

Water quality assessment using benthic macroinvertebrates in Malingin stream, *Campo Siete*, Minglanilla, Cebu

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Abstract

The Regional Centres of Expertise Cebu (RCE-Cebu) installed water filtering system in *Campo Siete*, Minglanilla, Cebu as a way of cleaning domestic wastewater that flows to the Malingin stream. This study was conducted to evaluate water quality of the said stream using benthic macroinvertebrates to provide baseline information for the long-term assessment of the effectiveness of the filtering system. Three sampling locations were established, each having five sampling sites. Multiparameter probe was used to gather physicochemical properties of the stream. In gathering the macroinvertebrates, the standard kick/sweep method was done with the use of a 1-meter mesh net (500 μ m). Macroinvertebrates were classified and identified up to the family level. Several metrics were used to analyze the macroinvertebrate data. The upstream area had a very good water quality (HBI score= 3.89) since it was located far from the residential area and with only a slight disturbance from the soil quarry nearby. Midstream area had slightly polluted water quality (HBI score= 4.04) since it was located on the residential area. Downstream area had excellent water quality (HBI score= 3.33) since it was also far from the residential area, and two tributaries supplied freshwater to the stream. Moreover, downstream had the most suitable physicochemical parameters for the survival of aquatic life. Overall, Malingin Stream in *Campo Siete*, Minglanilla, Cebu has a very good water quality with only a slight pollution.

Introduction

Rationale

As the world population increased, humans have started producing a lot of domestic wastes. The lack of garbage management being implemented in a community would resort humans to throw these wastes on rivers or the along riverbanks. The wastes being thrown in the river not only affect the organisms living in the water but also the health of the settlers near the streams. Through our approach to modernization and industrialization, humans have also started

generating a lot of toxic waste products from the industrial processes. Since factories and other large establishments produce huge amount of waste, they use rivers as their drainage system. These waste products are toxic and kill numerous species of organisms living in the river and streams thus, disturbing the ecological balance.

Assessment and monitoring of the water quality in rivers and streams are important to help prevent further introduction of pollutants in the river. This would also help create and implement environmental policies. Monitoring management together with strict environmental policies help lessen further future human impact on bodies of waters and natural ecosystems.

Regional Centres of Expertise Cebu (RCE-Cebu) together with Institute for Global Environmental Strategies-Asia-Pacific Forum for Environment and Development (IGES-APFED) encouraged the use of filtering system in Malingin stream, *Campo Siete*, Minglanilla, Cebu to clean domestic wastewater that flows to the stream.

Through this study, the community living along the Malingin stream in *Campo Siete*, Minglanilla, Cebu had been given the knowledge of how their activities affected the health of the river ecosystem and the water quality in the said stream. With this, their local government could implement strict laws and regulations regarding their household and pigpens drainage systems, and proper dumping sites for their garbage wastes.

Review of Related Literature

Rivers and streams are considered one of the sources of life on Earth. During prehistoric times, humans have already utilized rivers by settling along riverbanks for their source of freshwater and food. These early settlers have also used these streams for their hygienic purposes. Since rivers form networks of waterways around the Earth, they have been useful in transporting people, livestock, and cargos, specifically in Asia. In Indo-China region, most specially, rivers were also used to transport harvested fruits and vegetables, and even their marketplaces are located on rivers. Some places have been famous for having rivers as their tourist attraction site such as the Nile River in Africa and the Loboc River in Bohol, Philippines. For farmers, rivers have been of great help on their crops by supplying water for their irrigation system.

As the human population increases and as we approach to modern industrialization, rivers have become polluted through human activities. According to the United States Environmental Protection Agency (EPA), water pollutants are divided into six categories. First is the biodegradable waste which consists of the human and animal waste. These wastes provide energy source as organic carbon to bacteria. When there is a high level of organic matter in the water, bacteria multiply rapidly making all the oxygen unavailable to other aquatic organisms. The second category of water pollutants are the plant nutrients, especially the phosphate and nitrates. These nutrients came from sewage, livestock and fertilizer runoff, and industrial wastes. When the phosphate and nitrate levels in the water are high, algae starts to grow and eutrophication occurs. The third category of water pollution is the heat. When the water temperature is high, the amount of dissolved oxygen decreases. Living organisms require optimum temperature and oxygen levels in order to survive. Therefore, heat pollution reduces organism diversity in the water.

Sediment is the fourth and one of the most common causes of water pollution. The sediments are washed off into the river from construction sites, agricultural and livestock processes, logging, and flooding. Sediments can cause the water to become turbid and cloudy, which can cause increase absorption of solar radiation that leads to heat pollution. The fifth category is the hazardous and toxic chemicals. The pollution sources came from domestic and personal use of chemicals, industrial discharges and oil spills. The accumulation which leads to high levels of these toxic chemicals puts the aquatic life in great danger. The sixth category contributing to water pollution are the radioactive pollutants. These came from factories, hospitals, and uranium mines. Radioactive pollutants are very dangerous, when there is a high accumulation, to the organisms living in the water.

With the acquired knowledge of the possible sources of pollutants found in water systems, many environmental scientists have been interested in assessing and monitoring water qualities, especially on the streams and rivers. Water quality monitoring is the most direct and valid method available to assess water quality and its response to management and other factors (Coffey and Smolen, 1990).

The evaluation of physicochemical parameters is one of the used tools in assessing the quality of water. Physicochemical parameters pertain to both physical and chemical properties, changes, and reactions. Different studies have been carried out using physicochemical parameters alone, which proved its efficacy and accuracy (Agarwal and Saxena 2011; Sivakumar et al. 2011; Gasim et al. 2007). Physicochemical parameters work together with the biological indicators in determining water quality. In several studies, it was used to support the effectiveness of biological indicators in assessing the quality of water.

There was a study conducted by Uyanik and colleagues (2005) on the relationship between benthic macroinvertebrates and water quality parameters, such as biochemical oxygen demand (BOD), chemical oxygen demand (COD) and dissolved oxygen (DO), in a river in Turkey. It was carried out in order to assess the ecological impact of polluted water discharge into rivers. The kick sampling method was used in collecting benthic macroinvertebrates. The researchers used the Biological Monitoring Working Party (BMWP), Trent Biotic Index (TBI), and Chandler Score to quantify the conditions of the biota at the study sites. The results of their study supported its hypothesis that the use of macro-invertebrates as indicator in a water body is an ideal methodology for the assessment of the water quality.

Physicochemical parameter (Agarwal 2011) and macroinvertebrate indicator (Bode et al. 1995) were both effective in assessing in the quality of the water. However, the use of both of these indicators together may have significant relationship and have more accurate results. In 2009, George and his colleagues studied the benthic macroinvertebrate fauna and physico-chemical parameters in Okpoka creek sediments for a period of one year. They found out that the distribution pattern of the macro invertebrates in all the stations of the creek did not show major differences. Their results also showed strong relationship between the physico-chemical quality and the distribution of organisms along the creek they have studied.

Another study was conducted by Sharma and Chowdhary (2011) using both abiotic and biotic indicators. The relative diversity, species richness, dominance, evenness indices, physico-chemical parameters and percentage of Annelida + Arthropoda + Mollusca (AAM) individuals were determined. Significant relationships were recorded between physicochemical parameters and the occurrence of specific genera. They concluded that the changes in macroinvertebrate assemblages were primarily due to changes in water quality.

The use of biological indicators may work together with the physicochemical parameters. However, due to the high-cost chemicals and materials used in measuring the physicochemical parameters, researchers have resorted to less expensive indicators in assessing and monitoring water quality. One low-cost method of monitoring water quality is the evaluation of biotic factors. The assessment of the impact of degradable organic pollution, mainly sewage, on stream and river ecosystems using biological indicators has been widely used (Metcalf 1989) since the 1900's (Wallace et al 1996). Among the several biological indicators, macroinvertebrates has been commonly utilized by scientists and/or biologists from different environmental bureaus (Bode et al. 1996). Benthic macroinvertebrates are the bottom-dwelling organisms that live on aquatic areas and can be seen with the naked eye (Readel 2002). Several macroinvertebrates temporarily live on the water while still in their developing stages, while others of these organisms live on streambed throughout their lives. They play an important role in the food chain of aquatic systems and therefore can be used to determine the health of river ecosystem (Bode and Novak 1995). These organisms are affected by low quality of water to varying degrees. Benthic macroinvertebrates are grouped into pollution tolerant or those that can survive on a wide range of environmental conditions, and pollution intolerant or those that are sensitive to changes in the environment. Since most benthic macroinvertebrates are immobile and cling to riverbeds, they cannot escape harsh environmental conditions and basically die if the water quality is below their tolerance. They are easily sampled and manipulated, and they quickly react to environmental changes (Kusza 2004).The analysis of collected macroinvertebrate is both time and cost efficient compared to water quality assessment using chemical and physical parameters (Bode et al. 1996).

On a study conducted by Barton and Metcalfe in 1992, they investigated the responses of the resident and colonizing components of the benthic macroinvertebrate community to municipal/industrial versus agricultural pollution in a part basin. Their study evaluated the performances of seven different diversity and biotic indices in assessing water quality. They found out that other indices were less sensitive, accurate or temporally stable, or were otherwise inappropriate for use with certain sampling methods or for certain types of pollution. Based on all of the summary indices they used, the impact of agricultural practices on stream ecosystems in Yamaska River drainage basin in Quebec, Canada may be as severe as the impacts of municipal and industrial wastes.

Another study conducted by the United States Geological Survey, in cooperation with the Chester County Water Resources Authority analyzed the Delaware River Basin for a 17-year period. They found out that from the year 1981 until 1997, the river basin sites affected by wastewater-treatment discharge have improved water chemistry and the benthic macroinvertebrate communities indicated an improvement of stream quality.

In 2006, a study conducted by Duran showed the importance of seasonality when conducting biological indicators on the river. He assessed water quality using benthic macroinvertebrate fauna of Behzat Stream in Turkey. The study was carried out by establishing five sampling sites of two different sections of the stream between September 1998 and September 2002. The data results indicated that the upper section supported a more diverse community than the lower section. It was mentioned in the study that low macroinvertebrate abundance was observed during summer in the lower section, which may be accounted to high values of phosphate and nitrogen ions. In conclusion, Behzat Stream had a good water quality conditions.

In Metro Cebu, though there were only few articles that have been published regarding the assessment of water quality, but through physical observation, many rivers and creeks are at risk as they continue to degrade because of human activities. Guadalupe and Buhisan are two of the major rivers that pass through Cebu City. The Cebu City government with Kitakyushu City of Japan, Institute for Global Environmental Strategies (IGES), and United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), Cebu Uniting for Sustainable Water (CUSW) helped and actively participated in the workshop "Wastewater and Solid Waste Management of Guadalupe River." The workshop tackled priority problems and actions for the treatment of the said river. In 1999, the Cebu City Government enacted City Ordinance No. 1764 which created the Cebu City River-Eco Park Management Commission (CC-REPMC) for the purpose of the developing, managing, and rehabilitating the major rivers and streams within the political boundaries of the city. During 2004, City Ordinance No. 1764 was improved by City Ordinance No. 1997 renaming the CC-REPMC as Cebu City Rivers Management Council (CCRMC).

Objectives

This study aimed to assess the water quality of the Malingin stream in *Campo Siete*, Minglanilla, Cebu, through evaluation of the richness of benthic macroinvertebrate populations and through the measurement of the physicochemical parameters (temperature, pH, dissolved oxygen, and total dissolved solids). This study also aimed to serve as the baseline information for the long term assessment of the effectiveness of RCE's filtering system.

Materials and Methods

Study area

The stream located in Campo Siete, Minglanilla, Cebu (Figure 1) was the area of this study. There were 19 barangays in Minglanilla including the Campo Siete. With only less than 2,500 residents, Campo Siete is a small urban region in a protected forest area. It is a long drive from the main highway in Tabunok, Talisay City.

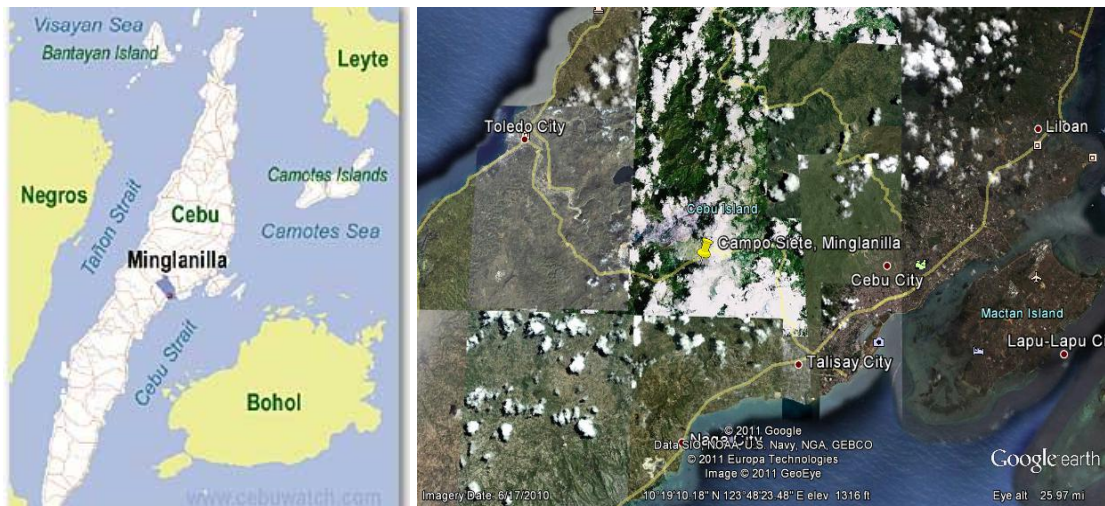


Figure 1. a. Map of Minglanilla, Cebu (adapted from cebuwatch.com); b. Map of Campo Siete, Minglanilla, Cebu (adapted from Google Earth).

Sampling locations

Three (3) sampling sites were established on the river; the upper stream area (N 10° 19' 27.4", E 123° 46' 29.5"), the middle stream area (N 10° 19' 18.7", E 123° 46' 22.9"), and the downstream area (N 10° 19' 03.7", E 123° 45' 57.3). The standard sampling area should have been 50 meters away from any human activities. However, the stream was only less than a kilometer long, which was why I maximized the length of the stream, and was able to establish sampling sites near

human activities. Each sampling sites had five (5) sampling points. The sampling points was established by marking every twenty (20) meter-interval in a 100-meter transect line placed parallel to the stream flow.

Data collection

- *Biological sampling by kick/sweep method*

The benthic macroinvertebrates were collected using a 1-meter, 500 μm mesh net (Prater et al. 1977) placed on the riverbed in a 45° angle. The kick/sweep method was done in a standard three-minute kick/sweep method (Armitage et al. 1990) by disturbing the riverbed in a kicking motion towards the direction of the scoop sampler in a kicking/sampling area of 1-meter². Large stones found on the sampling area were gently rubbed to let any clinging organisms be carried into the net. The sampling was done starting from the last sampling point on the downstream area towards the upper points.

The mesh net with the collected sample was then carefully turned inside out and shaken gently in a white plastic container filled with water. Leaves, twigs, rocks, and other debris were taken out of the collected sample. The sorting was done in the laboratory and the organisms were preserved in a 70% ethyl alcohol. The benthic macroinvertebrates was then identified using a dichotomous key (Bouchard 2004). Identification was done up to the family level since species level identification was neither time nor cost efficient and can even require the identification of several life stages of a single species (Resh et al. 1975; Bailey et al. 2001).

- *Physicochemical measurements*

A multiparameter probe was used to gather data on the pH, temperature, dissolved oxygen, and total dissolved solids stream water. The probe was placed in

the water column, and after the reading stabilizes, the data was recorded. The physicochemical properties were measured on every sampling point on the river.

Data analysis

In analyzing the data gathered, standard metrics from the United States Environmental Protection Agency (1989) were used. The metrics were categorized according to the richness and composition measures, the tolerance measures, and trophic/habit measures of the benthic macroinvertebrates. The Biological Monitoring Working Party (BMWP; Armitage et al. 1990) score and Average Score Per Taxon of macroinvertebrates were also calculated.

In calculating the richness measurement several metrics was used including the total number of individuals collected in the sample (Number of organisms). More organisms in the sample may indicate a good quality of the water. The total number of families present in the sample was also counted (Family richness; Weber 1973). The decrease in family richness may indicate a high disturbance in the river. Another metric used was the number of mayfly, stonefly and caddisfly families within a sample (Ephemeroptera, Plecoptera, Trichoptera; EPT richness; Bode et al. 1995). These three families were considered least tolerant to organic pollution, thus, a sample with high EPT richness was considered indicative of good quality water (Wenn 2008).

The tolerance measures, was also evaluated by using the measure taxa richness of those organisms considered to be sensitive to perturbation (Number of intolerant families). High number of intolerant taxa may indicate a good quality. The percent of macroinvertebrates considered to be tolerant of various types of perturbation (Percent tolerant organisms) was also computed since increased number of this metric may indicate an increase pollution level. Hilsenhoff Biotic Index

(HBI; Barton 1992) which uses tolerance values (Appendix A, Table1) to weight abundance in an estimate of overall pollution was also calculated. HBI was originally designed to evaluate organic pollution. High index value indicated a high perturbation in the area (Appendix A, Table 1a).

For the purpose of habit measure, the percent of insects having fixed retreats or adaptations for attachment to surfaces in flowing water (Percent clingers) was computed. In evaluating the trophic measure, the percent of each functional feeding group (Percent filterers, Percent shredders, Percent gatherers, Percent predators, and Percent scrapers) was also calculated. Low values of these metrics have variable indications as to the human disturbance. However, most of these metrics decreases as the perturbation increases.

Each group or family in the Biological Monitoring Working Party (BMWP) corresponded to a score between 1 and 10, according to the sensitivity level to the environmental disturbance (Appendix A, Table 2). The most sensitive organisms, such as the stoneflies, were given the score of 10 and the least sensitive, such as oligochaete worms, was allotted to have the score of 1. The scores for each family represented in the sample were then summed to give the BMWP score.

The Average Score Per Taxon (ASPT) was also calculated to reduce the effects of sample size, sampling effort, and sampling efficiency on the results obtained through the sampling methods used. This was calculated by dividing the BMWP score by the total number of taxa (families) present in the collected sample. A BMWP score greater than 100, together with an ASPT value greater than 4, generally indicates good water quality.

Results and Discussion

Physicochemical parameters

All the three sampling sites were of the same substrate (Table 1), but each has different perturbations rendered by human activities. Human activities affect the chemical properties, richness, and abundance of macroinvertebrate communities living on the riverbed.

Table 1. Description of sampling sites in Malingin stream, *Campo Siete*, Minglanilla, Cebu.

	Upstream	Midstream	Downstream
Characteristics	<ul style="list-style-type: none"> • Large rocks dominate the substrate • Trees cover both sides of the stream 	<ul style="list-style-type: none"> • Medium-sized rocks cover the substrate • Plastic garbage were observed 	<ul style="list-style-type: none"> • Medium-sized rocks cover the substrate • Grasses were found along riverbanks
Anthropogenic activities	<ul style="list-style-type: none"> • Soil quarry on the upper area • Plant nursery nearby 	<ul style="list-style-type: none"> • Residential area • Domestic waste drainage • Pigpen drainages • Bridge construction on the upper region 	<ul style="list-style-type: none"> • Water tributaries on the upper region • Laundry area on the lower region of the tributaries

Since trees are just a few feet away from the stream on the upstream area, most of the leaves were found flowing and settling on the riverbed. Most of the periphytons were observed to have been attached to the rocks on the downstream area. Midstream area had the most turbid water when compared to the upstream and the downstream area. This may be due to the domestic drainage system and high human activities which caused water to become cloudy. Moreover, garbage such as plastic bags and diapers were observed in the midstream area. Detergent soap was

assumed to have been drained on the downstream since a laundry area was observed just above its upper region. Two (2) water tributaries were observed on the upper region of the downstream area. These tributaries supply fresh water to the stream.

pH

The highest pH level was observed on the midstream area (Figure 2). Since the optimal pH value for a freshwater river is 6.50-8.00, the midstream area and the downstream area were observed to have values beyond the optimal level.

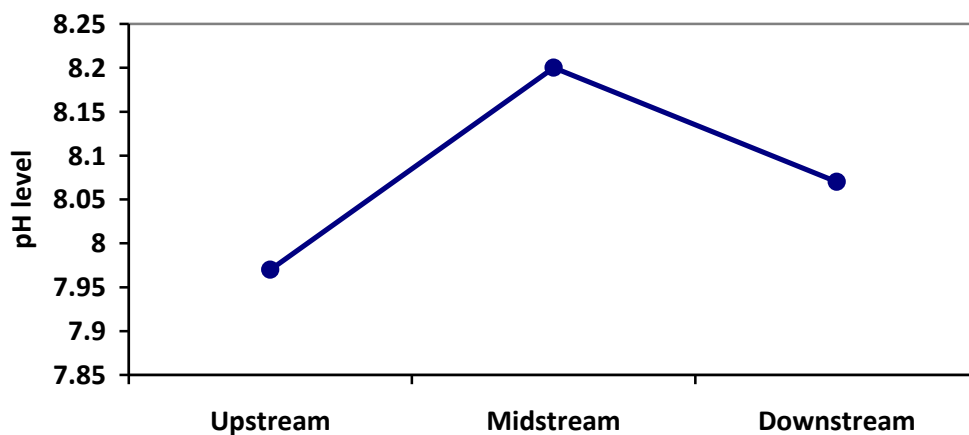


Figure 2. pH level on the different sampling sites in Malingin stream, *Campo Siete*, Minglanilla, Cebu.

A good detergent soap must have a pH level of 9 to 11. The detergent soaps used from the residences on the midstream and the laundry area on the downstream has been assumed to have contributed to the high pH level on the said areas. However, water sample was not sent for laboratory analysis, hence, only assumptions were made.

Dissolved oxygen (DO)

The highest dissolved oxygen value was observed in the downstream area , while the least value was observed on the upstream area (Figure 3). For a river to sustain aquatic life, it must have minimum dissolved oxygen of 6 mg O₂/L. The three sampling sites have DO level above maximum which indicated that the stream was capable of supplying enough oxygen to sustain macroinvertebrates.

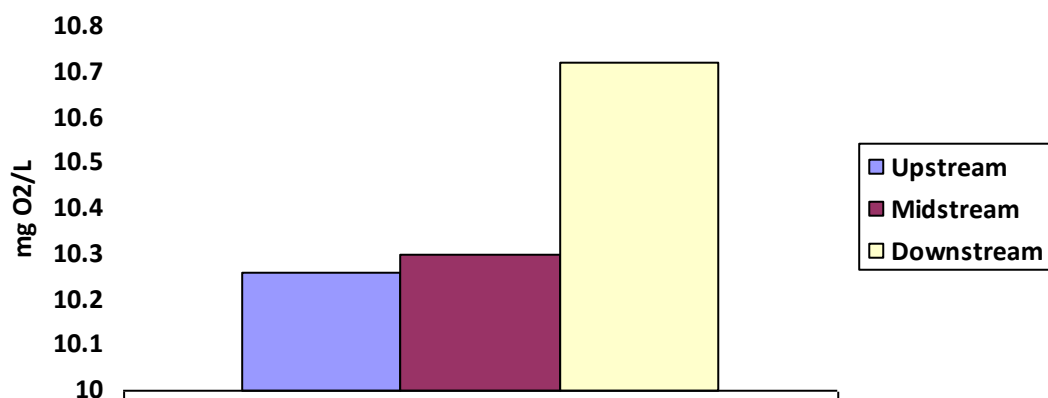


Figure 3. Dissolved oxygen level on the different sampling sites in Malingin stream, Campo Siete, Minglanilla, Cebu.

Dissolved oxygen is the measurement of the amount of gaseous oxygen dissolved in an aqueous solution. Oxygen gets into water by diffusion from the surrounding air, by aeration or rapid movement, and as a waste product of photosynthesis. Upstream area had the lowest DO level since it has the calmest stream flow among the three sampling sites. Downstream area had the highest DO level since most riffles were observed that caused rapid movement of the stream. This implies that downstream area can sustain more macroinvertebrates compared to the other two sampling sites.

Total Dissolved Solids (TDS)

The highest level of TDS was observed on the midstream while the lowest level was observed on the downstream (Figure 4). The maximum contamination level of a freshwater is 500 mg/L. When the TDS level exceeds 1000 mg/L it is generally considered unfit for human consumption. The three sampling sites were observed to have TDS below the maximum contamination level.

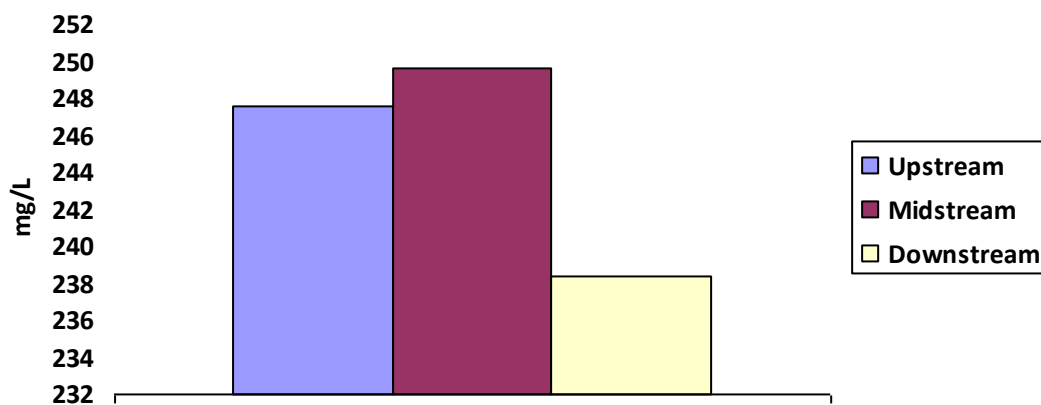


Figure 4. Total Dissolved Solids on the different sampling sites in Malingin stream, Campo Siete, Minglanilla, Cebu.

TDS is a measure of the dissolved matters such as salts, organic matter, minerals, etc. in water. Although TDS is not generally considered a primary pollutant it is used as an indication of aesthetic characteristics of potable water and as a total indicator of the presence of a wide range of chemical contaminants.

Temperature

In this study, only the temperature on the surface water was measured. Highest temperature level was observed in the midstream area while the coldest is observed in the upstream area (Figure 5).

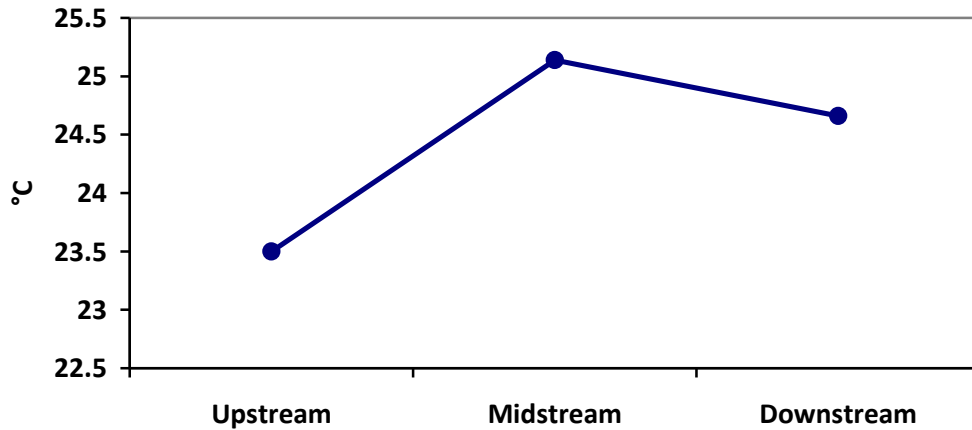


Figure 5. Temperature levels on the different sampling sites in Malingin stream, Campo Siete, Minglanilla, Cebu.

There were no published articles specifying a certain temperature range wherein macroinvertebrates and other aquatic life forms can survive. However, water temperature affects streams indirectly by influencing the DO concentrations. Warm water can hold less oxygen in solution than cold water.

Biological Parameter

Richness and composition measures

Overall, the total number of macroinvertebrate individuals with 1,641 present belonging to 32 families. The number of individuals may vary from season to season, but since no study was yet published in the area of study, comparison through seasons was not done. According to the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), the month of January had the La Niña condition which means that the country experienced normal rainfall distribution. The sampling was done on the third week of January which implied that the volume of water in the river could be higher than the usual, and the temperature is colder, which means that the stream is favorable for macroinvertebrates' survival.

Most number of macroinvertebrates was observed on the downstream while the midstream area had the least number collected macroinvertebrates (Figure 6).

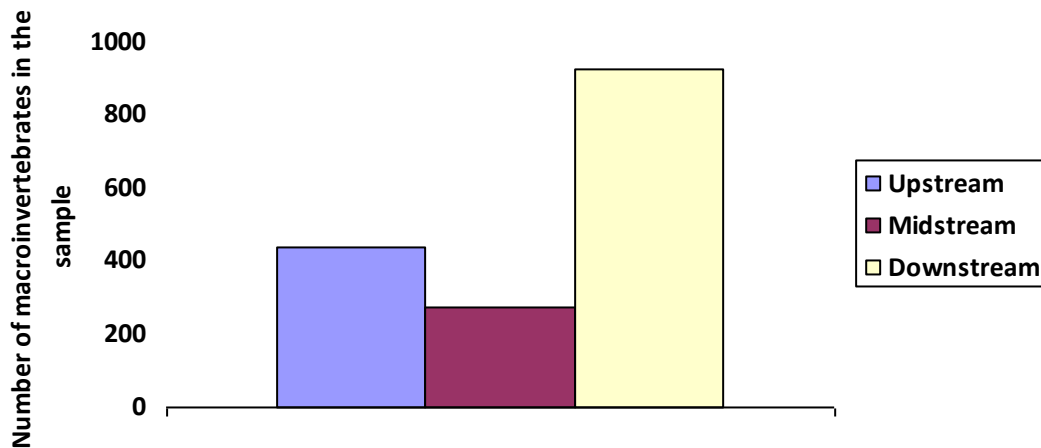


Figure 6. Number of individual macroinvertebrates collected on different sampling sites in Malingin stream in *Campo Siete*, Minglanilla, Cebu.

The lowest score obtained by the midstream area was accounted to the high level of domestic sewage from the residential area. Upstream having the second lowest may be due to the soil quarry in the upper area near the site. Highest number was observed on the downstream area because of its distance from the residential area and the flowing tributaries on the upper area of the said sampling site.

The highest family richness was observed on the downstream area. It is followed by the upstream area and the least family richness was observed on the midstream area (Figure 7). However, the upstream area had higher EPT family richness relative to its overall family richness, when compared to the upstream area. Organisms that belong to the EPT taxa are considered to be highly sensitive to pollution and human perturbation

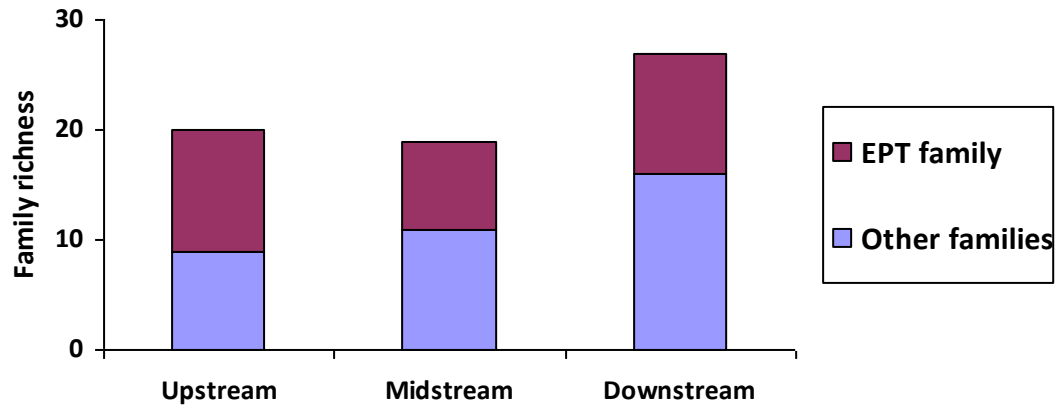


Figure 7. Family richness and composition measure of macroinvertebrates collected on the three sites in Malingin stream in *Campo Siete*, Minglanilla, Cebu.

This would imply that downstream area had exhibited a more diverse macroinvertebrate community, thus, resulted to less EPT family richness relative to its total family richness.

Tolerance measures

In this study, not only the EPT families, which were considered to be the most sensitive to pollution, were measured but also the overall intolerant family measurement. Upstream area still had higher number of intolerant families, but the difference is relatively insignificant when compared to the intolerant families in the downstream area (Figure 8). Midstream area had the lowest number of intolerant families.

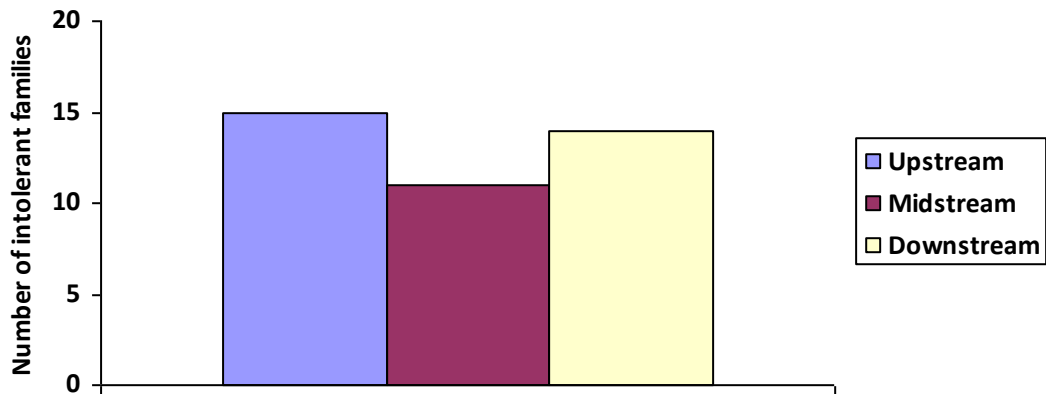


Figure 8. Number of intolerant family of macroinvertebrates collected on the different sites in Malingin stream in *Campo Siete*, Minglanilla, Cebu.

The data showed consistent results; upstream area had higher EPT and other intolerant families followed by the downstream area, while midstream area had the lowest count. This may be accounted back to the human activities near the sampling sites. Since midstream had the highest possible human perturbation and pollutant in the stream, it resulted to less abundance and diversity of the macroinvertebrates. Upstream area relatively had the highest intolerant families than the two other sampling sites but downstream area had highest number of macroinvertebrate individuals and highest number of family richness. This implied that downstream area had the most diverse macroinvertebrate community than the two other sampling sites, only that, it was represented by few intolerant families.

For emphasis of showing the relatively more polluted sampling site, the percent of tolerant organisms was also measured. Midstream area showed the highest percent of tolerant organisms (Figure 9).

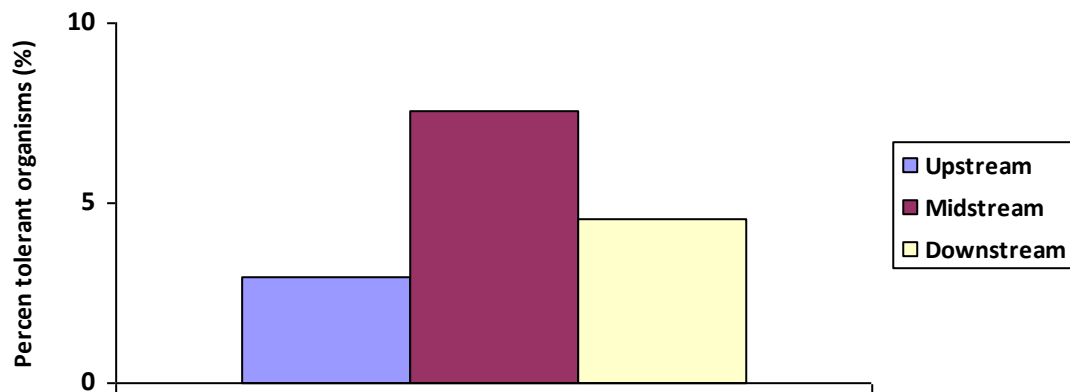


Figure 9. Percent of tolerant family of macroinvertebrates collected on the different sites in Malingin stream in *Campo Siete*, Minglanilla, Cebu.

Tolerant macroinvertebrates are the ones that can thrive into different conditions of their environment; even the harsh conditions wherein high pollutants are found. Higher percent of pollution tolerant macroinvertebrates and less percent of sensitive ones could indicate poor water or habitat quality index. The domestic, pigpen drainage systems, and high human activities contributed to the high percent of tolerant organisms in the midstream area.

Hilsenhoff Biotic Index (HBI; Bode 1988, Lehmkühl 1979) is a measure of the macroinvertebrate assemblage tolerance toward organic enrichment. It measures the health of a stream on a scale of 1-10 that is based on the macroinvertebrate communities present. The lower the index score is, the healthier the stream water. Midstream area had the highest HBI score while downstream area had the lowest HBI score (Table 2). Upstream and midstream area had scores which indicated a very good water quality (3.51-4.50) with only a slight organic pollution. On the other hand, the downstream area had a score which indicated to have an excellent water quality (0.00-3.50) and without apparent organic pollution.

Table 2. Hilsenhoff Biotic Index scores on the different sites in Malingin stream in Campo Siete, Minglanilla, Cebu.

	Upstream	Midstream	Downstream
Hilsenhoff Biotic Index	3.89	4.04	3.33

Trophic/habit measures

Percent clingers are the percent of insects having fixed retreats or adaptations for attachment to surfaces in flowing water. Upstream area had the highest percent of clingers (Figure 10) since its substrate was composed of large rocks.

Shredders are macroinvertebrates that shreds leaves and is one of the organisms that are more sensitive and are thought to be well represented in healthy streams. Highest percent of shredders are found on the upstream area since both sides of the river are surrounded with trees and the leaves fall directly on the stream. The highest percent of predators were also found on the upstream area since it is assumed that more foods were available for them in order to survive.

The percent of the macroinvertebrates that gather was the largest portion of the sample. Midstream area had the highest percent of gatherers since a wide range of food can be found in the area, where there are also high waste products from domestic drainages.

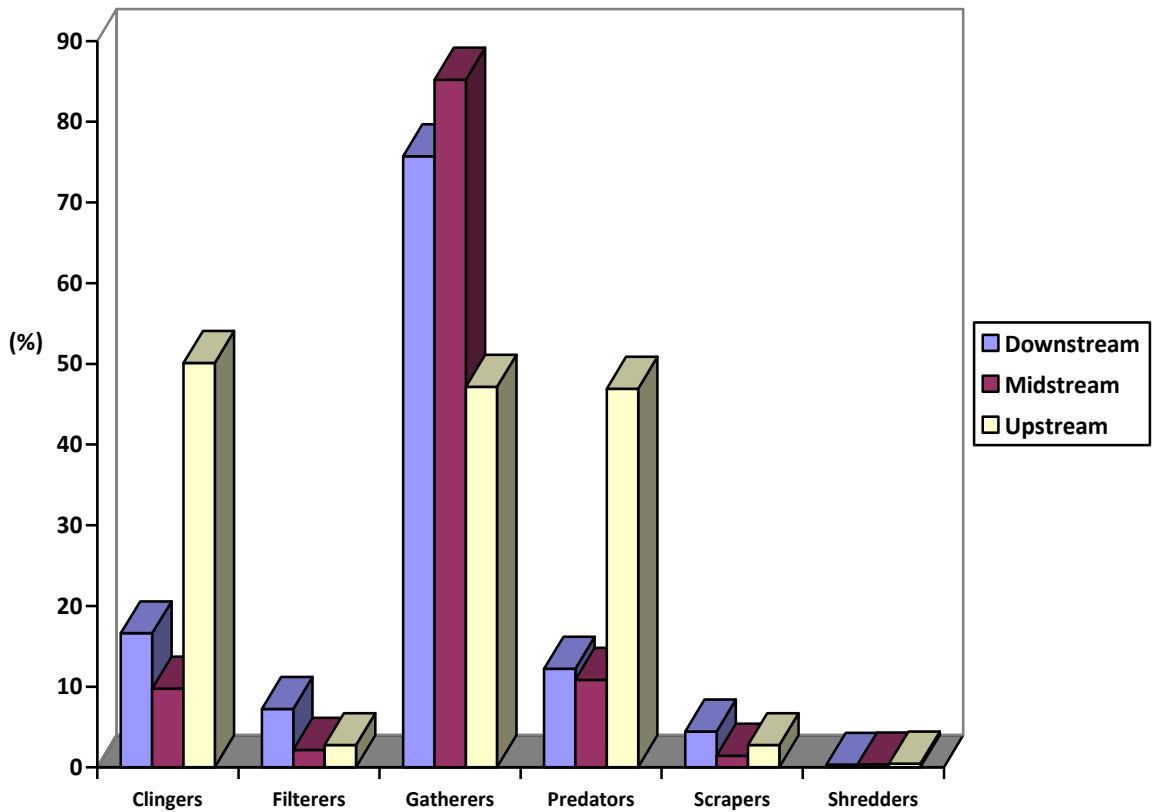


Figure 10. Percent of different functional feeding groups on the different sites in Malingin stream in *Campo Siete*, Minglanilla, Cebu.

Percent filterers is the percent of the macroinvertebrates that filter fine particulate organic matter (FPOM) from either the water column or sediment. These percentages decrease with increasing perturbation. Filter feeders are also sensitive in low-gradient streams (Wallace et al. 1977). The highest percent filterer was observed on downstream site.

Scrapers mostly consume the periphytons attached to the rocks on the substrate of riverbeds. Highest percent scraper was found in the downstream area, since it had the area with the most algae found attached to the rocks on the riverbed.

Biological Monitoring Working Party (BMWP) and Average Score Per Taxon (ASPT)

A river having a BMWP score greater than 100 is categorized as having a very good water quality. This would indicate an unpolluted and unimpacted river. All the sampling sites in the river had scores greater than 100 (Table 3).

Table 3. BMWP and ASPT values calculated on the three sampling sites in Malingin stream, *Campo Siete*, Minglanilla, Cebu.

	Upstream	Midstream	Downstream	Total/Average
BMWP	132	118	161	137
ASPT	6.6	6.2	5.96	6.25

Downstream area had the greatest BMWP score, since it was far from the residence area and the tributaries located near the area supply cleaner water to the stream. The upstream was the area having the second highest score since it was far from the residence area. Due to the soil quarry located just above the source of water, the BMWP score of the upstream is lower than the downstream. Midstream had the lowest BMWP since the site is located on the residence area, but it had still a score greater than 100, thus, was still considered having good water quality.

An ASPT value greater than 4 generally indicates good water quality. All the three sites had good water quality since they all had ASPT values greater than 4.

Upstream area had the highest ASPT score while the downstream area had the lowest ASPT value. This was due to the high number of intolerant families relative to its overall family richness in the upstream area, thus having the highest value.

Summary

Monitoring the water quality of the stream can be carried out through the use of macroinvertebrate as biological indicators, together with the measurement of the physical parameters. The measurements used responded to the varying human perturbation along the stream (Table 4).

Table 4. Summarized metrics and other measurements on the three sampling sites in Malingin stream, *Campo Siete*, Minglanilla, Cebu

	Upstream	Midstream	Downstream
Characteristics	Rocky (large) substrate, trees cover both sides of the stream	Rocky (medium-sized) substrate, plastic garbage were observed	Rocky (medium-sized) substrate, grasses were found along riverbanks
Anthropogenic activities	Soil quarry on the upper area, plant nursery nearby	Residential area, domestic waste drainage, pigpen drainage, bridge construction	Laundry area on the upper region
Physicochemical measures			
pH	7.97	8.20	8.07
Dissolved oxygen	10.26 mg O ₂ /L	10.30 mg O ₂ /L	10.72 mg O ₂ /z
Total Dissolved Solids	247.6 mg/L	249.6 mg/L	238.4 mg/L
Temperature	23.5°C	25.14°C	24.66°C
%EPT	55.00	42.11	40.74
Tolerance measures			
Number of intolerant family	15	11	14
% Tolerant organisms	2.97	7.58	4.53
Hilsenhoff Biotic Index	3.89	4.04	3.33

Table 4. Continued

	Upstream	Midstream	Downstream
Trophic/habit measures			
% Clingers	50.11	9.75	16.61
% Filterers	2.75	2.17	7.23
% Shredders	0.46	0.36	0.32
% Gatherers	47.14	85.20	75.73
% Predators	46.91	10.83	12.20
% Scrapers	2.75	1.44	4.42
BMWP and ASPT values			
BMWP	132	118	161
ASPT	6.6	6.2	5.96

The different human activities along the stream had influenced the physicochemical characteristics of the water. Macroinvertebrates need optimum characteristics of water in order to survive. When there are changes in the physicochemical parameters of the stream water, the abundance and richness of the macroinvertebrate community was affected as well.

Conclusion

The biological metric calculations indicated that midstream area had slightly polluted water quality since it was located on the residential area where human perturbation and organic pollution was high. The upstream area had a very good water quality since it was located far from the residential area and with only a slight disturbance from the soil quarry on its upper region. Downstream area had excellent water quality since it was also far from the residential area, and two tributaries supplied freshwater to the stream. Moreover, downstream had the most suitable physicochemical parameters for the survival of aquatic life. Overall, Malingin Stream in *Campo Siete*, Minglanilla, Cebu had a very good water quality with only a slight pollution.

Recommendation

For future studies, I highly recommend to consider the seasonality for the collection of samples. Since macroinvertebrate population also react to changes in the physicochemical properties, temperature, and current velocity in rivers, it is best to compare the abundance and richness across the different seasons throughout the year. I also recommend to measure chloride, nitrate, and phosphate concentration of the water sample through laboratory analysis.

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Appendix A

Table 1. Family-level pollution tolerance scores for the HBI. Adapted from Bode (1988), Hilsenhoff (1988), and Lemkuhl 1979).

Plecoptera	Capniidae 1, Chloroperlidae 1, Leuctridae 0, Nemouridae 2, Perlidae 1, Perlodidae 2, Pteronarcyidae 0, Taeniopterygidae 2
Ephemeroptera	Baetidae 4, Baetiscidae 3, Caenidae 7, Ephemerellidae 1, Ephemeridae 4, Heptageniidae 4, Leptophlebiidae 2, Metretopodiidae 2, Oligoneuriidae 2, Polymitarcyidae 2, Potomanthidae 4, Siphonuridae 7
Tricorythidae	4
Odonata	Aeshnidae 3, Calopterygidae 5, Coenagrionidae 9, Cordulegastridae 3, Corduliidae 5, Gomphidae 1, Lestidae 9, Libellulidae 9, Macromiidae 3
Trichoptera	Brachycentridae 1, Glososomatidae 0, Helicopsychidae 3, Hydropsychidae 4, Hydroptilidae 4, Lepidostomatidae 1, Leptoceridae 4, Limnephilidae 4, Molannidae 6, Odontoceridae 0, Philopotamidae 3, Phryganeidae 4, Polycentropodidae 6, Psychomyiidae 2, Rhyacophilidae 0, Sericostomatidae 3
Megaloptera	Corydalidae 0, Sialidae 4
Lepidoptera	Pyralidae 5
Coleoptera	Dryopidae 5, Elmidae 4, Psephenidae 4
Diptera	Athericidae 2, Blephariceridae 0, Ceratopogonidae 6, blood-red Chironomidae (Chironomini) 8, Other (including pink) Chironimidae 6, Dolichopodidae 4, Empididae 6, Ephydriidae 6, Psychodidae 10, Simuliidae 6, Muscidae 6, Syrphidae 10, Tabanidae 6, Ptilidae 3
Amphipoda	Gammaridae 4, Talitridae 8
Isopoda	Asellidae 8
Acariformes	4
Decapoda	6
Gastropoda	Amnicola 8, Bithynia 8, Ferrissia 6, Gyraulus 8, Helisoma 6, Lymnaea 6, Physa 8, Sphariidae 8
Oligochaeta	Chaetogaster 6, Dero 10, Nais barbata 8, Nais beningi 6, Nais bretscheri 6, Nais communis 8, Nais elinguis 10, Nais pardalis 8, Nais simplex 6, Nais verbaalis 10, Pristina, Stylaria 8, Tubificidae: Aulodrilus 8, Limnodrilus 10
Hirudinae	Helobdella 10
Tubellaria	4

Table 1a. Water quality based on Family Biotic Index (adapted from Hilsenhoff, 1977)

Biotic index	Water quality	Degree of organic pollution
0.00-3.50	Excellent	No apparent organic pollution
3.51-4.50	Very good	Possible slight organic pollution
4.51-5.50	Good	Some organic pollution
5.51-6.50	Fair	Fairly significant organic pollution
7.51-8.50	Poor	Very significant organic pollution
8.51-10.0	Very poor	Severe organic pollution

Table 2. Biological Monitoring Working Party (BMWP) score for each group of macroinvertebrate.

Score	Groups of organisms
10	Siphonuridae, Heptageniidae, Leptophlebiidae, Ephemerellidae, Potamanthidae, Ephemeridae, Taeniopterygidae, Leuctridae, Capniidae, Perlolodaem Perlidae, Chloroperlidae, Aphelocheiridae Phryganeidae, Molannidae, Beraeidae, Odontoceridae, Leptoceridae, Goeridae, Lepidostomatidae, Brachycentridae, Sericostomatidae
8	Astacidae Lestidae, Agriidae, Gomphidae, Cordulegasteridae, Aeshnidae, Corduliidae, Libellulidae, Psychomyiidae (Ecnomidae), Phylopotamidae
7	Caenidae Nemouridae Rhyacophilidae (Glossosomatidae), Polycentropodidae, Limniphilidae
6	Nertidae, Viviparidae, Ancylidae (Acroloxidae) Hydroptilidae Unionidae Corophiidae, Gammaridae (Crangonyctidae) Platycnemididae, Coenagriidae
5	Mesovelidaem Hydrimetridae, Gerridae, Nepidae, Nausoridae, Notonectidae, Pleidae, Corixidae, Halipidae, Hygrobiidae, Dytiscidae (Noteridae), Gyrinidae, Hydrphilidae (Hyaenidae), Clambidaem Sciritidae, Dryopidae, Elmidae Hydropsychidae Tipulidae, Simuliidae Planariidae (Dogediidae), Dendrocoelidae
4	Baetidae Sialidae Pisicolidae
3	Valvatidae, Hydrobiidae (Bithyniidae), Lynnaeidae, Physidae, Planorbidae, Spheriidae Glossiphoniidae, Hirdinidae, Erpobdelidae
2	Chironomidae
1	Oligochaeta

Appendix B

Table 1. Raw data of the richness and composition measure of macroinvertebrates collected on the three sampling sites in Malingin stream, *Campo Siete*, Minglanilla, Cebu.

	Upstream	Midstream	Downstream	Average
Number of organisms	437	277	927	Total: 1,641
Family richness	20	19	27	22
EPT family richness	11	8	11	10

Table 2. Raw data of the tolerance measures of macroinvertebrates collected on the three sampling sites in Malingin stream, *Campo Siete*, Minglanilla, Cebu.

	Upstream	Midstream	Downstream	Average
Number of intolerant family	15	11	14	13.33
% Tolerant organisms	2.97	7.58	4.53	5.03
Hilsenhoff Biotic Index	3.89	4.04	3.33	3.75

Table 3. Trophic/habit measures of macroinvertebrates collected on the three sampling sites in Malingin stream, *Campo Siete*, Minglanilla, Cebu.

	Upstream	Midstream	Downstream	Total/Average
% Clingers	50.11	9.75	16.61	25.49
% Filterers	2.75	2.17	7.23	4.05
% Shredders	0.46	0.36	0.32	0.38
% Gatherers	47.14	85.20	75.73	69.36
% Predators	46.91	10.83	12.20	23.31
% Scrapers	2.75	1.44	4.42	2.87

Table 4. Physical measurements of Malingin stream in *Campo Siete*, Minglanilla, Cebu.

	Upstream	Midstream	Downstream
Width	3.58 m	3.27 m	8.76 m
Depth	0.11 m	0.11 m	0.11 m
Current	0.27 m/sec	0.54 m/sec	0.57 m/sec

Appendix C

Table 1. Some of the collected benthic macroinvertebrates in Malingin stream, Campo Siete,




Photo	Identification
	<p>Common name: Common net-spinner caddisflies Order: Trichoptera Family: Hydropsychidae Magnification: 14x</p>
	<p>Common name: Common stoneflies Order: Plecoptera Family: Perlidae Magnification: 14x</p>
	<p>Common name: Dragonfly Order: Odonata Family: Libellulidae Magnification: 14x</p>

Table 1. *Continued*






Photo	Identification
	<p>Common name: Finger-net caddisflies Order: Trichoptera Family: Philopotamidae Magnification: 14x</p>
	<p>Common name: Freshwater crab Order: Decapoda Family: Potamidae</p>
	<p>Common name: Long-toed water beetles Order: Coleoptera Family: Dryopidae Magnification: 14x</p>
	<p>Common name: Prong-gilled mayflies Order: Ephemeroptera Family: Leptophlebiidae Magnification: 14x</p>

Table 1. *Continued*

Photo	Identification
 A small, yellowish-brown nymph of a minnow mayfly, viewed from the side. It has a segmented body, long antennae, and a prominent head with large eyes.	<p>Common name: Small minnow mayflies Order: Ephemeroptera Family: Baetidae Magnification: 14x</p>
 A small, brownish nymph of a square-gill mayfly, viewed from the side. It has a segmented body, long antennae, and a prominent head with large eyes.	<p>Common name: Small square-gill mayflies Order: Ephemeroptera Family: Caenidae Magnification: 14x</p>
 A large, oval-shaped nymph of a water penny, viewed from the side. It has a segmented body, long antennae, and a prominent head with large eyes.	<p>Common name: Water pennies Order: Coleoptera Family: Psephenidae Magnification: 14x</p>

Curriculum Vitae

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