Ecological Assessment of Lake Hora, Ethiopia, Using Benthic and Weed-bed Fauna

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ABSTRACT

Urbanization and human settlement in close proximity to the Ethiopian lakes are among the potential causes of changes in water quality and quantity. The drastic changes occurred into one of the Bishoftu crater lakes (Kilole) best exemplify this phenomenon. The purpose of this study was ecological assessment of Lake Hora using benthic and weed-bed fauna. Samples of benthic and weed-bed were collected monthly from September 2009 to March 2010 at 3 sampling stations (A, B, C), with a standard Ekman grab. Station A is in front of Ras Hotel, Station B is place of Irecha and station C was to the south crater of the lake. The benthic and weed-bed fauna of Lake Hora included a total of 6958 individuals within 27 taxa belonging principally to Copepod (2812) and Chironomidae (1460) and Ecdyonuridae (735). A high number of organisms were observed mainly at stations B and A (3198 and 2342respectively). The correlation result indicates that oxygen showed strong relation to benthic and weed bed fauna distribution and abundance. There were high number of individuals, taxa diversity, evenness and grate number of rare taxa of benthic and weed-bed fauna at stations A and B, but these stations were affected by the community around the lake area for different reasons (for example washing clothes, boat parking and others).However low density and abundance of macroinvertabrates at station C could be due to: low organic matter load at station C which was free of human interactions; steeply slope geographical setting of the profoundly and its catchment and low vegetation cover. The Family Biotic Index result for all the sampling stations was 7.55, according to Hilsenhoff Family Biotic Index this value is indicating likely severe organic pollution and very poor water quality in all sampling sites. As this research finding indicates Lake Hora needs protection management strategies to maintain its sustainable use.

Key words: Benthic Fauna, Ethiopia, Lake Hora, Specimens, Weed-bed.

1. INTRODUCTION

Urbanization and human settlement in close proximity to the Ethiopian lakes are among the potential causes of changes in water quality and quantity. The drastic changes occurred into one of the Bishoftu crater lakes (Kilole) best exemplify this phenomenon (Prosser et al., 1968). Most of the fast-growing towns, like Zwai, Awassa, and Arbaminch, are in the neighborhood of the rift-valley lakes, and the Bishoftu crater lakes are in the vicinity of the flourishing city of Debre-Zeit. Diversion of the inflows for irrigation purposes and flushing from deforested and heavily grazed catchment may also have contributed to the decrease in the water level and the increase in the concentrations of ions (Zinabu Gebre-Mariam and Elias Dadebo, 1989). Although the changes in salinity can take place due to evapotranspiration and solute inputs, the intensity of the human activity in their catchments must have contributed to the contrasting trends in their salinity.

At the present day, most of the biological method for lake monitoring is based on their trophic level definition through analyses of nutrient concentrations and/or pelagic primary producers or through analyses of consumer communities (Oligochaeta, Diptera Chironomidae, and Fishes) whose characteristics are then considered as a trophic level result (Saether, 1979; Wiederholm, 1980). Measurement of ecosystem health using functional attributes of benthic invertebrates is generally in the development stage in Africa and Ethiopia.

In Ethiopia and to larger extent the whole of Africa, the use of macroinvertebrate characteristics for assessment and monitoring of lake conditions is less common. However, a South Africa Scoring System for rapid bioassessment of water quality in rivers is being used in a National Biomonitoring Programme in South Africa (Dallas, 1997). In Ethiopia also Baye Sitotaw (2006) has done research on the Assessment of Benthic-Macroinvertabrate structure in relation to Environmental Degradation in some Ethiopian Rivers. So far some studies have been conducted on the lakes of Ethiopia, for example; Tilahun Kibret and Harrison (1989) assessed Lake Awasa using benthic and weed-bed fauna. However no study was done in crater lakes of Ethiopia using macroinvertabrates as an assessment method. The purpose of this project was, therefore, to do ecological assessment of Lake Hora using benthic and weed-bed fauna. General objective of this study was to assess ecological quality of Lake Hora using the distribution, composition and abundance of benthic fauna in relation to the type of bottom sediment organic pollution and vegetation. Specific Objectives of this project were to determine the relations of benthic and weed bed fauna to the physico-chemical limnology of the lake; to assess the distribution of benthic fauna in relation to aquatic macrophytes, sediment texture and total organic matter; assess ecological integrity of the lake using Hilsenhoff Family Biotic Index (H-FBI) and diversity indices.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

Lake Hora is a small (1.03 Km^2) lake and it is a double crater with a maximum depth (in meters) of 38 (North crater) and 31 (South crater) and a mean depth of 17.5 m (Fig 1). Like all the other volcanic crater lakes in this area, Hora is a closed system, surrounded by very steep and rocky hills and cliffs. Mohr (1961), estimated the age of LakeHora along with other Bishoftu crater lakes as early Holocene (≈ 7000 years). The catchment of the lake is formed from volcanic rocks of basalt, rhyolite and tuff. Some morphometric and physico-chemical features of the present study lake are given in Table 1.

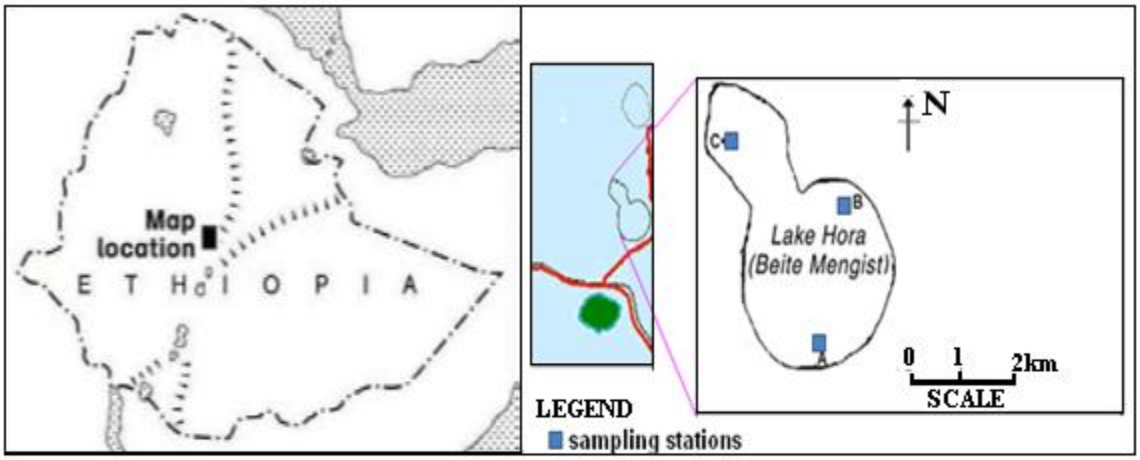

Figure1. Lake Hora with sampling sites (enlarged image) and other related lakes.

The sample stations selected for this study were: In front of Ras hotel (station A), around Irecha place (Traditional celebration of Oromo culture) (station B) and Hora ilmo the South crater of the lake (station C). These sites were chosen to represent the littoral and profundal and benthic zones of the lake and also sites that were impacted by human activities (A and B) and station C was relatively free from human influence.

The phytoplankton community is dominated by the colonial cyanobacterium *Microcystis aeruginosa* (Kütz) (Wood and Tallinig, 1988). The zooplankton community of Lake Hora includes the rotifers *Asplanchna sieboldi* Leydig, *Brachionus calyciflorus* Pallas, *and B. dimidiatus* Bryce, *B. urceolaris* Müller and *Hexarthra jenkinae* de Beauchamp (Tamiru Gebre, 2006). The Lake supports a piscifauna, which is exclusively composed of Tilapia (*Oreocromis niloticus L*) although not much fishing is done (Baxter and Wood, 1965).

2.2. Benthic and Weed-bed Fauna Sampling Processing and Identification

Samples of benthic and weed-bed were collected monthly from September 2009 to March 2010 at 3 sampling stations (A, B, C). Stations A and B has wide macrophyte zone and weed bed area with littoral and sub-littoral zones as compared to station C. Station C has sloppy hillside not accessible for human interference and less nutrient input from the catchments.

Table1. Some limnological features of Lake Hora (Source: Chemical data from Baxter, 2002; Morphometric data from Prosser et al., 1968).

Parameters	***Measured values***
Surface area (Km^2)	1.03
Maximum depth (m)	38
Mean Depth (m)	17.5
Volume (km^3)	0.018
Conductivity ($\mu S\ cm^{-1}$)	2350
Salinity ($g\ l^{-1}$)	2.57
Alkalinity ($meq\ l^{-1}$)	26.5
$_pH$	9.2
NO_3-N ($\mu g\ l^{-1}$)	10 – 20*
PO_4–P ($\mu g\ l^{-1}$)	16.86 - 69.50*
SiO_2 ($mg\ l^{-1}$)	17.48 to 46.96*
Sum of cations ($meq\ l^{-1}$)	29.5
Sum of anions ($meq\ l^{-1}$)	32.9
Na^+ ($meq\ l^{-1}$)	23.9
Cl^- ($meq\ l^{-1}$)	5.7
Chlorophyll " a"($\mu g\ l^{-1}$)	19.1 - 47.6*
* Abebaw Wondie (2007) for a central station	

Stations A and B were faced with human disturbance and station C was free from human interaction. Because station A is in front of Ras Hotel, local people use it for entertainment (refreshment), fishing and boat parking purposes. Station B is place of Irecha (place of traditional Oromo people celebration). Stations (A and B) were not free from human interference and the lake gets nutrients from these two stations. Samples were taken from each station and date at 3 depths (0-1m, 1-3m and 3-5m), which means that to the one meter depth it is littoral, 1-3 meter depth sub-littoral and after that it is benthic. However station C was very steep and had no sub-littoral zone, so this site was sampled only at 2 sampling depths (0-1m, 4-11m). Samples were taken with 3 replicates at each sampling point. Weed-bed samples were taken using hand net, that hand net has 3meters longer, so we were capable of getting samples up to 3 meter depth and the mesh size of the hand net was less than 80micrometer. Bottom samples and benthic fauna were sampled with a standard Ekman grab, (15cm x 15cm) area and sub sampling method was used. Samples were transferred to the plastic bags and preserved immediately in 5% formalin and then washed in a nitex net with 0.20mm mesh. A compound microscope was used for detail identification.

The benthic and weed bed fauna was identified in the laboratory to the family level using different keys from literature (Michael, 2006). Macrophytes of the three stations were identified at Addis Ababa University National Herbarium.

2.3. Biological parameters

Biological parameter of Lake Hora was assessed by using different diversity indices (Species Richness, Simpson's Index of Diversity (D), Shannon Weaver Index (Shannon and Weaver, 1963), Evenness index and Hilsenhoff Family Biotic Index (H-FBI).

2.4. Physicochemical Parameters

In situ measurements of temperature and dissolved oxygen were made in the field with oxygen-temperature probe (model Co-411) on each sampling date. Total organic matter in the sediment was determined by drying the mud in a drying oven at 80°C to constant weight; and then incinerated the dried samples in a muffle furnace at 500°C. The organic matter content of the samples was determined by loss of weight on ignition. The sediment texture (grain size) was determined according to Bouyoucos hydrometer method. A hydrometer measures the density in (g/l) of the suspension at the hydrometer's center of buoyancy Bouyoucos (1936).

2.4. Data Analysis

Data collected for the environmental parameters and benthic macroinvertebrates were subjected to statistical analysis using Analysis of variance (ANOVA) and correlation to determine variations at stations and seasons and correlations between different factors and macroinvertebrates.

3. RESULTS AND DISCUSSION

3.1. Biological Parameters

3.1.1. Distribution of Benthic and Weed-bed Fauna in Relation to Stations' Water Depth and Sediments

Benthic and weed-bed fauna of Lake Hora included a total of 6958 specimens within 27 taxa belonging principally to Copepod (2812), Chironomidae (1460) and Ecdyonuridae (735). A high number of organisms were observed mainly at stations B and A (3198 and 2342respectively) and lower taxa numbers were observed at station C (1419). Taxa richness at the stations ranged from 15 (station, C) to 21 (station, B). Among the 28 families collected, 12 were common and the rest

16 were rare. The bathymetric distribution of taxa showed higher species richness in the weed-bed (0-3m) and it decreased as depth increased. In general, distribution and abundance of macroinvertabrates increase with substrate stability and the presence of organic detritus in stations of A and B.

Figure 2 shows recorded taxa common for the three stations. Most of the rare families were collected from stations A and B. Family Cyclopidae has recorded high number at stations B and C. At station A Chironomidae was the highest in number. Nertidae, Mesovelidae and Enchytraeidae were small in number at the three stations (A, B and C respectively). Stations A and B show similarity in their recorded families and 16 families were present in both of these stations.

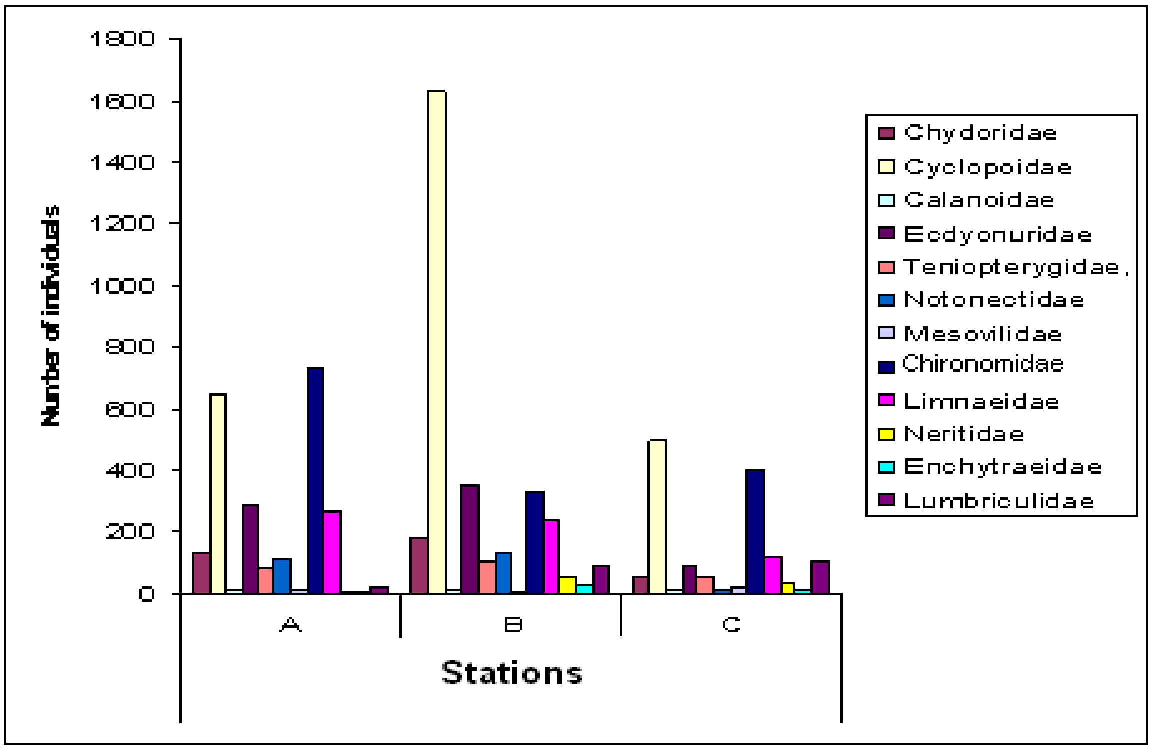

Figure 2. Common families for the three stations.

3.1.1.1. Benthic Fauna

11 families were collected from the benthic sediment and these had a mean total of 288 individuals. Table 2 lists the fauna of the bottom mud down to a depth of 3-11m the Ekman grab brought up a community consisting mainly of Lymnidae, Chironomidae and Lumbriculidae. Lymnidae were about 42.7% of this, most of them were *Myxas glitunosa* and a small number of

Lymnaea ovata. The Chironomids were about 31.6% and Lumbriculidae were about 14.8% of the total benthic fauna.

Table 2. BenthicFauna of Lake Hora.

Taxa list	***Mean No(n=5)***	***Standard Deviation***	***% Total***
Odonata			
Lestidae	1	±1.2	<0.1
Hemiptera			
Notonectidae	*	±0.8	<0.1
Mesovilidae	4	±8	1.4
Diptera			
Chironomidae	92	±109.27	31.6
Syphyridae	3	±5.2	1.03
Anisoptera			
Coruliidae	*	±0.4	<0.1
Gastropoda			
Lymnidae	124	±83.18	42.7
Neritidae	18	±14.65	6.24
Ancylidae	*	±0.4	<0.1
Oligochaeta			
Enchytraeidae	3	±2.7	1.03
Lumbriculidae	43	±43.55	14.80
Total mean	288	±269.37	100
Note: *= their total abundance is less than 5			

3.1.1.2. Weed-Bed Fauna

5522 organisms were identified from 25 families from the hand net samples making a mean of 1099 organisms per sample with standard error of 1325.68 (Table 3). Crustacean mainly Copepoda, were quantitatively predominant in all stations, followed by Chironomidae and Ecdyonuridae. Copepoda reached very high abundance at all stations B, A, C (1632, 647, 493 respectively) dominant species were *Cyclops sp.* typical Cyclopods of weed-bed zone.

3.1.2. Macrophytes

Typha latifolia and *Schoenoplectus carymbosus* were present in some areas in the shore sites of stations A and B. Station C was low in vegetation and only *Oxytenanthera abyssinica* was observed. There was water level fluctuation in the lake and macrophytes were reduced during dry season and also sub-littoral macrophytes were totally absent during March. Water level fluctuation was also shown to reduce the diversity or alter the composition of littoral habitats

(Baxter, 1977; Hutchinson, 1957), and affected the littoral food chain through the loss of macrophytes as a food resource (Hill et al., 1998; Wilcox and Meeker, 1991).

Table 3. Weed-bed fauna of Lake Hora.

Taxa list	***Mean No(n=5)***	***Standard Deviation***	***% Total***
Cladocera			
Chydoridae	72	±132.91	6.48
Copepod			
Cyclopoidae	554	±685.19	49.86
Calanoidae	8	±9.81	0.72
Ephemeroptera			
Ecdyonuridae	147	±132.38	13.23
Ephemeridae	*	±0.4	<0.1
Odonata			
Coenagriidae	*	±0.4	<0.1
Lestidae	2	±3.27	0.18
Plecoptera			
Isoperlidae	4	±8.8	0.36
Teniopterygidae,	49	±57.99	4.41
Hemiptera			
Notonectidae	51	±43.89	4.56
Mesoveliidae	4	±9.24	0.36
Trichoptera			
Rhyacophillidae	*	±0.4	<0.1
Hydroptilidae	*	±0.4	<0.1
Coleoptera			
Dytiscidae	1	±1.6	<0.1
Lycidae	*	±0.8	<0.1
Diptera			
Chironomidae	200	±226.33	18
Syphyridae	1	±2	<0.1
Stratiomyidae	*	±0.4	<0.1
Corethrellidae?	*	±0.4	<0.1
Anisoptera			
Taxa list	**Mean No (n=5)**	**Standard Deviation**	**% Total**
Gampidae?	*	±0.4	<0.1
Coruliidae	*	±0.4	<0.1
Gastropod			
Neritidae	1	±1.9	<0.1
Arachinda			<0.1
Argyronetidae?	*	±0.4	<0.1
Oligochaeta			
Enchytraeidae	5	±3.48	0.45
Lumbriculidae	1	±2.4	<0.1
Total mean	1099	±1325.688	100
Note: *= their total abundance is less than 5; ?=not confirmed			

3.2. Physicochemical Parameters

3.2.1. Temperature

Surface water temperature of the lake varied between stations from 21.3^{0}C (February) at station C to 26^{0}C (March) at station A and from 20^{0}C (February) at station B to 25.8^{0}C (September) at profundal waters of station A. Temperature of the lake decreased when we go deep from the littoral zone but sometimes higher temperature was recorded such as that for 25.8^{0}C September 2009 at station B of the profundal zone.

3.2.2. Dissolved Oxygen

There was high concentration of dissolved oxygen (16.7mg/l) (October) in the weed-bed and 15.3mg/l in the profundal. Concentration of dissolved oxygen decreased in December in the weed-bed and profundal (3.21mg/l and 3mg/l, respectively). As compared to stations A and B, station C was cooler in its water temperature but its dissolved oxygen content was not higher except in September. The concentration of oxygen was higher in October and lower in December, and it showed similarity during September, February and March.

3.2.3. Organic matter determination of the sediment

Analysis of sediment samples taken at various depths in Lake Hora show that the organic matter at the weed-bed ranged from 2.3% (March) of station C to 31% (March) at station B and at the profundal it ranged from 3.3% (March) at station C and 23% (March) of station A. Result of this study indicates that total organic matter content of the 3 stations increased from littoral to the profundal zone of the lake but sometimes higher organic matter content were recorded such as that for 23.5% during October, 2009 at station C of the profundal zone. And it showed monthly reduction from October to March with few exceptions of the three stations. Generally total organic matter content of station C was lower than A and B.

3.2.4. Sediment Texture Determination

The result obtained showed that sand dominated across the weed bed which revealed sandy loam texture. The profundal of the lake was loam soil. A loam soil is a mixture of sand, silt and clay that exhibits the properties of that separate in about equal proportions (Brady and Weil, 1999). Loam soils often contain a good amount of organic matter.

3.3. Ecological Integrity of Lake Hora in Relation to Diversity Indices and Hilsenhoff Family Biotic Index

3.3.1. Spatial diversity

Species-richness remained 15 at station C, 20 at station A and 21 at station B. It is clear that benthic and weed bed fauna richness are considerably higher at stations B and A, and this is believed to reflect the higher content of total organic matter at station B and A, coupled with quantitative increases in the levels of organic inputs.

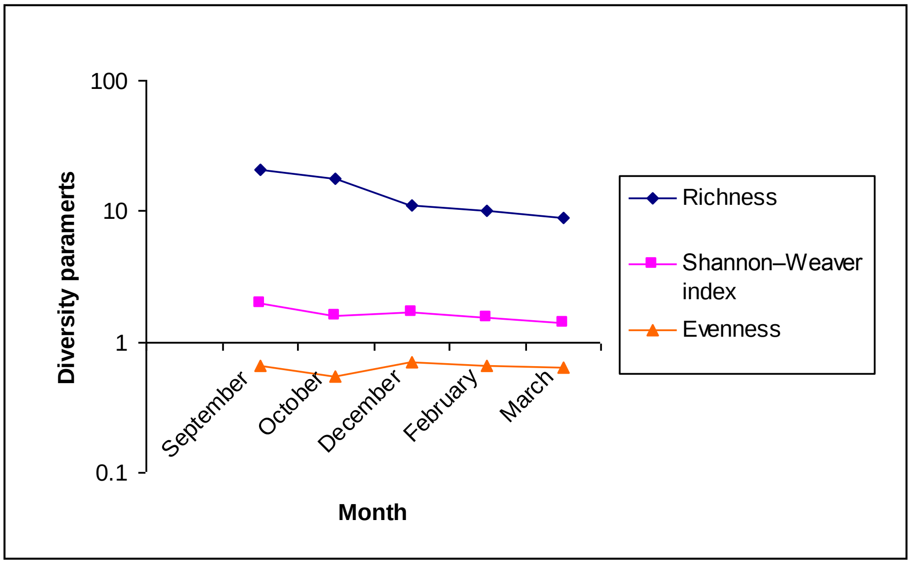

Figure 3. Monthly diversity indices of benthic and weed-bed fauna.

Table4. Correlation of macroinvertebrates to oxygen, temperature and total organic matter. (Disolvedo=disolved oxygen; Organicm=organic matter; Macroinv.=macroinvertebrates, Temp.=temprature).

		MACROINV.	TEMP.	DISOLVEDO	ORGANICM
MACROINV.	Pearson Correlation	1	.095	.707**	.376
	Sig. (2-tailed)		.737	.003	.167
	N	15	15	15	15
TEMP.	Pearson Correlation	.095	1	-.042	-.224
	Sig. (2-tailed)	.737		.882	.421
	N	15	15	15	15
DISOLVEDO	Pearson Correlation	.707**	-.042	1	.477
	Sig. (2-tailed)	.003	.882		.072
	N	15	15	15	15
ORGANICM	Pearson Correlation	.376	-.224	.477	1
	Sig. (2-tailed)	.167	.421	.072	
	N	15	15	15	15

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

3.3.2. Seasonal diversity

As figure 3 indicates, family richness was high in September (21) but it was reduced in March (9) and it varied between these months. Equitability of the recorded families was high in

December but it was lower in October. There were high number of benthic and weed-bed organisms in October (3835) and their number were reduced in March (638).

3.3.3. Hilsenhoff Family Biotic Index

This assessment was done by using Hilsenoff Family Biotic Index (Hilsenhoff, 1988).The FBI values of the 3 stations indicate that stations A and B were much poorer than that of station C. As a whole, the H-FBI value for all of the sampling stations was 7.55, indicating likely severe organic pollution and very poor water quality throughout the study area. The increasing H-FBI values found within the study area are a result of the increasing pollution tolerant Chironomids and their higher tolerance values.

3.4. Correlation between Macroinvertebrates and Physicochemical Parameters

Correlation between macroinvertebrates and temperature and total organic matter was insignificant ($P>0.05$).The correlation result (Table 4) indicates that oxygen showed strong relation to benthic and weed bed fauna distribution and abundence.

4. CONCLUSION

It has been shown that there are a number of hydromorphological and physicochemical alterations that may impair ecological status of lakes. As benthic invertebrates are much less mobile than fish, and exhibit a much higher dependence on littoral habitat types, shoreline developments would be expected to have considerably more severe impacts on invertebrate communities.

The benthic and weed bed fauna analysis of the 3 stations sampled showed that there was a difference in the distribution, diversity and abundance of benthic and weed bed invertebrates and these were much higher at stations A and B. The Family Biotic Index result indicates that the water quality at stations A and B, was of poor quality than that of station C, and also the whole lake water quality was very poor with an average H-FBI value of 7.55.

In Lake Hora, there were high number of individuals, taxa diversity, evenness and great number of rare taxa of benthic and weed bed fauna were recorded at stations of A and B and this were human influenced areas affected by the community around the lake area, used by different purposes (for example washing clothes, boat parking and others) these activities could; influence the benthos at stations A and B. However low density and abundance of macroinvertabrates at station C could be due to a)low organic matter load at station C which was free of human interactions, b) steep and slope geographical setting of the profundal and its catchment; and c) low vegetation cover.

In the future, functional measures of ecosystem health, such as chronic measures of toxicity or stress, should be incorporated into any assessment process in addition to using benthos for bio assessment purpose. Further investigation is needed to understand the distribution of littoral invertebrates and their relationship to nutrients and hydromorphological modifications. As this research result indicates Lake Hora needs protection to maintain its sustainable use.

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