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Macroinvertebrates as Indicators of Water Quality in Three Estuary Sites in Iligan City, Philippines

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Abstract

Macroinvertebrate assemblages were used as indicators to assess the water quality of the three estuary sites in Iligan City. A total of six orders of macroinvertebrates (Decapoda, Diptera, Odonata, Archaeognatha, Gastropoda, and Oligochaeta) were recorded during the four sampling periods. Arthropoda was the most diverse group, and it was present in the three estuaries due to its high tolerance to organic pollution. The overall diversity indices in the three estuaries obtained low values implying that the areas were composed only of a small variety of macroinvertebrate assemblage. Tambacan area has the highest value of Field Biotic Index, which was influenced by anthropogenic disturbances. The highest rating of water quality was in Timoga, and the lowest value was obtained in Tambacan. Associating dissolved oxygen with the macroinvertebrates in Timoga site signified that the macroinvertebrates in the area were sensitive since they were abundant in highly oxygenated streams. The estuaries in Iligan City showed a poor abundance of macroinvertebrates due to the low water quality that could be caused by the disturbances arising from human activities.

Keywords: diversity, oxygen, pollution, streams, tolerance

Introduction

Macroinvertebrates are animals that have no backbone and can be seen with the naked eyes. They generally include insects, crustaceans, molluscs, arachnids, and annelids. These organisms are important link in the food chain of freshwater ecosystems (Hussain, 2012) and can inhabit all types of running water (Tupinambás et al., 2015; Nair et al., 2015; Kazanci et al., 2015). Estuaries provide habitats for macroinvertebrates due to the presence of high levels of nutrients from the inflows of both seawater and fresh water. However, estuaries have been subjected to prolonged and escalating human disturbance (Orwa et al., 2012). The macroinvertebrates in estuaries are not only exposed to the natural changes in their habitats that cause them to respond in different ways but to anthropogenic disturbances as well (Roozbahani et al., 2010; Tweedley et al., 2015).

Bioassessment has been used to evaluate the ecological status of estuaries with implications for water management (Nebra et al., 2014). Integrating the biological assessment into the physicochemical evaluation of the estuaries provides a holistic approach to understanding how the ecosystem functions with implications for its protection and management (Duran & Suicmez, 2007). Several studies showed that macroinvertebrates are good biological indicators in estuarine ecosystems (Dudgeon, 2007; Hepp & Santos, 2009; Giblock & Crain, 2013; Chadwick et al., 2012). Macroinvertebrates are good indicators of freshwater health because of their long life period and limited mobility (Superales & Zafaralla, 2008; Cheimonopoulou et al., 2011; Sharma & Chowdhary, 2011; Flores & Zafaralla, 2012; Tampus et al., 2012). Moreover, due to the sensitivity of these organisms to changes in the physical, chemical and biological conditions of their environment, they are often used as biotic indices of habitat disturbance (Flores & Zafaralla, 2012; Tampus et al., 2012). Benthic macroinvertebrates are considered appropriate indicators of anthropogenic disturbance in estuaries (Tweedley et al., 2015). The existence of pollution-sensitive aquatic macroinvertebrates indicates very good water quality while the presence of pollution-tolerant organisms indicates water pollution (Dacayana et al., 2013).

In Iligan City, Mandulog River and Iligan River are two major riverine systems that flow into the estuaries. These rivers serve as the habitat for macroinvertebrates. However, anthropogenic impacts along the banks most notably in downstream resulted to river pollution (Tampus et al., 2012). Comparing these rivers with other freshwater environments in Northern Mindanao, the waters of Bulod River in Lanao del Norte (Dacayana et al., 2013) and Labo River of Misamis Occidental (Mapi-ot & Enguito, 2014) were less polluted supporting a higher species richness of macroinvertebrates. Quarrying, sprawling urbanization, and water pollution are common issues in Mandulog and Iligan rivers that have threatened the quality of freshwater in the area. Water quality of the riverine system of Iligan City decreases as it approaches downstream affecting macroinvertebrate assemblage (Tampus et al., 2012; Vedra & Ocampo, 2014). The presence of industries and other anthropogenic activities in Iligan City may have contributed to the deteriorating conditions of the rivers.

The estuaries of Iligan City, therefore, need attention taking into account the disturbances occurring in the ecosystem. Hence, assessing the water quality of estuaries in Iligan City is necessary for conservation management. This study aimed to evaluate the water quality of Mandulog, Tambacan and Timoga estuaries in Iligan City using macroinvertebrates as the bioindicators. Specifically, this paper aimed to determine the distribution, relative abundance, taxa richness of macroinvertebrates and calculate the diversity indices. The field biotic index, the physicochemical properties and quality index of water were also determined. The paper also explored the relationship between the physicochemical properties of water and the macroinvertebrates in the area.

Materials and Methods

Sampling areas

The sampling areas were established in the semi-closed coastal body of water in three estuary sites in Iligan City (Figure 1). The three estuary areas are Mandulog in Bayug Island (8^0 15’ 0” North latitude and 124^0 21’ 0” East longitude), Tambacan near the Wet Market (8^0 22’ 04” North latitude and 124^0 23’ 24” East longitude), and Timoga (Creek) in Buru-un (8^0 11' 28" North latitude and 124^0 10' 47" East longitude.)

The 50-km Mandulog River with headwaters that come from the Kalatungan Range in Bukidnon flows into the Mandulog estuary. Tubod River with a length of 9.15 km whose headwaters emanate from Lanao del Sur empties into Tambacan estuary (Tampus et al., 2012). Lawis River in Buru-un drains into Timoga estuary.

Figure 1. Location map of the three estuaries in Iligan City with pictures of actual sites (Source: googlemap.com- Map of the Philippines and Iligan City).

Sampling of macroinvertebrates

Field sampling was conducted from May to August 2012. Dip net and kick net were used to collect the macroinvertebrates from each sampling station once a month with three replicates. The dip net was submerged into the water and was moved into the vegetation banks where root wads, snags, and logs were found. The kick net was placed downstream of the habitat about one-meter square and disturbed so that any dislodged invertebrates are carried by the current into the net. Macroinvertebrates that were easily seen in all habitats were captured with the use of forceps and carefully transferred to the bucket. Each macroinvertebrate was gently handled to avoid breaking of appendages. The dichotomous key was used to identify and classify the macroinvertebrates up to the genus level. The distribution of macroinvertebrates in the sampling sites was then determined.

Water sampling

Water temperature, pH, salinity, dissolved oxygen (DO), biological oxygen demand (BOD), and total suspended solids (TSS) were determined in situ. Water sample was collected in 350 mL-bottle from each sampling site and kept in the refrigerator until transported to the laboratory for nutrient analysis of phosphate and nitrite following the Standard Methods for the Examination of Water and Wastewater (Federation & American Public Health Association, 2005).

Data analysis

The relative abundance of macroinvertebrates, taxa richness, and the biological indices were calculated. The Field Biotic Index (FBI) by Hilsenhoff (1988) and the Water Quality Index (WQI) by Oram (2012) were also calculated to determine the water quality of estuary sites. The Canonical Correspondence Analysis (CCA) was used to determine the association between the physicochemical parameters and macroinvertebrates.

A. Field biotic index (Hilsenhoff, 1988)**.** The index is based on the family level identification of organisms in streams and rivers including estuaries. Arthropods, insects, amphipods, isopods, and other macroinvertebrates are the organisms that can indicate the water quality with the use of FBI. It is not as sensitive as species-based indices, but it has the advantage of rapid stream/estuary assessment. The indications of water quality based on Field Biotic Index scores are shown in Table 1. The Field Biotic Index was calculated using the formula:

$$\mathrm{FBI} = \frac{\Sigma[(TV\mathrm{i})(n\mathrm{i})]}{\mathrm{N}}$$

where FBI is the field biotic index, $TV\mathrm{i}$ is the tolerance value for each taxon, $n\mathrm{i}$ is the number of individuals in the taxon, and N is the total number of individuals in the collection.

Table 1. Interpretation of FBI scores (Hilsenhoff, 1988).

FBI	Water Quality	Degree of Organic Pollution
0.00-3.5	Excellent	No apparent organic pollution
3.51-4.5	Very Good	Possible slight organic pollution
4.51-5.50	Good	Some organic pollution
5.51-6.50	Fair	Fairly significant organic pollution
6.51-7.50	Fairly Poor	Significant organic pollution
7.51-8.50	Poor	Very significant organic pollution
8.51-10.00	Very Poor	Severe organic pollution

The FBI is a quantitative measure that requires counting of individuals in each family. It is based on a scale of 10 (Table 2). High values indicate high pollution tolerance and lower values indicate pollution intolerance.

Table 2. List of macroinvertebrates and their tolerance values.

Taxa	Tolerance
Arthropoda	
Decapoda (shrimps and crabs)	6
Archaeognatha	
Machilidae (bristletail)	2
Diptera (true fly)	
Simuliidae (blackfly)	6
Chironomidae (midges)	8
Odonata	
Coenagrionidae (damselflies)	9
Mollusca	
Gastropoda	
Neritidae (nerites)	2
Lymnaeidae (pond snails)	9
Annelida	
Oligochaeta	
Lumbriculidae (aquatic worm)	9

B. Water quality index (WQI). Water samples were collected from May to August 2012 for water quality monitoring. The water quality index was computed using the WQI calculator (www.water-research.net/watrqualindex/waterqualityindex.htm). Table 3 shows the range of WQI corresponding to the general descriptive terms.

Table 3. Water quality index and its suggested quality range.

Range	Quality
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very Bad

C. Canonical Correspondence Analysis (CCA). This method was used to determine the association between physicochemical parameters and macroinvertebrates. The diagram is composed of four quadrants: Q_1, Q_2, Q_3, and Q_4. Each quadrant has a different weight as to the significance of the results. The order of the significance is from greatest to the least: $Q_1 > Q_2 > Q_3 > Q_4$.

Results and Discussion

Distribution of macroinvertebrates

Among the three major phyla, Arthropoda was the most diverse group consisting of eight families whereas Annelida was the least diverse group in the study sites. Within the Arthropoda group, Tambacan has the highest number of macroinvertebrate families. Six orders were recorded (Table 4) in the sampling sites during the four sampling periods.

The macroinvertebrates were grouped as Decapoda (Panopeidae, Ocypodidae, Portunidae, Penaeidae), Archaeognatha (Machilidae), Diptera (Simuliidae, Chironomidae), Odonata (Coenagrionidae), Gastropoda (Neritidae, Lymnaeidae), and Oligochaeta (Lumbriculidae). Families such as Panopeidae, Ocypodidae, Penaeidae, and Coenagrionidae dominated in Mandulog site. Portunidae, Machilidae and Neritidae were found only in Timoga site. Panopeidae, Ocypodidae, Coenagrionidae, Lymnaeidae, and Lumbriculidae dominated the Tambacan estuary.

Table 4. Systematic list of taxa of macroinvertebrates found in the three estuaries.

Phylum	Order	Family	Genus name	Common name	Mandulog	Tambacan	Timoga
Arthropoda	Decapoda	Panopeidae	*Scylla* sp.	Mud crab (juvenile)	+	+	-
		Ocypodidae	*Uca* sp.	Fiddler crab	+	+	-
		Portunidae	*Carcinus* sp.	Shore crab (juvenile)	-	-	+
		Penaeidae	*Penaeus* sp.	Shrimp (juvenile)	+	+	-
	Archaeognatha	Machilidae	*Petrobius* sp.	Jumping bristletail	-	-	+
	Diptera	Simuliidae	*Simulium* sp.	Blackfly	+	+	-
		Chironomidae	*Chironomus* sp.	Midges (larvae)	-	+	-
	Odonata	Coenagrionidae	*Enallagma* sp.	Damselfly nymph	+	+	-
Mollusca	Gastropoda	Neritidae	*Nerita* sp.	Nerites	-	-	+
		Lymnaeidae	*Lymnaea* sp.	Pond snail	-	+	-
Annelida	Oligochaeta	Lumbriculidae	*Limnodrilus* sp.	Aquatic worm	-	+	-

+ Present
- Absent

Macroinvertebrates that belong to Family Panopiedae are called mud crabs that inhabit mostly the estuaries and mangrove forests (Micu et al., 2010; Shelley & Lovatelli, 2011). In this study, the mud crabs observed were juvenile and belong to genus *Scylla*. Migration of juvenile crabs occurs, and the brackish waters in the Philippines provide protection, shelter, and food. The salinity tolerance of these crabs allows them to thrive in hypersaline conditions for extended periods and their regular air exposure after a routine burrowing enables them to leave waters with low dissolved oxygen. These crabs, like most intertidal organisms, respond to key environmental factors such as temperature and salinity (Shelley & Lovatelli, 2011).

The fiddler crabs (Family Ocypodidae) are semi-terrestrial organisms that also inhabit coastal estuarine where they could burrow during low tide (Jordão et al., 2007). In the present study, crabs observed belong to genus *Uca*. As noted, most of the activities of these crabs such as mating, foraging, hiding from predators occur on their burrows. They are considered effective bioindicators of estuarine health and are negatively influenced by anthropogenic (Giblock & Crain, 2013) as well as natural disturbances (Tweedley et al., 2015). Temperature, salinity, and turbidity in addition to competition could be the limiting factors that influence their population density in the estuarine ecosystem (Giblock & Crain, 2013).

Shore crabs are among the members of Family Portunidae that can swim (Hardy et al., 2010). These macroinvertebrates are predatory (Albaina et al., 2010) and invasive (Tepolt & Somero, 2014). In this study, the shore crabs observed were juvenile and belong to genus *Carcinus*. Being eurythermal may have facilitated the crabs to invade other habitats. There is high predation mortality of shore crab juveniles, and nursery habitat plays an important role in their survival (Moksnes et al., 1998). These epibenthic crabs are found only in Timoga and less predation in the area could be the reason they survive.

Shrimps belong to Family Penaeidae. These widespread and abundant macroinvertebrates have high economic value (Tenório at al., 2015). Shrimps inhabit the coast or estuaries, rivers, and lakes. In this study, the shrimps observed in Mandulog and Tambacan were juvenile and belong to genus *Penaeus*. Warm water facilitates the presence of shrimp larva over a longer period (Félix-Ortiz et al., 2014).

Jumping bristletails are members of Family Machilidae. These macroinvertebrates can inhabit various environments, but they prefer moist areas. They were only found in Timoga. Their presence in Timoga could be attributed to the rocky substratum of the area because they usually live in rock crevices as well as in leaf litters (Jong, 2014). Blackflies are members of Family Simuliidae. Their breeding ground is the flowing water. These insects have different ecological niches but are more associated with high elevated streams (Sriphirom et al., 2014).

Blackflies recorded in Mandulog and Tambacan belong to genus *Simulium*. This group is also present in streams with intermediate urban pollution impacts (Docile at al., 2015). Midges are nonbiting and belong to Family Chironomidae. They are the most widely and frequently most numerous insects in freshwater (Armitage et al., 2012). The midges recorded in Tambacan were juvenile and belong to genus *Chironomus*. The larvae of midges are pollution-tolerant and can adapt in aquatic environment with low oxygen, high or low pH, and warmer water (Walsh, 2006).

Damselflies are insects that belong to Family Coenagrionidae with few members that can breed in brackish water. The damselflies recorded in Mandulog and Tambacan were nymphs belonging to genus *Enallagma*. Food limitation, cannibalism, intraguild predation and habitat drying regulate the nymph or larval stage of damselfly (Fincke, 1994; Johnson, 1991). Species of the genus *Enallagma* are widespread, common and inhabit all types of aquatic environment even in low pH (Dow, 2009). Nerites are snails that belong to Family Neritidae. These snails are herbivores (Holzer et al., 2011). Another snail recorded in Tambacan belongs to genus *Lymnaea* and is called pond snail. It is a large air-breathing freshwater snail. *Lymnaea* species are copper-tolerant and can be used for ecological assessment (Côte et al., 2015).

The aquatic worms are members of Family Lumbriculidae. The species recorded in Tambacan belongs to genus *Limnodrilus*. This species is a pollutant-resistant worm and can survive in an ecosystem with the poor water quality (Jabłońska, 2014).

Relative abundance

Figure 2 shows the similarity analysis of the relative abundance of macroinvertebrate community composition clustered in three sampling estuary sites. Among the six orders, the Decapoda group under phylum Arthropoda has the highest abundance of macroinvertebrates, followed by Diptera, and Odonata group. Archaeognatha, Gastropoda, and Lumbriculida groups have 0% abundance in the three estuaries.

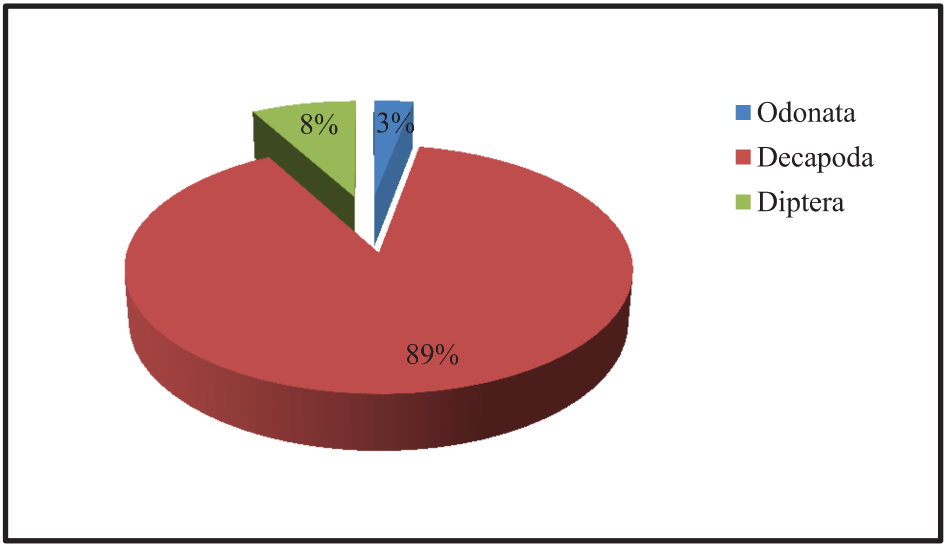

Figure 2. Relative abundance of macroinvertebrates (per order) sampled in three estuaries from May to August 2012.

Taxa richness

Figure 3 shows the taxa richness of macroinvertebrates in the three sampling sites. Gastropoda had the highest taxa richness with Neritidae having 640 individuals recorded in Timoga site only. However, Lymnaeidae (Gastropoda) that was found only in Tambacan site had the least number of individuals counted. Decapoda that was found in the three estuaries followed in rank as to taxa richness. The highest number of Decapoda (300) was recorded in Mandulog, followed by Tambacan, and the least number was in Timoga. Next to Decapoda as to taxa richness was Archaeognatha with 250 individuals. This taxon was found only in Timoga site. Whereas, Diptera that was found in Mandulog and Tambacan estuaries had low number of individuals recorded. Odonata that was found both in Mandulog and Tambacan as well as the Oligochaeta that was found only in Tambacan were among the taxa having the lowest number of individuals recorded.

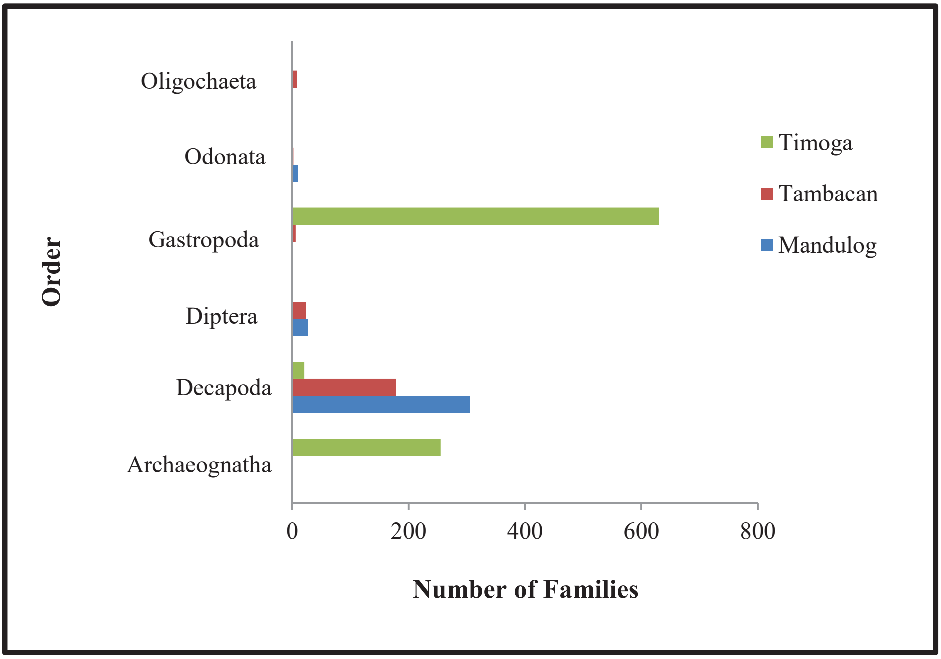

Figure 3. Taxa richness of macroinvertebrates in the sampling sites.

Biodiversity indices

Biodiversity indices of macroinvertebrates in the three estuaries are listed in Table 5. The overall Shannon index obtained a high value in the month of May which implies that the distribution of individuals among families was even throughout this period. The index showed no dominant species found in the three estuaries. The other diversity indices of macroinvertebrates in the three estuaries obtained low values implying that the estuary system was composed only of a small variety of macroinvertebrate assemblage. Timoga site has the highest taxa richness among the three sites. However, the family representatives collected were very few which were not evenly distributed as a diverse group.

Table 5. Biodiversity indices of macroinvertebrates in the three sampling sites.

	Dominance	Simpson	Shannon	Evenness	Margalef
Mandulog					
May	0.4551	0.5449	1.086*	0.5927	0.8846
June	0.5225	0.4775	0.9944	0.5406	0.9004
July	0.569	0.431	0.9087	0.4962	0.9004
August	0.594	0.406	0.835	0.461	0.9181
Tambacan					
May	0.6267	0.3733	0.8113	0.4502	0.977
June	0.3948	0.6052	1.199*	0.5529	1.242*
July	0.4327	0.5673	1.243*	0.4953	1.542*
August	0.3656	0.6344	1.16*	0.6378	1.007*
Timoga					
May	0.5602	0.4398	0.7171	0.6828	0.3981
June	0.5502	0.4498	0.72	0.6848	0.3727
July	0.5932	0.4068	0.6438	0.6345	0.3527
August	0.5413	0.4587	0.7404	0.5242	0.5426
Overall					
May	0.3805	0.6195	1.029*	0.9323	0.3498
June	0.4456	0.5544	0.9387	0.8522	0.3406
July	0.5053	0.4947	0.8576	0.7859	0.3290
August	0.4935	0.5065	0.8732	0.7982	0.3362

*High distribution of macroinvertebrate families.

Field Biotic Index

Figure 4 illustrates the FBI values in the three sites obtained during the sampling period. Tambacan site obtained the highest FBI score of 5.30-5.38, followed by Mandulog with the score of 4.68-4.80, and the lowest FBI score was obtained in Timoga with the value range of 2.03-2.15. Tambacan and Mandulog have values that indicate only good water quality with some organic pollution based on the interpretation of the FBI scores. On the other hand, Timoga has a score that indicates an excellent water quality (0.00-3.50) without apparent organic pollution.

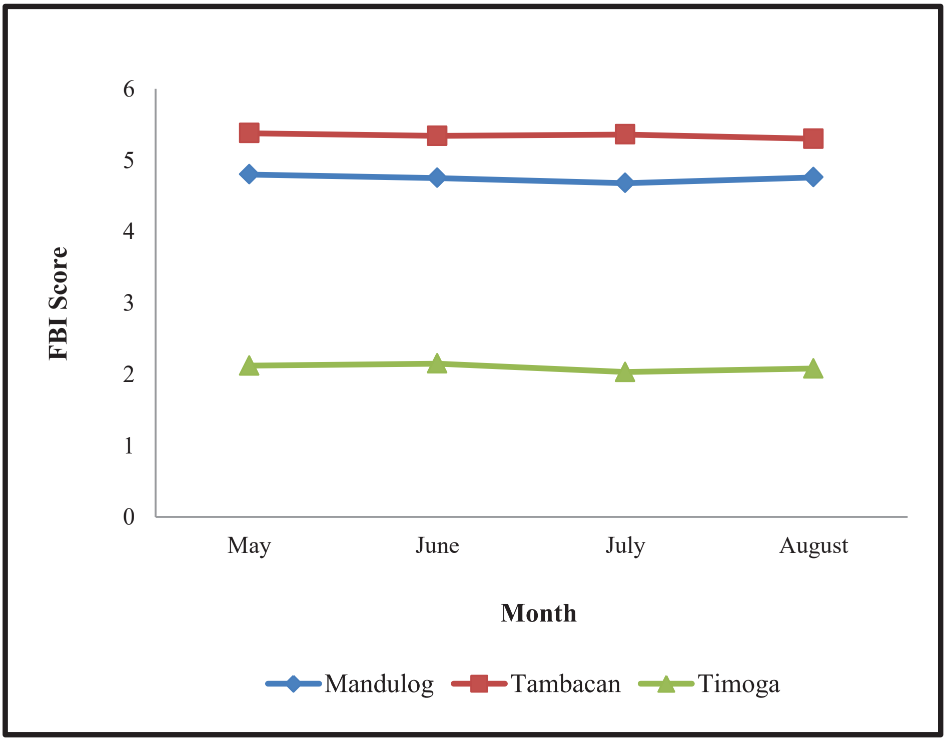

Figure 4. Comparison of FBI scores in three estuaries.

The FBI values in Tambacan and Mandulog sites suggest that only tolerant macroinvertebrates survive in those polluted streams (Hilsenhoff, 1988; Tampus et al., 2012). The presence of these macroinvertebrate groups in the polluted areas indicates heavy pollution

(Kobingi et al., 2009). The rich organic waste from slum dwelling and riparian zone acted as food for these tolerant groups. Relatively, Timoga has low FBI scores that indicate the presence of some sensitive macroinvertebrates in the clean stream (Hilsenhoff, 1988). These organisms are influenced by the fast-flowing water from the pool on the site (Hata-as, 1995).

Physicochemical properties of waters in estuaries

Table 6 shows the physicochemical properties of the waters in the three estuaries. The mean temperature of the water was highest in May with 25.1°C as the highest value recorded. Vijayakumar et al. (2014) and Dixit et al. (2013) showed similar results. This month falls within the dry season (Duran, 2006) and higher temperature values in estuaries in the dry season are expected due to the heat from the sunlight that elevates the surface water temperature (Vijayakumar et al., 2014). The mean reading was lowest in July due to the continuous rainfall observed between 5:00 p.m. and 6:00 a.m. The lowest average temperature of 20.4°C was recorded in this month. Despite fluctuations in values, the readings were within the acceptable range of 20°C - 33°C as recommended for aquatic life in the tropical region (Efe et al., 2012).

Among the three estuaries, Mandulog had the highest water temperature mean reading during the sampling period. In 2011, a flash flood hit the area that may have affected the water quality. The mean water temperature in Tambacan was also high. The result could be due to the presence of massive household wastes and construction. Guimaraes et al. (2009) observed similar result in their study of urban streams. Relatively, the mean temperature (22.5°C) of water in Timoga was lowest. The result may be due to the fast flowing water current and the presence of woody plants and aquatic vegetation. Yimer and Mengistou (2009) also reported similar findings in a study on water quality parameters in aquatic ecosystem.

Table 6. Physicochemical profile of the three estuaries in different sampling periods.

Parameter	Site	Months								Overall Mean
		May		June		July		August		
		Range	Mean	Range	Mean	Range	Mean	Range	Mean	
Water Temperature (^{0}C)	Mandulog	22.7-25.1	23.9	22.2-23.8	23.0	22.3-23.3	22.8	22.1-23.7	22.9	23.2
	Tambacan	22.3-23.5	22.9	23.6-24.0	23.8	22.0-23.5	22.8	22.0-23.4	22.7	23.1
	Timoga	21.2-23.8	22.5	21.2-22.5	21.9	20.4-23.9	22.2	22.6-24.1	23.4	22.5
	Overall mean		23.1		22.9		22.6		23.0	
pH	Mandulog	9.1-9.2	9.2	8.2-8.4	8.3	7.2-8.0	7.6	8.1-8.4	8.3	8.4
	Tambacan	8.8-9.3	9.1	8.7-9.1	8.9	7.4-8.8	8.1	6.4-6.9	6.7	8.2
	Timoga	7.0-8.2	7.6	7.0-7.2	7.1	6.9-7.7	7.3	6.9-7.7	7.3	7.3
	Overall Mean		8.6		8.1		7.7		7.4	
Salinity (parts per thousand-ppt)	Mandulog	7.0-10.0	8.5	6.0-9.0	7.5	5.0-9.0	7.0	7.0-8.0	7.5	7.6
	Tambacan	4.0-7.0	5.5	4.0-6.0	5.0	4.0-7.0	5.5	4.0-6.0	5.0	5.3
	Timoga	0.0-8.0	4.0	0.0-6.0	3.0	0.0-6.0	3.0	0.0-8.0	4.0	3.5
	Overall mean		6.0		5.2		5.2		5.5	
DO (mg/L)	Mandulog	5.0-6.3	5.7	6.2-6.9	6.6	6.0-6.2	6.1	6.4-6.6	6.5	6.2
	Tambacan	5.1-5.9	5.5	5.5-5.6	5.6	5.6-6.0	5.8	5.8-6.0	5.9	5.7
	Timoga	6.8-7.2	7.0	7.0-7.2	7.1	7.1-7.5	7.3	7.0-7.2	7.1	7.1
	Overall mean		6.1		6.4		6.4		6.5	

Table 6. Continued: Physicochemical profile of the three estuaries in different sampling periods.

Parameter	Site	Months								Overall Mean
		May		June		July		August		
		Range	Mean	Range	Mean	Range	Mean	Range	Mean	
BOD (mg/L)	Mandulog	2.8-3.2	3.0	3.4-3.7	3.6	2.7-3.1	2.9	3.0-3.7	3.4	3.2
	Tambacan	3.9-4.2	4.1	4.3-4.5	4.4	4.1-4.8	4.5	4.2-5.0	4.6	4.4
	Timoga	1.5-1.9	1.7	1.7-2.0	1.9	1.1-1.6	1.4	1.1-2.1	1.6	1.7
	Overall mean		2.9		3.3		2.9		3.2	
TSS (mg/L)	Mandulog	86.7-123.3	105.0	76.0-96.4	86.2	56.3-72.4	64.4	98.6-109.0	103.8	89.9
	Tambacan	91.0-106.0	98.5	81.4-88.3	84.9	68.5-77.5	73.0	74.8-95.0	84.9	85.3
	Timoga	13.3-23.3	18.3	13.5-25.0	19.3	7.4-11.1	9.3	8.53-26.8	17.4	16.1
	Overall mean		73.9		63.5		48.9		68.7	
Phosphate (mgP/L)	Mandulog	0.08-0.10	0.09	0.07-0.10	0.09	0.07-0.10	0.09	0.09-0.11	0.10	0.09
	Tambacan	0.16-0.18	0.17	0.16-0.18	0.17	0.17-0.18	0.18	0.16-0.17	0.17	0.17
	Timoga	0.03-0.04	0.04	0.03-0.05	0.05	0.03-0.04	0.04	0.03-0.04	0.04	0.04
	Overall mean		0.10		0.10		0.10		0.10	
Nitrite (mgN/L)	Mandulog	0.06-0.07	0.07	0.05-0.06	0.06	0.05-0.06	0.06	0.05-0.06	0.06	0.06
	Tambacan	0.24-0.25	0.25	0.24-0.26	0.25	0.24-0.25	0.25	0.22-0.24	0.23	0.25
	Timoga	0.05-0.06	0.06	0.04-0.05	0.05	0.04-0.05	0.05	0.04-0.05	0.05	0.05
	Overall mean		0.13		0.12		0.12		0.11	

The mean pH was highest in May and decreasing in the months of June to August. The highest pH value of 9.2 was recorded in May while the lowest pH value of 6.4 was noted in July. The high mean pH in May could be the effect of the high temperature during this dry season (Vijayakumar et al., 2014; Dixit et al., 2013). Rivers with higher water temperatures will have higher pH levels (Wurts & Durborow, 1992). The recorded high summer pH in this study might be due to the influence of seawater penetration, high biological activity, and the occurrence of high photosynthetic activity (Govindasamy et al., 2000; Sridhar et al., 2006; Saravanakumar et al., 2008). Rainwater, low temperature, and decomposition of organic matter influence the low pH observed during the wet season (Manikannan et al., 2011).

Mandulog had the highest overall mean pH (8.4) while Timoga had the lowest value (7.3). The pH level that ranged from 7.6 to 9.2 in Mandulog was alkaline which could be due to the carbonates and bicarbonates dissolved in the water that serve as natural buffering system of the estuary (Ohrel & Register, 2006). The pH in Tambacan ranged from 6.7 to 9.1. The low pH (6.7) recorded in Tambacan in August may be due to the human waste observed in the area. Efe et al. (2012) reported similar result in a river study. The pH in Timoga that ranged from 7.09 to 7.67 falls within the pH standard of 6.5 to 9.0 that supports aquatic invertebrates and other aquatic life (Barre, 2008). The mean pH in Timoga relative to the other sites could be due to the presence of rocky substratum and car wash as Efe et al. (2012) also showed. Despite fluctuations in pH values, the mean readings in the three estuaries were within the acceptable range from 6.5 to 9.0 except for the recorded mean values in Mandulog and Tambacan in May. Values outside the acceptable pH range in an estuary cannot support aquatic life. The pH in an estuary tends to remain constant because the chemical components in seawater resist large changes in pH, however, human-related activities and other biological activities may significantly alter the pH in an estuary (Barre, 2008).

Salinity in estuaries can range from 0.5 to 35 ppt depending on their location, the daily tides, weather (Levinton, 1995) and the volume of fresh water flowing into the estuary. In May and August, mean readings of salinity were highest which could be due to the high temperatures observed during these months. Salinity levels usually rise in higher temperatures as evaporation in the estuary increases (Barre, 2008). There was a significant positive correlation between salinity and water temperature (Vijayakumar et al., 2014). The low temperature in July may have contributed to the low salinity. During the rainy season, rainfall and freshwater inflow from the land may moderately reduce the salinity in estuaries. The low salinity in rainy months could also be due to the low pH.

In this study, the salinity levels in the three estuaries vary from being oligohaline to mesohaline. The result could be attributed to the time of sampling done between 6:00 a.m. to 8:00 a.m. which was characterized by low tide. The salinity was lower at low tide compared to high tide (Alvis, 2012). The result could also be attributed to the water temperature, pH, and freshwater inflow. The highest salinity mean values in Mandulog that ranged from 7.0 to 8.5 ppt falls within the 5.0-18.0 ppt range for mesohaline estuary (Mitsch & Gosselink, 2007). The salinity in Tambacan that ranged from 5.0 to 5.5 ppt was also considered mesohaline. The salinity in Mandulog and Tambacan could be due to tidal influence (Alvis, 2012), high water temperature and pH (Vijayakumar et al., 2014). Salinity was lowest in Timoga that ranged from 3.0 to 4.0 ppt which is considered oligohaline (Mitsch & Gosselink, 2007). The result could be due to the fast flowing current of the stream coming from the Timoga Spring Pool that freely exits to the sea which Hata-as (1995) also reported. A large quantity of freshwater inflow lowered the salinity of an estuary (Vijayakumar et al., 2014). Moreover, the low water temperature and pH in Timoga may also contribute to its low salinity.

The mean value of DO in this study was highest in August and lowest in May. Dissolved oxygen is usually higher during the wet season in tropics as Braide et al. (2004) reported. The high values recorded during wet season could be due to inflow from runoffs and decomposition of organic matter (Vijayakumar et al., 2014). Whereas, the lower DO concentration observed during the hot and dry season compared to the rainy season may be due to the higher salinity of the water, higher temperature, and lesser inflow of freshwater. In the paper of Dixit et al. (2013), DO was minimum during summer period but maximum during the rainy season. Increased consumption of available oxygen by the organisms for respiration and active decomposition of organic matter during summer also contributed to the low DO (Srilatha et al., 2012).

Only the mean reading of DO (7.1 mg/L)) in Timoga reached the acceptable limit of 6.8 mg/L recommended for aquatic life (Efe et al., 2012). The DO concentration in water is an indicator of prevailing water quality and ability of water body to support a well-balanced aquatic life (Vijayakumar et al., 2014). A good water quality supports high abundance of aquatic organisms (Roozbahani et al. 2010). Relatively, the DO (5.3 mg/L) in Tambacan was the lowest among the three estuaries and below the acceptable limit. The DO in Mandulog did not also reach the acceptable limit. Low DO may indicate the presence of biological stressors such as high nutrient levels, anthropogenic impacts, and release of domestic and industrial effluents (Glover et al., 2008). Bacteria and other decomposer organisms in polluted estuaries may reduce DO levels because they consume oxygen while breaking down organic matter. Moreover, DO levels in the estuaries may have been influenced by temperature and salinity (Barre, 2008). The low water temperature and salinity in Timoga may have increased the solubility of oxygen in water. The high temperature and salinity in Mandulog and Tambacan may have decreased the ability of oxygen to dissolve in water thereby reducing the DO in the sites.

In this study, the mean reading of BOD was highest in May and lowest in July. The higher BOD values in May could be due to high temperature and pH during this month. Vijayakumar et al. (2014) showed a positive correlation of BOD with temperature, pH, and salinity. The high BOD in summer could also be due to high nutrient concentration from domestic wastes. Seasonal changes in BOD with low values during wet seasons in this study may be due to increased surface runoffs, soil erosion, and effluents discharged into the receiving estuaries.

Tambacan had the highest BOD while Timoga had the lowest value. Although some waters are naturally organic-rich, a high BOD often indicates polluted or eutrophic waters (Ohrel & Register, 2006). The higher BOD in Tambacan could suggest the presence of more organic load from urban settlement in the area and would likely increase the microbe population. Efe et al. (2012), Vijayakumar et al. (2014), and Dixit et al. (2013) also reported similar findings in their studies of urban estuaries. The lowest BOD values observed in Timoga may indicate less organic load with low demand of dissolved oxygen by microorganisms. The demand for oxygen by microorganisms is less in estuaries with less organic load to decompose (Zimmerman, 1993). However, the mean BOD values in this study were less than 5 mg/L, which is the minimum limit that indicates water pollution in estuaries (Monitoring Water Quality, 2010) except in Tambacan having 5 mg/L as the highest value recorded in August. All BOD values in Mandulog and Timoga still do not indicate pollution, but water monitoring in Tambacan is important taking into account the increasing urbanization in the area.

In this study, the TSS was highest in May but lowest in July. High TSS values reported in May could be due to less rainfall during this month (Duran, 2006). Mandulog site had the highest TSS values recorded among the sampling sites whereas Timoga had the lowest values. The muddy substrate and degradation of riparian vegetation in Mandulog could probably explain the result. Moretti and Callisto (2005) also observed similar finding. The low TSS in Timoga could be due to the fast flowing current along its stream. The Philippines does not have a specific standard for TSS, but other countries consider less than 40 mg/L as the acceptable limit for estuaries (PHILMINAQ, 2010). Using this limit as the reference, the TSS values in Mandulog and Tambacan exceeded the acceptable value and thereby require attention.

Phosphate and nitrite levels in the three estuaries were almost similar during the sampling periods taking into account the mean values. However, the highest mean values in phosphate (0.17 mgP/L) and nitrite (0.25 mgN/L) were recorded in Tambacan. The results could be due to human activities and sewage disposal near this site. High concentrations of phosphate and nitrite could reduce the DO (Kobingi et al., 2009) that could have negative impact on the water quality. Nutrient values recorded in Mandulog were relatively lower compared to Tambacan site but higher than in Timoga. Human activities in Mandulog could also contribute to the nutrient level in the water. The slow moving water in Mandulog and Tambacan with muddy or sandy substrate and increased light penetration may have also influenced the high nutrient levels in the sites compared to Timoga.

Water quality index

Comparing the water quality of the three estuaries within the four-month sampling periods (May to August) using the water quality index, Timoga had the highest range of 74-79 which was an indication of a good water quality (Figure 5). Mandulog estuary scored 55-71 indicating a good water quality with a slight organic pollution. The lowest water quality index was in Tambacan (55.88-64) which indicated organic pollution. The water quality index, therefore, shows vulnerability of the area (Bharti & Katyal, 2011)

The domestic waste, community sewage disposal, and other human-related activities in Mandulog could contribute to the slight organic pollution in the area. The higher scale of human-related activities in Tambacan compared to Mandulog could be the contributing factor to the organic pollution in the area as Tampus et al. (2012) also reported.

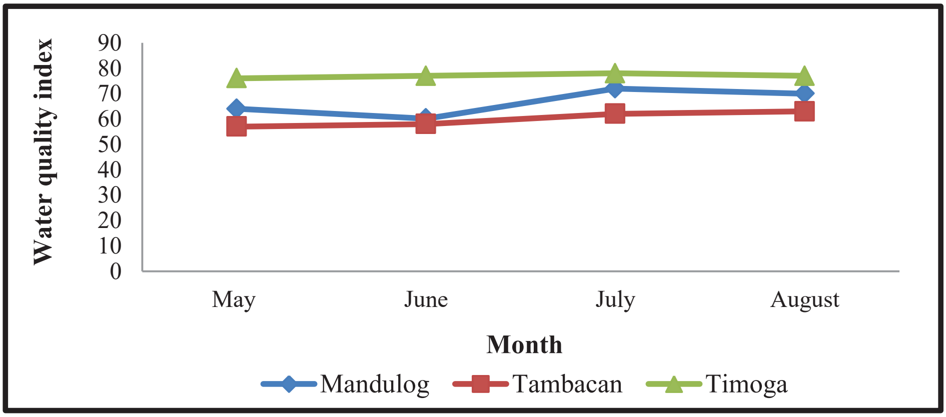

Figure 5. Comparison of water quality indices in three estuaries (from May to August 2012).

Relationship between physicochemical parameters and macroinvertebrates

Based on the canonical correspondence analysis, the Odonata and Decapoda are the macroinvertebrates in Mandulog that have association with salinity (Figure 6). *Enallagma* sp. (damselfly nymph) of the Order Odonata was mostly correlated with salinity indicating that it is tolerant to high salinity levels in Mandulog (Chen & Chia, 1996).

Decapoda such as the crustaceans *Scylla* sp. (mud crab) and *Penaeus* sp. (shrimp juvenile) observed in Mandulog was more tolerant to salinity than any other macroinvertebrates as well as to anthropogenic impacts, high water temperature, and nutrient levels. The result also supports the study of Hawksworth and Ritchie (1993) on invertebrates.

In this study, the presence of Lumbriculidae and Chironomidae indicates the presence of high organic pollution due to human activities and sewage disposal that may have contributed to increased pH, BOD, TSS, phosphate in Tambacan as Sharma and Chowdhary (2011) also reported. These organisms are common inhabitants of polluted waters that are rich in nutrients and poor in oxygen with high BOD (Efe et al., 2012). The presence of pollution-tolerant organisms such as Oligochaeta (Lumbriculidae) in this site indicates the presence of human pressures such as anthropogenic stress, municipal sewage, and domestic waste. The presence of bioindicators such as Gastropoda (Lymnaeidae) in Tambacan also indicates the high organic load in the estuary (Sharma & Chowdhary, 2011). The taxa richness of Lymnaeidae and Lumbriculidae in this study was very poor compared to the other macroinvertebrates. Diptera directly points to the shifting status of the stream from non-polluted to polluted with the presence of some pollution bioindicators such as *Chironomus* sp. and *Simulium* sp. (Sharma & Chowdhary, 2011). This study also showed that within the most diverse Arthropoda group, Tambacan has the highest number of macroinvertebrate families due to its great adaptability and high tolerance to the physical and chemical conditions as well as to the human stressors in the area.

In Timoga, the presence of Archaeognatha and Gastropoda is associated with DO. The association of DO to the macroinvertebrates in Timoga signifies that these organisms are relatively sensitive since they are abundant in high oxygenated streams (Zimmerman, 1993). Portunidae, Machilidae, and Neritidae were only found in Timoga due to the high dissolved oxygen availability in its fast flowing water. The high taxa richness of Gastropoda (Neritidae) and Archaeognatha can be attributed to the high DO levels in Timoga. These macroinvertebrates which require high concentration of dissolved oxygen can thrive more in Timoga than in other sites where DO is depleted. These organisms could be eliminated and replaced by pollution-tolerant organisms

(Zimmerman, 1993). The fast flowing water such as upland streams contributes to the high DO levels in the area. The presence of vegetation in this site provides the food supply for large collectors and shredders (Maagad, 2012).

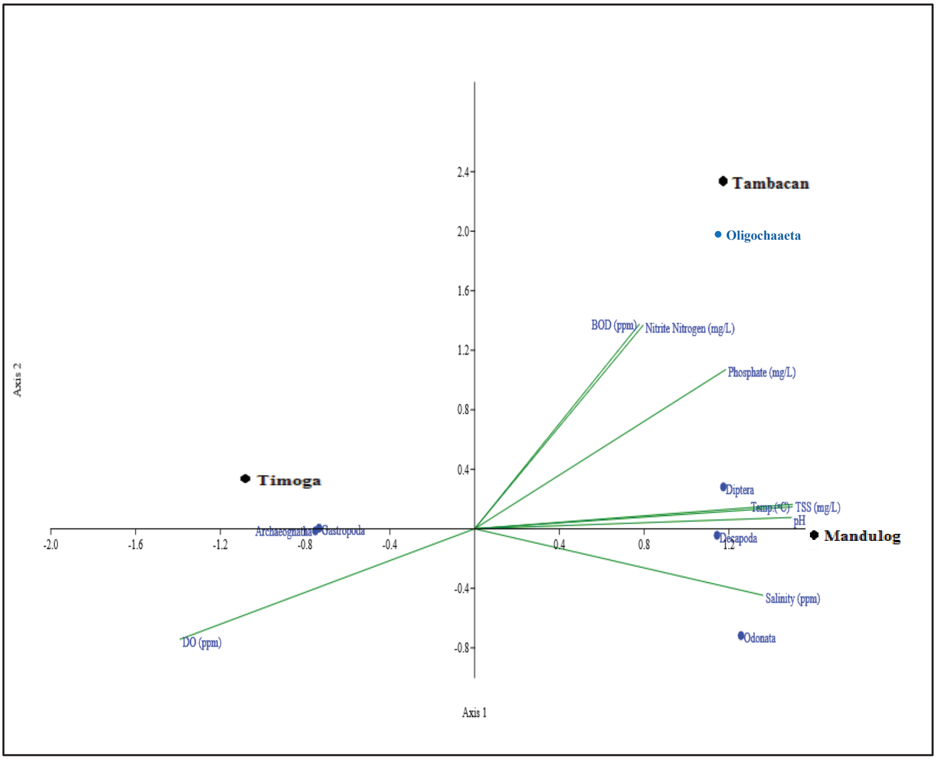

Figure 6. Canonical correspondence analysis showing the relationship between physicochemical parameters and macroinvertebrates in the three sampling sites.

In this study, the physicochemical properties of water that are affected by human activities influenced the distribution of macroinvertebrates as Orwa et al. (2012) also reported. The physical and chemical conditions of the estuaries are the major factors that affect the quality of the aquatic environment where the life processes of the organisms including the variation of their relative abundance can be influenced by water quality (Efe et al., 2012; Maagad, 2012). The low family distribution in Mandulog and Tambacan can be attributed to the presence of human disturbance near the estuaries. Orwa et al. (2012) also showed similar results in areas with higher human disturbance compared to the less disturbed sites. Chemical pollution is one of the prime factors that are usually influenced by human activities (Suleiman & Abdullahi, 2011). Near-stream human activities and the associated physical disturbance and chemical inputs had negative impact on macroinvertebrate assemblage (Kobingi et al., 2009). Unpredicted floods can cause disturbance in stream ecosystem including family distribution. Moreover, abundance and taxa richness of macroinvertebrates can also be the consequences of biological factors. These factors may include predation risk, temporal changes in macrophyte community during the growth period, and trophic resource availability (Moretti & Callisto, 2005).

Conclusion and Recommendation

The presence and richness of macroinvertebrates are dependent on their location and tolerance to the environment in which they live. The estuaries in Iligan City have poor abundance of macroinvertebrates due to the low water quality which could be caused by disturbance that is human-induced. Macroinvertebrates sensitive to high nutrients and temperature have been found in the estuary site with high DO value and low temperature which are required in their life cycle. Since it is commonly known that aquatic insects inhabit the freshwater environment including estuaries, macroinvertebrates are indeed good indicators to assess and monitor the quality of the water systems over time. In this regard, regular monitoring of the sampling sites is recommended.

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