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ımpacts of Human Activities on selected Physico-Chemical Parameters and Macroinvertebretes of Lake Tana, North-western Ethiopia

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Abstract

Human activities degraded the water quality and biodiversity of Lake Tana. This study is; therefore, aimed to analyse the impact of anthropogenic activities on Lake Tana based on a correlation study of physico-chemical parameters and macroinvertebrates. Samples were collected in eleven sites in the littoral zone of the lake. Physico-chemical parameters were measured following water quality assessment protocols. Collected macroinvertebrates were identified using standard keys. Correlation analysis between physico-chemical, heavy metal and coliform parameters and macroinvertebrates was conducted by using multivariate (Pearson) correlation.Similarly, physico-chemical parameters and macroinvertebrate taxa were highly positively correlated with each other ($P < 0.01$). Some of the physico-chemical parameters and macroinvertebrate taxa correlations positively significant at 0.01 level were TDS and Muscidae (0.673), As and Chironomidae (0.812), Pb and Gerridae (0.811), Pb and Corixidae (0.591), Pb and Notenoctidae (0.780). We conclude that the main threat to Lake Tana arises from agricultural activities, urbanization and industrialization that deteriorated its water quality and biodiversity which is pronounced by the physico-chemical parameters & macroinvertabrate indicators amount. Thus, proper management of Lake Tana should be put in place to improve water quality and biodiversity of the lake for sustainable development.

Keywords: *correlation analysis; Macroinvertebartes; physico-chemical parameters; anthropogenic pressures*

Introduction

Over the last many years in Ethiopia, a considerable population growth has taken place with an increase in urbanization and industrial and agricultural activities which affected the natural environment. All these activities have an effect on the change of the physico-chemical characteristics of water bodies and have caused undesirable effects on the macroinvertebrate communities of the aquatic environment (Birhanu, 2008; Tenalem, 2004).

Water quality guidelines and standards are designed to enable the provision of clean and safe water for human consumption. These are usually based on scientifically assessed acceptable levels of toxicity to humans and aquatic organisms. Guidelines for the protection of aquatic life are more difficult to set because aquatic ecosystems vary in their composition both spatially and temporally. Therefore, there is an effort made by the scientific and regulatory research community to use standards and guidelines for the assessment

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of aquatic life (Robertson *et al.*, 2006).

Recently, global citizens are facing a crisis of water shortage due to degraded water quality emanated from polluting activities. Agricultural runoff and domestic human wastes disposal into surface waters are common problems in Africa (Birhanu, 2008). Water pollution is also a problem to Ethiopia in a similar way it is for other African countries. Major pollution sources are agricultural runoff, domestic (municipal) wastes and industrial effluents to Lake Tana (Ayalew, 2010; Stave *et al.*, 2017). In the catchment areas of Lake Tana, there are numerous human activities. Thus, it is possible to say that human activities in the lake basin are major causes of water quality (physico-chemical) changes in the lake (Habiba, 2010).

Increased concentrations of pollutants in Lake Tana have affected the aquatic community (Habiba, 2010). As a result, change in the physico-chemical and biological parameters was pronounced in the aquatic ecosystem (Stave *et al.*, 2017). Physical loss of habitat and changes in the physico-chemical characteristics of water can inhibit species ability to grow, reproduce and interact with other species in the ecosystem including macroinvertebrates (Birhanu, 2008). Thus, aquatic resources may be under stress posed by a multitude of human practices within a watershed. To restore and maintain the factors (chemical, physical, and biological integrity of the water body), these parameters should be monitored in the form of integration and correlation analysis (Baye, 2006). Thus, correlation analysis of the physico-chemical characteristics and macroinvertebrate communities' composition can provide an ideal indicator response serving as a pertinent measure for water quality and resource use of Lake Tana. Therfore, this study is aimed to analyse the correlation among physico-chemical parameters and macroinvertebrates of Lake Tana.

Materials and Methods

Study area

Lake Tana, the study area occupies a wide depression in the Ethiopian plateau. It is located in the northwestern highlands of Ethiopia, which lies between 36044'46" to 38014'19" E longitude and 12046'40" to 16056'47" N latitude. It is the largest lake in Ethiopia and the third largest in the Nile Basin watersheds with a surface area of 3200 km2 (Berhan et al., 2016). It comprises 50% of the total freshwater resources of Ethiopia with a mean depth of 8m and the maximum depth of 14 m and an altitude of about 1,800 masl (Shimelis *et al.*, 2011; Dereje, 2014). It is also the source of Blue Nile (Abay), which carries more than 80% of the total water of the Nile River (Shimelis *et al*, 2008; Gizachew *et al.*, 2015). The Perinial Rivers such as Gumara, Ribb, Megech, Gilgel Abbay, Gelda, Arnno-Garnno, Gumara-Maksegnit, and Dirma and more than 60 seasonal rivers feed the lake (Gizachew *et al.*, 2015). The major tributaries of the Lake Tana are Gilgel Abbay, Gumera, Ribb and Megech rivers that contribute more than 90% of the water inflow (Dereje, 2014). Lake Tana and its wetlands are rich in biodiversity with many endemic species and provide cultural services, such as archeological sites. The lake trophic level is based on macroinvertebrates community structure and function (Shimelis *et al.*, 2011).

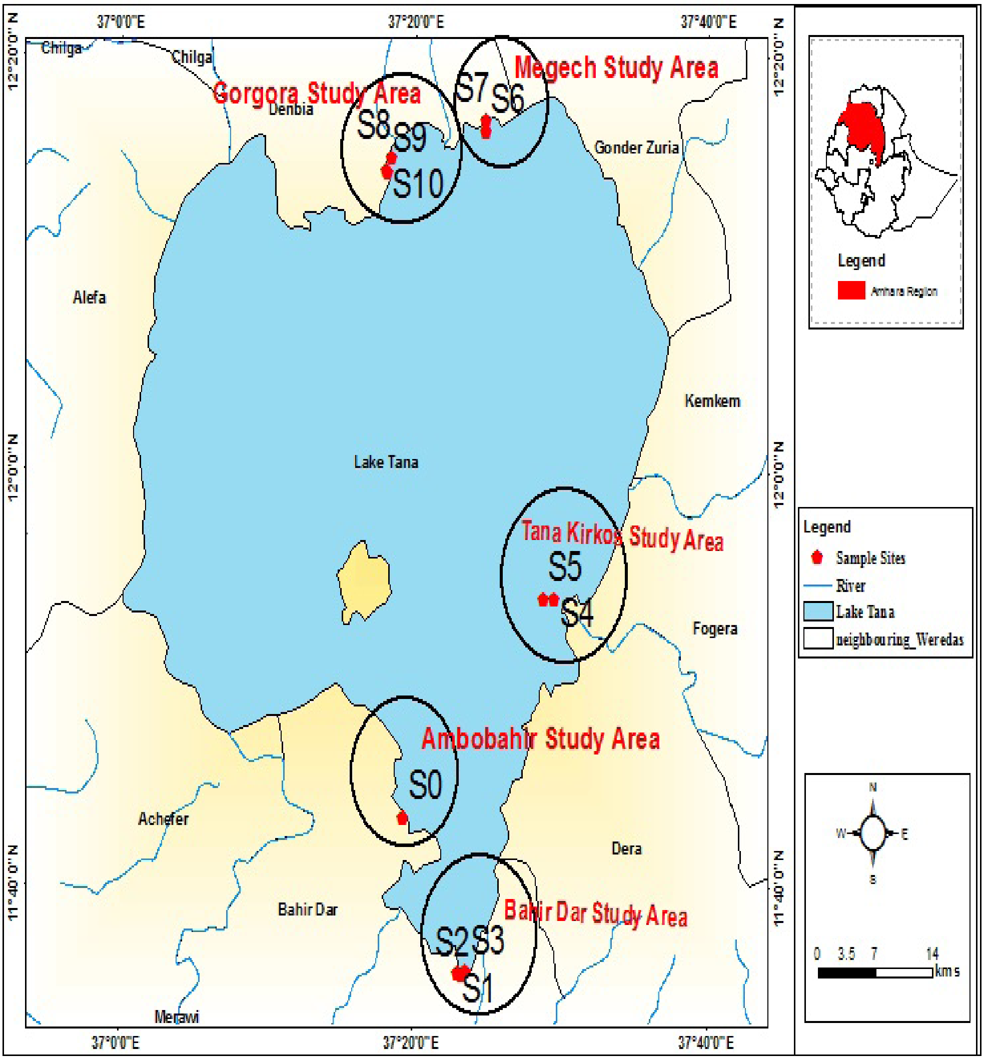

Figure 1. Map of Lake Tana showing the study sites (S_0 to S_{10}).

The anthropogenic impact of Lake Tana was studied because Lake Tana has domestic use values, has agricultural values, is home to biodiversity (supporting values), has recreational value and is source of livelihood. But, all these values were inferred by anthropogenic activities because the Lake is the main recipient of most urban wastes, agricultural and industrial pollutants. As a result, algal blooms and a decline in biodiversity are observed in some parts of the lake (Eshete, 2003).

Selection of sampling sites

All sampling sites were selected from areas with known pressure categories. The categories included those areas that are expected to be less polluted, moderately polluted and highly polluted based on the human practice and the information gained from reseachers.

The other categories were based on areas which are influenced by urban and agricultural activities. In addition, the other criterion in the selection of sites was the expected pollution load of the lake.

This study was conducted in five study areas of Lake Tana (Figure 1). Bahir Dar city (S_1, S_2 and S_3) and Gorgora town (S_8, S_9 and S_{10}) are the two urban centers, where Bahir Dar city was highly impacted, while Gorgora town was minimaly impacted by domestic wastes. The other category included two agricultural centers: Megech area (S6 and S7) which was highly impacted and Tana Kirkos area (S_4 and S_5) which was minimaly impacted. Ambobahir was a reference site (S_0) which is a less likely impacted area. This site was used for comparison of impacted areas based on the criteria indicated in section 2.5.

All the sampling sites were in the littoral zone of the lake, in a region bounded by latitudes 11°35’50”N to 12°16’52”N and by longitudes 37o23’22”E to 37° 24’49”E with altitude ranging from 1,773 to 1,791 m a.s.l (Figure 1).

Water sampling and physico-chemical parameters analyses

Water samples were taken along the lake shorelines at all sites in wet and dry seasons for one year. Water samples were collected two times from each site in plastic bottles and water quality parameters were tested.

Surface water samples were collected seasonally (wet and dry seasons) from the selected sampling zones at 10cm below the surface of the lake water, as stated by Das and Acharya (2003). The samples were colleted and analyzed based on the standard methods and protocols used for water analysis (APHA, 2005).

Water samples were collected for analysis of sulphate (SO_4), nitrate (NO_3), ammonia (NH_3), orthophosphate (PO_4^{3-}), sulphide (S^{2-}), chemical oxygen demand (COD) and biological oxygen demand (BOD_5) as chemical parameters and surface water temperature (T), pH and electrical conductivity (EC) included as physical parameters were measured following water quality assessment protocols.

NH_3, NO_2, PO_4^{3-}, S^{2-}, SO_4^{2-}, TSS, TDS and COD were determined with spectrophotometer (HACH DR/2010, USA) instructions that use standard chemicals and instruments. BOD_5 and Nitrate were determined using standard methods for examination of waste water manual that uses standard chemicals and instruments, Jenway Model 6305 UV/Vis., Spectrophotometer (APHA, 2005; Mohamed *et al.*, 2009).

Metals: Cr, Cu, Mn, As, Pb, Fe and Cd were determined using atomic absorption Spectrophotometer (Buck Scientific Model 210 VGP, USA), according to standard methods (APHA, 2005).

Coliforms were tested by the Most Probable Number test (MPN) and Membrane Filtration tests (MF). The MPN technique, referred to as the Multiple Tube Fermentation Technique, is a technique based on serial dilution of the sample in test tubes containing a selective liquid media. At the end of the incubation, the analyst counts the number of positive test tubes to estimate the number of coliforms in the sample. The MF test refers to a technique where 100 mL of the sample is filtered onto a membrane. The membrane is placed on a growth selective media for coliforms. After incubation, colonies were counted as used by Rhonda *et al.* (2006).

Macroinvertebrate sampling and analysis

Macroinvertebrates were collected to provide a quantitative and qualitative description of the community composition of Lake Tana at all sites in wet and dry seasons for one year based on South African aquatic macroinvertebrates field guide (Gerber and Gabriel, 2002).

All the 11 sampling sites were along the shorelines of Lake Tana. The samplings were conducted seasonally (wet and dry seasons) for comparison purposes. Macroinvertebrate samples were analyzed to family level according to Teodora et al. (2013) and South African aquatic macroinvertebrates field guide (Gerber and Gabriel, 2002).

Reference Conditions

Finding the reference site in Lake Tana was a difficult task because there is no region of the lake without human disturbance. Therefore, the reference site has been selected based on minimally or least disturbed attributes (Gregory et al., 1991). It was identified based on the following criteria as indicated by Jennifer et al. (2003):
1) Same water body type, size and chemical characteristics as treated sites,
2) Within same watershed as treated sites,
3) Minimal impacts within the last few years, and
4) Limited anthropogenic inputs

A reference site was selected to compare against the highly human impacted sites.

Data analysis

Correlation analysis between physico-chemical parameters and macroinvertebrate assemblages was conducted by using multivariate (Pearson) correlation analysis using SPSS Version 23 because macroinvertebrates abundance is expected to be influenced by physicochemical variations. Significant values ($P < 0.05$ and < 0.001) were obtained and least significant difference test was subsequently applied to detect wether there were significant differences between selected parameters among different sampling points or not. Canonical redundency analysis (RDA) was also used to test the correlation between physico-chemical parameters and macroinvertebrate assemblages using Canoco for Windows, version 4.5 (Canoco, 2002).

Results and Discussion

It was found that physico-chemical parameters and macroinvertebrate taxa were highly positively correlated with each other ($P < 0.01$). Positive correlation values exhibited ($P< 0.05$), which indicates a moderate or weak correlation (Appendix 1). Physico-chemical parameters and macroinvertebrate taxa that correlated positively at 0.01 level were: TDS and Muscidae (0.673), As and Chironomidae (0.812), Pb and Gerridae (0.811), Pb and Corixidae (0.591), Pb and Notenoctidae (0.780). Besides, correlations negatively significant at 0.01 level were temperature and Naucoridae (-0.574) where as weakly positively correlated (correlation significant at the 0.05 level) were pH and Simuliidae (0.533), pH and Corbiculidae (0.505), NO_2- and Muscidae (0.444), NH_3 and Belostomatidae (0.463), PO_4^{3-} and Elimidae (0.426), Cr and Velidae (0.445) and E.*coli* and Naucoridae (0.442); however, weakly negatively correlated parameters (correlation significant at the 0.05 level) were temperature and Capniidae (-0.450), temperature and Calopterygidae (-0.440), temperature and Gomphidae (-0.450), temperature and Hydrometridae (-0.450), temperature and Pleidae (-0.450), temperature and Velidae (-0.435), EC and Hydropsychidae (-0.442), COD and Hydropsychidae (-0.439) and pH and Coenogrionidae (-0.445) (Appendix 1), while, according to Popoola *et al.* (2019), pH and Chironomidae is 0.029 and PO_4^{3-} and Chironomidae is 0.416.

The results of the correlation analysis of the macroinvertebrate fauna with physico-chemical parameters in Lake Tana indicated that the benthic fauna was significantly correlated with pH, temperature, EC, N Cr, Cu, Mn, As, Pb, Fe and C_d O_3, TDS, NH_3, PO_4^{3-}, Cr, As and Pb. However, temperature was negatively correlated ($P < 0.05$) with many macroinvertebrate taxa, such as temperature and Capniidae (-0.450), temperature and Calopterygidae (-0.440), temperature and Gomphidae (-0.450), temperature and Hydrometridae (-0.450), temperature and Pleidae (-0.450), temperature and Velidae (-0.435), EC and Hydropsychidae (-0.442), COD and Hydropsychidae (-0.439) and pH and Coenogrionidae (-0.445). Nonetheless, according to Popoola et al. (2019) negative correlation was exhibited between temperature and Naucoridae (-0.089) and temperature and Hydrometridae (-0.089). The data in Appendix 1 depicts the correlation between physicochemical variables and macroinvertebrate fauna composition in Lake Tana for a study time of one year.

Canonical redundency analysis (RDA) ordination diagram, because Eigenvalues were horizontal Axis = 0.330 and vertical Axis = 0.224, <3 with 41 macroinvertebrate and bacterial indicators and 20 quantitative environmental parameters. The environmental factors are: SO_4^{2-}, Pb, Cd, pH, S_2-, water temperature, BOD_5, TDS, TSS, COD, PO_4^{3-}, conductivity (EC), NO_2-, Cu, NH_3, Mn, Fe and NO_3-. The RDA ordination of the species-environmental parameters relationship indicated that pH, Cd, Pb and SO_4^{2-} and Veliidae, Chironomidae, Physidae, Gerridae, Corixidae, Dytiscidae, Caenidae, Coenagrionidae, Simuliidae and Psephenidae were positively correlated, while Muscidae negatively correlated with these environmental parameters (Figure 2).

TDS, TSS, Cu, Conductivity (EC), NO_2-, NH_3, As, Mn, Fe, NO_3-, COD and PO_4^{3-} were negatively correlated with macroinvertebrate families: Veliidae, Chironomidae, Physidae, Gerridae, Corixidae, Dytiscidae, Caenidae, Coenagrionidae, Simuliidae and Psephenidae. These environmental parameters that are segregated in the RDA ordination analysis of the left bottom side of the plot were positively correlated with the macroinvertebrate family of Muscidae. Relatively high value of BOD5 was related with high abundance of Elmidae, Planorbidae, Culicidae, F. *colifrom*, E.*coli,* T. *coliform*, Haliplidae and Notenoctidae. These macroinvertebrate families had a positive, but very weak correlation with water temperature and S2. The environmental parameters (BOD_5, water temperature and S^{2-}) had a negative relationship with the following macroinvertebrate families: Tipulidae, Tabanidae, Gyrinidae, Pleidae, Nepidae, Hydrophilidae, Aeshnidae, Belostomatidae and some others (Figure 2).

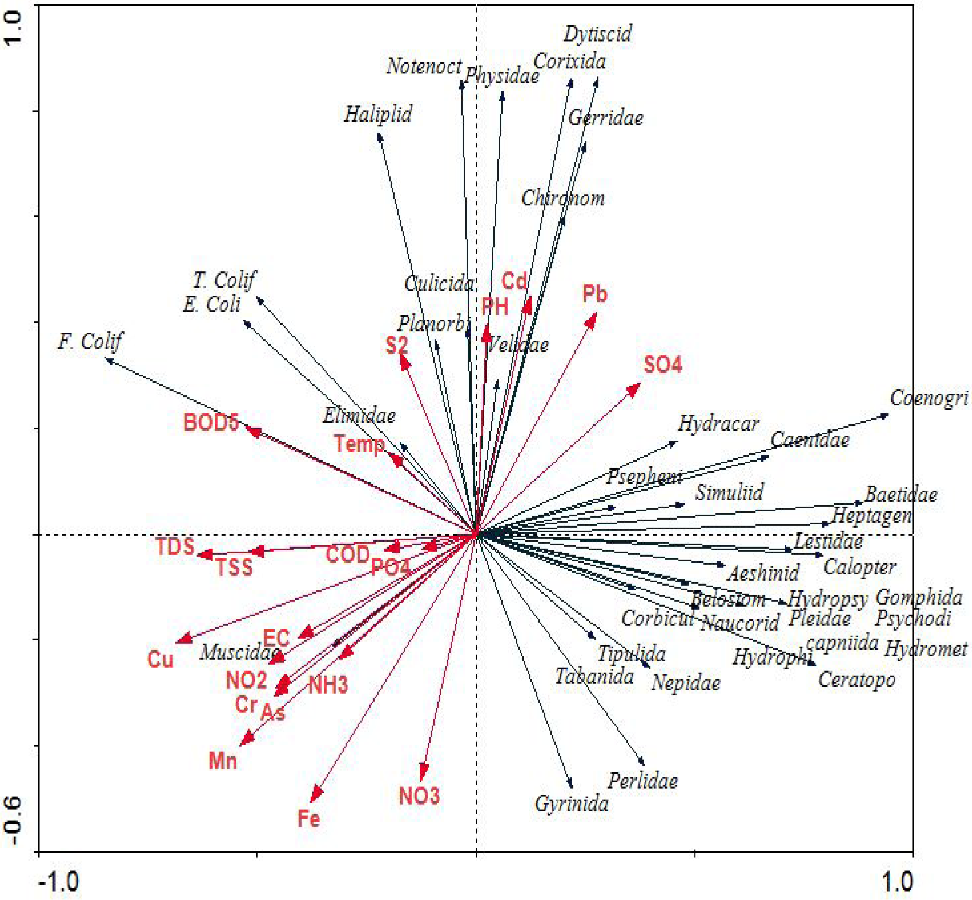

Figure 2. Canonical redundancy analysis (RDA) ordination diagram, black arrows refer macroinvertebrate family data and red arrows refer environmental parameters.

The ordination diagram displays, simultaneously, the patterns of macroinvertebrate community variations that reflect environmental variation and the main pattern of the tolerances of macroinvertebrate families with respect to the environmental parameters. In Figure 2, macroinvertebrate family arrows correspond to their approximate abundance in the two-dimensional ordination axis based on their weighted average, which indicates the macroinvertebrate family distribution along an environmental parameter. Differences in weighted averages among macroinvertebrate families indicate differences in their tolerances along the corresponding environmental parameter. Environmental parameters and macroinvertebrate families are represented by arrows, which point in the direction of maximum change across the ordination diagram (Figure 2). The length of the arrows in the ordination diagram is proportional to the rate of change in this direction. Environmental parameters and macroinvertebrates with long arrows display a stronger correlation with the ordination axes than those with short arrows where signified by the coordinates of the arrow head. Environmental parameters that are strongly correlated with the ordination axes are more closely related to the pattern of macroinvertebrate family variation shown in the ordination diagram (Figure 2) as described by Gary and Pauline (2003). The rule for quantitative interpretation is that each arrow is an environmental parameter that determines a direction or axis in the diagram and macroinvertebrate family arrow is projected. That is, macroinvertebrate families with their perpendicular projection end arrows near to or beyond the tip of an arrow will be strongly positively correlated with and influenced by the environmental parameter represented by that arrow. Those macroinvertebrate families whose projections lie near the origin will be less strongly affected (Canoco, 2002; Gary and Pauline, 2003). The plots in Figure 2 show definite trends relating environmental parameters to macroinvertebrate family composition.

Figure 2 shows a slightly different ordination of macroinvertebrate families in relation to the environmental parameters; these reflect water quality changes in family composition. Macroinvertebrate families at the right of the diagram are organic load sensitive, whilst those at the bottom left (Muscidae) are metal and organic load tolerant. This result is in line with the study of Gary and Pauline (2003). Pollution indicators (sensitive and tolerant) of macroinvrtebrate families were negatively and positively correlated with families, respectively with the water quality detoraration indicator environmental parameters such as BOD_5, COD and metals as identified from the ordination diagrams (Figure 2), which is in line with the study of Gary and Pauline (2003). In the diagram plots, metal and pollution tolerant macroinvertebrates were identified in the lower left section of the plot and metal and pollution sensitive families in the lower right section. According to Gaskill (2014), most families frequently identified as tolerant were Lestidae, Coenagrionidae, Corbiculidae, Physidae, Nepidae, Gerridae, Corixidae, Belostomatidae, Psychodidae, Culicidae and Chironomidae and abundant in Lake Tana with elevated concentrations of pollutants. However, sensitive families identified were Aeshnidae, Perlidae, Cordulegastridae, Notenoctidae and Tipulidae. These results are in agreement with those reported in other studies in which families from the orders Ephemeroptera, Tricoptera and Plecoptera were absent from polluted surface waters (Whiting and Clifford, 1983; Casper, 1994; Gower *et al.*, 1994, 1995) as cited by Gary and Pauline (2003).

In identifying the macroinvertebrate families that are tolerant and sensitive to pollution loading, the RDA analyses demonstrate that EPT families are particularly sensitive to elevated pollutant levels, which are in agreement with the results of Malmqvist and Hoffsten (1999) and Clements *et al.* (2000) as cited by Gary and Pauline (2003). The absence of the most sensitive EPT families and the presence of Baetidae (mayflies) and their position in the families-environment ordination diagrams (Figure 2) supports the findings of Gower *et al.* (1994, 1995) as cited by Gary and Pauline (2003) that they have moderate pollution tolerance. However, within each family, tolerances vary between species, indicating the importance of species identification (Gaskill, 2014).

Water quality, substrate and size of a lake significantly affected species diversity. In lakes with a low-nutrient level, species richness was higher than in more eutrophic (significant correlation between number of species and total nitrogen, total phosphorus and nitrate) (Roque, 2013; Szoszkiewicz *et al.*, 2014). The input of increasing load of pollutants and toxic substance into the surface waters has been reported to cause serious disturbances in the aquatic ecosystems. However, this depends on the nature and quantity of pollutants. Usually, various physico-chemical methods are used to detect the effect of pollution on the water quality and there effect on macroinvertebrates (Akaahan *et al.*, 2014; Sarang and Sharma, 2015). Alterations in water quality are very well reflected in the structure and composition of biotic community as shown by occurrence, diversity and abundance pattern of species (Roque, 2013; Akaahan *et al.*, 2014; Sarang and Sharma, 2015). According to Roque (2013), macroinvertebrates and temperature have positive correlation, which was evident in this study (TDS, As, Pb, NO_2-, PO_4^{3-} and Cr were positively correlated with macroinvertebrate taxa). In the Lake Tana ecosystem, pH is another important parameter affecting species diversity and distribution. Alkaline pH is associated with a greater number of macroinvertebrate species to found (Sarang and Sharma, 2015). Higher pH values are indicators of pollutant intrusion (Akaahan et al., 2014; Sarang and Sharma, 2015). Many species would probably be able to withstand at low pH because organisms must continually survive with some amount of environmental change. To the reverse, highest pH values may affect negatively macroinvertebrate communities. We observed a direct increase in percent composition of mayflies (Ephemeroptera) and caddisflies (Trichoptera) as pH increased (Appendix 1). This is consistent with the report of Gaskill (2014). Ephemeroptera are widely accepted to be one of the most sensitive orders to acidification that consist of many important indicator species (Gaskill, 2014). It was also observed that abundance of Ephemeroptera declined significantly as the pH declined (Simpson *et al.* (1985), Courtney and Clements (1998), and Smith *et al.* (1989) as cited by Sarang and Sharma (2015)).

Simpson *et al.* (1985) as cited by Gaskill (2014) examined sites with a moderate pH (5.8-7.32) and lower pH (4.4-5.0). They found that the site with the moderate pH value had a higher diversity of macroinvertebrates than the site with the lower pH. In moderate pH value, high diversity of macroinvertebrates was observed in this study. Akaahan *et al.* (2014) also found that species regimes change with pH. This is in agreement with our study. The study done by Sarang and Sharma (2015) showed that increased acidification is strongly correlated with a decline in the number of benthic macroinvertebrates that are able to survive.

Streams continually receive water that contains dissolved soils with little buffering capacity: however, lakes are generally composed of more homogeneous water. In streams, discharge and water chemistry is completely dependent on upstream occurrences. This means that macroinvertebrates living in streams have to face a wider range of disturbances that occur at a greater frequency than macroinvertebrates in lakes. It is very possible that macroinvertebrates in lakes are more vulnerable to withstand disturbances than those in streams since disturbances are not as common in lakes as in rivers. The fact that many stream studies have found the threshold for declines in macroinvertebrate diversity at a much lower pH value in streams, but the reverse is true to lakes (Gaskill, 2014). The study of Gaskill (2014) agrees with the finding of this study. It was found that reductions in pH correlated with decreased benthic macroinvertebrate richness. As the result, Smith et al. (1998) cited by Sarang and Sharma (2015) showed increased sensitivity of Ephemeroptera to even slight environmental stressors and Trichoptera species, observing declines as disturbances increased (Appendix 1). As the number of taxa decrease, it appears that the percent composition of a few types of taxa increases. This suggests that more tolerant taxa are able to replace sensitive ones, and causing a shift in the macroinvertebrate assemblages in the lake. The tolerant taxa not affected by the pH changes increased in number and replaced individual taxa that were negatively affected by low pH. Even if a particular taxon is able to survive at a decreased pH, individuals may be less successful to thrive energy and reproduce at the rate experienced in less stressful conditions. This creates an opportunity for taxa that are not affected by the increasing stressors to flourish. So, overall numbers of macroinvertebrates may not change even though the taxonomic diversity changes (Gaskill, 2014).

Phosphorus and nitrogen are the basic nutrients which are important to determine the productivity of lakes. Akaahan et al. (2014) stated that inorganic phosphate of more than 0.5 mg/l is an indicator of organic pollution. In eutrophic lake, phosphorus and nitrogen levels were comparatively much higher (Roque, 2013; Sarang and Sharma, 2015). In this study, phosphate and nitrate are positively correlated with macroinvertebrate taxa; as the amount of physico-chemical parameter increased the number of macroinvertebrate taxa increased.

The presence of nitrate in a lake system mostly depends on the characteristics of the catchments area, domestics and agricultural sources. Similar trends of nitrate were reported in surface waters studied by Akaahan et al. (2014). The mean nitrate value in this study (0.492 ± 0.070) may be due to the agricultural activities in the catchment of Lake Tana.

Phosphorus is present in the form of phosphate in natural waters and generally occurs in low concentration, and it is a nutrient for plant growth and a fundamental element in the metabolic reaction of plants and animals (Roque, 2013). Nevertheless, the result of this study agrees with that of Sarang and Sharma (2015). The reason for higher concentration of phosphate may be attributed to runoff from the catchement. Phospahate in water is source of nutrient for the growth of planktons which may serve as source of food for the fish and macroinvertebrates population (Akaahan *et al.*, 2014). In the mean while, it was a cause for eutrophication that was obsereved in the Megch study area.

Surface water temperature is an indispensable ecological factor that regulates the physiological behaviour and distribution of aquatic organisms (macroinvertebrates). Lower temperature is reported to reduce metabolism and growth of macroinvertebrates (Tapan *et al.*, 2014). The surface water temperature range in this study may be attributed to the atmospheric temperature that was obtained in the data collection. Although WHO does not set any limit value for surface water temperature, values above 30.00 oC may lead to the suppression of all benthic organisms (Akaahan *et al.,* 2014).

The total dissolved solids (TDS) in water consist of inorganic salts and dissolved materials that could affect aquatic life forms when it is beyond the natural system (Akaahan *et al.*, 2014). This result conforms as TDS has positive and negative correlation to macroinvertebrates distribution as per their level of sensitivity.

Total Suspended Solids (TSS) is an indication of the amount of erosion that took place upstream. The concentration of TSS in this study is due to the level of surface run off to Lake Tana. Bilotta and Brazier (2008) as cited by Steve *et al.* (2015) reported that excess TSS (8.00 mg/l) increased the rate of drift of macroinvertebrates in surface water. Based on the finding by Bilotta and Brazier (2008) as cited by Steve *et al.*, (2015), the TSS concentration in Lake Tana during the course of this study may contribute to the drift of the benthic fauna (macroinvertebrates). The TSS concentration between 80-100 mg/l would cause injury to the gills of the fish (Fadaeiferd et al., 2012) as cited by Akaahan *et al.* (2014); (Roque, 2013). The TSS concentration of the water samples at some instances may cause injury to the gills of the fish of Lake Tana. That might be one reason for the death of fish observed in the field survey.

Sulphate is a source nutrient that facilitates the growth of planktons that support the fish population but endangered macroinvertebrate with excess concentration (Akaahan *et al.*, 2014). However, the results of this study indicated that the sulphate concentration was not correlated with macroinvertebrates abundance. High concentaration was reported at

Tana Kirkos study area.

Copper is an important element that facilitates the action of some enzymes in the body of humans but not known to affect the reproduction of macroinvertebrates. In the other way; arsenic, lead and cromimum are known with toxicity at any concentaration in the water bodies (Roque, 2013; Akaahan *et al.*, 2014). Possible sources of copper, arsenic, lead and cromium in Lake Tana may be due to the municipal waste and lecahtes that are washed into Lake Tana through feeding rivers and streams and affect macroinvertebrates.

The major factors that affects the occurrence and distribution of benthic fauna in lotic and lentic systems include, physicochemistry, the nature of the substrate (bed material), water current, food availability, flood, drought, vegetation and shade (Roque, 2013). At the same time, during this study, surface water temperature, pH and nitrate correlate significantly with the benthic fauna group in the study period. Other studies reported significant correlation between surface water temperature, pH, nitrate and benthic fauna group (Akaahan *et al.*, 2014).

It is important that environmental stressors have to be minimized in order to preserve greater diversity at low trophic levels as stressor such as low pH value decrease diversity in ecosystems. Tanya et al. (2014) found that macroinvertebrate assemblages immediately decreased downstream of dams, where much different assemblages are recorded than upstream of dams. Gaskill (2014) concluded that disturbances due to the dam construction or other human activities changed macroinvertebrate structure and function and suggested several causes of the changes including high concentrations of trace metals and physico-chemical parameters change the diversity. It was observed that the increase in physico-chemical values from the standard or natural system (Lakes) decreases in Ephemeroptera and increases in Diptera (Chironomidae) (Tanya *et al.*, 2014). This was true in this study. The Chara Chara dam construction (at the outlet of Blue Nile River) and the whole sampling sites physico-chemical parameters change might be the reasons for the decrease in Ephemeroptera, Plecopetra and Tricoptera and the increase in Odonata and Diptera (Chironomidae) in this study.

Conclusion

This is to conclude that the main threat to aquatic ecosystems arises from the cultivation of surrounding land in addition to urbanization and industrialization. The present study revealed that the pollution status of Lake Tana was highly related with the deterioration of their physico-chemical qualities due to the human activities present in the study area. Moreover, the correlations observed among these elevated physico-chemical parameters reflect the presence of anthropogenic sources of pollution. In this regard, the pysicochemical parameters were noticed to be correlated significantly with the macroinveretebrates fauna which indicated the impact level of Lake Tana. Also, the study indicated that macroinvertebrates in the lake are affected by physico-chemical parameters change because it appears that as sensitive taxa (namely Ephemeroptera, plecoptera and Trichoptera) declined, more tolerant taxa increased in number where it is a phenomenon of an impact. This has a potential to cause disruptions on food web for some fish species and others might not be able to acquire sufficient nutrients or energy from these alternative preys. The most notable difference is that macroinvertebrates in the lake appear to be more sensitive to disturbances, experiencing significant changes in richness over physico-chemical parameters.

More importantly, drainage of wastes to the lake had the highest positive contribution to macroinvertebrates distribution. Thus, pollution plays a key role in structuring aquatic communities that would help to improve management of aquatic ecosystems. Habitat degradation negatively impacts macroinvertebrate communities, which in turn results in decreased nutrient cycling. Thus, the increasing levels of pollutants in Lake Tana and its wetlands were results of agricultural, industrial, urban and domestic waste where it is an issue of concern on water quality, human health and quality of aquatic environment expressed interms of physico-chemical and macroinvertebrate parameters correlation. Therefore, the study urges the government and the community to take enough and preventive measures to manage and sustainably use Lake Tana.

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	Tem (oC)	pH	EC	BOD$_5$	COD	TSS	TDS	NO$_3$	NO$_2$	NH$_3$	PO$_4$	SO$_4$	S^{-2}	Cr	Mn	As	Cd	Cu	Pb	Fe	E. Coli	F. Coliform	T. Coliform
Baetidae	.196	.069	-.107	-.110	-.088	-.226	-.274	-.173	-.179	-.178	-.137	-.175	-.291	-.331	-.143	-.154	-.145	-.273	-.190	-.213	-.208	-.287	-.319
Caenidae	.172	.099	-.015	-.067	-.022	-.205	-.181	-.099	-.156	-.065	-.114	-.167	-.247	-.226	-.144	-.138	-.071	-.224	-.190	-.200	-.152	-.248	-.303
Heptageniidae	-.057	-.199	-.160	-.270	-.087	-.234	-.240	-.094	-.153	-.129	-.118	.142	.192	.399	-.151	.280	.237	-.052	.226	-.095	-.140	.281	.272
Perlidae	.093	.181	-.063	-.097	-.130	-.314	-.247	-.155	-.218	.121	-.143	-.089	-.185	-.344	-.132	-.149	-.262	-.244	-.099	-.141	-.206	-.176	-.031
capniidae	-.450*	-.292	-.322	-.256	-.301	-.152	-.081	-.033	-.097	-.102	-.069	-.023	.016	.205	-.110	-.056	-.107	-.156	-.132	-.127	-.178	-.190	-.246
Hydropsychidae	-.326	-.276	-.441*	-.321	-.439*	-.259	-.225	-.159	-.159	-.148	-.100	-.152	-.166	.002	-.125	-.104	-.208	-.226	-.191	-.185	-.232	-.275	-.327
Hydracarina	.000	-.088	-.287	-.187	-.305	-.204	-.229	-.186	-.121	-.102	-.069	-.188	-.245	-.203	-.063	-.087	-.181	-.156	-.132	-.127	-.142	-.190	-.205
Aeshinidae	-.158	.152	-.130	-.132	.219	-.294	-.300	-.228	-.212	-.339	-.190	.176	-.074	-.182	-.167	-.046	-.178	-.382	-.138	-.115	.148	-.177	-.045
Calopterygidae	-.440*	-.321	-.321	-.244	-.273	-.087	-.094	-.043	-.100	-.112	-.078	-.002	.048	.211	-.121	-.056	-.092	-.175	-.116	-.130	-.186	-.159	-.212
Coenogrionidae	-.372	-.445*	-.416	-.362	-.404	-.261	-.258	.025	-.215	-.210	-.148	-.025	.084	.263	-.182	.296	.033	-.280	.020	-.196	-.211	-.173	-.163
Gomphidae	-.450*	-.292	-.322	-.256	-.301	-.152	-.081	-.033	-.097	-.102	-.069	-.023	.016	.205	-.110	-.056	-.107	-.156	-.132	-.127	-.178	-.190	-.246
Lestidae	-.045	.167	-.240	-.104	-.266	-.256	-.175	-.122	-.240	-.144	-.165	-.302	-.340	-.190	-.233	-.193	-.302	-.248	-.077	-.287	-.273	-.379	-.378
Dytiscidae	-.143	-.029	-.166	.050	.050	-.152	-.075	-.128	-.112	-.194	-.202	.085	.131	.125	-.189	.342	.146	-.019	.418	-.170	.258	.322	.404
Elimidae	.064	.204	.036	.093	-.046	.252	.050	.144	-.087	.182	.426*	-.295	-.120	.084	-.156	-.138	-.083	-.086	-.180	.417	-.116	-.119	-.162
Gyrinidae	-.055	-.141	-.106	-.076	-.101	.143	-.115	-.137	-.003	.338	-.140	.105	.136	-.071	-.109	-.091	-.093	-.157	-.060	-.121	-.165	.168	.282
Haliplidae	.120	.190	-.092	.298	-.047	-.141	.115	-.276	-.066	-.089	-.072	-.188	-.175	-.203	-.063	-.087	-.107	.149	-.067	-.120	.072	.168	.174
Hydrophilidae	-.138	-.120	-.205	-.273	-.139	-.198	-.186	-.274	-.112	.099	-.086	.133	.115	.347	-.143	-.067	.097	.056	.123	-.079	-.128	.391	.319
Psephenidae	-.375	-.083	-.336	-.297	-.333	.251	-.080	.158	-.122	-.088	.143	-.055	.023	.190	-.225	-.131	-.161	-.233	-.148	.075	-.279	-.320	-.386
Ceratopogonidae	-.415	-.415	-.320	-.260	-.157	.042	-.161	-.158	-.115	-.129	-.116	.152	.224	.393	-.178	-.057	.040	-.157	.025	-.126	-.227	.138	.063
Chironomidae	.243	-.181	.077	.202	.023	-.190	-.075	.304	-.156	-.204	-.116	-.070	.149	.067	-.091	.812**	.299	-.115	.167	-.131	.038	-.067	.078
Culicidae	.097	.122	-.113	.044	-.176	-.277	-.083	-.254	-.190	.110	-.132	-.049	-.112	-.319	-.123	-.138	-.150	-.090	-.197	-.144	-.085	.033	.114
Muscidae	.105	.190	.321	.182	.192	.113	.673**	-.267	.444*	-.076	-.064	-.164	-.245	-.131	.151	-.087	-.181	.123	-.161	-.038	-.089	-.099	-.092
Psychodidae	.000	-.088	-.287	-.187	-.305	-.204	-.229	-.186	-.121	-.102	-.069	-.188	-.245	-.203	-.063	-.087	-.181	-.156	-.132	-.127	-.142	-.190	-.205
Simuliidae	.290	.533*	.162	-.065	.228	-.136	-.134	-.005	-.115	-.198	-.092	-.178	-.296	-.235	-.106	-.106	-.094	-.191	.070	-.122	-.091	-.224	-.151
Tabanidae	.217	.197	.089	.007	.294	.294	-.159	-.050	-.084	-.177	-.105	.002	-.006	-.101	-.125	-.060	.007	-.226	.163	-.084	-.102	.037	.119
Tipulidae	.337	.304	.253	.242	.328	-.165	-.143	-.059	-.107	-.172	-.112	-.221	-.283	-.282	-.108	-.126	-.154	-.170	.045	-.151	-.154	-.245	-.218
Belostomatidae	.022	.045	-.215	-.236	-.416	-.241	-.195	.044	-.187	.463*	-.072	-.180	-.146	-.177	-.109	.168	-.111	-.113	-.108	-.145	-.015	-.105	.018
Corixidae	-.030	-.061	-.176	-.064	-.152	.085	-.138	.147	-.171	-.250	-.172	.052	.138	-.033	-.194	.409	.127	-.172	.591**	-.151	.081	.002	.112
Gerridae	-.335	-.112	-.251	-.244	-.183	-.129	-.139	-.240	-.150	-.171	-.135	.042	.037	.109	-.152	-.088	.051	-.134	.811**	-.029	.155	.255	.260
Hydrometridae	-.450*	-.292	-.322	-.256	-.301	-.152	-.081	-.033	-.097	-.102	-.069	-.023	.016	.205	-.110	-.056	-.107	-.156	-.132	-.127	-.178	-.190	-.246
Naucoridae	-.574**	-.068	-.410	-.270	.051	-.193	-.224	-.185	-.135	-.207	-.126	.152	-.050	.133	-.167	.046	-.150	-.265	-.225	-.126	.442*	-.134	-.118
Nepidae	.219	-.121	.076	.298	.109	-.195	-.180	-.164	-.101	-.116	-.105	-.214	-.226	-.272	-.086	-.119	-.180	-.144	-.092	-.161	-.194	-.221	-.275

Notenoctidae	-.330	-.030	-.187	-.255	-.058	.031	-.147	-.145	-.081	-.062	-.122	.112	.076	.003	-.121	-.071	.033	-.121	.780**	-.015	.248	.253	.300
Pleidae	-.450*	-.292	-.322	-.256	-.301	-.152	-.081	-.033	-.097	-.102	-.069	-.023	.016	.205	-.110	-.056	-.107	-.156	-.132	-.127	-.178	-.190	-.246
Velidae	-.434*	-.033	-.206	-.210	.270	-.120	-.160	-.245	-.077	-.114	-.104	.378	.212	.445*	-.160	.072	.115	-.042	.045	-.030	.415	.359	.335
Physidae	-.146	.068	-.222	.132	.114	-.095	-.057	-.237	-.201	-.307	-.201	.110	.100	.126	-.239	.271	.121	-.055	.383	-.148	.413	.343	.417
Planorbidae	.225	.246	-.025	.228	-.095	.061	.086	-.051	-.097	-.174	-.065	-.141	-.145	-.197	-.110	-.087	-.107	.009	.096	-.113	-.089	-.099	-.101
Corbiculidae	.233	.505*	.130	-.073	.190	-.120	-.118	.003	-.099	-.164	-.077	-.169	-.270	-.199	-.089	-.090	-.110	-.158	.095	-.099	-.075	-.195	-.108

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).