ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

STUDY ON MACROINVBERTEBRATES ABUNDANCE AND COMMUNITY STRUCTURE OF LAKE KURIFTU, ETHIOPIA

A thesis presented to the School of Graduate Studies Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Science in Biology

By

Tujuba Ayele

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DECLARATION

I, the undersigned, hereby declare that this thesis is my original work, has not been presented for a degree in any other University and all source of materials used for the study have been duly acknowledged.

Name: Tujuba Ayele

Signature: ________________

Place: Addis Ababa University

Date of Submission____________

This work has been presented with my approval as supervisor.

Name: Seyoum Mengistou (PhD)

Signature: ________________

Date: ________________

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ABSTRACT

The aim of the study was to investigate the abundance, diversity and community structure of macrobenthos in relation to some environmental variables. Benthic macroinvertebrates of Lake Kuriftu were sampled on a monthly basis from September 2009 to February 2010. Ekman grab (0.0225m^2) samples were obtained from three stations. Organic matter content of the bottom sediment was determined by loss on ignition method. Benthic macroinbvertebrates were identified and their distribution was reported in relation to depth, bottom substrate, organic matter content, dissolved oxygen and macrophytes. Bottom samples of the lake contained larvae of insects, Oligochaetes, and Nematodes. In this study a total of 20443, 18251, and 4388 ind/m^{2}of benthic macroinvertebrates were collected from littoral, profundal and benthic regions, respectively. Diptera larvae were the most abundant benthic macroinvertebrate in littoral, profundal and benthic regions with mean abundance of 12545, 14003 and 3215 ind/m^2, respectively. Chironomidae larvae were highly abundant in profundal region. Ephemeroptera and Oligochaetaes were also numerous in littoral and profundal zones. Diptrea larvae and Oligochaetes were consistently found in the sediment at all depths. The abundance of benthic macroinvertebrates was correlated with temperature and depth. Bottom substrates from benthic and littoral were clay in texture and sandy clay in profundal region. The result shows that vegetated littoral regions of the lake bottom had similar and higher organic matter content than the bottom of the non-vegetated regions (profundal and benthic). The littoral region had highest diversity (H = 1.26) and richness (d=2.72) and benthic community density20443 ind/m^2. In Lake Kuriftu Benthic fauna were concentrated in the littoral region in association with macrophytes. The profundal region is also colonized by numerous macroinvertebrates probably due to suitability of the bottom substrate. The overall variation in benthic mcroinvertebrates abundance and community structure in Lake Kuriftu were due to the slight variation of physic-chemical and sedement quality.

KEY WORDS: Benthic macroinvertebrates, Kuriftu, Littoral, Macrophytes, Profundal

1. INTRODUCTION

Freshwater ecosystems are important habitats for different organisms ranging from microorganisms (bacteria, fungi, and protozoan), micro and macroinvertebrates, large vertebrate fauna such as fish species and fish larvae, and other vertebrates. They support a diverse range of flora and fauna, which provide a variety of habitat at range of depths. This favors a diversified species to live in the ecosystem because of the different habitats present within the water body. For instance, littoral macrophytic zone is rich in taxon diversity of macroinvertaberates which vary with the type of vegetation type and substratum (Smart *et al.,* 1999). Benthic macroinverteberates are organisms that live on or inside the deposit at the bottom of a water body (Barnes and Hughes, 1988; Idowu and Ugwumba, 2005) which constitute the main food items of most fish species in lake especially the juveniles, therefore, forming an important trophic link. They are widespread in their distribution and can live on all bottom types, even on manmade objects. The invertebrate fauna of freshwater ecosystems consist largely of oligochaetas, chironomides, mollusks, nematodes and other insect larvae. These invertebrates are adapted to colonize different zones of lakes and streams. Some of them colonize near shore associated with emerged and submerged macrophytes, while others are limited to the bottom mud. The bottom or benthic sediment of lakes incorporates the entire habitat in contact with land, barring the shallow vegetated shore areas. The benthic region is capable of hosting a large number of organisms, as nutrient and mineral rich sediments are available as food source. These bottom dwelling invertebrates are key components of the lake ecosystem, and their community characteristics are comprehensive indicators of water quality, especially of nutrient status of lakes (Chen, 2008).

Many species of benthos are able to move around and expand their distribution by drifting with currents to a new location during the aquatic phase of their life or by flying to a new stream during their terrestrial phase. These organisms play a vital role in the circulation and recirculation of nutrients in aquatic ecosystems. They also constitute the link between the unavailable nutrients in detritus and useful protein materials in fin fish and shellfish. Most benthic organisms feed on debris that settle on the bottom of the water and in turn serve as food for a wide range of fishes (Oke, 1990; Idowu and Ugwumba, 2005). Benthic macroinvertebrates are an important component in the freshwater biotic community. Boyd (1970) reported that macrobenthos are involved in the mineralization and recycling of organic matter produced in the open water, or that brought in from external sources, and important in linking trophic sequence of aquatic communities. They also accelerate the breakdown of decaying organic matter into simpler inorganic forms such as phosphates and nitrates (Gallep *et al*., 1978). All forms of aquatic plants, which are the first link of several food chains existing in aquatic environment, can utilize the nutrients. These organisms, therefore, form a major linkage in the food chain as most of fishes, birds and mammals depend directly or indirectly on the benthos for their food supply (Barnes and Hughes, 1988).

According to Mwebaza-Ndawula (1990) benthos enhances primary production and release nutrients in the lake, thus contributing in the recycling of energy. The source of energy for organisms in littoral region of lakes is the sun, but it does not penetrate deep into bottom of lakes. Thus, organic matter from higher up in the water column that drifts down to the depths becomes the energy source for the benthos. The dead and decaying organic matter at bottom supports the benthic food chain. According to Gophen *et al.* (1983), many benthic insect larvae are major food source for demersal fish and also serve as indicators of environmental disturbances.

The macrobenthos fauna inhabiting benthic sediment plays an important role in releasing nutrients to the overlying water column through disturbance and perturbation of the bottom layer. They have also significant role in aquatic ecosystem in mineralization process, mixing of sediments and flux of oxygen into sediments, cycling of organic matter and in effort to assess the quality of inland water (Khan *et al*., 2007). The amounts of nutrients released by the sediments depend on the mineralizing capacity of the benthic community. Benthic invertebrates such as oligochaetes and chironomids serve as useful bio-indicators of environmental perturbations and ecosystem health. They have been used as bioassay organisms to monitor pollution levels in waters. Accordingly, the study of macroinvertebrate fauna is crucial as they foresee changes of the ecosystem.

Benthic fauna are extremely diverse and represented by nearly all phyla from protozoans through large macroinvertebrates and vertebrates (Wetzel, 1983). The benthic fauna of lakes constitute an extremely diverse assemblage, containing representatives of almost every major group of animals living in fresh water (Hutchinson, 1993). Most littoral species show associations with allochthonous input or substrate heterogeneity provided by external inputs or incoming streams (Ramsey and White, 2007). The physical structure, organic matter deposition, depth and substrate composition also appear to be the primary factors structuring benthic fauna (waters, 1995). The benthic invertebrate fauna of freshwater ecosystems are primarily composed of aquatic insects, crustaceans, mollusks and other invertebrate taxa. The insect fauna consists of Odonata (dragonflies and damselflies), Ephemeroptera (mayflies), Plecoptera (stoneflies), Megaloptera (alderflies and dobsonflies), Coleoptera (beetles), Trichoptera (caddisflies), occasionally Lepidoptera (moths) and Diptera (true flies). Crustaceans (including amphipods, isopods, and crayfish) are also important component of benthic diversity that can also be found in small streams. Microcrustaceans such as Cladocerans, Ostracods, and Copepods also constitute the diversity. Other common invertebrates found in freshwater include nematodes, oligochaetes, turbellarians, and mollusks such as snails, limpets and finger-nail clams. The present study was intended to describe species composition, abundance and community structure of benthic macroinvertebrates in association with some physico-chemical factors that govern their distribution, and not with habitat or ecological quality.

Benthic macroinvertebrates composition, distribution, and abundance appear to be regulated by both abiotic and biotic factors (Dumnicka and Galas, 2006).The distribution of the diverse benthic macroinvertebrate fauna within lakes and streams is extremely heterogeneous, in part a product of variable requirements for feeding, growth and reproduction. The requirements are strongly influenced by changes in the substratum and overlying water column of oxygen content, temperature, and inputs of living and dead organic matter (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 bottom-dwelling (benthic) organisms in freshwater even for those biota that spend some of their life cycle in planktonic form. Water level fluctuation also affect indirectly 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). In this study, type of aquatic vegetations, substrate (bottom) texture, dissolved oxygen, temperature and organic matter content were studied to determine distribution, species composition and abundance of benthic macroinvertebrates.

The macroinvertebrate communities form crucial links in the transfer of energy from primary producers and detritus to fish, and fish biomass and production have been correlated with macroinvertebrate biomass and production (Richardson *et al*., 2002). The spatial distribution of freshwater macrinvertebrates has thus been the subject of many investigators, most of which have been carried out in the temperate regions. In temperate lakes the habitat use of the macroinvertebrates seems to be strongly influenced by vegetation characteristics, depth, and/or complexity of the substrate (Hansen *et al*., 1989). Substratum composition, complexity and particle size seem to be very important factors affecting the distribution, structure and composition of macroinvertebrate communities in temperate lakes and running waters (Grzybkowska and Witzak, 1990). Information on distribution and abundance of benthic macroinvertebrates in relation to abiotic factors (temperature, dissolved oxygen, pH and ionic concentration) and biotic factors (competitive abilities and predators) are available in the temperate regions of the world (Peterson, 1975; McAuliffe, 1984). However, there have been far fewer studies on tropical lakes. The spatial patterns of macroinvertebrates assemblages in tropical Africa are less understood compared with the temperate communities. In East Africa the knowledge of benthic macroinvertebrate communities is derived mainly from the studies on Lake Victoria and George. These include works related to colonization of artificial substrata, biomass, standing crop and spatial distribution (Burgis *et al.,* 1973; Greenwood, 1976; Mothersill *et al*., 1980).

Studies on benthos of lakes in Ethiopia are few, but these systems are often critical to local fisheries and water quality. Especially, studies on benthic macroinvertebrtes of freshwater are extremely scarce, even though Ethiopia has a considerable network of water resources comprising of lakes (many in the Rift-Valley basin), reservoirs, rivers and other small water bodies. For instance, Ethiopia has about 35 lakes and reservoirs covering a total area of about 7400 km^2 and rivers totaling more than 7000 km in length (Wood & Talling, 1988). The pioneer works on benthic macroinvertebrtes in Ethiopian lakes were that of two saline lakes, Shala and Abjata (Tudorancea and Harrison, 1988), and benthic and wed bed fauna of Lake Hawasa (Tilahun Kibret, 1989). A recent studies by Dereje Tewabe (2009) on Lake Tana; Betael Assafa (2010) on Lake Hayq have also investigated the distributrion and abundance of benthic macroinvertebrates. Benthic macroinvertebrate studies have not been yet done in most of Ethiopian lakes, streams and rivers except these carried out for assessment of pollution impact (eg. Baye Sitotaw, 2006). Seyoum Mengistou (2006) also revealed in his review that the study of invertebrates in Ethiopia has lagged behind. Even though benthic studies of lakes and rivers in Ethiopia were few, these systems are a lot critical to local fisheries and water quality. For instance, Ministry of Agriculture (MOA) cited in (Eshete Asseffa, 2009) reported that Ethiopia has a fish potential of 28000 tones in the lakes and reservoirs, and 23000 tones in the rivers. Since much of the production of these higher trophic levels depend on invertebrate production, more investigations are needed to be directed towards the role of benthic macroinvertebrate communities in freshwaters.

The Bishoftu crater lakes of Ethiopia have been the subject of a number of recent limnological studies. So far there were different physico-chemical and biological studies of the lakes by MSc. students from Addis Ababa University and other researchers from different institutes, but benthic macroinnvertebbrates were not considered. For instance, Brook Lemma *et al*. (2001) studied the interaction among Cladocerans and their response to fish predation in Lake Kuriftu using enclosure experiments. Zelalem Dessalegn (2007) also studied the temporal dynamics of biomass and primary production of phytoplankton in relation to some physico-chemical factors in the same lake and obtained phytoplankton biomass measured as *chlorophyll* '*a*' varied from 18.35 to 45.18 mg Chl *a* m^3 at the near-shore station and from 17.24 to 55.6 mg *Chl a* m^{-3} at the central station and photosynthetic production varied between 0.686 and 1.05 g O_2 m^{-2} h^{-1}. Girum Tamire (2006) studied zooplankton grazing rates in the same lake and found the mean grazing rates at the natural density of zooplankton was 59.3% per day during his study. Eshete Assefa (2009) also studied major zooplankton biomass and production in the lake. So far no study has been conducted on macroinvertebrates of the Bishoftu crater lakes of Ethiopia. Therefore, there is no scientific data, and the present study was the first of its type on benthic macroinvertebrate of Lake Kuriftu with regard to their species composition, abundance and community structure.

2. OBJECTIVES

2.1 General Objectives

The general objective of the research was to investigate benthic macroinvertebrate community structure in relation to some environmental variables and assess their role in food web of Lake Kuriftu.

2.2 Specific Objectives

- To describe abundance, species composition and community structure of macroinvertebrate fauna of Lake Kuriftu.
- To assess the relationship between factors such as sediment texture, organic matter content, dissolved oxygen and distribution of benthic macroinvertebrates
- To provide further base line data on the role of benthic macroinnvertebrates in food web of the lake.

2.3 Research Questions

The study attempted to answer the following questions: -

1. What types of benthic macroinvertebrates are present in Lake Kuriftu?
2. What is the abundance and community structure of macroinvertebrates in Lake Kuriftu?
3. What environmental factors govern distribution of benthic fauna in the lake?
4. What is the role of macroinvertebrates in the food web of Lake Kuriftu ecosystem?

3. DESCRIPTION OF THE STUDY AREA

Lake Kuriftu is one of the Bishoftu crater lakes located 47km southeast of Addis Ababa in Bishoftu town within the main rift valley. The lake is located at 8^0 47' North and $39^0$00' East, and found at an altitude of 1860m (Figure 1). It is an artificial lake formed by diverting and damming Belbela River, a tributary of Mojo into an empty crater depression some 40 years ago. The purpose was to introduce fish and to initiate small scale horticulture for the local people (Seifu Kebede *et al*., 2001). Conserving the water and introducing fish to the lake in order to provide supplementary protein to the surrounding population was other reasons for diverting the river (Brook Lemma *et al*., 2001). At present it is a well established shallow lake. The lake is fed by surface run-off and direct rainfall and has low salinity (0.26g/l) despite lacking any outlet **(**Zinabu Geberemariam *et al*., 2002). 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 was highly decreasing due to the obstruction of the supplying river for irrigation by locally organized farmers. The lake has an area of 0.4km^2 and maximum depth of 6 m. The bottom of the lake is covered predominantly with a blanket of gray muddy clay except the near shore sediments (personal observation). The littoral macrophytes present around the lake are Polygonaceae (*Persicaria senegalensis) and Cyperaceae (Cyperus alopecuroides* and other *Cyperus spp*). In some parts, the lake is surrounded by terrestrial macrophytes and plantations of 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. The other sides are bare and openly accessible to the local dwellers. Since the lake is partly exposed to human interference, there is a need for proper management plan for the lake.

The Lake morphometry and physico-chemical parameters (Table 1) were previously studied by other researchers such as Lamb (2001), Brook Lemma *et al.* (2001), Seifu Kebede *et al*. (2001), and Zinabu Geberemariam *et al*. (2002). In the past five years the different biological and chemical characteristics have been investigated by MSc. students from Addis Ababa University and other researchers. The Zooplankton community structure of Lake Kuriftu was not well described. However, Girum Tamire (2006) studied community structure (Table 2) and grazing rates. Eshete Aseffa (2009) described the zooplankton such as cyclopoid copepods (*Thermocyclops consmilis*) which accounted for about 71%, and others; 14% and 15%, rotifers and cladocerans, respectively. In his study he reported that the production estimates of the copepod *T. consmilis* and the rotifer *Brachionus calyciflorus* were 0.78mg DW day^{-1} and 180.38µg DW day^{-1}, respectively.

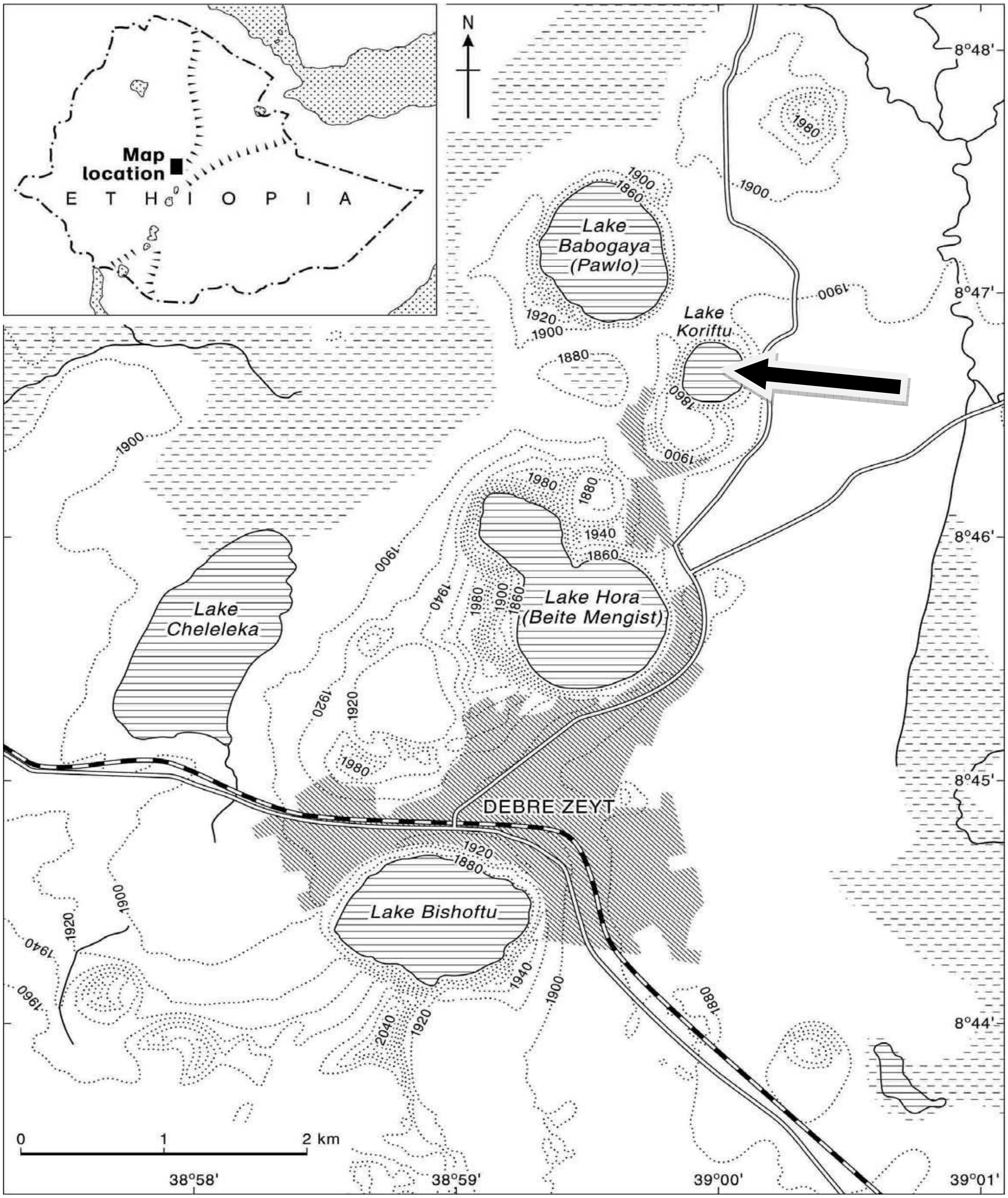

Figure 1. Map showing the location of Lake Kuriftu relative to Bishoftu crater lakes (After Lamb, 2001).

Table 1 Physco-chemical characterstics of Lake Kuriftu (After [a]Seifu Kebede *et al*., 2001; [b]Zinabu Geberemariam *et al*., 2002; [c]Brook Lemma *et al.*, 2001 and [d]Zelalem Desalegn 2007).

Parameters	Value
Altitude (m) [a]	1860
Area (km^2) [C]	0.4
Maximum depth (m) [C]	6
Mean depth (m) [d]	2
Volume (m^3) [c]	3.0×10^6
Secchi depth (m) [c]	0.15-0.20
pH [C]	7.9-8.4
Alkalinity (meq l^{-1})	2.3-3.1[d]
	2.89[b]
Conductivity, K25 ($\mu S\ cm^{-1}$) [b]	319
Salinity (gl^{-1}) [b]	0.26
Cations ((meq l^{-1}) [b]	3.187
Na^+ (meq l^{-1}) [b]	1
K^+ (meq l) [b]	0.154
Ca^{++}(meq l^{-1}) [b]	1.25
Mg^{++}(meq l^{-1}) [b]	0.783
Cl^- (meq l^{-1}) [b]	0.571

The fish and phytoplankton species found in the lake were not exhaustively reported. However *Oreochromis niloticus, Cyprinus carpio* and *Barbus* species were introduced to the lake, but only the first two species were known to establish in the lake (Tenalem Ayenew, 2009). According to Girum Tamire (2006), the phytoplankton species composition of the lake was mainly represented by colonial algae and filamentous cyanobacterial forms. Zelalem Desalegn (2007) identified 25 species of phytoplankton. On the other hand, Eshete Assefa (2009) identified 44 species of phytoplankton in his study of major zooplankton production in the Lake (Table 3). During this study, Lake kuriftu was teeming with blooms of algae (personal observation).

Table 2 Zooplankton taxa identified from Lake Kuriftu by Girum Tamire, (2006).

Copepods	Cladocera	Rotifera
Mesocyclops aequatorialis[a]	*Ceriodaphnia sp.*	*Asplanchna sp.*[a]
Thermocyclops consimilis [++]	*Diaphanosoma excisum*	*Brachionus bidentata*
	Moina micrura	*B. calycyflorus*
		B. caudatus
		B. falcatus[++]
		Filinia sp.[a]
		Karatella sp. [a]

[++] Dominant species; [a] rare

Table 3 List of the major phytoplankton species identified from Lake Kuriftu by Eshete Assefa, (2009).

Phytoplankton group	Species name
Cyanophyceae Cyanobacteria (Blue-green algae)	*Cylindrospermopsis africana* Kom. and Kaling *C. curvispora* M.Watanbe *C.curvispora* *Lyngbya circumcera* *Planktolyngebya tallingii* Kom. and Kaling *Planktolyngebya contorta* (Lemm.)Anagn. And Kom. *Microcystis aeruginosa* Rab. *Anabaena circinalis* Rab. *Anabaena nygaerdinom* *Psuedoanabaena sp*.
Chlorophyceae (Green algae)	*Pediastrum simplex* Meyen *P. duplex* Meyen *P.tetras* *Scenedesmus armatus* Chod. *S.acuminatus* *S.denticulatus* *S. dimorphus* (Turp.)Kutz. *S. quadricauda* (Turp).Breb. *S.bicudata* *Chlamydomonas reticula* *Coelestrum micropsporum* *C.acutum* *Phacotus lenticularis* (Ehr.) Stein *Monoraphidium minutum*
Bacillariophyceae (Diatoms)	*M.contoratum* *Pseodosphaerocystic lacustris* *P.angustus* *Tetrastrum netercanthium*

Table 2 continued on next page

Bacillariophyceae (Diatoms)	*Thalassiosira sp*. *Cymbella naviculiformis* Bacillariophyceae (Diatoms).*gracilis* Var Lunata *Navicula cryptocephala* Kutz. *Nitzschia vermicularis* (Kutz.)Grun. *N. rostellate* Synedra ulna
Dinophyceae (Dinoflagellates)	*Peridinium sp*.
Cryptophyceae (Cryptomonads)	*Cryptomonas obovata* Skuja *C.marssioni* *C.orata*
Euglenophyceae (Euglenoids)	*Phacus longicauda* (Ehr.) Duj. *P.tortus* *Lepocincilis sp.*

The water level of Lake Kuriftu fluctuates in relation to seasonal variability of rainfall and the volume of water increases during the rainy season. The area obtains relatively high rainfall during August and becomes minimal during October and February (Fig.2). Data from the National Meteorological Agency of Ethiopia shows that mean maximum temperature of the area during 2009-2010 was above 25^{o}C and the mean minimum temperature was below 15^{o}C (Fig. 3). Based on these data, the mean monthly rainfall ranges between 3.2-243.9 mm. There was no rain during February and October. The region around the lake is characterized by moderate rainfall, relatively high incident solar radiation and low relative humidity.

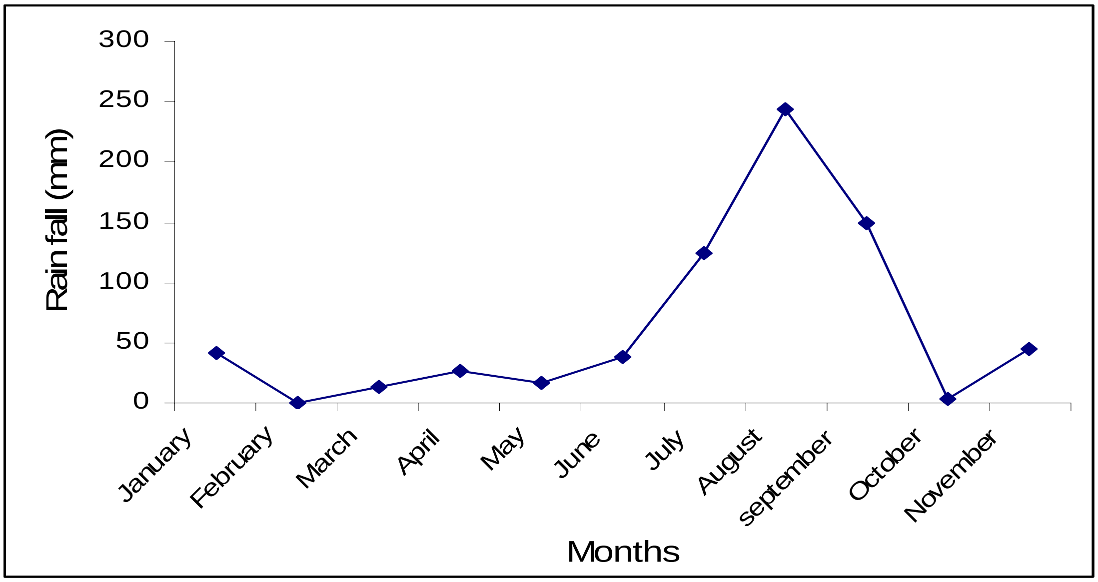

Figure 2. Mean monthly rainfall (mm) of the Lake Kuriftu area during the years 2009-2010 (Data from the National Metrological Agency of Ethiopia).

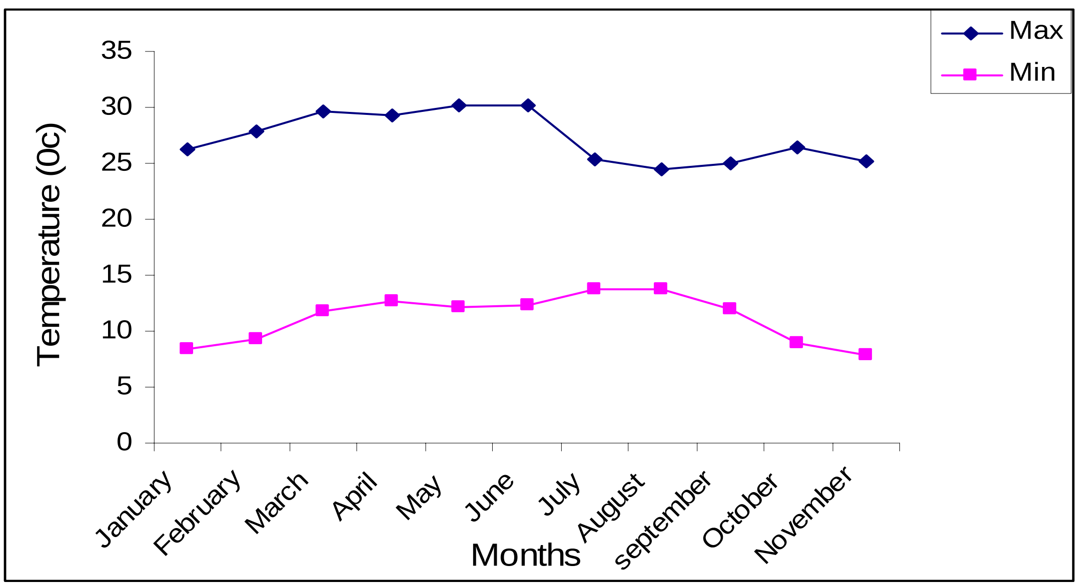

Figure 3. Mean maximum and mean minimum air temperature (^{0}C) of Lake Kuriftu area during the year 2009 (Data from the National Metrological Agency of Ethiopia).

4. MATERIALS AND METHODS

4.1 Environmental Parameters

4.1.1 Sediment texture

The sediment texture (grain size) was determined according to Bouyoucos hydrometer method. Three samples from different depths were taken to determine the particle size of the sediment. Sediment samples were taken to the National Soil Testing Center to determine texture. A hydrometer measures the density (g/l) of the suspension at the hydrometer's center 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 to settle out of suspension. Therefore, after two hours, it is assumed that only clay-sized particles (<0.002 mm) remain in suspension.

4.1.2 Organic matter analysis

Sediment grab samples for the determination of organic matter were taken at each sampling site using Ekman grab. The total organic matter of the bottom sediment was determined by loss on ignition (LOI) method (Tilahun Kibret and Harison, 1989). The aliquot of the bottom mud were dried in Philip Harris heat oven at 80^0C for 24 hours and incinerated in electric Fisher muffle furnace (Model 184A) at 550^0C for four hours. Sartorius analytic balance was used for weighing 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: -

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

where **DW** is the dried weight of the mud sample, **Ash w** is the weight of the burnt sample,and **LOI** is loss on ignition.

4.1.3 Temperature and Oxygen

Environmental parameters were measured *in situ* just above the sediment at each site. The water temperature (^{0}C) and dissolved oxygen (mg/l) were measured *in situ* using a digital oxygen meter (CO-411 model).

4.2 Macroinvertebrate sampling techniques

Sampling was carried at three stations each with three sampling sites from September 2009 to February 2010 (except November). The sampling stations include both near shore and open water sites. The selection of sampling stations was done systematically from three stations at different depths. The sampling covered some months of wet season and dry season. Samples were taken from each site using Ekman grab of 0.0225 m^2 area.

4.3 Benthic Macroinvertebrates identification and abundance

Macroinvertebrate samples were obtained from all sites at the three stations using Ekman grab (0.0225 m^2 area). Triplicate grabs were taken from each station. Samples were washed through sieve of mesh size 0.2mm to reduce the bulk, and organisms were sorted out alive and preserved in 5% formalin and transported to Limnology laboratory. Bigger organisms were sorted out against the white background of enamel dish and identified. Smaller ones were identified under a dissecting microscope. For detailed identification, a compound microscope was used. The macroinvertebrates were identified to the lowest taxonomic category possible with available key of Pinder (1978), Durand and Leveque (1981), and Bouchard (2004). The abundance of macroinvertebrates in a square meter area was calculated following Jhingran *et al.* (1989) as follows:

$$\mathbf{N = \frac{n}{A}}$$

where, N= Number of macro-invertebrates in a square meter; n= number of macro-invertebrates per sample, A = area of the Ekman grab in square meter ($0.0225m^2$).

4.4 Biological indices

The data gathered from monthly samples were pooled to furnish the values of 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).

4.5 Statistical analysis

For statistical analysis, SPSS-version 13.1 (Statistical Package for Social Sciences) was used. Data of the physico-chemical factors and macroinvertebrate abunndance were subjected to correlation. The macroinvertebrate taxa count of each family (species) were averaged and used to estimate the abundance of individual species in meter square. The dominance (%) of each of the major macroinvertebrate groups was calculated out of the total macroinvertebrates and demonstrated using simple bar graphs.

5. RESULTS

5.1 Sediment composition and texture

Particle size analysis showed that sediment sample from the littoral site was composed of three major particle size catagories (Table 4). Thus, the texture of the sediment was found to be clay at the littoral and benthic regions, and sandy clay at the profundal region (Table 4).

Table 4 Percentage composition of silt, sand, and clay in sediment samples of littoral, profundal and benthic sites from Lake Kuriftu.

	Sites		
Texture	Littoral	Profundal	Benthic
Silt	14	10	10
Sand	36	50	30
Clay	50	40	60
Sediment texture	Clay	Sandy Clay	Clay

5.2 Organic matter content of sediment

The dry organic matter content (Table 5) in sediment sampled from the littoral region ranged from 1.11 gm (7.38%) to 1.18 gm (9.81%). In this region the organic matter content was more or less similar during the study period. The dry organic matter content of profundal zone was between 0.67gm (5.58%) in September and 1.70gm (11.30%) in February. In benthic region, organic matter content exhibited an increment from 0.67gm (7.00%) in September to 1.86gm (12.40%) in February. The overall mean values of sediment organic matter content were 1.14gm (7.96%), 0.91gm (6.30%) and 1.19gm (8.44%) for littoral, profundal and benthic regions, respectively (Table 5). The mean values of organic matter content of littoral and benthic sites were more or less similar. In profundal region the organic matter obtained during February was almost double of that obtained in September.

Table 5 Monthly dry weight (gm) and percentage (in brackets) of organic matter of sediment samples at littoral, profundal and benthic sites of Lake Kuriftu.

	Sites		
Months	Littoral	Profundal	Benthic
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)
Grand Mean	1.14(7.60) $\pm$ 0.03	0.91(6.07)$\pm$ 0.41	1.19(7.93) $\pm$ 0.44

5.3 Temperature and Dissolved Oxygen

The dissolved oxygen and temperature at various depths of littoral, profundal and benthic 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 6. The mean dissolved oxygen recorded in the littoral region was 8.03mg/l at mean temperature of 23.49ºC. In profundal region, at mean depth of 1.88m and 23.02 ^{o}C dissolved oxygen was 7.12mg/l. Compared with the littoral region, there is little variation at profundal region. In littoral region, the greater mean value in dissolved oxygen was probably due to higher density of photosynthetic organisms. At mean depth of 3.28 and 22.47^{o}C, the dissolved oxygen in benthic region was 6.33mg/l. The small variation in oxygen level with depth was related with biological demand and the use of oxygen for decomposition of organic matter in deep water.

Table 6 Mean monthly temperature (T) and dissolved Oxygen (DO) at various depths (D in meter) of littoral, profundal and benthic sites of Lake Kuriftu.

	Sites								
	Littoral			Profundal			Benthic		
Month	D(m)	T (^{o}C)	DO (mg/l)	D(m)	T (^{o}C)	DO (mg/l)	D(m)	T (^{o}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

5.4 Benthic Macroinvertebrate

The list of benthic macroinvertebrates identified from littoral, profundal and benthic sites of Lake Kuriftu is presented in Table 7. Sediments from Lake Kuriftu contained insect (larvae), Oligochaetes and nematodes. Insect larvae were represented by Diptera, Ephemeroptera, Coleoptera, Trichoptera, Plecoptera, Odonata and Lepidoptera. Diptera larvae were represented by six families, Ephemeroptera, and Plecoptera were each represented by five families, and Coloptera was represented by Dryopidae, Dytiscidae and Hydrophilidae. The remaining Trichoptera, Odonata and Lepidoptera were each represented by one family. The families Enchytridae, Tubificidae, Naidae and Lumbriculidae were the Oligochaetes identified from the sediment samples. Mollusks were not observed during the study period. Thus, the benthic macroinvertebrate fauna of Lake Kuriftu was composed of 21 famlies of Insecta, four famlies of Oligochaetes and nematodes. In terms of family and genera, Diptera was the most diversified insect followed by Ephemeroptera and Plecoptera.

Benthic macroinvertebrates were highly dominant in the littoral regions in association with macrophytes such as Polygonaceae (*Persicaria senegalensis) and Cyperaceae (Cyperus alopecuroides* and others (*Cyperus spps*.).The profundal region is also rich in Diptera and olligochaete group while the benthic region is far less in benthic macroinvertebrates compared with littoral and profundal sites. In benthic region some macroinvertebrate groups such as Diptera (Chironomids, Ephydridae, Tabnidae and Tipulidae) and Oligochaetes were present.

5.4.1 Abundance and density

The estimated mean density of benthic macroinvertebrates in littoral, profundal, and benthic regions is presented in Table 7. The mean total densities of macrobenthos were 20443, 18251 and 4388 individuals/m^2 in littoral, profundal and benthic regions, respectively. The largest densities of macroinnvertebrate were obtained in the littoral region with the least in benthic region. Class Insecta accounted for the highest proportion of the abundance in littoral, profundal, and benthic regions than other macroinvertebrates, with an abundance of 18980, 15518 and 3215 individuals/m^2, respectively (Table 7). Diptera larvae were dominat with 11816, 13375 and 2927 individuals/m^2 in littoral, profundal and benthic regions. Both in profundal and benthic regions, Chironmidae were dominant followed by Oligochaetes. Oligochaetes were more abundant in the profundal (2590 individual/m^2) region than littoral (1265 individual/m^2) and benthic (1173 individual/m^2) regions. Nematodes were least abundant in the three sites while mollusks were not present. Macroinvertebrates such as Coleoptera, Ephemeroptera, Trichoptera, Plecoptera, Lipdoptera and Odonata larvae were not present in the benthic region. In Lake Kuriftu, the abundance of macroinvertebrates exhibit significant correlation with temperature and depth ($P<0.05$) but did not show significance with dissolved oxygen and organic matter content probably due to its shallowness.

Table 7 Abundance (total individual/m^2, n=15) of benthic macroinvertebrates in sediment samples from littoral, profundal and benthic zones of Lake Kuriftu. Each number is rounded to the nearest whole number.

	Sites		
Taxa	**Littoral**	**Profundal**	**Benthic**
Insecta	18980	15518	3215
Diptera	12545	14003	3215
Chironomidae (*Chironomus spps)*	11816	13375	2927
Macromidae	50	0	0
Culcidae	330	95	0
Ephydridae	44	36	27
Tabanidae	175	95	71
Tipulidae *(Tibula spps)*	124	403	190
Coloptera	1692	495	0
Dryopidae (*Helmis maugi* Bed)	767	59	0
Dytiscidae (*Lacophilluus spp)*	924	276	0
Hydrophilidae (*Hydrous piceus)*	0	160	0
Ephemeroptera	3215	533	0
Baetidae	2510	533	0
Baetis spp	960	225	0
Cloeon spp	1550	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 spps?)*	130	80	0
Trichoptera	154	0	0
Limnephilidae	154	0	0
Hesperophylax designatus	154	0	0
Plecoptera	817	63	0
Perlidae	204	27	0
Leuctridae *(Leuctra spp)*	299	0	0
Taenioptergidae	270	0	0
Taeniopteryx nibolusa (?)	270	0	0

Table 7 continues

Table 7 continued

Capnidae			
Allocapnia spp	44	36	0
Odonata	154	0	0
Platycnemidae (*Platycnemis pennipes)*	154	0	0
Lepidoptera	403	424	0
Psychodidae (*Psychoda spp*)	403	424	0
Oligochaeta	1265	2590	1173
Enchytridae *(Lumbriculus spp)*	379	607	373
Lumbriculidae *(Lumbriculus variegetus)*	279	907	228
Naididae (*Nais)*	373	945	353
Tubificidae	139	130	219
Cladocera	95	0	0
Bosminidae *(Bosminia* longirostris*)*	95	0	0
Nematoda	74	30	0
others	124	113	0
Total	20443	18251	4388

Diptera larvae (Chironomidae) were abundant in littoral, profundal, and benthic sites (11816, 13375 and 2927 individuals/ m^2, respectively), but highest in the profundal region. Ephemeroptera (3215 individuals/m^2) and Oligochaeta (1265 individuals/m^2) were the next abundant macroinvertebrates in littoral and profundal sites, respectively. The difference in relative abundance (%) of each taxon of macrobennthos in littoral, profundal and benthic regions is clearly depicted in Figure 4 and Figure 5. In littoral region, the dominant macroinvertebrates were Diptera (61.97%), Ephemeroptera (15.47%), Oligochaetae (6.09%), Plecoptera (3.96%), and Lepidoptera (1.94%). In profundal region, Diptera (76.52%), Oligochaetae (14.05%), Ephemeroptera (3.33%), Coleoptera (2.69%), and

Lipdoptera (2.30%). Dipterans such as Chironomidae, Ephydridae, Tabnidae and Tipulidae and Oligochaetes (Tubificidae, Lumbriculidae, Naidae and Enchytridae) were present in the benthic region.

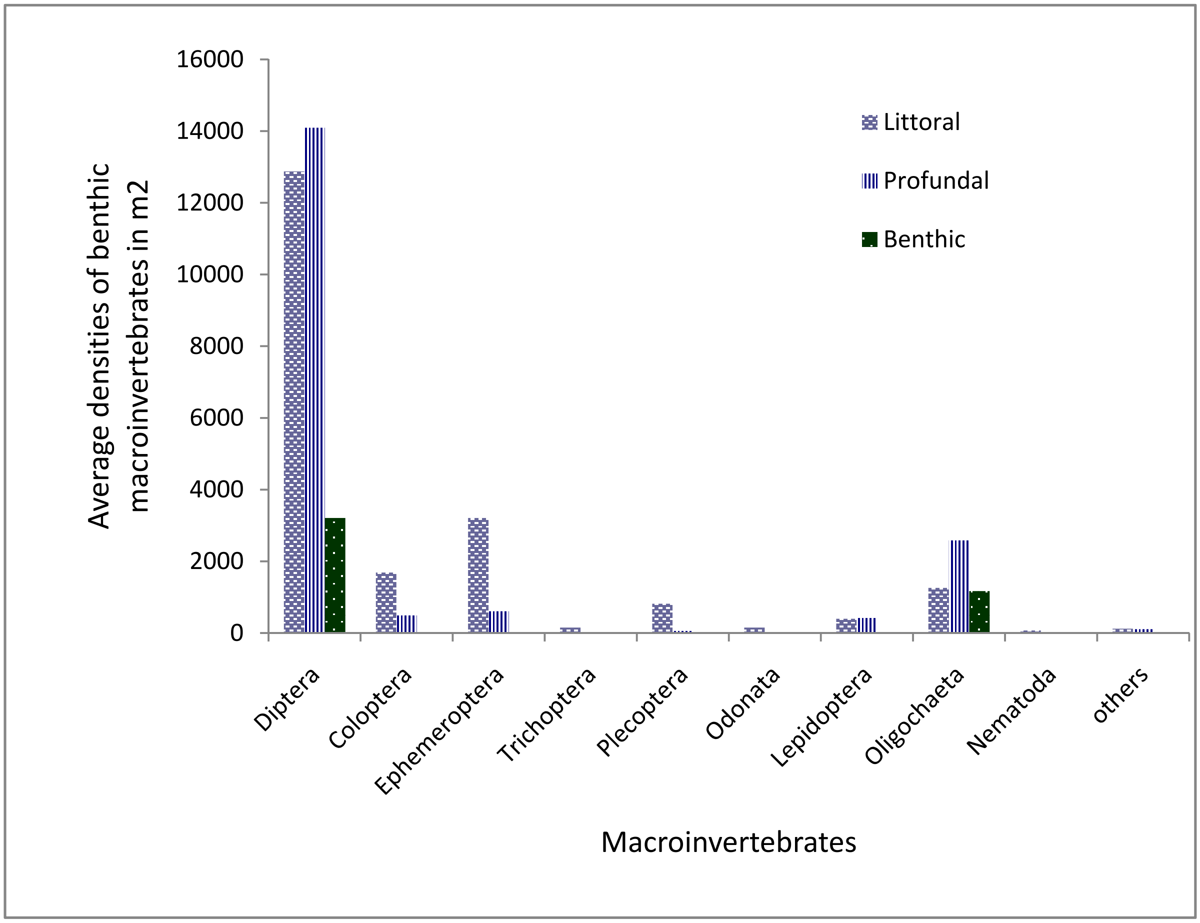

Figure 4. Average densities (individual/m^2) of benthic macroinvertebrate taxa at littoral, profundal and benthic sites of Lake Kuriftu.

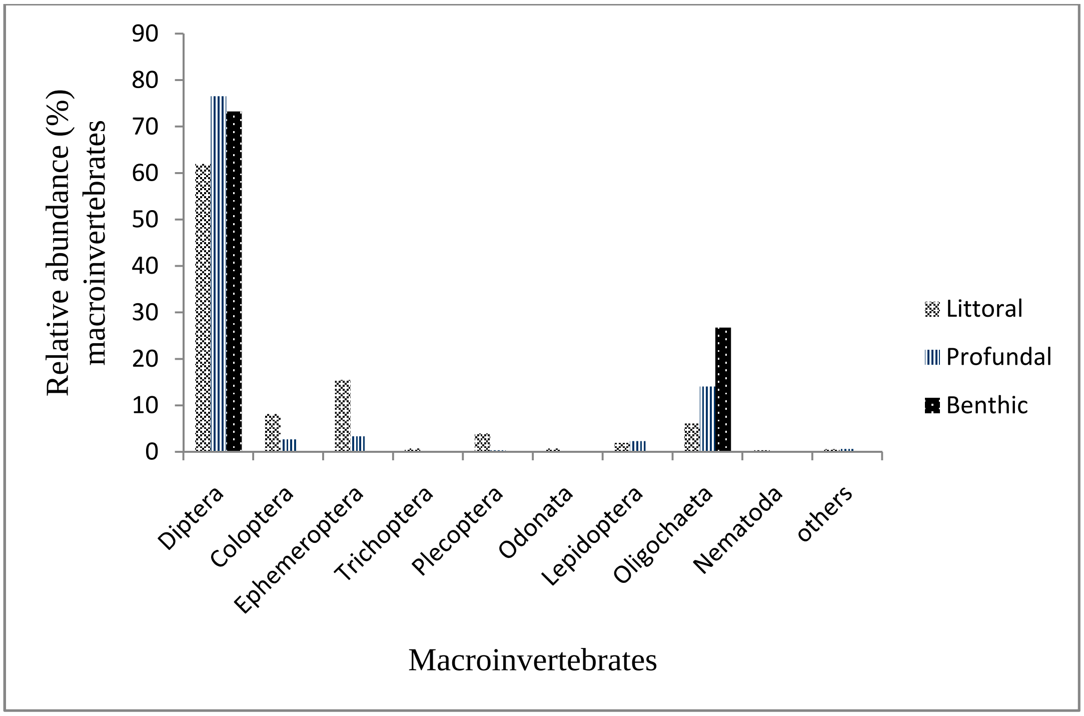

Figure 5. Relative abundance (%) of benthic macroinvertebrate taxa in littoral, profundal and benthic regions of Lake Kuriftu.

4.5.2 Species diversity, evenness and richness

Result of species richness, evenness and Shannon diversity for littoral, profundal and benthic regions of for Lake Kuriftu is presented in Table 8. Shannon index value of littoral region was more than twice that of the profundal and benthic sites, implying suitability of the habitat for macroinvertebrates. The littoral region had the largest value of Shannon diversity index (H’=1.26) followed by the profundal (H’=0.60) and the benthic (H’=0.58) regions. The highest species richness value also recorded in the littoral region (d= 2.72). Species richness values were 1.53 and 0.83 for the profundal and benthic regions, respectively. Evenness values were 0.38, 0.22 and 0.28 in littoral, profundal and benthic regions, respectively.

Table 8 Shannon diversity, richness and evenness indices of the three sampling sites (littoral, profundal and benthic sites) of Lake Kuriftu.

Index	Sites		
	littoral	profundal	benthic
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

5. DISCUSSION

The present study showed that Lake Kuriftu has high density and species richness of macroinvertebrates in the littoral region. The pattern of species richness and density showed a decrease from littoral along the depth gradient. In relation to depth profiles, species richness and diversity also showed decrease in abundance of macroinvertebrates community. Similarly, Smiljkov *et al* (2008) reported that the distribution and community structure of macrozoobenthos was determined by depth gradient both in quantitative and qualitative terms. In accordance with many studies (Mistri *et al*. 2000; Hedgel and Kriwoken, 2001) higher richness and diversity of macroinvertebrates are found in the littoral and sub-littoral regions of a lake, where aquatic vegetation was present. Betael Assefa (2010) also reported similar result in Lake Hayq. For most lakes, the number of benthic taxa is highest in the littoral zone and decreases as the depth increases (Salmoiraghi *et al.* 2001). The littoral habitat of lakes usually supports larger and more diverse populations of benthic invertebrates than do the sublittoral and profundal habitats. The vegetation and substrate heterogeneity of the littoral habitat provide an abundance of microhabitats occupied by a varied fauna, which in turn enhances invertebrate production. The littoral habitat is also highly variable due to seasonal influences, land use patterns, riparian variation, and direct climatic effects producing high-energy areas (Mandaville 2002). Similarly, in Lake Kuriftu, distribution of the benthic macroinvertebrates was high in littoral and showed decreasing trend in profundal and benthic regions along with depth. The littoral region was with the highest diversity and species richness of macroinvertebrates.

Recent study such as Findlay (2006) has shown that areas with concentrated plant growth have significantly higher levels of dissolved oxygen than areas without aquatic plants and supports more aquatic fauna. Tilahun Kibret and Harrison (1988) also showed that littoral region adjacent to the macrophyte zone of Lake Hawasa was rich in macroinvertebrates. Higher dissolved oxygen levels are able to support the more sensitive macroinvertebrates as well as the low-oxygen tolerant ones, producing a wider array of species. In deep lakes with hypoxia and anoxic conditions, dissolved oxygen is a major influence on the structure and low diversity of the benthic community (Muli, 2005). For instance, Willam and McClintock (1977) reported that changes in the species composition, diversity and density of macroinvertebbrates were significantly related with the concentration of dissolved oxygen. However, in Lake Kuriftu, there was not such close relation between dissolved oxygen and benthic macroinvertebrates probably due to its shallowness. Lake kuriftu has a maximum depth of less than 6m, so that it can mix continuously to its bottom and the mean dissolved oxygen at the bottom of benthic region was not less than 6mg/l. Macroinvertebrate abundance in Lake Kuriftu showed significant correlation with temperature and depth, but not with dissolved oxygen and organic matter due to its shallowness. The non-macrophytic profundal region of Lake Kuriftu supported larvae of sensitive macroinvertebrates such as Ephemeropetera and Plecoptera as well as the low-oxygen tolerant such as chironomids and oligochaetes producing a wider array of species, but the benthic region (mean depth of 3.28m) supported fewer numbers and less variety of benthic macroinvertebrates than littoral and profundal regions.

According to Scheffer *et al*. (1984), vegetation pattern is the main factor determining the spatial distribution of macroinvertebrates. In lakes, different vegetation types differed considerably in total faunal density. It was clearly seen that most benthic taxa of Lake Kuriftu were likely concentrated in littoral region in association with the presence of macrophytes. The bottom of macrophyte zone can therefore be considered as a site of good habitat for macroinvertebrates in Lake Kuriftu. The diversity and richness of macroinvertebrates was shown by diversity index. The littoral region had with higher diversity index indicating greater species diversity and richness when compared with the vegetation free region. In profundal region, the sandy clay sediment texture may be suitable for macroinvertebrates colonization compared with the muddy clay benthic region.

Numerous studies have shown that bottom substrate (sediment texture) is also the primary environmental variable affecting the taxa richness and density of macroinvertebrates (Wood and Armitage 1997; Duan *et al.* 2008). Macroinvertebrate assemblage is significantly affected by grain size, porosity and interstitial dimensions of the substrate, but rarely affected by the shape and surface roughness (Pauls *et al.* 2008). Parker (1989) also revealed substrate composition has an influence on detritus accumulation and macroinnvertebrate distribution and abundance. Patterns of organic matter deposition, depth and substrate composition appear to be factors structuring the macrobenthos (Ramsey and White 2007). In the benthic region of Lake Kuriftu, the presence of flocculant clay sediments may affect macroinvertebrates. Some researchers identified that the accumulation of fine sediments change the suitability of the substrate for some taxa, increase macroinvertebrate drift and affect respiration and feeding activities by reducing the food value (Culp *et al.*, 1986; Graham, 1990; Waters, 1995). Martin and Neely (2001) examined the effect of clay texture on macroinvertebrate communities. In this study, they found that total invertebrate density, insect density, and number of insect families decreased significantly in sediment dominated by clay. More specifically, densities of Coleoptera larvae, Diptera larvae, Odonata larvae, Pelecypoda, and Gastropoda were adversely affected. Densities of specific families such as the Diptera (larvae) and Coleoptera were also affected.

In Lake Kuriftu, the fine sediment particles of clay texture may overwhelm the colonization of macroinvertebrates in benthic region. The sticky nature and the low interstitial space of the clay texture may also deter their feeding activities and then their abundance. Macroinvertebrate taxa such as Chironomidae and Oligochaeta present frequently in fine sediment texture or muddy clay due to their burrowing ability (Waters, 1995). Research, which has examined invertebrate communities with respect to a broader range of particle sizes, supports that invertebrate communities differ with substratum type (Bazairi *et al.* 2003). These findings suggest that substrata of visually distinguishable size fractions do influence the functional composition of invertebrate communities. According to McLachlan (1970), the physical properties of substrate particles themselves are of considerable importance and may under certain circumstances be the primary factor affecting substrate selection of benthic macroinvertebrates. In Lake Kuriftu, the profundal region has a bottom of sandyclay texture and less organic matter content compared to benthic region of the lake. The overriding influence of substrate composition in the distribution and abundance of benthic fauna (McLachlan and McLachlan, 1971) can explain the significantly lower benthic densities in the macrophyte-free zone. The same was also true in the profundal and benthic regions of Lake Kuriftu.

Nichols and Allen (1981) reported the presence of vegetation should lead to a reduced grain size of sediment texture and to an increased content of organic matter. Distribution patterns of organic matter were influenced by factors such as vegetation, allochthonous inputs, particle sizes, and depth. Such factors were also used to determine habitat types. Similar distribution patterns of organic matter in response to these physical variables have been reported by others (Lancaster and Hildrew, 1993). According to Reice and Wohlenberg (1993), sediment organic matter tends to increase as the clay content increases. The bonds between surface of clay particles and organic matter slow down the decomposition process and sediments with higher clay content increases the potential for aggregate formation and macroaggregates physically protect the organic matter molecules from further mineralization caused by microbial attack. In Lake Kuriftu, at the littoral and benthic regions the bottom texture was found to be clay. Organic matter content was also found to be higher and almost similar at the bottom of the vegetated regions with weak positive correlation with macroinvertebrate abundance.

There were also differences in the density and relative abundance of macroinvertebrates among the regions. The differences may be reflected due to protection from predators afforded by the various macrophytes. Some studies in temperate lakes have linked fish predation to the structure, distribution and abundance of macroinvertebrates assemblages (Ogutu-Ohwayo, 1993; Schofield and Chapman 1999). Macroinvertebrates in the littoral region are far less utilized by juvenile fish compared with non-macrophytic region (Schofield and Chapman 1999). Numerically, Chironomids, Ephemeroptera, and Oligochaetes were dominant taxon in littoral and profundal region which may reflect an abundance of suitable habitats in Lake Kuriftu. In benthic region far less abundance of macroinvertebrates taxon may be related to non suitability of the bottom substratum and exposure to predation.   Some macroinvertebrates such as mollusks were absent in Lake Kuriftu. This is probably related to the physical and chemical characterstics of the lake. For example, Tudorancea and Harrison (1988) reported the absence of some macroinvertebrates and mollusks in highly saline lakes of Shala and Abjata. Tilahun Kibret (1989) reported that the absence of some mollusks from Lake Hawasa could be due to high content of sodium bicarbonate and conductivity (>860μScm^{-1}). Leveque *et al.* (1983) also found all mollusks disappeared from the bottom of Lake Chad when conductivities rose above 750μScm^{-1}. Mullusks were probably unable to colonize Lake Kuriftu due to its low salinity (0.26g/l) and conductivity, which is 319μScm^{-1}(Zinabu Gebremariam, 2002).

Benthic macroinvertebrates are highly diversified in their functional feeding group (Merritt and Cummins 1996). They facilitate energy flow from primary producers to secondary consumers and are very important prey for several fish species (Peter 1970). Benthic invertebrate communities serve as food source for some adult fish species and almost all-juvenile fish in lakes. Hence, they are important in trophic interactions and transfer of energy in aquatic environments (Horne and Goldman, 1994). They also link the aquatic and terrestrial ecosystems and source of food supply for both aquatic and terrestrial vertebrate consumers (e.g., fishes, turtles, and birds). The role of macroinvertebrates in the food web of Lake Kuriftu was not dealt in the present study. However, it gives baseline information for further investigation.

6. CONCLUSION AND RECOMENDATIONS

Based on the findings of the present study, the following conclusions and recommendations are forwarded.

Conclusions:

- In Lake Kuriftu, the dominant benthic macroinvertebrate were the Diptera (Chironomidae) at all the sampling regions. Chironomidae succeed in the littoral, profundal and benthic regions of Lake Kuriftu.
- In the littoral region of Lake Kuriftu, larvae of Diptera, Ephemeroptera, Coleoptera, Oligochaeta and Plecoptera were found to be dominant. In profundal and benthic regions some larvae of Diptera and oligochaetes were present.
- The presence of macrophytes and organic matter provided the right conditions for higher diversity and species richness of macroinvertebrates in the littoral region than profundal and benthic regions.
- Diptera larvae and Oligochaetes can tolerate large gradient of depth and oxygen concentration, thus they are able to live in littoral, profundal and benthic zones. However, Lake Kuriftu is shallow lake and does not experience prominent physico-chemical gradient with depth.
- The sediment texture is also another important factor in determining macroinvertebrate community structure and abundance. The texture of bottom substrate of Lake Kuriftu was found to be clay in littoral and benthic regions, and sandy clay in profundal.

- The diversity index showed that both macroinvertebrate species diversity and richness were high in littoral region and decrease with depth. In Lake Kuriftu, abundance and community structure of macroinvertebrates was related to macrophytes, temperature, and depth.

Recommendations:

- The present study on macroinvertebrates in Lake Kuriftu covered only some months of wet and dry seasons. Further, a whole year study is required to investigate the seasonality of benthic macroinvertebrates abundance and species composition in the lake.
- In Lake Kuriftu, the role of benthic macroinvertebrates in food web and production are also crucial to estimate the fishery potential of the lake.
- The absence of some macroinvertebrates such as mollusks in Lake Kuriftu also needs detailed study while present in the nearby lakes such as Hora and Babogaya.
- In general, baseline benthos study is important for monitoring of the biological and population parameters of Lake Kuriftu in order to provide accurate and updated information relevant for the Lake Ecosystem management and sustainable use.

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8. APPENDICES

Appendix 1. Depth, Temperature and Oxygen Data of three stations during sampling periods

Station one

Months	Sites								
	Littoral			Profundal			Benthic		
	Depth (m)	T (^{0}C)	DO (mg/l)	Depth (m)	T (^{0}C)	DO (mg/l)	Depth (m)	T (^{0}C)	DO (mg/l)
September	0.30	26.50	6.27	1.50	25.70	6.02	2.50	25.10	5.82
October	0.20	23.8	8.50	1.65	22.80	8.10	2.80	22.70	7.60
December	0.35	21.4	8.20	1.60	21.30	8.12	3.80	20.60	5.70
January	0.28	22.8	8.12	1.60	22.60	7.90	3.60	21.80	5.80
February	0.25	23.60	8.24	1.55	23.40	7.80	2.70	23.30	7.40

Station two

Months	Site								
	Littoral			Profundal			Benthic		
	Depth (m)	T (^{0}C)	DO (g/l)	Depth (m)	T (^{0}C)	DO (g/l)	Depth (m)	T (^{0}C)	DO (g/l)
September	0.25	26.30	7.40	1.20	26.10	6.91	2.0	25.40	5.67
October	0.32	24.0	8.40	1.35	23.60	7.60	3.85	21.80	6.70
December	0.20	20.70	8.21	2.70	20.30	5.87	3.65	19.80	4.67
January	0.10	22.40	8.32	1.40	22.12	6.40	3.5	21.80	6.30
February	0.10	23.50	8.42	1.80	23.30	6.55	3.1	23.30	5.60

Station three

Months	Site								
	Littoral			Profundal			Benthic		
	Depth (m)	T (^{0}C)	DO (mg/l)	Depth (m)	T (^{0}C)	DO (mg/l)	Depth (m)	T (^{0}C)	DO (mg/l)
September	0.45	23.90	8.90	1.80	23.70	8.70	3.80	23.4	8.70
October	0.40	24.0	9.20	1.80	23.80	7.60	3.80	23.7	7.00
December	0.30	22.60	6.50	2.80	20.50	6.25	3.65	20.2	5.80
January	0.10	22.70	8.60	2.65	22.12	6.22	3.25	21.8	5.60
February	0.10	24.20	7.12	2.80	24.0	6.80	3.20	22.4	6.56

Appendix 2. Averege density and abundance of benthic macroinvertebrates (n=15, ind/m^2) from littoral, profundal and benthic sites of Lake Kuriftu.

Taxa	Sites								
	Littoral			Profundal			Benthic		
	Total	Av	Id/m2	Total	Av	Id/m2	Total	Av	Id/m2
Diptera	**4234**	**282.27**	**12545.18**	**4726**	**315.06**	**14002.96**	**1085**	**72.33**	**3214.81**
Chironomidae (*Chironomus spp)*	**3988**	**265.87**	**11816.30**	**4514**	**300.93**	**13374.8**	**988**	**65.87**	**2927.41**
Macromidae	**17**	**1.13**	**50.37**	**0**	**0**	**0**	**0**	**0**	**0**
Culcidae	**113**	**7.53**	**334.81**	**32**	**2.14**	**95.11**	**0**	**0**	**0**
Ephydridae	**15**	**1**	**44.44**	**12**	**0.8**	**35.56**	**9**	**0.6**	**26.67**
Tabnidae	**59**	**3.93**	**174.81**	**32**	**2.13**	**94.81**	**24**	**1.6**	**71.11**
Tipulidae *(Tibula spp)*	**42**	**2.8**	**124.44**	**136**	**9.07**	**402.96**	**64**	**4.27**	**189.63**
Coloptera	**571**	**38.07**	**1691.85**	**167**	**11.13**	**494.81**	**0**	**0**	**0**
Dryopidae (*Helmis maugi* Bed)	**259**	**17.27**	**767.4**	**20**	**1.33**	**59.26**	**0**	**0**	**0**
Dytiscidae (*Lacophilluus spp)*	**312**	**20.8**	**924.44**	**93**	**6.2**	**275.56**	**0**	**0**	**0**
Hydrophilidae (*Hydrous piceus)*	**0**	**0**	**0**	**54**	**3.6**	**160**	**0**	**0**	**0**
Ephemeroptera	**1004**	**66.93**	**2974.81**	**180**	**12**	**533.34**	**0**	**0**	**0**
Baetidae	**847**	**56.47**	**2509.63**	**180**	**12**	**533.34**	**0**	**0**	**0**
Baetis spps	**324**	**21.6**	**960**	**76**	**5.07**	**225.19**	**0**	**0**	**0**
Cloeon spp	**523**	**34.87**	**1549.63**	**104**	**6.93**	**308.15**	**0**	**0**	**0**
Leptophlebiidae (*Leptophlebia spp)*	**27**	**1.8**	**80**	**0**	**0**	**0**	**0**	**0**	**0**
Ecdyonuridae	**81**	**5.4**	**240**	**0**	**0**	**0**	**0**	**0**	**0**
Heptagenia spps	**32**	**2.13**	**94.81**	**0**	**0**	**0**	**0**	**0**	**0**
Rhithrogena spp	**49**	**3.27**	**145.19**	**0**	**0**	**0**	**0**	**0**	**0**
Ephemeridae *(Ephemera vulgate)*	**5**	**0.33**	**14.81**	**0**	**0**	**0**	**0**	**0**	**0**
Sphlonuridae *(Sphlonurus spp)*	**44**	**2.93**	**130.37**	**27**	**1.8**	**80**	**0**	**0**	**0**
Trichoptera	**52**	**3.47**	**154.07**	**0**	**0**	**0**	**0**	**0**	**0**

Lemnephelidae	52	3.47	154.07	0	0	0	0	0	0
Hesperophylax designatus	52	3.47	154.07	0	0	0	0	0	0
Plecoptera	276	18.4	817.77	21	1.4	62.22	0	0	0
Perlidae	69	4.6	204.44	9	0.6	26.67	0	0	0
Leuctridae*(Leuctra spps)*	101	6.73	299.26	0	0	0	0	0	0
Taenioptergidae	91	6.07	269.63	0.8	35.56	0	0	0	0
Taeniopteryx nibolusa	91	6.07	269.63	0	0	0	0	0	0
Capnidae	15	1	44.44	12	0.8	35.56	0	0	0
Allocapnia spp	15	1	44.44	12	0.8	35.56	0	0	0
Odonata	52	3.47	154.07	0	0	0	0	0	0
Platycnemidae (*Platycnemis pennipes)*	52	3.47	154.07	0	0	0	0	0	0
Lepidoptera	136	9.07	402.96	143	9.53	423.7	0	0	0
Psychodidae (*Psychoda spp*)	136	9.07	402.96	143	9.53	423.7	0	0	0
Oligochaeta	427	28.47	1265.18	874	58.27	2589.63	396	26.4	1173.33
Enchytridae *(Lumbriculus spp)*	128	8.53	379.26	205	13.67	607.41	126	8.4	373.33
Lumbriculidae *(Lumbriculus variegetus)*	94	6.27	278.52	306	20.4	906.67	77	5.13	228.15
Bosminidae *(Bosminia longirotis)*	32	2.13	94.81	0	0	0	0	0	0
Naidae (*Nais varbilis)*	126	8.4	373.33	319	21.27	945.19	119	7.93	352.59
Tubificidae	47	3.13	139.26	44	2.93	130.37	74	4.93	219.26
Nematoda	25	1.67	74.07	10	0.67	29.62	0	0	0
others	42	2.8	124	38	2.53	112.59	0	0	0
Total	6819		20443.16	6159		18250.89	1481		4387.7