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Diversity and Distribution of Freshwater Fish Assemblages in Lake Taal River Systems in Batangas, Philippines

ABSTRACT

An ichthyofaunal survey was conducted to evaluate the diversity and distribution of freshwater fishes in Looc, Magapi (inlets), and Pansipit (outlet) rivers surrounding Lake Taal (Batangas, Philippines) during the wet (July) and dry season (January) of 2011. The study collected 3,342 individuals comprising 37 species (19 families). In terms of fish species richness, 36 species were identified in Pansipit, whereas Looc and Magapi had 21 species each. The fish samples were mostly included eurayhaline, secondary freshwater fishes. The three most abundant groups were eleotrids, cichlids, and gobiids. Shannon-Weiner's diversity indices ranged from 2.17–3.05, which suggest that the studied rivers were moderately to slightly impacted. Significant differences in the composition and abundance of native and introduced fishes for the two sampling seasons were also observed (P<0.05), with native species being generally more diverse and abundant than non-native species. A high similarity level (>76%) was computed in the abundance data among the studied rivers. Canonical correspondence analysis identified the distance to the adjacent sea, depth, and vegetation as the most important environmental parameters influencing the distribution of fish assemblages. Baseline dataset from this study can be coordinated to concerned entities as a rational basis for future conservation and rehabilitation endeavors of Lake Taal river systems.

Key words: *diversity, freshwater fish, Lake Taal, Pansipit River, Shannon's index*

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INTRODUCTION

Current conservation status of stream freshwater fish assemblage under the Taal Volcano Protected Landscape (TVPL) in Batangas, Philippines is poorly evaluated. Despite of the conservation and mitigation efforts for TVPL, its streams remain under the continued threats from anthropogenically-induced pollution and habitat degradation (*Araullo 2001; Ong, Afuang and Rosell-Ambal 2002; DENR-PAWB 2005*). It is worsened by lack of local awareness and community-based education on most native freshwater fishes. The volume of scientific and research endeavors in Lake Taal is biased towards fisheries and aquaculture studies of commercially important fish species (e.g., *Caranx ignobilis, Oreochromis niloticus,* and *Sardinella tawilis*) as well as limno-ecological aspect of the lake (*Papa and Mamaril Sr. 2011*), whereas conservation studies for the indigenous, diminutive fluvial freshwater fish species are often overlooked.

Fish community structures are excellent ecological indicators and descriptors of fisheries stability (*Welcomme 1995*), impacts of habitat deterioration, invasive alien species, and climate change in a certain aquatic environment across spatial and temporal scales (*Niskikawa and Nakano 1998*; *Zampella and Bunnell 1998*; *Guerrero 2002*; *Vescovi et al. 2009*). Hence, fish assemblage data could reflect the health condition of the river systems. From such baseline data set, conservation and management schemes can be updated and integrated into regional and national environmental policies.

Several diversity indices are commonly applied to the study of fish composition and distribution, primarily to assess the current health status of rivers and adjacent tributaries (*Ramsundar 2004*; *Kwak and Peterson 2007*; *Corpuz, Paller and Ocampo 2015b*). Likewise, multivariate gradient analyses are being employed to associate the patterns of fish community data to multiple environmental parameters (*Ter Braak and Verdonschot 1995*; *Angermeier and Davideanu 2004*; *Corpuz, Paller and Ocampo 2015a*).

This paper characterized the freshwater fish assemblage within the longitudinal gradient of Pansipit River (outlet), Looc River, and Magapi River (inlets) in the Lake Taal watersheds (Batangas, Philippines) by comparing fish assemblages among the rivers and between sampling seasons (wet and dry seasons). Specifically, the study described the spatio-temporal variations of the native and introduced fish assemblages, and their relations to environmental/ habitat characteristics.

MATERIALS AND METHODS

Study areas

Freshwater fishes were inventoried in the three rivers of Batangas, Philippines representing the inlets (Looc and Magapi) and outlet (Pansipit) of Lake Taal. Magapi and Looc are small, shallow inlets, which are water-fed by the springs and run–offs from the highland areas of Batangas province and Tagaytay Ridge. The islets are located in the northeastern portion of the lake, approximately 18.5 km heading about 235° towards the mouth of Pansipit. The inlet sites presented a substrate composed mainly by gravel and rocks in upstream to midstream, and sand-silt characteristic in downstream. Land and water uses include irrigation, agriculture, livestock, human settlement, sand mining, and coconut plantation. Pansipit river is the only drainage system of Lake Taal and consists of sandy to black cotton soil. It is a 9 km-river, located southwest of the lake (13°55'51"N, 120°56'58"E) which drains to Balayan Bay (13°52'N, 120°55'E). The river-side plains include grasslands, crop and coconut plantation, and residential areas. Some areas in the riverbanks are generally lined by mosses, ferns, and other riparian vegetation structure, with some steep areas surrounded with secondary forest, bryophytes, and perennial weeds. The sediments in the sampling sites are mostly sandy and clay loam. Most of the inhabitants are engaged in fishing, farming, and livestock raising (*Corpuz, Paller and Ocampo 2015a*).

Sampling Design

Twelve stations were selected for the three sites (**Figure 1**). A 60 to 75-m stream reach was selected at each station. Three 20 to 25-m sampling run were surveyed, which were considered replicates within each the station. Unit area sampled was equal to the maximum length of beach seine net (8 m) multiplied by the distance seined. Individual sampling run lasted ca. 40 min and was done during day time. A four-day sampling was carried-out once per day from 21–24 January and once per day from 5–8 July 2011 to represent wet and dry season, respectively. In Batangas, the dry season extends from November to May and the wet season from June to October. A total of 48 samples were made (24 sampling sites x two seasons).

Fish specimens were collected using a beach seine net (1.2 x 1.2-mm mesh), hand nets, fish trap, angling, and

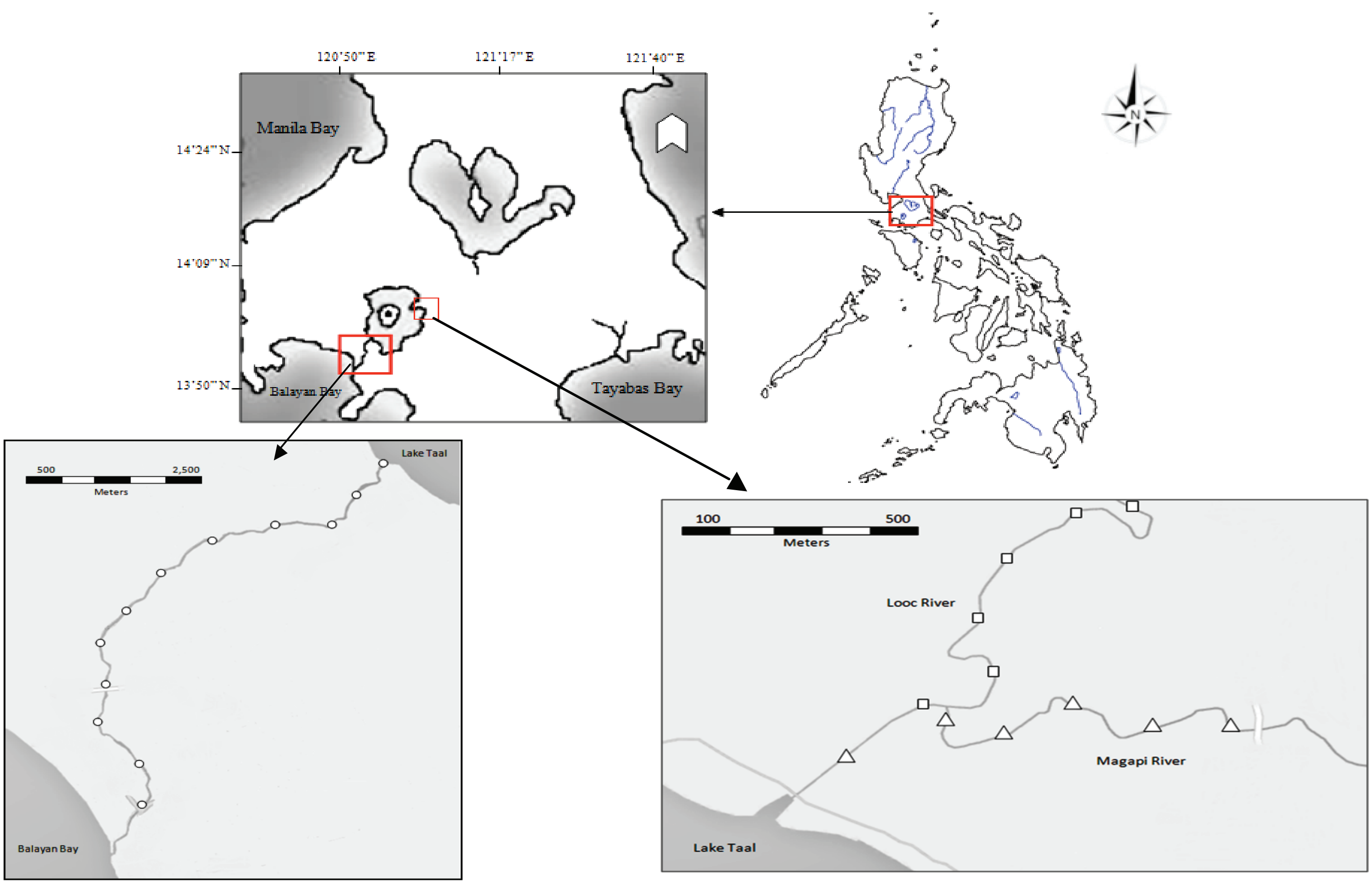

Figure 1. Map outline of studied sites of and Pansipit River (○), Looc River (□), and Magapi River (∆) in Batangas, Philippines.

12-v backpack electro-fishing equipment. Captured fish were immediately counted and identified at lowest possible taxon. Specimens were either housed in laboratory as live samples or preserved in 10% buffered formaldehyde for further documentation and identification. Some voucher specimens were deposited in the piscine collection of UPLB Museum of Natural History, Philippines.

Prior to fish collection, dissolved oxygen (DO, mgl^{-1}, Hanna HI 3810), water temperature (oC), pH (Oakton pH tester 30), and salinity (ppt, Atago hand refractometer) were recorded for each site. Geographic position and elevation were also recorded for each sampling station using a GPS device (CarNAVi Pro 400). Depth (cm) was measured using an improvised wooden ruler at two or three points in each site. Stream flow ($m\ s^{-1}$) was measured using a simple float. Dominant bottom type was recorded and categorized as organic detritus, silt, mud, sand (0.02–2 mm), gravel (2–64 mm), cobble (64–256 mm), boulder (>256 mm) (*May and Brown 2000*). Visual estimation of vegetation cover (%) was determined by the relative amount of submerged and floating aquatic plants to sampling path as well as those occupying both sides of the riverbanks.

Data Analyses

Different descriptors of diversity were used in this study. Species richness was determined by the number of species present in a community. The relative abundance for each species was calculated as:

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

where: a_i is the number of individuals collected in the ith species and A is the total number of species collected in one sampling area during a sampling period.

Diversity index was computed following the Shannon-Weiner diversity index (*H'*) (*Shannon and Weaver 1949*):

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

where: s is the number of species; p is the proportion of individuals found in the ith species and ln is the natural logarithm.

Evenness (*J'*) was computed following the Shannon's diversity index:

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

where: S is the total number of species.

Species dominance was computed using the Simpson's index formula (λ) (*Simpson 1949*):

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

where: s is the number of species, ni is the number of individuals in the ith species and N is the total number of individuals.

Abundance data were log10 (x+1) transformed to linearize the relationship. Normality (Kolmogorov-Smirnov test) and homoscedasticity (Levene's test) of variances were tested for abundance data, species richness, habitat variables, and water parameters. The standardized abundance data among sites and between seasons were examined using analysis of variance (ANOVA, $P<0.05$). Variables that did not meet any of the assumptions were subjected to univariate nonparametric tests (Kruskal-Wallis *H*-test, and Mann-Whitney *U*-test, $P<0.05$). Shannon's diversity and evenness of the three rivers were compared using diversity *t*-test as described by *Hutcheson* (*1970*). Morisita-Horn Index (*Wolda 1981*) was used to measure the similarity between rivers and the unweight pair group average method was used to cluster similar group or rivers according to log-transformed abundance data. Descriptive statistics of environmental variables were also computed.

Reduction analysis using Spearman's rank order correlation coefficients (r_s) was performed to decrease the number of redundant variables (*Humpl and Pivnicka 2006*). Only the factors with $r_s<0.35$ ($\alpha<0.05$) were retained in the analyses. Four factors were eliminated including bottom type, water velocity, elevation, and number of settlements.

Wilk's lambda statistic ($P<0.05$) was used to examine temporal variation of group centroids of pooled native and introduced fish assemblages. Pairwise comparisons between sample groupings were made using Hotelling's T^2 test ($P<0.05$). The direct gradient canonical correspondence analysis (CCA) was used to investigate the association of the fish species and the 24 sampling sites with environmental and habitat variables. This multivariate statistics also identified variables correlated maximally with species and sites data. Monte Carlo test with 1,000 random permutations was applied to test the significance ($P<0.05$) of the fish assemblage structure and sites to environmental variables (*Ter Braak and Verdonschot 1995*; *Legendre and Legendre 1998*). All statistical analyses were performed using SPSS version 17 and Statistica version 7.0.

RESULTS AND DISCUSSION

Species Richness and Abundance

The ichthyofaunal survey collected a total of 3,346 individuals comprising 37 species (19 families) (**Table 1**). Fish species composition mainly included native species (26 spp.) of which the most diverse in terms of number of species in each family were Gobiidae (7 spp.) followed by Eleotridae (4 spp.) and Syngnathidae (4 spp.). Pooled species richness differed significantly among the three areas (H=9.37, P<0.05), with the inlets having statistically similar richness (z= -0.24, P>0.05) and significantly different to Pansipit [(Pansipit vs Looc: z= -2.35, P<0.05); (Pansipit vs Magapi: z = -2.54, P<0.05)]. No significant variation in species richness, however, was observed between seasons (z= -0.46, P>0.05). Log-transformed abundance varied significantly among the three rivers (F=7.41, P<0.05), being highest in Pansipit, which was significantly different from Looc (Q=4.02, P<0.05) and Magapi (Q=4.24, P<0.05). Significant variation in fish abundance was also found between seasons (Q=3.60, P<0.05). A similar patterwas n also observed in Pansipit, but not in Looc and Magapi. Overall, the number of fish collected in the wet season (2,228) was more than half (50.02%) of that in the dry season (1,118).

The riverine ichthyofaunas were comprised of relatively numerous fish species but with few dominant ones each having not more than 30% of its total contribution to overall fish count. Overall, the most dominant groups in terms of abundance were eleotriids, cichlids, and gobiids. The most dominant species (in order of importance) in Looc in both seasons combined were *Giuris margaritacea*, *Oreochromis niloticus*, *Poecilia sphenops* and *Glossogobius giuris*, which contributed 57.14% of the total fish abundance. In Magapi, four species (*G. margaritacea*, *P. sphenops*, *O. niloticus*, and *Glossogobius celebius*) contributed 63.43% of the total abundance. Seven species (*O. niloticus*, *G. margaritacea*, *Ambassis interrupta*, *Toxotes jaculatrix*, *Leiopotherapon plumbeus*, *P. sphenops*, and *Apogon hyalosoma*) represented 51.24% of the total abundance in Pansipit. The most distributed native species throughout the sampling sites of inlets were *G. margaritacea*, *G. celebius*, *G. giuris*, and *L. plumbeus*. Likewise, all fish species jointly with *A. hyalosoma*, *Oligolepis acutipennis*, *Doryichthys martensii*, and *T. jaculatrix* were also distributed in Pansipit sampling sites. The observed dominance of gobioid assemblage is parallel to the monumental works of *Herre* (*1927, 1953*). During his Philippine expedition between 1910 to late 30s, he identified 35 species in Pansipit, in which 4 species were still recorded by this survey. Early fisheries assessment was done about 8 decades ago by *Villadolid* (*1937*) (as cited in *Papa and Mamaril Sr. 2011*), in which 101 fish species belonging to 32 families were inventoried in Lake Taal, Pansipit and Balayan Bay. To date, The most recent survey in Pansipit was facilitated by *Mendoza and her collegues* (*2015*), of which 12 species where identified.

Conspicuous seasonal variation was observed in the site-pooled abundance of the native fish samples, having the fish counts more abundant during wet season and mostly represented by juveniles. Our findings were also congruent with *Mendoza et al.* (*2015*). In an ecological viewpoint, the role of amphidromy (either associated to breeding or profusion of trophic resources) caused by seasonal changes is one of the major factors that may account for these differences. In fact, most of the native fishes documented in this study are migratory in nature (*Froese and Pauly 2011*). Another interesting observation is the occurrence of a number of juvenile samples suggesting a continuous and successful recruitment within the studied rivers.

Variation in Fish Diversity

Shannon-Weiner's diversity index (H') for the three rivers varied from 2.32 to 3.04 with Pansipit River being the most diverse among the three sites. The dry season had slightly higher H' (Looc=2.53, Magapi=2.43) as compared to the wet season (Looc=2.32, Magapi=2.29). Diversity t-test showed significant difference between the outlet and inlets (P<0.05), albeit Looc and Magapi were significantly similar (P>0.05). The diversity indices in the TVPL river systems were higher as compared to the mountain streams of Mt. Makiling Forest Reserve including Dampalit (species=12, H'=1.12), Cambantoc (species=9, H'=0.85), and Molawin (species=12, H'=1.19) (*Paller et al. 2011*). Fish diversity is likewise low in the Tayabas River system (species=16, H'=1.55) of the Mount Banahaw Protected Landscape (*Paller, Corpuz and Ocampo 2013*). Nevertheless, there is no available previous H' record for TVPL river systems which can be used to compare with the present study. According to *Namin and Spurny's* (*2004*) method of categorizing the estimated Shannon-Weiner values based on the impact of anthropogenic disturbances, Looc and Magapi are considered moderately impacted, while Pansipit is moderately to slightly impacted.

High evenness (J') values (range: 0.7–0.85) were observed. In contrast, low Simpson's dominance indices were calculated (range: 0.06–0.14). The distribution of fish assemblage can be therefore described as having a very low dominance and high evenness, indicating that the allocation of niche spaces is equitably distributed for dominant and non-dominant fish species (*Ramsundar 2004*). The very low dominance is attributed to few dominant species (those with relative abundance of <30%, and fluctuated seasonally). The very high J' reflects a fish assemblage coexisting equitably within the river systems. The different fish species may able to coexist primarily due to the variety of available microhabitats, giving rise to some degree of niche partitioning (*Herder and Freyhof 2006*; *Higgins and*

Table 1. Checklist of fish species, feeding habits, ecology, and density (fish 10 sqm^{-1}) collected from the three streams of Lake Taal, Batangas. L= Looc, M = Magapi, P = Pansipit.

Species	Code	Feeding Habits	Ecology	Wet season			Dry season		
				L	M	P	L	M	P
Ambassidae (perchlets)*									
Ambassis interrupta	Aint	O, mainly detritus and plankton	E, A	0	0	6.64	0	0	3.00
Apogonidae (cardinalfish)*									
Apogon hyalosoma	Ahya	O, mainly fish, insects, invertebrates	E, A, BP	0.50	0	5.09	0.67	0.30	0.55
Atherinidae (silversides)*									
Atherinomosus lacunosus	Alac	O, mainly zooplankton, benthic invertebrates	E, A, BP	0	0	2.18	0	0	0
Blennidae (blennies)*									
Omobranchus ferox	Ofer	C	E, D	0	0	1.27	0	0	0
Carangidae (Jacks)*									
Caranx ignobilis	Cign	C	E, HM, P	0	0	0.18	0	0	0
Eleotridae (sleepers and gudgeons)*									
Bostrychus sinensis	Bsin	C	E, A, BP	0	0	0.36	0	0	0.73
Butis butis	Bbut	C	E, A, BP	0	0	0.64	0	0	0.45
Giuris margaritacea	Gmar	O, variety of algae and small fishes	E, A, BP	24.67	19.55	9.45	12.0	7.73	0.45
Hypseleotris cyprinoides	Hcyp	O, mainly small fish and invertebrates	E, BP	0	0	0.64	0	0	0
Gobiidae (true gobies)*									
Glossogobius celebius	Gcel	C	E, D	9.17	13.94	3.27	6.33	8.64	0
Glossogobius giuris	Ggiu	C	E, D	11.67	7.88	2.64	5.50	6.21	0.09
Odontamblyopus lacepedii	Olac	C	E, D	0	0	0.09	0	0	0
Oligolepis acutipennis	Oacu	C	E, D	0	0	4.82	0	0	0.18
Psammagobius biocellatus	Pbio	C	E, D	0	0	0.27	0	0	0
Redigobius bikolanus	Rbik	O, mainly feed on small fishes and invertebrates	E, BP, A	0.83	2.12	0.27	5.55	1.52	0
Redigobius roemeri	Rroe	O, diets are composed of invertebrates	E, D	0.33	3.48	2.18	1.67	2.58	0
Hemiramphidae (halfbeak)*									
Rhynchorhampus georgii	Rgeo	O, mainly invetebrates	E, P	0.34	0.30	1.27	0.50	0.61	1.54
Zenarchopterus buffonis	Zbuf	O, mainlyaquatic insects	E, P	0.17	0	1.27	0.67	0.15	0
Mugilidae (mullets)*									
Crenimugil heterocheilos	Chet	O, mainly plankton, benthic species, detritus	E, D, HM	0	0	0.82	0	0	4.64
Scatophagidae (scats)*									
Scatophagus argus	Sarg	O, mainly plant matters, algae	E, P, HM	0	0	0.18	0	0	0
Syngnathidae (pipefishes)*									
Doryichthys boaja	Dboa	O, mainly fish larvae, invertebrates, plankton	S, BP	0.17	0.45	1.00	0.33	0.15	0.55
Doryichthys sp.	Dmar	O, mainly plankton, benthos, insect larvae	S, BP	0.13	1.36	3.73	1.17	0.45	0.55
Microphis brachyurus	Mbra	O, mainly plankton, worms, benthos	S, BP	1.17	1.06	2.00	0.67	0.45	0

* Native fish family; C = carnivore (flesh eater); O = omnivore (eating both animals and plant matters); E = euryhaline (can tolerate a wide range of salinity); S = stenohaline (can tolerate a narrow range of salinity); A = amphidromous (can migrate from fresh water to the seas or vice versa, but not intended for reproduction); Po = potamodromous (migration occur wholly within freshwater); BP = benthopelagic (fish that occupy water just above the bottom); HM = highly migratory (migration from marine to freshwater or vice versa with the intention to reproduce); D = demersal (live on the bottom or near the bottom of the water); P = pelagic (live near the surface of the water or in the water column).

Sources: *Froese and Pauly* (*2011*); *UPLB-LRS* (*2011*); *Mendoza et al.* (*2015*)

Table 1. Checklist of fish species, feeding habits, ecology, and density (fish 10 sqm^{-1}) collected from the three streams of Lake Taal, Batangas. L= Looc, M = Magapi, P = Pansipit (cont.)

Species	Code	Feeding Habits	Ecology	Wet season			Dry season		
				L	M	P	L	M	P
Hippichthys heptagonus	Hhep	O, mainly plankton, benthos, insect larvae	S, D	1.68	0.61	1.45	0.50	0.30	0.36
Terapontidae (grunters)*									
Leiopotherapon plumbeus	Lplum	O, mainly benthos, plankton, invertebrates	E, A, P	2.17	3.03	6.82	4.83	4.39	0
Toxotidae (archerfishes)*									
Toxotes jaculatrix	Tjac	O, mainly small fish, invertebrates, plant matter	E, BP, A	0.34	0.15	7.00	1.17	1.06	0
Channidae (murrels)									
Channa striata	Cstr	C	S, D, A, Po	3.33	1.97	5.45	10.83	5.30	0.09
Clariidae (freshwater catfishes)									
Clarias batrachus	Claria	C	S, D, A	1.50	0.76	0.91	1.00	1.21	0
Cichlidae (cichlids)									
Oreochromis mossambicus	Omos	O, mainly algae, plankton, shrimps, small insects, and detritus	E, BP	0	0	0.27	0	0	0
Oreochromis niloticus	Onil	O, mainly algae, plankton, shrimps, small insects, and detritus	E, BP, Po	10.0	13.3	15.64	11.5	11.67	0.64
Parachromis managuensis	Pman	C	E, D, Po	3.83	1.51	5.27	2.50	3.94	0.18
Cyprinidae (carps and minnows)									
Cyprinus carpio	Ccar	O	S, BP, Po	6.00	3.18	0.54	1.5	1.52	0
Carassius carassius	Ccas	O, mainly plant materials, and plankton	S, D, Po	0.67	0.15	0.09	0.33	0.45	0
Osphronemidae (gouramis)									
Trichopodus pectoralis	Tpec	O, mainly aquatic plants and invertebrate	S, BP, Po	0	0	1.36	0	0	
Trichopodus trichopterus	Ttri	O, mainly aquatic plants and invertebrate	S, BP, Po	0	0	1.18	0	0	0.64
Poeciliidae (poecillids)									
Poecilia sphenops	Psph	O, feeds variety of foods	S, P, Po	9.67	11.36	5.82	8.33	15.76	0.09
Number of species for each site				21	19	36	21	21	17

Strauss 2008). Habitat specialization (*Fausch 1984*) and differentiated feeding efficiency and preference (*Nishikawa and Nakano 1998*; *Mendoza et al. 2015*) are some of the key factors that structure the fish assemblages. In this study, several observations on niche differentiation are worth mentioning such as the prevalence of flathead gobiids in rocky and fast-flowing zones, *T. jaculatrix*, cichlids, and poeciliid in open water, *Clarias batrachus* in muddy waters, *Omobranchus ferox* and *O. acutipennis* in sandy bottom with submerged macrophytes, high occurrence of eleotrids, cyprinids, and osphronemids in floating and riparian vegetation, and presence of pipefishes in submerged plants with vertical arrangements.

Variation in Native and Introduced Fish Assemblages

Abundance percentage of native fish species were higher than that of introduced fish species in Pansipit during the wet (native=64.20%, introduced=35.80%) and dry (native=80.90%, introduced=19.10%) sampling seasons and both seasons combined (66.50%). A similar trend was also observed for inlets (native: >50%), except during the dry season in Magapi (native=46.40%, introduced=53.60%) (**Figure 2**). Discriminant analysis also confirmed the temporal abundance differentiation in native and introduced fish assemblage within and across seasons (Wilk's Lambda=0.52, approx. $F_{(9, 163)}$=5.42, P<0.001). Abundance of native fishes changed significantly across seasons (Hotelling's T^2 =37.90, P<0.05), so as with the introduced fishes (Hotelling's T^2 =19.92, P<0.05), with wet season being more abundant relative to the dry season. Similar observations in reproductive periodicity and abundance upsurge were also reported by other authors (*Emmanuel and Modupe 2010*; *Paller, Corpuz and Ocampo 2013*; *Mendoza et al. 2015*). These support the supposition that rainy months, as a reproductive season are vital during the recruitment phase of stream fishes in these tropical river systems.

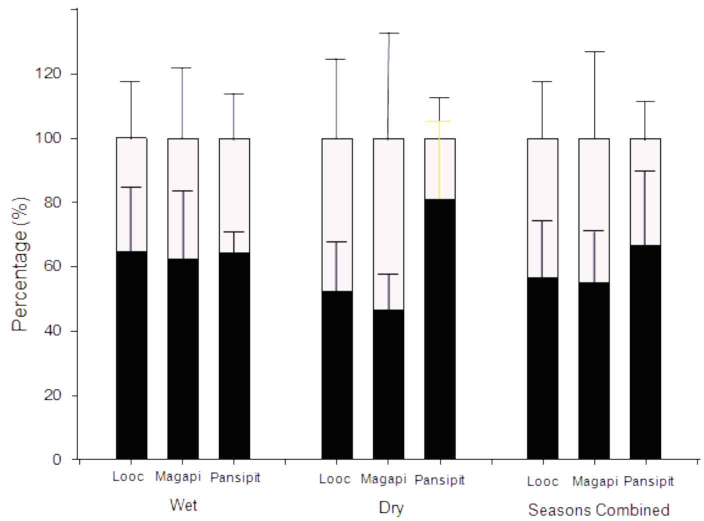

Figure 2. Stacked bar of percent representation in abundances of native (black bars) and introduced (gray bars) freshwater fish species from the three sampling sites in two sampling seasons and seasons combined (error bars = SE).

Similarity

Similarity analysis revealed the clustering of the three rivers in two sampling seasons. A very high similarity was registered between Looc and Magapi (both seasons), having not less than 96%. As shown in the dendogram (**Figure 3**), the wet season of Pansipit was deviated from the inlets (both seasons) at ca.76% level of similarity. Interestingly, the least significant similarity was found between the sampling seasons of Pansipit with abundance characteristics that overlapped had ca. 50% (**Figure 3**).

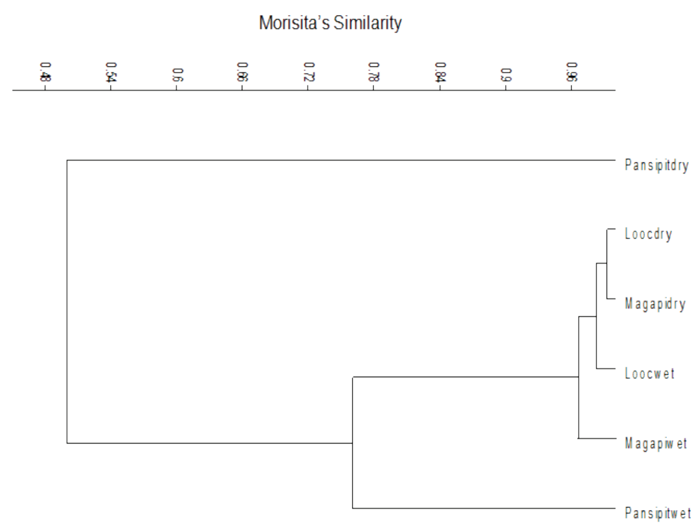

Figure 3. A dendrogram from unweighted pair-group average showing a cluster of the fish abundance data among the three rivers in two sampling seasons. (Pansipitdry = Pansipit in dry season; Pansipitwet = Pansipit in wet season; Loocdry = Looc in dry season; Loocwet = Looc in wet season; Magapidry = Magapi in dry season; Magapiwet = Magapi in wet season).

Canonical Correspondence Analysis

In CCA, fish assemblages were significantly different between the inlets and Pansipit (P<0.001). The sites-environment relationships had eigenvalues of 0.28 and 0.18 on the first two axes, with 80.04% variability in fish assemblages explained. Magapi and Looc scores were clearly aggregated, albeit separated from Pansipit on the first ordination axis (49.05%) (**Table 2**, **Figure 4A**). CCA recognized mean depth and distance of sites from the adjacent sea as the most weighted contributory factors influencing the stream sites variation (**Table 2**). The second ordination axis (30.99%) explains the sites distribution caused by the difference in the amount of hydrophyte structures within the sampling areas. Similar to previous analysis, the distribution of species scores revealed the gradient of fish assemblage variation caused mainly by habitat characteristics (depth, distance to the sea, and vegetation) (**Table 2**, **Figure 4B**). The ordination diagram displays fish species mostly correlated to hydrophytes structures and those that are commonly occurring in the inlets. Secondary freshwater fishes including *Odontamblyopus lacepedii*, *Bostrychus sinensis*, *Butis butis*, *Crenimugil heterocheilos*, *Psammagobius biocellatus*, *Caranx ignobilis*, and *Scatophagus argus* are the typical inhabitants of the sampling sites near the Balayan Bay (**Figure 4**).

The findings indicate that the diversity and distribution of fish assemblages in TVPL streams are environmentally induced by three factors: connection to the sea, water level, and vegetation. Higher fish diversity in Pansipit as compared to inlet group is primarily attributed to its connection to an adjacent sea (*Mercene and Alzona 1990*). Because of the proximity of Pansipit to Balayan Bay, species of marine origins use Pansipit as pathway to Lake Taal, permitting the passage of euryhaline migratory species. Furthermore, Pansipit is influenced by the entry of brackishwater from the Balayan Bay, and by inflow of freshwater from several headwaters and local creeks. These factors create the heterogeneity of fish communities consisting of primary and secondary freshwater fish species as well as estuarine fish species. This is similar to the report of V*elasquez, Cendejas and Alberto* (*2008*) about an estuarine systemaffected by fresh water influxes. The size of the river also plays a role in structuring fish assemblage. In related studies, larger and deeper streams generally have higher fish abundance (*Raz-Guzman and Hiudobro 2002*; *Mendoza et al. 2015*), and harbor both groups of diminutive and large active swimming fishes (*Azmir and Samat 2010*). The estimated vegetation cover ranged from 25–60% and was mainly consisted of *Eichhornia crassipes*, *Pistia stratiotes*, *Ipomoea aquatica*, *Hydrilla* sp., *Salvinia* sp. and among others. These hydrophytes create ephemeral micro-habitats within the river, which further diversified the available localized niches. Several studies have documented a number of important potential functions of submerged and floating aquatic plants in structuring fish community (*Olson et al. 1994; Batzer 1998*). One of these includes the availability of feeding and breeding grounds for diminutive fishes (*Brendonck et al. 2003*).

Water parameters

The physicochemical properties of three streams were relatively uniform but fluctuated seasonally (**Table 2**). Spatial and temporal significant variations (P<0.05) were computed only among the means of pH. Conditions of pH were fairly neutral to basic ($\bar{X}$=7.62, range=6.9–8.8). Means of the rest of water parameters were significantly stable (P>0.05) among the three streams and between seasons. Lower DO level was observed in Pansipit, but DO levels remained significantly comparable (P>0.05) among the three rivers ($\bar{X}$=5.71 mg l^{-1}, range=6.9–8.8 mg l^{-1}). Water temperatures varied only according to the time of the day when the parameters were recorded ($\bar{X}$=28.14°C, range= 25.40–31.00°C). Freshwater conditions were observed (≤0.05 ppt) in all sites. In CCA, however, all of the aforementioned physicochemical parameters were not identified as strong contributory variables influencing the fish assemblages and sites variation.

Table 2. Correlations of significant environmental variables of the first two CCA ordination axes. Most significant weights on CCA 1 and CCA 2 are in bold.

Environmental/ Habitat Variables	Canonical coefficient	
	Axis 1	Axis 2
Temperature	0.240	0.310
Dissolved oxygen (DO)	0.028	0.317
pH	-0.102	-0.169
Bottom types	-0.180	0.381
Depth	0.910	0.044
Vegetation	0.172	-0.665
Distance from the sea	-0.729	0.346
% variation of species-environment relation	49.05	30.99
Eigenvalue	0.287	0.181

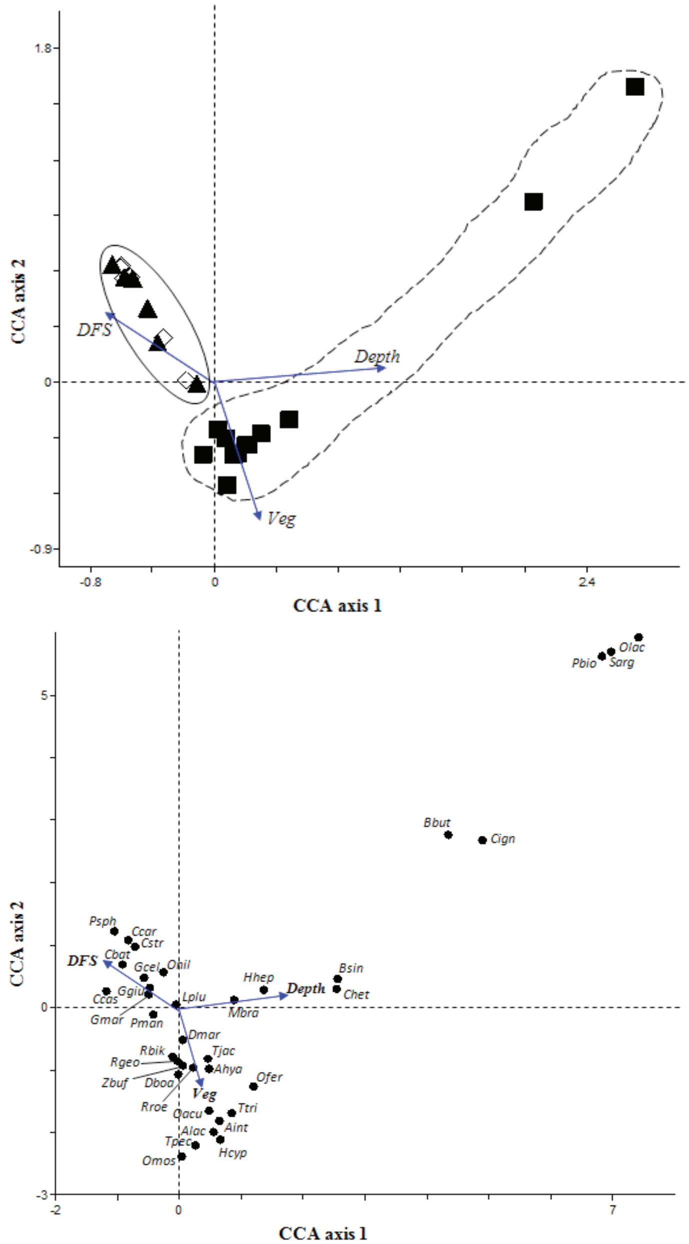

Figure 4. Canonical correspondence analysis (CCA) plot scores on the first two axes derived from the effect of most significant environmental variables (P<0.05) on the distribution of sampling sites (A), and fish assemblage (abundance data) (B). The first axis explains 49.05% and the second axis 30.99%. Species codes are given in Table 1. *DFS* = distance away from the sea, *Veg* = vegetation, ■ = Pansipit, Δ = Looc, ○ = Magapi, ● = species scores.

Anthropogenic Disturbances

Lake Taal and its river systems have been subjected to different anthropogenic pressures as a repercussion of the growing demand of communities for accessible quality life. Unregulated installation of fish pens and fish corrals in Pansipit were reported to cause over-fishing and have thwarted the migration of several commercial fish species including *C. ignobilis* and *Chanos chanos* (*Ramos 1996*; *DENR-PAWB 2005*). Similarly, intensive large-based farming (>100 fish m^{-3}) of tilapia in cages of Lake Taal was identified as a prospective culprit of the occurrence of massive fishkills (both of cultured and native species) (*Yambot 2000*; *Araullo 2001*; *Vista et al. 2006*). Soil erosion in the lake is also potentially high, with about 32% of the land classified as highly susceptible to erosion (*DENR-PAWB 2005*). Moreover, the introduction of jaguar guapote, locally called as dugong (*P. managuensis*), a cichlid from Central America was noted to have predated on and displaced native fishes (*L. plumbeus* and *G. giurus*) in the lake (*Rosana et al. 2006*).

In the present study, records of siltation brought by gravel diggings, land excavations, livestocks and domestic run-offs were pointed out as main contributors of pollution (*Balete and Agoncillo Municipal Agricultural Officers pers. comm.*). These were also observed during the course of our survey, in which some of the sampling areas in inlets and mouth of Pansipit had murky and turbid water characteristics due to effluents released to the streams. These may have direct negative effects on fish populations by perturbing the substrate and the water quality, availability of food, and spawning and nursery areas (*Vescovi et al. 2009*). Correlation analyses of fish assemblage and anthropogenically induced habitat degradation in TVPL would be valuable in assessing the trophic fate and impacts of pollutants in TVPL riverine ecosystems. Although the present study emphasizes quantitative community ecology and biodiversity of freshwater fishes, it is noteworthy to take account of the various anthropogenic-based pressures in the rivers. Such information can be used as rational bases for sustainable conservation and rehabilitation endeavors, and legal intervention programs by the Protected Area Management Board, Protected Area Superintendent of the DENR, and Local Government Units.

CONCLUSION AND RECOMMENDATION

The salient feature of TVPL river systems is their relatively diverse ichthyofauna, represented mostly by native secondary freshwater fishes. The gobioid assemblage is the most distributed and diverse group, albeit introduced fishes including cichlids and poeciliids are some of the most abundant. The diversity and distribution of freshwater fishes in the three rivers are driven by interacting environmental variables, seasonal changes, and to some extent, anthropogenic pressures. Still, uncertainties of survival of native fish populations in the Lake Taal river systems, cause for concern given the occurrence of alien invasive fish species, anthropogenic environmental degradation, and habitat loss. The findings can be used to predict the changes on fluvial fish assemblage structure as informed by parameters on environmental change and habitat loss across spatial and temporal scale. Our study also updated the record of freshwater fishes in the three streams of Lake Taal and provided baseline key dataset for inclusive limno-ecological conservation strategies of any concerned entities. Although the current scope of the study is limited to selected TPVL river systems for two seasons, this study is hoped to instigate awareness and serve as a model for further conservation studies on Philippine freshwater fish assemblages.

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