INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 6, No. 9, p. 62-73, 2015

RESEARCH PAPER OPEN ACCESS

Macroinvertebrates as bioindicators of water quality in Labo and Clarin rivers, Misamis Occidental, Philippines

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Key words: Ephemeroptera, Organic pollution, Plecoptera, Pollution-sensitive, Trichoptera.

http://dx.doi.org/10.12692/ijb/6.9.62-73 Article published on May 08, 2015

Abstract

Aquatic macroinvertebrates are affected by physical, chemical and biological conditions of the stream. Some of them are pollution-sensitive while others are pollution-tolerant. They are good indicators of stream health. This study was conducted to determine the status of Labo and Clarin Rivers using macroinvertebrates as bioindicators. Dip-net and kick-net methods were employed. Results showed that sampling sites in forested areas in Labo and Clarin rivers had a higher macroinvertebrate taxa richness and abundance. Mayflies (Ephemeroptera) were the dominant macroinvertebrates. Ephemeroptera, Plecoptera, and Trichoptera (EPT) and %EPT indices were higher in Clarin than Labo River. Based on Family-level biotic index (FBI), the water quality of sampling site 1 in Clarin (forested site) was excellent (organic pollution is unlikely) and very good (possible slight organic pollution) for site 1 in the Labo River but decreased downstream (fair to good quality). MANOVA results revealed a significant difference in the macroinvertebrate abundance in the agricultural sites of Labo River and forest sites of Clarin River. Cluster analysis showed that among the macroinvertebrates, mayflies (Ephemeroptera) were distinct in the forest sites and bugs (Hemiptera) in agricultural sites on Clarin River. Fly larvae (Diptera) and beetles (Coleoptera) were distinct in agroforest sites of the Clarin River while abundant in agricultural sites on Labo River. Results indicate a need for monitoring and proper management of Labo and Clarin rivers to prevent increasing deterioration of water quality.

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Introduction

Bioassessment has been mainly used to assess river health because it depends on living organisms that are exposed to the integration of conditions in the watershed (Bellucci *et al.,* 2013). These living organisms are the bioindicators. Bioindicators are organisms used as surrogates for environmental quality (Clarke *et al.,* 2003). There are many organisms that have been used to assess water quality or monitor effects of pollutants in aquatic ecosystems but many studies in different parts of the world show that benthic macroinvertebrates are generally good biological indicators of stream health (Dudgeon, 2007; Hepp*et al.,* 2010; Chadwick *et al.,* 2012). Macroinvertebrates are related strongly to local stressors such as chemical degradation and riparian degradation because of their long life history and limited mobility (Cheimonopoulou *et al.,* 2011).

Aquatic insects are very important in the flow of energy and matter through the river ecosystems and their roles are best described into functional groups or trophic groups that include shredders, collectors/filter feeders, scrapers, piercers, and predators, and are based on their morpho-behavioral mechanisms for gathering food rather than taxonomic relationships (Mandaville, 2002). The presence of aquatic insects depends not only on consumable resources but also on microclimate. Temperature is an important factor (New, 2009). Many insects actually show non-linear relationships with temperature, metabolic rate, and development. Lamberti and Resh (1985) reported that no macroinvertebrates are found in water with temperatures equal to or above 45ºC, but the highest density (mainly midges of Diptera: Chironomidae) occurred at 34ºC, with maximum species richness at a much more tolerable 27ºC. Both midges and caddisflies (Trichoptera) are most common at sites that are several degrees below their lethal thermal thresholds, which suggests some leeway in the system should temperatures suddenly rise. Li *et al.* (2013) reported that the species that are associated with low water temperatures are representatives of the orders Epheremoptera, Diptera, Plecoptera and Trichoptera. The high-water temperature species are *Paratyacompressa*, *Platycnemis,* *Sympetrum,* and*Baetis*. Other important factors affecting the presence of macroinvertebrates are nutrients and dissolved oxygen. The higher values of nutrients and lower dissolved oxygen obtained in urban streams are the effects of the input of organic materials in the water that will strongly influence the community structure and composition (Hepp *et al.,* 2010).

The risk of extinction for freshwater organisms is higher than that of organisms in almost all other ecosystems (Revenga *et al.,* 2005) and freshwater biodiversity has declined faster than either terrestrial or marine biodiversity (Xenopoulous *et al.,* 2005). According to Samways (2007), majority of entomologists conclude that the most serious class of threat to insects is the land use change, particularly habitat destruction and fragmentation. Different human activities cause the alteration of physical, chemical, and biological processes associated with water resources. The deeply deforested river basins often demonstrate drastic changes in the river morphology that will result to riverside erosion. During erosion, there will be increased inputs of sediments in the river; substrates are unstable, less complex with less coarse organic particulate matter for the fauna (Schulz, 2001; Rios and Bailey, 2006; Nessimian *et al.,* 2008). Hepp *et al.* (2010) showed that urban and agricultural impacts affect the water quality and aquatic diversity. The higher values of nutrients and lower dissolved oxygen obtained in urban streams are the effects of the input of organic materials in the water that will strongly influence the community structure and composition.

In the study of Tampus *et al.* (2012), the variation in the number of macroinvertebrates in every area is due to the different factors affecting the activity of benthos. Macroinvertebrates were highest in number near tributaries where there is the presence of food while lowest in the impacted areas. Dumbrava-Dodoaca and Petrovici (2010) reported that the deterioration of water quality downstream led to changes in the abundance of macroinvertebrate communities. This is also true in the study conducted by Raescu *et al.* (2011) where the progressive deterioration of water quality is marked by the decrease in the biotic index EPT/Ch (Ephemeroptera, Plecoptera, Trichoptera/Chironomidae) value. The great concentration of organic substance downstream is shown by the dominance of Oligochaeta. Agricultural activities together with pesticide runoff, urbanization and other anthropogenic activities cause the reduction of macroinvertebrate taxa richness. In both urban sites and pastures, macroinvertebrate density is higher and species richness is significantly lower than in conserved area (Hepp and Santos, 2009).

Labo and Clarin Rivers are major river systems in Misamis Occidental. With the rising demand of water for domestic, agricultural and recreational purposes are the increasing man-made and natural threats to the water quality of these rivers. Thus, this study was conducted to evaluate the water quality status of Labo and Clarin Rivers using macroinvertebrates. Specifically, the study determined the level of organic pollution in water of Labo and Clarin Rivers based on different biological indices.

Materials and methods

Study Area

Misamis Occidental is found at Region X of Mindanao, Philippines. It has five major river systems including Labo and Clarin Rivers. Labo River is located within 123°49'8" to 123° 51' 52” east longitude and 8°10'31" to 8° 11' 32" north latitude. It is a natural boundary between Tangub City and Ozamiz City. Clarin River is located within 123⁰ 37' 30” to 123⁰ 13' 10” east longitude and 8⁰ 7'30” to 8 ⁰ 13'10” north latitude (Fig. 1). It is the natural boundary between the municipality of Clarin and the city of Ozamiz.

Sampling Sites

Field sampling was conducted in October 2010 and May 2011 to represent the wet and dry seasons, respectively in Clarin and Labo Rivers. Three sampling sites were established in each river. Sampling site 1 was the portion of the river located along the forest area. Sampling site 2 was the part of the river along the agroforest area, while the third sampling site was the part of the river along the agricultural area. In each sampling site, three sampling stations were chosen.

Sampling of Macroinvertebrates

Dip-netting and kick-netting methods were employed to collect macroinvertebrates from each sampling site. Macroinvertebrates were identified using the dichotomous key and were classified according to family. Family-level Biotic Index and other biological indices were calculated to determine the extent of organic pollution. Physico-chemical parameters were determined following the Standard Methods for the Examination of Water and Wastewater (American Public Health Association *et al.,* 2005).

Statistical analysis

The significant difference of macroinvertebrates between rivers and between sites was determined using MANOVA (Hotelling's Pairwise) and cluster analysis (Euclidean similarity). The significant difference of physico-chemical parameters among samplings sites was calculated using one-way ANOVA.

Results and discussion

Four classes with 31 families consisting of 1217 individuals in Labo River and 26 families comprising 2205 individuals in Clarin River were recorded (Table 1). Clarin River had a higher abundance of Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies) and Hemiptera (True Bugs). Tampus*et al.,* 2012 reported that these groups are considered as good indicators of water quality. On the other hand, Labo River had greater number of Diptera (especially Chironomidae), Coleoptera (beetles), Odonata (dragonflies and damselfies) and Oligochaeta. These groups are known to be pollution-sensitive.

Compared to the agroforest and agricultural sites, the water at the forested portion of Clarin and Labo Rivers had the greater number of larvae and nymphs of aquatic insects which are known as good indicators. The higher number of aquatic insects is due to the large canopy cover providing shade to the water and more food to the shredders, leaf litters and collectors such as the three prime insects (mayflies, stoneflies and caddisflies) and less tolerant species of Odonata (Mandaville, 2002). Similar pattern was noted by Jomoc *et al.* (2013) where a high species richness of Odonata was recorded in sampling sites with semi-pristine characteristics.

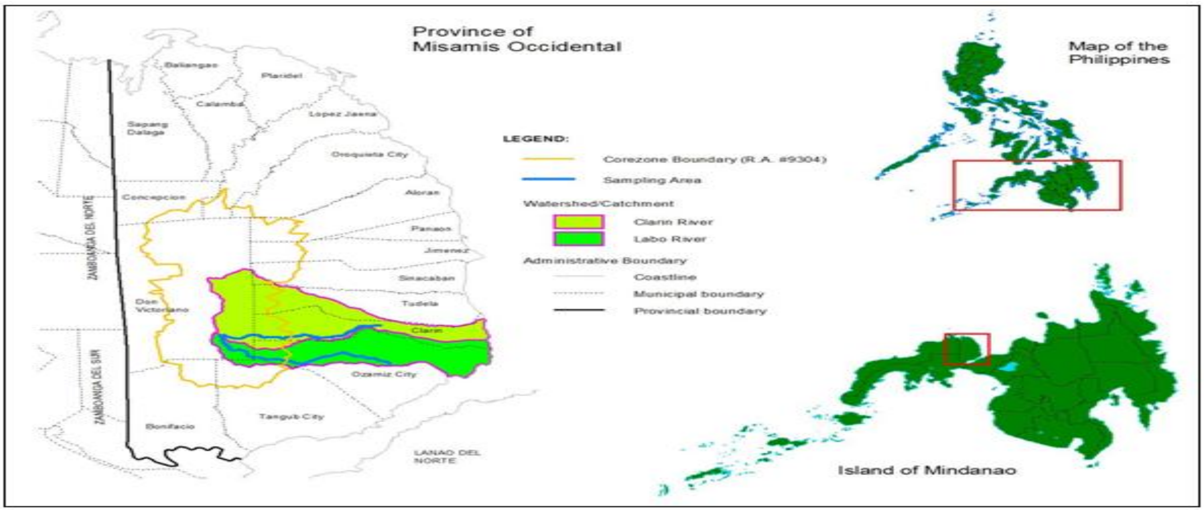

Fig. 1. Map of Mt. Malindang showing Labo and Clarin Rivers, Misamis Occidental.

The sites had less disturbed lotic waters surrounded with dipterocarp trees and natural vegetation. Many insects thrive on these areas and spend part of their life history in the water. The abundant aquatic plants in the forested site of Labo and Clarin rivers provide surface for the macroinvertebrates to live and balance the water flow, light availability, and lower temperature around them. Species that are associated with low temperatures are representative of the orders Ephemeroptera, Diptera, Plecoptera and Trichoptera (Li *et al.,* 2013). The amount of oxygen (or any gas) that can dissolve in pure water (saturation point) is inversely proportional to the temperature of water. This area had colder water, therefore more dissolved oxygen. The mayflies, stoneflies and caddisfliesnymphs of aquatic insects are very sensitive to most pollutants and cannot survive if a stream's dissolved oxygen falls below a certain level. If there are no mayflies, stoneflies, and caddisflies present in an area that used to support them, then, dissolved oxygen has fallen to a point that keeps them from reproducing or killed them directly. Certain macroinvertebrates require high levels of dissolved oxygen (clean water) to survive, and others thrive in lower levels of dissolved oxygen (more pollution).

Dobsonfly larvae (Sialidae) were found mostly in forest and agroforest sites of Labo and Clarin rivers. These are considered as fairly intolerant of pollution. They are found in fast-moving waters and indicate ample oxygen supply (Kannel *et al.,* 2011). Dragonflies, mostly families of Aeshnidae and Lestidae, were found in lower stations of forest and all stations of agroforest sites. These often reflect waters with lower dissolved oxygen levels. There are lesser aquatic plants that were found in the area, causing a warmer temperature therefore lesser dissolved oxygen (Labajo-Villantes and Nuñeza, 2014). Midge flies (Chironomidae), bugs (Hydrometridae, Gerridae, and Corixidae) were recorded in agroforest and agricultural areas while worms (Class Oligochaeta) were only recorded in agricultural areas. These macroinvertebrates are indicators of poor water quality and tolerant of pollution.

In Labo River, the highest number (505) of macroinvertebrates was collected from the water at the agricultural stations followed by the forested stations (446) while the least number (266) was from the agroforest stations. In the agricultural stations, larvae of chironomids, species of beetles (Psephenidae and Hydrophilidae), bugs (Hydrometridae and Gerridae) and oligochaeteswere abundant. The presence of these groups in high numbers indicates polluted water (Dumbrava-Dodoaca and Petrovici, 2010). Moreover, there is a decrease in the number of taxa that are less tolerant to modifications in the water quality together with an increase in the number of pollution-tolerant taxa (Smith and Lamp, 2008).In this portion of Labo River, unclear water, domestic animals, and domestic garbage were observed. In forested sites, mayflies of families Baetidae, Caenidae and Heptageniidae dominated the area. Stoneflies of family Peltoperlidae and Perlidae, caddisflies of family Hydroptilidae and Lestidae and Aeshnidae of Class Odonata were moderately abundant.

Table 1. Macroinvertebrate composition and abundance in Labo and Clarin rivers by sampling site.

Macroinvertebrates	Labo river			Clarin river		
	Number of Organisms			Number of Organisms		
	Forest	Agroforest	Agricultural	Forest	Agroforest	Agricultural
PHYLUM ARTHROPODA						
CLASSHEXAPODA (Insecta)						
Order Ephemeroptera (Mayflies)						
Baetidae	159	35	0	318	205	54
Caenidae	74	48	12	42	93	23
Heptageniidae	44	2	0	186	27	15
Ephemerellidae	0	0	0	14	0	2
Ephemeridae	6	2	2	7	1	0
Tricorythidae				11	6	0
Order Plecoptera (Stoneflies)						
Nemouridae	2	0	0	59	14	0
Peltoperlidae	15	1	0	22	3	0
Perlidae	27	2	0	109	45	2
Order Trichoptera (Caddisflies)						
Glossosomatidae	2	5	1	59	28	4
Hydropsychidae	6	3	0	13	2	0
Hydroptilidae	14	2	0	102	14	2
Lepidostomatidae	2	0	0	1	0	0
Philopotamidae				78	14	0
Polycentropodidae				2	17	1
Order Odonata (Dragonflies and Damselflies)						
Lestidae	19	11	22	6	12	2
Aeshnidae	14	13	9	33	18	1
Libellulidae	3	1	14	2	9	0
Gomphidae				8	4	0
Order Megaloptera (Alderflies and Dobsonflies)						
Sialidae	6	1	2	4	5	0
Order Diptera (True Flies)						
Culicidae	2	4	21	0	18	9
Chironomidae	0	8	116	0	25	52
Simuliidae	0	13	48	2	16	33
Order Coleoptera (Beetles)						
Elmidae	2	16	62	12	11	5
Psephenidae	8	18	41	16	22	2
Hydrophilidae	10	2	39	1	1	5
Order Hemiptera (True Bugs)						
Belostomatidae	2	16	1	0	1	2
Corixidae	10	6	0	8	19	6
Hydrometridae	0	16	29	2	13	79
Gerridae	19	41	36	13	66	35
CLASS MALACOSTRACA						
Order Decapoda (Shrimp)				3	15	0
PHYLUM ANNELIDA						
CLASS HIRUDINEA						
Erpobdellidae	0	0	9	0	0	6
CLASS OLIGOCHAETA	0	0	41	0	0	11
Total no. of individuals (by sampling site)	446	266	505	1130	724	351
Over-all Total (by river)	1217			2205		
Total no. of families	22	23	18	28	29	22
Total no. of classes	1	1	3	2	2	3

In Clarin river, majority of macroinvertebrates were collected from the forested stations (1130), followed by agroforest (666) and agricultural stations (249). Stations in forested area had very high taxa richness (28). Of these groups, mayflies of family Baetidae dominated the samples followed by Heptageniidae, stoneflies (family Perlidae) and caddisflies (family Hydroptilidae). The presence of these groups in forested portion of Clarin River is attributed to the very dense vegetation along the river bank. These groups of macroinvertebrates are shredders (fragment the litter into particle sizes and used by other invertebrate groups) that thrive in the area because of continuous falling of leaves and other debris into the water (Moss, 2010).

Table 2. The mean±SE of the physicochemical parameters per sampling site of Labo and Clarin rivers.

	Labo river				Clarin river			
Parameters	Forest	Agroforest	Agricultural	F value	Forest	Agroforest	Agricultural	F value
Water temperature (°C)	21.67±0.58	25±1.73	25.17±0.76	8.96*	19.0±1.0	20.0±1.0	23.0±1.0	13.0*
Turbidity (NTU)	0.25±0.06	0.33±0.04	0.5±0.02	24.20*	0.14±0.02	0.16±0.06	0.11±0.04	2.74
Total Dissolved Solids (mg/L)	52.67±5.03	63.33±4.04	67.67±3.06	10.52*	27.83±1.04	42±2.0	59±3.61	121*
pH range	7.98-8.17	7.33-8.27	7.89-8.05	.155	6.92-7.19	6.42-6.97	6.40-6.53	6.86*
Acidity (mg/L)	16.56±0.73	15.63±0.71	18.11±0.99	7.01*	18.51±0.75	16.92±0.46	15.90±0.32	14.5*
Alkanity (mg/L)	63.55±2.38	69.62±2.39	79.52±4.58	18.1*	36.05±3.16	51.30±2.43	59.02±3.18	47.3*
Total Hardness (mg/L as $CaCO_3$)	64.00±5.29	69.67±0.58	72.33±2.52	4.70	39.67±1.53	51.00±2.65	64.33±1.53	118*
Calcium (mg/L)	1.66±0.04	1.70±0.03	1.84±0.15	3.21	0.71±0.03	1.14±0.08	1.37±0.08	72.4*
Magnesium (mg/L)	15.33±0.25	16.10±0.10	16.56±0.19	32.1*	9.20±0.27	11.65±0.33	15.03±0.63	133*
Dissolved oxygen (mg/L)	9.3±1.21	5.76±0.57	3.57±1.04	26.2*	10.40±1.21	6.97±0.80	4.00±0.32	60.4*
Biological oxygen demand (mg/L)	0.97±0.16	2.30±0.30	2.50±0.46	20.1*	0.23±0.14	1.86±0.30	2.03±0.41	31.5*
Nitrate (mg/L NO_3-N)	0.36±0.12	0.30±0.17	0.56±0.12	1.50	0.30±0.17	0.46±0.08	0.45±0.06	1.79
Phosphate (mg/L PO_4-P)	0.07±0.02	0.07±0.01	0.08±0.01	.973	0.06±0.01	0.07±0.04	0.137±0.050	3.68
River discharge (m^3/s)	18.31±2.44	12.23±5.14	5.31±3.22	.188	7.76±1.46	4.17±2.42	3.66±2.87	2.77
Average velocity (m/s)	4.17±0.15	2.77±0.78	2.90±0.72	4.65	3.30±0.06	2.71±0.52	2.48±1.96	.390

* Mean difference is significant at p<0.05 level using One-Way ANOVA.

In the total population of macroinvertebrates collected, the dominant organisms were the aquatic insects belonging to class Hexapoda while the leeches of class Hirudinea were the least in both rivers. Labo and Clarin Rivers provide a variety of potential niches and greater stability in the face of geological and climate changes that is why the availability of the water is one of the most important abiotic variables influencing the distribution of animal species, especially small ones like insects (Addo-Bediako *et al.*,2000). The abundance of aquatic insects in Clarin River is higher than Labo River. This is due to a larger canopy cover and dense vegetation present in forest portion of Clarin than Labo River. On the other hand, a higher number of oligochaeteswere recorded in Labo than Clarin River especially in agricultural stations. Runoff from domestic sewage, domesticated animals, and agricultural activities contributed to the presence of these pollution-tolerant macroinvertebrates (Hepp *et al.*, 2010).

The mayflies (Ephemeroptera) were the most abundant aquatic insects in Labo River with 384 individuals and in Clarin River with 1004 individuals. In Labo River, fly larvae (Diptera), beetles (Coleoptera) and water bugs (Hemiptera) were moderately abundant. All functional feeding groups of the Dipterans were represented. In Clarin River, there were caddisflies (Trichoptera), stoneflies (Plecoptera) and true fly larvae (Diptera) that were also abundant, next to mayflies.

Table 2 shows that dissolved oxygen (F=26.2 for Labo and F=60.4 for Clarin, p<0.05) had significant difference among sampling sites. The absence of most stoneflies and caddisflies in the agricultural areas may not only be due to underoxygenated water that flows slowly, but due to very high water temperatures

(F=8.96 for Labo and F=13.0 for Clarin, p<0.05) caused by the absence of trees and other plants in the riparian areas and of pollutants discharged from run-off in farmlands and domestic discharges. The habitat degradation causes excess sand or silt on the stream bottom affecting the aquatic insects sheltering areas, or other conditions (Labajo-Villantes and Nuñeza, 2014).

Table 3. Biological indices measured in Labo and Clarin rivers.

Biological Indices	Labo river	Clarin river
Ephemeroptera, Plecoptera, Trichoptera(EPT)	466	1595
%EPT	22.61%	77.39%
Ephemeroptera, Trichoptera and Odonata (ETO) Index	525	1436
Ephemeroptera, Plecoptera, Trichoptera/Chironomidae(EPT/C)	3.76	20.71

In agricultural areas, there was a high organic matter from decayed logs and plants and continuing increase of agricultural run-off and domestic sewages from nearby settlements. This will affect the biological oxygen demand (Martinez and Galera, 2011). Biological oxygen demand (BOD) has significant difference (F=20.1 for Labo and F=31.5 for Clarin, p<0.05). Increase in organic matter means an increase of water-borne bacteria. Environmental modifications and pollution on these sampling areas alter macroinvertebrate communities.

Table 4. Family-level Biotic Index (FBI) mean readings in three sampling sites of Labo and Clarin rivers.

Sampling site	Labo river			Clarin river		
	FBI	Water Quality	Implication	FBI	Water Quality	Implication
1 (Forest)	4.01	Very Good	Possible slight organic pollution	3.24	Excellent	Organic pollution unlikely
2 (Agroforest)	4.48	Good	Some organic pollution probable	3.94	Very Good	Possible slight organic pollution
3 (Agricultural)	5.36	Fair	Fairly susbtantial pollution likely	4.67	Good	Some organic pollution probable

There was a significant difference in turbidity among sampling stations of Labo river (F=24.20, p<0.05). There was highly turbid water in lower stream and the light penetration was reduced, affecting photosynthesis of plants, thus increasing the temperature and lessening dissolved oxygen in the water. This was also affected by the higher levels of dissolved solids which has also a significant difference (F=10.52 for Labo and F=121 for Clarin, p<0.05) among areas in agricultural areas of lower streams. This will affect the movement, feeding, habitat and reproduction of some of macroinvertebrates (Hepp *et al.,* 2010).

High levels of nutrients in the form of nitrogen and phosphorous from fertilizers and waste waters of the local communities surrounding the agroforest and agricultural areas can activate excessive algal growth (Conley *et al.*, 2009). The death and decay of these algae can produce toxins and stagnant conditions. In these conditions, macroinvertebrate community diversity is usually reduced, but there is generally an increase in the abundance of a few species. This may be the cause why the agricultural areas had the lesser abundance and diversity of macroinvertebrates among the three sampling sites of both rivers.

Table 3 shows the Ephemeroptera, Plecoptera, Trichoptera (EPT) and %EPT indices calculated in Labo and Clarin rivers. Clarin river had higher EPT (1595) and %EPT (77.39%) than Labo river (EPT- 466 and %EPT - 22.61%). Based on these two biological indices, Clarin river has better water quality than Labo River.

The abundance of Ephemeroptera, Plecoptera, Trichoptera versus Chironomidae (EPT/C) implies the balance of the community since EPT is considered to be more sensitive and Chironomidae less sensitive to environmental stress (Plafkin*et al.,* 1989), so EPT/C was also calculated. It is known that EPT/C of the Clarin River was higher than Labo River. This means that there is more uneven distribution among the mayflies, stoneflies, caddis flies and midges in Clarin River than Labo River. This is because of the presence of high abundance of EPT at the forest sites and rare or absent at agricultural sites. On the other hand, the very high number of Chironomidae at the agricultural site of Labo River indicates environmental issues such as input of organic materials in the water.

Table 5. Hotelling's Pairwise comparison of macroinvertebrates among the sampling sites of Labo and Clarin rivers.

	Labo			Clarin		
	(Forest)	(Agroforest)	(Agricultural)	(Forest)	(Agroforest)	(Agricultural)
Labo (Forest)		0.746	0.040	0.758	0.921	0.367
Labo (Agroforest)			0.225	0.586	0.891	0.550
Labo (Agricultural)				0.049	0.242	0.199
Clarin (Forest)					0.844	0.409
Clarin (Agroforest)						0.495
Clarin (Agricultural)						

Family-level Biotic Index (Hilsenhoff, 1988) is another biological index used to describe water quality based on pollution tolerance values for benthic macroinvertebrate families. Based on table 4, sampling site 1 (forest) of Labo river is considered to have a very good water quality which means that a possible slight organic pollution is present while sampling site 1 (forest) of Clarin river is considered to be excellent. This means that in this portion of the river, organic pollution is unlikely.

The presence of secondary growth forest along the riparian zone of Clarin River provides the best shelter, the most food, and the most dissolved oxygen needed by pollution sensitive macroinvertebrates. Sampling site 2 (agroforest) of Labo River which is considered as good indicates the probability of some organic pollution while in Clarin River, it was very good. The presence of farmlands and few settlements in these areas contributed to the presence of organic matter into the water. The increasing runoff from farmlands, household wastes, quarrying and other urbanization impacts appears to decrease the quality of water (Fair quality) especially in sampling site 3 of Labo River. During the sampling, cattle, hogs and other poultry animals were in the river banks. Big trucks with sand and gravel were also observed passing by.

MANOVA results showed a significant difference in the macroinvertebrate abundance in the agricultural sites of Labo River (Table 5). A significant difference (0.040, $p<0.05$) was analyzed. There was a high number of somewhat sensitive to pollution-tolerant organisms such as bugs, beetles, fly larvae, and worms. The presence of farming, quarrying, indiscriminate garbage disposal, and other anthropogenic activities minimize the diversity of macroinvertebrates in these sites. On the other hand, there was a significant difference (0.049, $p<0.05$) in forest sites of Clarin. The presence of vegetation along the riparian zone contributes to the healthy portion of this river.

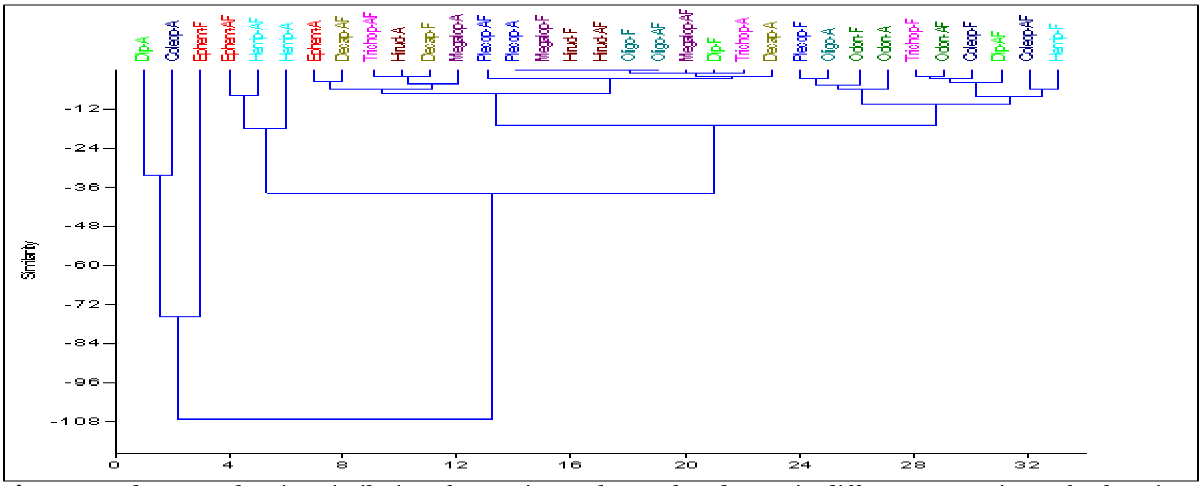

Fig. 2. Dendrogram showing similarity of macroinvertebrate abundances in different vegetations of Labo River.

The similarity of macroinvertebrate abundance across vegetations was analyzed by cluster analysis using PAST: Paleontological Statistics Software Package (Hammer *et al.*, 2001). Fig. 2 shows the dendrogram of similarity of macroinvertebrate abundances in different vegetations of Labo River. In Labo River, mayflies (Ephemeroptera) in forested sites were clustered with midges (Diptera) and bugs (Coleoptera) in agricultural sites due to similarity of aquatic insects under family Caenidae and Ephemeridae. The bugs (Hemiptera) in agricultural sites were clustered with mayflies and bugs in agroforest sites because of the presence of macroinvertebrates under Hydrometridae and Gerridae families.

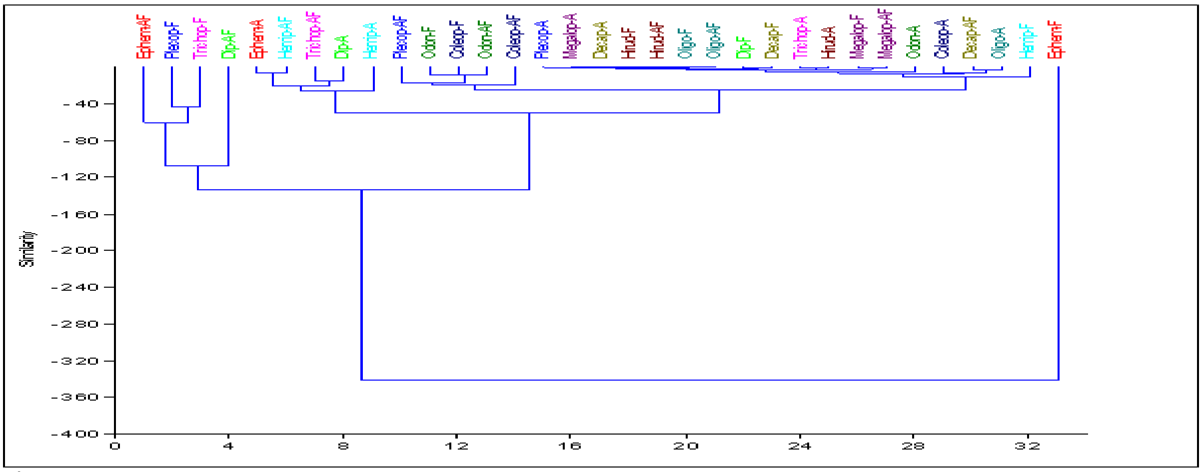

Fig. 3. Dendrogram showing similarity of macroinvertebrate abundances in different vegetations of Clarin River.

Fig. 3 shows the dendrogram of similarity of macroinvertebrate abundance in different vegetations of Clarin River. Mayflies (Ephemeroptera) were distinct in the forest sites. The presence of Baetidae and Heptageniidae in forested areas in high abundance separates these groups of macroinvertebrates from the others. Plecoptera and Trichoptera in forest sites were clustered with Ephemeroptera of agroforest. Odonata in forest and agroforest and Coleoptera in forest were clustered into Plecoptera in agroforest. These groups are ecologically similar due to dense and natural vegetation. Fly larvae (Diptera) and beetles (Coleoptera) were clustered in agroforest sites of Clarin River.

Conclusion

Macroinvertebrate taxa richness and abundance varied among sampling sites and between rivers. Ephemeroptera, Plecoptera, and Trichoptera organisms were normally found in forested sites while Hemiptera, Diptera and Coloeptera usually were abundant in agroforest and forest sites of rivers. Physico-chemical quality of sampling site had directly or indirectly affected macroinvertebrate assemblages. Based on biological indices analyzed, Clarin River is healthier and cleaner than Labo River.

Acknowledgement

We would like to express our gratitude to the Misamis University, Ozamiz City for giving the financial support throughout the conduct of the study.

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