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PRELIMINARY SURVEY ON THE DIVERSITY AND COMMUNITY ASSEMBLY OF MACROINVERTEBRATES ALONG THE DAKIL RIVER, UNIVERSITY OF THE PHILIPPINES LAGUNA LAND GRANT, PAETE, LAGUNA, PHILIPPINES

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ABSTRACT – Benthic macroinvertebrates are important components of running water because many of its members are fundamental connectors among the different trophic levels as integral parts of aquatic food webs, effective surrogates of ecosystem attributes and functional groups abundance can be used to assess stream health. This study aimed to determine the water physico-chemical characters of the river system, determine the diversity and community assembly patterns of macroinvertebrates and to correlate the species richness and abundance with selected environmental variables in the Dakil River system of Laguna Land Grant, Paete, Laguna, Philippines. A total of 572 individuals (7 classes, 15 orders, and 29 families) were collected from the all stations. Hexapods (16 families) constituted 55% of total abundance, followed by gastropods (21%) with five families. UPLLG had high diversity index (H'=2.64), taxon evenness (E=0.48) and taxon dominance (E=0.11). Species accumulation curve exhibited ß-dominated diversity pattern with having completeness ratio of 0.75. Macroinvertebrates in the Dakil River system in the UP Laguna Land Grant have preferred microhabitat within the site as supported by Canonical Correspondence Analysis (CCA). The Generalized Linear Mixed Model (GLMM) revealed that species richness was highly predicted by pH while abundance predicted by the river velocity, canopy cover, and conductivity. The present study suggested that environmental variables highly influence macroinvertebrates diversity in streams and can be good ecological indicators of the health of ecosystem.

Keywords: abundance, Dakil River, macroinvertebrates diversity, streams

INTRODUCTION

In a tropical ecosystem, one of the major fauna are the macroinvertebrates (e.g. arthropods, mollusks, and worms), and one of the highest diversity is concentrated along with the riparian areas (Flores and Zafaralla, 2012; Dodds, 2002; Tumwesigye et al., 2000). The benthic macroinvertebrates are important components of running water because many of its members are fundamental connectors among the

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different trophic levels (Costa and Melo, 2008) as integral parts of aquatic food webs (Dodds, 2002; Mantel et al., 2004; Bouchard, 2004). Macroinvertebrates break down materials from primary production thereby facilitating energy and nutrient cycling and, are also key prey items of vertebrates. Moreover, macroinvertebrates are effective surrogates of ecosystem attributes and the abundance of functional groups may indicate anthropogenic impact (Merritt and Cummins, 2006) and are used to assess stream health (Mantel et al., 2004; Bouchard, 2004).

Several studies on aquatic invertebrate diversity have been conducted in the Philippines (Freitag, 2005; Flores and Zafaralla, 2012; Dacayana et al., 2013). However, many species still remain understudied, both biologically and ecologically (Palmer et al. 1997). Thus, there is a need to conduct baseline studies focused on their diversity and community assemblage in tropical streams to understand better organic-matter processing, energy flow, trophic relationships and management actions needed to conserve these vital natural resources.

One of the ideal sites for freshwater macroinvertebrate study is in the watershed streams of University of the Philippines Laguna Land Grant (UPLLG) in Paete, Laguna. The UPLLG has the only natural grown secondary forests between Pakil and Paete. The site was included as an Important Biodiversity Area (IBA) in 2001 due to the many threatened and restricted-range birds of the Luzon Endemic Bird Area in the area. This IBA is also a stronghold for various lowland rat species, civets, and fruit bats, and supports heavily hunted large mammals, such as Philippine Warty Pig (*Sus philippensis*) and Long-tailed Macaque (*Macaca fascicularis*) (Birdlife International, 2016).

At present, there is no study on the diversity of benthic macroinvertebrates in the watershed streams of UPLLG. Understanding the macroinvertebrates diversity could help assess the environment and ecological conditions in the watershed. Thus, this study aimed to (1) determine water physico-chemical characteristics of the four tributaries and the Dakil River, (2) determine the diversity of benthic macroinvertebrates in the Dakil river system (3) to correlate the species richness and abundance with selected environmental variables.

MATERIALS AND METHODS

Study Site

The UP Laguna Land Grant (14° 23' N, 121° 29' E) is an area owned by the University of the Philippines. It is located along with the municipalities of Paete and Kalayaan in the province of Laguna and partly of Real, Quezon province (Figure 1). It is a mountainous area 300 to 400 m.a.s.l., containing mostly disturbed lowland Dipterocarp forests and secondary growth. Much of the original areas have been heavily exploited by logging and slash-and-burn farming, especially on the outlying areas of Balian and Saray in Pakil (Gonzalez, 1995). The UPLLG includes some areas of permanent agriculture (including rice paddies), kaingin, plantations, small settlements and rural gardens (Birdlife International, 2016). Albeit, the area is not declared as a protected area, its protection is managed by the University of the Philippines Los Baños through the effort of Laguna Land Grant Management Office (LLGMO). The UPLLG has a total land cover of 3,435.4 ha comprising four major rivers that run to the LLG namely: Dakil, Tibag, Papatahan, and Ginabihan. The Dakil River has the largest watershed area covering with 2,989 hectares. All these rivers drain towards the Lamon Bay in Quezon Province.

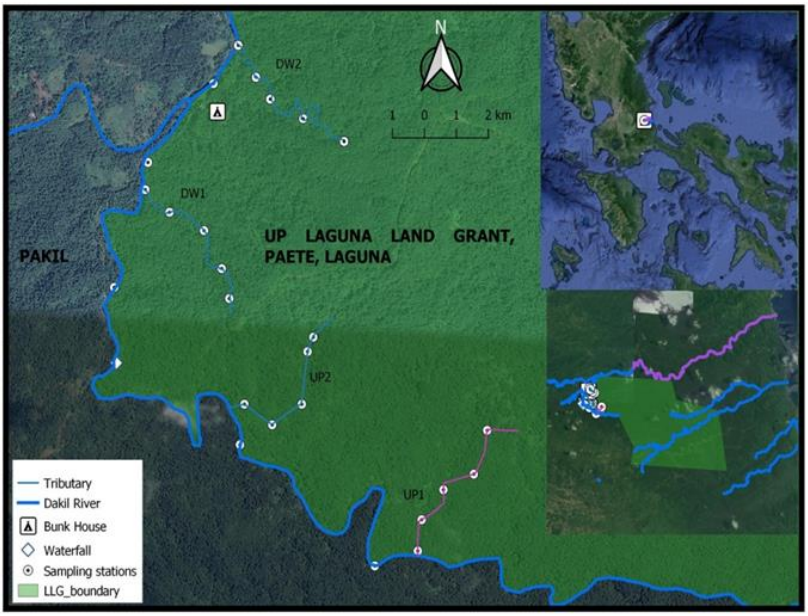

Figure 1. Map of the study site, along the Dakil River, boundary of the UP Laguna Land Grant, Paete, Laguna (Google Earth satellite image using QGIS ver 3.4 Madiera).

Biological Sampling

The study samples were obtained from the four tributaries and the main river during the rainy season (October 2016). Tributaries were named UP1 and UP2 in the upstream, DW1 and DW2 (downstream) and MR for the main Dakil River. The four tributaries are first-order streams with a width ranging from 0.5m to 1m and the Dakil River width averaging 3.5 meters. All four tributaries have forested catchments with protected secondary vegetation. The streambeds were composed of gravel, pebbles, sand, and mud. A total of 25 3x5 m (15 m^2) quadrats were randomly established along the tributaries and the main Dakil River, at least 10 m apart in every tributary to avoid pseudo-replication. The physico-chemical variables were obtained at each site, simultaneously with macroinvertebrates sampling. Water temperature, pH, and conductivity were measured *in situ* using a water meter (HANNA instrument 584 Park East Drive Woonsocket, RI 02895) at least three readings at were taken at each sampling sites while the canopy cover was described using densitometer (Forest Suppliers, Inc. USA). The average water current velocity was measured using the floatation method (Singh, 2003; Dobriyal et al., 2016) with 5 readings taken at each sampling site at equally spaced distances along the quadrat and average together. All Geographic coordinates and elevations were recorded per quadrat using Garmin e Trex 10 GPS. Rapid macroinvertebrate standardized sampling (15 min per person/quadrat) were conducted using direct handpick, and kick and sweep technique (Flores and Zafaralla, 2012; Soldner et al., 2003). Using a D- frame net (0.5 mm mesh), aquatic macroinvertebrates were collected in running water and pools in each station. To dislodge the macroinvertebrates, a 3-minute kick sample was done. The content of the net was poured into a basin with water. Any non-macroinvertebrates caught was returned to the stream. Moreover, sediment were collected and additional cascade sieving of substrates using 2, 1 and 0.5 mm steel mesh was conducted thereafter. All samples were fixed in 70% ethanol. Sorted invertebrates were identified at least to family level following published taxonomic keys. Collected specimens were all deposited as vouchers at the UPLB-Museum of Natural History.

Figure 2. Some survey stations along Dakil River, UP Laguna Land Grant, Paete, Laguna. A) LLG Staff House, B) Waterfalls, boundary reference of upstream and downstream, C) upstream tributary station, D) Main Dakil River.

Statistical Analysis

Species richness and relative abundance per quadrat were determined. Individual counts for a species were considered as species abundance and the total number of species per site as the species richness. Standard diversity indices (Shannon-Weiner, Dominance, and Evenness) were calculated. Species accumulation curve (Colwell 2006) for each site plotted to determine the sampling efficiency. It was evaluated by computing the completeness ratio (C.R=estimated number of species/observed number of species). To assess the community patterns across the sampling stations, Bray-Curtis Similarity Index was computed and utilized to generate a cluster dendrogram using PAST version 1.94 (Hammer, Harper, and Ryan, 2001). Clusters were formed according to similar sites in species composition and are measured by a chosen ecological distance. It provides a summary of the similarity of species composition on different sites. Canonical Correspondence Analysis (CCA) was carried out to examine broad-scale relationships between the freshwater snail and environmental factors using Canonical Community Ordination (CANOCO) version 4.5. The relationship of environmental variables on different molluscan species and sampling sites was also analyzed using Canonical Correspondence Analysis (CCA) (ter Baak, 1992). Other quantitative data obtained from ecological measurements were subjected to t-Test using Statistical Package for Social Sciences (SPSS) for Windows (version 11.5.0, SPSS, Chicago, Illinois, USA).

In addition, information-theoretic technique through model averaging (Grueber et al., 2011) was conducted to measure the influence of the river together with other physicochemical on the species richness and abundance of macroinvertebrates in the Dakil River. We used a generalized linear mixed-effect model (GLMM) to the data using R software (R Development Core Team, Vienna, Austria). In defining model parameters, the number of species and abundance were coded as response variables while temperature, conductivity, pH, canopy cover, river velocity, and depth were identified as fixed effects while quadrat per site was identified as the random variable. Each model was assigned a Poisson error distribution and log ink function (Burnham and Anderson, 2002). We first fitted a global GLMM using the *lme4* package (Bates & Maechler 2009). After the global model was defined, we standardized the input variables using *arm* package (Gelman et al., 2009). This generated a summary of variables estimates with their standard error (extreme values suggest poor model convergence) and relative importance (a value of 1.0 being the most significant). All residual data generated did not show evidence of overdispersion. To extract a sub model from the global model, a dredge function was implemented in the *MuMln* package (Barton 2009). In the final model averaging step, Akaike's information criterion corrected for small sample size (AICc) was used to assess model support, ranking each using ΔAICc (Burnham & Anderson 2002). The most parsimonious model was indicated by the biggest AICc weight. The values were obtained by extracting the top 5 AICc, using the function model in the *MuMln* package.

RESULTS AND DISCUSSION

Environmental Variables

Water temperature was found to be relatively uniform between stations (24 °C). The downstream (DW2) and main Dakil River (MR) stations were found to have the deepest water with 32.17±0.86 cm and 43.9±3.14 cm respectively. The fast running water was recorded in the upstream (UP2) station and DW2 station with a velocity of 6.54 ± 0.1 m/s and 7.07± 0.71 m/s respectively. The highest canopy cover was recorded in the downstream (DW1) stations with 76%. Relatively low water pH was recorded in all stations ranging from 5.08 to 6.37 (Table 1).

Table 1. Water quality and habitat characteristics of Dakil River in UP Laguna Land Grant.

Environmental Variables	UP1	UP2	DW1	DW2	MR
Temperature (°C)	24.54±0.02	24.1±0.00	24.0±0.00	24.23±0.12	24.5± 0.22
Water pH	5.08±0.28	6.37± 0.10	6.09 ± 0.17	6.20 ± 0.30	6.21± 0.19
Conductivity (µS/cm)	22.39±0.12	25.14±0.12	29.7 ± 0.43	32.17±0.86	22.7±0.60
Water velocity (m/s)	8.51± 0.91	6.54 ± 0.16	10.17±1.89	7.07± 0.71	8.19± 1.71
Water depth (cm)	18.2±0. 36	14.9± 1.16	14.30±1.74	30.68±6.32	43.9±3.14
Canopy Cover (%)	37 ± 6.24	61± 8.72	76.0± 7.31	60.0±10.61	4±2.45
Substratum	G, P, S,	G, P, S	G, P, S,	G, S, M	S, G, M

G – gravel; P – pebble; S – sand, Mud – mud

Macroinvertebrates Community

A total of 572 individuals were obtained from the five stations. These belong to 7 classes under 15 orders with 29 families. (Table 2). Hexapods belonging to 16 families constituted 55% of total abundance, followed by the gastropods with five families making up 21%. The rest of the macroinvertebrates belonged to Class Malacostraca (crabs and shrimps) with 10%, Class Bivalvia (4%), Nematomorpha (4%) Hirudinea 3%), and Oligochaeta (3%) (Fig. 3 A and B). The total number of individuals sampled in UP1, UP2, DW1, DW2, and MR were 113, 60, 149, 152 and 98 respectively; while the total number of families per station were 18, 16, 21, 13, and 14 respectively (Table 3).

Table 2. Macroinvertebrates found in Dakil River, UP Laguna Land Grant, Paete, Laguna.

	UP1	UP2	DW1	DW2	MR	UPLLG
Phylum Arthropoda						
Hexapoda						
Coleoptera						
Elmidae	2	16	12	14	15	**59**
Eulichadidae	2	0	0	0	0	**2**
Gyrinidae	0	0	5	0	0	**5**
Lycidae	2	0	0	0	1	**3**
Psephenidae	4	0	5	2	0	**11**
Scirtidae	1	0	0	0	0	**1**
Diptera						
Chironomidae	5	3	0	0	0	**8**
Psychodidae	1	0	0	0	0	**1**
Tabanidae	0	0	1	0	2	**3**
Tipulidae	1	0	0	0	0	**1**
Ephemeroptera						
Caenidae	2	2	2	0	1	**7**
Hemiptera						
Gerridae	8	8	8	8	11	**43**
Notonectidae	0	0	0	2	4	**6**
Veliidae	10	12	11	11	9	**53**
Odonata						
Caenagrionidae	0	0	0	0	8	**8**
Gomphidae	2	4	6	0	11	**23**
Trichoptera						
Hydroptilidae	0	1	1	2	0	**4**
Malacostraca						
Decapoda						
Palaemonidae	31	1	33	80	0	**145**
Potamidae	3	2	3	5	0	**13**
Isopoda						
Asellidae	2	0	5	0	0	**7**
Phylum Mollusca						
Gastropoda						
Archeoastropoda						
Neritidae	0	0	3	0	0	**3**
Basommatophora						
Lymnaeidae	0	0	5	0	0	**5**
Mesogastropoda						
Ampullariidae	0	0	3	1	13	**17**
Thiaridae	0	0	28	0	5	**33**
Viviparidae	0	0	5	0	7	**14**
Veneroida						
Cyrenidae	31	4	3	18	8	**63**
Nematomorpha	1	0	1	1	0	**3**
PHYLUM Annelida						
Oligochaeta	3	7	3	3	1	**17**
Cletillata						
Hirudenia	0	0	1	0	0	**1**
	113	**60**	**149**	**152**	**98**	**572**

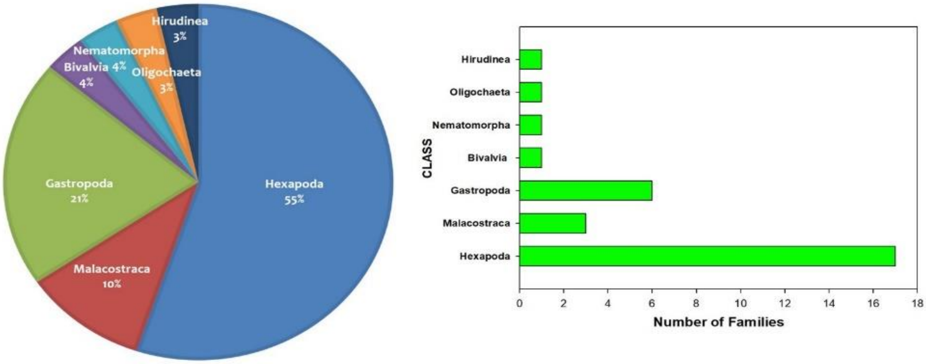

Figure 3. Relative abundance of macroinvertebrates per class (A) and Number of macroinvertebrate families (taxa richness) per class (B) in Dakil River, Paete, Laguna

The high relative abundance of Hexapods is not uncommon in freshwater systems. Dacayana, et al. (2013) and Flores & Zafaralla (2012) also reported high abundances of Hexapoda in tropical freshwater systems. High hexapod abundance may indicate good water quality, as this group is said to be vulnerable to pollution (Dacayana, et al., 2013). This is also supported by other studies (Joshi et al. 2007; Flores & Zafaralla, 2012) which revealed the dominance of immature hexapods.

Among orders (Figure 4), Coleoptera had the highest number of families recorded represented by six families, these are Elmidae, Euchalidae, Gyrinidae, Lycidae, Psephenidae, and Scirtidae while order

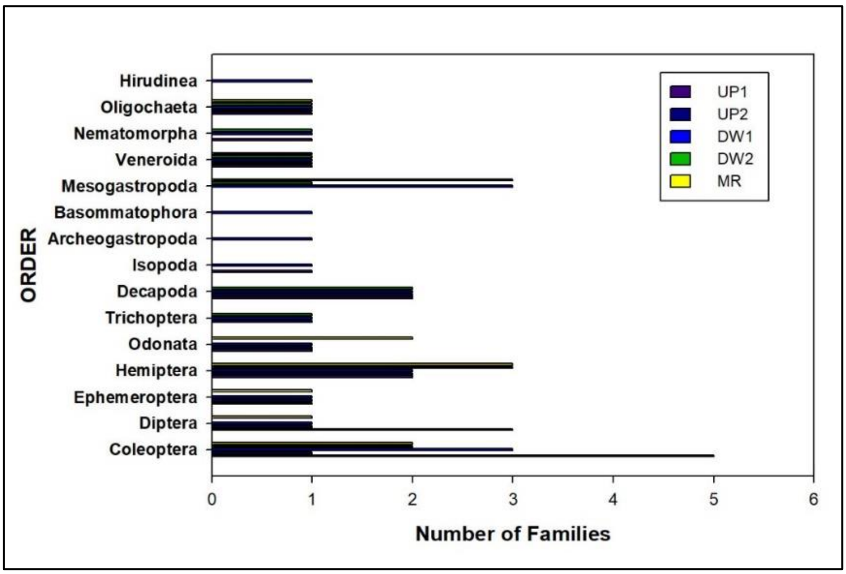

Figure 4. Number of macroinvertebrate families (taxa richness) per order, Dakil River, Paete, Laguna.

Diptera was represented by four families (Chironomidae, Psychodidae, Tabanidae, and Tipulidae). The order Hemiptera was represented by three families, these are Gerridae Notonectidae and Veliidae. Family Gerridae and Veliidae were the common hemipterans encountered in five stations. Moreover, order Odonata (dragonflies and damselflies) nymphs were represented by two families (Caenagrionidae, Gomphidae) while decapods were represented by two families (Potamidae and Palaemonidae). Both Ephemeroptera and Trichoptera represented by one family. Mollusks were the most abundant among the non-insect macroinvertebrates represented by six families with seven species, including *Pomacea canaliculata, Vivipara angularis, Radix quadrasi, Curbicula flumenia*, *Melanoides maculata*, *Melanoides tuberculata,* and *Nertina* sp. Juvenile *C. flumenia* were the most abundant mollusk encountered in five stations (n=63). On the other hand, decapods were represented by two families (crabs and shrimps) while isopods represented only one. Palaemonids shrimp was the most abundant macroinvertebrate collected, with a total of 145 individuals among all stations.

Species Diversity Indices

The overall diversity of the Dakil River system in UPLLG is considered high with H'=2.64, while individual stations range from 1.69 to 2.59 (Table 3). Both downstream stations had the highest (DW1 = 2.59) and lowest (DW2 = 1.69) diversity index. The dominance index revealed the difference in value among five stations with DW2 in the downstream having the highest (0.311) while DW1 and MR were the lowest both have 0.10. All stations are quite even where the highest evenness value (0.72) was recorded in MR station while DW2 had the lowest (0.41). Magurran (2004) considered the diversity index in the natural ecosystem range from 1.5 to 3.5 wherein the value above 3.0 indicates a stable habitat while under 1.0 indicates a highly disturbed environment. However, Flores and Zafaralla, (2012) stated that a diversity index lesser than 2.5 is relatively low, thus, the four stations in this study have a low diversity index. Only one station in the downstream (DW1) obtained a higher value than 2.5. Consequently, this low diversity index value of the sampling sites would make sense if the sampling was done in two seasons (wet and dry season), noting that in this present work sampling was done for the wet season only.

Table 3. Diversity indices in five sampling station in watershed streams of UP Laguna Land Grant.

	UP1	UP2	DW1	DW2	MR	UPLLG
Diversity	18	16	21	13	14	29
Abundance	113	60	149	152	98	572
Dominance	0.17	0.16	0.11	0.31	0.10	0.11
Shannon	2.21	2.07	2.59	1.69	2.40	2.64
Evenness	0.51	0.72	0.64	0.41	0.78	0.48

Figure 5 shows the relative species richness and abundance per 15m^2. It shows the species richness of the five stations is quite close to each other. This is further supported by the different numbers of taxa (Table 3) from the diversity indices. This suggests that there is a minimal difference between the taxa found in the five stations and thus, would not be too different in terms of their respective communities. However, in terms of abundance, there are statistically more individuals collected in the downstream stations (DW1 and DW2). This implies that the abiotic conditions in the downstream part of the river are much more conducive to the survival and growth of macroinvertebrates (Marti et al., 2004).

Species Accumulation Curve

Species accumulation curve (Figure 6) showed the ß-dominated pattern for macroinvertebrates in all five stations. This suggests species richness was dictated by turnover across the river velocity gradient, meaning diversity was relatively spread and not concentrated in a few small areas. This was further demonstrated in the close evenness values (Evenness = 0.48) between areas (Table 3).

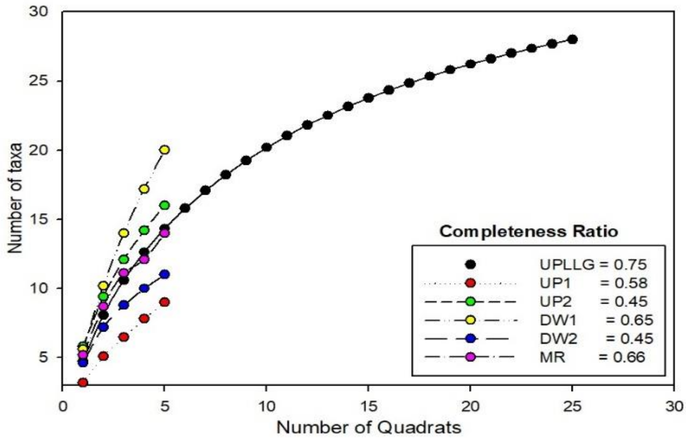

Figure 6. Taxon accumulation curve for macroinvertebrates along Dakil river and its tributaries in UP Laguna Land Grant.

Overall, the completeness ratio value of the river system in UPLLG was 0.75 which is not really close to the maximum completeness value of 1. The main river (MR) had the highest sampling completeness ratio (0.66) while other stations have a low completeness ratio indicating that more macroinvertebrates taxa can still be sampled in these areas. The highest completeness ratio implied efficient macroinvertebrates sampling. It was shown that macroinvertebrate sampling was still not yet complete. Adding more quadrats (> 50), seasonality, and utilizing more sampling techniques to the future survey could facilitate the asymptotic curve.

Bray-Curtis Similarity

Figure 7 shows the similarity of macroinvertebrate assembly in the Dakil River system. Among stations, UP1, DW2, and DW1 have the most similar macroinvertebrate taxa with more than 55% compared to UP2 and MR with a 50 % similarity. The high macroinvertebrate assembly similarity among three stations was possibly due to both stations having almost the same number of taxa of macroinvertebrates due to very comparable habitat features such. All sampling sites had runs and riffles as well as similar substratum found along the river. Analysis of substratum type and reveal a significant correlation (α=0.042) with the densities of macroinvertebrates from both stations, specifically favoring a combination of pebbles and the sandy substrate over others. It could also attribute to the wide distribution of quadrat as well as similar substratum found along the river. Moreover, close similarities of site environmental variables such as temperature, pH, canopy cover, water velocity, conductivity, and water depth also contribute to the significant similarity exhibited among stations. Clustering is influenced by dominant species, but the effect of the dominant species a greater when the large variation between species number exists (Michie, 1982).

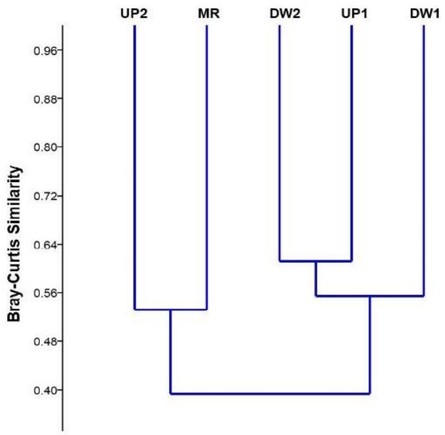

Figure 7. Macroinvertebrates taxon assemblage similarity across the Dakil River system in UP Laguna Land Grant.

Canonical Correspondence Analysis

Ordination using CCA of the macroinvertebrate families, sampling sites, and environmental variables revealed variable community assemblage patterns (Fig. 8). Unrestricted Monte Carlo test was significant for CCA1 ($p = 0.34$) and not significant in CCA2 ($p = 0.47$). The first two CCA axes accounted for 44.13% and 23.37% variation in the taxon composition. Based on CCA, macroinvertebrate communities were strongly influenced by temperature, water depth, Conductivity, pH, river velocity and canopy cover. Among all environmental parameters, depth had the greatest effect on the distribution of gastropods such as *Pomacea canaliculata* (Ampullariidae) and *Vivipara angularis* (Viviparidae). These gastropods occurred exclusively in low-depth marshes with plenty of floating, emergent, and submerged vegetation (Estebenet and Martin, 2002). Moreover, the Odonata family Gomphidae was also found to be correlated with depth. As depth increases, it could be said that the amount of penetrated light decreases, and thus could indicate water visibility, which then could be related to Secchi depth (Remsburg, 2011).

Temperature had an ezffect on the distribution Caenogrionidae (pond damselflies), Gomphomidae (clubtail dragonflies), Tabanidae (horse flies). A correlation of Tabanidae and temperature was also observed by Hackenberger et al. (2009) for two axes using CCA. For conductivity, a correlation with family Palaemonidae was found. However, previous studies on palaemonid-conductivity correlations were varied. In the study of Bialetzki, et al (1997), densities of *Macrobrachium* juvenile and larvae in Paraná River, Brazil were found to be positively correlated to conductivity and were attributed to intense reproduction during the rainy wet season, accompanied by an increase in conductivity. These findings suggest that the

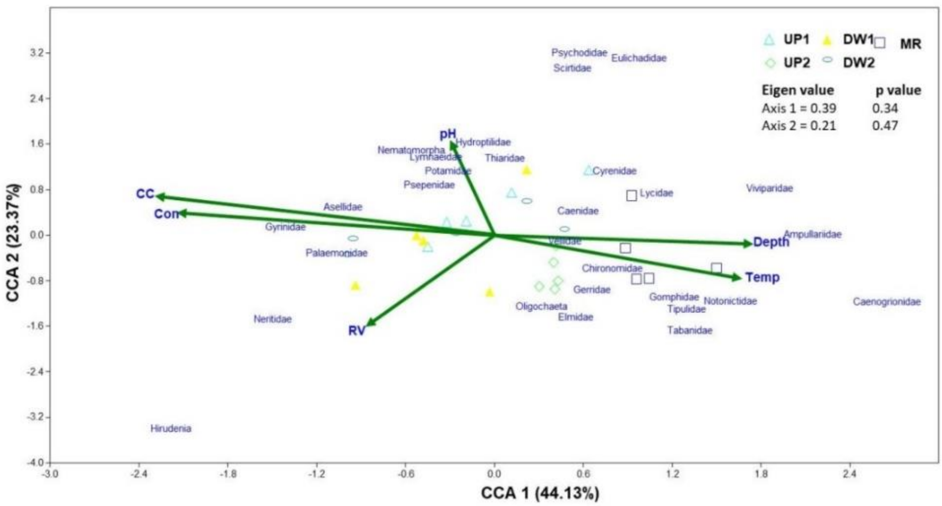

Figure 8. First two axis of canonical correspondence analysis for macroinvertebrates and environmental variables among watershed streams in UP Laguna Land Grant.

relationship of Palaemonidae with conductivity may be co-influenced by other physiochemical factors which may vary among different water system locality. With respect to pH, correspondence was also observed in several macroinvertebrates in Dakil River system. Insects such as Scirctidae (beetle), Psychodidae (drainfly), Eulichadidae (stream beetle), Psepenidae (water penny), and gastropods (Lymnaidae and Thiaridae) were found in basic pH, while Elmidae (riffle beetle), Caenogrionidae (pond damselflies), Chironomidae (midges) and Gerridae (water striders) had high correspondence with acidic water. The dominance of this of these predatory insects could be attributed to the riparian vegetation as a primary source of food for their prey items on which feed on allochthonous organic matters mainly leaves as their major source of energy. Gastropods such as *Pomacea canaliculata* and *Vivipara angularis* preferred to occupy low canopy cover with slow or non-moving water. This can relate to food present for mollusk in non-shading areas in which algae are abundant because of light availability. Shading and nutrient limitation in forest streams usually result in low standing stocks of algae (Dudgeon, 2008) which are probably insufficient to sustain diverse molluscan communities. Leeches (Hirudenia) was observed in slow-moving water, they can be found mostly in the protected shallows where there is a little disturbance from currents. Their abundance is highly variable but generally increases in productive freshwaters. Finally, the observed variability in microhabitat preference among macroinvertebrate groups demonstrated possible niche partitioning within community assemblage in order to maximize interspecies competition (Clarke et al.,2008; Merritt and Cummins, 2006; Misrendino, 2001)

Generalized Linear Mixed Modelling

After running the GLMM in a global model (Table 4), the standardized parameter estimates revealed that water pH is the most significant predictor of species richness (E = 0.3777, $p<0.05$) of benthic macroinvertebrates (Table 4). In general, the estimate values showed a positive relationship between the response variables and the quad/rats. The most significant predictor of macroinvertebrate species abundance, on the other hand, were canopy cover (E = -1.0181, p< 0.001), water conductivity (E = 0.1944, p< 0.001) and river velocity (E=-0.1059, p<0.01). Moreover, since the parameter estimate values were relatively close to each other, model averaging was performed to generate sub-models to further explain more clearly the above response variables by considering the top 5 AICc (Table 5). For species richness, pH is the most parsimonious model (ΔAIC_c=0.00, $wAIC_c$=0.26). However, it was shown that the combination of CC+Cond+RV was vital in supporting abundance and population of macroinvertebrates (ΔAIC_c=0.00, $wAIC_c$=0.65).

Table 4. Generalized linear mixed models (GLMM) testing each environmental variable on the species richness and abundance of macroinvertebrates along the Dakil river in UP Land Grant.

Parameter	Estimate*	SE	*P*	Relative Importance
Species Richness				
pH	0.3777	0.1590	0.0252*	0.86
Depth	-0.0114	0.0080	0.1801	0.31
CC	0.0022	0.0040	0.5933	0.15
Temp	-0.2403	0.3621	0.5291	0.15
Cond	0.0123	0.0589	0.7579	0.12
RV	-0.0054	0.0300	0.8647	0.09
Abundance				
CC	-1.0181	0.0046	0.0002 ***	1.0
Cond	0.1944	0.0273	< 2e-16 ***	1.0
RV	-0.1059	0.0301	0.0010 **	1.0
Depth	-0.0082	0.0094	0.4157	0.13
pH	0.0959	0.1512	0.5539	0.11
Temperature	0.1626	0.3571	0.6709	0.10

*Effect sizes has been standardized on two SD following Gelman (2008)
Significant code *** (0.001), ** (0.01), * (0.05)

Table 5. Summary statistics of model averaging for species and abundance of macroinvertebrates along the Dakil River in UP Laguna Land Grant (n=25). Models are ranked based on Akaike's Information Criterion corrected for small size (AIC_C). RV (river velocity), CC (canopy cover), Temp (temperature).

Components Model	k*	AICs	Δ AICs	wAICs
Species Richness				
pH	4	115.17	0.00	0.26
Depth+pH	5	115.84	0.67	0.18
CC+pH	5	117.33	2.16	0.09
pH+Temp	5	117.33	2.16	0.09
Null	3	118.03	2.87	0.06
Abundance				
CC+Cond+RV	6	167.63	0.00	0.65
CC+Cond+Depth+RV	7	170.81	3.19	0.13
CC+Cond+pH+RV	7	171.15	3.52	0.11
CC+Cond+RV+Temp	7	171.35	3.72	0.10

*k number of parameters

Based on the GLMM, we found out that the water pH was significantly positively correlated with macroinvertebrates richness but not significantly correlated with the abundance (Table 4). The pH range in our study site was 5.08 to 6.37 which has slightly acidic water that can be attributed possibly due to the acidic nature of forest soil (pH 5-6) in UPLLG. Slightly acidic water can be associated with lower diversity (Thomsen and Friberg, 2002). The lower diversity of macroinvertebrates could be attributed to the decreased of emergence rates (Hall et al, 1980), egg failure (Willoughby and Mappin, 1988) and physiological problems as they have difficulties in regulating ions within their body to absorb calcium needed for exoskeleton (Hall et al., 1980). Our results seem in agreement with the result of Ramirez and Pringle (2006) who reported a positive correlation between pH and elmids whereas disagreeing in terms of richness. Although not significant in abundance but this could be explained by the highest abundance of Elmidae (n=59) in our study site.

On other hand, abundance was significantly predicted by the canopy cover, river velocity, and conductivity (Table 4). A negative correlation between abundance and canopy cover was shown in the model similar to the result of Chawaka et al. (2018). It could be the abundance of macroinvertebrate may be varied due to the availability of dead or dying insects prey that falling into the stream as they feed on since there is low canopy cover in some stations of our study site. Dobson et al. (2007) indicate the importance of canopy cover by observations on the reproduction in freshwater crabs (*Potamonautes* spp.) is more successful in forest streams which serve as nurseries from which adults migrate downstream. The river velocity was also negatively correlated with the abundance of macroinvertebrates in our study site. Current velocity plays an important role in water oxygenation and functional feeding of some macroinvertebrate groups such as filterers (Flores & Zafaralla, 2012). During sampling, the river velocity rate was from 4.17± 0.77 to 10.87± 0.81 m/s. Higher velocities were associated with a richer and more abundant invertebrate assemblage (Flores & Zafaralla, 2012). Behrend et al. (2009) listed the said factors during different phases of a river system and they found out that Oligochaeta abundance was said to be increased by a presence of drift velocity, high oxygen content and sandy substrate. A positive correlation between macroinvertebrate abundance and conductivity is also shown in this study. This result is similar to the result of Kefford (1998) who reported a positive relationship of macroinvertebrates and electric conductivity in the four river catchments in south-west Victoria, Australia. In our study, the conductivity range (22 to 32 μS/cm) which is not suitable for certain species of macroinvertebrates. Stream supporting good water conductivity suitable for fish and macroinvertebrates should between 50 and 1500 μS/cm (USEPA, 1986, 1997). However, our results were not conclusive since our data is one season sample only. But with the support of sub-model AIC, the combination of canopy cover, conductivity and river velocity were most essential in supporting the population of macroinvertebrates as indicated in the biggest AICc weight (Table 5).

SUMMARY AND CONCLUSION

The macroinvertebrate community of the Dakil River system in the UP Laguna Land grant was shown to be diverse and abundant. This diversity was determined through the collection and assessment of samples collected from the four tributaries and main river stations. The study determined the incidence of 572 macroinvertebrates (7 classes, 15 orders, and 29 families) along the river and tributaries of the Dakil River. Taxa assessment found a high presence of individuals under Hexapoda (55%/15 families), followed by Gastropod (21%/6 families) and by Malacostraca (10%/3 families). Though mean densities and species richness were not found to be significantly different between stations, the significantly larger abundance found in the downstream stations. Dominance index revealed the difference in value among five stations, the Shannon diversity index showed a range of 2.59 – 1.69 which is quite low and all stations are quite even. In terms of abundance, there are significantly more individuals collected from the DW1 and DW2 station. Species accumulation curve showed the ß-dominated pattern for macroinvertebrates in all stations. The Bray-Curtis similarity shows the similarity of macroinvertebrates found in the Dakil River, UP Laguna Land Grant. Ordination via CCA of the macroinvertebrate families, sampling sites, and environmental variables revealed variable community assemblage patterns and GLMM revealed that water pH is the most significant predictor in determining the species richness while canopy cover, conductivity and river velocity has influence factor in the abundance of macroinvertebrates. Composition and structure of biological communities in Dakil River system UPLLG, as species richness and abundance alone is not enough to measure ecosystem health and function. Increased sampling of sediments in other areas of the river system, as well as the inclusion of other sampling sites, is recommended for further study. The collection based on seasonality is similarly proposed to assess the difference between environmental conditions. The addition of other physico-chemical parameters (i.e. dissolved oxygen, total dissolved solids, and TSS) would increase the parameter of determination to measure ecosystem health and function. Nonetheless, the preliminary data generated from the present study could be utilized in assessing the health conditions of the streams for further study. The greatest potential for degradation in the UPLLG watershed arises from illegal logging, crop cultivation and overgrazing of livestock in nearby barangay. The loss of soil and vegetation reduces the effectiveness of watersheds in moderating the flow of water, sediments, and other waterborne substances Thus, watershed management through conservation practices, maintains the protection of the area against illegal logger and tree planting is recommended to the management to prevent the degradation of riparian community leading to low water quality. Water and soil conservation can be managed for sustainable use by following the principles of water conservation with environmental protection.

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