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Dietary Habits and Distribution of Some Fish Species in the Pansipit River-Lake Taal Connection, Luzon Island, Philippines

ABSTRACT

The interface between lakes and their outlet rivers is an interesting research site for fish community dynamics because it is immediately exposed to disturbances in lake ecosystems. In this paper, observations on the species composition, dietary habits and distribution of fish in the upstream area of Pansipit River - sole outlet of Lake Taal, were presented. Fish samples comprised of juvenile fish from 12 species, including four that were introduced. These non-native species were more abundant than native fish caught. Dietary analyses suggest that non-native fish have a wider dietary breadth compared to native fish and may be one reason why introduced fish populations have exceeded native fish populations in the area. Fish activity varied depending on time of day in certain sub-sites and these fishes aggregated in intermittent deep pools when water depth is uniformly low in the river during the dry season. These suggest that fish abundance in the area is associated with river water depth and other environmental factors. Overall, the study stresses the need for more in-depth research in Pansipit River given its importance as a migratory path and its potential as a refugia for the riverine fish community.

Key words: *diet analysis, echo-sounder, hydroacoustic survey, river refugia, tropical caldera lakes*

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INTRODUCTION

Rapid changes in the ecological conditions of rivers occur in its interface with lakes. When these areas are connected, certain hydrological processes are also spatially linked and influences material transport and retention between the two ecosystems (*Tetzlaff et al. 2007; Lexartza-Artza 2009*). However, it appears that research on the interactions between lakes and their outlets, especially among branching drainage river networks, has yet to garner the attention of many limnologists. Presently, there have been calls to explicitly incorporate lakes in stream ecology research, and reciprocally, streams in the study of lake ecological concepts (*Arp and Baker 2007; Jones 2010*). Changes in the ecological characteristics of these outlets may have a significant impact on river fish communities.

The dietary habits and distribution of fish assemblages are potential markers of changes in riverine ecosystems. Fish distribution can be appropriate indicators of trends in aquatic environments (*Ayoola and Kuton 2009*) as they have been utilized as predictors of environmental changes through the use of temporal and spatial fish distribution models (*Elith and Leathwick 2009*). Conversely, fish dietary patterns may reflect how potentially invasive fish species affect native fish populations either through displacement by competition or direct predation (*Fugi, Luz-Agustinho and Agustinho; Leunda et al. 2008*). The effects of the dietary habits and patchy distributions of fish have even been suggested to produce hotspots of nutrient cycling in stream ecosystems (*McIntyre et al. 2008*). There are now many established indices used in dietary analysis to describe fish foraging habits (*Hynes 1950; Hyslop 1980; Amundsen, Gabler and Staldvik 1996*). Hydroacoustics, on the other hand, provide a useful means for estimating fish distribution, and is considered as a tool for fish studies (*MacLennan and Simmonds 1992; Brandt 1996*), even in shallow aquatic environments (*Simmonds and MacLennan 2005; Boswell, Wilson and Wilson 2007*). These analyses help clarify specific fish behavior, and in turn, reveal the response of river fish communities to natural or anthropogenic disturbances.

This paper presents results of a preliminary survey using hydroacoustics, available fishing methods and dietary analysis to describe the species composition, dietary habits and diel distribution of fish in the lake-river interface of Pansipit River. The river, being the sole outlet of Lake Taal, serves various important ecosystem and human functions. However, very little research seems to have been published regarding the river's fish community dynamics, and to the potential changes of the river's ecological characteristics due to various recorded anthropogenic disturbances. It is hypothesized that fish have the tendency to cluster in deep pools during the day to protect against predation or for more efficient feeding, but have a more uniform distribution in the river when sunlight is low during the early mornings or evenings. Ultimately, this study aims to present an update on the ecology of fish assemblages in Pansipit River, of which very little is still known.

MATERIALS AND METHODS

Study Site

Pansipit River is an 8.2 km channel located in the province of Batangas, south of Luzon Island, Philippines (**Figure 1**). It is connected to the south basin of Lake Taal and drains water to Balayan Bay together with Palanas River, a short (>1 km) outlet stream that branches out from Pansipit River proximate to its sea-side end. While there are at least 37 inlet tributaries flowing into Lake Taal from the surrounding watershed, Pansipit River serves as the sole drainage outlet of the lake. The river has an average depth of 4 m and an estimated channel width of 10-15 m in most areas. It is regarded as an important freshwater resource for coastal communities. The river is most notably known as an important pathway for commercially utilized migratory fish species to the lake (*Villadolid 1937; Mercene and Alzona 1990*), but in the past two decades, increased pollution and the rampant installation of illegal fishing structures had been reported to disrupt annual fish migration patterns (*Santos 1993*). This has prompted the Philippine Government to enact laws to preserve the river and mandate the permanent removal of fishing structures that were potential migration blockages (*Ramos 1996*). The river is now characterized as a protected area under the Taal Volcano Protected Landscape.

Hydroacoustic survey

Each survey trip is a 1.2 km stretch from the confluence of the river the Lake Taal side. The total fish echoes and the deepest river depth for every 25 m were tallied and recorded, respectively. An echo-sounder unit (Lowrance LCX-27c) was used to record echograms during 6:00 h, 12:00 h, and 18:00 h of each survey trip. The boat avoidance, especially in the shallower areas, was considered since it may produce a bias on fish counts towards deeper areas. This is a problem inherent to researching fish populations in shallow river ecology. To regulate this, the researchers did not use the boat engine as it would have immediately disrupted fish behaviour. Rather, the boat was allowed to drift with the river current aided by wooden oars. The resulting boat speed was maintained to an average of 3 km h^{-1}, while the echo-sounder transducer was oriented for vertical beaming using a frequency of 200 kHz. Fish counts were monitored from April to September 2012, excluding July because of inclement weather. Simultaneously, the dissolved oxygen (DO mg L^{-1}) levels, surface water temperature (^{o}C), and flow rate (m s^{-1}) were recorded using an Xplorer GLX multi-sensor unit (PASCO Scientific), in three different points of the study site: at the lake-river interface (0 km), and at the 0.6

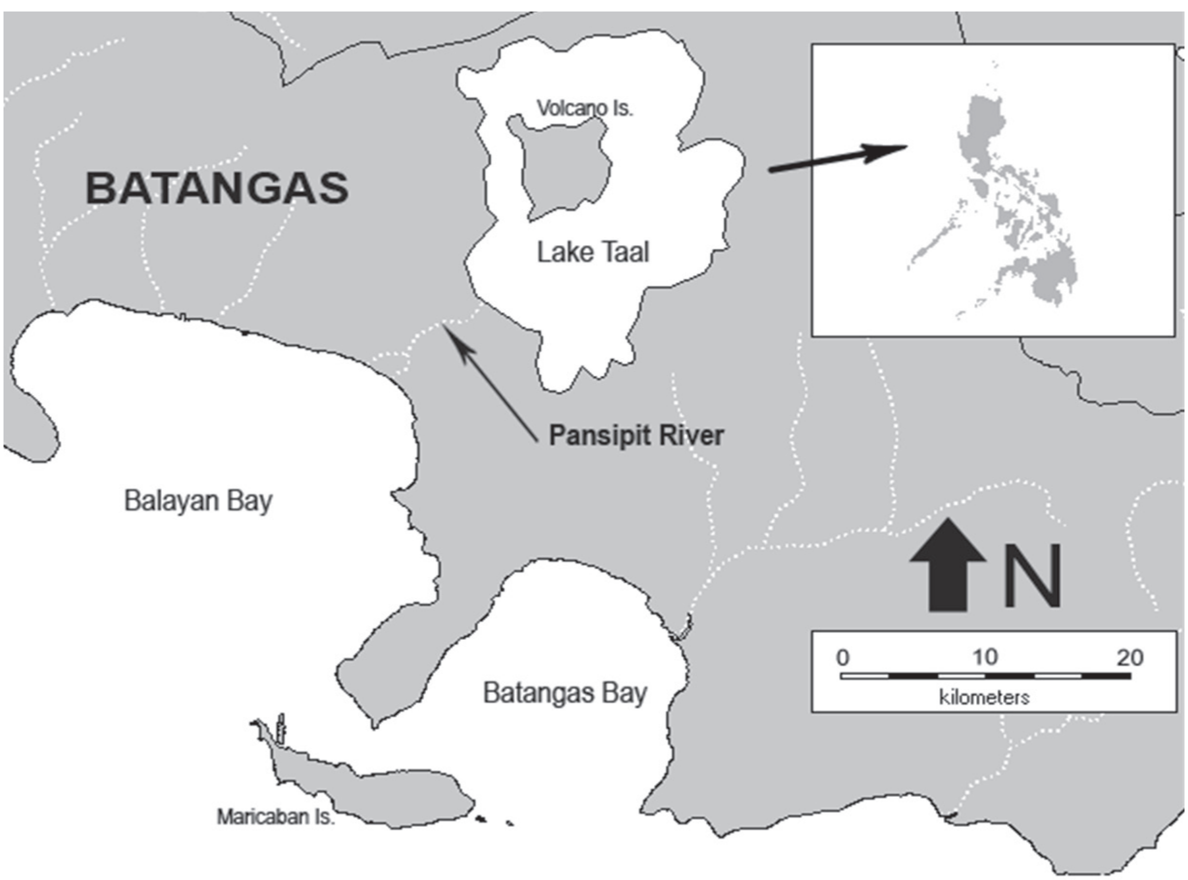

Figure 1. Map of Lake Taal and Pansipit River located in Batangas Province of Luzon Island, Philippines. The Pansipit River drains to Balayan Bay and is the only outlet of Lake Taal.

km and 1.2 km point of the river going towards Balayan Bay. Individual fish counts were identified from fish echoes. This was later validated by analyzing the echograms under varying sensitivity levels to further differentiate fish echoes from macrophyte assemblages, bubble entrails and the river bottom using the Lowrance Sonar Viewer software (version 2.1.2).

Fish sampling and Diet analysis

The fish were sampled with the aid of local fishermen using fishing rods, hand nets and seine nets for 3 h from 06:00 h to 09:00 h every sampling trip. Active day sampling was the only option since temporary structures and passive sampling for fishing purposes had been banned in the river by the Philippine Government to preserve the passageway of migratory fish into the lake (*Ramos 1996*). Collected fish samples were identified, counted, and preserved in 10% formalin. After which, the gut of each specimen was extracted and opened, with the gut contents flushed and placed in individual containers. The gut contents were then fixed in 10% formalin for 7 d, and subsequently transferred in 70% ethanol for long-term storage and diet analysis.

The %F index or Percent Frequency of Occurrence (*Hynes 1950; Hyslop 1980; Bowen 1996*) was used to describe fish diet based on the recovered gut contents. The %F is equivalent to the number of stomachs per fish species where a specific food item was found, divided by the total number of fish stomachs examined per fish species and expressed as a percentage.

Statistical Analyses

The G-test or goodness-of-fit adapted from (*McDonald 2009*) was used to determine if fish counts varied depending on time of day. The 06:00 h, 12:00 h and 18:00 h fish counts that were tallied for every 25 m of the study site were subjected to individual G-tests to check the null hypothesis that observed counts will not differ from an expected 1:1:1 ratio. This will determine if counts change based on time of the day for individual sub-sites. After which, these individual G-values were totalled, as well as the values for the degrees of freedom (df) and then referenced to a Chi^2 distribution. This was to assess if the potential differences in fish count for each sub-site was the overall situation for the entire study area. The result of this "total G-value" is further expounded by testing for a "pooled G-value" obtained by subjecting the pooled values of 06:00 h, 12:00 h and 18:00 h fish counts to a single G-test with a df equivalent to the total class types minus 1. The significance of the pooled G-value will reveal whether the pooled data set deviates from the 1:1:1 expected ratio. Lastly, a "heterogeneity G-value" and "heterogeneity df" were computed by subtracting the pooled G-value and its df from the total G-value and total df. A significant heterogeneity G-value will determine if pooled data should not be used, and will rather hint to a focused comparison on the results of the individual G-tests.

The possible association of 06:00 h, 12:00 h and 18:00 h fish counts with river water depth was also tested. First, the Shapiro-Wilk test was used to determine the normality of each univariate dataset. However, it was determined that the river water depth data and fish count data did not have a normal distribution (all $W \sim 0.97$, all p-values < 0.01) even after data transformation. Because of this, the non-parametric Spearman rank correlation was used to determine potential associations between river water depth and the 06:00 h, 12:00 h and 18:00 h fish counts. A significance of $\alpha=0.05$ was used for all statistical tests. A spreadsheet program adopted from *McDonald (2009*) was used to perform all G-tests, while PAST 3.01 was used to perform the normality and correlation tests (November 2013 version (*Hammer, Harper and Ryan 2001*).

RESULTS

Overall species composition

There were 118 specimens retrieved in the duration of the study, all of which were juvenile fish. From these, 12 fish species were identified, with 8 species native to the Philippines, namely: *Ambassis interrupta*, *Caranx ignobilis*, *Chanos chanos*, *Glossogobius giuris*, *Hyporhampus affinis*, *Kuhlia marginata*, *Leiopotherapon plumbeus* and *Mugil cephalus*. Non-indigenous fish species observed were *Channa striata*, *Oreochromis niloticus*, *Parachromis managuensis*, and *Trichogaster pectoralis*. Although there were more species of native fish present, introduced species were more abundant in the samples caught. From all the specimens retrieved, 56.8% were *O. niloticus* and 25.4% were *C. striata*.

Dietary patterns

The sampled fish fed on various food items such as zooplankton (cladocera, copepoda), zoobenthos (amphipod, chironomid larvae, and shrimp), fish eggs and fry, epiphytes and phytoplankton (**Table 1**). Chironomid larvae were the most common prey item, which was included in the diet of six out of the 12 fish species retrieved. This was followed by zooplankton and phytoplankton, which was consumed by four and five out of the 12 fish species, respectively. Although fish fed on various food items, there seems to be a noticeable difference between the dietary habits of native fish species to introduced species.

Most introduced fish species appear to have a wider dietary breadth than native fish. Native species, such as *A. interrupta*, *H. affinis* and *K. marginata* have been observed to feed mainly on cladocera, chironomid larvae, crab and/or

Table 1. Percent frequency of occurrence (%F) of the food items for the fish species from the Pansipit River starting from the river-lake interface up to 1.2 km downstream going towards Balayan Bay, Philippines.

Fish Species	Copepoda	Cladocera	Chironomid larvae	Amphipoda	Shrimp	Crab	Larval fish	Fish egg	Algae	Epiphyte
Ambassis interrupta	-	100	100	-	-	-	-	-	-	-
Chanos chanos	-	-	-	-	-	-	-	-	-	-
Caranx ignobilis	-	-	-	-	-	-	-	-	-	-
*Channa striata**	4.3	30.4	52.2	26.1	-	-	-	4.3	8.7	8.7
Glossogobius giuris	20	-	20	-	20	-	-	20	20	60
Hyporhamphus affinis	-	-	100	-	-	-	-	-	-	-
Kuhlia marginata	-	100	-	-	-	100	-	-	100	-
Leiopotherapon plumbeus	-	-	-	-	-	-	-	-	-	-
Mugil cephalus	-	-	-	-	-	-	-	-	-	-
*Oreochromis niloticus**	31.8	9.1	4.5	1.5	-	4.5	4.5	40.9	31.8	18.2
*Parachromis managuensis**	100	-	-	-	-	-	-	-	100	-
*Trichogaster pectoralis**	-	-	25	-	-	-	-	-	-	75

* Non-indigenous fish species

phytoplankton (all %F = 100). On the contrary, introduced fish, such as *C. striata* and *O. niloticus*, variably feed on more food item types that include different zooplankton, zoobenthos, fish, phytoplankton and macrophytes. Notably, the majority of the diet of *C. striata* consisted of zooplankton (cladocera %F = 30.4) and zoobenthos (chironomid larvae %F = 52.2, amphipods %F = 26.1), while that of *O. niloticus* was of copepods (%F = 31.8), fish eggs (%F = 40.9) and phytoplankton (%F = 31.8).

Fish temporal and spatial distribution

Fish counts varied depending on the time of day when sub-sites were individually assessed, with different implications for every sampling month (**Figure 2**). Overall, detected fish counts ranged from 1 to 39 fish echoes per 25 m sub-site. For April, 15 of 48 sub-sites had fish counts that varied significantly depending on time of day (heterogeneity G=170.87, df=47, p<0.001), but with no overall observable trend (i.e. some of the 15 sub-sites had more fish counts in evenings, while others had more fish counts at noon time). For May, 23 sub-sites had significant differences in fish counts with very few fish echoes observed during mornings (heterogeneity G=205.16, df=94, p<0.001). A trend is observed for June (heterogeneity G=277.21, df=94, p<0.001) and August (heterogeneity G=287.59, df=94, p<0.001), wherein 22 and 24 of the 48 sub-sites, had a reduction in fish counts at noon time, and a slight increase in fish activity either during mornings or evenings. A completely different situation was observed during September, wherein only 8 of 48 sub-sites had varied fish counts when each sub-site is individually considered (heterogeneity G=114.11, p=0.077). However, when the fish counts were pooled, there is an overall invariant higher fish activity during the evenings as compared to mornings and noon time in the whole study area (pooled G=62.95, df=2, p<0.001). These suggest how fish activity varies during the day but it seems that regardless of time, fish counts seem to be well associated with changes in river water depth.

Fish counts were more abundant in months or in areas of the river that were deeper (**Figure 2**). During summer months like April and May when water depth in the study site was less than 0.7 m in most areas, it was observed that fish counts were higher in specific sub-sites downstream that had ~2 m depth. Around June, it was detected an overall increase in morning, noon, and evening fish counts with a similar trend from that of the summer months still observed. August was the peak time where river depth was deepest among the sampling months which also coincided with the highest fish counts recorded. Fish counts then decreased during September, when river depth in the study site ranged intermittently from ~1.5 m to ~3 m. These observations were validated by statistical analysis, revealing that pooled monthly data on fish counts during mornings (Spearman rs=0.39, p<0.001), noon time (Spearman rs=0.37, p<0.001), and evenings (Spearman rs=0.43, p<0.001) as all significantly positively correlated with water depth. However, this trend was less pronounced with fish counts near the river-lake interface as compared to those recorded downstream of the study area.

It seems that other environmental factors may have contributed to the spatial and temporal variability of the observed fish counts (**Figure 3**). Dissolved Oxygen (DO) levels in the lake–river interface at the 0.6 km point and 1.2 km point of the study area did not significantly vary across sub-sites. But rather varied across sampling months. During April when the lowest fish counts were recorded, the DO level was only 1.5 mg L^{-1} as compared to other sampling months that had DO levels of 5.5 mg L^{-1}. The highest temperatures were recorded on April and May (32 ^oC) while the lowest (28 ^oC) was recorded on August. In contrast, river flow rate varied across months and also in the different sub-sites. Flow rate was almost always high in the lake-river interface as compared to the 0.6 km point and 1.2 km point of the study

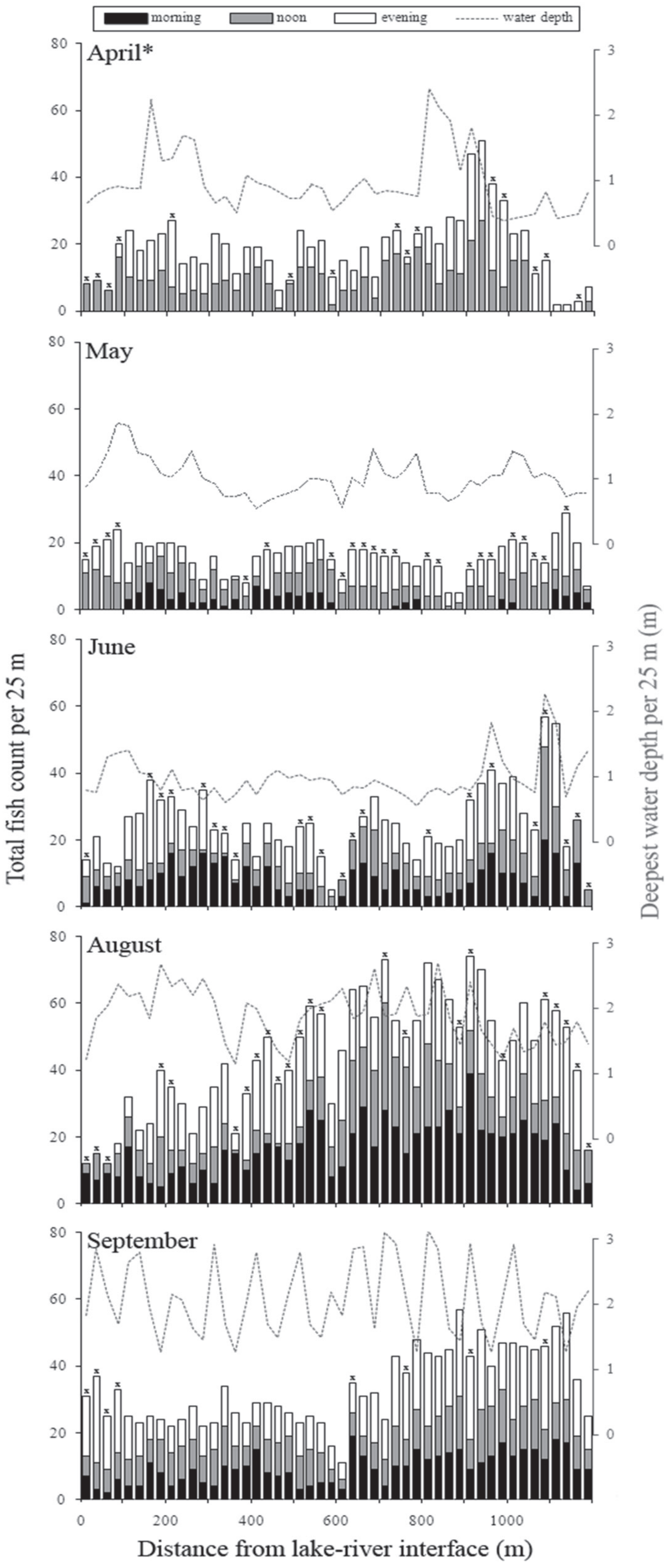

Figure 2. Total fish counts and deepest water depth values recorded every 25 m from the river-lake interface (0 km) up to 1.2 km of the river going towards Balayan Bay. Fish counts were recorded during 6:00 h, 12:00 h, and 18:00 h of each survey trip. X represents a significant individual G-test with p-value < 0.05. * represents no available data on morning fish counts during April.

area, and was fastest during April (~1.8 m s^{-1}). The slowest flow rate values were observed on August (~0.3 m s^{-1}), coinciding with the highest fish counts observed throughout the sub-sites.

DISCUSSION

Certain areas of Pansipit River may serve as refugia for the riverine fish community, especially during the dry season when the river is shallow. Fish assemblages thrived in intermittent deep pools throughout the study site, and were more active during low-light conditions. These areas were not as evident during August and September when most of the sampling sites were more than 2 m deep. This may be due to high precipitation in Lake Taal, noted by a nearby Philippine government weather station (PAGASA Weather Station), resulting to an average of 603.5 mm and 280.1 mm of rainfall during August and September, respectively. On the contrary, the study's echo-sounder detected that fish were more abundant in these refugia (approx. 1.5-2.5 m in depth) during April, May and June when the river was less than 1 m in most areas. This was concurrent with low precipitation in Lake Taal, with only an average of 119.5 and 210.7 mm recorded rainfall during May and June, respectively, and little to no rainfall (less than 0.1 mm) recorded during April.

Indeed, environmental conditions in these aquatic refugia are mainly driven by hydrological events (*Santos 1993*; *Webb, Thoms and Reid 2012*), with water depth as an important factor in determining the spatial distribution of fish in many limnological studies (*Brosse and Lek 2002*; *Matthews, Gido and Gelwick 2004*; *Prchalova et al. 2008*). High DO levels, coupled with low temperature and low flow rate conditions, favor high fish abundance in the study site. It may be possible that refugia in the river offer thermal buffer areas for the development of larval and juvenile fish (*Tate, Lancaster and Lile 2007*), and may even provide refuge for migrating fish by helping reduce disease development and increase recovery from physiological stress due to exposure to high temperatures (*Mathes et al. 2010*). Notably, commercially important migratory fish species such as *Caranx ignobilis*, commonly known as the "giant trevally" have been observed to utilize Pansipit River to migrate from Balayan Bay into Lake Taal (*Herre 1927*; *Magistrado and Mercene 1994*). It would be interesting to determine if refugia presently play a vital role in the migration efforts of *C. ignobilis* populations through Pansipit River, looking into the possible effects of the above-mentioned environmental conditions. Many present researches on fisheries management and conservation focus on modelling fish distribution (*Buisson, Blanc and Grenouillet 2007*) and predicting fish stock-specific responses (*Martins et al. 2011*) to extreme temperature changes brought about by global climate warming, and also the implications of the hydrologic alterations of rivers for human use (*Naiman et al*

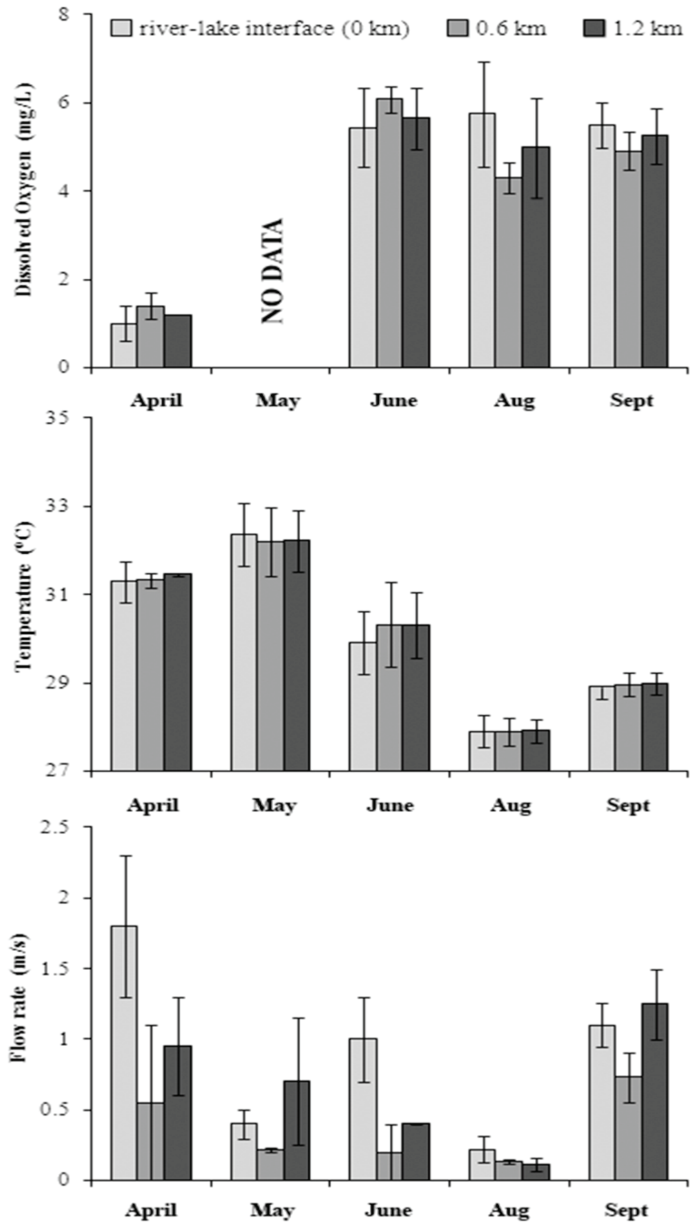

Figure 3. Mean and standard error values of dissolved oxygen, water temperature and flow rate data from 3 different sub-sites (0, 0.6 and 1.2 km) of the study area. Values were computed from the abiotic data taken every morning, noon and evening per sampling effort.

2008; *Arthington and Balcombe 2011*). Aquatic refugia may contribute to the spawning continuity and migration success of native fish in Pansipit River, of which the present status and dynamics is still unclear.

The upstream area of Pansipit River is potentially utilized as a fish recruitment ground. All of the fish specimens retrieved were juveniles, but this is subject to limitations in fishing gear and sampling restrictions. Nevertheless, these results help confirm previous local reports that the river has been utilized as a spawning ground for adults and nursery ground for juveniles (*Herre 1927*; *Mercene and Alzona 1990*; *Villadolid 1931*) by both migrating and riverine fish species. However, the means as to how these larval fish survive and mature when subjected to the intra- and inter-annual changes in environmental conditions in Pansipit River is still poorly understood. It is suspect that as fish larva mature, it may move to deeper habitats in the river such as refugia where potential food resources are abundant and also to avoid predation risks. This is similar to other studies wherein vertical stratification is observed among different fish size classes, with smaller fish preferring to stay near the surface and utilize current speed for transport and dispersion (*Michalsen et al. 1996*) while larger fish prefer to stay in deeper zones, especially during summer seasons, to avoid predation (*Axenrot et al. 2004*).

The echo-sounder results may not reflect a definite measure of fish size, due to the limitations set by using a non-calibrated model, which cannot discriminate fishes according to size. Nevertheless, it suggests that fish seem to thrive more in deep pool areas when river depth is low and are rather uniform in distribution when water level is uniformly high all throughout the sampling site. This clustering may also be driven by current flow rate and other environmental factors (*Ayoola and Kuton 2009*).

There is a growing body of evidence stating that critical aspects of the life history strategies of certain fish species, including spawning and recruitment, are linked to a river's natural flow regime (*King, Tonkin and Mahoney 2008*). It has been observed that the abundance of certain fish species, due to their life history requirements, is affected by temperature (*Roberts, Duivenvoorden and Stuart 2008*) and the interactions of multiple scales of temporal river flow variability (*Stewart-Koster et al. 2011*). One reason is that the timing of river flow change produces substantial sediment motion, such as erosion or deposition, which may either be detrimental or beneficial to the spawning and recruitment of certain fish species (*Unfer, Hauer and Lautsch 2011*). This scenario is exploited by some introduced fish species, immediately moving out of refugia and utilizing a more diverse array of riverine micro-habitats for spawning or post-recruitment, and eventually outnumbering local fish populations (*Rayner, Jenkins and Kingsford 2009*). It is therefore important to discern the dynamics of the interactions between the introduced fish species and native fish population of Pansipit River.

The dietary analyses may hint clues as to how introduced fish have colonized Pansipit River and exceeded native fish populations. Although the majority of the samples are represented by introduced species, it is still interesting to point out the observed difference between the dietary breadth of native and non-native fish species in the study site since no research on this topic has yet been published for Pansipit River fish to date. The study has shown that the juveniles of introduced fish species, such as *Oreochromis niloticus* and *Channa striata*, have a wider dietary breadth than the juveniles of retrieved native fish species in the river. This is aggravated by the fact that a significant portion of juvenile *O. niloticus* diet comprise of fish eggs (%F=40.9) and smaller larval fish (%F=4.5). It suggests that not only do introduced fish juveniles feed on a wider range of prey items which can lead to faster growth and spawning, but they may also directly prey on developing native fish. This is an emerging issue that must be considered and studied further. Indeed, some studies have noted how direct predation and overlapping diet by introduced fish has had a negative consequence to native fish populations (*Sampson, Chick and Pegg 2009*). However, this has proven to be difficult to characterize because fish undergo various ontogenic diet shifts, resulting to different degrees of intra- and interspecific competition (*Arismendi et al. 2012*).

A study by *Pintor and Sih* (*2011*) noted that prey biomass, rather than prey diversity, may be a significant driver for invasion success in small spatial scales. While a meta-analysis, summarized from 49 biological invasion studies, revealed that climate/habitat match was the only trait that was consistently correlated with invasive behaviour (characterized as exotic range size) across various plant and animal taxa (*Hayes and Barry 2008*). At one time, at least 80 fish species have been recorded in Pansipit River (*Villadolid 1937*). However, a study ~70 years later had noted a reduced number in the river's fish species composition, with only a total of 33 fish species retrieved (*Pagulayan and Magbanua 1999*). This was congruent with recorded ecosystem disturbances in Lake Taal such as fish kills, decline in water quality, and introduction of alien species linked with the under-regulated proliferation of aquaculture (*Papa and Mamaril Sr. 2011*). Our study, although only limited to 1.2 of the 8.2 km stretch of Pansipit River, only detected 12 fish species, wherein 4 were introduced. This apparent trend in declining species number is a matter of concern, and only reinforces the need to re-evaluate the current status of the Pansipit River fish community.

CONCLUSIONS AND RECOMMENDATIONS

The research serves as an update on what little is known about the fish community dynamics of Pansipit River. This study documented a temporal snapshot of the distribution of fish in the river and determined that fish have a tendency to utilize deep pools as refugia when river water depth is low during dry season. Also, it was observed that introduced fish feed on a wider range of prey items and also feed on fish eggs and larval fish as compared to native fish in the river. This is one of the reasons to the successful colonization of introduced fish species in Pansipit River, which should be an immediate concern for conservation policy makers. It is unfortunate to note that the study is only among a handful of researches about Pansipit River's limno-ecology. Future studies should further look into the current environmental status of Pansipit River, in line with the many potential threats to its native biota, its importance as a migratory path and its presently revealed potential as a recruitment ground and refugia for the river fish community.

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