barb) is an endangered species in India as recorded by the IUCN Redlist of threatened species was collected in Santa Cruz River System (*Abraham 2015*). A possible mode of introduction is through ornamental or aquarium trade because of its filamentous dorsal fin. Based on published literatures, this is the first time to document this species in the Philippines.

Santa Cruz was found to have the highest richness with 14 species, followed by Calumpang with 11, Nagcarlan with 8, and Liliw with 6. Shannon-Weiner Diversity index showed high values in all the stations but Calumpang and Santa Cruz had the highest with 1.98 and 1.91 correspondingly, and 1.82 and 1.69 for Nagcarlan and Liliw. The diversity index is the total number of species, in proportion to the number of individuals considering its evenness. Although Santa Cruz is high in the number of species and individuals, it is dominated by *Glossogobius lacustris* which causes the evenness values to drop. Species diversity in all sampling stations is high considering that the natural ecosystem diversity index ranges from 1.5 to 3.5, where 3.0 indicates habitat stability while 1.0 or less indicates a disturbed environment (*Magurran 2004*).

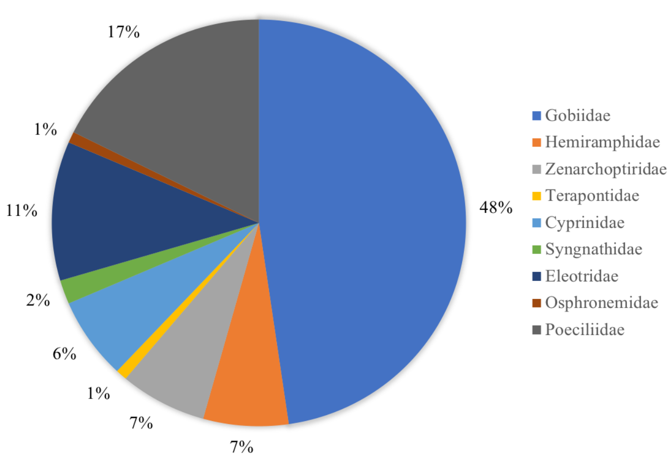

Figure 2. Percent distribution of diminutive freshwater fish in the Santa Cruz river system.

Compared to the other mountain freshwater habitat in Southern Tagalog region, the indices of the Santa Cruz River System appeared to be more diverse. The richness and diversity indices of the Santa Cruz River System are comparatively higher than that of Tayabas River (species=15, H'=1.55) (*Paller et al. 2013*) which is also part of the Mount Banahaw-San Cristobal Protected Landscape (MBSCPL). Dampalit Creek in Mount Makiling Forest Reserve has 12 species with a 1.12 diversity index and Molawin Creek in the same forest reserve with the same number of species 12 and 1.19 diversity index (*Paller et al. 2011*); Tikob Lake in Tiaong, Quezon with 9 species and 1.87 diversity index (*Labatos Jr. and Briones 2014*); Bulusan River in Sorsogon, but lower than Pansipit River in Batangas with 21 species and diversity index of 3.05 and Camarines Sur with 29 species and 2.07 diversity index (*Corpuz et al. 2015*).

Pilou's evenness was similar to that of the Shannon-Weiner diversity indices with 0.69 as the highest evenness value from Calumpang, followed by those from Santa Cruz, Nagcarlan, and Liliw with 0.66, 0.63, and 0.58 respectively. Dominance on the other hand had an inverse relationship with diversity and evenness. Santa Cruz with 0.32 showed a significantly high dominance value while Calumpang had the lowest with 0.16. Dominance in Santa Cruz is weighted towards the abundance of the *G. lacustris* which comes in large schools and is known to be endemic in Laguna de Bay.

The Assemblage of Diminutive Freshwater Fish in the Santa Cruz River System

The freshwater fish during the first sampling showed the highest frequency value (*F=378*) of *Gobiopterus lacustris* from the family Gobiidae while *Trichopodus trichopterus* from the family Osphronemidae has the lowest frequency (*F=3*). This is probably because of the endemicity of *G. lacustris* in Laguna de Bay where the sampling station is near at, while the *T. trichopterus* is an introduced species in the area. The freshwater fish during the second sampling revealed that *Giuris margaritacea* from the family Eleotridae has the highest frequency (*F=99*) while the *Trichopodus pectoralis* from the family Osphronemidae has the lowest frequency value (*F=1*). During the third sampling, the *Glossogobius aureus* from the family Gobiidae has the highest frequency value (*F=59*) while the *Leiopotherapon plumbeus* from the family Terapontidae and *Trichopodus trichopterus* from the family Osphronemidae had the lowest frequency value (*F=2*). There were no sighting of *Zenarchopterus philippinus*, *Barbodes binotatus* and *Dawkinsia arulius* during the first sampling in December 2016, while the *Gobiopterus lacustris, Nomorhamphus pectoralis, Dawkinsia arulius, Trichopodus pectoralis* and *Xiphophorus hellerii* were absent during the third sampling of May 2017 (**Table 2**). *Chea et al.* (*2020*) and *Mohd Shafiq et al.* (*2014*) reported that shifts in functional structure, migration, seasonal structure, feeding habits, and accessory respiratory adaptations are some of the possible reasons for the changes in community structure.

During the first sampling on December 2016, the Santa Cruz station accounted for eight different species among other stations with 439 individuals. However, the area had a lot of domineering species like *Gobiopterus lacustris*. This account reflected that Santa Cruz had the lowest diversity value based on Simpson (0.25) and Shannon diversity (0.59). The second sampling revealed that the Santa Cruz station had the highest species richness with 254 individuals. However, the Nagcarlan station showed more diversity based on Simpson (0.80) and Shannon index (1.73). The third sampling showed higher species richness (8) in Santa Cruz with 90 individuals. The Nagcarlan station had the highest dominance value (0.35), but the Calumpang station was more diverse (0.72) based on the Simpson index while Santa Cruz was more diverse based on the Shannon index (1.49). However, the distribution of freshwater fish was more even in Nagcarlan station (0.98) (**Table 3**).

The NMDS ordination with a stress value of 0.13 indicated a potentially useful ordination of the data. Group 1 revealed a similar composition of freshwater fish across three different sampling schedules (**Figure 3**). The ANOSIM value (R=-0.08102, P=0.7932) supported the similarity of the freshwater fish composition across different sampling schedules.

The results from the species-clustering analysis (UPGMA) revealed three main groups at a 60 % similarity value (**Figure 4**). The first group was composed of Liliw station during the first and second sampling schedules and Nagcarlan during the second sampling schedule. The second group was composed of Nagcarlan and Calumpang during the first sample schedule and Liliw station during the third sampling schedule. The third group was composed of Calumpang during the second and third sampling schedule and Santa Cruz during the second sampling.

Native and Introduced Species

From the 1,474 individuals collected, 1,178 are native

Table 2. Frequencies of freshwater fish across different sampling schedules

Species	Family	Frequency					Relative Frequency		
		1st	2nd	3rd	Total	Mean	1st	2nd	3rd
Glossogobius aureus	Gobiidae	54	60	59	173	57.67	0.08	0.14	0.22
Glossogobius cf illimis	Gobiidae	38	51	28	117	39.00	0.06	0.12	0.10
Gobiopterus lacustris	Gobiidae	378	35	0	413	137.67	0.57	0.08	0.00
Nomorhamphus pectoralis	Hemiramphidae	39	59	0	98	32.67	0.06	0.14	0.00
Zenarchopterus philippinus	Zenarchoptiridae	0	73	27	100	33.33	0.00	0.17	0.10
Leiopotherapon plumbeus	Terapontidae	9	2	2	13	4.33	0.01	0.00	0.01
Barbodes binotatus	Cyprinidae	0	42	31	73	24.33	0.00	0.10	0.11
Dawkinsia arulius	Cyprinidae	0	23	0	23	7.67	0.00	0.05	0.00
Giuris margaritacea	Eleotridae	35	99	29	163	54.33	0.05	0.23	0.11
Micropis brachyurus brachyurus	Syngnathidae	4	14	10	28	9.33	0.01	0.03	0.04
Trichopodus pectoralis	Osphronemidae	5	1	0	6	2.00	0.01	0.00	0.00
Trichopodus trichopterus	Osphronemidae	3	2	2	7	2.33	0.00	0.00	0.01
Poecilia sphenops	Poeciliidae	37	69	58	164	54.67	0.06	0.16	0.21
Poecilia reticulata	Poeciliidae	48	4	26	78	26.00	0.07	0.01	0.10
Xiphophorus hellerii	Poeciliidae	16	2	0	18	6.00	0.02	0.00	0.00

Note: 1st sampling (December), 2nd sampling (March), 3rd sampling (June)

Table 3. Diversity indices summary of freshwater fish across different sampling schedules.

		Richness	Abundance	Dominance	Simpson	Shannon	Evenness
1st Sampling	Liliw	4	58	0.40	0.60	1.05	0.72
	Nagcarlan	5	85	0.20	0.80	1.60	0.99
	Calumpang	6	84	0.22	0.78	1.63	0.85
	Sta Cruz	8	439	0.75	0.25	0.59	0.23
2nd Sampling	Liliw	6	84	0.25	0.75	1.48	0.73
	Nagcarlan	8	109	0.20	0.80	1.73	0.71
	Calumpang	6	89	0.24	0.76	1.56	0.79
	Sta Cruz	10	254	0.24	0.76	1.69	0.54
3rd Sampling	Liliw	4	67	0.30	0.70	1.29	0.90
	Nagcarlan	3	25	0.35	0.65	1.07	0.98
	Calumpang	5	90	0.28	0.72	1.38	0.79
	Sta Cruz	8	90	0.29	0.71	1.49	0.56

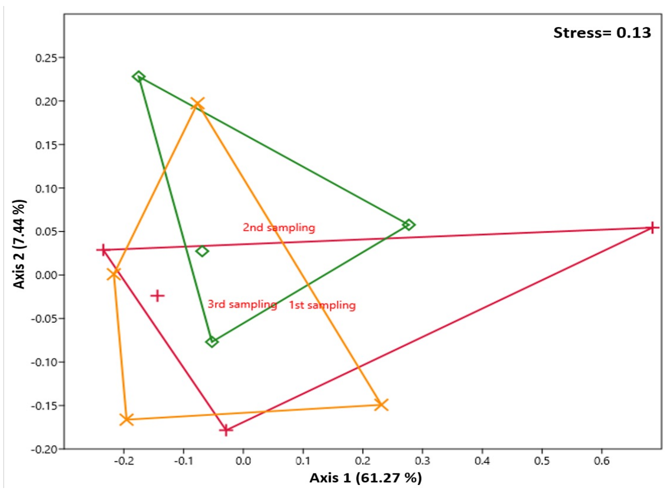

Figure 3. Non-metric multidimensional scaling (NMDS). Pairwise dissimilarity of sampling schedule of the freshwater fish survey in a low-dimensional space.

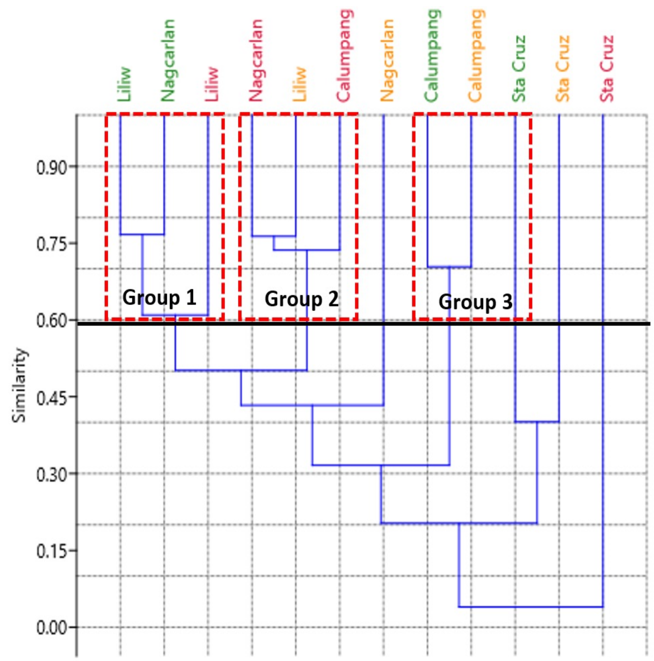

Figure 4. Species-clustering-analysis dendrogram (UPGMA) provided from binary sampling.

species and 296 are introduced. Native species belongs toseven families with nine species, the most abundant is Gobiidae family where *Gobiopterus lacustris* comprise the 35%, followed by *Glossogobius aureus* (14%), and *Glossogobius cf. illimis* (10%). Introduced species belongs to three families with six species; the most abundant is Poeciliidae family where *Poecilia sphenops* comprise the 53% followed by *Poecilia reticulata* with 25%.Ichthyofaunal surveys conducted in Southern Luzon discovered that gobies are the most abundant and diverse group of native fish thriving in the area (*Ocampo et al. 2010*). These are gobies (Gobiidae and Eleotridae), cyprinids (Cyprinidae), pipefishes (Syngnathidae) and halfbeaks (Hemiramphidae).

In the Philippines, 330 species are recorded as Philippine endemics and 127 are Gobioid, this includes *Giuris margaritacea, Glossogobius aureus, Glossogobius cf. illimis* and *Gobiopterus lacustris* (*Herre 1927*). The occurrence of *Glossogobius cf. illimis* and *Glossogobius aureus* has not been recorded in the extensive study conducted in Southern Luzon (*Corpuz et al. 2013; Labatos Jr. et al. 2014; Paller et al. 2011*). Although, as described by (*Hoese and Allen 2011*) *G. illimis* was found in Negros, La Union, and Negros Oriental.

In the Philippines, Nomorhamphus is endemic with seven species (*N. bakeri, N. manifesta, N. pectoralis, N. philippina, N. pinnimaculata, N. rossi* and *N. vivipara*) and Sulawesi with 9 species (*Huylebrouck et al. 2012*). During Herre's Philippine expedition, *Meisner* (*2001*) identified the occurrence of *N. pectorals*, when *Dermogenys viviparous* was mixed among the collected species in Molawin Creek, Los Baños, Laguna.

Silver perch (*Leiopotherapon plumbeus*) is an endemic species in the freshwaters of the Philippines, specifically, in Laguna de Bay. Locally known as Ayungin, it was considered to be the most abundant freshwater fish species in Laguna Lake until 1991, which comprised about 70% of the total fish catch in the lake (*Mercene and Cabrera 1991*). However, decrease in abundance was observed by (*Palma et al. 2002*) due probably too intense fishing pressure and introduction of knife fish in Laguna Lake.

Introduction of freshwater fishes in the county were used as ornamental, aquaculture, mosquito control and fisheries. Typically, species meant for mosquito control and fisheries are allowed to be released to natural waters, whereas other species should be confined in facilities (*Casal et al. 2007*). From the list of aquaculture species introduced in the Philippines, 93% were composed of freshwater fish, others were mollusk, crustaceans and turtles (*Cagauan 2007*). Once these introduced species were released, there is a tendency to adopt a niche that differs from that of its native environment. These species may affect the native species through predation, competition, habitat changes, genetic changes, and introduction of parasites and disease.

Poeciliidae was among the largest group collected in Sta. Cruz river system. *P. sphenops* and *Xipophorus helleri* was introduced through aquarium trade, while *P. reticula* was used as biological control. *P. sphenops* and *X. helleri* is known to occur in Central America from Cambodia to Mexico (*Lucinda 2003*) a very popular aquarium fish and is marketed throughout the world (*Welcomme 1988*), but studies on the possibility of using *P. sphenops* as a mosquito control is also been looked into (*Sumithra et al. 2014*). *P. reticulata* on the other hand, has been initially introduced in Asia including Philippines (*Casal et al. 2007; Juliano et al. 1989*) as a bio-control agent for mosquito larvae during the Antimalaria Campaign in 1905. Guppies were released into mosquito breeding grounds, such as canals, ditches and swamps. Additionally, the guppies were also distributed as ornamental fishes (*Froese and Pauly 2022*). Like any other introduced species, this species may cause harm to native fishes, because of its ability to reproduce rapidly (*Mousavi-Sabet and Eagderi 2014*), known carrier of parasitic nematode and feeds on the eggs of native species (*Eldredge 2000*). Poeciliids have been also associated with the decline of damselflies in Hawaii due to its ability to prey on the insects (*Englund 1999*). Swordtails are reported to displace the native fish by fin nipping.

CONCLUSION

Diminutive freshwater fish in the Santa Cruz River System is reported to be more diverse compared to other mountain freshwater habitat in the Southern Tagalog region dominated by Gobiidae, Poeciliidae, and Eleotridae. Santa Cruz River has the highest number of individuals, but Calumpang river is the most diverse. Amidst the expansive nature of introduced species, native species such as Gobiidae still dominate the waters of Santa Cruz River System. Although introduced species are found in the all sampling stations.

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