Community structure of freshwater fishes from the Sibugay River, Mindanao, Philippines

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Abstract. This study aimed to evaluate the diversity and distribution of freshwater fishes in Bayog Watershed, Bayog, Zamboanga del Sur, Philippines. A total of 1408 fish individuals were collected, comprising 11 families, 13 genera, and 19 species. Out of the 19 species, 11 were identified as endemic and native, while eight were introduced species. The presence of *Pterygoplichthys disjunctivus* is the most concerning since it would be a possible pest in this area. The two most abundant species comprised 51% of the overall count: *Oreochromis niloticus* (25.99%) and *Barbodes binotatus* (25.5%). Shannon-Weiner's diversity indices calculated for the six sampling sites varied from 1.67 to 2.05 (H’=2.04), which is relatively good. However, the abundance of many introduced species may disrupt the population structures of the native/endemic freshwater species in the different sites. The information generated in this study may serve as one of the bases for different conservation strategies for the fish of the area.
Key Words: Bayog watershed, diversity, freshwater fishes.

Introduction. Inland waters such as rivers and lakes are considered important for hydrology sources and fisheries (Costanza et al 1997; Kent 1997; Groombridge & Jenkins 1998; Jenkins 2003; Mutia et al 2018; Mogalekar & Canciyal 2018). These waters are considered a source of food in many poor communities in the world (Briones et al 2004; Valentin & Berja 2012; Van der Ploeg et al 2017). Their contribution to the economy of the Philippines is important (delos Angeles et al 1990; Israel 2008). However, pollution, overexploitation, invasive species, and rapid land-use transitions have led to a severe decline in biodiversity in these many aquatic resources (Kottelat & Whitten 1996; Araullo 2001; Ong et al 2002; Dudgeon et al 2006; Appleton et al 2006; UNEP 2008; Zhang et al 2011; Ahmad et al 2013; Biña-de Guzman et al 2013; Guerrero III 2014; Macusi et al 2015; Curvin-Aralar 2016; Nieves et al 2020; Su et al 2021). These even pose biosecurity issues such as outbreaks and the spread of diseases (Pruder 2004; Lightner 2005; Mendoza et al 2019). Aquaculture is one of the most critical industries in the Philippines; therefore, these resources must be conserved, protected, and properly managed. One of the efforts supporting these actions is comprised of looking into the inventory of fishes present as ecological indicators and descriptors of fisheries stability, as well as the ecological integrity of aquatic habitats (Karr 1991; Welcomme 1995; Zampella & Bunnell 1998; Angermeier & Davideanu 2004; Kwak & Peterson 2007; Ikpi & Offem 2011), impacts of habitat deterioration, invasive alien species, and climate change in a particular aquatic environment across spatial and temporal scales (Ter Braak & Verdonschot 1995; Nisikawa & Nakano 1998; Zampella & Bunnell 1998; Angermeier & Davideanu 2004; Ramsundar 2005; Kwak & Peterson 2007; Cagauan 2007; Vescovi et al 2009; Guerrero III 2014; Anticamara & Go 2016). Many studies conducted in the Philippines have shown the importance of biodiversity assessment of many inland aquatic resources to the integrity of the aquatic ecosystem (Paul & Meyer 2001; Corpuz et al 2009;Bradford & Heinonen 2008; Uy 2010; Paller et al 2011; Curvin-Aralar 2016; Paler et al 2013; Romero et al 2016; Paller et al 2013; Guzman & Capaque 2014; Natividad et al 2015; 2015a, 2015b, 2016; Romero et al 2016; Briones et al 2016; Quimpang et al

2016; Estal-Mercado 2018; Paller et al 2017; Garcia et al 2018; Baysa et al 2019; Roque et al 2019; Mukhtiar et al 2020). In this study, information on the status of freshwater fish assemblages in the Bayog watershed are needed as a valuable resource to assess future environmental impacts of development and conservation efforts.

Material and Method

Description of the study sites. The study was conducted in the Bayog Watershed, Bayog, Zamboanga del Sur (7.9281°N, 123.0564°E) that stretches downwards to Diplahan (7.744989N, 122.9685E) and Imelda (7.6578^{0}N, 122.9444^{0}E), Zamboanga Sibugay, Mindanao, Philippines. Six sites were chosen, with three sampling stations at each site. The sampling area would cover the upper portion of Sibugay River down to the lower part of Diplahan, which measures an approximately 43 km distance (Figure 1). Site 1 to site 4 are located in Supon, Dipili, Depore and Damit, Zamboanga del Sur, while site 5 and site 6 are in Guinoman and Balangao, Zamboanga Sibugay.

Sampling. The study was conducted in a 6-month period from April to September 2018. Three stations in each site were selected to serve as replicates. A total of 18 sampling stations were established (Figure 1). Two sites are located in the main river, and the four sites are distributed in each of the four river tributaries. Sampling was done reaching 200–250 m of the stream three times in each station. The individual sampling lasted 45-55 min and was done during the daytime (Paller et al 2013).

Fish specimens were collected using a seine net (1.2x1.2-mm mesh), hand nets, fish traps, and 12-v electric-fishing equipment. The captured fish were immediately counted and identified at the lowest possible taxon. Some specimens were housed as live samples, and some were preserved in the freezer for further documentation and identification. Fish were identified based on Conlu (1986) and Froese & Pauly (2012).

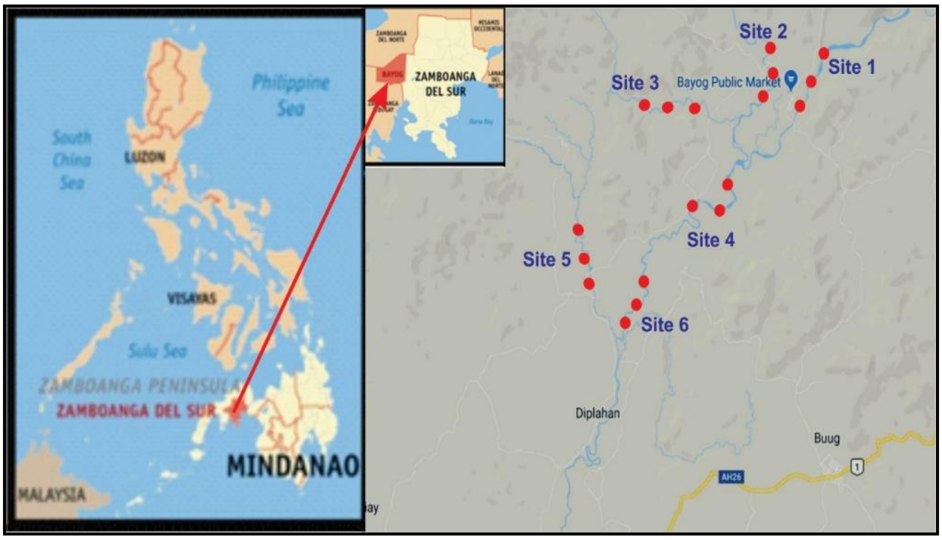

Figure 1. Map showing the location of the sampling sites (googlemaps.com).

Data analyses. Species richness was determined by the number of species present in a community (Paller et al 2017). The relative abundance for each species was calculated as:

Abundance = $(a_i/A) \times 100$

Where: ai is the number of individuals caught in the ith species, and A is the total number of species collected in one sampling area during a sampling period. The diversity index was computed following the Shannon-Weiner diversity index (H') (Shannon & Weaver 1949):

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

Where: s is the number of species, and p is the proportion of individuals found in the i^{th} species. Evenness (J') was computed following Shannon's diversity index:

$J' = H' / \ln S$

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

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

Where: s is the number of species, n_i is the number of individuals in the i^{th} species, and N is the total number of individuals.

A comparison of Shannon-Weiner diversity indices among the river sites was examined using the diversity t-test described by Magurran (1998).

Results and Discussion

Abundance and species composition. During the field sampling, 1408 fish samples were collected from the six sampling sites in Bayog Watershed. Site1, which is located in Sibugay, had the highest number of collected specimens (n=300), followed by site 3 (Depore) with 245 individuals, Site 2 (Dipili) with 234, site 5 (Guinoman) with 225, site 4 (Damit) with 216 and, lastly, site 6 (Balangao) with the lowest number of individuals (188) (Table 1).

Identification of samples showed that 19 species, 13 genera, and 11 families were recorded. The family that dominated was Cyprinidae, with three genera (*Barbodes, Rasbora, and Cyprinus*) and five taxa (Table 1). Out of the 19 recorded species, four were endemic (*Barbodes bantolanensis, Barbodes manguaoensis, Rasbora sp.,* and *Zenarchopterus dispar*); seven species were native (*Anguilla australis, Anguilla marmorata, Clarias macrocephalus, Barbodes binotatus, Glossogobius circumspect, Glossogobius sp.,* and *Megalops cyprinoides*); eight species were introduced (*Anabas testudineus, Channa striata, Oreochromis aureus, Oreochromis niloticus, Clarias batrachus, Cyprinus carpio, Pterygoplichthys disjunctivus,* and *Trichopodus trichopterus*).

Regarding economic values, only three native species were identified with high economic values. These were *A. australis, A. marmorata,* and *Clarias macrocephalus.* The other native and endemic species had less to no economic values. Introduced species such as *C. striata, O. aureus, O. niloticus, C. batrachus,* and *C. carpio* appeared because of their livelihood potential and economic benefits. The others are recreational fishes with no economic value, such as *A. testudineus, T. trichoptera,* and *P. disjunctivus*, which escaped to the river system and multiplied.

Table 1

Checklist of fish species collected from Bayog Watershed

Family	*Scientific name*	*Local name*	*Occurrence*	*Economic value*
Anabantidae	*Anabas testudineus*	Puyo	Introduced	+
Anguillidae	*Anguilla australis*	Kasili	Native	++
	Anguilla marmorata	Kasili	Native	++
Channidae	*Channa striata*	Haloan	Introduced	++
Cichlidae	*Oreochromis aureus*	Tilapia	Introduced	++
	Oreochromis niloticus	Tilapia	Introduced	++
Clariidae	*Clarias batrachus*	Pantat	Introduced	++
	Clarias macrocephalus	Pantat	Native	++
Cyprinidae	*Barbodes bantolanensis*	Paitan/Pait-pait	Endemic	+
	Barbodes binotatus	Paitan/Pait-pait	Native	+
	Barbodes manguaoensis	Paitan/Pait-pait	Endemic	+
	Rasbora sp	Lapisan	Endemic	-
	Cyprinus carpio	Karpa	Introduced	++
Gobiidae	*Glossogobius circumspectus*	Bagtis	Native	-
	Glossogobius sp	Bunog	Native	+
Loricariidae	*Pterygoplichthys disjunctivus*	Janitor fish	Introduced	-
Megalopidae	*Megalops cyprinoides*	Bulan-bulan	Native	+
Osphronemidae	*Trichopodus trichopterus*	Gourami	Introduced	+
Zenarchopteridae	*Zenarchopterus dispar*	Suloy-suloy	Endemic	-

Table 2 and Figure 2 show the community structure of freshwater fish species recorded from the six studied sites in Bayog Watershed. Site 1 has the highest number of endemic/native taxa with 11 out of 14 taxa, followed by site 2, with 8 out of 13 taxa, and the lowest number of endemic/native species was found in site 6, with 4 out of 11 taxa. Out of 19 species, 11 are endemic/native, and eight are introduced species. The distribution of some species is specific. This might be due to the physicochemical parameters of each site. For instance, *A. australis*, *C. batrachus,* and *C. macrocephalus* were found in site 1, but not in the other sites, while *A. testudineus, C. striata,* and *T. trichopterus* were commonly found in sites 2, 3, 4, 5, and 6, but absent in site 1. Additionally, *C. carpio* could only be found at sites 4 and 6, and *A. marmorata* was recorded only at sites 1 and 4. On the other hand, some species were distributed in all study sites, meaning they have a wide range of habitat adaptations. In native and endemic species, *B. bantolanensis, B. binotatus,* and *B. manguaoensis* have a wide distribution range, while *O. aureus,* and *O. niloticus* had a wide range from the introduced species.

The native/endemic species widely distributed in all sites are part of the Cyprinidae family, namely *B. bantolanensis, B. binotatus,* and *B. manguaoensis*. These species might have a higher tolerance to environmental disturbances. The other endemic species are concentrated only at site 1. From an ecological point of view, the manifestation of these fish populations is usually reliant on the environmental status and habitat attributes of their ecosystem, including vegetation (Vorwerk et al 2007), elevation (May & Brown 2002), water depth (Ross 1986), water velocity (Herder & Freyhof 2006), and substrate type. Due to their reliance on habitat properties, these native fish species can be considered critical bioindicators of river health (Zampella & Bunnell 1998; Angermeier & Davideanu 2004; Cagauan 2007). The presence of the secondary forest can still be seen in the other half of the river in site 1, while the other sites were exposed to agricultural and other stressors. This might be why more native species were present.

Table 2

Distribution of freshwater fish species recorded from the six sites in the Sibugay River

Species	*Occurrence*	*Site 1*	*Site 2*	*Site 3*	*Site 4*	*Site 5*	*Site 6*	*Abundance*
A. testudineus	Introduced	-	+	+	+	+	+	20
A. australis	Native	+	-	-	-	-	-	3
A. marmorata	Native	+	-	-	+	-	-	3
C. striata	Introduced	-	+	+	+	+	+	14
O. aureus	Introduced	+	+	+	+	+	+	193
O. niloticus	Introduced	+	+	+	+	+	+	366
C. batrachus	Introduced	+	-	-	-	-	-	2
C. macrocephalus	Native	+	-	-	-	-	-	2
B. bantolanensis	Endemic	+	+	+	+	+	+	146
B. binotatus	Native	+	+	+	+	+	+	359
B. manguaoensis	Endemic	+	+	+	+	+	+	136
Rasbora sp.	Endemic	+	+	+	-	+	-	53
C. carpio	Introduced	-	-	-	+	-	+	8
G. circumspectus	Native	+	+	-	+	-	-	5
Glossogobius sp.	Native	+	+	+	-	+	-	18
P. disjunctivus	Introduced	-	-	+	+	-	+	21
M. cyprinoides	Native	+	+	-	+	-	+	7
T. trichopterus	Introduced	-	+	+	+	+	+	42
Z. dispar	Endemic	+	+	-	+	+	-	10
Total number of species from each site		300	234	245	216	225	188	1408

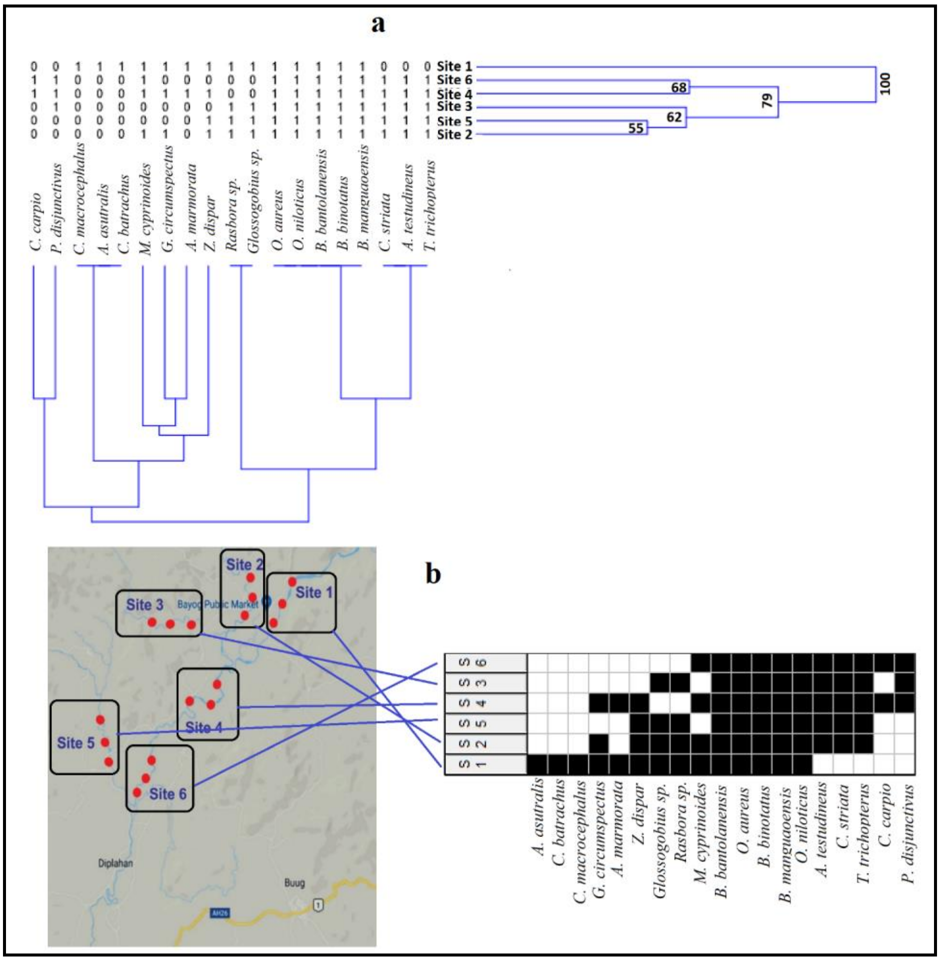

Figure 2. Community structures of the freshwater species in the six sites; a - cluster analysis; b - seriation.

An introduced species, such as the cichlids, established a feral population in all sites, while the others like *A. testudineus*, *A. striata,* and *T. trichopterus* are proliferating in sites 2 to 6. Janitor fish (*P. disjunctivus*) are starting to inhabit some parts of the Bayog watershed, such as sites 3, 4, and 6. It was identified by IUCN (www.iucngisd.org) as a potential pest. According to some local people, this species has never been seen before. It is now starting to increase in numbers in some rivers of the Bayog watershed. A study by Hubilla et al (2007) documented the presence of this species in Agusan Marsh that posed threats to the fish fauna diversity.

Introduced species recorded in this study can be considered highly prolific, habitat generalists, and can decrease fish diversity by competing with natives (Cagauan 2007; Guerrero III 2014). Being highly adaptive to a wide range of habitat conditions and efficient resource user are the reasons for their establishment and invasion success (Burnett et al 2006). Introduced species often occur due to accidental escaping from nearby ponds and deliberate introduction by fishermen (Humpl & Pivnicka 2006). It is known that the most damaging effect of aquaculture on biodiversity loss is the escapement of introduced cultivated fish species and their potential to be invasive (Diana 2009). Due to predation, one detrimental effect is the depletion of the stock of the valued smaller commercial and non-commercial fish species.

Agricultural effluents and residential waste also threaten the vulnerable native fish (Natividad et al 2015). Anthropogenic activities and climatic changes could deteriorate the riverine system, eventually affecting diversity and losing susceptible groups such as native fish species (Paller et al 2013).

Diversity indices. Species richness and the number of individual and biological indices are summarized in Table 3. Among the six sampling sites, sites 1 and 4 had the highest species richness with 14 taxa, followed by site 2 with 11 taxa, and sites 3, 5, and 6 with only 11 taxa. Shannon-Weiner's diversity indices for the six sampling sites varied from 1.67 to 2.05 (Table 3). Spatially, site 1 showed the highest diversity among the sites, with a value of 2.05, but is not significantly different (p<0.05) from the other sites, except site 5, with 1.67 (Table 3).

Table 3

The number of taxa, and diversity indices recorded from 6 studied sites in Bayog watershed

Biological indices	*Site 1*	*Site 2*	*Site 3*	*Site 4*	*Site 5*	*Site 6*	*Overall*
Species richness	14	13	11	14	11	11	19
Individual	300	234	245	216	225	188	1408
H’	2.05^{a}	1.928^{a}	1.915^{a}	1.995^{a}	1.671^{b}	1.912^{a}	2.041
J’	0.7767a	0.7516a	0.7985a	0.7558a	0.6968b	0.7975a	0.693
λ	0.1578^{a}	0.1884^{b}	0.1873^{ab}	0.1823^{ab}	0.2328^{c}	0.1866^{ab}	0.1746

Note: H’ - Shannon-Weiner diversity index; J’ - Shannon evenness Index; λ - Simpson's species dominance index; different superscripts in the same row show significant differences (p<0.05).

Shannon's evenness indices did not show the same trend pattern as Shannon-Weiner's diversity indices. Evenness values ranged from 0.697 to 0.799 (Table 3). The highest values appeared for sites 3 (0.799) and 6 (0.798). Site 5 had the lowest value, which is significantly low (p<0.05) in evenness compared to all sites. The values from all the other sites are not significantly different.

Dominance values were calculated using Simpson's dominance index. Its values ranged from 0.158 to 0.233, which has an inverse correlation with diversity indices and evenness values. Site 1 has the lowest dominance (0.158), and site 5 has the highest (0.233). Statistically (p<0.05), the value from site 1 is significantly lower in dominance than that of sites 2 and 5. On the other hand, site 5 has a significantly higher dominance value than other sites.

Overall, Bayog Watershed exhibits a moderate to good freshwater fish diversity with Shannon-Weiner's diversity index value of 2.041, represented mainly by native and endemic species. The higher diversity index shows a balance between total species and individuals of every species (Muchlisin & Azizah 2009). The richness and diversity of this area are relatively higher compared to the Tayabas river (species=15, H'=1.55) (Paller et al 2013), but lower than those calculated in freshwater habitats in Camarines Sur (species=19, H'=2.04), Bulusan River in Sorsogon (species=16, H'=2.41) and Pansipit River in Batangas (species=21, H'=3.05) (Corpuz et al 2009, 2015a,b; 2016).

Conclusions. The study of freshwater fishes in selected sites of Bayog Watershed showed that the diversity indices ranged from 1.67 to 2.05. Site 1 had the highest diversity index and the highest number of endemic/native species. The genera *Oreochromis,* an introduced species, and *Barbodes* (native) are the most abundant and dominant in all sites. The diversity of freshwater fishes in the Bayog watershed with a Shannon-Weiner's diversity index value of 2.041 is considered moderate to good. It can be concluded that, while diversity is relatively good in the rivers of the watershed, introduced species may disrupt the population structures of the freshwater species in the different sites.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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