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# MAJOR FACTORS THAT STRUCTURE THE BENTHIC FAUNA OF A SHALLOW, TROPICAL LAKE, LAKE KURIFTU, ETHIOPIA

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**ABSTRACT:** The aim of this study was to determine the community structure of the benthos in Lake Kuriftu in relation to some environmental variables. Benthic samples were collected with an Ekman grab (0.0225 $m^2$) from three sites (littoral, sub-littoral and profundal zones) on a monthly basis from September 2009 to February 2010. Dissolved oxygen and temperature were measured with a probe at different depths of each site. Sediment texture was determined by the Bouyoucos hydrometer and organic matter content by loss on ignition method. Chironomids, EPT (Ephemeroptera, Plecoptera, Trichoptera), oligochaetes and coleopterans were abundant in littoral and sub-littoral zones, with EPT much higher in the vegetated littoral area. The mean density of benthic macro-invertebrates in littoral, sub-littoral and profundal zones was 20,443, 18,251, and 4,388 ind/$m^2$, and that of Chironomids was 12,545, 14,003 and 3,215 ind/$m^2$, respectively. The profundal zone had the lowest diversity with abundant oligochaetes but no EPT samples, despite the high oxygen content of the profundal zone (6.33 mg/l). Chironomids and oligochaetes were present in all zones which had negligible difference in dissolved oxygen and organic matter content. The littoral zone had highest diversity (H'=1.26) and richness (d=2.72). Our results indicate that abundance of benthic macro-invertebrates of Lake Kuriftu was best correlated with the presence of vegetation in the littoral zone and sediment texture (high clay) in the littoral and profundal zones. We conclude that benthic macro-invertebrate community structure in Lake Kuriftu is mainly influenced by spatial variation in vegetation, sediment texture and temperature, but not dissolved oxygen and organic matter content.

**Key words/phrases**: Benthic macro-invertebrates, Lake Kuriftu, Littoral, Profundal, Sub-littoral.

## INTRODUCTION

Benthic invertebrates play an essential role in key processes within lake ecosystems such as food chain dynamics, productivity, nutrient cycling and decomposition (Reice and Wohlenberg, 1993). Benthic macro-invertebrates form an important link between primary producers, detrital deposits and higher trophic levels in aquatic food webs (Barnes and Hughes, 1988). Boyd (1970) reported that macrobenthos are involved in the mineralization and

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recycling of organic matter from autochthonous and allochthonous sources. They also accelerate the mineralization of decaying organic matter into inorganic forms such as phosphates and nitrates (Gallep *et al*., 1978). These organisms, therefore, form a major linkage in the food chain as most fishes, birds and mammals depend directly or indirectly on the benthos for their food supply.

Benthic macro-invertebrates composition, distribution, and abundance is regulated by both abiotic and biotic factors (Dumnicka and Galas, 2006) and the distribution of benthic macro-invertebrates appears to be extremely heterogeneous, in part, due to differences of these factors spatially and temporally. The requirements of benthic fauna for feeding, growth and reproduction are strongly influenced by bottom substrate texture, inputs of living and dead organic matter and by oxygen content and temperature of the water in the overlying water column (Parsons *et al*., 2010). Abiotic factors such as pH, dissolved oxygen, conductivity, temperature, bottom substrate and depth play important roles in determining the biological diversity and abundance of benthic organisms in fresh waters. Water level fluctuation also indirectly affect benthos by influencing the appearance and growth patterns of aquatic vegetation (Furey *et al*., 2006; Bogut *et al*., 2007). Biotic factors such as presence or absence of aquatic vegetation, predation and competition also combine to define the limitations experienced by benthic organisms causing variation in community composition (Cochrane *et al*., 1998). Information on distribution and abundance of benthic macro-invertebrates in relation to abiotic factors (temperature, dissolved oxygen, pH and ionic concentration) and biotic factors (vegetation, competition and predators) are available from temperate regions of the world (e.g. Peterson, 1975; McAuliffe, 1984). In temperate lakes, the habitat use of the macro-invertebrates seems to be strongly influenced by vegetation characteristics, depth, and/or complexity of the substrate (Hansen *et al*., 1998). Grzybkowska and Witczak (1990) concluded that substrate composition, complexity and particle size are important factors affecting the distribution, structure and composition of macro-invertebrate communities in temperate lakes and running waters. The spatial patterns of macro-invertebrates assemblages in tropical Africa have been less investigated compared with the temperate communities. In East Africa, the knowledge of benthic macro-invertebrate communities was derived mainly from the studies on Lakes Victoria, Chad and George. Most of these studies were related to colonization of artificial substrates, standing crop biomass and spatial distribution of the benthic communities

(Greenwood, 1976; Mothersill *et al*., 1980; Leveque *et al*., 1983).

Studies on benthos of lakes in Ethiopia are few. The pioneer works on benthic macro-invertebrates in Ethiopian lakes include those of two saline lakes, Shala and Abjata (Tudorancea and Harrison, 1988), and benthic and weed-bed fauna of Lake Hawasa (Tilahun Kibret and Harrison, 1989). Recent studies by Dereje Tewabe (2009) and Betael Assefa (2010) investigated the distribution and abundance of benthic macro-invertebrates in Lakes Tana and Hayq, respectively. Most of these studies considered the inventory of the benthic fauna and their correlation with abiotic factors. Other studies tried to relate benthic distribution with degree of human impacts such as organic pollution and storm water runoff (e.g. Baye Sitotaw, 2006; Solomon Akalu *et al*., 2011; Beneberu *et al*., 2014). Seyoum Mengistou (2006) indicated earlier in his review that the study of invertebrates in Ethiopia has lagged far behind; hence both types of studies on benthic fauna in relation to factors affecting their composition and their usefulness as bio-indicators of ecological impacts are required for the country.

Despite many limnological studies on the Bishoftu crater lakes, few of them gave serious attention to the benthic fauna; hence the present study was undertaken to fill this gap to some extent. We also aimed to determine which factors were more important in structuring benthic community composition and abundance in the shallow Lake Kuriftu. We considered factors such as temperature, dissolved oxygen, organic matter content, sediment texture, and vegetation cover in the benthos of the lake.

## MATERIALS AND METHODS

### Study area

Lake Kuriftu is one of the Bishoftu crater lakes located 47 km southeast of Addis Ababa in Bishoftu town within the main Rift Valley (Fig. 1). The lake is located at 8° 47' North and 39° 00' East, at an altitude of 1,860 m, has an area of 0.4 $km^2$ and maximum depth of 6 m. It is an artificial lake formed by diverting and damming Belbela River, a tributary of Modjo into an empty crater depression some 40 years ago. The purpose of the lake was to introduce fish and to initiate small scale horticulture for the local people (Brook Lemma *et al*., 2001). The lake is fed by surface run-off and direct rainfall and has low salinity (0.26 g/l) despite lacking any outlet. It appears that the considerable water input during the rainy season is sufficient to maintain the hydrological balance of the lake. During the study period, the water level of the lake dropped considerably due to the diversion of the inflowing river for irrigation by local farmers. The bottom of the lake is covered predominantly with a blanket of grey-muddy clay, except in the inshore area (personal observation). The littoral macrophytes present around the lake are Polygonaceae (*Persicaria senegalensis*) and Cyperaceae (*Cyperus alopecuroides* and *Cyperus* spp). In some parts, the lake is bounded by trees such as *Acacia abyssinica*, *Jacaranda mimosifolia* and species of *Eucalyptus* and *Juniperus*. Bamboo (*Oxytenanthera abyssinica*) is also a dominant plant growing on the rocky rim of the lake (pers. obs.).

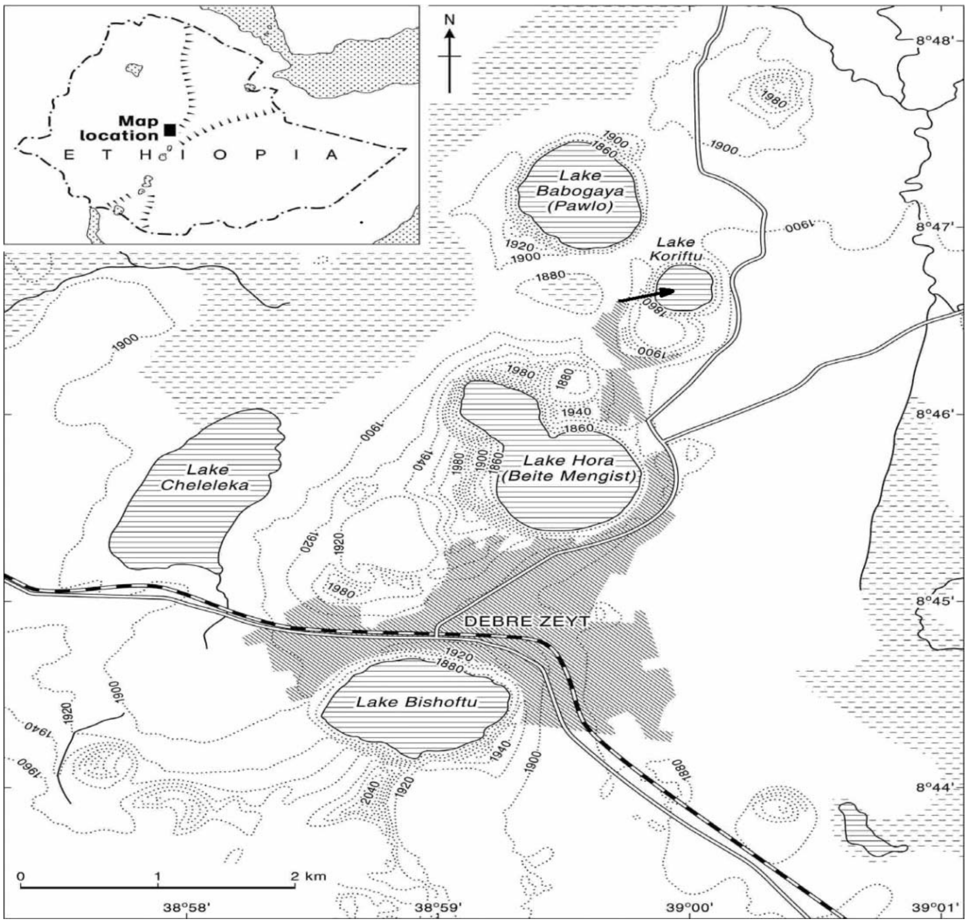


Fig. 1. Map of Lake Kuriftu (arrow) in the Bishoftu area.

## Abiotic factors

### Sediment texture

The sediment texture (grain size) was determined according to Bouyoucos hydrometer method (Bouyoucos, 1936). Three samples from different depths were taken to determine the particle size of the sediment. Sediment samples were taken to the National Soil Testing Centre, Addis Ababa to determine texture. A hydrometer measures the density (g/l) of the suspension at the hydrometer's centre of buoyancy. Bouyoucos (1936) found that sand-sized particles (2.0 to 0.05 mm) settle out of suspension in 40 seconds, whereas silt-sized particles (0.05 to 0.002 mm) require approximately 2 hours settling out of suspension. Therefore, after two hours, it is assumed that only clay-sized particles (<0.002 mm) remain in suspension.

### Organic matter content

Bottom samples for the determination of organic matter were taken at each sampling site with an Ekman grab. The total organic matter of the bottom sediment was determined by loss on ignition (LOI) method (c.f. Tilahun Kibret and Harrison, 1989). The whole bottom mud was dried in Philip Harris heat oven at 80°C for 24 hours and incinerated in electric Fisher muffle furnace (Model 184A) at 550°C for four hours. Sartorius analytic balance was used to weigh the samples. Percentage of total organic matter in the sediment was estimated from bottom samples at each site from the weight difference of the dried and burnt samples as given below:-

$$OM = \frac{(DW - Ash\ w)}{DW} * 100$$

where DW is the dried weight of the mud sample, Ash w is the weight of the burnt sample, and Organic matter (OM) is loss on ignition.

### Temperature and oxygen content

The water temperature (°C) and dissolved oxygen content (mg/l) were measured *in situ* just above the bottom at each site with a digital oxygen metre (CO-411). The depths at which samples were taken each month are indicated in Table 3.

### Macro-invertebrate sampling techniques

Sampling was carried at three stations from September 2009 to February 2010 (except November) at both near-shore and open water sites. The selection of sampling stations was done systematically from three regions at different depths and covered months in both wet and dry season. The littoral station was defined by the vegetated area extending up to about 1 m depth;

the sub-littoral station represents the aphotic region from the end of the littoral to the euphotic zone (approximately 1.5-2.7 m depth range) and the deepest part of the lake (depth range >3 m) was taken as the profundal zone. Because of the large areas covered by each zone, triplicate samples were taken from each station at different depths.

### Benthic macro-invertebrates identification

Samples were washed through sieve of mesh size 0.2 mm to reduce the bulk, and organisms were sorted out alive and preserved in 5% formalin. Bigger organisms were sorted out against a white background of enamel dish and identified on site. Large macro-invertebrates could be identified on site, at least to order and sometimes to family level. Smaller ones were identified under a dissecting microscope and for detailed identification, a compound microscope was used. The macro-invertebrates were identified to the lowest taxonomic category using identification key of Pinder (1978), Leveque *et al*. (1983) and Bouchard (2004). The abundance of macro-invertebrates in a square metre area was calculated following Jhingran *et al*. (1989).

### Biological indices

The data gathered from monthly samples were pooled to calculate diversity index (Shannon and Weaver, 1949), richness (Margalef, 1958) and evenness (Pielou, 1966) as shown below:-

(1) Diversity index (H') = $- \Sigma$ pi ln pi

(2) Richness index (d) = (S – 1)/ln N

(3) Evenness (Pielou, 1966): J (e) = H'/ln S

where pi=ni/N, ni=number of individuals of species i (in this study individuals of families), N=the total number of individuals in a sample, S=total species number (in this study total family number).

### Statistical analysis

For statistical analysis, SPSS-version 13.1 (Statistical Package for Social Sciences) was used. Correlation analysis was done on data of the physico-chemical factors and macro-invertebrate abundance. The dominance (%) of each of the major macro-invertebrate groups was calculated in relation to the total number of macro-invertebrates.

# RESULTS

## Sediment composition and texture

Particle size analysis showed that benthic samples of Lake Kuriftu were composed of three major particle-size categories. The texture of the sediment was found to be mainly clay at the littoral and profundal zones, and sandy clay at the sub-littoral zone (Table 1). Clay was highest in the profundal (60%) but the slightly higher organic matter here (8.44%) was not significantly different from the other two zones. EPT were found in lower numbers in the sub-littoral zone, probably due to the sandy nature of this station but were absent from the profundal with its high clay, and high oxygen and organic matter content.

Table 1. Percentage composition of silt, sand and clay in sediment samples of littoral, sub-littoral and profundal sites from Lake Kuriftu.

| | Sites | | |
|---|---|---|---|
| **Texture** | **Littoral** | **Sub-littoral** | **Profundal** |
| Silt | 14 | 10 | 10 |
| Sand | 36 | 50 | 30 |
| Clay | 50 | 40 | 60 |
| Sediment texture | Clay | Sandy clay | Clay |

## Organic matter content of sediment

The organic matter content from the littoral zone ranged from 1.11 gm (7.38%) to 1.18 gm (9.81%) and was more or less uniform during the study period (Table 2). The dry organic matter content of sub-littoral zone showed seasonal variation with 0.67 gm (5.58%) in September and 1.70 gm (11.30%) in February. In the profundal, organic matter content exhibited highest increment from 0.67 gm (7.00%) in September to 1.86 gm (12.40%) in February. The overall mean values of sediment organic matter content were 1.14 gm (7.96%), 0.91 gm (6.30%) and 1.19 gm (8.44%) for littoral, sub-littoral and profundal zones, respectively (Table 2). The mean values of organic matter content of the three sites were more or less similar, indicating that organic matter content did not influence benthic distribution in this shallow lake.

Table 2. Monthly dry weight (gm) and percentage (in brackets) of organic matter of sediment samples at littoral, sub-littoral and profundal sites of Lake Kuriftu.

| | Sites | | |
|---|---|---|---|
| **Months** | **Littoral** | **Sub-littoral** | **Profundal** |
| September (2009) | 1.18 (7.87) | 0.67 (4.47) | 0.67 (4.47) |
| October (2009) | 1.11 (7.38) | 0.71 (4.73) | 0.79 (5.27) |
| December (2009) | 1.15 (7.67) | 0.81 (5.40) | 1.31 (8.73) |
| January (2010) | 1.10 (7.33) | 0.67 (4.47) | 1.31 (8.73) |
| February (2010) | 1.14 (7.60) | 1.70 (11.30) | 1.86 (12.40) |
| Mean | 1.14 (7.60) ± 0.03 | 0.91 (6.07) ± 0.41 | 1.19 (7.93) ± 0.44 |

## Temperature and dissolved oxygen content

Dissolved oxygen and temperature profiles at the three sites during two months of wet season (September and October 2009) and three months of dry season (December 2009-February 2010) are presented in Table 3. The mean dissolved oxygen recorded in the littoral zone was 8.03 mg/l at mean temperature of 23.49°C but it was slightly lower in the sub-littoral zone (at 23.02°C, dissolved oxygen was 7.12 mg/l). Compared with the littoral zone, there was little variation of temperature and dissolved oxygen in the sub-littoral zone. In the littoral zone, the greater mean value in dissolved oxygen was probably due to high density of the macrophytes. At mean depth of 3.28 m and 22.47°C, the dissolved oxygen in the profundal zone was 6.33 mg/l and much lower than in the sub-littoral or littoral zones. The small decline in oxygen level with depth may be related with biological demand and the use of oxygen for decomposition of organic matter in deep waters. Nevertheless, in the shallow Lake Kuriftu, the lake bottom did not experience anoxia or low temperature, as is often the case in deep lakes.

Table 3. Mean monthly temperatures (T) and dissolved oxygen (DO) at various depths (D in metre) of littoral, sub-littoral and profundal sites of Lake Kuriftu.

| | Sites | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Littoral** | | | **Sub-littoral** | | | **Profundal** | | |
| **Month** | **D(m)** | **T (°C)** | **DO (mg/l)** | **D(m)** | **T (°C)** | **DO (mg/l)** | **D(m)** | **T (°C)** | **DO (mg/l)** |
| September | 0.33 | 25.57 | 7.52 | 1.50 | 25.17 | 7.21 | 2.77 | 24.63 | 6.73 |
| October | 0.30 | 23.93 | 8.70 | 1.60 | 23.4 | 7.77 | 3.48 | 22.73 | 7.10 |
| December | 0.28 | 21.57 | 7.64 | 2.36 | 20.7 | 6.75 | 3.70 | 20.2 | 5.39 |
| January | 0.28 | 22.63 | 8.35 | 1.88 | 22.28 | 6.84 | 3.45 | 21.8 | 5.90 |
| February | 0.25 | 23.77 | 7.96 | 2.05 | 23.57 | 7.05 | 3.00 | 23.00 | 6.52 |
| Mean | 0.29 | 23.49 | 8.03 | 1.88 | 23.02 | 7.12 | 3.28 | 22.47 | 6.33 |

## Benthic macro-invertebrate taxa

The list of benthic macro-invertebrates identified from littoral, sub-littoral and profundal sites of Lake Kuriftu is presented in Table 4. Benthic samples from Lake Kuriftu contained mainly insects (larvae), oligochaetes and nematodes. Insect larvae were represented by Diptera, Ephemeroptera, Coleoptera, Trichoptera, Plecoptera, Odonata and Lepidoptera. Diptera larvae were represented by six families of which the Chironomidae were the most abundant, Ephemeroptera, and Plecoptera were each represented by five families, and Coleoptera was represented by Dryopidae, Dytiscidae and Hydrophilidae. The remaining Trichoptera, Odonata and Lepidoptera were each represented by one family. Of the Oligochaeta, the families Enchytridae, Tubificidae, Naididae and Lumbriculidae were collected. A few bivalves and gastropods were collected during the study period (included in ‘others’ in Table 4). Thus, the benthic macro-invertebrate fauna of Lake Kuriftu was composed of 21 families of Insecta, four families of Oligochaeta and Nematoda. In terms of family and genera, Diptera was the most diversified, followed by Ephemeroptera and Plecoptera.

Macro-invertebrates were highly dominant in the littoral zone in association with macrophytes such as Polygonaceae (*Persicaria senegalensis*) and Cyperaceae (*Cyperus alopecuroides*) and others (*Cyperus* spp.). The sub-littoral zone is also rich in Diptera, Coleoptera, a few EPT and Oligochaeta, while the profundal zone is depauperate with a limited number of macro-invertebrate groups such as Diptera (Chironomidae, Ephydridae, Tabanidae and Tipulidae) and Oligochaetes. No EPT were recovered from the profundal zone, even though dissolved oxygen and organic matter were adequate for their survival.

## Abundance and density of macro-invertebrates

The mean density of benthic macro-invertebrates in littoral, sub-littoral, and profundal zones were 20,443, 18,251 and 4,388 individuals/m$^2$, respectively (Table 4). The highest density was recorded from the littoral zone and the lowest from the profundal zone. Class Insecta accounted for the highest proportion of the abundance in littoral, sub-littoral, and profundal zones with an abundance of 18,980, 15,518 and 3,215 individuals/m$^2$, respectively (Table 4). Diptera larvae were dominant with 11,816, 13,375 and 2,927 individuals/m$^2$ in littoral, sub-littoral and profundal zones. Both in sub-littoral and profundal zones, Chironomidae were dominant followed by oligochaetes. Oligochaetes were more abundant in the sub-littoral (2,590 individual/m$^2$) zone than littoral (1,265 individual/m$^2$) and profundal (1,173 individual/m$^2$) zones. Nematodes were least abundant in the three sites while mollusks were only recovered sporadically. Macro-invertebrates such as Coleoptera, Ephemeroptera, Trichoptera, Plecoptera, Lepidoptera and Odonata larvae were not present in the profundal zone. The abundance of macro-invertebrates exhibited a significant correlation with temperature and depth ($P<0.05$) but did not show a significant relationship with dissolved oxygen and organic matter content.

Table 4. Abundance (individuals/m$^2$, n=15) of benthic macro-invertebrates in sediment samples from littoral, sub-littoral and profundal sites of Lake Kuriftu. Each number is rounded to the nearest whole number.

| | **Sites** | | |
|---|---|---|---|
| **Taxa** | **Littoral** | **Sub-littoral** | **Profundal** |
| Insecta | 18,980 | 15,518 | 3,215 |
| Diptera | 12,545 | 14,003 | 3,215 |
| Chironomidae | 11,816 | 13,375 | 2,927 |
| Macromidae | 50 | 0 | 0 |
| Culicidae | 330 | 95 | 0 |
| Ephydridae | 44 | 36 | 27 |
| Tabanidae | 175 | 95 | 71 |
| Tipulidae (*Tibula* spp) | 124 | 403 | 190 |
| Coleoptera | | | |
| Dryopidae (*Helmis maugi* Bed) | 767 | 59 | 0 |
| Dytiscidae (*Lacophilluus* spp) | 924 | 276 | 0 |
| Hydrophilidae (*Hydrous piceus*) | 0 | 160 | 0 |
| Ephemeroptera | | | |
| Baetidae | 2,510 | 533 | 0 |
| *Baetis* spp | 960 | 225 | 0 |
| *Cloeon* spp | 1,550 | 308 | 0 |
| Leptophlebiidae (*Leptophlebia* spps) | 80 | 0 | 0 |
| Ecdyonuridae | 240 | 0 | 0 |
| *Heptagenia* spp | 95 | 0 | 0 |
| *Rhithrogena* spp | 145 | 0 | 0 |
| Ephemeridae (*Ephemera vulgate*) | 15 | 0 | 0 |
| Sphlonuridae (*Sphlonurus* spp?) | 130 | 80 | 0 |
| Trichoptera | | | |
| Limnephilidae | 154 | 0 | 0 |
| *Hesperophylax designatus* | 154 | 0 | 0 |
| Plecoptera | | | |
| Perlidae | 204 | 27 | 0 |
| Leuctridae (Leuctra spp) | 299 | 0 | 0 |
| Taenioptergidae | 270 | 0 | 0 |
| *Taeniopteryx nibolusa* (?) | 270 | 0 | 0 |
| Capnidae | | | |
| *Allocapnia* spp | 44 | 36 | 0 |
| Odonata | | | |
| Platycnemidae (*Platycnemis pennipes*) | 154 | 0 | 0 |
| Lepidoptera | | | |
| Psychodidae (*Psychoda* spp) | 403 | 424 | 0 |

| | Sites | | |
|---|---|---|---|
| **Taxa** | **Littoral** | **Sub-littoral** | **Profundal** |
| Oligochaeta | | | |
| Enchytridae (*Lumbriculus* spp) | 379 | 607 | 373 |
| Lumbriculidae (*Lumbriculus variegetus*) | 279 | 907 | 228 |
| Naididae (Nais) | 373 | 945 | 353 |
| Tubificidae | 139 | 130 | 219 |
| Cladocera | | | |
| Bosminidae (*Bosminia longirostris*) | | | |
| Nematoda | | | |
| Others | 124 | 113 | 0 |
| Total | 20,443 | 18,251 | 4,388 |

Diptera larvae (Chironomidae) were abundant in littoral, sub-littoral and profundal sites (11,816, 13,375 and 2,927 individuals/m$^2$, respectively), but had highest density in the sub-littoral zone. The difference in relative abundance (%) of each taxon of macrobenthos in littoral, sub-littoral and profundal zones is indicated in Fig. 2. In the littoral zone, Diptera (61.97%) and Ephemeroptera (15.47%) constituted about 80%, while in the sub-littoral zone, Diptera (76.52%) and Oligochaetae (14.05%) accounted for more than 80% of the total community. Dipterans such as Chironomidae, Ephydridae, Tabanidae and Tipulidae and Oligochaetes (Tubificidae, Lumbriculidae, Naidae and Enchytridae) were also dominant in the profundal region.

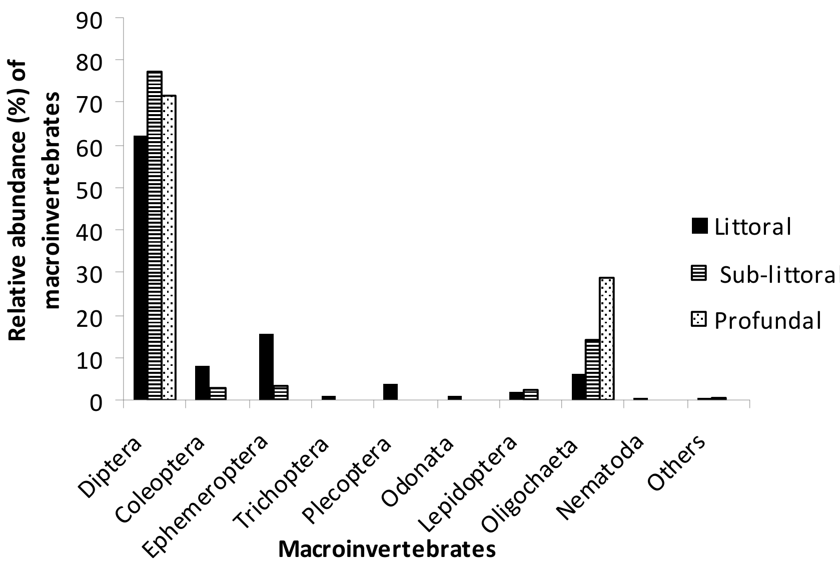


Fig. 2. Relative abundance (%) of benthic macro-invertebrate taxa in littoral, sub-littoral and profundal zones of Lake Kuriftu.

### Species diversity, richness and evenness

The species richness, evenness and Shannon diversity based on numbers per family for littoral, sub-littoral and profundal zones is presented in Table 5. Shannon index value of littoral zone was more than twice that of the sub-littoral and profundal sites, implying suitability of the habitat for macro-invertebrates. The littoral zone had the largest value of Shannon diversity index (H'=1.26) followed by the sub-littoral (H'=0.60) and the profundal (H'=0.58) zones. The highest species richness value also recorded in the littoral zone (d=2.72). Species richness values were 1.53 and 0.83 for the sub-littoral and profundal zones, respectively. Evenness values were highest in the littoral (0.38 vs 0.22 and 0.28 in sub-littoral and profundal zones), indicating that this habitat harboured high abundance of macro-invertebrates.

Table 5. Shannon diversity, richness and evenness indices of the three sampling sites (littoral, sub-littoral and profundal sites) of Lake Kuriftu.

| | **Sites** | | |
|---|---|---|---|
| **Index** | **Littoral** | **Sub-littoral** | **Profundal** |
| Shannon diversity (H') | 1.26 | 0.60 | 0.58 |
| Richness (d) | 2.72 | 1.53 | 0.83 |
| Evenness (J(e)) | 0.38 | 0.22 | 0.28 |

## DISCUSSION

The present study shows that Lake Kuriftu has high densities and high species richness of macro-invertebrates in the littoral zone. The pattern of species richness, diversity and density showed a decrease from littoral along the depth gradient. Smiljkov *et al*. (2008) also reported that the distribution and community structure of macrozoobenthos was determined by depth gradient both in quantitative and qualitative terms. Other studies have also reported higher richness and diversity of macro-invertebrates in the littoral and sub-littoral regions of a lake, where aquatic vegetation is present (Mistri *et al*., 2000; Hedgel and Kriwoken, 2001). Betael Assefa (2010) also reported similar result in Lake Hayq, Ethiopia. Scheffer *et al*. (1984) observed that vegetation pattern is the main factor determining the spatial distribution of macro-invertebrates. It was clearly seen that most benthic taxa of Lake Kuriftu were likely concentrated in littoral zone in association with the presence of macrophytes. The bottom of the macrophyte zone can therefore be considered as a site of good habitat for macro-invertebrates in Lake Kuriftu. The vegetation and substrate heterogeneity of the littoral habitat provide additional microhabitats not present in other lake regions.

The higher macro-invertebrate densities in the macrophytes zone is due to several factors. The littoral zone affords protection from fish and other predators which may increase the number and diversity of macro-invertebrates that live there (Ogutu-Ohwayo, 1993). Nichols and Allen (1981) reported that the presence of vegetation should lead to a reduced grain size of sediment texture and to an increased content of organic matter. Recent studies such as Findlay (2006) have shown that areas with concentrated plant growth have significantly higher levels of dissolved oxygen and support more aquatic fauna. Tilahun Kibret and Harrison (1989) also showed that littoral zone adjacent to the macrophyte zone of Lake Hawasa was rich in macro-invertebrates. Higher dissolved oxygen levels are able to support the more sensitive macro-invertebrates as well as the low-oxygen tolerant ones, producing a wider array of species. William and McClintock (1977) reported that changes in the species composition, diversity and density of macro-invertebrates were significantly related with the concentration of dissolved oxygen in deep lakes. However, in Lake Kuriftu, there was not such close relation between dissolved oxygen and benthic macro-invertebrates probably due to its shallowness and the lack of a stable thermocline. Lake Kuriftu has a maximum depth of less than 6 m, and it can mix continuously to its bottom and the mean dissolved oxygen at the profundal was never less than 6 mg/l. Therefore, macro-invertebrate abundance in Lake Kuriftu showed significant correlation with temperature and depth, but not with dissolved oxygen and organic matter. Possibly, rapid mineralization of the organic matter in the profundal precludes its use as food by macro-invertebrates in the bottom of this shallow lake.

The non-vegetated sub-littoral zone of Lake Kuriftu supported larvae of oxygen-sensitive macro-invertebrates such as Ephemeroptera and Plecoptera as well as the low-oxygen tolerant such as chironomids and oligochaetes producing a wider array of species, but the profundal (depth >3.28 m) supported fewer numbers and less diversity of benthic macro-invertebrates than littoral and sub-littoral zones. It is also noteworthy that despite the high oxygen level in the profundal (6.33 mg/l), oxygen-sensitive taxa such as the EPT were absent from this region in Lake Kuriftu. They were present only in small numbers in sub-littoral sites, with its slightly higher oxygen level (7.12 mg/l). This suggests that the usefulness of EPT macro-invertebrates as bio-indicators of absence of organic pollution and anoxia may be questionable in shallow lakes.

In the sub-littoral zone, soil texture may be more important in determining macro-invertebrate community structure. The sandy clay sediment texture of the sub-littoral zone may be more favourable for colonization by some macro-invertebrate taxa compared with the muddy clay of the littoral and profundal zones. Macro-invertebrate assemblage is significantly affected by grain size, porosity and interstitial dimensions of the substrate, but rarely by the shape and surface roughness (Duan *et al*., 2008). The inclusion of taxa such as Coleoptera, Chironomidae, Lepidoptera and some EP in the sub-littoral zone may be associated with their use of the sandy substrate and high organic matter in the interstitial spaces (e.g. Lancaster and Hildrew, 1993). Numerous studies have shown that sediment texture is the primary environmental variable affecting the taxa richness and densities of macro-invertebrates (Wood and Armitage, 1997; Duan *et al*., 2008).

The profundal zone had higher organic matter in clay texture and was populated by Diptera and Oligochaeta, and no EPT were recovered in Lake Kuriftu. Here, the presence of flocculent clay sediments may change the suitability of the substrate for some taxa and favour dipterans and oligochaetes. For instance, Martin and Neely (2001) examined the effect of clay texture on macro-invertebrate communities and found that total invertebrate density, insect density, and number of insect families decreased significantly in sediment dominated by clay. Clay sediments increase macro-invertebrate drift and affect respiration and feeding activities by reducing the food value (Graham, 1990; Waters, 1995). Rapid oxidation of organic matter in the profundal region could reduce its food value in this shallow lake. On the other hand, according to Reice and Wohlenberg (1993), sediment organic matter tends to increase as the clay content increases, but in this study, both clay content and organic matter were not significantly different between the three sites.

In Lake Kuriftu, the fine sediment particles of clay texture may not favour the colonization of macro-invertebrates in the profundal region. The sticky nature and the low interstitial space of the clay texture may also deter their feeding activities and their abundance. The physical properties of substrate particles may be more important than their organic content. Some taxa such as the EPT were absent from the profundal zone more due to this reason rather than organic matter content, which was highest in the this zone. However, some macro-invertebrate taxa such as Chironomidae and Oligochaeta prefer the fine sediment texture or muddy clay due to their burrowing ability (Waters, 1995).

In conclusion, the benthic fauna in the shallow Lake Kuriftu displayed a distribution pattern governed mainly by vegetation cover and sediment texture. Some taxa such as Chironomidae and Oligochaeta were found in all three benthic regions. EPT were highest in littoral, limited in the sub-littoral and absent from the profundal zone, even though dissolved oxygen and organic matter were high in the profundal region. The sandy sediment texture was more important in the sub-littoral zone where large taxa such as Chironomidae, Coleoptera and some EP were recovered. Oligochaetes use the soft clay with higher organic matter and were recovered in larger numbers in the profundal, but they were present at all stations and depths. The pattern of distribution of macro-invertebrates in the shallow Lake Kuriftu suggests that macrophytes, temperature and sediment texture are the critical factors, but not dissolved oxygen and organic matter content. Therefore, the accepted norm of using EPT as indicators of good water quality with plenty of oxygen, and Chironomidae as indicators of anoxic conditions, needs to be re-evaluated when considering bio-assessment studies in shallow lakes.

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