Macroinvertebrate Composition, Diversity and Richness in Relation to the Water Quality Status of Mananga River, Cebu, Philippines

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The water quality of Mananga River was assessed between February and December 2006 using selected physicochemical factors in combination with macroinvertebrate composition and diversity indices. Three sampling stations, each 100 m long, were established. Alkalinity, total phosphates and nitrate-nitrogen were similar in all sampling stations. The significant variation in stream depth, width and stream bed profile resulted in diminishing velocity but increasing discharge downstream. These physical characteristics led to increased total suspended solids, water temperature, and biological oxygen demand, but decreased pH and dissolved oxygen levels downstream. The physicochemical factors influenced the composition and diversity of macroinvertebrates in Mananga River. A total of 37 families representing 15 orders were recorded. Aquatic insects (Class Hexapoda) made up 58.6% of total abundance followed by the gastropods (Class Gastropoda) at 39.9%. The order Ephemeroptera of Hexapoda had the highest abundance (47.6% of total) and highest richness (6 families). Family Thiaridae was the most persistent and the most abundant macroinvertebrate taxa followed by Caenidae. Almost all taxa were represented in the upper stations, except for Neritidae, Grapsidae and Nereididae, which were limited to the downstream station. Macroinvertebrate richness and diversity were significantly higher in the upper stations, but there was an apparent lack of seasonal variation. Signs of increasing water quality deterioration were evident in the results of the physicochemical analyses, and validated by the diversity index where the upper stations came out as moderately polluted, and the downstream station as moderately to highly polluted.

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INTRODUCTION

The Mananga River is one of the biggest, more accessible rivers in Metropolitan Cebu, Philippines. To meet the water demands of a fast growing metropolis, the river was tapped by the Metropolitan Cebu Water District (MCWD), the main water utility firm of Metro Cebu, to increase the recharge rate of its infiltration facility in Jaclupan Valley, Talisay City. Studies are therefore needed to assess the water quality status of Mananga River and identify the factors that have contributed to such a state.

A river's unique form and function are the results of the processes and interactions occurring along its longitudinal gradient (Vannote et al. 1980), as well as of those occurring in the land around it (Hynes 1975, Leopold et al. 1964). The physical gradient from source to mouth, modify the chemical system, an interaction that in turn impinges on the biological system that is constituted by the organisms and the interrelations among themselves and with their environment.

Biological communities can serve as integrators of the dynamic physicochemical relations in a river. Their ability to do so can be determined through a study of community structure and functional rates. Aquatic macroinvertebrates have been found sensitive to changes in their environment, a feature that has been proven useful in the quest to find indicators of environmental conditions. The community characteristics of macroinvertebrates, such as diversity and richness, are often used as indicators of the degree of pollution of bodies of water to supplement and deepen the meanings of physicochemical information (Abel 1989, Arimoro et al. 2007, Barton 1996, Hellawell 1978, Plafkin et al. 1989, Silva et al. 2009, Wright et al. 1984). This ability of macroinvertebrates, although well documented in temperate streams, has not yet been elucidated with examples in the Philippines.

This study aims to assess the water quality status of Mananga River and how this influences macroinvertebrate diversity and richness. Results of the study could serve as an important reference for evaluating future water quality changes, as well as providing insights on how to protect the river and its biodiversity.

MATERIALS AND METHODS

The study site

The Mananga River starts in the middle of Cebu Island and goes to the south as it traverses the high mountain range at the eastern part of the province. It drains into the southwestern part of the watersheds of Mananga, Kotkot, and Lusaran through a narrow gorge in Jaclupan, and finally traverses through Talisay City.

Three sampling stations, each 100 m long, were established to determine the longitudinal profile of Mananga River (Fig. 1).

Station 1 (S1) was upstream in Bonbon, Cebu City (10º22'24.2"N, 123º49'53.3"E), which is about 38 km from the city proper. It is an area of the watershed where the headwaters converge. Activities like washing and bathing were common at this site due to the presence of a spring. Riparian vegetation was generally of the grass and shrub types with few coconut trees. Few macrophytes were seen in the river.

Station 2 (S2), located midstream at Camp IV, Talisay City (10º19'06.1"N, 123º49'06.3"E) where there were agricultural and residential activities, is about 6.3 km downstream of S1. Sand quarrying was evident downstream of the site. Riparian vegetation was also of the grass and shrub types with few trees. Few macrophytes were observed growing in the river.

Station 3 (S3) was downstream, near a closed dumpsite in Dumlog, Talisay City (10º14'38.2"N, 123º50'05.5"E), a site impacted by industrial, agricultural, as well as domestic activities. It is about 8.4 km from S2. It had poor riparian vegetation cover of grass and low-shrub types. No macrophytes were observed in the river.

Physicochemical measurements

Water samples were collected six times at each station between 0700 and 1100 hrs in the year 2006, specifically on February 18, April 5, May 3, May 16, September 23 and December 2. On-site measurements were done in replicates for dissolved oxygen (DO), pH, temperature, flow velocity, stream flow or discharge, stream width, and depth, using protocols adopted from the United States Environmental Protection Agency (USEPA) Volunteer Stream Monitoring Methods Manual (1997).

To measure flow velocity and stream flow or discharge, a piece of local orange ('dalanghita') was used as a float. The stream stretch of 7 meters chosen for the measurement of stream flow or discharge was straight (no bends), at least 15 cm deep, and did not contain an area of slow water. The length was measured. The upper and lower ends were marked by running a transect line across the stream perpendicular to the shore. The nylon transect was anchored with wooden stakes to ensure that the line was taut and near the water surface. The upstream transect was designated as Transect 1 while the downstream transect as Transect 2.

Calculating the flow involved an equation showing the relationship of several variables including stream cross-sectional area, stream length, and water velocity.

$$FLOW = alc / t$$

Where:

a	= average cross-sectional area of stream (stream width x average water depth)
l	= length of reach of stream measured (7 meters is suggested)
c	= a coefficient or correction factor (0.8 for rocky-bottom streams)
t	= time, in seconds, for the float ('dalanghita') to travel the length, l

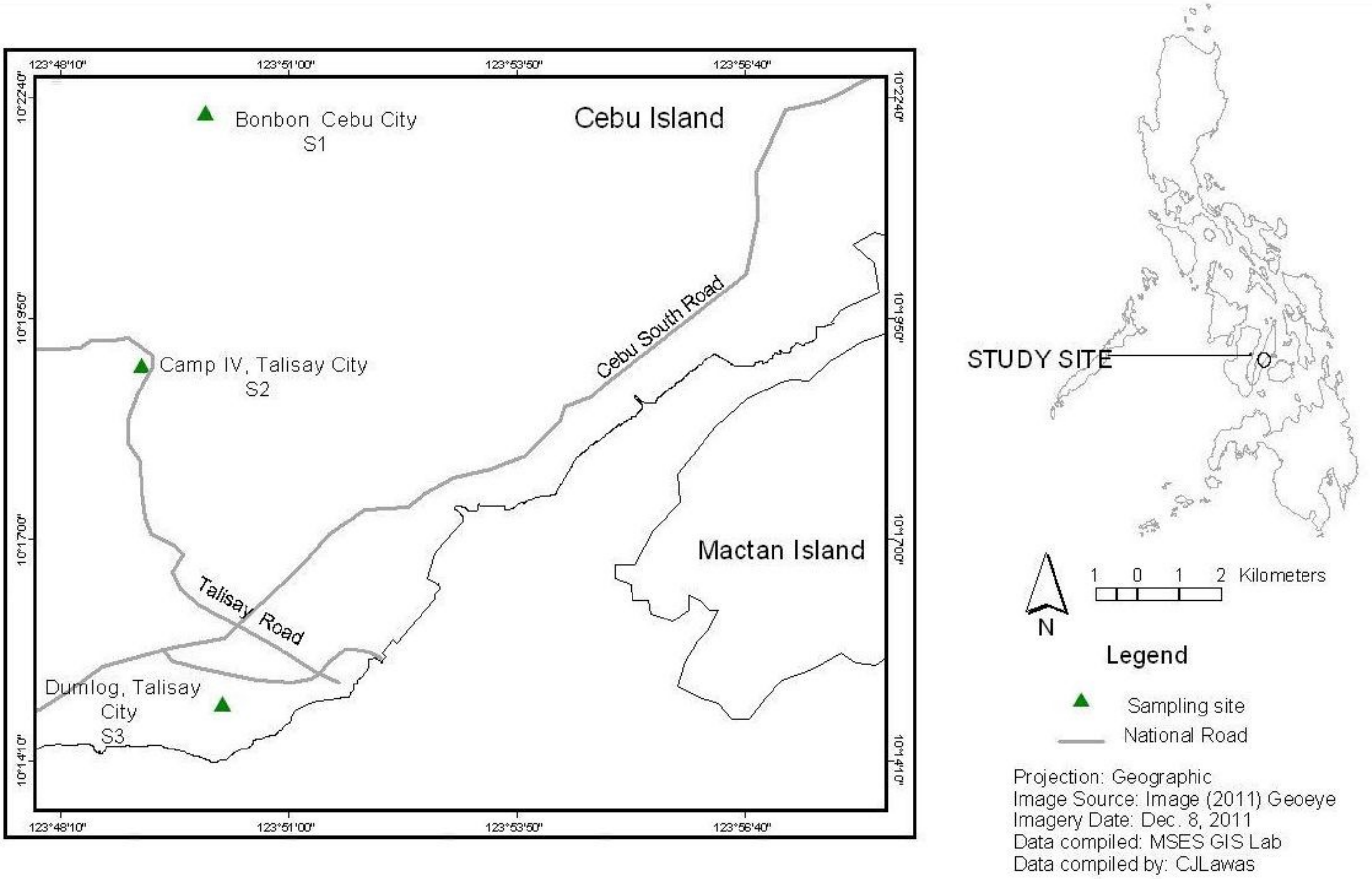

Figure 1. The study site and the sampling stations.

Substrate composition in each station was determined using the 'pebble count' by Harrelson et al. (1994) and classifying them according to the Wentworth Scale (Allan 1995). For the analyses of alkalinity, nitrate-nitrogen (NO3-N), total phosphates, total suspended solids (TSS), and biological oxygen demand (BOD5), water samples were brought to A Kaschel Laboratory Company (Technolab), which used methods adapted from APHA (1998).

Macroinvertebrate sampling

Using a D-frame net (500 µm mesh), macroinvertebrates were collected six times between February to December 2006 at productive spots (i.e. riffles and runs) in each station, at the same period the physicochemical measurements were done. To dislodge the macroinvertebrates, a 3-min kick sample was done where a designated "kicker" thoroughly stirred up with his/her feet the first few inches of stream sediment in the 2-feet by 2-feet sampling area for 3 minutes, starting at the upstream edge of the sampling area and working downstream moving towards the D-frame net. All the dislodged organisms were carried by the water into the net. Then the net was removed from the stream with a forward scooping motion to prevent any of the organisms it contained to wash away; after which the contents of the net were poured into a white basin with water. All debris and organisms were handpicked from the net. Any non-macroinvertebrate (i.e., fish, amphibians, or reptiles) caught were immediately returned to the stream. The above procedures were then repeated for the collection of the second and third samples within the same station.

Following the protocols from the USEPA Volunteer Stream Monitoring Methods Manual (1997), all three samples collected in a station were combined to obtain one large sample in a method called compositing. The samples were then preserved in 70% ethyl alcohol. In the laboratory, the macroinvertebrates were carefully separated from the substrate (if present) with the aid of a forceps. This study was limited to the identification of the aquatic macroinvertebrates to the family level for consistency among samples, as this was one of the considerations in the protocols adopted from the USEPA (1997) with regards to the taxonomic identification of the organisms.

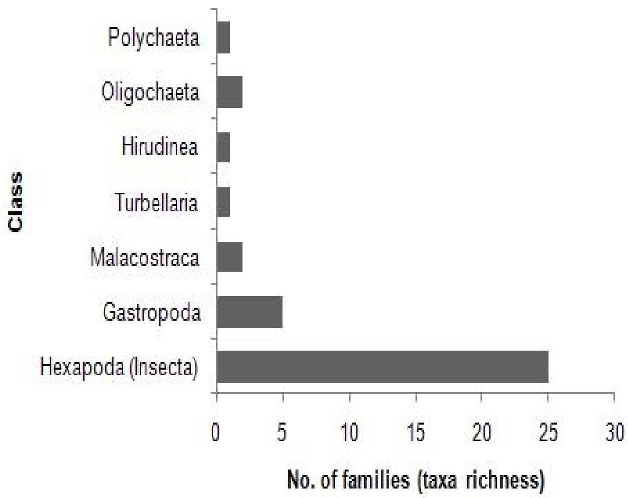

Figure 2. Number of macroinvertebrate families (taxa richness) per class, Mananga River, February to December 2006.

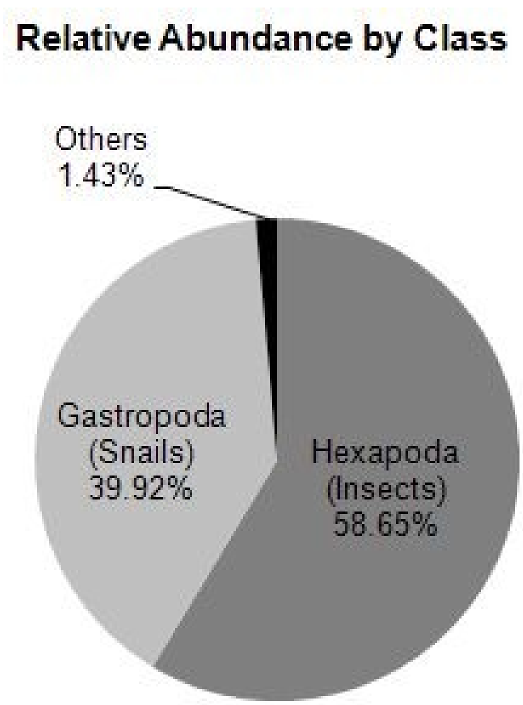

Figure 3. Relative abundance of macroinvertebrates per class, Mananga River, February to December 2006.

Data analyses

Diversity was computed using the Shannon-Wiener Index or H' (Mason 1996). Number of taxa (taxa richness or Taxa S) was measured by counting the number of macroinvertebrate families found in the samples (USEPA 1997). For the statistical analysis, the data were subjected to the Statistical Package for Social Sciences (SPSS) Version 10 software licensed to the University of the Philippines Cebu. The macroinvertebrate attributes and the physicochemical variables were compared using the one-way Analysis of Variance (ANOVA). Pearson correlation was used to determine the magnitude of the significance and nature of the relationship between variables.

RESULTS

Physicochemical component

Table 1 shows that all factors, except for alkalinity, total phosphates, and nitrate-nitrogen (NO3-N) varied significantly ($p<0.05$) with location. There was an increase in total suspended solids (TSS), water temperature, stream width, water depth, and biological oxygen demand (BOD5), but decreased flow velocity, pH, and dissolved oxygen (DO) levels downstream.

At 37% to 54%, gravel and pebble dominated the river bed substrate of the sampled sections of Mananga River. Cobbles and boulders were rarely encountered and did not exceed 11% in any station. The finer particles of sand took up about 15% of the substrate in S1, 2% in S2, and none in S3.

Macroinvertebrate composition, abundance and distribution

A total of 37 families under 15 orders representing 7 classes, and comprising 13574 individuals were collected from the three sampling stations. Aquatic insects belonging to 25 families (Fig. 2) made up 58.6% of total abundance (Fig. 3). This was followed by the gastropods, with 5 families (Fig. 2), making up 39.9% of all individuals collected (Fig. 3). The rest of the organisms belonged to the orders Decapoda and Tubificida (2 families each), Arhynchobdellida, Errantida, and Seriata (1 family each). The major macroinvertebrate orders in terms of abundance were Ephemeroptera, Mesogastropoda and Basommatophora. The total number of taxa present in Stations 1, 2 and 3 were 30, 22 and 9, respectively. Meanwhile, the total individuals collected were 5949, 5672 and 1953 (Table 2).

The Ephemeropterans was composed of six families (Fig. 4) and a total of 6457 individuals, or 47.6% of total abundance (Fig. 5). Ephemeroptera was represented by families Ephemerellidae, Leptophlebiidae, Baetidae, Heptageniidae, Tricorythidae and Caenidae, the latter of which was the most preponderant and most abundant in the group (21% of total abundance).

Trichoptera was represented by five families (Fig. 4). Hydropsychidae and Hydroptilidae, encountered in S1 and S2, were the most numerous of the group. Hydroptilidae was significantly abundant in S1 ($F=4.47$, $p<0.05$). Philopotamidae and Polycentropodidae, with only one organism each, were restricted only to S2.

Dipteran larvae with five representative families (Fig. 4) were mostly restricted to the upstream station S1. Chironomidae, the most numerous of the group, was the only Dipteran observed in all the sampling stations but was significantly abundant in S1 ($F=6.61$, $p<0.05$). Tipulidae, Dolichopodidae, Culicidae had only one individual each, while six individuals were collected for Stratiomyidae.

The beetles (Coleoptera) were represented by three families (Fig. 4). Psephenidae with ten individuals collected, was restricted only to S1. Hydrophilidae and Elmidae were found in S1 and S2 but only Elmidae, with 223 individuals collected, was significantly abundant ($F=6.87$, $p<0.05$).

The few Odonatan nymphs were represented by three families (Fig. 4). Cordulegastridae with seven individuals and Coenagrionidae with one individual, were found only in S1. Libellulidae was the most numerous with a total of 35 individuals collected in S1 and S2 but was significantly abundant in S1 ($F=7.59$, $p<0.05$).

The rare Hemipterans, represented by two families (Fig. 4), were restricted to S1. There were three individuals recorded for Gerridae and only one individual for Veliidae.

The Lepidopterans were represented by one family (Fig. 4), Pyralidae. Although this group was encountered in S1 and S2, it was more numerous in S1 with 170 individuals.

Among the non-insect groups, the gastropods ranked first in abundance. The Basommatophora was represented by three families (Fig. 4), Physidae, Lymnaeidae and Planorbidae. Physidae was present in all stations but its abundance was not significantly different among stations ($p<0.05$). The abundance of Lymnaeidae and Planorbidae, however, were significantly higher in S1 ($F=5.833$, $p<0.05$; $F=8.10$, $p<0.05$ respectively) than in any other station.

The most abundant of the macroinvertebrate families was the mesogastropod family Thiaridae with a total of 3045 individuals collected in all stations, or 22.4% of all individuals collected (Table 2, Fig. 5). However, its abundance was not significantly different among stations ($p<0.05$). Neritidae of Archaeogastropodida was limited only to S3, and was significantly abundant in this station ($F=4.99$, $p<0.05$).

The elusive decapods were represented by Palaemonidae (6 individuals) and Grapsidae (4 individuals) with the former found in S2 and S3, while the latter was restricted only to S3. On the other hand, the lone Seriatan flatworm Planariidae had 13 individuals collected only from S1.

The annelids were represented by three orders, Arhynchobdellida, Tubificida and Errantida. Erpobdellidae (Arhynchobdellida) had six individuals found only in S2. Tubificida with families Tubificidae and Naididae were generally found in S1. Only Nereididae (Errantida) was significantly abundant ($F=5.33$, $p<0.05$) with 116 individuals restricted only to S3.

Taxa richness and diversity

Table 3 shows the significant spatial variability in taxa richness (Taxa S) or number of families present ($F=54.68$, $p<0.05$). Station 1 had the highest recorded Taxa S of 21 families, while S3 had the lowest with 3 families (Table 4, Fig. 6).

Diversity calculations for Mananga River showed a range of 0.643 to 2.384 (Table 4). Results in Table 3 also revealed that there was a significant difference in the Shannon-Wiener diversity index (H') between stations ($F=10.69$, $p<0.05$). On a periodic basis, S1 had the highest at 2.384, while S3 had the lowest with 0.643 (Table 4).

The February 18 sampling yielded the highest Taxa S of 21 families, and May 3 had the lowest with 3 families (Fig. 6). The differences however, were not significant ($p<0.05$). Similar to Taxa S, there was also an apparent lack of seasonality for H'.

Table 5 shows that Taxa S had a significant negative relationship with water temperature ($r = -0.723$, $p<0.01$), BOD5 ($r = -0.584$, $p<0.05$), and TSS ($r = -0.602$, $p<0.01$). It was positively correlated with pH ($r = 0.603$, $p<0.01$) and flow velocity (0.492, $p<0.05$). Meanwhile, H' had a negative relationship with water temperature ($r = -0.530$, $p<0.05$) and BOD5 ($r = -0.474$, $p<0.05$), but a positive relationship with pH ($r = 0.536$, $p<0.05$). All the other parameters did not show strong correlation with Taxa S, H', or both.

DISCUSSION

The water quality parameters of Mananga River in the three sampling stations were significantly different, except for alkalinity, total phosphates, and NO3-N (Table 1). The significant changes in these factors could be attributed to natural change in slope gradient, channel width, water depth and stream bed profile resulting in diminishing flow velocity and DO, but significantly increasing discharge thereby increasing TSS, and BOD5 downstream. The river continuum concept by Vannote et al. (1980) points to a longitudinal connectivity of the physicochemical and biological relations over the entire length of a river. A river flowing through a landscape influences land and is in turn influenced by it. The physicochemical profile directly affects the biological composition of streams and rivers since it provides the template upon which the ecological organization and dynamics of flowing ecosystems are observed (Minshall 1988, Poff and Ward 1989, Resh et al. 1988, Townsend and Hildrew 1994) and alteration of these habitats can

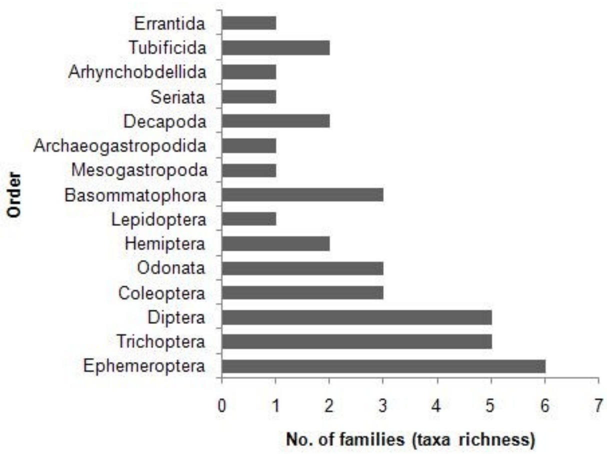

Figure 4. Number of macroinvertebrate families (taxa richness) per order, Mananga River, February to December 2006.

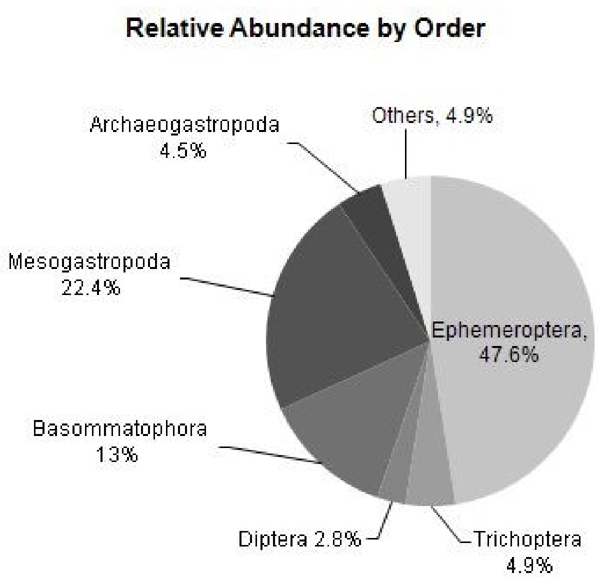

Figure 5. Relative abundance of macro-invertebrates per order, Mananga River, February to December 2006.

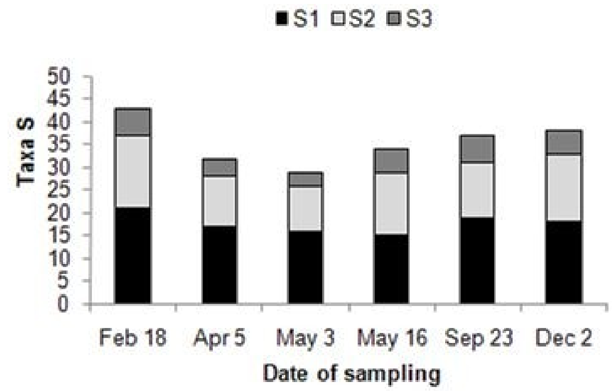

Figure 6. Macroinvertebrate taxa richness per station of Mananga River, February to December 2006.

have dramatic and persistent impacts on community assemblages (Niemi et al. 1990). Substrate, suspended sediment, gradient, water temperature, stream order and width were observed to have significant influence over biomass and diversity of macroinvertebrates (Newlon and Rabe 1977). Food availability is another important factor affecting abundance of benthic invertebrates (Arimoro et al. 2007).

The dominance of the immature stages of aquatic insects is not uncommon in Asian rivers (e.g., Boonsoong and Sangpradub 2008, Derleth 2003, Joshi et al. 2007). About 75% of all animals on earth are insects, and about 3% of all species of insects live in freshwater. Ephemeroptera was the most abundant insect order in Mananga River (Fig. 5). The immature stages of Ephemeroptera all live in freshwater, and are much more numerous in running waters (i.e. rivers) than in any other freshwater body (Daly et al. 1998).

The family Thiaridae was the most persistent and the most abundant macroinvertebrate family (Table 2). This was followed in abundance by Caenidae, Baetidae and Physidae. Thiaridae is known to colonize quickly; is tolerant to habitat diversity and variability due to a very strong and thick shell; most are parthenogenic females so only one snail is needed to produce more in a short time, viviparous, operculate, and has average longevity of five years (Contreras-Arquieta 1998). The Physidae group is generally cosmopolitan in nature. Its life cycle is rapid. One or two generations per year may be produced with complete replacement of individuals (Brown 1991). These snails are hermaphroditic and two snails are enough to get large numbers of them in relatively short time. However, few gastropods are good indicators of water quality because they can be found in areas with good water quality, as well as in areas with high

Table 1. The mean ± SE (minimum and maximum values in parentheses) of the physicochemical variables per station of Mananga River, February to December 2006.

Parameter	Station 1 (S1)[a]	Station 2 (S2)[b]	Station 3 (S3)[c]	F value
Water temperature (°C)	26.00 ± 0.59 (22.00-31.00)	26.64 ± 0.19 (25.00-28.00)	28.94 ± 0.47 (27.00-32.00)	11.95*
pH	8.76 ± 0.10 (8.20-9.60)	8.55 ± 0.12 (8.00-9.50)	8.03 ± 0.14 (7.30-9.20)	9.49*
Dissolved oxygen (mg L^{-1})	6.52 ± 0.24 (5.30-8.40)	6.87 ± 0.35 (4.80-8.60)	5.45 ± 0.22 (3.60-6.60)	7.19*
Flow velocity (m s^{-1})	0.34 ± 0.03 (0.11-0.59)	0.35 ± 0.03 (0.13-0.58)	0.23 ± 0.04 (0.05-0.51)	3.77*
Water depth (m)	0.12 ± 0.02 (0.03-0.24)	0.21 ± 0.01 (0.15-0.27)	0.20 ± 0.02 (0.13-0.28)	9.58*
Stream width (m)	8.27 ± 1.10 (3.10-13.10)	15.65 ± 1.32 (9.16-21.70)	16.26 ± 2.23 (7.30-27.62)	7.49*
Discharge rate (m^3 s^{-1})	0.24 ± 0.04 (0.08-0.53)	1.00 ± 0.15 (0.22-1.84)	0.54 ± 0.091 (0.08-1.19)	14.58*
BOD_5 (mg L^{-1})	1.98 ± 0.49 (0.80-3.20)	1.900 ± 0.431 (0.80-3.30)	4.60 ± 1.09 (2.00-9.00)	4.40*
Alkalinity (mg L^{-1})	180.78 ± 11.48 (87-234)	211.28 ± 25.93 (80-436)	224.2 ± 14.19 (160-339)	1.48
Total phosphates (mg L^{-1})	1.97 ± 0.58 (0.01-7.01)	2.19 ± 0.67 (0.01-9.63)	2.30 ± 0.46 (0.01-5.25)	0.09
Nitrate-nitrogen (mg L^{-1})	2.28 ± 1.06 (0.01-12.00)	2.90 ± 1.43 (0.03-18.20)	3.15 ± 0.98 (0.01-12.00)	0.15
Total suspended solids (mg L^{-1})	15.33 ± 2.79 (4-38)	15.17 ± 2.93 (4-34)	56.17 ± 12.48 (20-160)	9.72*

* The mean difference is significant at $p<0.05$ level (One-Way ANOVA)
[a]Upstream station; [b]Midstream station; [c]Downstream station

organic matter load and low DO (Hutchinson 1993, Kellogg 1994).

The higher temperatures probably favored the densities and diversity of Baetidae and Caenidae in the Mananga River. Temperature is one of the major factors determining the distribution of Baetidae, where most of the species exhibit higher densities in warmer waters (Zamora-Muñoz et al. 1993). Ephemeropterans, except for a few species, graze on algae and are especially sensitive to chemical pollution (Pollock 2003). Ephemeroptera, Plecoptera and Trichoptera are often used as indicators of good water quality (Rosenberg and Resh 1993). The family Caenidae however, is one of those Ephemeropterans not sensitive to decrease in water quality (Zimmerman 1993). No Plecopteran family was ever recorded in this study. Diversity of Plecopteran families is generally low in tropical Asian streams (Covich 1988). However, studies of rivers in Thailand and the Philippines had revealed the presence of Perlidae, Nemouridae, Leuctridae, and Peltoperlidae (Boonsoong and Sangpradub 2008, Manaog 2003 unpub., Sangpradub et al. 1997). The absence of the order in Mananga River could be due to unfavorable conditions (i.e. temperature) for its growth and reproduction. The Plecopteran order is typical of cooler, more northern latitudes (Dudgeon 1999).

The Neritidae, Grapsidae and Nereididae were significantly less favored in the upper stations S1 and S2 (Table 2). These groups are more associated with the marine environment but have developed special morphological adaptations to be able to inhabit the freshwater zone in lower parts of some rivers (Anger 1995, Pamplin et al. 2007, Thompson 2000).

The apparent lack of seasonality in the richness and diversity of macroinvertebrates in Mananga River could mean the presence of active and growing benthic invertebrate populations during the entire year. Ramirez and Pringle (1998), in their study of invertebrates in a lowland neotropical stream in Costa Rica also observed a lack of seasonality, suggesting that benthic communities are subject to similar stresses throughout the year, and that populations grow and reproduce continuously. Benke and colleagues as cited in Ramirez and Pringle (1998) also observed a similar phenomenon in subtropical lowland rivers. According to Wolda and Flowers (1985), the absence of a distinct cold season in tropical areas allows many species to be present all year round.

The direct correlation of pH with richness and diversity (Table 5) implies that many species favored an increasingly basic habitat. The USEPA (1976, 1986) indicates that a pH range of 6.5 to 9.0 provides adequate protection for the life of freshwater fish and bottom-dwelling macroinvertebrates. Some studies (i.e., Clenaghan et al. 1998) report that taxa richness, density of invertebrates and diversity increased along a river continuum with increases in pH, hardness and nutrients.

The direct correlation of flow velocity with richness (Table 5) is indicative of macroinvertebrates favoring faster currents. Many studies have established that micro-flow dynamics play a key role in the small-scale distribution of benthic communities (Hart et al. 1996, Statzner and Holm, 1982). Fenoglio et al. (2004) cite in their study of a neotropical stream, that both invertebrate density and taxonomical richness increased with increasing current velocity. Higher velocities were associated with a richer and more abundant invertebrate assemblage. This could be because current velocity plays a key role in water oxygenation, and in the functional feeding of some macroinvertebrate groups, such as filterers.

Apparently, water temperature, BOD5 and TSS levels negatively affected Taxa S or H' or both (Table 5). The USEPA (1997) notes that suspended particles in the water absorb heat thus, could increase water temperatures. This, in turn, could reduce the oxygen content of the water since warm water holds less DO than cold. Macroinvertebrates, especially the bottom-dwellers, are sensitive to temperature and will move to areas in the stream where they find their optimal temperature. If temperatures are outside their optimal range for a prolonged period of time, organisms are stressed and can die. A study of the diversity and abundance of aquatic macroinvertebrates in a stream in Brazil reports that the sampling station with the lowest temperature and highest DO level had the highest Shannon diversity index (Silva et al. 2009). High TSS in a water body can often mean higher concentrations of bacteria, nutrients, pesticides, and metals in the water (Murphy 2007) because suspended particles provide attachment places for these other pollutants (Michaud 1994). A study of the Cheon headwater in Thailand attributed the high BOD level in the impacted sites to the high TSS level in the water column (Sangpradub et al. 1997).

Since diversity values for real communities are often found to fall between 1.0 and 6.0 (Stiling 1996), this means that diversity in all the sampling stations of Mananga River were relatively low since none had an H' value higher than 2.5 (Table 4). Wilhm and Dorris (1968) had set the diversity index of less than 1 for highly polluted, 1-3 for moderately polluted, and greater than 4 for unpolluted water bodies. Stations 1 and 2 (Table 4) would come out as moderately polluted, and S3 as moderately to highly polluted. Macroinvertebrate diversity in Mananga River could have been affected by the presence of pollution in the river.

CONCLUSIONS

The river's environmental factors had directly and/or indirectly affected macroinvertebrate assemblages, showing that macroinvertebrates were useful indicators of water quality in Mananga River. Macroinvertebrate taxa richness and diversity significantly decreased downstream indicating better water quality (lower water temperature, TSS, BOD5, and high DO), as well as more favorable conditions for macroinvertebrate communities in the upper stations. A remarkable variety and abundance of macroinvertebrates were recorded from the Mananga River with the insects (Class Hexapoda) dominating, followed by the snails (Class Gastropoda). However,

Table 2. Macroinvertebrate composition and abundance in Mananga River by station, February to December 2006.

ORGANISM	No. of individuals S1	S2	S3	Total
PHYLUM ARTHROPODA				
CLASS HEXAPODA (Insects)				
Order Ephemeroptera (Mayflies)				
Family Ephemerellidae	4	-	-	4
Family Leptophlebiidae	28	94	-	122
Family Baetidae	489	1135	-	1624
Family Heptageniidae	4	6	-	10
Family Tricorythidae	858	988	-	1846
Family Caenidae	607	2239	5	2851
Order Trichoptera (Caddisflies)				
Family Philopotamidae	-	1	-	1
Family Hydropsychidae	109	246	-	355
Family Hydroptilidae	233	16	-	249
Family Limnephilidae	33	21	-	54
Family Polycentropodidae	-	1	-	1
Order Diptera (True flies)				
Family Tipulidae	1	-	-	1
Family Dolichopodidae	1	-	-	1
Family Chironomidae	221	142	4	367
Family Culicidae	1	-	-	1
Family Stratiomyidae	6	-	-	6
Order Coleoptera (Beetles)				
Family Psephenidae	10	-	-	10
Family Elmidae	123	100	-	223
Family Hydrophilidae	1	2	-	3
Order Odonata (Dragonflies & Damselflies)				
Family Cordulegastridae	7	-	-	7
Family Libellulidae	25	10	-	35
Family Coenagrionidae	1	-	-	1
Order Hemiptera (Bugs)				
Family Gerridae	3	-	-	3
Family Veliidae	1	-	-	1
Order Lepidoptera (Butterflies & Moths)				
Family Pyralidae	15	170	-	185
PHYLUM ARTHROPODA				
CLASS MALACOSTRACA				
Order Decapoda (Shrimps & Crabs)				
Family Palaemonidae	-	2	4	6
Family Grapsidae	-	-	4	4
PHYLUM MOLLUSCA				
CLASS GASTROPODA (Snails)				
Order Basommatophora				
Family Lymnaeidae	13	2	1	16
Family Planorbidae	27	1	-	28
Family Physidae	1285	431	3	1719
Order Mesogastropoda				
Family Thiaridae	1782	58	1205	3045
Order Archaeogastropoda				
Family Neritidae	-	-	611	611
PHYLUM PLATYHELMINTHES				
CLASS TURBELLARIA (Flatworms)				
Order Seriata (Planarian)				
Family Planariidae	13	-	-	13
PHYLUM ANNELIDA				
CLASS HIRUDINEA (Leeches)				
Order Arhynchobdellida				
Family Erpobdellidae	-	6	-	6
CLASS OLIGOCHAETA (Earthworms)				
Order Tubificida				
Family Tubificidae	34	-	-	34
Family Naididae	14	1	-	15
CLASS POLYCHAETA (Clam worms)				
Order Errantida				
Family Nereididae	-	-	116	116
Total no. of taxa (families)	**30**	**22**	**9**	
Total no. of individuals	**5949**	**5672**	**1953**	**13574**

Table 3. Summary of the biological indices at the study stations of Mananga River. Values are Mean ± SE (minimum and maximum values in parentheses).

Sampling station	Taxa richness (Taxa S)	H'[a]
S1	17.17 ± 1.01 (14-21)	1.90 ± 0.180 (1.25-2.38)
S2	12.50 ± 0.99 (9-16)	1.49 ± 0.07 (1.26-1.77)
S3	4.67 ± 0.42 (3-6)	1.03 ± 0.13 (0.64-1.51)
F-value	54.68*	10.69*

* The mean difference is significant at $p<0.05$ level (ANOVA)

[a] Shannon-Wiener diversity index

Table 4. Taxa richness and diversity of macroinvertebrates in Mananga River study stations, February to December 2006.

Date of sampling	S1 Taxa richness[a]	S1 H'	S2 Taxa richness[a]	S2 H'	S3 Taxa richness[a]	S3 H'
Feb 18	21	1.840	16	1.261	6	1.507
Apr 5	17	2.103	11	1.771	4	1.071
May 3	15	1.249	9	1.444	3	0.643
May 16	14	1.552	13	1.493	5	1.131
Sep 23	18	2.384	12	1.467	5	0.689
Dec 2	18	2.280	14	1.504	5	1.114

[a] no. of families

there were signs of deterioration of the river's water quality. The abundance of less-sensitive organisms such as Thiaridae, Physidae, and Caenidae, and the total absence of the sensitive order Plecoptera could be an indication of increasing organic pollution even in the upper stations of the Mananga River. However, there were few pollution-sensitive (i.e., Ephemerellidae, Leptophlebiidae, Philopotamidae, Cordulegastridae, and Tipulidae), and some moderately-sensitive families (i.e., Heptageniidae, Baetidae, Tricorythidae, Hydropsychidae, Hydroptilidae, Limnephilidae, Pyralidae, Planariidae, Psephenidae, Elmidae, Hydrophilidae, and Dolichopodidae), which implies that the upper stations were not as polluted as the downstream. This observation was confirmed by the diversity index where the upper stations came out as moderately polluted, and the downstream station as moderately to highly polluted.

RECOMMENDATIONS

The river's water quality could continue to deteriorate if natural and anthropogenic sources of organic matter would continually be introduced. Thus, there should be constant monitoring of the river to be able to immediately identify the necessary mitigating measures that can be applied to prevent the further deterioration of the Mananga River.

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CONFLICTS OF INTEREST

None

Table 5. Pearson correlation coefficient between selected physicochemical factors and macroinvertebrate diversity and richness of the Mananga River.

Parameter	Taxa S	H'
Water temperature	-.723(**)	-.530(*)
pH	.603(**)	.536(*)
Dissolved oxygen (DO)	.428	.322
Flow velocity	.492(*)	.106
Water depth	-.421	-.391
Stream width	-.385	-.336
Discharge rate	.009	-.242
Biological Oxygen Demand (BOD_5)	-.584(*)	-.474(*)
Alkalinity	-.252	-.168
Total phosphate	.077	-.108
Nitrate-nitrogen	-.064	-.036
Total Suspended Solids (TSS)	-.602(**)	-.408

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

CONTRIBUTIONS OF INDIVIDUAL AUTHORS

The gathering of data and writing of the research, which is part of a PhD dissertation, was done mostly by Dr. Mary Joyce L. Flores. Dr. Macrina T. Zafaralla, served as her major adviser and provided the major recommendations and inputs to improve the work.

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