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Evaluation of land use impact on river water quality using macroinvertebrates as bioindicator in Lahumoko Watershed, Buton Island, Indonesia

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Abstract. *Kahirun, Sabaruddin L, Mukhtar, Kilowasid LMH. 2019. Evaluation of land use impact on river water quality using macroinvertebrates as bioindicator in Lahumoko Watershed, Buton Island, Indonesia. Biodiversitas 20: 1658-1670.* The Lahumoko Watershed, a small watershed, that empties into the sea is sensitive to water quality changes due to land use changes by humans. Uncontrolled land use changes can threaten the sustainability of the river ecological functions of the watershed. It is important to examine the comparison of river water quality in locations that represent land uses. So, the objectives of this study were to reveal the impact of land use on biological water quality in rivers and to analyze the relationship between macroinvertebrates communities with parameters of biodiversity and physicochemical at the observation locations that represented land use. Biological samplings were done using a hand net with a hole size of 0.5 mm mesh, at five stations, each with three replications, with a length of 30 m of each replication, 60 minutes per station. The results of the study showed that individual abundance, family biotic index and diversity index parameters indicated that the water quality was quite good in the upstream watershed (LM1, LM2, and LM3 stations) and somewhat worse in the middle (LM4 station) and downstream of the watershed (LM5 station). The Spearman's correlation, Dendrogram, and Canonical Correspondent Analysis (CCA) showed that there were similarities among LM1, LM2 and LM3 stations, and also between LM4 and LM5 stations. Physicochemical parameters, especially the velocity and flow rate of the river flow had significant correlation with individual richness and density.

Keywords: Biodiversity, landuse, physicochemical parameters, water quality, watershed

INTRODUCTION

Ecosystem services of a watershed in the forms of water supply, water risk mitigation, and cultural benefits play a vital role in the sustainability of human welfare (Hamel et al. 2017). Uncontrolled land use changes in the watershed adversely affect the sustainability of watershed functions in the tropics, both large and small watersheds in small islands (Zhang et al. 2013; Shafie et al. 2017). A watershed is often used as a unit to evaluate the impact of land use changes on river water quality (Chen and Lu 2014; Flotemersch et al. 2016; Cheng et al. 2018). Small size watersheds have an area of not more than 10,000 hectares (Uhlenbrook et al. 2004). Changes of forest land to agricultural areas, settlements, and infrastructure are associated with a decrease in the quality of river water flowing in a watershed (Mophin-Kani K and Murugesan 2014; Pullanikkatil et al. 2015; Kim et al. 2016; Jonsson et al. 2017).

In Buton Island, Southeast Sulawesi Province, there is a small watershed, i.e., Lahumuko watershed. Currently, there are three land use types in the Lahumoko Watershed, namely forest, farmland, and settlements. The land use of forest dominates the upstream part of the watershed, while the agricultural land use is in the middle part, and residential land use interspersed with agricultural use is located in the downstream. Since North Buton District was declared a new autonomous region on January 2, 2007, forest land in the Lahumoko Watershed had been converted into a mixed plantation area, seasonal crop fields and rural settlements with the rate of change of 0.84% per year in the period from 2007 to 2017 (Land Use Map of North Buton, pers. obs.). The reduction in forest cover area is always followed by an increase in the surface flow rate, the transport of soil particles, organic material, and nutrient to enter the river water bodies in the rainy season (Silva et al. 2012; Hepp et al. 2013). Agricultural activities in the form of dryland farming with rice and secondary crops and the use of fertilizers and pesticides are the source of river water pollution (Andrade et al. 2011; Silva et al. 2012; Mori et al. 2015).

Land use changes affect the physicochemical characteristics of water that determine the quantity and quality of river water. Water quantity is measured by runoff parameters through discharge, and velocity (Khatri and Tyagi 2015; Tesfaye et al. 2017). Likewise, other human activities can also alter other physical-chemical variables such as pH, DO, Conductivity, and TDS (Niyogi et al. 2004; Silva et al. 2012; Zhang et al. 2013).

Subsequently, macroinvertebrates provide an ecological response to the river's new environmental conditions in the form of changes in composition, abundance, and diversity (Lewin et al. 2015). Macroinvertebrates play a key role in regulating carbon, nutrient deposition and decomposition of organic matter in river ecosystems (Pinna et al. 2003; Fonnesu et al. 2004; Sangiorgio et al. 2004; Minshall et al. 2014). To date, macroinvertebrates frequently receive particular attention in the evaluation of the impact of land use changes on the quality and health of river ecosystems (Ojija and Laizer 2016; Thampy et al. 2013). The use of macroinvertebrates for bioindicators of changes in river water quality is related to its biological characteristics, namely limited mobility, long life period. A number of taxa are very sensitive and certain taxa are highly sensitive and tolerant to changes in water discharge, flow velocity, pH, DO, organic matter content, other pollutant loads and drought events (Di Sabatino et al. 2014; Pinna et al. 2016; Dacayana et al. 2013; Heino et al. 2014; Patrick et al. 2015). Most studies related to the impact of land use change on river macroinvertebrates communities were carried out in rivers on the continent, but few such investigations have been reported for rivers in small offshore islands (Bass 2003; Niyogi et al. 2004; Pullanikkatil et al. 2015; Shafie et al. 2017).

Changes in the diversity of aquatic macroinvertebrates (Hepp et al. 2013; Shafie et al. 2017) and abundance (Gimenez et al. 2015; Ojija and Kavishe 2016) have been studied to monitor river water quality due to the increased intensity of land use change. Ecologists have used various biological indices in different countries. The most commonly used indices in biological evaluation of rivers include species richness, evenness, diversity, dominance, and biotic indices (Yazdian et al. 2014). Thus, the purposes of this study were: (i) studying the impact of land use on the ecological indicators of water quality from the Lahumoko River, and (ii) analyzing the correlation between the parameters of macroinvertebrates communities and physicochemical parameters of river water quality and the differences among land uses.

MATERIALS AND METHODS

Characteristics of study site

This research was carried out along the Lahumoko River located at 04^0 57' 57 "-04^0 59' 05" S latitude and 122^0 52' 40 "-122^0 56' 47" E longitude. The Lahumoko Watershed is a small watershed in Buton Island, Southeast Sulawesi, Indonesia, an offshore island with an area of about 560,000 hectares having many small watersheds (Patterson et al. 2017). The Lahumoko Watershed occupies around 5,190.35 hectares of a total of 193,000 hectares of North Buton District and is located in the northern part of Buton Island (Land Use Map of North Buton, pers. obs.).

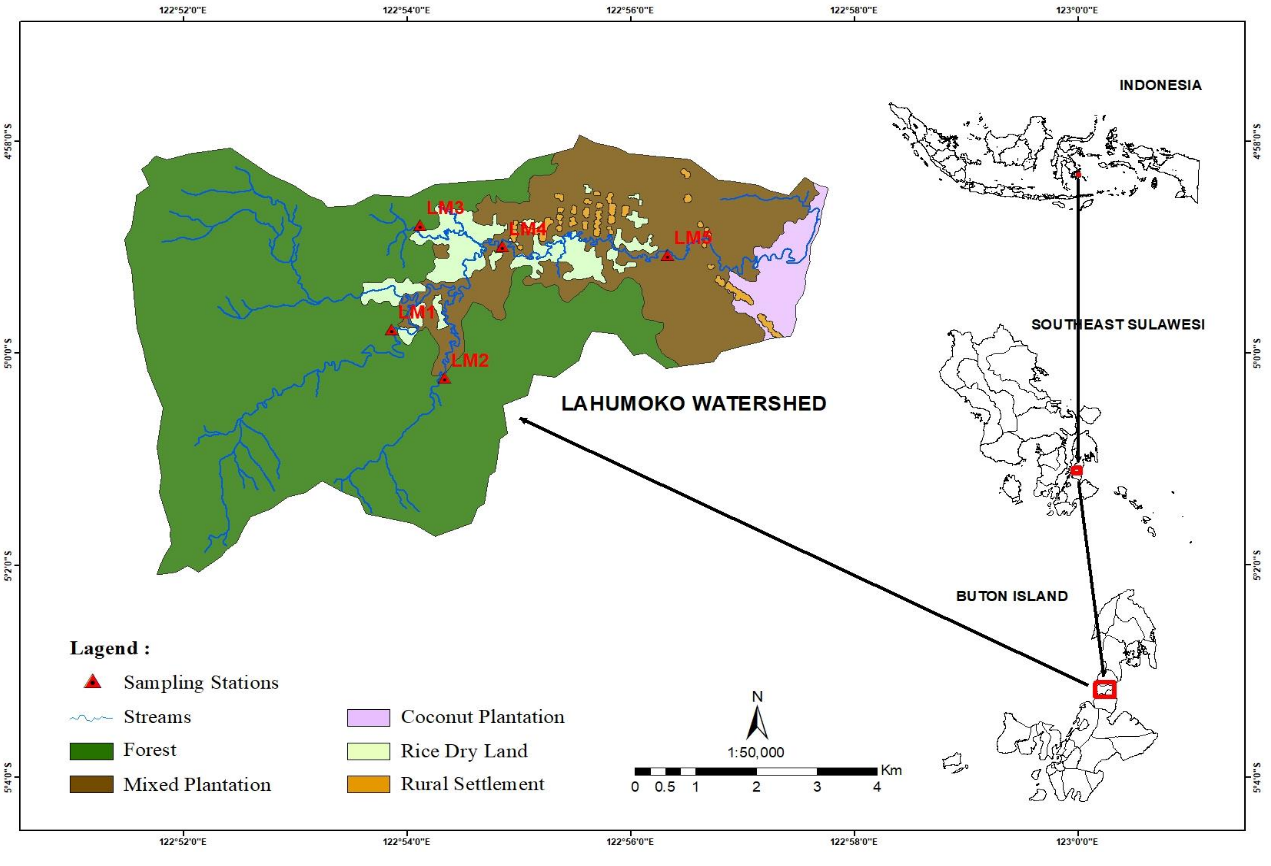

Figure 1. Map of the study area in Lahumoko Watershed, North Buton (Buton Island), Southeast Sulawesi, Indonesia

Table 1. Description of sampling stations

Sampling station codes	Geographic stations	Land use
LM1	04^{0} 59' 46 " S and 122^{0} 53 ' 51" E	The station that covers the sub-watersheds with land use dominated by 97.60% forests area and the rest (2.40%) is agriculture land area.
LM2	04^{0} 59' 29 " S and 122^{0} 54' 25 " E	The station that covers the sub-watersheds with land use dominated by 81.01% forests area and the rest (18.98%) is agriculture land area.
LM3	04^{0} 58' 37 " S and 122^{0} 54 ' 10" E	The station that covers the sub-watersheds with land use dominated by 80.09% forests area and the rest (19.91%) is agriculture land area.
LM4	04^{0} 59 '02" S and 122^{0} 54' 40 " E	The station that covers the middle part of the Lahumoko Watershed with mixed land use types, consisting of agriculture plantation, forest plantation, and annual cultivation.
LM5	04^{0} 59 '15" S and 122^{0} 56' 34 " E	The station that covers the downstream part of the Lahumoko Watershed with settlement land use interspersed with mixed plantations.

Lahumoko Watershed has the highest altitude of around 800 meters above sea level (Martin et al. 2017). Climatic conditions are characterized by an average rainfall of 1,751 mm year^{-1} and an average air temperature of 27.5°C. The rainy season lasts from November to June and the dry season lasts from July to September, and the highest rainfall occurs between April and June (Whitten et al. 2002; Patterson et al. 2017). The topography of the Lahumoko Watershed is generally hilly and slightly flat. Geomorphologically, the Lahumoko Watershed is dominated by the shape of a steep hill above marl with limestone outcrops covering 61%, and the rest consists of hills with an asymmetric non-oriented sedimentary ridge covering 28%, intertidal mud plains in under halophyte covering 6%, and sloping non-volcanic alluvial fan covering 5%. Geologically, it is dominated by Tmtc (Tondo Formation) rocks, covering approximately 78%, alluvium 16%, and swamps and beaches 6% (Smith and Silver 1991; Sikumbang et al. 1995). The type of soil in the Lahumoko Watershed is dominated by Cambisol soil with an area of 66%, and the rest is podsolic soil, 28% and Gleisol soil, 6%, spread around rivers and beaches. (Map Land Type of North Buton Regency, Not Published). Limestone rocks produce calcareous soils, that are frequently thin and free draining, although sometimes they contain considerable amounts of clay and organic components known as Cambisol soil types. Sandstones and conglomerates produce acid soils which are generally poor in nutrients known as podzolic. The river valleys and coastal areas contain alluvial deposits which can vary greatly in composition, depending on the sediment washed away by the river flow, known as Gleisol soil (Powling et al. 2015).

Sampling location

Sampling was done to represent the upstream use of watershed with forest land use, the central part of the watershed used as an area of agriculture and mixed gardens, and downstream used as plantations and settlements. In the upper watershed area, there were three observation stations (LM1, LM2, and LM3) located in the third river tributaries branching, one station (LM4) in the middle stream, and one station (LM5) in the downstream (Table 1).

Sample collection

Aquatic macroinvertebrates were sampled using aquatic D-hand net with a dimension of 900 cm frame, 250 µm mesh, 50 cm length. At each sampling station, the aquatic insects were sampled in rivers influenced by forest area (no or little anthropogenic disturbances), agricultural area, and rural settlement area. Each sampling site covered approximately 100 m-long river water. Three replicates of each of the six important habitats (run, riffle, pool, leaf litter, aquatic vegetation and stone substrate) were collected at each station, considering all possible microhabitats over representative sections of the stream. The sampling time at each habitat was 3 minutes. All aquatic insects were sorted and preserved in 80% ethanol. The aquatic insects were identified to the family level with a guidebook.

Physicochemical parameters measurements were done at the same time as the collection of samples of aquatic insects. At each sampling station, physicochemical parameters i.e. Dissolved Oxygen (DO), Conductivity, pH, Total Dissolved Sediment (TDS), water temperature, velocity, and river flow were measured with three replications. Dissolved oxygen (DO) was measured directly in the field using portable oxygen tester in water (DO-8401). Conductivity, pH, and TDS were measured directly using portable high precision conductivity meters (AZ8306). Flow velocity and river flow were measured directly in the field using a Flow Meter type instrument Global Water FP 111 Current Meter.

Statistical analyses

The parameters of macroinvertebrates community were analyzed, namely the number of the families, family diversity index, and Family Biotic Index (FBI). The family diversity index stated in Shannon's diversity index, maximum diversity index (H_{max}), Pielou evenness index, and Margalef richness index (Magurran 2004; Zaiha et al. 2015). The Shannon-Wienner Index was calculated using the formula: $H' = -\sum_{i=1}^{n}\left(\frac{ni}{n}\right) ln\left(\frac{ni}{n}\right)$ in which H' is Shannon index, ni is the number of individuals of family i, and N is number of all individuals (Shannon 1948). The value of H_{max} was calculated using the formula: $H_{max} = \sum_{i=1}^{s} \left(\frac{1}{s}\right) \log\left(\frac{1}{S}\right) = \log s$ in which s is the number of families. Pielou evenness index was calculated using the formula: $J = H'/H_{max}$ (Troussellier and Legendre 1981). Margalef richness index was calculated using the formula: $D_{Mg} = \frac{s-1}{\ln(n)}$ in which s is the number of families and n is the number of individuals (Legendre and Legendre 1998). The Family Biotic Index was calculated using the formula developed by Hilsenhoff (1998): $FBI = \sum_{i=1}^{i=n} [(TV_i / n_i)]/N$, in which FBI states the benthic macroinvertebrate index, i states the order of the families composing the macroinvertebrate community, ni states the number of the individual belonging to family i, TVi states the value of tolerance of the family i, and N states the number of all individuals composing the macroinvertebrate community (Sharifinia et al. 2016).

Variant analysis (ANOVA), at p level of 0.05 was used to test the difference in density, diversity index, and the index of macroinvertebrate biotic among different land uses. If the difference was significant, then LSD test at 0.05 level was conducted. The exploration of the correlation between species and environmental variables was done using multivariate correlation using SPSS 23 and PAST (PAleontological STatistics) Version 3.23 software. Data of family density and environmental variables (except pH) were transformed to log (x + 1). Spearman correlation analysis was conducted to determine correlation among the environmental variables. Only correlation of $r \geq 0.60$ ($p < 0.05$) was considered significant. Lastly, the cluster analysis and CCA (*Canonical Correspondence Analysis*) were conducted using PAST software.

RESULTS AND DISCUSSION

Biodiversity of aquatic macroinvertebrate communities

A total of 2869 individuals of aquatic macroinvertebrates were collected, distributed among 13 families and 8 orders. LM3 and LM4 had the highest taxa richness of macroinvertebrates (8 families and 7 orders, respectively) belonging to orders Trichoptera, Ephemeroptera, Gastropoda, Crustacea, Coleoptera, Odonata, Diptera, and Hemiptera. Meanwhile, LM5 had the lowest taxa (6 families and 4 orders) represented by orders Gastropoda, Crustacea, Trichoptera and Hemiptera. The total number of individuals recorded at LM3 was 1,492 individuals which were the highest, followed by that of LM1 with 712 individuals, while the least total number of individuals were recorded at LM4 and LM5 with 213 and 116 individuals respectively (Table 2).

At LM3, the highest number of individuals was found in the families Thiaridae, Atyidae, Parathelpusidae, Goeridae and Heptageniidae which were significantly different from the other stations followed by LM1 and LM 2. While at LM4 and LM5, the family mentioned above were added with the families Mesovellidae, Cordulidae, and Dytiscidae, but the number of individuals was the lowest.

Table 2. Mean population and difference of aquatic macroinvertebrates (means±sd, n =3) at each station along Lahumoko River, North Buton (Buton Island), Southeast Sulawesi, Indonesia

Order and Family	**Observation stations**					**LSD (p< 0.05)**
	LM 1	**LM 2**	**LM 3**	**LM 4**	**LM 5**	
Order Gastropoda						
Thiaridae	330.30 ± 5.25^{d}	122.38 ± 5.58^{c}	723.16 ± 9.78^{e}	98.89 ± 1.92^{b}	25.54 ± 4.31^{a}	4.76
Physidae	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	11.73 ± 2.39^{b}	0.99
Order Crustacea						
Atyidae	142.42 ± 10.50^{b}	148.15 ± 2.79^{c}	299.43 ± 9.78^{d}	34.44 ± 1.93^{a}	32.44 ± 2.39^{a}	4.80
Parathelpusidae	84.85 ± 10.50^{b}	25.76 ± 2.79^{a}	209.04 ± 25.89^{c}	28.89 ± 1.92^{a}	23.46 ± 3.17^{a}	8.83
Agridae	33.33 ± 5.25^{b}	0.00^{a}	73.45 ± 19.57^{c}	0.00^{a}	0.00^{a}	3.17
Palemonidae	0.00^{a}	0.00^{a}	0.00^{a}	4.45 ± 3.85^{b}	0.00^{a}	0.60
OrderTrichoptera						
Goeridae	39.39 ± 5.25^{d}	25.76 ± 7.38^{c}	96.04 ± 9.78^{e}	7.78 ± 1.92^{b}	2.76 ± 1.20^{a}	3.72
Order Ephemeroptera						
Heptageniidae	57.58 ± 5.25^{c}	12.88 ± 2.79^{b}	56.50 ± 9.79^{c}	0.00^{a}	0.00^{a}	4.62
Order Hemiptera						
Mesovellidae	0.00^{a}	3.22 ± 2.79^{b}	0.00^{a}	34.44 ± 1.92^{d}	20.01 ± 3.16^{c}	1.08
Order Odonata						
Corduliidae	24.24 ± 5.25^{c}	0.00^{a}	0.00^{a}	2.22 ± 3.85^{b}	0.00^{a}	2.70
Amphipterygidae	0.00^{a}	0.00^{a}	11.3 ± 9.78^{b}	0.00^{a}	0.00^{a}	1.53
Order Diptera						
Tipulidae	0.00^{a}	0.00^{a}	22.60 ± 9.78^{b}	0.00^{a}	0.00^{a}	4.05
Order Coleoptera						
Dytiscidae	0.00^{a}	0.00^{a}	0.00^{a}	2.22 ± 3.85^{b}	0.00^{a}	1.60

Note: Numbers followed by different letters in the same row show significant differences according to the LSD test at level 0.05.

Table 3. The physicochemical parameters (means±sd, n =3) at five observation stations in Lahumoko River, North Buton (Buton Island), Southeast Sulawesi, Indonesia

Parameters	**Observation stations**					**LSD ($p <$ 0.05)**
	Sta.LM1	**Sta.LM2**	**Sta.LM3**	**Sta.LM4**	**Sta.LM5**	
Velocity (m det^{-1})	0.93 ± 0.014^{b}	0.79 ± 0.028^{b}	0.50 ± 0.071^{a}	$1.30\pm0{,}212^{c}$	1.48 ± 0.240^{c}	0.22
Discharge (m^{3} det^{-1})	1.09 ± 0.042^{b}	1.81 ± 0.071^{c}	$0.36\pm0{,}057^{a}$	$4.76\pm0{,}078^{d}$	7.13 ± 0.028^{e}	0.09
Temperature (^{o}C)	28.3 ± 0.141^{ab}	28.00 ± 0.212^{a}	28.40 ± 0.283^{ab}	29.20 ± 0.354^{c}	28.5 ± 0.424^{b}	0.45
pH	7.88 ± 0.021^{bc}	7.82 ± 0.028^{a}	7.85 ± 0.042^{ab}	7.91 ± 0.035^{cd}	7.95 ± 0.014^{d}	0.04
Dissolved oxygen (mg l^{-1})	6.92 ± 0.077^{e}	6.79 ± 0.049^{d}	$6{,}53\pm0{,}035^{c}$	6.30 ± 0.028^{b}	6.23 ± 0.035^{a}	0.06
Total dissolved suspended (mg l^{-1})	41.20 ± 0.919^{c}	36.50 ± 0.778^{a}	39.40 ± 0.566^{b}	41.30 ± 0.849^{c}	45.20 ± 1.061^{d}	1.26
Conductivity (µS cm^{-1})	722 ± 3.536^{a}	730 ± 1.414^{b}	753 ± 2.828^{c}	787 ± 4.243^{d}	796 ± 2.121^{e}	4.46

Note: Numbers followed by different letters in the same row show significant differences according to the LSD test at 0.05 level.

Physico-chemical parameters of the river water quality

The physicochemical parameters, i.e. velocity, discharge, pH level, temperature, DO, TDS and conductivity were significantly different among five sampling stations in Lahumoko River. Table 3 shows that the largest flow velocity and discharge were found at LM5, significantly different from that of the other stations except for LM4. The lowest flow velocity and discharge in the upstream watershed were found at LM3, significantly different from that of the other four stations. The next lowest flow velocity and discharge were found in LM 1 and LM 2 in which both differed significantly.

The water temperature at LM1, LM2, and LM3 was not different from each other, but significantly different from that at LM4. The lowest water temperature was at the LM2, but not significantly different from that at LM1, LM3, and LM5. The highest temperature was found at LM4, different from that at the other stations.

The highest concentration of dissolved oxygen (DO) was recorded at the LM1, followed by LM2 and LM3, while the lowest DO was found at LM5 and LM4. In contrast, total suspended solids (TSS) and conductivity were found in LM4 and LM5, which were higher than those in LM1, LM2, and LM3.

Furthermore, the similarity of individual abundance and the similarity of physicochemical variables at each location of observation stations could be analyzed by analyzing dendrogram clusters (Figures 2 and 3).

Figures 2 and 3 show the results of hierarchical cluster analysis showing the results of hierarchical cluster analysis at each observation location based on family density and physicochemical variables using a distance or similarity measure of the Bray-Curtis Similarity Index with the Single Linkage Algorithm method. LM1, LM2, and LM3 had a high similarity, both in family density and physicochemical variables, due to the similarity of land use in the three stations which are dominated by forest. LM4 and LM5 stations also had a similarity in both family density and physicochemical variables because of the similarity of land use in the two stations, where LM4, is a mixed plantation and a field, while land use at LM5 station is a rural settlement interspersed with mixed plantations.

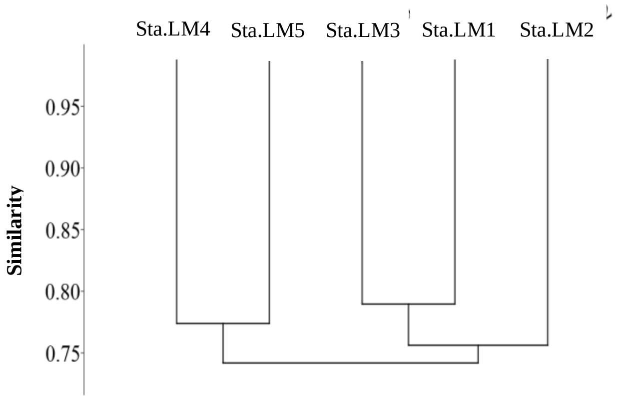

Figure 2. The results of hierarchical clustering analysis of location/station based on family density with the distance size of the Bray-Curtis Similarity Index and the Single Linkage Algorithm

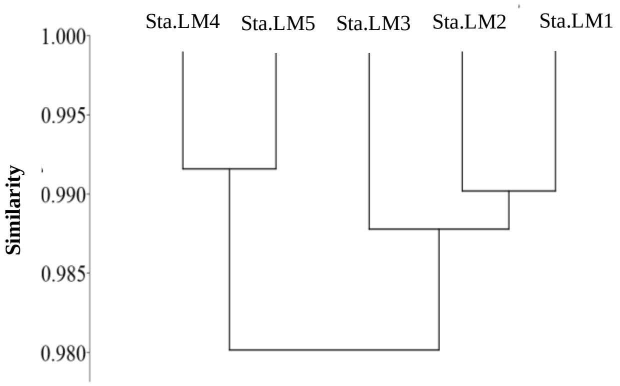

Figure 3. The results of hierarchical clustering analysis location/station based on physicochemical variables with the distance size of the Bray-Curtis Similarity Index and the Single Linkage Algorithm.

Table 4. Differences in ecological indicators of water quality (means±SD, n =3) among five stations in Lahumoko river in Lahumoko Watershed, North Buton (Buton Island), Southeast Sulawesi, Indonesia

Indicator	**Observation stations**					**LSD ($p <$ 0.05)**
	LM1	**LM2**	**LM3**	**LM4**	**LM5**	
Total of individual density (Ind. m^{-2})	712.11±37.85^{d}	338.16±22.14^{c}	1491.53±84.74^{e}	213.34±18.57^{b}	115.94±15.63^{a}	40.67
Family Biotic Index (FBI)	5.40±0.21^{ab}	5.16± 0.17^{a}	5.61±0.19^{bc}	5.78±0.14^{cd}	6.07±0.34^{d}	0.33
Shannon's diversity index (H')	1.55±0.03^{bc}	1.27±0.07^{a}	1.49±0.08^{b}	1.47±0.16^{b}	1.63±0.02^{c}	0.09
Maximum diversity index (H'_{max})	1.89±0.09^{bc}	1.73±0.11^{a}	2.04±0.08^{c}	1.82±0.24^{ab}	1.73±0.11^{a}	0.14
Pielou evenness index (J') = H'/ H'_{max}	0.82±0.04^{b}	0.73±0.02^{a}	0.73±0.02^{a}	0.81±0.02^{b}	0.94±0.05^{c}	0.03
Margalef richness index (D'_{mg})	1.38±0.02^{c}	0.94±0.02^{a}	1.49±0.11^{d}	1.12±0.12^{b}	1.16±0.14^{b}	0.11

Note: Numbers in the same row followed by different letters show significant differences according to the LSD test at level of 0.05.

Measurement of ecological indicators of river water quality

The total individual density, family biotic index, Shannon's diversity index, maximum diversity index, Pielou evenness index, and Margalef richness index varied among observation stations (Table 4). The total individual density was found at LM3, followed by LM1 and LM2.

LM5 had the highest value of the Family Biotic Index, significantly different from that at LM1, LM 2, and LM3, but was not significantly different from that of LM4. The lowest FBI value was found at LM2, significantly different from that at LM3, LM4, and LM5, but not significantly different from that at LM1.

Shannon's diversity index at LM5 was the highest, significantly different from that at LM2, LM3, and LM 4, but not significantly different from that at LM1. At LM2 the diversity index was the lowest and significantly different that of the other four stations. Maximum diversity index at LM3 was the highest, but not significantly different from that at LM1, while at LM2 and LM5 were the lowest, but not significantly different from that at LM4.

Pielou evenness index at LM5 was the highest, significantly different from that of the other four stations, while at both LM2 and LM3 were the lowest, which were also significantly different from those of the other three stations. The evenness Index provides a picture of the equality or similarity of species in the community.

The highest Margalef richness index was found at LM3, significantly different that of the other four stations, while the lowest was at LM2, which was significantly different from that of the other four stations. Meanwhile, the Margalef richness index at LM4 was not significantly different from that at LM5, but significantly different from that at LM1.

Correlation between physicochemical parameters and ecological indicators of water quality based on macroinvertebrates

Spearman's bivariate correlation analysis showed that the abundance of several macroinvertebrates families and the ecological measure of water quality were significantly correlated with a number of physicochemical parameters from the Lahumoko river's water (Table 5). The ecological parameters of water quality which include total abundance, the FBI index, and J'Evenness were significantly correlated with some physicochemical parameters, while others were not significant. Heptageniides with DO were correlated significantly positively ($p = 0.005$), whereas the conductivity was correlated significantly negatively ($p = 0.029$). Goeridae with streamflow velocity, streamflow discharge ($p = 0.037$), and pH ($p = 0.037$) were correlated significantly negatively ($p = 0.000$). Similarly, Mesovellidae was correlated significantly positively with streamflow discharge ($p = 0.014$), while Thiaridae was correlated significantly negatively with streamflow discharge ($p = 0.037$). Meanwhile, Atyidae was correlated significantly negatively ($p = 0.028$) with temperature. The total abundance of river macroinvertebrates was correlated significantly negatively with streamflow velocity ($p = 0.037$) and streamflow discharge ($p = 0.00$). Significantly positive correlation was also shown between FBI index with pH ($p = 0.037$) and conductivity ($p = 0.014$). Furthermore, the correlation between J'Eveness with velocity ($p = 0.014$), pH ($p = 0.014$) and TDS ($p = 0.005$) was significant.

Correlations among dominant families, environmental parameters, diversity measures, and locations were identified using the CCA triplot analysis as in Figure 4. The first axis has an Eigenvalue of 0.086 (variance 54.06 %), showing positive association among dominant families namely Heptageniidae, Goeridae, Atyidae, Agridae, Thiaridae, Amphipterygidae, Cordullidae, and Tipulidae; physicochemical parameters, namely DO; Biodiversity parameters were the total individuals, H'Max, and R'Margalef at locations LM1, LM2, and LM3 stations. Whereas negative association occurred among the dominant families, namely Parathepusidae, Palemonidae, Physidae, Mesovellidae, and Dytiscidae; with physicochemical parameters, namely Velocity, Discharge, pH, Temperature, TDS, and Conductivity; and biodiversity parameters, namely FBI, H 'Shannon and J'Evenness at LM4 and LM5.

The second axis has an Eigenvalue of 0.038 (variance 23.74%) showing positive association among dominant families, namely Heptageniidae, Agridae, Atyidae, Amphipterygidae, Tipulidae, Parathepusidae, and Physidae; with physicochemical parameters, namely Temperature, pH, TDS, Conductivity, and DO; and Biodiversity parameters, namely FBI, H' Max, J 'Evenness and H 'Shannon at LM2, LM3 and LM5. Whereas negative association occurred among the dominant families, namely Goeridae, Palemonidae, Cordullidae, Mesovellidae, and Dytiscidae; physicochemical parameters, namely Discharge and Velocity; and Biodiversity parameters, namely total individuals and D' Margalef at LM1 and LM4.

Table 5. Spearman's correlation between physicochemical condition, and ecological indicators of water quality based on macroinvertebrates communities in Lahumoko's river at Lahumoko Watershed, North Buton, Southeast Sulawesi, Indonesia

Ecological indicator	**Physicochemical indicator**						
	Velocity	**Discharge**	**Temp.**	**pH**	**DO**	**TDS**	**Conductivity**
Family abundance							
Heptageniidae	-0.632	-0.791	-0.471	-0.632	**0.973****	-0.460	**-0.917***
Goeridae	**-1.000****	**-0.900***	-0.447	**-0.900***	0.564	-0.872	-0.632
Atyidae	-0.718	-0.462	**-0.918***	-0.821	0.500	-0.763	-0.649
Parathepulsidae	-0.051	-0.205	0.344	0.359	-0.395	0.368	0.487
Agridae	-0.577	-0.866	0.000	-0.289	0.592	-0.148	-0.456
Palemonidae	0.354	0.354	0.791	0.354	-0.544	0.181	0.559
Thiaridae	-0.700	**-0.900***	0.224	-0.400	0.410	-0.359	-0.316
Physidae	0.707	0.707	0.000	0.707	-0.544	0.725	0.559
Amphipterygidae	-0.707	-0.707	0.000	-0.354	0.000	-0.363	0.000
Cordullidae	0.224	-0.112	0.500	0.224	0.344	0.287	-0.177
Mesovellidae	0.791	**0.949***	0.354	0.632	-0.811	0.487	0.750
Tipulidae	-0.707	-0.707	0.000	-0.354	0.000	-0.363	0.000
Dytiscidae	0.354	0.354	0.791	0.354	-0.544	0.181	0.559
Measurement of ecological indicators of river water quality							
Total of individual	**-0.900***	**-1.000****	-0.224	-0.700	0.667	-0.616	-0.632
Total of density	**-0.900***	**-1.000****	-0.224	-0.700	0.667	-0.616	-0.632
Family Biotic Index (FBI)	0.700	0.600	0.671	**0.900***	-0.872	0.821	**0.949***
Shannon's diversity index (H')	0.500	0.200	0.224	0.700	-0.154	0.821	0.316
Maximum diversity index (H'$_{max}$)	-0.564	-0.821	-0.344	0.205	0.289	-0.158	-0.162
Pielou evenness index (J') = H'/ H'$_{max}$	**0.949***	0.738	0.471	**0.949***	-0.460	**0.973****	0.583
Margalef richness index (D'$_{mg}$)	-0.400	-0.700	0.447	0.000	0.154	0.051	0.000

Note: * states a significant correlation at p of 0.05 level; ** states significant correlation at p of 0.01 level

Discussion

Biodiversity of aquatic macroinvertebrates communities

The results of the study indicated that land use had a significant impact on water quality in the watershed. Forested areas had better water quality than both agricultural land use and rural settlements as shown in Figure 4, due to the low anthropogenic input on forested land. Human disturbances to the forest land use are prime factors controlling macroinvertebrates communities in the river water (Gimenez et al. 2015; Santhosh et al. 2014). Species richness refers to the number of species present in an area determined by the island area and watershed in each region (Bass 2003; Shafie et al. 2017). The pollution due to land use activities influences the ecological quality of river waters (Selvanayagam and Abril 2016). LM1, LM2, and LM3, located in the tributary upper river, is dominated by forest land use which has little disturbance, so they had abundant macroinvertebrates, a bioindicator of undisturbed areas (Azmi and Geok 2016; Kim et al. 2016; dos Reis et al. 2017). The Lahumoko's upstream watershed area is represented by LM1, LM2, and LM3, showing that Ephemeroptera Order's Heptageniidae family and Trichoptera Order's Goeridae family had been found. This group of organisms belongs to the EPT group, very sensitive to pollution, so if these macroinvertebrates are found in the water, the water could be considered unpolluted, so the water quality of those three stations was considered slightly polluted (Young et al. 2014; Lewin et al. 2015). According to River Continuum Concept, the upstream is dominated by scrapper and shredder (Vannote et al. 1980). Shedders, predators, and scrapper species characterize the group of upstream biota at rough substrate upstream which is characterized by high elevation or mountains. Many scrapper species are present at the land used for agriculture and settlements with high pollution which is related to the increased water volume and river width and substrate dominated Mud and Clay's (Rosenberg and Resh 1993; Fu et al. 2016). Some shredder groups such as Ephemeroptera, Plecoptera, and Trichoptera on mountains and upstream area are sensitive to organic pollution and may serve as a river water bioindicator of unpolluted forest (Elias et al. 2014; Kim et al. 2016). The highest abundance is found in the upstream watershed and the lowest in the downstream which is characterized by flow velocities (Szczerkowska-Majchrzak and Grzybkowska 2015) and place heights according to river order, food and other environmental parameters (Jiang et al. 2011; Fu et al. 2016). The Coleoptera family is generally associated with calm and lentic water conditions and the Odonata family is mostly associated with moderate water pollution (Olomukoro and Dirisu 2014).

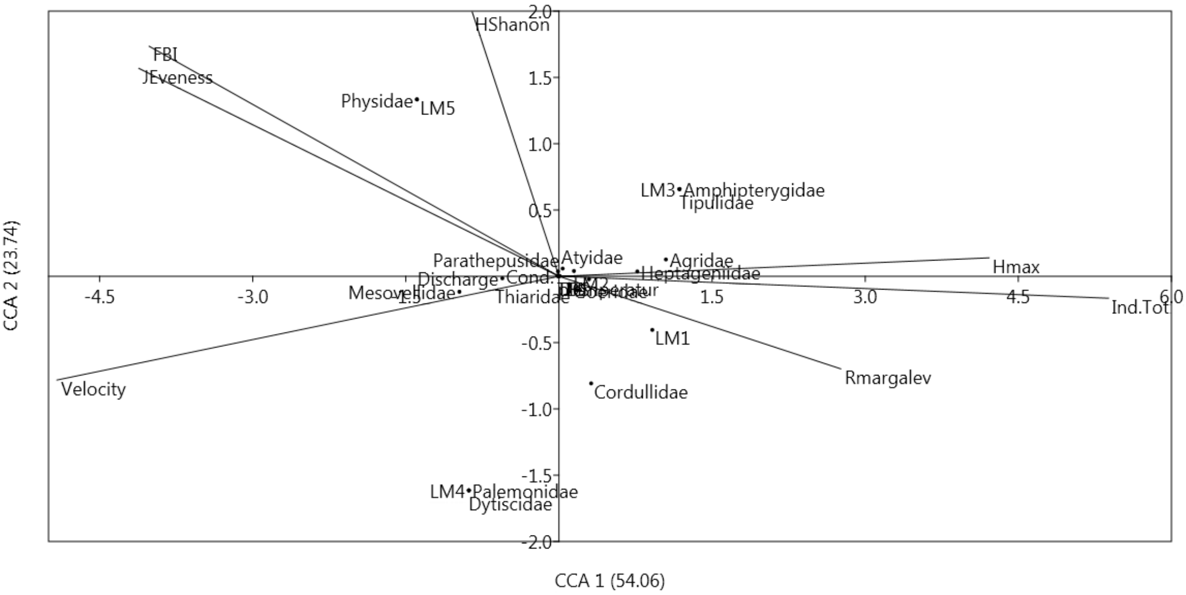

Figure 4. Results triplot CCA analysis showing an association among the dominant families, physicochemical parameters, ecological water quality indicators, and observation stations

Meanwhile, in LM4 and LM5 in the middle and downstream areas of the Lahumoko Watershed, human-disturbed areas, macroinvertebrate families found were Thiaridae and Phisidae of the Order Gastropods and family Atydae and Parathepusidae of the Order Crustacean which has larger number than other families (Edward et al. 2015). Both stations are agricultural areas and rural settlements. At LM 4 and LM 5, the family Goeridae of Trichoptera Order was found in a small number, indicating that the two stations were categorized as having moderately polluted water quality (Bouchard 2004; Copatti et al. 2013). This showed that this area was dominated by scrapper groups, both insects and non-insects of EPT in small number which could function as indicators for agricultural areas and settlements and the water was contaminated with organic contamination. The influence of the strength of the river flows in the middle and downstream areas causes a drastic reduction in the EPT group (Harikumar et al. 2014; Wang et al. 2016). The strength of river flow on the agricultural areas of the watershed which indicated by the decreased vegetation in the banks of the river has a strong influence on the presence of macroinvertebrates as an indicator of degradation of land use (Masese et al. 2014; Gerth et al. 2017). In the middle area of the Lahumoko Watershed, many agricultural activities could cause high soil erosion and riverbank erosion, in addition to other human activities such as bathing, and washing in the river causing changes in the physicochemical parameters of river water thus affecting macroinvertebrates abundance and water quality (Ojija and Laizer 2016). The use of nitrate fertilizer, phosphate, and pesticides on agricultural land has the effect of pollution on river water (Kripa et al. 2013). The pressure of human disturbance on land use can explain macroinvertebrates variability, especially the type of EPT, a finding that needs to be studied further, especially with regard to the intensity and scale of human disturbance (Ligeiro et al. 2013; Hepp et al. 2013).

Physicochemical parameters of the river water quality

The physicochemical characteristics in Lahumoko Watershed varied across different land use types. The relatively high variation of water quality parameters related to various types of land use are characteristics that can be used to inform or predict aspects of water quality in rivers that lack data. In this study, physicochemical parameters were significantly different among the stations as the measure in observing water quality that was related to the presence of macroinvertebrates (Mophin-Kani K and Murugesan 2014; Fierro et al. 2015; Shokri et al. 2014). Water temperature in the upstream of the watershed was low due to the closure of the water body by the forest compared to the middle and downstream part which was already opened, especially at the edge of the river (Rezende et al. 2016). Water temperature greatly influences organisms in the river and is inversely proportional to DO and Conductivity (Brooks et al. 2013; Gimenez et al. 2015; Patrick et al. 2015). This is shown in this study that TDS and Conductivity increased towards the downstream, accompanied by a decrease in DO (Shafie et al. 2017; Pina et al. 2016; Sharifinia et al. 2016). Low pH, high EC, low dissolved oxygen (DO), and high BOD were recorded, which characterize the degradation of water quality (Saviour 2012; Aazami et al. 2015). The pH value ranged from 7.82 as the lowest at the upstream to 7.95 as the highest at the downstream of the Lahumoko river, indicating an increasing trend towards downstream. Increased conductivity is associated with organic pollution (which might have caused high levels of nitrogen) and high pH values (Silva et al. 2012; Gimenez et al. 2014). The pH at aquatic ecosystem is important because it is related to biological productivity. Although the value of the tolerance of each individual varies, in general, the pH value ranging from 6.5 to 8.5 is usually a good indicator of water quality (Dutta et al. 2014). River flow velocities and discharges are strongly influenced by land use activities by which downstream in flat areas is characterized by agricultural activities and settlements resulting in high surface flow (Mori et al. 2015; Ambarita et al. 2016). The human intervention on the Lahumoko Watershed in the form of agricultural land use and rural settlements have an effect on soil compaction, so it will cause changes in aquatic ecosystems, namely increasing river flow due to riverbank erosion, and changing physicochemical conditions in water (Almeida et al. 2009; Doll et al. 2016; dos Reis et al. 2017).

Measurement of ecological indicators of river water quality

Based on the FBI value according to Hilsenhoff (1998), the predicted water quality at different sampling stations ranged from fair, indicating fairly substantial pollution likely of organic pollution degree at three stations (LM1, LM2 and LM3) to fairly poor at two stations (LM4 and LM5), indicating substantial pollution of organic pollution (Dutta et al. 2014; Moran 2016; Krisanti et al. 2017). In the downstream river area where there was a settlement there were macroinvertebrates as an indicator of high levels of pollution with an FBI value> 6 (Bourassa et al. 2017).

The Shannon diversity index (H'), richness index (C), and evenness index (E) are widely used to predict aquatic environmental conditions based on the biological components (Maneechan and Prommi 2015; Patang et al. 2018). The higher Shannon diversity index means, the better the quality of water: the value of H' smaller than one indicates high water pollution, between one and three moderate pollutions and greater than four no pollution (Wilhm and Dorris 1968). The Shannon diversity index (H') values at all stations on the Lahumoko River were above one, so the water at all the observation stations was moderately polluted (Barman and Gupta 2016).

In this study, the diversity in the upstream and downstream areas did not show differences, but there was a tendency for the upstream to increase the diversity. This was supported by dominance and evenness index, which showed that the diversity value at the upstream area was higher (Magurran 2004; Chirwa and Chilima 2017). All stations of Lahumoko rivers had dominance index value with low to moderate richness, but the evenness of species was high, so they had moderate diversity according to H' index (Magurran 2004; Hepp et al. 2013).

Correlation between physicochemical parameters and ecological indicators of water quality based on macroinvertebrates

The abundance of aquatic macroinvertebrates observed was influenced by sampling locations (upstream, middle and downstream) including natural conditions (forest) and the presence of anthropogenic activities (development of agriculture and rural settlements). There were correlations between environmental factors and species abundance and ecological indicators of river water quality index (Table 5). The velocity and discharge had significantly negative correlation with total individual and family abundance especially Goeridae, and Thiaridae (Lewin et al. 2015; Jun et al. 2016; Mathers et al. 2017), but significantly positive correlation with family Messovelidae that tolerates a high velocity (Wang et al. 2016; Nguyen et al. 2018). Stream velocity and flow discharge are the most important variable which influences diversity, community composition and spatial pattern abundance of macroinvertebrates (Rawi et al. 2013; Nguyen et al. 2018). Water temperature was significantly negatively correlated with family abundance especially Atyidae. Many studies reported about the removal of riparian vegetation because of the increasing use of agricultural land increased temperature and light level (Rutherford et al. 2004; Theodoropoulos et al. 2015), increasing runoff water which had a negative impact on macroinvertebrates communities. The pH had significantly negative correlation with Goeridae family and significantly positive correlation with the family biotic and evenness indexes. Similarly, dissolved oxygen had a significantly positive correlation with the family Heptagenidae (Jonsson et al. 2017). Factors that can result in variations in DO levels may include reduced oxygen produced from excessive amount of nutrients that usually limits plant growth. Low DO level is sometimes associated with agriculture and rural settlement land use. The pH values were within the acceptable range and dissolved oxygen was above the threshold. The effects of forest and disturbed area on the pH and dissolved oxygen are significant at relatively large riparian widths (Zhang et al. 2013; Jun et al. 2016). Meanwhile, TDS with evenness index were correlated significantly positively. Furthermore, conductivity was significantly negatively correlated with the family Heptagenidae and index of biotic family (Theodoropoulos et al. 2014).

The CCA ordination analysis showed that variation in aquatic macroinvertebrates families was related to environmental parameters, diversity indexes, and station locations (be analyzed in Figure 4). The significant positive correlations were observed between dissolved oxygen, dominant families (Heptageniidae, Goeridae, Atyidae, Agridae, Thiaridae, Amphipterygidae, Cordullidae, and Tipulidae), biodiversity parameters (total individuals, H'Max, and R'Margalef) and station locations (LM1, LM2, and LM3). Dissolved oxygen plays a very important role in the survival of aquatic macroinvertebrates because aquatic organisms use oxygen in the process of respiration (Maneechan and Prommi 2015; Prommi and Payakka 2015; Shafie et al. 2017). The high amount of dissolved oxygen in the upstream area was caused by the dominant forest cover (Zhang et al. 2013; Ambarita et al. 2016). The macroinvertebrates taxa recorded in this study, Decapods were the most ubiquitous and abundant group in all sampling stations, followed by Gastropoda, Ephemeroptera and Trichoptera, and Odonata. Generally, the Ephemeroptera, Trichoptera and Odonata groups prefer habitats that have a lot of water vegetation especially in the upstream area (Arimoro et al. 2015). Overall the observation stations, family Thiaridae of Gastropods Order, and Atydae and family Parathepusidae of Decapoda Orde were the most frequently found at all stations since that family posses high tolerance to pollution (Bouchard 2004). The abundance of family Thiaridae at all observation stations indicated that the condition of the waters in all stations contained pollutants from organic materials because these organisms were macroinvertebrates groups that are resistant to pollutants.

According to the results of CCA, several small macroinvertebrates taxa (Parathepusidae, Palemonidae, Physidae, Mesovellidae, and Dytiscidae) had significantly negative correlations with several physicochemical parameters (velocity, discharge, pH, temperature, TDS, and conductivity), and diversity indexes (FBI, Shannon and J'Evenness) and the location of observation stations in the middle and downstream areas of the watershed (LM4 and LM5). The study conducted by Olomukoro and Azubuike (2009) reported the abundance of mollusks (snails) that are commonly associated with high pH levels, and a slight decrease in acidity and increased alkalinity can determine the changes in the abundance of mollusks. The low abundance of macroinvertebrates taxa in agricultural and settlements areas were caused by the high of velocity and peak discharge due to reduced forest land cover. Forest reduction was closely related to rising water temperature. The runoff carrying sediments due to soil erosion causes increased TDS and water Conductivity (Wang et al. 2016). So, the changes of environmental parameters in the middle and downstream areas of the watershed due to agricultural activities and settlements could cause a decrease in abundance and the number of water macroinvertebrates. Sampling sites with low richness and density macroinvertebrates communities were associated with conductivity and non-forest areas. These variables related to activities in anthropogenic regions have more scattered sources of organic and inorganic material, especially water bodies without vegetative protection, resulted in higher conductivity (Johnson et al. 2012; Rezende et al. 2014).

Species richness, diversity and evenness indices at the various sampling stations appear to reflect water quality conditions at each location. High species diversity at LM1, LM2, and LM3 were associated with less polluted conditions, while lower biodiversity at LM4 and LM5 signified environmental stress due to gradually increasing human influence on water quality conditions in these locations. The relative abundance of Ephemeroptera and Trichoptera taxa was greater at LM1, LM2, and LM3, which showed better water conditions than in LM4 and LM5. At the upstream of the river, there was high environmental heterogeneity that supported fauna life, which differentiated it from the middle and downstream areas (Bae et al. 2016). Most macroinvertebrates taxa from Ephemoptera and Trichoptera were negatively correlated with gradient streams, positively correlated with altitude. Several studies showed that these taxa have a negative correlation with river flow altitude (Lewin et al. 2015).

Each station had dominant macroinvertebrates, depending on sensitivity to the physical and chemical conditions, so it can be seen whether the biota is tolerant of poor water quality or not (Ligeiro et al. 2013). Hemiptera and Coleoptera are natural predatory organisms that have a high tolerance to environmental conditions. In this study, family Mesovelidae of Hemiptera was positively correlated with the flow velocity and DO, especially in the middle and downstream areas which serve as an indication that the water quality in the area was medium to good. These organisms also indicate that the area has been occupied, so the presence and density of these species determine the health of aquatic ecosystems (Barman and Gupta 2016).

In conclusion, land use changes in the Lahumoko Watersheds had direct impacts on water quality parameters in rivers, in upstream, middle stream and downstream of the watershed as a result of anthropogenic activities associated with land use types. Forest land use resulted in the best water quality, so agroforestry system should be practiced in the agricultural and settlement areas to improve the currently poor water quality due to human activities.

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