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Spatial and Temporal Variations in the Diversity of Microalgae in Lake Hawassa, Ethiopia

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Abstract

Aquatic ecosystem consists large numbers of algal diversity. The aim of the present study is to explore the spatial and temporal variations of microalgae diversity in Lake Hawassa. 288 water samples in 45mL sterile glass bottles were collected from 14 sites during three seasons. All collected samples were preserved in 4% formalin solution and identified using inverted microscope. The result revealed that 63 microalgal species belonging to five classes, Chlorophyceae, Cyanophyceae, Bacillariophyta, Euglenophyceae and Cryptophyceae. The Chlorophyceae (46 %) members were dominant followed by Cyanophyceae (26.9 %) and Bacillariophyceae (23.81%) both spatially and temporally. Cylindrospermopsis(RA= 33.7%) and Microcystis aeruginosa(RA=21.2%), were abundant in all the sampling sites and seasons. These two species are primary toxin- producing cyanobacteria can have a negative impact on aquatic food webs and human use of freshwaters. However Chlorophyta are dominant it is indicators of good water quality. PH varied from 7.2-8.0; 8.5-9.3; and 7.1-7.8 during the winter, spring and summer seasons respectively. Annual mean transparency was 56.9-83.4 in all 3 seasons. In all three seasons high diversity index was recorded during spring season and lower diversity in winter season. There was a positive relation between water PH, transparency and species diversity during the study period.

Keywords: Microalgae, Spatial, Temporal, Diversity, Variation, Hawassa

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Introduction

The aquatic environments are subjected to high temporal and special variability. This is due to the abundance and microalgal species composition as a result of interaction between physical, chemical and biological variables. The causes explained not only by the equilibrium approach (which permits the coexistence of species limited by different resources), but also by the non-equilibrium approach (which accepts the frequency of environmental variability, allowing species that share the same resources to coexist (Connell, 1978). Spatial patterns in algal community structure often relate to changes in water chemistry (Crump et al., 2007; Fierer et al., 2007). Lake Hawasa was investigated extensively during the 1980s and early 1990s. Phytoplankton biomass and primary production in relation to nutrients and light were studied during this time (Kifle and Belay, 1990 and Kebede and Belay, 1994) and some dominant phytoplankton species were identified including Lyngbya nyassae Schmidle, 1902, Botryococcus braunii Kützing, 1849 and Microcystis species. Previous studies were carried out to show temporal and spatial variations of phytoplankton primary production in lake Hawassa (Kifle, 1985). Microalgae are dominant among microorganism in aquatic habitats with sufficient nutrients and light available. They are one of the major primary producers in freshwater aquatic ecosystems such as rivers, lakes, ponds and canals[1] (Anahas et al., 2013 and Muthukumar et al., 2007). Microalgal species composition and growth of species are useful indicators of nutrient enrichment (Dynes et al., 2006). They are widely used in biotechnological applications mainly for bioremediation, nutriceutical and pharmaceutical purposes, as well as for bioenergy production (Barra et al., 2014). Microalgal species are capable of synthesizing all amino acids; they can also be a source of the high protein content (Sankaran and Thiruneelagandan, 2015). They also help as maintenance of nutrient recycling, trophic structures balance and most importantly harbours diverse floral communities in the ecosystem. The green algae play an important role acting as primary producers (Dhyani et al., 2007).

Most developing countries depend heavily on the resources provided by lakes and these resources are found among in very poor rural communities whose livelihood depends on their exploitation because most lakes are important natural resources with diverse ecological, economical and aesthetic significance (IUCN, 1996). Among all the African countries Ethiopia is quite unique due to its geographic conditions, rich water resources, extensive green fields, varied animal husbandry and overall, diversity of flora and fauna (Shonga, 2015). In Ethiopia, the major lakes that are of ecological and economic importance are concentrated in the Rift Valley (IBC, 2010). These lakes include the southern lakes (Abaya, Chamo, Chew Bahr and small portion of Turkana), the central lakes (Hawassa, Shalla, Abijata, Langano, Ziway, Cheleleka /Abaya) and man-made Lake Koka)) and the saline Northern lakes (Beseka, Afdera, Asale and Abbe). There are also crater lakes such as the high plateau Bishoftu group (Lake Hora, Arenguade, Bishoftu, Kiloles and Pawlo) and Lake Chitu in the Rift valley (Tesfaye, 2011). Rift valley lakes gifted with many beautiful lakes, numerous hot springs, warm and pleasant climate and a variety of wildlife. These lakes considered as one of the most ideal areas for the development of international tourism in Ethiopia and anybody can be relaxing sports for fishing. Nile perch, catfish, tilapia and tiger fish can be fished in these lakes. Lake Hawasa is located in the vicinity of the growing city of Hawasa, and some of the many potential adverse effects facing the lake include lack of proper sewage treatment system, poor land-use management and high levels of recreational activity. Moreover, the nearby Hawasa Textile Factory drains its effluent into the lake, apparently with little treatment (Gebremariam and Desta, 2002). An experiment made by Gebremariam and Desta (2002) showed that the effluent from the Hawassa textile factory contains relatively high concentrations of heavy metals and other trace elements of toxic nature as well as major ions and plant nutrients which ends up in the Lake Hawassa, will bring about eutrophication to the lake. Runoff from the eastern wall of the caldera feeds another small lake called Lake Cheleleka(fig.1) Overflow from Lake Cheleleka drains into Lake Hawassa through the Tikur-Wuha River, which is the only major affluent river (Sai, 2014). Lake Hawasa has long been exposed to anthropogenic threats including over-fishing, irrigation, deforestation, overgrazing and indiscriminate use of pesticides and fertilizers in their catchment areas for the last 15–20 years (Tenalem, 2004). Lake Hawassa has an important nature value, as it provides habitat for a diverse avifauna and an important population of hippopotamus. The lake also has an important touristic potential and is a popular resort for local and foreign visitors. The lake is also crucial for the subsistence of the local communities as it is an important fishing ground, including commercial species such as Nile tilapia, Oreochromis niloticus; African catfish, Clarias gariepinus and Labeobarbus species. According to Shonga, (2015) there is large variety of species related to phytoplankton scattered in Lake Hawassa and Lake Abaya. Lake Hawassa is actual and potential sources of food and income for local communities. Furthermore, their range of variations in morphometric characterization and physical and chemical features offers opportunities for outstanding comparative limnological studies. Microalgal diversity and physico- chemical characterstics of the lake information is important to understand the factor influencing rise, fall and change in algal population and to study the effect of anthropogenic (environmental pollution or pollutant originating from human activities) pressure upon aquatic habitats of the lake (Round, 1981). Certain groups of phytoplankton, especially blue green algae can degrade recreational value of surface waters and in higher densities can cause deoxygenating of water and diatoms are good indicators of water quality (Whitton, 2000).

Microalgae biodiversity of water bodies has been studied by several workers in Ethiopia (Shrivastava et al., 2014). However, there is limited knowledge on the microalgal diversity of the middle rift valley soda lakes of Ethiopia. The general objective of this research was to study spatial and temporal variation in microalgal diversity in Lake Hawassa.

Material And Methods

Study area description

Lake Hawassa is an endorheic basin, located in the main Ethiopian Rift valley and situated 275 km away from the capital city Addis Ababa towards the south near the city of Hawassa, the capital city of southern province (SNNPR) (figure 1)

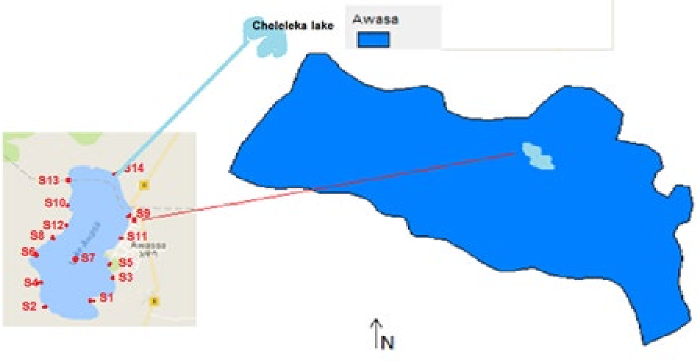


Figure1: Map showing location of Lake Hawassa (station 1- station 14)

(S1=Hospital site, S2= hospital opposite, S3=Fish selling/Amoragedel, S4= Fish selling/Amoragedel opposite, S5= Lewi resort, S6= Lewi resort opposite, S7= center, S8= center opposite, S9=Haile resort, S10= Haile resort opposite, S11= Fiker Hayq, S12= Fiker Hayq opposite, S13= human and animal intervention area and S14=Tikur Wuha)

The lake has 16 kilometers length, 9 kilometers width and it has a mean depth of 11 meters and is located at 7° 3′0′′N and 38° 26′0′′• E at an elevation of 1,708 m a.s.l. It is a terminal lake with no surface out flow and receives surface inflow through Tikur Wuha River (LFDP, 1997). Lake Hawassa is the most studied of the Rift Valley lakes in Ethiopia because it is relatively accessible to scientists (University of Waterloo website, 2006).

Study design and Sample size

Stratified random sampling design was conducted in Lake Hawassa of Ethiopia in winter, spring and summer seasons at 2017G.C to assess temporal and spatial variability in the diversity of microalgae. 288 water samples from 14 sampling stations and three seasons were collected from Lake Hawassa (fig. 1). Geographical parameter data like longitude, latitude and altitude are the most important steps in identifying the sampling locations for proper sampling. Physico chemical Parameter Measurements such as water pH was measured in situ using a portable pH meter. Water transparency was measured using a white color Secchi disc of 20 cm diameter. Altitude was measured using portable GPS (Gpsmap 64s/GARMIN).

Sampling and Identification

Sampling was done using sterile glass bottles starting from site one to fourteen in offshore by considering depth and representativeness of the sample for the sites. The fresh water sample was fixed with 1ml of 4% of formaldehyde solution (purchased from a local pharmacy). Then the mixture was allowed to settle for 24 h. Later the supernatant was discarded and the settled part of the solution was transferred to 100ml black capped bottle (Hosmani, 2010). Finally samples were transported to the laboratory for identification of microalgal species. The preserved water samples were examined using inverted microscope (WILD M 40), at a magnification of x40. Species identification was done by placing six drops of water on a glass slide until no more new microalgae species found. The identification to genus or species level was made on the basis of various descriptors of microalgae (John et al., 2002; Janse et al., 2006; John and Robert, 2002 and Bellinger E, and Sigee D, 2010) .

Data Analysis

To evaluate the significance of spatial and temporal variations of microalgae, analyzed through one way analysis of variance (ANOVA) the SPSS version 20.0 was used. The abundance of the species were got by counting microalgae species observed using microscope(frequency of each species). Microalgal diversity was analyzed by calculating different diversity indices (DI)

Shannon Diversity Index (H)

The Shannon diversity index was calculated by following Odum(1969)

Diversity Index (H) = – Σ Pi In Pi, Where Pi = S / N

S = Number of individuals of one species

N = Total number of all individuals in the sample

In = Logarithm to base e

Similarly the Evenness Index (EH) was calculated by following Pielou (1967).

EH= H/Hmax,

Where H max is the maximum value of diversity: Hmax= (InS)

Results And Discussion

Seasonal and temporal variation of pH and transparency

In Lake Hawassa pH varied from 7.2-8.0; 8.5-9.3; and 7.1-7.8 during the winter, spring and summer seasons respectively (Table 1)

season	pH	Transparency	Altitude
Winter	7.2-8.0	8cm-77cm	1679m-1686m a.s.l
Spring	8.5-9.3	37cm-102cm	1682m-1686m a.s.l
Summer	7.1-7.8	32cm-71cm	1682m-1687m a.s.l

Table1: Seasonal variation of pH, transparency, altitude and GPS data during rainy, spring and dry seasons

PH values showed a seasonal trend of variation with higher values in spring then showed a slight reduction through winter and summer seasons. The highest pH values were recorded from lewi resort (S5) and Haile resort opposite (S10) during summer. According to Elizabeth and Amha (1994) the pH of surface water of lake Hawassa was slightly decreased from January to April. In all sites, transparency values were very high throughout the year; but also showed a seasonal trend of variation. In all three seasons, transparency was lowest in the winter season but was found to gradually rise in spring and summer seasons. Annual mean transparency was (56.9-83.4) in all three seasons. There were observed temporal fluctuations in water transparency at the station of Tikur Wuha (S14), which were slightly associated with the changes in the water level of the lake due to seasonal rainfall distribution pattern during the winter season. Water transparency were considerably lower at Tikur Wuha site in all seasons probably due to easy re-suspension of sediments/mud due to wind action and/or wading flamingo and other aquatic birds and also inflows of organic materials from rivers feeding the lake during winter season which may have contributed to low Secchi disc readings. Pearson and spearman Correlation between pH and transparency with season were significant at p <0.01(Annex 2). This observation is supported by Oduor (2000) who associated the high turbidity with the daily re-suspension of the sediments by the winds coupled with shallowness of lake. In contrast, the comparatively high Secchi disc readings recorded at the rest of sites were may be the sites had less influence of water inflow (no sediment/mud) of rivers and also less anthropogenic effect.

Spatial and temporal distribution of Microalgae

A total of 63 microalgal species belonging to five classes were identified at fourteen stations of the lake during the three seasons (winter, spring and summer) of the study period. Chlorophyceae was the most abundant microalgae with 29 species representing 46 %. The dominant (The species that predominates in a community) species of Chlorophyceae were Cosmarium sp (RA= 8.9%), Tetraedron sp (RA= 10.6%) and Chlamydomonas sp (RA= 10.5%). Cyanophyceae was the second most abundant group with 17 species representing 26.9 %. It was dominated by

Cylindrospermopsis sp (RA= 33.7%), Microcystis aeruginosa (RA=21.2%), Merismopedia sp (RA=13.6%) and Gloeocapsa sp (RA= 13.5%). Bacillariophyceae was the third abundant with 15 species (23.81%). The relative abundance of some species in this class was Synedra sp (26.2%), Cycotella sp (17.6%), Thallasoria sp (14%), Navicula sp (12.9%), Melisora sp (8.7%) and Nitzschia sp (5.4%). two species (3.17 %) in the division Euglenophyceae identified. relative abundance of the species were Phacus sp (90%) and Euglenopsis vorax (10%). Cryptomonas ovate was the only species in the group of Cryptophyta (1.59 %) identified. The dominance of Chlorophyta species was also observed by other researchers, Elizabeth and Amha (1994) and Sai (2014) in the same lake.

The temporal and spatial distributions of microalgae showed that Cylindrospermopsis and Microcystis aeruginosa were abundant in all the sampling sites and seasons (figure 2).

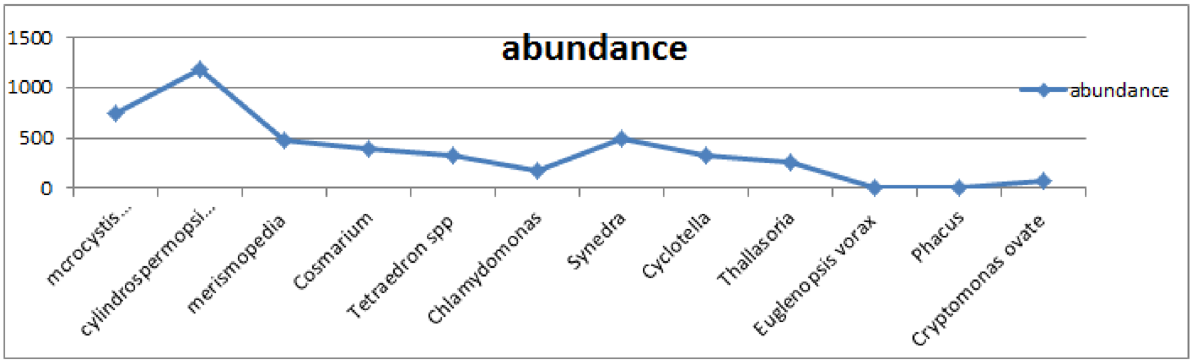


Figure 2: The temporal and spatial distributions of microalgae in all seasons and sampling stations

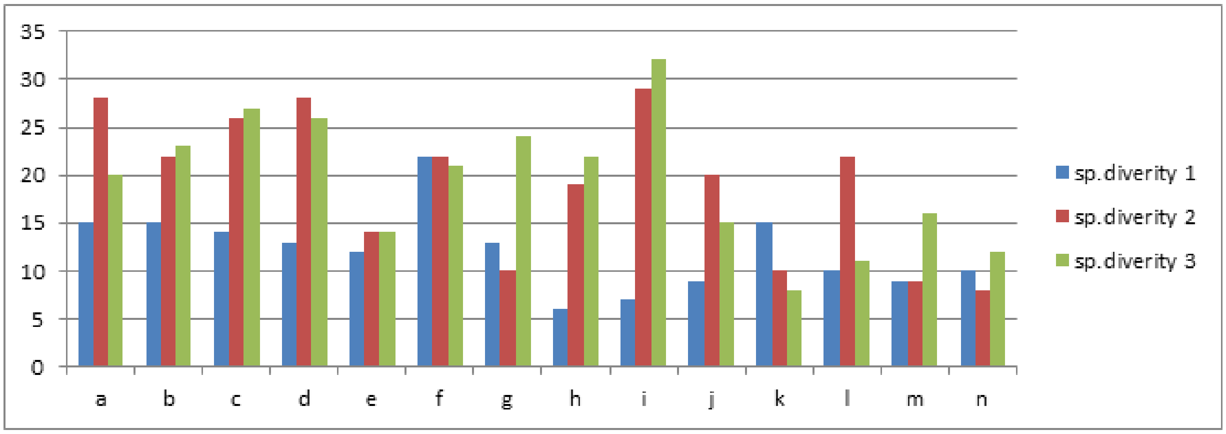


Figure 3: Species diversity in all seasons and sampling stations (sp. diversity 1, 2, 3= species diversity at rainy season, spring season and dry season respectively).

Note: a and b= hospital and its opposite site, c and d= Amora Gedel and its opposite, e and f = fiker Hayq and its opposite, g and h= lewi resort and its opposite, i and j= Haile resort and it's opposite, k and l center and its opposite, m= Tikur Wuha site and n= animal intervention site

There were large seasonal differences in microalgae species composition during the study period (2017). The lowest species diversity showed a decline at the onset of the winter season at S14, S5, S6, S9 and S10 sites. This is probably due to low transparency and high inflow of flood/ erosion in to the lake during this period. According to Talling and Lemoalle, (1998) during this period heavy precipitation seems to change the thermal stability and nutrient-status of the water column. The heavy rainfalls thicken the mixed layer depth by eroding at least the upper part of the metalimnetic region and injecting nutrients into the water column. Low density of microalgae during the winter season is due to high influx of flood water and rain washings and ultimately much of it was also lost in the heavy draw-down (Escaravage and Prins, 1999). The highest species diversity was observed in the summer and spring season at the site of S3 and S9 (fig. 1). This may be due to nutrient enrichment, low turbidity and sufficient sunlight (Sugunan, 2000). In addition to this, the occurrence of Bacillariophyceae and Chlorophyceae increased may be due to available nutrients in the lake water by inflow of water from rivers during spring and summer season. This study supported by Elizabeth and Amha (1994), that total microalgae biomass increased with the onset of stratification after the mixing of the water column in December, and in the beginning of destratification in May at lake Hawassa. This may reflect redistribution of algae and change in the temperature and light, gradient and nutrient availability and climate variability.

Lake Hawassa- Shannon Diversity Indices (H), Max Diversity Index (Hmax) and Evenness Index (EH) (figure 4, 5 and 6)

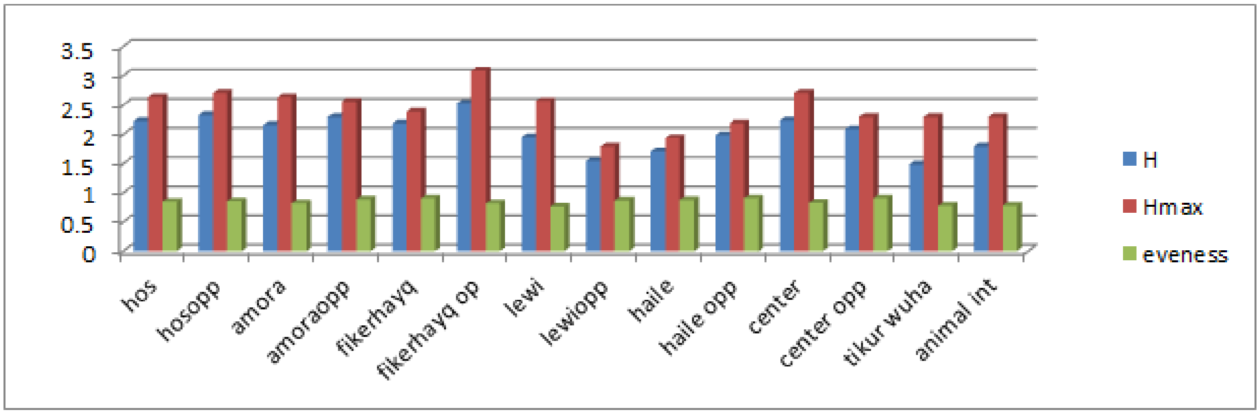


Figure 4: Lake Hawassa (H), (Hmax) and EH index during rainy season

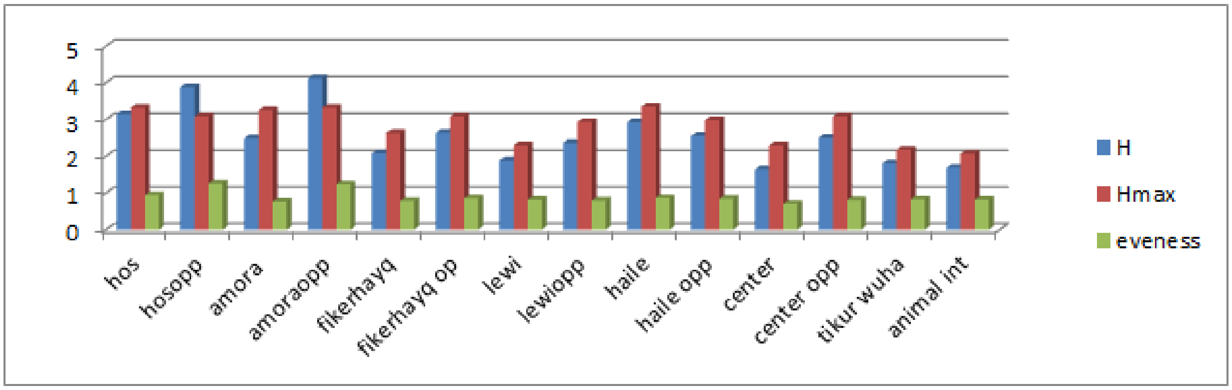


Figure 5: Lake Hawassa (H), (Hmax) and EH index during spring

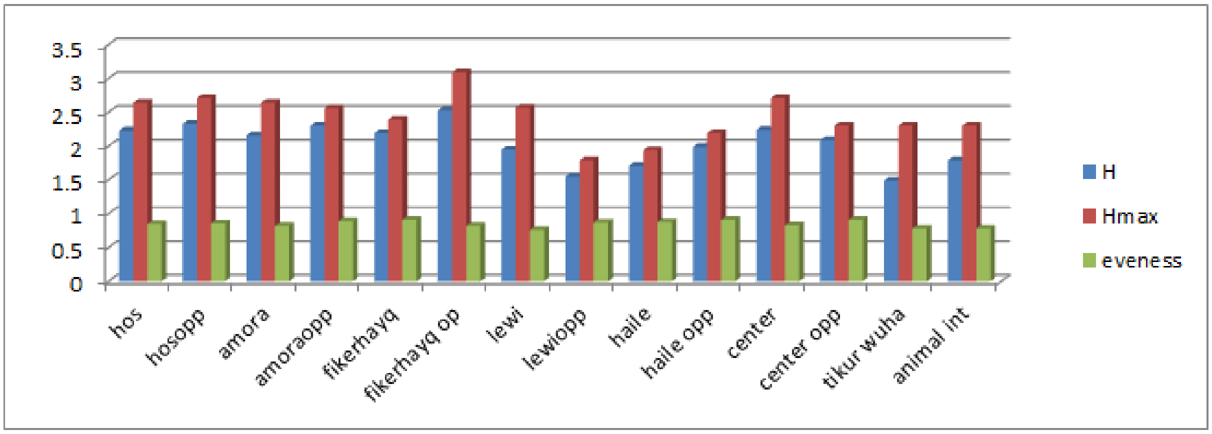


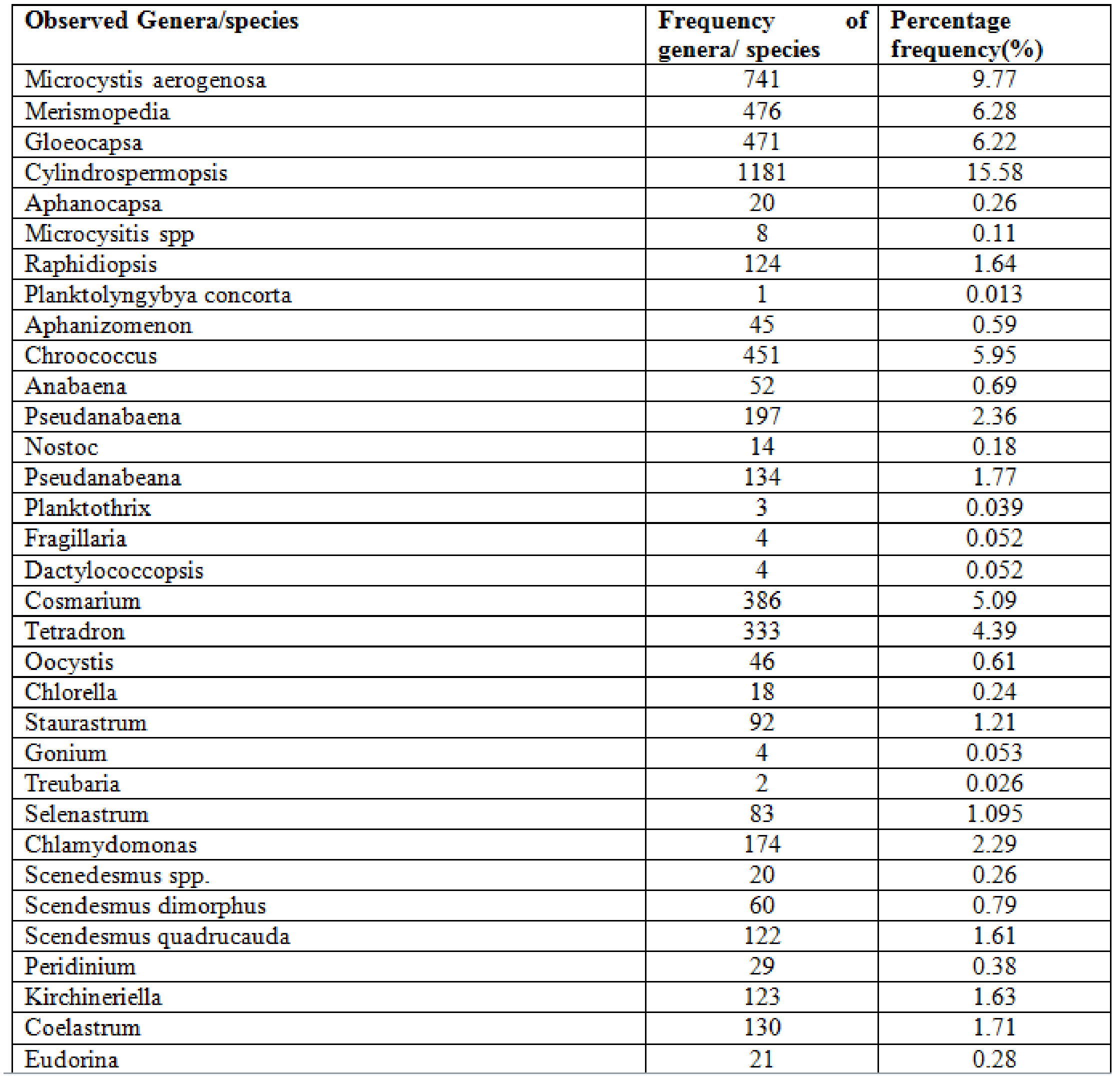
Figure 6: Lake Hawassa (H), (Hmax) and (EH) index during winter

The seasonal and spatial variation of microalgae showed a defined pattern. During the winter season H and EH values increased at S12 (2.19) and S14 showed lower diversity (1.49). S4 showed high diversity (4.13) and S7 showed low diversity index (1.65) during spring. Also S6 and S7 sites showed high diversity and low diversity index (2.79, 1.67) among all stations. In all three seasons high diversity index was recorded during spring season and lower diversity was showed in winter season. There is significance difference in H and EH between seasons and among sampling sites ($p< 0.05$) (annex 1). Correlation between sampling H and EH among the sampling sites were significant at $p <0.01$(annex 1). Species diversity measured by Shannon index is directly proportional to the number of species in the sample and the uniformity of the species distribution in the total abundance. According to Kajak (1983) in the lakes species diversity was relatively high; this indicates good environmental conditions favorable to the growing of many species. Cyanobacteria dominance in lakes is an increasing problem that impacts of recreation, ecosystem integrity, and human and animal health. Some Cyanobacteria produce toxins during growth or decay that kills aquatic animals (Sivottctt 1996).

The following figures show the Shannon diversity (H), maximum diversity (Hmax) and evenness index (EH) values for fourteen stations and three seasons.

Relation between water pH and transparency with species diversity in lake Hawassa

This study shows that there was a positive relation between water PH, transparency and species diversity during the study period, when water pH and transparency values decreases during winter seasons, the species diversity will also decreases. The pH value will also affect the growth rate of microalgae, it will be easier for microalgae to capture CO_2 in the atmosphere when the growing condition is alkaline, which can produce more biomass (Zang et al., 2011). Water transparency depends on the amount of particles in the water. In other words, when the water is murky or cloudy and contains a lot of particles, the light cannot penetrate as deeply into the water column and there was lower species diversity in winter. The low water transparency observed, due to re-suspension of sediments favored cyanobacteria species over other microalgae because of their ability to float on water surface as they possess gas vacuoles for buoyancy regulation (Walsby, 1978).



Observed Genera/species	Frequency of genera/ species	Percentage frequency(%)
Microcystis aerogenosa	741	9.77
Merismopedia	476	6.28
Gloeocapsa	471	6.22
Cylindrospermopsis	1181	15.58
Aphanocapsa	20	0.26
Microcysitis spp	8	0.11
Raphidiopsis	124	1.64
Planktolyngybya concorta	1	0.013
Aphanizomenon	45	0.59
Chroococcus	451	5.95
Anabaena	52	0.69
Pseudanabaena	197	2.36
Nostoc	14	0.18
Pseudanabeana	134	1.77
Planktothrix	3	0.039
Fragillaria	4	0.052
Dactylococcopsis	4	0.052
Cosmarium	386	5.09
Tetradron	333	4.39
Oocystis	46	0.61
Chlorella	18	0.24
Staurastrum	92	1.21
Gonium	4	0.053
Treubaria	2	0.026
Selenastrum	83	1.095
Chlamydomonas	174	2.29
Scenedesmus spp.	20	0.26
Scendesmus dimorphus	60	0.79
Scendesmus quadrucauda	122	1.61
Peridinium	29	0.38
Kirchineriella	123	1.63
Coelastrum	130	1.71
Eudorina	21	0.28

Ankistrodesmus	7	0.09
Scenedesmus acutus	26	0.34
Scenedesmus acuminatus	22	0.29
Pediastrum	24	0.31
Monoraphidium	2	0.026
Scenedesmus obliquus	17	0.22
Haematococcus	107	1.41
Schroederia	12	0.16
Dictyosphaerium	8	0.11
Planktosphaeria	5	0.66
Chlorococcum	19	0.25
Cymbella turgida	3	0.039
Synedra	494	6.51
Nitszchia	102	1.35
Navicula	243	3.2
Melosira	164	2.1
Cyclotella	331	4.37
Cymbella	23	0.30
Cymbella cistula	2	0.026
Achnanthes	2	0.026
Thallasoria	64	0.84
Suririella	105	1.39
Fragilleria	60	0.79
Aulocaseira	6	0.079
Amphora	11	0.145
Suririella spp	73	0.95
Euglenopsis vortex	1	0.013
Phacus	9	0.117
Cryptomonas ovate	68	0.89
	7579	100%

Conclusion

The current results indicated dominance and relative abundance of Chlorophyta and Cyanophyta both spatially and temporally in Lake Hawassa, which Chlorophyta are indicators of good water quality. Temporal and spatial distributions of microalgae showed that Cylindrospermopsis and Microcystis aeruginosa species were dominant in all the sampling sites and seasons. The two species are primary toxin-producing cyanobacteria can have a negative impact on aquatic food webs and human use of freshwaters. The highest species diversity was observed in the dry and spring season at the site of Amora Gedel and Haile resort and the lowest species diversity showed a certain decline at the onset of the rainy season and at the site of Tikur Wuha as well as Lewi and Haile resort and their opposites. In all three seasons high diversity index was showed during spring and dry season and lower diversity was showed in rainy season. Significance difference in H and EH were recorded between seasons and among sampling sites. Correlation between H and EH are significant at $p < 0.01$. Spring and dry season were favorable for the growth of microalgae. This might be due to availability of nutrients from inflow of river water. The finding of this study provides necessary theoretical and data support for the diversity of microalgae in Hawassa Lake. However, further studies are still needed on the species composition, quantity characteristics and distribution characteristics of the microalgae species in Hawassa Lake for the upkeep of biodiversity.

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