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Impacts of Anthropogenic Disturbances on Macroinvertebrate Communities in Streams of Catanduanes Watershed Forest Reserve, Catanduanes, Philippines and the Need for Conservation

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ABSTRACT

Macroinvertebrate communities at nine streams located in three towns (Virac, Bato, and San Miguel) spanning the Catanduanes Watershed Forest Reserve in Catanduanes, Philippines, were assessed in terms of their responses to three anthropogenic disturbances: domestic, agricultural, and quarry. Macroinvertebrate sampling was done using a $1m^2$ bottom kick net. A total of 62 macroinvertebrate taxa distributed to 53 Families were identified. Insect orders Ephemeroptera, Trichoptera, and Plecoptera which are known indicators of good water quality, were relatively abundant in most streams compared to other groups. Macroinvertebrate density and richness in relatively undisturbed stations were significantly higher ($p<0.05$) than those recorded in streams with quarrying activities, which fall in Q3 of SIGNAL 2 biplot, suggesting negative effects of quarrying. Macroinvertebrate density showed positive correlation with dissolved oxygen and stream depth, width, and velocity, and was found to increase upstream with increasing stream width. Macroinvertebrate taxa richness generated a negative correlation to stream width and temperature. Overall, most streams in Catanduanes Watershed Forest Reserve are still in good condition however, with the negative effects of anthropogenic activities, condition of streams may change without proper watershed management. This study demonstrates the need to further strengthen policies on stream management to protect and conserve them.

Key words: anthropogenic disturbance, macroinvertebrates, stream condition, watershed

INTRODUCTION

Conservation and protection of streams have long been daunting as a result of alarming rate of habitat degradation due to increased population growth. Aquatic life present in watershed forest reserves will only survive in good quality surface waters. Streams and rivers in the watershed transport water and nutrients over long distances and provide habitat for numerous plants and animals. They also offer areas for recreational use and as source of livelihood to the communities. At present, the Catanduanes Watershed Forest Reserve (CWFR) faces various environmental pressures, mainly population growth in the uplands that eventually lead to the increase in demand of settlements, food production, and agricultural development. These anthropogenic pressures can affect the future supply and quality of water which can be reflected in the biological composition and diversity in the area. Therefore, it is important to establish water quality monitoring that can aid in the management of surface water within the watershed forest, like – for example –using benthic macroinvertebrates as bioindicators of pollution.

The use of benthic macroinvertebrates to assess water quality is a globally- accepted method. It is considered as the most reliable and suitable method in determining the impact of environmental perturbations as well as the overall health status of aquatic environment (Hodkinson & Jackson, 2005; Olomukoro & Dirisu, 2013). Macrobenthic invertebrates are useful bioindicators in understanding ecological health, as opposed to the use of chemical and microbiological data, since they reflect the cumulative effects of present and past conditions. It also serves as a model for monitoring, restoring and maintaining the quality of stream ecosystem (Rosenberg & Resh, 1993 as cited by Mesa *et al*.., 2013).

Development of certain water quality regulation and monitoring methods involves the use of indicator organisms (e.g. invertebrates) that are sensitive to the slightest change in their environment (Hodkinson & Jackson, 2005). Macroinvertebrates which were utilized in aquatic pollution studies include mayflies (Ephemeroptera), caddisflies (Trichoptera), stoneflies (Plecoptera), beetles (Coleoptera), crayfish and amphids (Crustaceans), aquatic snails (Mollusca), biting midges (Chironomidae), and leeches (Hirudinea). These organisms are used to characterize the current status and predict significant changes in the water quality and habitat stability (Olomukoro & Dirisu, 2013).

In this study, we assessed stream health based on macroinvertebrate community composition of selected streams in the Catanduanes Watershed Forest Reserve. Physical and chemical characteristics were also compared among streams that are subjected to major land uses (i.e. domestic, agricultural, and quarry).

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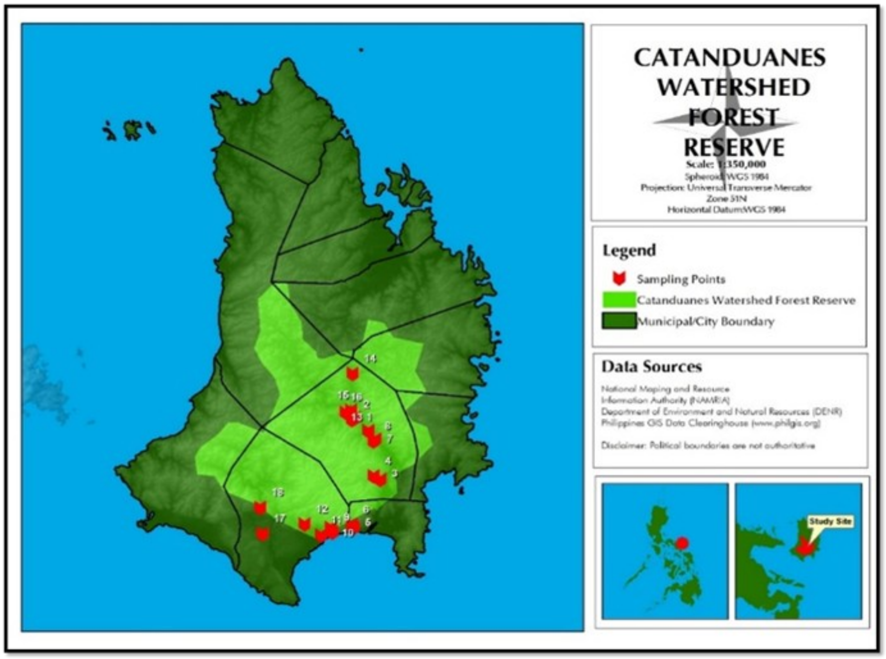

Figure 1. Location of surveyed stations, within and adjacent to CWFR.

MATERIALS AND METHODS

Study area

The study was conducted in the Catanduanes Watershed Forest Reserve (CWFR), which lies between 124.05˚ and 124.21˚East longitude and 13.35˚ to 13.51˚ North latitude (Figure 1). It covers forested areas, including some lands from different municipalities. The area is under Type II climate classification thus, having no distinct dry season with a very pronounced rainfall which is usually from November to January when storms are more frequent and low pressure systems are active. The island is often visited by typhoons since it is situated within the typhoon belt. Inland waters in the province have an intricate network of rivers, streams, and creeks that serve as natural drainage. Catanduanes has 22 river basins with a total drainage area of 1,485 square kilometers, four of which are considered principal waterways namely Bato River, Pajo River, Viga River, and Manuria River. The study included river basins covered by and adjacent to the CWFR.

Selection of study sites

A map of CWFR was obtained from the Provincial Environment and Natural Resources Office (PENRO) and used as guide to locate rivers and streams within or adjacent to the watershed. Three major land uses in the province – agricultural, domestic and quarrying activities – were selected based on the key management issues and threats listed in the CWFR Adaptive Management Plan of DENR.

Three replicate sites for each major land use were identified. Selected streams were grouped according to the disturbances present near the water bodies. Pagsangahan, Progreso and Sto. Domingo are the replicate sites exposed to quarrying activities; Mabato, Siban'an and Sto. Nino, to agricultural activities; and Balatohan, Maribini and Solong to domestic activities. Two stations at each replicate site were sampled: the upstream (US) station or relatively undisturbed, and the downstream (DS) station or those affected by anthropogenic activities. Upstream sections were established at approximately 500 meters upstream of sampling stations for each stream. Study sites were located in the municipalities of Virac, Bato, and San Miguel. The selected streams of Balatohan, Mabato, Pagsangahan, Progreso, and Solong are located in the municipality of San Miguel while Maribina is located in the municipality of Bato. Three of the streams are located in the municipality of Virac namely Siban'an, Sto. Niño, and Sto. Domingo. All their headwaters originate from the upstream areas of CWFR.

A total of eighteen sampling stations were established. The coordinates and elevations of sampling stations were determined using a Global Positioning System (GPS) unit (Garmin, Etrex 10). Site reconnaissance in areas near CWFR was undertaken prior to the actual survey to facilitate familiarization of the area. This was to expedite the establishment of sampling points. The reconnaissance was aided by barangay officials from the local community.

Measurement of physical and chemical instream parameters

On-site measurements were done in three replicates for physical and chemical instream parameters at each sampling station. Flow velocity, stream width, and depth, were measured using protocols adapted from the United States Environmental Protection Agency (USEPA) and Volunteer Stream Monitoring Methods Manual (1997). Dissolved oxygen (DO), pH, temperature and conductivity were measured in-situ using handheld water quality meters (Hanna, Merck Inc.).

Macroinvertebrate sampling

Benthic macroinvertebrates were collected from a 100-meter stream reach. Using a bottom kick net (1 mm mesh size), collection of samples was done on wadeable productive spots (i.e. riffles and runs) and also near bank habitats where most species are found. With the kick net facing upstream, macroinvertebrates were dislodged through kicking and disturbing sediments within the area of one square meter. All dislodged organisms were carried by the water into the net. Collected macroinvertebrates were transferred into resealable storage bags. Two replicate samples were collected from each longitudinal stretch per site. All collected samples were immediately fixed with 10% formaldehyde in the field, properly labelled, and were transferred to the laboratory for sorting and identification.

Macroinvertebrate sampling was undertaken for a period of six months, from February 2014 to August 2014.

Habitat assessment

Standard procedures on habitat assessment made by the U.S. Environmental Protection Agency (USEPA, 1999) were done using a modified USEPA physical characterization field data sheet. It involves the assessment of the quality of in-stream and riparian habitat that influences the structure and function of the aquatic community in a stream. The procedure uses the same 100-meter reach of every sampling site from which the biological sampling was conducted. It also uses parameters that require an observation of a broader section of the catchment than just the sampling reach. A closer look at the habitat features was done to make an adequate assessment.

Community and biotic indices

Macroinvertebrate community indices such as species richness, density, diversity (Shannon-Wiener Diversity Index, H'), and evenness (e) were computed. The Hilsenhoff Biotic Index (HBI) was also used to determine water quality of selected sites. This involves the identification of family-level pollution tolerance scores of the identified organisms. Tolerance values on a 0 (sensitive to pollution) to 10 (tolerance of pollution) scales were assigned to invertebrate taxa. The biotic index was originally developed to detect the effects of organic pollution. The HBI is the average tolerance for the community, weighted by the number of individuals in each family (Hilsenhoff, 1977). Lastly, SIGNAL 2 scores were computed to give an indication of water quality in the river from where the samples were collected. Rivers with high Signal Scores are likely to have low levels of salinity, turbidity and nutrients such as nitrogen and phosphorus. They also have high levels of dissolved oxygen (Chessman, 2003). Each type of macroinvertebrate was assigned a 'grade number' between 1 and 10. Weight factors were used in calculating Signal scores.

Statistical analysis

Pearson correlation was used to describe the relationship of the macroinvertebrate basic matrices for richness, composition, to the physical and chemical parameters of streams. The macroinvertebrate attributes and physical/chemical variables were compared using the one-way Analysis of Variance (ANOVA). The extension of ANOVA, which is the analysis of covariance (ANCOVA) was used to explore the differences between groups. In addition, Canonical Correspondence Analysis (CCA), a multivariate method was used to explain the relationships between biological assemblages of species and their environment. It was used in describing and visualizing the differential habitat preferences of taxa via an ordination diagram.

RESULTS

Rapid Habitat Assessment

Habitat assessment on streams was done in order to determine whether the streams are supporting the aquatic life or not. It is also used to characterize the existence and severity of habitat degradation. Table 1 shows the rapid habitat assessment scores of the selected streams. All streams that were assessed were classified as high gradient streams since all had exhibited riffle/pool sequences. Results revealed that upstream sections of the streams had good habitat conditions while downstream sections had habitat conditions ranging from poor to good conditions. Among all the disturbed stream sections assessed, only Pagsangahan and Progreso had good habitat condition. Meanwhile, downstream sections of Mabato, Solong, Sto. Domingo and Balatohan had fair habitat condition. Moreover, downstream sections of Siban'an, Maribina and Sto. Niño had poor habitat condition. These streams had low epifaunal substrate providing only few surfaces in which aquatic organisms can live. The bottom structures of the streams were covered with sand and silt leaving little room for organisms to the structure for cover, resting, spawning and feeding. These streams also had poor bank stability since non-vegetated banks, exposed tree roots and exposed soil were observed in the area. The streams also had no riparian vegetation due to anthropogenic activities.

Macroinvertebrate Composition

A total of 20,427 individuals of benthic macroinvertebrates were collected from nine selected streams within and adjacent to CWFR from February to May and from July to August 2014. The most dominant group was Class Insecta representing 95.74% of the total abundance. Relatively lower counts were recorded for Phylum Mollusca and Class Turbellaria comprising 0.65% and 0.18% of the total macroinvertebrates, respectively (Table 2).

A total of 62 taxa of macroinvertebrates classified under 53 families were identified. Class Insecta had the highest number of families enumerated, with a total of 43 families. The streams were grouped according to land-uses that are present in the area. Streams with domestic land-uses had the most number of taxa of macroinvertebrates identified, with a total of forty-seven (47) taxa. On the other hand, agriculture and quarry groups had a total of forty-six (46) and forty-seven (47) macroinvertebrate identified taxa, respectively.

Progreso had the highest average number of macroinvertebrate taxa recorded among the nine surveyed streams, with a total of twenty-six (26) taxa. Meanwhile, twenty-four (24) macroinvertebrate taxa were identified in Mabato, and twenty-three (23) taxa were recorded in both Solong and Balatohan. Sto. Niño had the least number of taxa recorded with only sixteen (16) identified macroinvertebrates.

Table 1. Rapid Habitat Assessment (RHA) scores of eighteen sampling stations in Catanduanes Watershed Forest

Habitat Parameters	Mb1	Si1	So1	Pg1	Pr1	SD1	Ba1	Ma1	Sn1	Mb2	Si2	So2	Pg2	Pr2	SD2	Ba2S	Ma2	Sn2
Epifaunal substrate/ Available Cover	17	17	16	16	14	12	16	18	17	14	10	10	14	15	10	13	10	9
Embededdedness	17	18	15	16	14	17	14	13	13	12	8	10	10	15	5	13	8	5
Velocity/Depth/ Regime	15	17	16	10	10	10	13	13	10	10	5	8	14	14	10	10	5	5
Sediment Deposition	20	20	15	20	20	20	20	20	20	10	5	17	15	15	10	16	10	10
Channel Flow Status	10	10	10	15	15	15	15	15	15	12	5	10	15	16	10	10	5	5
Channel Alteration	20	20	15	20	20	20	15	15	15	10	5	15	15	15	10	10	5	5
Frequency of Riffles	16	16	16	20	20	20	15	13	13	15	10	10	15	15	10	10	5	5
Bank Stability																		
left bank	8	9	8	8	8	8	10	8	10	5	2	5	8	8	5	5	5	5
right bank	8	8	8	8	8	8	8	8	8	5	2	5	8	8	5	5	5	5
Vegetation Protection																		
left bank	8	8	8	2	2	2	8	8	5	5	5	2	2	2	2	2	2	2
right bank	8	8	8	2	2	2	8	8	5	5	5	2	2	2	2	2	2	2
Riparian Vegetative Zone Width																		
left bank	8	8	8	10	8	10	8	8	8	2	2	5	8	8	5	2	2	2
right bank	8	8	8	10	8	10	8	8	8	2	2	5	8	8	5	2	2	2
TOTAL	163	167	151	157	149	154	158	155	147	107	66	104	134	141	89	100	66	62
RHA Score	0.82	0.84	0.76	0.79	0.75	0.77	0.79	0.78	0.74	0.54	0.33	0.52	0.67	0.71	0.45	0.50	0.33	0.31
	GC	GC	GC	GC	GC	GC	GC	GC	GC	FC	PC	FC	GC	GC	FC	FC	PC	PC

Descriptions: *GC= good condition, FC=fair condition PC=poor condition; Sites: 1= upstream, 2= downstream; Mb= Mabato, Si=Siban'an, So=Solong, Pg=Pagsangahan, Pr= Progreso, SD= Sto. Domingo, Ba= Balatohan, Ma=Maribina, Sn= Sto. Niño.*

Table 2. Relative abundance (%) and number of families represented within the major taxa of macroinvertebrates in the nine streams within and adjacent to Catanduanes Watershed Forest Reserve from February 2014 to August 2014.

MAJOR TAXA	TOTAL NO. OF FAMILIES	TOTAL NO. OF INDIVIDUALS	RELATIVE ABUNDANCE OF INDIVIDUALS (%)
Anneilda	2	221	1.08
Crustacea	2	481	2.35
Insecta	43	19556	95.74
Mollusca	5	132	0.65
Turbellaria	1	37	0.18
Total	**53**	**20427**	**100**

Table 3. Mean density of macroinvertebrates (±SD) in streams with domestic land uses as disturbance.

TAXA	BALATOHAN MEAN±SD	MARIBINA MEAN±SD	SOLONG MEAN±SD
Annelida	0	2 ±3.26	3 ±2.39
Crustacea	1±0.41	10 ±8.44	2 ±1.21
Coleoptera	33±9.26	8±6.23	15 ±7.11
Diptera	14±5.84	19 ±17.54	9 ±2.29
Ephemeroptera	95±94.11	21 ±14.74	84 ±74.75
Hemiptera	29±13.93	11 ±11.76	23 ±11.31
Lepidoptera	3±2.23	1±1.21	1 ±1.21
Odonata	7±3.69	2 ±0.84	2 ±1.60
Plecoptera	0	2 ±1.66	3 ±4.13
Trichoptera	25±7.17	9 ±10.91	38 ±13.07
Bivalvia	0	1 ±.20	0
Gastropoda	1±0.20	5 ±4.86	0
Turbellaria	1±.0.26	1 ±1.22	1±.42
TOTAL	**203±137.10**	**90±82.88**	**179±119.50**

Figure 2 shows the relative percentage composition of major macroinvertebrate taxa present in nine streams. Insects belonging to Orders Trichoptera, Ephemeroptera, Coleoptera and Diptera were present in all nine stations, which had higher percentage composition compared to other groups. Orders Ephemeroptera, Plecoptera and Trichoptera are known bioindicators of stream health. These insect orders are found in streams with high dissolved oxygen levels (Rosenberg & Resh, 1993). Trichoptera had the highest percentage composition in Progreso (35.7%). On the other hand, Order

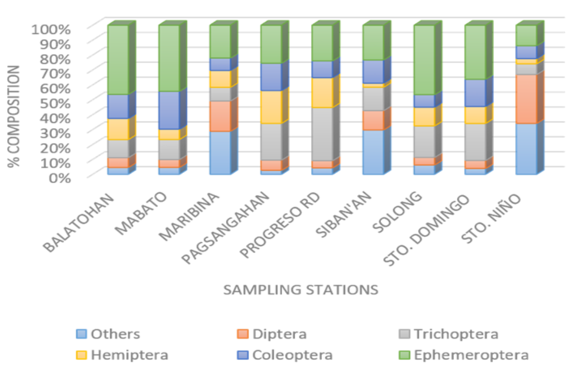

Figure 2. Overall percentage composition of macroinvertebrates in selected nine streams of Catanduanes Watershed Forest Reserve, February 2014 to May 2014 and July 2014 to August 2014.

Ephemeroptera was abundant in the streams of Balatohan (46.4%), Mabato (44.4%), Solong (46.6%) and Sto. Domingo (36.3%). Order Plecoptera was recoded only in Maribina (2.4%) and in Progreso (2.5%).

Macroinvertebrate community in Streams with Domestic Disturbance

Domestic land-uses were observed in the areas near the streams of Balatohan, Solong and Maribina. A total of forty-one taxa were recorded in Balatohan while Solong and Maribina had a total of forty-three (43) and thirty-nine (39) taxa, respectively. Balatohan had the highest number of taxa during the February sampling. Maribina had the lowest number of taxa recorded among the three streams in the month of July.

Mean densities of taxa

The overall mean density of macroinvertebrates in streams with domestic disturbance (Table 3) showed that Order Ephemeroptera had the highest density in all three sites: Balatohan, 945 individuals/m^2; Solong, 84 individuals/m^2; and Maribina, 21 individuals/m^2. The least dense major taxon was Order Turbellaria for which only 1 individual/m^2 was recorded each in Balatohan, Maribina and Solong. Among the three streams, Balatohan had the hightest total mean density of macroinvertebrates with 203 individuals/m^2 while Maribina had the least total mean density recorded with 90 individuals/m^2.

Table 4. Mean density of macroinvertebrates (±SD) in CWFR streams with quarrying activity.

TAXA	PAGSANGAHAN MEAN±SD	PROGRESO MEAN±SD	STO. DOMINGO MEAN±SD
Annelida	0	1±0.42	1±.42
Crustacea	1±.26	1±0.61	1±1.37
Coleoptera	46±20.21	46±16.16	36±26.60
Diptera	17±13.39	20±15.11	11±7.05
Ephemeroptera	64±35.07	97±65.28	72±14.32
Hemiptera	55±50.30	82±41	22±25.94
Lepidoptera	1±.1.41	1±1.16	4±9.96
Odonata	2±2.02	4±0.8	1±1.16
Plecoptera	3±2.75	10±6.96	1±0.41
Trichoptera	62±27.62	145±69.73	49±26.25
Bivalvia	0	1±.61	1±0.42
Gastropoda	0	1±.41	1±0.42
Turbellaria	1±.52	1±1.03	1±0.16
TOTAL	**251±153.53**	**406±219.53**	**198±114.57**

Table 5. Mean density of macroinvertebrates (±SD) in CWFR streams with agricultural land uses as disturbance.

TAXA	MABATO MEAN±SD	SIBAN'AN MEAN±SD	STO. NIÑO MEAN±SD
Annelida	0	14±12.82	0
Crustacea	1±1.72	3±2.50	22±12.58
Coleoptera	53±18.26	14±11.33	7±6.27
Diptera	11±4.12	11±5.22	28±12.12
Ephemeroptera	92±54.72	21±20.13	12±9.41
Hemiptera	14±10.41	2±2.11	3±2.56
Lepidoptera	1±.41	4±9.39	1±0.41
Odonata	6±3.97	1±1.13	1±1.20
Plecoptera	1±.94	1±0.82	1±0.84
Trichoptera	28±7.10	14±13.24	6±5.18
Bivalvia	0	0	1±0.41
Gastropoda	0	2±3.22	2±2.52
Turbellaria	1±1.40	0	1±0.26
TOTAL	**207±103.09**	**86±81.89**	**81±53.74**

In Balatohan downstream, Family Baetidae and Naucoridae had high mean densities with 36 individuals/ m^2 and 19 individuals/m^2, respectively. High densities of Family Baetidae (34 individuals/m^2) and Hydropsychidae (11 individuals/m^2) were observed in Solong. Family Chironomidae dominated other taxa in Maribina downstream with 15 individuals/m^2. High densities of Ephemeroptera were observed in the uptream sections of Balatohan (24 individuals/m^2), Solong (31 individuals/m^2), and Maribina (12 individuals/m^2). In addition, high densities of Family Naucoridae was recorded in the uptream sections of Balatohan (10 individuals/m^2) and Solong (12 individuals/m^2). Also, Family Heptageniidae was recorded with high density of 21 individuals/m^2, in Balatohan upstream.

The overall percentage composition of streams sampled with domestic disturbance revealed that the composition of the upstream and downstream sections was relatively the same across sampling periods. Order Ephemeroptera was recorded at high percentage composition during the six-month sampling period except in June when Order Diptera had the highest percentage composition, which was 33.46% downstream and 15.36 % upstream; and in August when Order Trichoptera had the highest percentage composition, representing 35.8% downstream and 26.15% upstream, of the total count, respectively.

Community structure of streams subjected to quarrying

Within the six-month sampling period, a total of forty-five (45) taxa were identified in Progreso, while thirty-four (34) taxa in Pagsangahan and thirty-one (31) taxa in Sto. Domingo. Progreso had the highest number of taxa recorded. A decline in the number of taxa was observed from February (32 taxa) to August (21 taxa). The number of macroinvertebrate taxa in Sto. Domingo fluctuated decreasing in number in April, with only nine recorded taxa.

Table 4 shows the mean density of major macroinvertebrate taxa in streams with quarrying activities. Order Ephemeroptera had the highest mean density among the streams that were sampled. The highest total mean density was recorded in Progreso with 406 individuals/m^2. High mean densities of Orders Trichoptera (145 individuals/m^2), Ephemeroptera (97 individuals/m^2), and Hemiptera (82 individuals/m^2) were also recorded.

All streams with quarrying acitivities were found to have relatively similar macroinvertebrate composition. Orders Ephemeroptera, Trichoptera, Coleoptera and Hemiptera had high percentage composition in both upstream and downstream sections during the six-month sampling period. High percentage composition of Order Trichoptera was observed in the downstream section of the streams during the months of May (48.26%), July (51.70%), and August (53.33%). Order Ephemeroptera was also present in high percentages in both uptream and downstream sections during the months of February (39.78% downstream, 40.28% upstream), March (26. 19% downstream, 31.76 upstream), and April (35. 29% downstream, 36.25 % upstream).

Community structure of streams subjected to agricultural disturbance

A total of forty-one (41) macroinvertebrate taxa were identified both in Mabato and Sto. Niño while in Siban'an, only forty (40) taxa were identified. Mabato had the highest number of identified macroinvertebrate taxa in February and July. The number of macroinvertebrate taxa decreased in all streams from March until May.

Table 5 shows the mean density of the major macroinvertebrate taxa identified in the sampled streams with agricultural disturbances. In Mabato, Orders Ephemeroptera and Coleoptera had high mean densities with 92 individuals/m^2 and 53 individuals/m^2, respectively. Under Order Ephemeroptera, Family Baetidae had the highest density (33 individuals/m^2) while under order Coleoptera, Family Psephenidae had the highest density (14 individuals/m^2). Siban'an also had high density of Order Ephemeroptera with 21 individuals/m^2. On the other hand, Order Diptera and Subphylum Crustacea dominated the stream of Sto. Niño with 28 individuals/m^2 and 22 individuals/m^2 mean densities, respectively. In addition, Family Chironomidae had a density of 20 individuals/m^2 in Sto. Niño.

Order Ephemeroptera had a high percentage composition in both upstream and downstream sections in February and May. Its composition decreased during the July and August sampling. Order Ephemeroptera dominated the downstream sections in February (47.39%) and May (47.42%). Furthermore, high percentage composition of Order Diptera (41.10%) was observed in April.

One-Way ANOVA of macroinvertebrate density and richness

One-way ANOVA (analysis of variance) was conducted to determine whether there are differences in densities and richness of macroinvertebrates subjected to different disturbances. ANOVA revealed that there are statistically significant difference $p< 0.05$ level in macroinvertebrate density: $F(3,104) = 8.17$, $p=.000$ among disturbances. However, the test also revealed that the variances among the three groups are not homogeneous.

The post hoc analysis revealed that the density of macroinvertebrates in upstream stations is significantly higher ($P <.05$) than that recorded in streams with quarrying activities. In addition, no significant difference ($P>.05$) was found between upstream stations and agriculture and domestically- disturbed streams. Both domestic and agriculturally- disturbed streams were found to be significantly different in streams with quarrying activities.

ANOVA also revealed a significant difference ($F_{3, 104} = 5.9$ $P < 0.05$) in richness of macroinvertebrates among habitat conditions. Post hoc analysis showed that macroinvertebrate taxa richness in upstream sections was also significantly higher ($p>0.05$) than that recorded in streams with quarrying activities. No significant difference was found ($p>0.05$) between upstream section and agriculturally- disturbed stream. Likewise, no significant difference was found between upstream stations and streams with domestic disturbance.

Species diversity and biotic index

Shannon-Weiner diversity index. Taxa diversity is a measure of the diversity within an ecological community that incorporates both taxa richness (the number of taxa in a community) and the evenness of taxa abundance. Among the streams with domestic disturbance, Solong had the highest diversity value (2.61 upstream and 2.25 downstream). For the streams with quarrying activities, Pagsangahan had the highest diversity index in both upstream and downstream – 1.35 and 1.36 respectively. On the other hand, Mabato had higher diversity index (2.55upstream, 2.38 downstream) compared to Siban'an and Sto. Niño. Undisturbed sections (upstream) had relatively higher diversity values compared to the disturbed areas (downstream). Streams with quarrying activities had the lowest diversity with index of 2.32.

Index of evenness. The index of evenness ranges from 0 to 1, where the value of 1 means that the taxa are equally represented. An ecosystem has a low taxa evenness if some species are represented by many individuals; while other taxa have very few individuals. The evenness value in upstream areas were higher than the downstream areas. For streams disturbed by domestic activities, evenness ranged from 0.32 (upstream) to 0.26 (downstream); while in stream with quarrying activities, evenness ranged from 0.26 (upstream) to 0.22 (downstream). The upstream portion of stream with agricultural disturbance had 0.30 evenness value; whereas, downstream has only 0.28 evenness.

Hilsenhoff's biotic index (HBI). The biological metrics will help assess the biological condition or health of the creeks. The water quality with reference to the degree of organic pollution was determined using modified Hilsenhoff's Biotic Index. HBI results revealed that both upstream and downstream stations had fair-to-good water quality. Stream sections with domestic disturbance (dowstream) had fair water quality based on thier computed HBI values. The same water quality was observed in the upstreams sections except in Balatohan which had a good water quality. For streams with agricultural disturbance, only Mabato had good water quality. Among the streams with quarry activities, only the downstream section of Progreso had good water quality.

Stream Invertebrate grade number (SIGNAL 2)

SIGNAL provides an indication of the types of pollution and other physical and chemical factors that are affecting

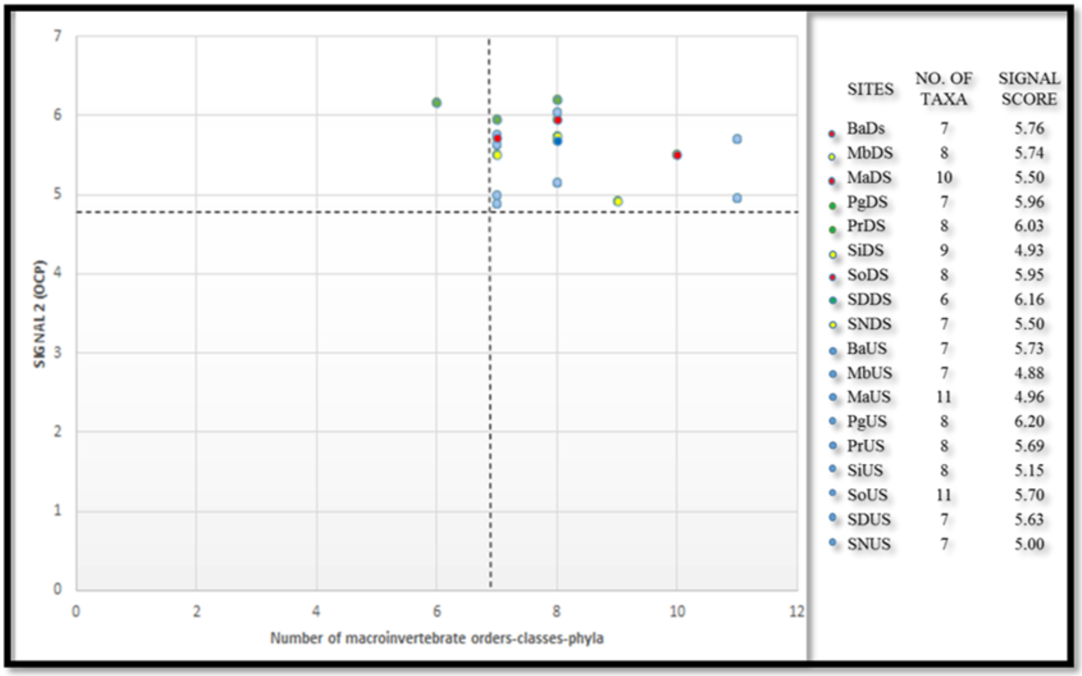

Figure 3. Biplot of SIGNAL 2 (OCP) scores of streams within Catanduanes Watershed Forest Reserve.

the macroinvertebrate communities. Based on the biplot shown in Figure 3, all sampling stations were placed in quadrant one which means that most of the streams had high values of both SIGNAL 2 scores and the number of macroinvertebrate types. Large number of types suggest that the diversity of the habitats is high and stressors such as pollution are not present. Sto. Domingo falls into quadrant 3 which implies that toxic pollution is present or the stream have harsh physical conditions.

Physical and Chemical Parameters

Dissolved Oxygen. Catanduanes watershed is the primary source of public water supply hence, the water quality should be protected and maintained in a safe and satisfactory condition. The Department of Environment and Natural Resources (DENR) water quality criteria of the different classifications range from freshwater from public water supply class 1(Class AA) to industrial water supply class II (Class D). Watershed should pass the water quality standard for Class AA for it to be utilized as public water supply.

Based on the standards for watersheds (class AA), dissolved oxygen (DO) should have a minimum level of 5 mg/L. The undisturbed sampling station (upstream) in Balatohan had dissolved oxygen values that exceed the standard minimum value all throughout the sampling period while disturbed station (downstream) had a low dissolved oxygen (4.35 mg/L) during the April sampling. Solong upstream had dissolved oxygen ranging from 6.25 mg/L to 8.7 mg/L while the downstream section had lower DO levels ranging from 5.1 mg/L to 7.7 mg/L. As for the stream of Maribina, both upstream and downstream stations had high DO levels except in March when 4.88 mg/L dissolved oxygen was recorded downstream.

Mabato downstream had lower dissolved oxygen levels than the upstream section. The lowest DO level in Mabato (4.95 mg/L) was recorded in April. Meanwhile, Siban'an had DO level above the minimum standard in both upstream and downstream sections. DO levels in the upstream section of Siban'an were relatively higher than its downstream section. Sto. Niño downstream had low DO in March (4.11 mg/L), May (3.28 mg/L), July (4.55 mg/L), and August (3.33mg/L). On the other hand, the Sto. Niño upstream had high DO levels ranging from 5.5 mg/L to 9.25 mg/L.

pH. The standard pH for watershed according to DENR ranges from 6.5-9.0 which is considered as optimum levels in which organisms can survive. Balatohan, Solong, and Maribina had pH levels which fall within the standard range in both upstream and downstream sections.

The pH levels in Mabato, Siban'an and Sto. Niño were also within the standard range. However, the pH of Siban'an downstream was slightly higher in May (8.71) and August (8.75). Progreso upstream had a slightly acidic pH (6.26) in February while the downstream section had a slightly basic pH (8.6) in April. Pagsangahan downstream had a basic pH from April to August with levels ranging from 8.8-8.9. The pH levels in Sto. Domingo were within the standard pH range except for the month of July when both upstream and downstream stations had slightly higher pH (8.8, 8.7 respectively). The average pH of all stations fall within the standard range, except at Pagsangahan downstream.

Conductivity. Conductivity of rivers ranges from 50 to 1500 µS/cm according to the United States Environmental Protection Agency (2001). Though conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows, a significant increase in conductivity may be an indicator that pollution discharges have entered the water.

Balatohan had low conductivity during the six-month sampling period. The upstream station had conductivity levels ranging from 148.32 µS/cm to 168.67 µS/cm while the conductivity at the downstream section ranged from 136.67 µS/cm to 168.33 µS/cm. Upstream and downstream sections of Solong also had lower conductivity than the minimum standard level of 150 µS/cm. On the other hand, Maribina had conductivity level within the standard range of 150 µS/cm to 500 µS/cm.

Mabato had levels of conductivity lower than 150 µS/cm. The lowest conductivity value was recorded during the months of July and August, both having a mean conductivity value of 110 µS/cm. Siban'an and Solong stations had mean conductivity values that were within the standard range; however, it was noticeable that the conductivity levels downstream were significantly higher than that recorded at the upstream section.

For the conductivity of streams with quarrying activities, Progreso upstream only reached the minimum standard value in February (156.5 µS/cm), May (159 µS/cm) and July (160 µS/cm). Downstream station had conductivity values ranging from 115 µS/cm to 149.17 µS/cm. Pagsangahan and Sto. Domingo had conductivity values higher than the minimum standard level (150 µS/cm). Meanwhile, lower conductivity levels were recorded in Progreso downstream during the months of April, July and August.

On the average, only the streams of Pagsangahan, Balatohan, Maribina, Siban'an, Sto. Niño and Sto. Domingo had conductivity levels that are within the standard conductivity range of 150 µS/cm to 500 µS/cm. Moreover, large difference in conductivity levels between the upstream and downstream sections of Siban'an and Sto. Niño were observed.

Temperature. Temperature of streams in the tropics should be between 20 °C to 30 °C in order for the aquatic organisms to survive and function optimally. This temperature range is also the standard set by DENR for Class AA water for watershed streams and rivers. Streams of Balatohan, Solong, and Maribina had temperatures which fall within the standard temperature range. Furthermore, it was observed that the downstream section had relatively higher temperature than that recorded at the upstream section.

Mabato had temperature values ranging from 24.6 °C to 30.2 °C. Siban'an also had temperature values within the standard range except at the downstream section in August, which were slightly higher than 30 °C. Similarly, Sto. Niño downstream had high temperature in April (30.45 °C) and in August (31.35 °C).

Both upstream and downstream sections of Sto. Domingo had high temperature values in August (32 °C and 32.2°C respectively). Meanwhile, Pagsangahan and Progreso had temperature levels between 20°C and 30°C. The temperature values of the streams were high in August. Downstream sections of all streams had relatively higher temperature than that recorded at the upstream stations; although on the average, all the streams had temperature ranges falling within the given standard.

Stream width, depth, velocity. Changes in width, depth, and velocity of streams can also affect the macroinvertebrate communities. Changes may be due to natural or anthropogenic disturbances. Streams with observed domestic disturbances (Balatohan, Solong, and Maribina) had higher velocity upstream than downstream. In terms of width and depth, upstream stations were relatively wider and deeper than downstream stations except for Solong downstream.

Sto. Domingo downstream was the widest among all streams with 22.0 m width. Progreso also had a wide channel with an average width of 14.7 meters upstream and 17.0 meters downstream. Since quarrying involves extracting sediments, stream depth is likely to change. The highest average depth of 40.75 cm was recorded at Sto. Domingo downstream followed by that recorded at Progreso downstream (32.86 cm), and Pagsangahan downstream (28 cm). The highest stream velocity was recorded in Progreso downstream (0.55 m/s) while the slowest was recorded in Maribina Downstream (0.22 m/s).

Streams influenced by agricultural activities had narrower width than other streams. Sto. Niño had the narrowest channel with an average width of only 2.45 m upstream and 2.65 m downstream. Sto. Niño downstream was the shallowest among all sampling stations with only 2.5 cm. The water flow downstream was faster than that recorded upstream.

Pearson correlation coefficient

The relationship between species richness, species density and environmental variables was investigated using Pearson product-moment correlation coefficient. Preliminary analyses were performed to ensure there was no violation of the assumptions of normality, linearity and homoscedasticity. Macroinvertebrate density had significant ($P<0.05$) medium correlation on most of the parameters: taxa richness (r= -0.385), conductivity (r= -424); Width (r= 0.435); depth (r= 0.355); and velocity (r=0.379). It also had a weak correlation with dissolved oxygen, r= 0.263 with $p<0.05$. Taxa richness, on the other hand, had a significant negative correlation with temperature and width (r= -0.204; and r= -0.393, respectively).

Analysis of covariance (ANCOVA)

Analysis of covariance (ANCOVA) was used to identify the marginal effects of the independent variables (dissolved oxygen, pH, temperature, conductivity, width, velocity, and habitat disturbance; domestic, quarry, agriculture) to the dependent variable (taxa density and richness) given the presence of the different types of disturbances. Results showed that pH, electrical conductivity, width, and velocity significantly contributed to the changes in variation of taxa density of macroinvertebrates such that in every unit increase in pH and electrical conductivity, taxa density decreased by 39.61% and 0.31% respectively. Furthermore, for every increase in width and velocity, macroinvertebrate density increased by 2.14% and 156.1% respectively. Based on the ANCOVA model, the independent variables significantly ($F_{11, 96} = 8.83$ $P<0.05$) explain the changes in macroinvertebrate density by 44.6 percent. The final model revealed that in streams with quarrying activities, the upstream width positively affects the macroinvertebrate density

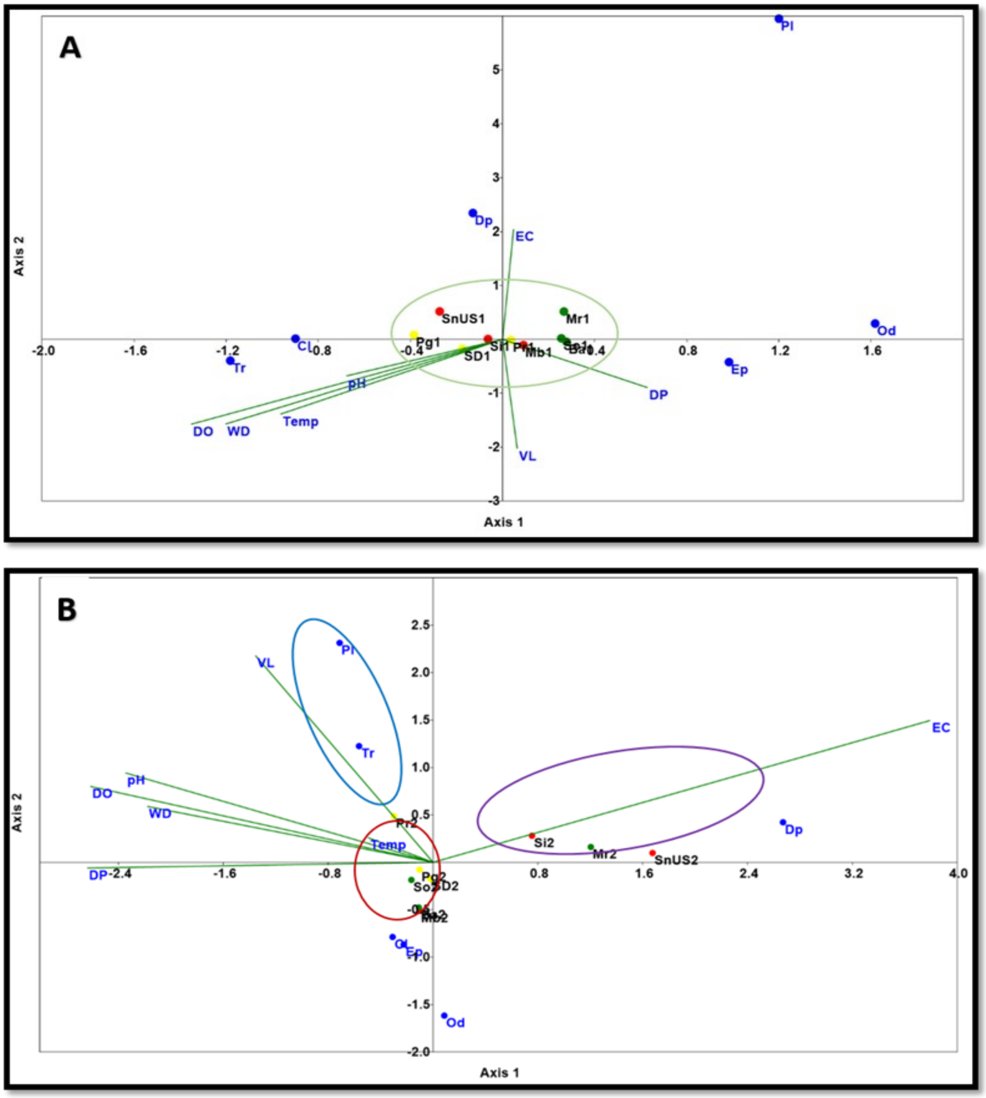

Figure 4A & B. Ordination diagram of CCA for five major indicator taxa of aquatic macroinvertebrates (blue dots) in streams of CWFR affected by different habitat disturbance. (Domestic = green dots; Agriculture = red dots; Quarry = yellow dots) with respect to seven environmental parameters (green lines); first axis is horizontal, second axis is vertical. The major macroinvertebrate taxa are: Cl=Coleoptera, Dp= Diptera, EP = Ephemeroptera, Od = Odonata, Pl = Plecoptera, Tr = Trichoptera. The sampling sites are: Mb = Mabato, Si= Siban'an, So = Solong, Pg = Pagsangahan, Pr = Progreso, SD = Sto. Domingo, Ba = Balatohan; Mr = Maribina, SnUS = Sto. Niño. The environmental variables are: DO = dissolved oxygen, pH, EC = electrical conductivity, Temp = temperature, WD =width, DP = depth, VL = velocity. ; A (upstream), B (downstream).

suggesting that when the upstream width increases, macroinvertebrate density also increases. On the other hand, width of the stream in the downstream section affects the macroinvertebrate density negatively in such a way that if the downstream width increases the macroinvertebrate density decreases.

Based on the ANCOVA model for taxa richness, the independent variables significantly ($F_{11,\ 96}$ = 3.01; P<0.05) explain the changes in taxa richness by 17 percent. Among all variables, only pH significantly contributed to the changes in variation of macroinvertebrate taxa richness such that in every unit increase in width, taxa richness decreases by 2.3 percent. The adjusted R-squared value (.171) was too low suggesting that environmental variables and habitat disturbances, only have weak significant effect on macroinvertebrate taxa richness. With this, the results of the analysis were not incorporated into the final model.

Canonical correspondence analysis

The ordinal diagram shows the pattern of variation in the densities of major macroinvertebrate taxa elucidated by the environmental variables *i.e.*, dissolved oxygen, pH, conductivity, pH, width, depth, velocity (Figure 4 A & B). Only the major indicator taxa (Coleoptera, Diptera, Ephemeroptera, Odonata, Plecoptera, and Trichoptera) were used to reflect influence of water quality conditions. The lines in the ordination diagram represented the environmental variables that could have influenced the variations in macroinvertebrate density. A close association with the line would mean that a certain environmental factor had major influences on the variable. The Eigen values of the upstream stations (A) suggest that the environmental variables explained 49.7% (axis 1) and 26.82% (axis 2) of variations in macroinvertebrate densities, while in downstream stations (B), environmental variables explained 67.6% (axis 1) and 27.5% (axis 2) of the observed variations in macroinvertebrate density. Dissolved oxygen, pH, and temperature were the environmental factors that had major influence on the variations of density upstream while for downstream sections, major contributions were provided by electrical conductivity, temperature and width. The CCA biplot of the undisturbed section revealed that the macroinvertebrate taxa were uniquely distributed in the plot. Only Order Diptera was observed in close correlation with electrical conductivity. The sites were clustered at the center of the diagram suggesting that there were minimal variations among sites in terms of environmental variables.

A stream environment with increasing electrical conductivity may indicate the presence of disturbance and poor quality of streams. With these observations, upper right-side part of the ordination diagram reflect poor stream condition while the opposite side would reflect good water condition. Results showed that among the streams with disturbances, Siban'an, Maribina, and Sto Niño have poor water quality conditions. These streams were shown to have close association with increasing electrical conductivity. Moreover, among the indicator taxa, only Order Diptera was found to be closely correlated with increasing conductivity. Order Diptera is a pollution-tolerant taxon that can survive in streams with poor condition. Pollution-sensitive taxa such as Plecoptera and Trichoptera were found in streams with good water with high affinity to increasing stream velocity. Based on the ordination diagram, Progresso had good water quality and had fast water flow. The other sites did not have close association with any environmental variables, indicating that these streams have intermediate water condition.

DISCUSSION

Benthic macroinvertebrate taxa density and richness in streams with no anthropogenic disturbances were relatively higher than those in streams with anthropogenic disturbances (i.e. domestic, agriculture and quarry). Most of the upstream sections that were sampled have higher vegetation cover compared to downstream sections. Iñiguez-Armijos *et al*. (2014) stated that macroinvertebrates and water quality are closely related with vegetation cover. Macroinvertebrate community assemblages are more diverse in catchments largely covered by vegetation. This is because of the abundant supply of coarse particulate organic matter, plants and coarse inorganic substrate provided by the vegetation (Herringshaw *et al*., 2012). Downstream sections were exposed to anthropogenic activities that often led to alteration on the physical and chemical characteristics of the streams as proven by many other investigations worldwide. A study conducted in India by Samal & Gedam (2012) revealed that in different anthropogenic activities around Bhima basin, such as the conversion of wasteland to agricultural land, construction of dams/reservoirs, and increased domestic and industrial water demand reduces the stream flow of the basin decreasing the diversity of aquatic organisms. A similar study on the effect of urbanization around Etowah River basin, in Georgia, USA also revealed that the increase in human activities decreases the diversity and assemblages of macroinvertebrates. Urbanization resulted to the increased sediment transport, reduced stream bed sediment size and increased solutes, decreasing habitat and food availability for macroinvertebrates (Roy *et al*., 2003).

Stream ecosystem, when frequently exposed to natural and human perturbation becomes unstable, affecting the living organisms associated with it. Streambed stability is the primary influential factor shaping the structure of benthic macroinvertebrate communities. According to Duan, Wang & Xu (2011), Stable stream had large number of individuals, abundant taxa and high diversity. Siban'an, Sto. Niño, and Maribina had poor habitat condition based on the rapid assessment of the streams. In addition, it was observed that the density of macroinvertebrate present in the said streams were lower compared to the undisturbed sections. Both Siban'an and Sto. Niño have agricultural disturbance present in the streams. Agricultural land use has often been linked to nutrient enrichment, habitat, degradation, hydrologic alteration, and loss of biotic integrity in streams (Allan 2004; Risen *et al.* 2011). The riparian natural vegetation of Siban'an and Sto. Niño have been converted to croplands. Cropland had strong negative effects on the invertebrate community. It can affect benthic communities by both altering structural habitats and by imposing water quality-related stresses through dissolved water contaminants (Risen *et al.,* 2011). Meanwhile in Maribina, domestic disturbance was observed. Conversion of land for human settlements, and construction of impervious covers, dams and dikes were the major contributors of the poor habitat and streams condition of Maribina. In addition, domestic waste water runoff have negative impact on the water quality of the streams (Adrianenssens, Goethals, & Niels, 2002; Wagner, 2008). These observations suggest that the disturbance present in the streams may have affected its stability resulting to its poor condition. Another possible explanation for the poor condition of the streams observed was the occurrence of natural perturbation such as typhoon, which happened last July 2014. Impacts of cumulative landscape alterations (domestic, agriculture, and quarry) are greater during storm events causing larger downstream changes in water quality variables (Bostad & Swank, 1997).

Most macroinvertebrates found in CWFR streams were aquatic insects. Many aquatic insect species are intolerant of pollutants and will not be found in polluted waters; thus, the presence of diverse and dense aquatic insects in the sampled streams could possibly mean that the water are still in good quality. All streams that were sampled in this study have high aquatic insect composition mostly from Orders Ephemeroptera and Trichoptera. Progreso had the highest number of macroinvertebrate taxa collected during the six-month sampling period which were mostly composed of the said Orders. Both are considered to be highly sensitive to pollution indicating that Progreso had good water quality. A study conducted by Dacayana, Hingo, & Del Socorro (2013) revealed that the upstream section of Bulod River in Lanao del Norte, had good water quality due to the presence of pollution-sensitive fauna such as Ephemeroptera, Trichoptera, and Plecoptera. A similar study in Langaran and Layawan River in Western Mindanao also reported abundance of the said macroinvertebrate Orders

(Gorospe-Villarino *et al*., 2006). On the other hand, Sto. Niño had the lowest number of macroinvertebrate taxa identified. The stream was dominated by Family Chironomidae which is under order Diptera. These insects are considered to be pollution- tolerant which means that they can survive even if the water has poor quality. Therefore, in the case of Sto. Niño, low macroinvertebrate richness with high density of tolerant taxa (Diptera and Crustacea) suggest poor water quality of the stream.

Aquatic insects are highly adapted to the physical and chemical attributes of streams thus making them vulnerable to slight changes in water quality, affecting their abundance and composition (Rosenberg & Resh 1992). Ephemeroptera, Trichoptera and Plecoptera are generally considered pollution sensitive and normally used to evaluate community balance (Gorospe-Villarino *et al*., 2006).

Streams with domestic disturbances

Spreading domestic land-use due to increasing population always has an impact on the natural hydrological regime of streams (Samal & Gedam, 2102). Downstream sections of Balatohan, Solong, and Maribina are the sampling stations with domestic disturbances. Impervious covers, dike and damn constructions as well as unmanaged solid wastes were present in these stream sections. Investigations on the relationship between domestic land -use and stream are widespread in stream ecology literature (Allan, 2004; Paul & Meyer, 2001). Constructions of impervious cover in streams with human population, are consistently related to many of the physical, chemical, and biological changes of the streams. The result of the study showed that the macroinvertebrate in both streams locations (upstream and downstream) were relatively the same in terms of composition but differed in density. Macroinvertebrates have relatively higher density and richness upstream than downstream. Maribina had the lowest richness and density of macroinvertebrates among the three streams. The presence of small dam and dikes alters the direction of stream waters and reduces the amount of water at the downstream section of the stream. Land-use in downstream section may have affected the stream in such a way that it loses the capacity to hold high density of macroinvertebrates. It specifically alters the hydrology and geomorphology of stream leading to increased loading of nutrients, metals, pesticides, and other contaminants to stream (Paul & Meyer, 2001). These resulted in the declined abundance and richness of algal, invertebrate and fish communities (Paul & Meyer, 2001; Pinto, Araujo & Hughes, 2006; Smith & Lamp, 2008; Wang *et al*., 2000). Scott (2006) stated that this kind of anthropogenic perturbation often results to more homogeneous biotic communities in streams within natural landscapes. Pollution- sensitive insects under Orders Plecoptera and Ephemeroptera were present in the downstream section of the streams suggesting that the absence or the presence of organic pollution are still at minimum level. It may also imply that the water in these streams is in good condition and can still support aquatic life. However, due to human perturbation and alterations, the streams lose their capacity to carry high density of macroinvertebrates.

Streams with agricultural disturbances

Agricultural land-use has been shown to degrade water quality, habitat, and biological condition in streams (Allan, 2004). Some studies describe relationships between stream features and agricultural land cover. Agricultural land cover is correlated with elevated concentrations of nutrients and pesticides. Also, the excess applications of fertilizer and manure are linked to elevated levels of nitrogen and decreased dissolved oxygen concentrations (Berka, Schreier &Hall, 2001; Meigan *et al*., 2007; Morgan *et al*., 2006; Wagner *et al*., 2008;). These factors greatly affect the water quality of the streams. Based on the result of the study, Sto. Niño had the lowest number of taxa but with high density of insects belonging to Orders Diptera and Crustacea. High densities of Diptera, specifically chironomids, indicate poor water quality (Virbickas, Pluirarte & Kesminas, 2011). Abundance of these pollution tolerant invertebrates suggests the presence of organic pollution. Delong (1998) in her study in Lapwai Creek, reported that agricultural alteration has influenced community structure, resulting in a relatively homogeneous assemblage of macroinvertebrates capable of tolerating agricultural nonpoint source pollution. On the other hand, high densities of Ephemeroptera and Trichoptera were observed in Mabato and upstream sections of Sto. Niño and Siban'an. According to Virbickas *et al*. (2011), forest shade and coverage increase the abundance and diversity of Orders Ephemeroptera, Plecoptera, and Trichoptera. This is due to high abundance of food source such as periphyton, and the small quantities of terrestrially- derived organic matter (Chara-Serna, 2012; Virbickas etal., 2011). Clearing of riparian vegetation was observed in Sto. Niño and Siban'an. Deforestation reduces the macroinvertebrate taxa and simplifying the insect composition (Groffman *et al*., 2003; Snyder *et al*., 2003). Siban'an and Solong had both diverse composition of macroinvertebrates but had lower density compared to Mabato. Among the three sampled streams, Mabato had relatively more intact riparian vegetation than Sto. Niño and Siban'an. Forest belts along river sides support good status of macroinvertebrate communities (Virbickas *et al*., 2011; Chara-Serna, 2012). Agricultural land-use affected the benthic communities by both altering structural habitats and contributing water-quality related stresses through dissolved water contaminants (Risen *et al*., 2011). Artificial drainage present in the sampling areas may have added instability to the streams through alteration of hydrology, bank erosion, changes in stream channel dimensions, sedimentation, elevated turbidity, and burying of coarse substrate in streams (Fitzpatrick *et al*., 2001; Risen *et al*., 2011; Delong, 1998). Absence of coarse substrate often lead to lesser areas for macroinvertebrates to hide, therefore vulnerable to predation. Reduction of coarse substrates increases the percentage of slow-flowing habitat. Slow-flowing streams are important indicators of habitat deterioration of stream ecosystem (Chara-Serna, 2012).

Streams with quarrying disturbance

Streams of Progreso, Pagsangahan and Sto. Domingo still have diverse composition of macroinvertebrates based on the total number of taxa found in the streams.

Insects classified under Orders Trichoptera, Ephemeroptera, Plecoptera and Coleoptera were present in the streams. These insect taxa are highly sensitive to organic pollution, which implies good water quality condition. Sto. Domingo had the lowest richness and density. Among the surveyed streams, the downstream section of Sto. Domingo had the most extensive quarrying activities. Quarrying is a method for acquiring various geological materials such as rocks, sand, and minerals. The changes in the macroinvertebrate assemblage structure was due to the extremely long duration of disturbance. Sorensen (1977) stated that turbidity and siltation cause an overall reduction in the number of bottom organism which resulted in the density, diversity, and community structures. Gravel dredging in Brazos River, Texas resulted to the loss of gravel habitat. The sediments were replaced by sand-silt bottom (Forshage & Carter, 1973 as cited by Sorensen *et al*, 1977). However, upon closure of the quarry, recovery of aquatic assemblages would be fast and successful because of nearby streams that may serve as a recolonizing source as observed in the Progreso and Pagsangahan (Milisa, Vesna & Habdija, 2010).

Species Biodiversity and Biotic Index

Diversity and evenness index. Theoretically, Shannon-Weiner diversity index increases as the species richness increases while index of evenness is inversely proportional to the number of species. The diversity index of macroinvertebrate communities present in the area considered the number of species as well as their relative abundance of species (BRP, 2004 as cited by Duya, 2011).

Based on the result, undisturbed areas had higher diversity compared to the disturbed downstream. The disturbances may have affected the water quality and stream condition such that only few macroinvertebrate species can inhabit the streams. Good quality streams have high density of macroinvertebrates as well as the presence of pollution-sensitive taxa like Orders Ephemeroptera and Trichoptera. These insect orders are mostly present upstream or in undisturbed section streams. Most species that belong to these groups are shredders and scrapers which are important in the transformation of the allocthonous particulate organic matter. Disturbance affecting the areas where these groups are present may not only lead to local diversity loss but also to alteration of downstream biota (Baptista *et al.,* 2001). On the other hand, the evenness index in undisturbed streams indicates that the total number of individuals was distributed more evenly among all possible species as compared to undisturbed streams. The lower evenness index in disturbed streams showed an increasing dominance of one or fewer species in the area. Only few species makeup the large percentage of the macroinvertebrate community in the area. Clearing of riparian vegetation and converting it for agricultural and domestic land uses affect the availability of food source present in the stream, which may lead to reduction of taxa and simplifying insect composition (Virbickas *et al.*, 2011).

Result of Hilsenhoff's biotic index revealed that Balatohan (upstream), Progreso (downstream), and Mabato (upstream and downstream) had good water quality with some organic pollution detected. These may be due to the particles of the soil that were eroded from the banks or from the organic effluents from the smaller streams. The results suggest that the disturbances present in these streams contributed minimal organic pollutants present in the water. Meanwhile, other streams had fair water quality, which means that the streams have fairly significant organic pollution. The disturbances present in the streams could be the nonpoint sources of the organic pollution of the streams. Domestic and agricultural run-off elevates the concentration of organic and inorganic pollutants (Virbickas *et al*., 2011;Heep *et al*., 2010).

Abundance of macroinvertebrate taxa also depends on the stream substrates. Signal 2 scores showed that quarrying activities had a great impact in the quality of streams in Sto. Domingo. Gravel dredging activities chage the natural condition of stream substrates. Sto. Domingo have bottom sediments composed of sand and silt. This reflects the instability of substrates and low availability of organic matter which lead to low diversity and richness of macroinvertebrates (Hawkins, 1984 as cited by Baptista *et al.,* 2001). On the other hand, other streams were observed to have stony and litter substrates where the established macroinvertebrate communities are more stable (Baptista *et al.,* 2001). The stones and sand serve as refugia for younger organisms. Baptista *et al*. (2001) also stated that litter substrate, is preffered by most macroinvertebrate taxa as it offers best shelter and feeding condition due to high habitat heterogeneity and rich periphytic flora.

Influence of environmental parameters on macroinvertebrate community

The macroinvertebrate communities changed in response to variations in the physical/chemical factors and available habitats. Macroinvertebrate density is negatively correlated with conductivity. Increasing conductivity leads to the decrease of macroinvertebrate density. Organisms surviving in low conductivity have adaptations to persist though stressful periods in a state of inactivity. Most macroinvertebrates are hyperosmotic. This means that they have the ability to eliminate water and retain ions. Thus, these organisms maintain higher internal ionic concentrations than the surrounding water. A sudden increase or decrease in conductivity in a body of water can indicate pollution. Agricultural runoff or a sewage leak will increase conductivity due to the additional chloride, phosphate and nitrate ions (EPA, 2012). High dissolved oxygen in streams is favourable for most of the macrobenthic organisms. With this condition, organisms can perform their normal physiological functions. High velocity of streams ensures movement and availability of food in the streams. High river flow and velocity also potentially carry the sediments from one place to another preventing the accumulation of sediment at the bottom which is a favourable habitat for macroinvertebrates. Increasing the stream width of the stream may also lead to high density of benthic macroinvertebrates since it offers large area for habitat. Large areas can also lower the risk of predation. Combined data of macroinvertebrate community structure and environmental parameters showed that undisturbed area offers a more habitable environment and supports different species of macroinvertebrates.

Dissolved oxygen. All streams sampled for this study have high average dissolved oxygen except for Sto Niño downstream. Effluent coming from the agricultural area may have high levels of phosphorus and nitrates, which are common due to the use of agricultural fertilizers. In addition, erosion in altered banks of Sto. Niño may have contributed to the phosphorus content of water speeding up eutrophication and thus reducing dissolved oxygen. Changes in riparian vegetation also decreases stream cover increasing water temperature. These factors may have contributed to the low concentration of DO. Many aquatic macroinvertebrate species depend on oxygen-rich water. Small changes in dissolved oxygen concentration can affect the composition of aquatic communities. Connolly *et al.* (2004) reported that all taxa were intolerant to DO saturation at 10%, indicating that there was a clear threshold of tolerance for most taxa. Aquatic macroinvertebrates possess a diverse array of structural and behavioral respiratory adaptations suggesting that different taxa differ in their oxygen requirements and tolerance to reduced dissolved oxygen content (Eriksen, Resh, Balling & Lamberti, 1984) . Some aquatic insects respire by diffusion through the cuticle, whereas some have tracheal or spiracular gills for respiration.

pH. There are many factors that can affect pH in water, both natural and man-made. pH can also fluctuate with precipitation, wastewater or mining discharges. The pH of water affects the normal physiological functions of aquatic organisms, including the exchange of ions with the water and respiration. Alabaster & Lloyd (1980) reported that such important physiological processes operate normally in most aquatic biota under a relatively wide pH range (6-9). The pH levels of all sampling sites are within the structural range of pH for stream (6.5-8.5). A slightly higher pH in Pagsangahan downstream was observed. Algal growth was observed in this area. High rate of photosynthesis of the algae could possibly contribute to the increase in pH. The majority of freshwater fishes and macroinvertebrates experience harmful effects at one or more life stages at pH values above 10 (Alabaster & Lloyd, 1980). On the other hand, acidic water also has effects on macroinvertebrates. A number of researchers have proposed that the toxic action of hydrogen ions on aquatic organisms (fish and macroinvertebrates) under acidic conditions involves interference with the exchange of respiratory gases and ions across the gills, precipitation of proteins within the epithelial cells, and/or acidosis of the blood (Ellis, 1937; Westfall, 1945).

Conductivity. Low conductivity values below standard level were recorded at Progreso, Mabato and Solong. Conductivity is a measure of the ability of water to pass an electrical current. It is affected primarily by the geology of the area through which water flows. This can be due to input of water from other sources that may have diluted the mineral concentrations. Progreso and Mabato have fast flow of water which means dissolved solids are not concentrated. On the other hand, Siban'an and Sto. Niño recorded a significantly higher conductivity compared to their upstream sections. This increase in conductivity could possibly mean that a discharge or some other source of pollution entered the stream water. Agriculture disturbances can increase the specific conductance of local waters. According to Swanson & Baldwin (1965), when water is used for irrigation, part of the water evaporates or is consumed by plants, concentrating the original amount of dissolved solids in less water; thus, the dissolved-solids concentration and the specific conductance in the remaining water is increased. The remaining higher specific-conductance water reenters the river as irrigation-return flow.

Temperature. All streams have recorded temperature that are within the standard range. Upstream sections have cooler water than downstream section because of vegetation cover. The physical aspects of the streams cause natural variation in temperature. Stream temperature increases as it moves downstream through urban, industrial and agricultural areas. Streams with riparian vegetation converted to agricultural land, have high stream temperature since it is more exposed to direct sunlight (Bellingham, 2009; USEPA, 2001; Allan, 1995). Fluctuations in temperature change the rate of chemical reactions in stream water, which in turn affect biological activity (USEPA, 2001). Warm water holds less oxygen than cool water which may affect aquatic life in the stream. In addition, high temperature would make the compounds in water more toxic to aquatic life.

Stream velocity. The velocity of stream increases as the volume of the water in the stream increases. It determines the kinds of organisms that live in the stream. According to Macan (1978), the behaviour of macroinvertebrates is related to the velocity flow since fast waters transport more nutrients in a determined period. Based on the result, velocity in the sampled streams were variable. Progreso, Pagsangahan, and Sto. Domingo have high water velocities since they have bigger streams and larger volume of water. Since stream velocity depends on the volume of water, changes in water direction by building dams, dikes, and irrigation for agriculture significantly affect the velocity. Such changes were observed downstream of Solong, Sto. Niño and Maribina. Dredging of sediments can affect stream flow as observed in Sto. Domingo (downstream).

Stream depth. The increase in depth was observed in quarry sites of Pagsangahan, Sto. Domingo. Quarrying involves the extraction of hard and soft rocks from the streambed. This causes the increase in depth of the stream. Riffle areas of the streams where organisms are usually abundant can possibly change into a pool area embedded with silt which usually cause decrease in abundance of organisms (Macan, 1978).

Stream width. Widening of rivers can be caused by either natural or anthropogenic perturbations. Variations in width in Progreso, Pagsangahan and Sto. Domingo can be explained by the quarrying activities present in the area. This activity may have led to changes of river width and channelization of streams. Changes in width were also observed in Siban'an because of the construction of dikes downstream. Stream width affects many other characteristics of a stream. A stream flowing through a wide, shallow channel will receive more sunlight throughout its water column. Increased sunlight will cause the shallow water to become warmer throughout thus affecting its chemical composition (Allan, 1995; USEPA, 2001).

The findings of the present study thus suggest that streams in CWFR are still in good condition. The bioindicative role of macroinvertebrate communities is crucial in determining stream health as evidenced by their varying responses to disturbances. Observance of a thorough watershed management will aid in counteracting the negative effects of anthropogenic activities occurring within the vicinity, hence promote protection and conservation of streams.

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REFERENCES

Adrianenssens, V., Goethals, P. L. M. and Niels, D. P. 2002. Assessment of Land-Use Impact on Macroinvertebrate Communities in the Zwalm River Basin (Flanders, Belgium) Using Multivariate Analysis and Geographic Information Systems. *The Scientific World Journal*, 546-557.

Andrew, P. A., Thomas R. W., David P. L., Philip , R. K. Raymond J. O., Robert M. H., Richard S. S., Sushil S. D., Ralph, O. B., Alan, T. H., and Steven, G. P. 1999. Concordance of taxonomic composition patterns across multiple lake assembages: effect of scale, body size and land use. *Canadian Journal of Fisheries and Aquatic Science*, 56: 2029-2040.

Alabaster, J. S., and Lloyd, R. 1980. Water quality criteria for freshwater fish. European Inland Fisheries Advisory Commission Report (FAO). Butterssworth, London-Boston. 297 pp.

Allan, J. D. 1995. Ecology Structure and Function of Running Waters. Springer Netherlands.

Allan, J. D. 2004. Landscapes and riverscapes: the influence of land use on stream ecosystems. *Annual Review of Ecology and Evolutionary Systematics*, 35: 257-284.

Ballingerd, G. 1979. Methods for Chemical Analysis of Water and Wastes. EPA.

Baptista, D. F., Buss, D. F., Dorville, L. F. M. and Nessimina, J. L. 2001. Diversity and habitat preference of aquatic insects along longitudinal gradient of the Macae river basin, Rio De Janiedo, *Brazil. Rev. Brazil Biology,* 61: 249-259.

Bellingham, K. 2009. Physicochemical Parameters of Natural Waters. Retrieved from http://www.stevenswater.com/articles/waterparameters.aspx#nitrate.

Berka, C., Schreier, H. and Hall, K. 2001. Linking water quality with agricultural intensification in a rural watershed. Water, Air, and Soil Pollution, 127: 389-401.

Bolstad, P. V. and Wayne, T. S. 1997. Cumulative Impacts of Land-use on Water Quality in a Southern Appalachian Watershed. *Journal of the American Water Resources Association*, 33: 519-533.

Booth, D. B., Derek, B. B., James, R. K., Sally, S., Christopher, P. K., Sarah, A. M., Marit, G. L. and Stephen, J. B. 2004. Reviving urban streams: land use, hydrology, biology, and human behaviour. *Journal of the American Water Resources Association*, 40: 1351-1364.

Boyd, R. S. 2010. Heavy Metal Pollutants and Chemical Ecology: *Exploring New Frontiers. Journal of Chemical Ecology*, 36: 46-48.

Cain, D. J. and Luoma, S. N. 1998. Metal exposures to native populations of the caddisfly *Hydropsyche* (Trichoptera: Hydrospsychidae) determined from cytosolic and whole body metal concentration. *Hydrobiologia,* 386:103-117.

Chandler, J. R. 1970. A biological approach to water quality management. *Journal of Water Pollution Control*, 69: 415-422.

Chessman, B. 2003. SIGNAL 2 – A scoring system for macroinvertebrate ('Water Bugs') in Australian Rivers, Monitoring River Health Initiative Technical Report no.31, Commonwealth of the Australian, Canberra.

Connolly, N. M., Crossland, M. R. and Pearson, R. G. 2004. Effect of low dissolved oxygen on survival, emergence, and drift of tropical stream macroinvertebrates. *Journal of the North American Benthological Society*, 23: 251-270.

Dacayana, C. M. L., Hingo, J.T. and Del Socorro, M. M. L. 2013. Benthic Macroinvertebrate Assemblage in Bulod River, Lanao del Norte, *Philippines. Journal of Multidisciplinary Studies.* ISSN: 2350-7020. DOI: http://dx.doi.org /10.7828/jmds.v2i1.398.

Delong, M. P. and Brusven, M. A. 1998. Macroinvertebrate community structure along the longitudinal Gradient of an Agricultural Impacted Stream. *Environmental Management,* 22: 445-47.

De Pauwn, N. and Vanhooren, G. 1983**.** Method for biological quality assessment of water courses in Belgium. *Hydrobiologia*, 100: 153-168.

Department of Environment and Natural Resources, 1990. Administrative Order No. 34 Series of 1990: Revised Water Usage and Classification/Water quality Criteria Amending Section No. 68 and 69, Chapter III of the 1978 NPCC Rules and Regulations. Retrieved from http://www.emb.gov.ph/laws/water%20quality%20management/dao90-34.pdf.

Department of Environment and Natural Resources – Catanduanes, (n. d.). Catanduanes Watershed Forest Reserve 5-Year Management Plan (2010–2014). Retrieved from http://denrcatanduanes.weebly.com.

Department of Environment and Natural Resources – Environmental Management Bureau, 2006. National Water Quality Status Report – 2001-2005. DENR, Quezon City, Philippines.

Duan, X. H., Wang, Z. Y. and Xu, M. Z. 2011. Effects of fluvial process and human activities on stream macroinvertebrates. *International Journal of Sediment Research,* 6: 416-430.

Duran, M. 2006. Monitoring water quality using benthic macroinvertebrates and physiochemical parameters of Behzat Stream in Turkey. *Polish Journal of Environmental Studies*, 15: 709-717.

Duya, C. G. 2011. Influence of Watershed Land-uses on the Water Quality, Macroinvertebrate and Fish Assemblages in the Tributaries of Los Baños and Bay, Laguna, Philipines. University of the Philippines Los Baños. Unpublished master's thesis.

Ellis, M. M. 1937. Detection and measurement of stream pollution. Bulletin of U.S. Bureau of Fisheries, 48: 365–437.

Environmental Protection Agency. 2012. Conductivity. In Water: Monitoring and Assessment. Retrieved from http://water.epa.gov/type/rsl/ monitoring/ vms59.cfm.

Eriksen, C. H., Resh, V. H., Balling, S. S. and Lamberti, G. A. 1984. Aquatic insect respiration. An introduction to the aquatic insects of North America. 2nd ed. Kendall/Hunt Publishing Company, Dubuque, Iowa p. 27-37.

Fitzpatrick, F. A., Scudder, B. C., Lenz, B. N. and Sullivan, D. J. 2001. Effects of multi-scale environmental characteristics on agricultural stream biota in eastern Wisconsin. Journal of the American Water Resources Association, 37:1489-1507.

Gorospe-Villarino, A., Bacaltos, D. G. B. , Roa, E. C. , Hansel, C. G., Nacua, S. S. , Seronay, R. A., Freire, F. F. M. , Roscom, B. A., Santamina, S. F. R. Jr. and Castro, M. J. L. 2006. Comparative Assessment of the Langaran and Layawan rivers. SEARCA. Biodiversity Research Programme Monograph Series No. 13.

Groffman, P. M., Peter, M. G., Daniel, J. B., Lawrence, E. B., Kenneth, T. B., Grace, S. B., Morgan, G. J., Richard, V. P., Ian, C. Y. and Wayne, C. Z. 2003. Down by the riverside: urban riparian ecology. Frontiers in Ecology and the Environment, 1: 315-321.

Hare, L. 1992. Aquatic insects and trace metals: bioavailability, bioaccumulation, and toxicity. Critical Reviews in Toxicology, 22(5-6), 327-369.

Herringshaw, C. J., Stewart, T. W., Thompson, J. R. and Anderson, P. F. 2011. Land use, stream habitat and benthic invertebrate assemblages in a highly-altered Iowa watershed. *American Midland Naturalist,* 165: 274-293.

Hepp, L. V., Milesi, S. V., Biasi, C. and Restello, R. M. 2010. Effects of agricultural and urban impacts on macroinvertebrates assemblages in Streams (Rio Grande, do Sul, Brazil). *Zoologia*, 27: 106-113.

Hilsenhoff, W. L. 1977. Use of arthropods to evaluate water quality of streams. Technical Bulletin No. 100, Department of Natural Resources, Madison, Wisconsin.

Hodkinsin, I. and. John, K. J. 2005. Terrestrial and aquatic invertebrates as bioindicators for environmental monitoring, with particular reference to mountain ecosystems. Environmental Management, 649-666.

Iñiguez-Armijos, C., Leiva, A., Frede, H. G., Hampel, H. and Breuer, L. 2014. Deforestation and benthic indicators: how much vegetation cover is needed to sustain healthy Andean streams? PLoS One 9: e105869. DOI: 10.1371/journal.pone.0105869.

Jacob, U., Hendrik, W. and Reinhard, K. 1984. Aquatic insect larvae as indicators of limiting minimal contents of dissolved oxygen – Part II. Aquatic Insects, 6: 185-190.

Lefcort, H., Ammann, E. and Eiger, S. M. 2000. Antipredatory behavior as an index of heavy-meatal pollution: a test using snail and caddisflies. *Environmental Contamination and toxicology,* 38(3): 311-316.

Macan, T. T. 1978. Freshwater Ecology. 2nd ed. London. p 343.

Mandaville, S. M. 2002. Benthic Macroinvertebrates in Freshwaters-Taxa Tolerance Values, Metrics, and Protocols. Soil & Water Conservation Society of Metro Halifax, 1-43.

McColl, R. H. S. 1972. Chemistry and trophic status of seven New Zealand lakes. *New Zealand Journal of Marine and Freshwater Research*, 6: 399–447.

Meigan, H. M., Nash, M. S., Neale, A. C. and Pitchford, A. M. 2007. Biological integrity in Mid-Atlantic coastal plains headwater streams. Environmental Monitoring and Assessment, 124: 141-156.

Mesa, L. M., Leticia, M. M., María, C. R., Marcela, D. V. C. and Martín, G. S. 2013. Effects of anthropogenic impacts on benthic macroinvertebrates assemblages in subtropical mountain streams, Iheringia, Series Zoologia, Porto Alegre, 103: 342-349.

Milisa, M., Vesna, Z. and Habdija, I. 2010. Destructive influence of quarry effluent on life in a mountain stream. *Biologia*, 65: 320-526.

Morgan, A. M., Royer, T. V., David, M. B. and Gentry, L. E. 2006. Relationships among nutrients, chlorophyll-a, and dissolved oxygen in agricultural streams in Illinois. *Journal of Environmental Quality*, 35: 1110-1117.

National Economic and Development Authority. 2011. Philippine Development Plan 2011-2016. NEDA.

National Water Resources Board. 2006. The Integrated Water Resources Management (IWRM) Plan Framework.

Norris, R. H. and Thomas, M. C. 1999. What is river health? *Freshwater Biology*, 41: 197–209.

Olomukoro, J. O., and Dirisu, A. R. 2013. Macroinvertebrate community and Pollution Tolerance Index in Wdion and Omodo River uin Derived Savannah wetlands in Southern Nigeria. *Jordan Journal of Biological Sciences*, 7: 19-24.

Pascal, S., Eric, G., Céline, V., Simon, D., Jean-François, F. and Jean-Nicolas, B. 2012. Effects of sublethal Cadmium exposure on antipredator behavioural and antitoxic responses in the invasive amphipod Dikerogammarus villosus. PLoS ONE, 7(8).

Paul, M. J. and Meyer, J. L. 2001. Streams in the urban landscape. *Annual Review of Ecology and Systematics,* 32: 333-365.

Pinto, B. C. T., Araujo, F. G. and Hughes, R. M. 2006. Effects of landscape and riparian condition on a fish index of biotic integrity in a large southeastern Brazil river. *Hydrobiologia*, 556: 69-83.

Risen, C. M., M. J. Wiley, R. W. Black, and Munn, M.D. 2011. Impacts of agricultural land use on biological integrity: a causal analysis. Ecological Society of America: *Ecological Applications* 21: 3128–3146.

Rosenberg, D. M., H. V. Danks, and Dennis, M. L. 1986. Importance of insects in the environmental impact assessment. *Environmental Management,* 10: 773-783.

Rosenberg, D. M., and Resh, V. H. 1993. Freshwater biomonitoring and benthic macroinvertebrates. Environmental Management. Chapman & Hall, 488 pages.

Roy, A. H., D. Rosemond, M. J. Paul, D. S. Leigh, and Wallace, J. B. 2003. Stream macroinvertebrate response to catchment urbanisation (Georgia, U.S.A.). *Freshwater Biology*, 48: 329–346.

Samal, D. R. and Gedam, S. S. 2012. Impact of Land-use Dynamics on Stream Flow: A case study in Upper Bhima basin, Maharashtra, India. Geoscience Remote Sensing Symposium. (IGARSS). IEEE International; Munich, p. 7165-7168.

Scott, M. C. 2006. Winners and losers among stream fishes in relation to land use legacies and urban development in the southeastern U.S. *Biological Conservation,* 127: 301-309.

Sharma, R. C. 1986. Effect of physicochemical factors on benthic fauna of Bhagirathi River, Garhwal Himalaya. *Indian Journal of Ecology,* 13: 133–137.

Smith R. F. and. Lamp, W. O. 2008. Comparison of insect communities between adjacent headwater and mainstem streams in urban and rural watersheds. Journal of the North American Benthological Society 27: 161 -175.

Snyder, C. D., J. A. Young, R. Villella, and Lemarie, D. P. 2003. Influences of upland and riparian land use patterns on stream biotic integrity. *Landscape Ecology ,* 18: 647-664.

Swanson, H. A., and Baldwin, H. L. 1965. A Primer on Water Quality. U.S. Geological Survey.

United States Environmental Protection Agency. 1992. Handbook for Sampling and Sample Preservation of Water and Wastewater. 18th Edition. Report No. EPA-600/4-82-029.

United States Environmental Protection Agency. 2001. Parameters of Water Quality Interpretation and Standards. Retrieved from http://www.epa.ie/pubs/advice/water/quality/Water_Quality.

United States Environmental Protection Agency. 1997. Volunteer Stream Monitoring: A Methods Manual on Monitoring Water Quality. EPA 841-B-97-003.

United States Environmental Protection Agency. 2009. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition.

United States Environmental Protection Agency. 2011**.** Nitrogen and Phosphorus in Streams in Watersheds. Watershed and Pollution Series.

Virbickas, T., V. Plūiraite, and Kesminas, V. 2011. Impact of agricultural landuse on Macroinvertebrate Fauna in Lituania. *Polish Journal of Environmental Studies ,* 20: 1327-1324.

Walley, W. J. and Hawkes, H. A. 1997. A computer-based development of the Biological Monitoring Party Score system incorporating abundance rating, biotope type and indicator value. *Water Research,* 31: 201.

Wang, L., J. Lyons, P. Kanehl, and Bannerman, R. 2000. Impacts of urbanization on stream habitat and fish across multiple spatial scales. *Environmental Management,* 28: 255-266

Wagner, C. N. 2008. Urbanization; 21st Century Issues and Challenges. Nova Science Publishers Inc. New York.

Wagner, L. E., P. Vindon, L. P. Tedesco, and Gray, M. 2008. Stream nitrate and DOC dynamics during three spring storms across land uses in glaciated landscapes of the Midwest Journal of Hydrology 362: 177-190.

Water Environment Partnership in Asia – Ministry of the Environment of Japan. 2003. State of water environmental issues, *Philippines: Environment Monitor*. Retrieved from http://www.wepa-db.net/policies/state/philippines/overview.htm.

Westfall, B. A. 1945. Coagulation anoxia in fishes. *Ecology,* 26:283–287

Woodiwiss, F. S. 1978. Comparative study of biological-eco-logical water quality assessment methods. Summary Report. Commission of the European Communities. Severn Trent Water Authority. UK, p 45.