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Environmental variables structuring the stream gobioid assemblages in the three protected areas in Southern Luzon, Philippines

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Abstract. Three estuarine-linked streams (Bulusan, Iyam, and Pansipit rivers) in different protected areas were investigated to evaluate the influence of environmental and habitat variables on gobioid assemblages (Gobiidae and Eleotridae). The study collected a total of 1,071 specimens belonging to 19 species, and 17 genera. Twelve gobiids and seven eleotrids were recorded from the three rivers. Four gobioid species comprised 57.17% of the total abundance. These were *Giuris margaritacea* (Eleotridae), *Glossogobius celebius* (Gobiidae) *Bostrychus sinensis* (Eleotridae) and *G. giuris* (Gobiidae) (in order of importance). Log_{10}-transformed abundance data were used in indirect (detrended correspondence analysis, DCA), and direct (canonical correspondence analysis, CCA) gradient ordination analysis. DCA (50.76% variability on the first and second ordination axes) revealed the gobioid assemblage variability as a response of species abundance to stream gradients. Species variation along the longitudinal stream gradient profile (upstream and downstream dwellers) was also emphasised. From the 19 environmental variables, CCA (71.49% variability on the first and second ordination axes) recognised substratum types, distance to sea, and land use pattern as the most weighted causative environmental parameters influencing the gobioid assemblages (within and between stream variations). Bray-Curtis similarity analysis using species and abundance data registered low similarity percentages (18–40%) between the three rivers, validating the high beta diversity estimated in DCA1 axis.

Key words. canonical correspondence analysis, gobiids, gobioid assemblage, Pansipit, substrate

INTRODUCTION

Tropical stream ecosystems are considered critical habitats for fishes completing key phases of their life histories in freshwaters (Benstead et al., 2003). In the Philippines, families from Gobiidae and Eleotridae are known to be the most diverse and widely distributed among the native stream fish assemblage (Herre, 1953; Froese & Pauly 2011; Paller et al., 2011, 2013). Because of their abundance in streams with direct connection to sea, gobioid assemblages comprise a considerable portion of artisanal and subsistence fisheries (*ipon* fisheries), and are thus economically important for the local communities (Herre, 1927; Manacop, 1953; Blanco, 1956).

The survival and expansion success of most gobioid species, like other stream fish communities are attributed to their capability to adapt in gradient changes in longitudinal stream profile (Humpl & Pivnicka, 2006; Paller et al., 2013). Furthermore, integrity of stream fish assemblage was reported to be largely dependent on substrate composition, heterogeneity of water type, degree of anthropogenic activities, and level of conservation and management applied for the rivers (Roth et al., 1996; Johnson et al., 2005; Rodriguez-Olarte et al., 2006). Being ecologically diverse, gobioid assemblages can also serves as a good research material in understanding the function of their assemblage in response to different environmental factors.

Several studies have been performed to quantify the contribution and influence of a number of habitat and environmental variables on fish assemblages (Angermeier & Winston, 1999; May & Brown, 2000; Herder & Freyhof, 2006; Tunesi et al., 2006; Vorwerk et al., 2007). The nature of these studies is not fully-well investigated in gobioid assemblages inhabiting in the different Philippine stream ecosystems. There are few stream fish surveys conducted in the Philippines after the monumental work of Herre (1924, 1927, 1953), mainly due to the limited fish surveys after the post-war period. Nevertheless, few ecological studies have been done for riverine fish assemblages due to the deficiency in current conservation status and data on native/endemic taxa within the jurisdiction of nationally declared Protected Areas (IUCN 2007; Paller et al., 2011). In retrospect, previous studies on Philippine gobioid assemblage had been only focused on aspects of their fishery, geographical distribution, and implications for conservation (Montilla, 1931; Manacop, 1953; Blanco, 1956; Vedra et al., 2013).

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To the best of our knowledge, there are no ichthyofaunal studies in scientific peer-reviewed literatures concerning variations of the stream gobioid assemblages in southern Luzon, Philippines. More so, there is no information on how different environmental and habitat factors can influence the gobioid assemblage structure from protected areas with limited human accessibility. Hence, the aim of this paper was to evaluate gobioid assemblages in three streams located in different nationally proclaimed Protected Areas. We also want to analyse the contribution of environmental variables in structuring the gobioid assemblages along the longitudinal gradient profile of the three streams.

MATERIAL AND METHODS

Study areas. Gobioid species (family Gobiidae and Eleotridae) were inventoried from the three main rivers in three protected areas in southern Luzon, Philippines (Fig. 1). The three rivers are: (1) Bulusan, Iyam-Alitaaw (referred herein as Iyam), and Pansipit. Bulusan is a 5-km long river under the jurisdiction of Bulusan Volcano National Park in Sorsogon province. The river runs through the tropical forest landscape, with areas being covered by pristine portion of deciduous and riparian forest. Upstream, the river flows to a substrate that is mainly composed of boulders and cobbles, whilst downstream, water flows to coarse sandy, and gravelly loam substrate; (2) Iyam (14°02'N, 121°31'E) is fed by the springs of Mount Banahaw and run-offs from highlands. The upland streams are located within the Mount Banahaw-San Cristobal Protected Landscape in Quezon province, and runs 8.5–9.0 km before draining to Tayabas Bay. The upstream of the river is surrounded by primary and secondary forest with varying height and deciduousness. Coconut plantations and grasslands are also predominant in the mid- and upstream riparia. The downstream channel flows within an urbanised area; (3) Pansipit (13°55' N, 120°57' E) is the only drainage system of Lake Taal and is under the Taal Lake Protected Landscape in Batangas province. It is a 9 km-river, located southwest of the lake that connects a freshwater lake to Balayan Bay. The streamside plains are occupied by grasslands, crop and coconut plantations, and a few number of residential units.

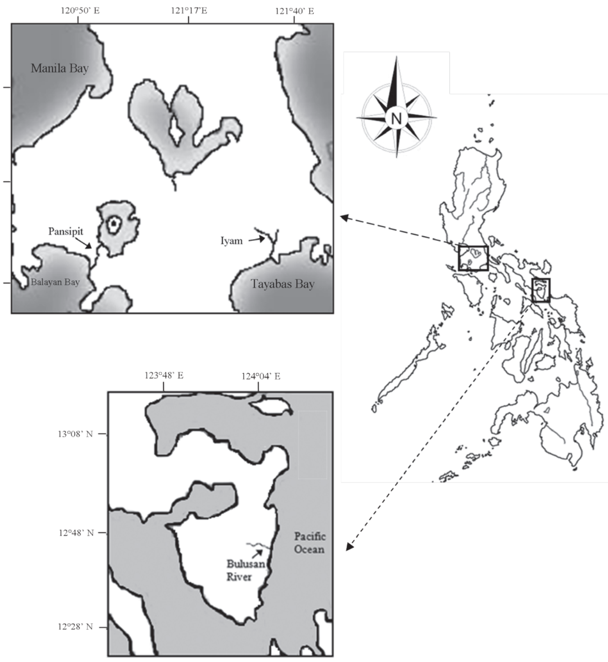

Fig. 1. Map of southern Luzon, Philippines showing the three studied sites.

Most of the local communities in all sites are involved in both fishing and farming. The studied areas have two pronounced season, a dry season from November to May and a wet season during the rest of the year.

Sampling design and fish collection. Twelve stations that are distributed in longitudinal profiles in each stream were selected. Four stream sections of around 60–75 m were sampled at each station, and were selected to cover the relative availability of distinct habitat types present in every river section. The four sample areas are considered replicates within each sampling station. Unit area sampled was equal to the length of seine net (8 × 1.2 m) multiplied to the distance sampled. In all circumstances, fish were sampled using a 12-v backpack electro-fishing gear, which was interchangeably operated by three persons. Seine net and hand-nets were only used as traps during electro-fishing, where they were placed at the end of the transect line to catch the stunned fishes that goes with the strong water current. Individual sampling run lasted about 40 mins and were done during day time. Two to three day samplings were carried out in the wet season during August 2010 and during July 2011 (wet season extends from June to October). Captured fish were immediately counted and identified at lowest possible taxon. Specimens were either housed in the laboratory as live specimens or preserved in 10% buffered formaldehyde solution for further documentation and identification. Specimens were identified using several fish identification materials (Herre 1924, 1927, 1953; Conlu, 1986; Vidthayanon, 2007; Froese & Pauly, 2011).

During collection, dissolved oxygen (DO, Hanna HI 3810), water temperature (°C), pH (Oakton pH tester 30), and salinity (Atago hand refractometer) were recorded in each site. Geographic position and elevation were also recorded for each sampling station using a GPS device (CarNAVi Pro 400). Depth, surface stream flow, and substrate were determined at three points within each sample area. Mean depth (cm) was measured using a wooden ruler. Stream flow ($m\ s^{-1}$) was measured using a simple float. Dominant bottom/subtrate type was estimated and categorised as organic detritus, silt, mud, sand (0.02–2 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 the time of sampling. Land use pattern is categorised based on the characteristic of riparian zone and adjacent landscape: agricultural sites (1); grassland (0.5); and forested areas (0.0).

Data analyses. Fish densities (number of individuals collected in one species/100 m^2) and relative abundances

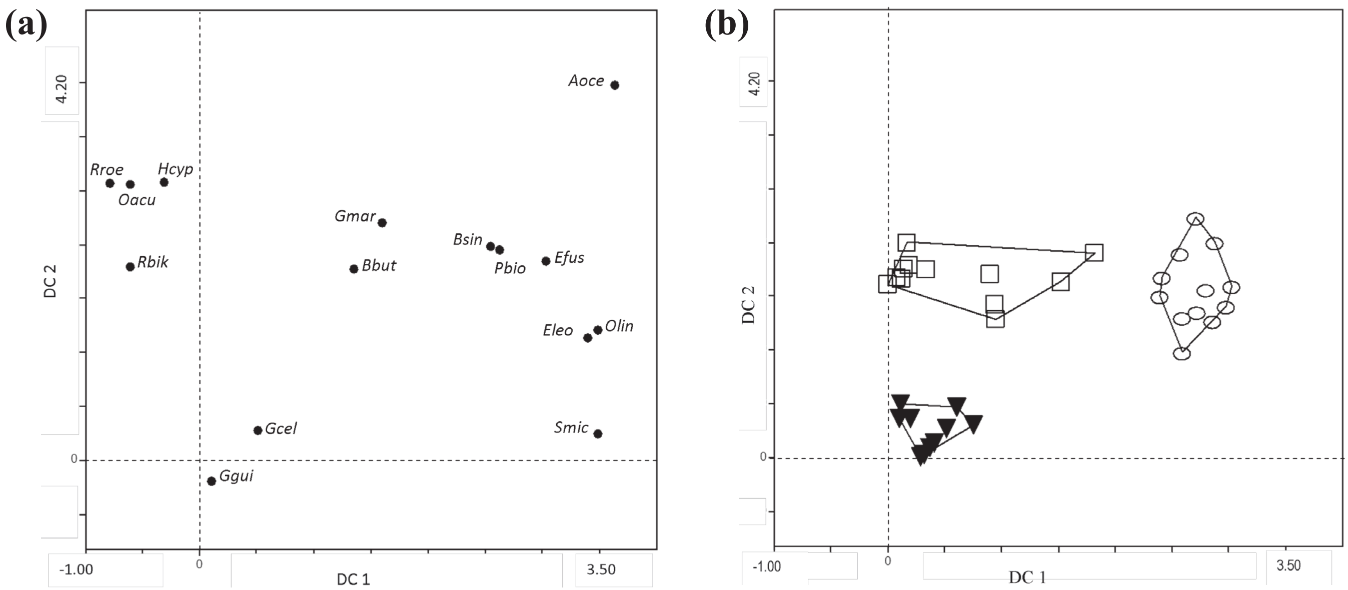

Fig. 2. Plot of scores of the first two axes from the detrended correspondence (DC) analysis for species, and sampling sites in southern Luzon, Philippines. (a) Species scores (see table 1 for species codes); (b) Sampling site scores: ○ Bulusan, ▼Iyam, and □ Pansipit. DC1=33.41%, DC2= 7.35%.

(number of individuals collected in one species/the total number of species collected) were computed for each sampling area. Cumulative fish density data did not follow the normality assumptions (Shapiro-Wilk test), and with that, Friedman test and Wilcoxon test were employed to determine the significant difference in median values of pooled density among and between the three sampling streams ($P < 0.05$).

Abundance data were $\log_{10}$ (x+1) transformed to linearise the relationship. Rare species with relative abundance of < 1% were not included in the analyses. Descriptive statistics of environmental variables were also computed. All variables that did not meet the parametric assumptions were subjected to Kruskal-Wallis *H*-test, and post hoc Tukey's Honest Significant Differences test ($P < 0.05$) (Zar, 2010).

Reduction analysis using Spearman's rank order correlation coefficients (r_s) was performed to exclude the redundant variables (Humpl & Pivnicka, 2006). Only the factors with $r_s < 0.32$ ($\alpha < 0.05$) were retained in the analyses. Six environmental variables were eliminated including salinity, water velocity, pH, cobble-type substrate, muddy bottom, and number of settlements.

The indirect gradient analysis (detrended correspondence analysis, DCA) was employed to evaluate the stream variability in the gobioid assemblages and described the most important gradient of species change. It also showed measure of beta diversity [Standard deviation (SD) units]. The direct gradient analysis (canonical correspondence analysis, CCA) was used to investigate the association of the fish species and the 36 sampling sites with environmental and habitat variables. This multivariate statistics also identified variables correlated maximally with species and sites data. Monte Carlo test with 999 random permutations was applied to test the significance ($P < 0.05$) of the gobioid assemblage and

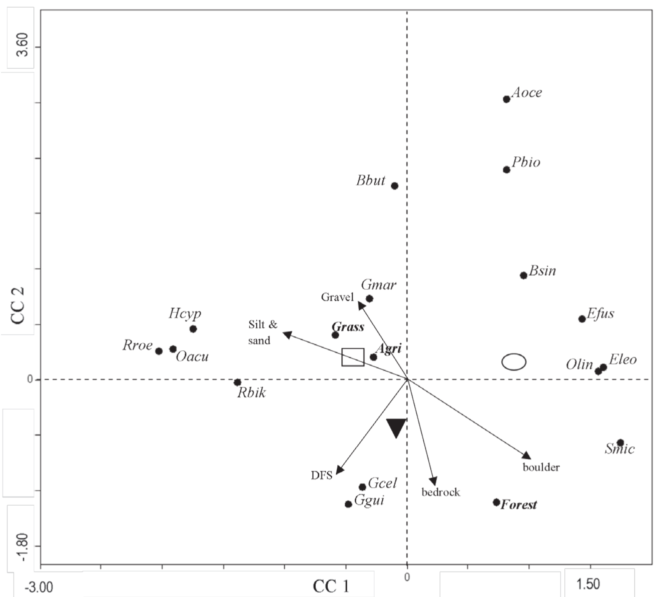

Fig. 3. Plot of the first two ordination axes of the final canonical correspondence (CC) analysis showing the inter-set correlations of the most significant environmental factors (DFS = distance away from the sea) on the gobioid assemblages (see table 1 for species codes). Sampling sites: ○ Bulusan, ▼ Iyam, and □ Pansipit. Land use pattern: *Grass*=grassland, *Agri*=agricultural area. CC1=45.74%, CC2=25.75%.

sites to environmental variables (Ter Braak & Verdonschot, 1995; Legendre & Legendre, 1998).

Bray-Curtis Index (Clarke, 1993) was used for multi-group comparison among river sections in each stream, and comparison of similar river sections between rivers. The unweight pair group method with arithmetic mean was used to classify the riverine groups according to species and

Table 1. Abiotic (median ± SE) and habitat characteristics of the three studied rivers.

Abiotic and Habitat Characters	**Bulusan**	**Iyam**	**Pansipit**	***H* values**
Water Temperature (°C)	25.65 ± 0.25[a]	24.7 ± 0.70[a]	27.48 ± 0.33[b]	19.49**
pH	7.4 ± 0.12[a]	7.25 ± 0.09[a]	7.49 ± 0.03[a]	3.54[NS]
Salinity (ppt)	0.16 ± 0.42[a]	0.11 ± 0.33[a]	0.00	–
Dissolved Oxygen (mg L^{-1})	6.25 ± 0.06[b]	5.11 ± 0.18[a]	5.03 ± 0.39[a]	7.12*
Riffle velocity (m s^{-1})	0.98 ± 0.07[a]	0.90 ± 0.19[a]	0.88 ± 0.08[a]	0.68[NS]
Depth (cm)	42.50 ± 7.45[b]	60.00 ± 6.19[b]	77.5 ± 10.72[a]	10.08**
Substrata	boulder + cobble + sandy	boulder + sandy	sandy to muddy	–
Dominant vegetation	bryophytes, riparian macrophytes	mosses, bryophytes, epiphytes	macroalgae, submerged, macrophytes, *Eichhornia crassipes*	–

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

Table 2. Distribution of freshwater fish species recorded from the three study sites.

Fish Species	Family	Code	Common Name	Bulusan	Iyam	Pansipit
Awaous ocellaris	G	*Aoce*	spotfin river goby	+	−	−
Bostrychus sinesis	E	*Bsin*	four-spotted sleeper	+	−	+
Butis butis	E	*Bbut*	duck-billed sleeper	−	+	+
Eleotris fusca	E	*Efus*	dusky sleeper	+	+	−
Eleotris sp.	E	*Eleo*	gudgeon	+	−	−
Giuris margaritacea	E	*Gmar*	snakehead gudgeon	+	−	+
Glossogobius celebius	G	*Gcel*	Celebes goby	+	+	+
Glossogobius giuris	G	*Ggiu*	white goby	+	+	+
Gobiopterus sp.*	G	*Gchu*	lacustrine goby	−	+	−
Hypseleotris cyprinoides	E	*Hcyp*	tropical carp gudgeon	−	−	+
*Odontamblyopus lacepedii**	G	*Olac*	eel goby	−	−	+
Oligolepis acutipennis	G	*Oacu*	sharp-tailed goby	−	−	+
Oxyeleotris lineonata	E	*Olin*	sleepy cod	+	−	−
Psammagobius biocellatus	G	*Pbio*	sleepy goby	+	−	+
Redigobius bikolanus	G	*Rbik*	speckled goby	−	+	+
Redigobius roemeri	G	*Rroe*	Roemer’s goby	−	−	+
Sicyopterus micrurus	G	*Smic*	clinging goby	+	−	−
*Stiphodon elegans**	G	*Sele*	golden neon goby	−	+	−
Sycopus sp.*	G	*Syco*	goby	−	+	−

E = Eleotridae, G = Gobiidae, (−) absent, (+) present, (*) not included in the ordination analyses

Table 3. Relative gobioid densities (fish per 100 m^2) and richness (in parenthesis) from the three studied stream.

Site	Bulusan	Iyam	Pansipit
1	15.00 (7)	14.76 (5)	47.20 (24)
2	26.88 (6)	10.00 (5)	59.60 (27)
3	26.88 (5)	9.05 (4)	80.00 (30)
4	21.25 (9)	16.67 (6)	46.00 (23)
5	26.25 (10)	10.95 (7)	43.20 (26)
6	19.38 (8)	19.05 (8)	57.20 (26)
7	21.25 (9)	10.48 (7)	62.80 (24)
8	21.25 (13)	19.05 (8)	49.60 (25)
9	22.50 (8)	23.81 (9)	43.60 (21)
10	16.88 (12)	26.67 (9)	31.60 (20)
11	16.88 (12)	21.43 (7)	10.40 (13)
12	30.00 (10)	26.67 (9)	9.60 (14)

Table 4. Analysis of similarity (%) between river sections in each stream and between the studied streams based from the gobioid composition and abundance data.

		Bulusan			**Iyam**			**Pansipit**		
		Us	**Ms**	**Ds**	**Us**	**Ms**	**Ds**	**Us**	**Ms**	**Ds**
Bulusan	Us	–	65.97	51.73	13.37	14.09	13.46	22.03	22.54	24.60
	Ms		–	63.77	10.12	11.51	6.97	21.46	20.80	24.42
	Ds			–	5.63	5.40	3.06	23.15	23.74	25.65
Iyam	Us				–	58.90	52.61	29.66	26.36	22.67
	Ms					–	65.47	41.69	34.37	28.83
	Ds						–	27.32	29.06	29.49
Pansipit	Us							–	74.48	35.83
	Ms								–	36.66
	Ds									–

Us = upstream, Ms = midstream, Ds = downstream

log_{10}-transformed abundance data. All statistical analyses were performed using Paleontological Statistic version 2.17 (Hammer et al., 2001) and Statistica version 6.0 (STATSOFT, 2001).

RESULTS

Environmental data. Abiotic and habitat features of the three streams are presented in Table 1. Temperature of Bulusan ($\bar{x}$=25.51°C; range=23.5–26.47°C) was significantly comparable with Iyam ($\bar{x}$ =24.5°C; range=26.45–29.6°C) (P > 0.05), but the temperatures of both were statistically lower as compared to Pansipit ($\bar{x}$ =27.86°C; 26.45–29.6°C) (P < 0.01). Conditions of pH were neutral to fairly basic (range=7.0–8.1). Water current, salinity levels, and pH were not significantly different among and between sites (P > 0.05). Significant spatial differences were recorded in DO levels (P < 0.05), albeit Iyam ($\bar{x}$ =5.72 mg L^{-1}; range=4.9–6.7 mg L^{-1}) and Pansipit ($\bar{x}$ =5.03 mg L^{-1}; range=3.06–6.83 mg L^{-1}) did not differ significantly. Water depth was significantly different among sites, with Pansipit ($\bar{x}$ =92.5 cm; range=60–170 cm) having deeper water level as compared to Iyam ($\bar{x}$=58.42 cm; range=22–90 cm) and Bulusan ($\bar{x}$ =52.92 cm; range=30–100 cm) (P < 0.05).

Abundance and composition. Overall, the ichthyofaunal survey collected a total of 1,071 specimens belonging to 19 species, and 17 genera (Table 2). Pansipit had the highest fish abundance (n=438) followed by Bulusan (n=422), and Iyam (n=211). In terms of richness, 12 gobiids and seven eleotrids were recorded from the three rivers. Pansipit had 7 gobiids and 4 eleotrids; Iyam had 6 gobiids and 2 eleotrids; Bulusan had equal number of gobiid and eleotrid species (5 species each).

Gobioid density and richness in each sampling site are presented in Table 3. Four gobioid species comprised the 57.17% of the total abundance collected from the three streams. These were *Giuris margaritacea* (Eleotridae), with relative abundance of 20.56%; *Glossogobius celebius* (Gobiidae) 13.28%; *Bostrychus sinensis* (Eleotridae) 13.22%, and *G. giuris* (Gobiidae) 10.00%. Numerically, the most

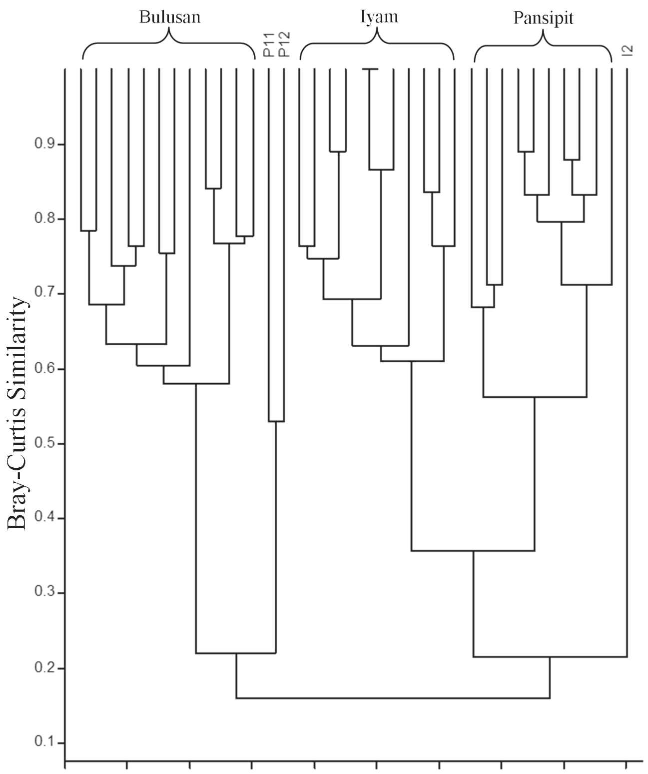

Fig. 4. A dendrogram from unweighted pair group method with arithmetic mean showing the relationship of sampling sites based on gobioid taxa and log-transformed abundance data. P11=11th site in Pansipit; P12=12th site in Pansipit; I2=2nd site in Iyam.

dominant gobioid species in Bulusan were *B. sinensis* and *Eleotris* sp. (ca. 50.00% of the cumulative relative abundance); *G. celebius* and *G. giuris* in Iyam (92.79%); and *Giuris margaritacea*, *Redigobius bikolanus*, and *Oligolepis acutipennis* in Pansipit (57.40%). Based from the specimens sampled from the three rivers, four out of 10 species sampled were exclusive to Bulusan; three out of seven species were exclusive to Iyam; and four out of 11 species were restricted to Pansipit. Pooled fish density was significantly different among the three sampling areas (Friedman test: χ^2=9.5, P<0.01); Pansipit had more fish catch per sample area than the other streams (Wilcoxon test: Z=2.67, P < 0.01); Iyam and Bulusan had comparable fish densities (Wilcoxon test: Z=1.73, P=0.09).

Similarity. Bray-Curtis similarity analysis for species composition and abundance data revealed the clustering of sampling sites of the three rivers (Fig. 4). A low similarity was registered between Iyam (all sites) and Pansipit (1st to 10th sites), having not more than 40% level of similarity. This Iyam-Pansipit group was deviated from Bulusan sites at not more than 20% level of similarity. Interestingly, the 11th and 12th sites of Pansipit were clustered with Bulusan at ca 23% level of similarity. Likewise, the 2nd site from Iyam was grouped in Pansipit at ca. 23% level of similarity.

Similarity between river sections in Bulusan (51.73–65.97%), and in Iyam (52.61–65.47%) registered relatively high percentages. In Pansipit, however, 74.48% similarity was computed between its upstream and midstream, but such river sections had low similarity percentages with the downstream, having not more than 37% (Table 4). Multiple comparisons among similar river sections between Bulusan and Iyam showed very low similarity percentages [upstream (us)=13.37%, midstream (ms)=11.51%, downstream (ds)=3.06%]. Likewise, low similarity percentages were observed between Bulusan and Pansipit (us=22.03%, ms=20.80%, ds=25.65%), and between Iyam and Pansipit (us=29.66%, ms=34.37%, ds=29.49%) (Table 4). The aforementioned similarity measures corresponded to the cluster analysis presented in Fig. 4.

Table 5. Relative eigenvalues, percentage of variation and weights of environmental variables (P < 0.01) of the first two canonical correspondences (CC) using log-transformed abundance data. Most significant weights of CC1 and CC2 are set in bold font.

	CC axis 1	**CC axis 2**
Variation (%)	45.74	25.75
Eigenvalues	0.46	0.26
Depth	(-) 0.34	0.38
Ve	0.28	(-) 0.10
DFS	(-) 0.38	(-) 0.78
Elev	0.33	(-) 0.46
Temperature	0.09	0.07
DO	(-) 0.28	(-) 0.08
Substrate types		
Bedrock	0.15	(-) 0.76
Boulders	0.64	(-) **0.53**
Gravel	(-) 0.40	0.54
Silt and sand	(-) 0.73	0.46
Land use		
Agri	0.28	0.39
Grassland	0.36	0.60
Forest	(-) 0.28	(-) 0.68

Veg = vegetation growth, DFS = distance away from sea, Elev = elevation, DO = dissolved oxygen, Agri = agricultural sites

Gobioid assemblage gradients. Thirteen significant environmental parameters were retained and were used in multivariate direct and indirect gradient analyses (P<0.05). The DCA produced two axes that contributed to 50.76% of the variability derived from the relative abundance of gobioid assemblage (Fig. 2a, b). The first ordination axis explained the 33.41% variation on gobioid assemblage as a function of stream longitudinal gradient (Fig. 2a). It is discernible in the plot the strong correlation of the most dominant species (e.g., *G. giuris*, and *G. celebius* for Iyam) in a particular river, and the gobioid species that are restricted to certain rivers. These caused a deviation of species and sites scores in the first ordination axis (left and right reading) (Fig. 2a, b). In sites plot, Pansipit scores are located in the start of the longitudinal gradient, so as with the more aggregated scores of Iyam sites. Bulusan, however, was clearly deviated from the Pansipit and Iyam sites at first ordination axis (Fig. 2b). The second ordination axis (17.35%) also displayed the gobioid assemblage change and sites' scores separation caused by unknown environmental parameters (Fig. 2a, b). The maximum gradient length was 3.08, and 2.68 SD units along the first ordination axis, and second ordination axis, respectively. Almost no species are shared at the opposite ends of the gradient. These observations satisfied the criteria to use CCA for unimodal direct gradient analyses.

Gobioid assemblage and environmental variables. Gobioid assemblages were highly significantly different among the three streams ($P<0.01$) (Fig. 3; Table 4). In CC1 (variation = 45.74%), Pansipit and Iyam deviated from Bulusan, while in CC2 (variation = 25.75%), Pansipit and Bulusan were relatively separated from Iyam (Fig. 3). The site-environment and species-environment relationships outlined by the CCA had eigenvalues of 0.46 and 0.26 on the first two axes, with 71.49% variability in fish assemblages explained (Table 4). The CCA ordination axis explained the fish assemblage differentiation primarily caused by the variation in longitudinal gradient profile of the three streams. CCA recognised various substratum types, distance from adjacent sea, and land use as the most weighted causative environmental parameters structuring the gobioid assemblage (Fig. 3; Table 4). In this analysis, boulder, and silt and sand substrata were highly correlated with the first ordination axis, while distance to sea, land use, bedrock and other substratum-type (boulders and gravel) were the parameters mostly correlated with the second ordination axis (Fig. 3; Table 4). Moreover, CCA diagram showed the land use pattern that is highly correlated in each stream. The land use pattern of Pansipit stream sites was strongly associated to grassland and agriculture, while Bulusan was correlated to forested areas. Iyam seem to have similar land use patterns of the two streams (Fig. 3).

DISCUSSION

The indirect gradient analysis reveals the gobioid assemblage variation as a response of species relative abundance to stream gradients (Fig. 2a, b). Most eleotrid specimens recorded in the present study were found in Bulusan, whereas *Glossogobius celebius* and *G. giuris*, although common inhabitants of the three rivers, are numerically prevalent in Iyam. Likewise, a number of gobiids such as *Redigobius bikolanus*, *R. roemeri*, and *Oligolepis acutipennis* are restricted to Pansipit. The DCA also expressed species variation along the longitudinal gradient profile of the rivers. Species scores at the lower part of the axis as well as those in the extreme left of the plot represent the upstream dwellers (*G. giuris*, *G. celebius*, *R. roemeri*, *Hypseleotris cyprinoides*, and *O. acutipennis*). They are clearly separated to common downstream dwellers (*Awaous ocellaris*, *Eleotris fusca*, *Eleotris* sp., *Oxyeleotris lineonata*, and *Sicyopterus micrurus*), which is located in the extreme right of the axis (Fig. 2a). This significant change in stream fish assemblage along the longitudinal stream profile was also observed in other ichthyofaunal studies (Eros et al., 2003; Shervette et al., 2007; Tunesi et al., 2006). In river sites variation, the notable divergence of Bulusan from Pansipit and Iyam may be attributed to the eleotrid-rich feature of the former (Fig. 2b).

The high species SD in DC1 axis indicates high beta diversity or high rate of species turnover from one assemblage to another along the stream gradients (Fig. 2a, b). It conforms to the very low similarity (Whittaker, 1967) observed for species abundance and composition between the three rivers and most predominantly, between Pansipit-Iyam vs. Bulusan sampling sites (Fig. 4). The lack of hydro-geographical connectivity between such streams can be one of the main causes of this significant spatial dissimilarity. Further, the interaction of geographically separated populations is almost implausible considering that gobioid species have weak dispersal mechanism as being diminutive (50–100 mm), poor swimmers, benthic dwellers, and have short pelagic larval stages (Herre, 1927; Ocampo et al., 2011; Mejri et al., 2012).

The observed variability in DCA was also expressed in CCA as the position of species scores and sites' group in the plot is rather comparable to both analyses (Figs. 2a, b, 3). In CCA, however, these variations were heightened (particularly for DC 2) and the most significant environmental factors influencing the gobioid assemblage were recognised. The most weighted of which is the structural complexity of substrate types, followed by the distance away from sea, and land use (riparian and landscape). These parameters were also regarded as good predictors of fish assemblage and were ascertained by some studies conducted in other streams (May & Brown, 2000; Humpl & Pivnicka, 2006; Tunesi et al., 2006; Pritchett & Pyron, 2011; Daga et al., 2012).

Based on CCA, substrate type is the most important factor that can cause a large proportion of gobioid assemblage variability. It is known that structural complexity of substrate type can create heterogeneous microhabitats within the river (Pritchett & Pyron, 2011), which can further diversifies the available habitats (Matthew, 1998) and promotes niche differences (Herder & Freyhof, 2006) for specialised and adaptive gobioid species. Upstream and midstream gobies are mainly well-adapted to rock-strewn, cool, lotic headwaters, whereas several downstream gobies are accustomed to soft bottom types, with influx of saline waters. Unlike the populations of *G. celebius* and *G. giuris* that are distributed throughout the whole stream sections, rare species were observed to be restricted in the upstream and downstream sites. This is particularly true to *Stiphodon semoni*, *Sicyopus* sp., and *R. roemeri*, which are exclusively inhabit the pool zone of a stream, and the air-breathing *Odontamblyopus lacepedii*, which is mostly associated to estuarine mudflat. Their occurrence and adaptation in different microhabitats within the streams may be linked with what we know about their biology. Mainly, because of their reliance in habitats in which they live, these native fish species can be considered as one of the ecologically important bioindicators of riverine health status (Zampella & Bunnell, 1998; Angermeier & Davideanu, 2004).

The second most important gradients identified by the second ordination axis are best explained by distance away from sea, and land use. Because of the proximity of the studied sites to seawater, species of marine origins frequented the three rivers, permitting the passage of amphidromous species like gobioids. Moreover, the influence of brackish waters and the inflow of fresh waters from several headwaters and local creeks create the heterogeneity of fish assemblage consisting of primary and secondary freshwater fish (Mercado-Silva et al., 2012). Land use is linked to anthropogenically-induced landscape and habitat alteration in riparian zones, which has been reported as one of the main drivers of change on fish assemblage structure (Kennen et al., 2005; Marsh-Matthews & Matthews, 2000).

The results from this study can be used in predicting the effects of environmental change and habitat loss on gobioid assemblage structure as well as on other important fluvial biota. From such baseline data set, conservation and management schemes for the streams within the protected areas can be updated and coordinated into regional and national environmental policies. The information is thus very essential for environmentalists, fishery technologists, policy-makers, and any concerned entities. This study also updated the inventory of gobioid fish species in the three studied rivers.

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LITERATURE CITED

Angermeier PL & Davideanu G (2004) Using fish community to assess streams in Romania: initial development of an index of biotic integrity. Hydrobiologia, 511: 65–78.

Angermeier MR & Winston MT (1999) Local vs. regional influences on local diversity across Virginia landscapes: prerequisite for conservation. Ecological Applications, 9: 335–349.

Benstead JP, de Rham PH, Gattolliat JL, Gibon FM, Loiselle PV, Sartori M, Sparks JS & Stiassny ML (2003) Conserving Madagascar's freshwater biodiversity. BioScience, 53: 1101–1111.

Blanco GJ (1956) Assay of the goby fry (ipon) fisheries of the Laoag river and its adjacent marine shores, Ilocos Norte Province. Philippine Journal of Fisheries, 4: 31–80.

Clarke KR (1993) Non-parametric multivariate analysis of changes in community structure. Australian Journal of Ecology, 18: 117–143.

Conlu PV (1986) Guide to Philippine Flora and Fauna: Fishes. Volume 9. National Resources Management Center, Ministry of Natural Resources, Quezon City, Philippines, 495 pp.

Daga SV, Gubiani EA, Cunico AM & Baumgartner G (2012) Effects of abiotic variables on the distribution of fish assemblages in streams with different anthropogenic activities in southern Brasil. Neotropical Ichthyology, 10: 643–652.

Eros T, Botta-Dukat Z & Grossman GD (2003) Assemblage structure and habitat use of fishes in a Central European submontane stream: a patched based approach. Ecology of Freshwater Fish, 12: 141–150.

Froese R & Pauly D (2011) FishBase. World Wide Web electronic publication. http://www.fishbase.org/search.php (Accessed 01 July 2011).

Hammer O, Harper DAT & Ryan PD (2001) PAST: Paleontological Statistics software package for education and data analysis. Palaeo Electronica, 4: 1–9.

Herder F & Freyhof J (2006) Resource partitioning in a tropical stream fish assemblage. Journal of Fish Biology, 69: 571–589.

Herre AH (1924) Distribution of true freshwater fishes in the Philippines. Philippine Journal of Science, 24: 1–308.

Herre AH (1927) Gobies of the Philippines and the China Sea. Monograph of the Bureau of Science, 23: 1–352.

Herre AH (1953) A Checklist of Philippine Fishes. Research Report Vol. 20. Fish and Wildlife Service, United States Department of Interior, Government Publishing Office, Washington, D.C. 977 pp.

Humpl M & Pivnicka K (2006) Fish assemblages as influenced by environmental factors in streams in protected areas of the Czech Republic. Ecology of Freshwater Fish, 15: 96–103.

IUCN [International Union for Conservation of Nature] (2007) 2007 IUCN Red List of Threatened Species. IUCN, Gland, Switzerland and Cambridge, UK. www.iucnredlist.org (Accessed 10 December 2010).

Johnson M, Giller P, O'Halloran J, O'Gorman K & Gallagher MB (2005) A novel approach to assess the impact of land use activity on chemical and biological parameters in river catchments. Freshwater Biology, 50: 1273–1289.

Kennen JG, Chang M & Tracy BH (2005) Effects of landscape change on fish assemblage structure in a rapidly growing metropolitan area in North Carolina, USA. American Fisheries Society Symposium, 47: 39–52.

Legendre P & Legendre L (1998) Numerical Ecology. 2nd English Edition. Elsevier, Amsterdam, 853 pp.

Manacop PR (1953) The life history and habits of the goby, *Sicyopterus extraneus* Herre (añga) Gobiidae with an account of the goby-fry fishery of Cagayan River, Oriental Misamis (Province, Mindanao, Philippines). Philippine Journal of Fisheries, 2: 1–60.

Matthews WJ (1998) Patterns in Freshwater Fish Ecology. Chapman & Hall, New York, 756 pp.

Marsh-Matthews E & Matthews WJ (2000) Geographic, terrestrial, and aquatic factors: which most influence structure of Midwestern USA stream fish assemblages? Ecology of Freshwater Fish, 9: 13–21.

May JT & Brown LR (2000) Fish community structure in relation to environmental variables within the Sacramento river basin and implications for the Greater Central Valley, California. US Geological Survey Report 00-247, Sacramento, California, 25 pp.

Mejri R, Lo Brutto S, Hassine N, Arculeo M & Hassine O (2012) Overlapping patterns of morphometric and genetic differentiation in the Mediterranean goby *Pomatoschistus tortonesei* Miller, 1968 (Perciformes, Gobiidae) in Tunisian lagoons. Zoology, 115: 239–244.

Mercado-Silva N, Lyons J, Pardo ED, Navarrete S & Hernandez AG (2012) Environmental factors associated with fish assemblage patterns in a high gradient river of the Gulf of Mexico slope. Revista Mexicana de Biodiversidad, 83: 117–128.

Montilla J (1931) The ipon fisheries of Northern Luzon. Philippine Journal Science, 45: 61–75.

Ocampo PP, Paller VGV, Camacho MV, Corpuz MC & Labatos BV (2011) Freshwater fishes of southern Luzon, Philippines. University of the Philippines Los Baños, Laguna, Philippines. 100 pp.

Paller VV, Labatos BV, Lontoc BM, Matalog OE & Ocampo PP (2011) Freshwater fish fauna in watersheds of Mt. Makiling Forest Reserve, Laguna, Philippines. Philippine Journal of Science, 140: 195–206.

Paller VV, Corpuz MC & Ocampo PP (2013) Diversity and distribution of freshwater fish assemblages in Tayabas River, Quezon (Philippines). Philippine Journal of Science, 142: 55–67.

Pritchett J & Pyron M (2011) Predicting fish assemblages from substrate variation in a Turbid River: grab samples compared with pole probing. North American Journal of Fisheries Management, 31: 574–579.

Rodríguez-Olarte D, Amaro A, Coronel J & Taphorn DC (2006) Integrity of fluvial fish communities is subject to environmental gradients in mountain streams, Sierra de Aroa, north Caribbean coast, Venezuela. Neotropical Ichthyology, 4: 319–328.

Roth NE, Allan JD & Erickson DL (1996) Landscape influences on stream biotic integrity assessed at multiple spatial scales. Landscape Ecology, 11: 141–156.

Shervette VR, Aguirre WE, Blacio E, Cevallos R, Gonzalez M, Pozo F & Gelwick F (2007) Fish communities of a disturbed mangrove wetland and an adjacent Tidal River in Palmar, Ecuador. Estuarine, Coastal and Shelf Science, 72: 115–128.

StatSoft Inc (2001) STATISTICA (data analysis software system), version 6.0 www.statsoft.com.

Ter Braak CJF & Verdonschot P (1995) Canonical correspondence analysis and related multivariate methods in aquatic ecology. Aquatic Science, 57: 255–289.

Tunesi L, Molinari A, Salvati E & Mori M (2006) Depth and substrate type driven patterns in the infralittoral fish assemblage of the NW Mediterranean Sea. Cybium, 30: 151–159.

Vedra SA, Ocampo PP, de Lara AV, Rebancos CM, Pacardo EP & Briones ND (2013) Indigenous goby population in Mandulog River system and its conservation by communities in Iligan City, Philippines. Journal of Environmental Science and Management, 16: 11–18.

Vidthayanon C (2007) Overview on freshwater fishes of the Philippines. In: Unpublished Lecture presented to the National Training Course on Freshwater Fish Identification. University of the Philippines Los Baños, Philippines. Pp. 1–8.

Vorwerk PD, Froneman PW & Paterson AW (2007) Recovery of the critically endangered river pipefish, *Syngnathus watermeyeri*, in the Karlega Estuary, Eastern Cape province. South African Journal of Science, 103: 199–201.

Whittaker RH (1967) Gradient analysis of vegetation. Biological Review (Cambridge), 42: 207–264.

Zampella RA & Bunnell JF (1998) Use of reference-site fish assemblages to assess aquatic degradation in Pinelands Streams. Ecological Applications, 8: 645–658.

Zar JH (2010) Biostatistical Analysis. 5th Edition. Prentice Hall, US, 929 pp.