Article

Freshwater fish fauna in four interconnected rivers traversing several communities in two Zamboanga Provinces, The Philippines

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Abstract

This study was conducted to assess the relationship between environmental factors and the composition of fish assemblages from four interconnected rivers traversing several communities of Bayog Watershed comprising two provinces of Zamboanga in the Philippines. The distribution, abundance, and diversity of fish species in relation to the physicochemical parameters of the Sibugay, Dipili, Depore, and Guinoman rivers were obtained. A total of 1,004 fish individuals were collected during the field sampling and distributed into 11 families, 13 genera, and 18 species. The genus *Oreochromis* and *Barbodes* had the highest abundance and were prevalent in all the sites. Sibugay river obtained the highest Shannon-Weiner diversity index value (H'=2.05) and several species (14), while Guinoman has the lowest (species=11; H'=1.671). Sibugay river has the highest pH value (7.53), while Depore has the most deficient and acidic sites. Water temperatures were higher in Depore and significantly different from all other sites except in Guinoman. Influenced of environmental factors on the assemblages of freshwater fishes showed that depth (-0.894), pH (-0.813), and water temperature (0.859) were the three factors that are highly correlated with the first ordination axis in the CCA while dissolving oxygen (-0.250), and pH (-0.308) were positively associated with the second ordination axis. The biplot obtained from abundance and environmental data revealed that *P. disjunctivus* and *T. trichopterus* are positively associated with elevated water temperature and low pH. These introduced species can tolerate high temperatures and slightly acidic water. As observed in the study, channel water from the residential area, industrial waste, and effluents from agricultural activities are of most concern among the activities that affect the ecosystem.

Keywords CCA; fish assemblages; environmental factors; Bayog watershed.

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1 Introduction

It was shown in many studies conducted in the Philippines that biodiversity assessment of many inland aquatic resources is important to evaluate/assess the integrity of the aquatic ecosystem (Cuvin-Aralar, 2016; Angeles, 2005; Romero et al., 2016; Paller et al., 2013; Corpuz et al., 2015a, 2015b, 2016; Guzman and Capaque, 2014; 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). The composition of species is distinctive to geographic locations because the diversity and distribution of living organisms vary in their responses to environmental characteristics (Belanger and Rodriguez, 2002). The relationship between fish assemblage and habitat parameters and is one of the main themes in aquatic ecology (Angermeier and Davideanu, 2004). The structure of fish assemblages generally depends on many biotic and abiotic (Ricklefs, 1987; Jackson and Harvey, 1989; Persson, 1997; Brown, 2000; Angermeier and Davideanu, 2004). These may act independently and constrain the presence and distribution of stream fishes through a hierarchy of nested environmental filters. Also, the features of fish assemblages in riverine ecosystems may depend on possible interactions of multiple ecological processes on changing temporal and spatial scales (Poff, 1997). Environmental characteristics are essential factors reflecting the status of freshwater fishes. It is generally known that habitat attributes influence fish composition (Li et al., 2012). With growing pressure from anthropological activities, their habitat and existence are being threatened by changing the biotic and abiotic components of the system (Jennings et al., 1999).

Deforestation, urban development, dam construction, diversions for irrigation, and agricultural and illegal mining activities modify the water and habitat quality of the river (May and Brown, 2002). The decreasing water quality has been recognized as a potential problem influencing aquatic species, leading to a decrease in diversity. With the increasing challenge on aquatic ecosystems, documenting the remaining richness and creating accurate evaluations of the scale of biodiversity loss caused by human disturbances is of particular concern (Murphy and Romanuk, 2014). The fish communities are considered indicators of ecological health (Moyle, 1994); thus, their presence and abundance can be linked to the water properties, habitat characteristics, and land-use activities. These provide a more detailed image of water quality and habitat within the river system. A particular interest in the current study is the three rivers (Depore, Dipili, and Guinoman) which interconnect with the Sibugay River, which runs along the various river communities of Zamboanga del Sur and Zamboanga Sibugay. These rivers receive agricultural runoffs, wastes from human settlements along the rivers, and goldmines in the rivers' upper areas. These rivers often experience overflow, especially after heavy rainfall, and become heavily silted. We, therefore, studied the relationship between fish assemblages and selected environmental factors in these four rivers, which may be necessary for the proper management not only of the biodiversity of the fishes but of the rivers.

2 Materials and Methods

2.1 Study area

The study was conducted in the Bayog Watershed, which extends from Bayog, Zamboanga del Sur (7.9281° N, 123.0564° E) towards Diplahan (7.744989N, 122.9685E) and Imelda (7.6578^0 N, 122.9444^{0}E) of Zamboanga Sibugay, Mindanao, Philippines (Fig. 1). A total of four sites were established to represent the river systems of the watershed. A total of 12 stations were identified for the four rivers, each with three sampling stations. Each station had approximately 600–700m streams reached with three 200–250 m sampling run/sites, considered replicates. The individual sampling run lasted 40–50 min and was done during the day. Station 1 is located in Sibugay River, station two is in Dipili River, station three is at Depore River, and station four is at Guinoman River.

(Source: Googlemap.com)

Fig. 1 Location of the study area. In the set is the map of the Philippines and a map of Zamboanga del Sur.

2.2 Sampling and data collection

Fishes were collected using a seine net (1.2 x 1.2-mm mesh), hand nets, fish trap, angling, and a 12-v electrofishing equipment. All captured fishes were immediately counted and identified at the lowest possible taxon. Specimens were housed in the laboratory as live samples or preserved in 10% buffered formaldehyde for further documentation and identification. Specimens were identified using several fish identification guides (Conlu, 1986; Froese and Pauly, 2012).

A pH meter, DO meter, and Temperature Tester Doubles Junction was used to determine the freshwater's pH, DO, and temperature in different sampling stations. The device probe was dipped on the water surface for one minute. The results were then recorded and tabulated in triplicates. The streamflow rate (m s^{-1}) was measured in every sampling site using the float method described in Intermountain Environmental Inc (IEI, 2017).

Depth (m) was measured using an improvised wooden ruler at two or three points in each sampling station, and their mean is considered the river depth. The dominant bottom type were composed of organic detritus, silt, mud, and sand (0.02—2 mm), gravel (2—64 mm), cobble (64—256 mm), and boulder (>256 mm) (May and Brown, 2000). Land use pattern in the area of study is categorized based on the characteristic of the landscape surrounding the riparian zone. These categories were agricultural, forested, grazing, and habitation.

2.3 Data analyses

Species richness was measured by the number of species present in a community. The relative abundance for each species and the diversity index was calculated following the Shannon-Weiner diversity index (H’) (Shannon and Weaver, 1949). Species dominance was computed using Simpson's index formula (Simpson, 1949). Mean values of environmental factors were compared to each site using ANOVA. The relationship between fish abundance and water quality parameters was determined by Principal Component Analysis (PCA) and Canonical Correspondence Analysis (CCA) using PAST version 1.89 (Hammer et al., 2001).

3 Results

A total of 11 families, 13 genera, and 18 species were recorded (Table 1) in the four rivers. Family Cyprinidae was the species-rich group among the assemblage composition.

In the Sibugay river, *B. binotatus* is the most abundant (24.33%), followed by *B. manguaoensis* (17.33%), *B. bantolanensis* (17.00%), and *O. niloticus* (15.33%). In the Dipili River, the abundance was in the following order - *B. binotatus* (27.35%) and *O. niloticus* (26.92%). The same two species were relatively abundant in the Depore and Guinoman rivers; *B. binotatus* and *O. niloticus* comprised more than 50% of the total catch in each site. The genus *Oreochromis* and *Barbodes* were the most prevalent species in all study sites. For the relative abundance, two fish species formed 51% of the total abundance collected from the four rivers. These were *O. niloticus* with a relative abundance of 25.40% and *B. binotatus* with a relative abundance of 25.10%.

Table 1 Fish species' abundance and distribution in Sibugay, Dipili, Depore and Guinoman rivers in Bayog Watershed.

Fish species	Local name	Sibugay river		Dipili river		Depore river		Guinoman river		Total Abundance (%)
		No.	Ab. (%)	No.	Ab. (%)	No.	Ab. (%)	No.	Ab. (%)	
Anabas testudineus	Puyo	0	0	3	1.28	4	1.63	2	0.89	0.90
Anguilla australis	Kasili	3	1.00	0	0	0	0	0	0	0.30
Anguilla marmorata	Kasili	2	0.67	0	0	0	0	0	0	0.20
Channa striata	Haloan	0	0	2	0.85	3	1.22	2	0.89	0.70
Oreochromis aureus	Tilapia	15	5.00	31	13.25	43	17.55	46	20.44	13.45
Oreochromis niloticus	Tilapia	46	15.33	63	26.92	76	31.02	70	31.11	25.40
Clarias batrachus	Pantat	2	0.67	0	0	0	0	0	0	0.20
Clarias macrocephalus	Pantat	2	0.67	0	0	0	0	0	0	0.20
Barbodes bantolanensis	Paitan	51	17.00	29	12.39	23	9.39	14	6.22	11.65
Barbodes binotatus	Pait-pait	73	24.33	64	27.35	50	20.41	65	28.89	25.10
Barbodes manguaoensis	paitan	52	17.33	16	6.84	17	6.94	18	8.00	10.26
Rasbora sp	Lapisan	32	10.67	11	4.70	8	3.27	2	0.89	5.28
Glossogobius circumspectus	Bagtis	3	1.00	1	0.43	0	0.00	0	0.00	0.40
Glossogobius sp	Bunog	12	4.00	3	1.28	1	0.41	2	0.89	1.79
Pterygoplichthys disjunctivus	Janitor fish	0	0	0	0	12	4.90	0	0	1.20
Megalops cyprinoides	Bulan-bulan	3	1.00	2	0.85	0	0	0	0	0.50
Trichopodus trichopterus	Gourami	0	0	6	2.56	8	3.27	3	1.33	1.69
Zenarchopterus dispar	Suloy-suloy	4	1.33	3	1.28	0	0.00	1	0.44	0.80
Total		300	100%	234	100%	245	100%	225	100%	100%

Species richness and biological indices were summarized in Table 2. The Sibugay River has the highest species richness among the four rivers with 14 species, followed by the Dipili river with 13 species. The Sibugay river showed the highest diversity, with Shannon-Weiner's diversity index value of 2.05. Still, it is not significantly ($p<0.05$) different from the other sites except in the Guinoman river. Shannon's evenness index values ranged from 0.697 to 0.799, with the Guinoman river having the lowest value, which is significantly lower ($p<0.05$) than the other sites. Dominance values were calculated using Simpson's dominance index. It further showed that the Guinoman river has the highest species dominance.

Table 2 Species richness and diversity indices recorded from Sibugay, Dipili, Depore, and Guinoman rivers in the Bayog watershed.

Biological indices	Sibugay river	Dipili river	Depore river	Guinoman river
Species richness	14	13	11	11
H'	2.05[a]	1.928[a]	1.915[a]	1.671[b]
J'	0.7767[a]	0.7516[a]	0.7985[a]	0.6968[b]
λ	0.1578[a]	0.1884[b]	0.1873[ab]	0.2328[c]

Note: H'= Shannon-Weiner diversity index; J'= Shannon evenness Index; λ= Simpson's species dominance index.

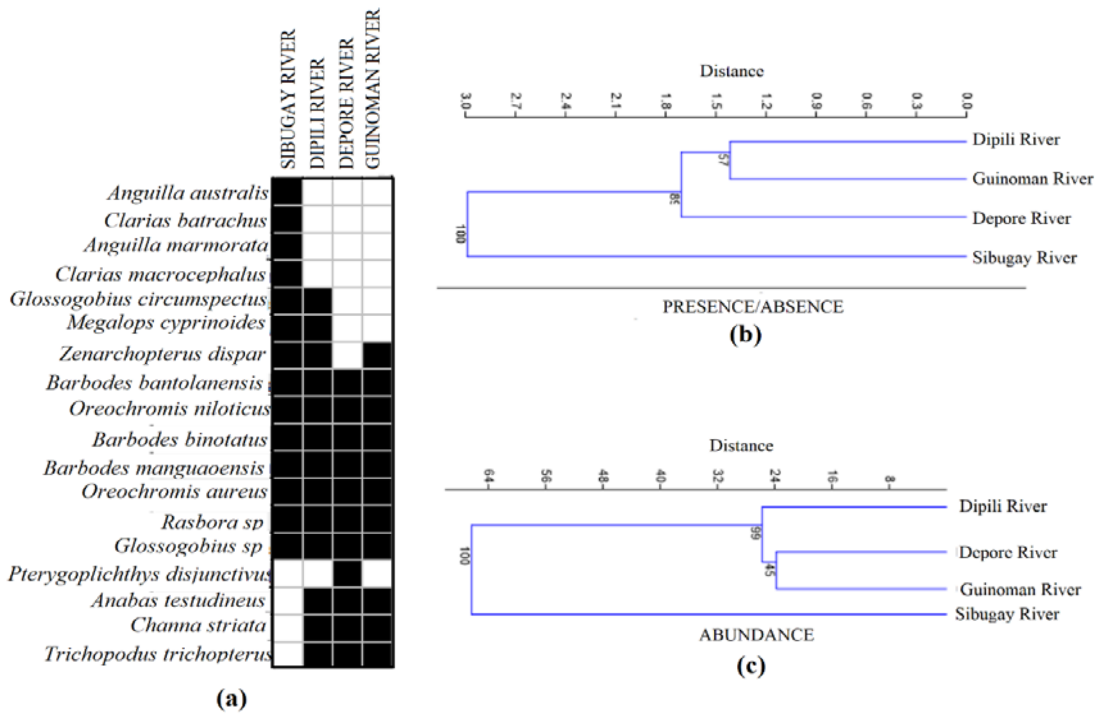

Fig. 2 Seriation (a) and cluster analysis (b) and (c) the relationships of the four rivers based on the presence/absence and abundance of the fishes.

Seriation and cluster analysis shows the similarities and differences between rivers based on the presence/absence and abundance of species (Fig. 2). The Sibugay river is distinct from the other 3 rivers as it has four species only found in the area – *Anguilla australis*, *Clarias batrachus*, *Anguilla marmorata*, *Clarias macrocephalus*. The Dipili and Sibugay rivers differ from the other 2 rivers for having 2 species only found in their areas – *Glossogobius circumspectus*, *Megalops cyprinoides*. The Depore river is different from the others since it has *Pterygoplicthys disjunctivus*, which is absent in other rivers.

Physico-chemical parameters and habitat characteristics of the four river sites are provided in Table 3. Significant spatial differences were recorded in pH levels ($p<0.05$), with the highest and lowest concentration in Sibugay and Depore rivers, respectively. Furthermore, the Sibugay river's pH value is significantly different from the Depore and Gunoman rivers but not the Dipili river. At the same time, the Depore river is substantially different from the Sibugay and Dipili rivers but not from the Guinoman river. Additionally, pH value further showed that the Sibugay and Dipili rivers have a neutral acidity while Depore and Guinoman rivers were relatively acidic. Water temperature in the Dipili rivers was significantly comparable to the Sibugay and Guinoman rivers, but it is statistically different ($p<0.05$) from the Depore river. For the in-stream depth, the Sibugay river is statistically similar to the Dipili river, but it was statistical different ($p<0.05$) from the Depore and Guinoman rivers. Dissolved oxygen concentration is statistically identical in all the rivers. Although surface velocity in the Sibugay river was slower than the other rivers, it didn't show significant differences ($p<0.05$). In terms of land use around the rivers, Depore, Dipili, and Guinoman areas were relatively had the same pattern but were different from Sibugay.

Table 3 The mean values (±SD) Physico-chemical parameters and habitat characteristics of Sibugay, Dipili, Depore, and Guinoman rivers in the Bayog watershed.

Parameters	Sibugay river	Dipili river	Depore river	Guinoman river
pH	7.53 ± 0.01^{a}	7.22 ± 0.04^{ab}	5.83 ± 0.79^{c}	6.28 ± 0.37^{bc}
DO (mg L^{-1})	6.40±0.76	7.05±0.87	6.60±0.57	6.56±0.59
Water Temperature (^{0}C)	27.50 ± 0.64^{a}	28.21 ± 0.30^{ab}	29.31 ± 0.18^{c}	28.71 ± 0.40^{bc}
Depth (m)	1.67 ± 0.29^{a}	01.11 ± 0.12^{ab}	0.81 ± 0.28^{b}	0.87 ± 0.10^{b}
Surface Velocity (m s^{-1})	0.62±0.21	0.72±0.06	0.83±0.26	0.82±0.24
Land use	Forested, agricultural	Agricultural, residential	Agricultural, residential	Agricultural, residential
Substrata	Sandy, gravel, cobble, boulder	Sandy, muddy, gravel, cobble	Muddy, sandy, gravel	Muddy, sandy, gravel

Dissolved Oxygen (DO) is dependent on the streamflow and the organic matter in a particular site. Thus it fluctuates between rivers (Bhalla et al., 2007). The difference in water temperature is considered one of the most significant variables of environmental variability in rivers. It affects the chemical and biological characteristics of the river and fish production (Rashleigh, 2004). Variation in depth between sites occurred regardless of their position from its origin, soil structure, and flow regulation due to several activities along course could be the reason. The physicochemical variations may be due to the land use activities in the area. Changes in the landscape, vegetation removal, and agricultural activities could lead to increased nutrient concentrations, mostly inorganic nitrogen (Pizarro et al., 2010). Furthermore, water velocity and habitat alterations linked with deforestation and urbanization affect habitat quality (Vyas et al., 2012; Ahmad et al., 2013).

Environmental variables were subjected to Principal Component Analysis (PCA), and sites were described as impacting the system. Five principal component scores were produced, which explained 100% of the variance in the data. The first two components explained 92.7% of the variances (Table 4). In PC1, which explained 69.7% of the total variance, two factors, pH and water temperature, contributed the highest loadings and were considered significant variables that explained the total variance in PC1. In PC2, accounting for 22.8% variance explained, DO was regarded as the essential factor, while in PC3, it was again the pH and Water Temperature. As shown in Table 4 and Fig. 2, the factors pH, water temperature, and DO contributed a lot in discriminating between sites of the four rivers. Moreover, DO has a higher association in the Dipili river, pH in the Sibugay river, and water temperature in the Depore and Guinoman rivers.

PCA results also specify that the patterns of physicochemical variations among the four rivers were characterized by differences in the habitat features governing the particular sites (Fig. 3).

Table 4 Principal Component Analysis of water quality parameters as studied from Sibugay, Dipili, Depore, and Guinoman rivers in the Bayog watershed.

Variables	Code	PC 1	PC 2	PC 3
pH	pH	**0.675**	0.055	**0.734**
Dissolved oxygen	DO	0.157	**0.949**	-0.214
Water temperature	TEM	**-0.645**	0.231	**0.547**
Depth	DEP	0.296	-0.175	-0.305
Surface velocity	SV	-0.127	-0.114	0.150
Eigenvalue		1.316	0.434	0.102
% Variance explained		69.741	22.971	5.403

Values bold are significant.

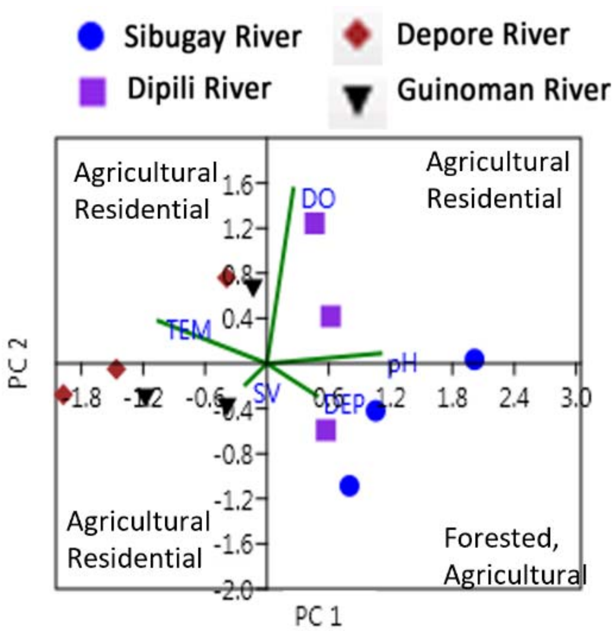

Fig. 3 Principal component analysis biplot for environmental variables and sampling sites.

Table 5 shows the inter-set correlations of environmental factors with CCA's first two ordination axes. The first two exes explained 80.46% and 11.70% variation in fish assemblages, and the eigenvalues of axis 1 and 2 accounted for 0.148 and 0.021, respectively. Depth (-0.894), pH (0.813), and water temperature (0.859) were the three factors that are highly correlated with the first ordination axis (Table 5). These factors represent the most critical environmental factors related to the structure of fish assemblages. Dissolve oxygen (-0.250), and pH (-0.308) were highly correlated with the second ordination axis (Table 5).

Table 5 Inter-set correlations of environmental factors with the ordination axes of CCA.

Variables	CCA 1	CCA 2
pH	**-0.813**	**-0.308**
Dissolved oxygen	0.147	**-0.250**
Water temperature	**0.859**	0.103
Depth	**-0.894**	0.183
Surface velocity	0.432	0.033
Eigenvalue	0.148	0.021
% Variance explained	80.460	11.70

Values in bold are significant.

The biplot obtained from abundance data (Fig. 4) revealed that Janitor fish (*P. disjunctivus*) and Gourami (*T. trichopterus*) were positively associated with elevated water temperature and negatively pH. This result means that these introduced species can tolerate high temperatures and slightly acidic water. The species *M. cyprinoides* (bulan-bulan), *Rasbora sp*. (Lapisan), and *G. circumspectus* (Bagtis) were positively associated with depth and had a negative association with temperature. Some species, such as Tilapia (*O. niloticus* and *O. aureus*) and *Barbodes* had no unique relationship with environmental variables. These species might have the capacity to tolerate disturbances from the environment.

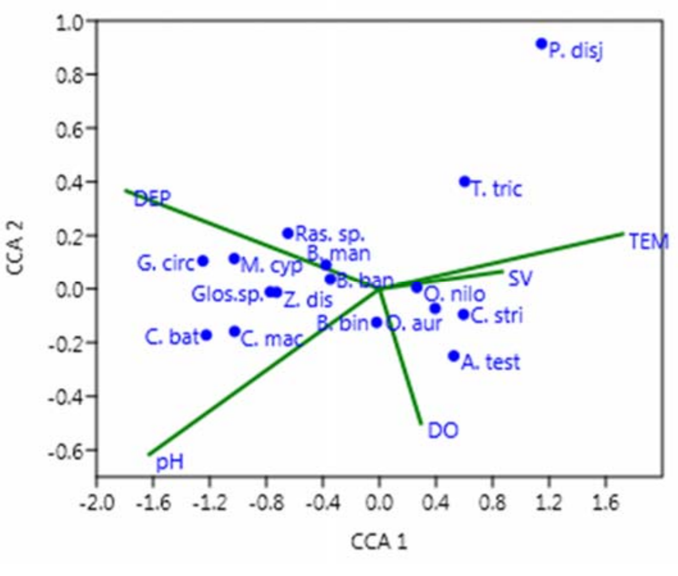

Fig. 4 CCA ordination diagram showing the effect of environmental factors on the structure of fish assemblages.

River systems' Physico-chemical factors were considered significant variables in structuring fish communities (Marchetti and Moyle, 2001; May and Brown, 2002). Several factors like the quality of water, habitat characteristics, flow velocity, and nutrient supplies from riparian habitats regulate the abundance and distribution of fish. These environmental factors are more accessible than other biotic components such as competition and predation. The results of this study validate the well-known information that ecological variables significantly influence both species richness and distribution of fish assemblages (Pouilly et al., 2006).

4 Discussion

In many studies conducted in the Philippines, it was shown the importance of biodiversity assessment of many inland aquatic resources to the integrity of the aquatic ecosystem (Angeles, 2005; Corpuz et al. 2009, 2010, 2011; Paller et al., 2011, 2013; Guzman and Capaque, 2014; Corpuz et al., 2015a, 2015b, Aralar, 2016; Briones et al., 2016; Corpuz et al 2016; Quimpang et al., 2016; Romero et al., 2016; Estal-Mercado, 2018; Garcia et al., 2018; Baysa et al., 2019; Roque et al., 2019; Ganzon eand Demayo, 2022; Gelsano and Demayo, 2022; Yagos et al., 2022).

Abundance, distribution, diversity, and the physicochemical parameters of Sibugay, Dipili, Depore, and Guinoman rivers obtained in this study show the genus *Oreochromis* and *Barbodes* had the highest abundance and were prevalent in all the sites. The Sibugay river got the highest Shannon-Weiner diversity index value (H'=2.05) and species number (14), while the Guinoman river has the lowest (species=11; H'=1.671). Regarding the physicochemical parameters of the river, the Sibugay river has the highest value (7.53), while Depore has the lowest and most acidic compared to all the sites. No significant difference was found in terms of DO and surface velocity. Water temperatures were higher in Depore and significantly different from all the areas except in the Guinoman River.

The influence of environmental factors on the assemblages of freshwater fishes in selected rivers of Bayog Watershed was also evaluated. The study revealed that depth (-0.894), pH (-0.813), and water temperature (0.859) were the three factors that are highly correlated with the first ordination axis in the CCA. The dissolved oxygen (-0.250) and pH (-0.308) were highly correlated with the second ordination axis. The biplot obtained from abundance data showed that Janitor fish (*P. disjunctivus*) and Gourami (*T. trichopterus*) are positively associated with elevated water temperature and negatively with pH. These introduced species can tolerate high temperatures and slightly acidic water. Some species, such as Tilapia (*O. niloticus* and *O. aureus*) and the genus Barbodes, their abundance had no unique relationship with any habitat variables.

Results of the study suggest that the quality of habitat and species diversity were connected. As observed during the study, wastewater from the residential area, effluents from industrial activities, and agricultural discharges were the most concerning sources affecting water quality. Practical actions in regulating these activities depend on the local community that administers the stretches of the river.

The impacts of habitat deterioration, invasive alien species, and climate change across spatial and temporal scales should also be included (Nisikawa and Nakano, 1998; Zampella and Bunnell, 1998; Guerrero, 2002; Ramsundar, 2004; Kwak and Peterson, 2007; Ter Braak and Verdonschot, 1995; Angermeier and Davideanu, 2004; Anticamara and Go, 2016).

5 Conclusion

This study was conducted to assess the relationship between environmental factors and the composition of fish assemblages from four interconnected rivers traversing several communities. Results of the study suggest that the quality of habitat and species diversity were connected. Likewise, as observed in the survey, household wastewater, industrial effluents, and agricultural wastes were the most concerning sources affecting the water quality of the rivers. More studies, therefore, are suggested especially on the possible impacts of habitat deterioration, invasive alien species, and climate change across spatial and temporal scales in the rivers.

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