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Limnological Assessment of Haramaya Lake for Fisheries Enhancement

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Keywords

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Physicho-chemical parameters,
phytoplankton,

Abstract

Monitoring and assessing both physico-chemical and biological parameters of water bodies help scientists and environmentalists understand the water quality, detect pollution sources, and develop appropriate management and conservation strategies of the lakes. Like that of other fresh water, Lake Haramaya is one of a sensitive fresh water lake. It is found in Eastern Ethiopia in Oromia Regional State, East Hararghe Zone in the Maya city administration. The lake was completely dried in the past decade and currently revived partly. The current study was conducted for two consecutive years (2021/22 and 2022/23),by collecting data quarterly (once every three months) to see the current status of physic-chemical and biological parameters in Lake Haramaya for fisheries development. For this study, three representative sites (named as "N" ,"C" and "S") were selected. Accordingly, physico-chemical and biological parameters of the lake were collected quarterly. Some parameters were measured in-situ while other parameters were analyzed at laboratory. Based on the current results, the mean values of all the studied parameters were not significantly different ($p>0.05$) across the study sites. Some parameters like TDS, Conductivity, and Turbidity, pH, Temperature and electrolyte concentrations slightly increased in year2022/23 as compared to the preceding year2021/22. Depth (m) of the Lake and Dissolved oxygen slightly decreased. The study revealed that there was high biomass of phytoplankton diversity which supports fish growth. The phytoplankton were dominated mainly by Chlorophyta division especially by Cosmarium species. The lake was also full of zooplankton diversity which supports fish production. Zooplankton was dominated by rotifers, copepods and daphnia. Generally, all studied parameters were in the range of fish requirement and hence the lake can support fish production as far as the water volume of the lake survived.

Introduction

Ethiopia is a country with diverse hydrology. Despite the fact that major part of the nation's land mass is arid or semi-arid and subject to climate extremes, it is frequently referred to as the "water tower of East Africa" because of its rugged highlands and abundant seasonal rainfall. Lake Haramaya is one of the Ethiopian fresh water lakes. For a long time, Lake Haramaya served as the source of water for the nearby towns of Harar, Aweday, and the surrounding area (Zinabu Tebeje, 2012).Lake Haramaya occupied an area of 366.70 ha (Sitotaw Haile*et al*., 2022).

Except for the periodic wash off, there were no streams or rivers entering or leaving this lake. As it is situated on a somewhat higher land, the nearby and northerly Lake Tinike spills into Haramaya during the wet seasons. Over the past 20 years, Lake Haramaya has been seen to gradually diminish due to changes in climate and human demographics. By 2004, the lake had completely dried up and had transformed into an ephemeral lake where some water still percolates at the lowest point of the original lake basin (Brook Lemma, 2011). From 2021, the lake's water level has increased to nearly its previous stage.

Even though Lake Haramaya is a productive lake for fisheries development and full of planktons, less about it is known on both limnological status and plankton diversity after revival of the lake; to plan for future development. Phytoplankton are the major primary producers in many aquatic systems and are an important food for consumers (Reynolds, 1994). The studies on phytoplankton photosynthesis in tropical Africa, particularly in the soda lakes of East Africa, have come up with reports of exceptionally high photosynthetic activity (Melack and Kilham, 1974).

Primary productivity and biomass of phytoplankton are affected by an array of chemical, physical, and biological factors. There is no doubt that in general the more frequently a lake is stirred by winds to the bottom, the faster the nutrients are recycled from the mud into the photosynthetic zone where they may accelerate the rate of productivity (Talling and Lemoalle, 1998). The depth of the water is thus, in principle, negatively correlated with the rate of productivity (Cole, 1983). The aim of the current study is therefore to assess the physico-chemical parameters of Lake Haramaya and identify the abundance of planktons of the lake for future development in order to exploit the resources from the fisheries

Materials and Methods

Description of the study area

The study was conducted at Lake Haramaya (Fig. 1) in Eastern Ethiopia at distance of525 kilometers from Addis Ababa, the capital city. Lake Haramayais situated in high altitude at about 2010 meters above sea level,found in Haramaya District (currently known as Maya City), in Eastern Hararghe Zone of Oromia Regional State. Astronomically the lake is found at 42^0 02'E and 9^0 24.5'N (Zinabu Tebeje, 2012).Catchment of Lake Haramaya covers areas with elevation ranging between 2000 and 2343 m.a.s.l (Zinabu Tebeje, 2012). The total area of the catchment is 5032 ha and encompasses a small part of Haramaya town, the Haramaya university campus, three villages(Damota, Ifa-Bate and Tiji-Gebissa) fully and another two partially, Ifa-Oromia (90%) and Gubi-Selama (10%) (Setegn *et al*., 2011).

There are 4 Lakes around Maya city. The 1^{st} big is Haramaya Lake, the 2^{nd} big is Xiniqe Lake which flows to Haramaya, the 3^{rd} is Adele Lake and the 4^{th} is Jitu Lake

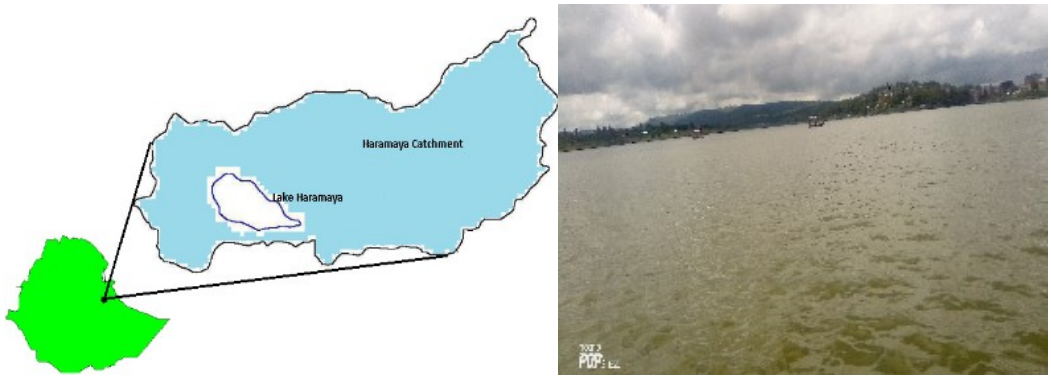

Fig 1: Location map of Lake Haramaya Basin(Source: ZinabuTebeje, 2012) and Authors photo

Sampling procedures

First, a survey was conducted at the start of the project to choose the best sampling sites that were used to collect all of the desired parameters. Accordingly, three suitable sites (the N (N), C (C), and S (S) parts were chosen for data gathering. The data were collected once quarterly (Q1 = July-September, Q2 = October - December, Q3 = January – March and Q4 = April – May) for two years from September2021 to May 2023.from the selected sites of Lake Haramaya.

Physico chemical and biological parameter determination

Physico chemical determination

Physico-chemical parameters of the lakes like pH, Temperature, Depth, Turbidity, were measured *in-situ* using Hanan Instrument HI 9829 Multimeter with GPS, turbidimeter and Vexilar LPS-1 Handheld digital depth sounder. Other parameters like NO3-N, NO2-N, and phosphate were analyzed at Laboratory as of (APHA, 1995) methods (Fig 2). Potassium, Sodium and Calcium were analyzed by flame photometer.

Generally, a total of 10 NO_3-N samples and 16NO_2-N, 9TDS, 9conductivity,21pH, 24 Temperature, 27 turbidity, 24 depth meter, 9 DO, 15 Secchi depths, 17 phosphate, 8 resistivity,15 K, 13 Ca, and 15 Na readings were collected and analyzed for this research.

Fig 2: Chemical preparation, mixing with samples and read for the result at laboratory

Biological parameters determination

Phytoplankton biomass

Phytoplankton was sampled both by horizontal and vertical hauling using 20 µm net from the euphotic zone and the samples were concentrated and preserved by 5% logol's iodine solution. Then, the samples were brought to laboratory and phytoplankton diversity was observed (Fig 3) and identified under inverted microscope called Carl ZEISS Microscope.

Zooplankton abundance

To determine abundance, Zooplankton sample was taken from the water column using 55 µm net. The concentrated samples were preserved in 5% formalin with 1% sucrose. Preserved water samples were observed (Fig 3) under inverted microscope called Carl ZEISS**.** Finally, diversity of zooplankton identified under different magnification power of the microscope**.**

Fig 3: Zooplankton and phytoplankton identification under microscope

Data analysis

The data of three sites in the lake were analyzed by One-way ANOVA in SPSS version 20. Their results were presented in description, tabulate and graphical form.

Results and Discussion

The productivity and biomass of planktons are affected by an array of chemical, physical, and biological factors of the water body. From the current study result, physical, chemical and biological parameters of a two years data of Lake Haramaya was in a good condition which supports the production and productivity of the fishery sector and the result was indicated in Table 1, Table 2 and Table 3.

Physical parameters

Physical parameters of water quality refer to the measurable characteristics of water that are related to its physical properties. The most important physical parameters studied were Temperature (°C) with values of 21.58±1.95 °C, 21.67±1.71 °C and 21.68±1.72 °C; Turbidity (NTU) with values of9.18±7.15 NTU, 9.58±7.15 NTU, 9.45±5.88 NTU; TDS (mgL^{-1}) with values of 768.67±88 $mg.L^{-1}$, 770.33±87.4 $mg.L^{-1}$, 769.0±86.79 $mg.L^{-1}$; Conductivity (µs/cm) with values of 1021.3±238.08 µs/cm, 1019.7±243.2 µs/cm, 1014.3±242.4 µs/cm; and the depth (Ft) data of the lake with values of 11.15±1.74 Ft, 11.19±1.33 Ft, 10.72±1.53 Ftat N, C and Ssampling sites of the lake respectively for all parameters.Results of all the parameterwere not statistically different across the sampling sites (Table 1). The parameters were in the suitable range of fish requirement.

Table 1: Mean ± SD of some Physical parameters of Lake Haramaya at three points.

Parameters	N	C	S	Sig	WHO (2011)
Temperature(°C)	21.58±1.95	21.67±1.71	21.68±1.72	0.992	standard
TDS (mg.L^{-1})	768.67±88	770.33±87.4	769.0±86.79	1.0	500-1500
Conduct. (µs/cm)	1021.3±238.08	1019.7±243.2	1014.3±242.4	0.999	**200-1500**
Turbidity (NTU)	9.18±7.15	9.58±7.15	9.45±5.88	0.991	<10(EPA, 2001)
Secchi depth (cm)	65.6±23.8	64.4±19.92	64.6±19.43	0.995	-
Lake depth (Ft)	11.15±1.74	11.19±1.33	10.72±1.53	0.83	-
Resistivity (kΩ)	0.96±0.09	0.96. ± 0.09	0.96±0.09	1.0	-

When compared to the previous studies, TDS was less than a value recorded by Haile Arefayne (2018) for Lake Adele a lake around Lake Haramaya and greater than a value recorded by ZinabuTebeje (2012) for samples from different borehole points of Lake Haramaya.Other parameters like conductivity, turbidity and temperature of Lake Adele recorded by Haile Arefayne (2018) were also greater than the current value and it was slightly similar with a value recorded by ZinabuTebeje (2012) as shown in (Table 2). Even though the lakes Haramaya and Adele found in the same area, the current variation may be occurred due to the difference in anthropogenic activities around the two lakes. In situ water quality parameters change rapidly due to environmental conditions (Environmental Protection Policy, 2009).

When compared with previous studies conducted in the past two decades, Conductivity µs/cm, was almost similar with Brook Lemma (2003) while Secchi depthwas less than a previous study (0.8-0.9 m) and Dissolved oxygen was also greater than (6.0-10.0 mg 02 L^{-1}) the current value. In the same way, water depth (m) of the current finding is slightly less than a value recorded by Brook Lemma (2003) which was 3-3.5 m. Water temperature (oC) of the current study was almost similar with previous study (Table 3).According to EbaMuluneh (2017), the mean annual rainfall and temperature around Lake Haramaya water shade will increase in the coming thirty years until 2050 GC. So, Kiremt season rainfall will increase from the baseline of 107.55 mm/yr to 135.79 and 136.27 mm/yr under RCP4.5 and RCP8.5, respectively. In the same way, EbaMuluneh (2017) forecast that, under high emission scenario of RCP8.5, the annual maximum temperature could rise from 24.73°C baseline to 25.41°C

Table 2: Mean and SD of some physical parameters of L.Haramaya and Ladle (ZinabuTebeje, 2012; Haile Arefayne, 2018).

Parameters	Lake Haramaya	Lake Adele
Temperature(°C)	21.5-23.8	23.6
TDS (ppm)	488 ± 35	990
Conductivity (µs/cm)	971 ± 75	1477.6±0.00
Turbidity (NTU)	0-14.37	43±4.24

Table 3: Some limnological parameters of Lake Haramaya (Brook Lemma, 2003).

Parameters	In 1986/1987	In 1999 /2000
Temperature (°C)	19,0-23.0 °C	19,3-24.0 °C
Secchi depth (m)	0.98-1.81 m	0.8-0.9 m
Conduct. (µs/cm)	960-1180 µs/ cm $^{-1}$	990-1200 µs/ cm $^{-1}$
Surface area (km ^{2})	4.72 km ^{2}	2.17 km ^{2}
Volume (km ^{3})	0.15 km ^{3}	0.005 km ^{3}
DO (mg.L^{-1})	3.0-5.0 mg 0_2 L $^{-1}$	6.0-10.0 mg 0_2 L^{-1}
pH	7.4-8.8	8.0-9.2
Maximum Depth (m)	7.0-8.5 m	3.0-3.5 m
Mean Depth (m)	3.13 m	1.33 m

Chemical parameters

Chemical parameters of water quality are measures of the various chemical substances present in water. These indicate the chemical composition of water, which include the existence of natural and anthropogenic contaminants. From the current study, pH of the lake over the two years was 8.58±0.44, 8.58±0.48, 8.56±0.48 in N, C and S points of Lake Haramaya. DO (mg.L^{-1}) of the lake was 4.27±1.16 mg.L^{-1}, 4.0±1.1 mg.L^{-1} and 4.31±1.18 mg.L^{-1} at N, C and S points also.NO3-N (ppm) was 13.65±3.93 ppm at the N, 12.08±2.81ppm at C and 14.50±2.73 ppm at the S points. The value of NO2-N (ppm) was 0.20±0.024 ppm, 0.20±0.024 ppm and phosphate werethe same 0.16±0.29 ppm at all points (Composite sample). The value of electrolytes was presented in µg.L^{-1}and it was with the order of Ca>Na>K across the sites (Table 4). Generally speaking, all the parameters were not statistically different across the sampling sites.

Table 4: Mean ± SD of some chemical parameters of Lake Haramaya at three sampling points.

Parameters	N	C	S	Sig	WHO standard.
pH	8.58±0.44	8.58±0.48	8.56±0.48	0.996	6.5-8.5
NO_3-N (ppm)	13.65±3.93	12.08±2.81	14.50±2.73	0.676	50
NO_2-N (ppm)	0.20±0.024	0.20±0.024	0.32±0.07	0.47	0-20
Phosphate (ppm)	0.16±0.29	0.16±0.29	0.16±0.29	1.0	0.05,1.5
K (µg.L^{-1})	5.08±1.39	4.69±0.80	4.51±0.46	0.64	12,000
Na (µg.L^{-1})	66.06±27.86	60.24±17.75	56.23±17.0	0.371	200,000
Ca (µg.L^{-1})	69.32±12.33	67.34±15.71	59.48±17.2	0.227	75,000

Year wise, Lake Haramaya had no differences in its mean physico-chemical parameters between the two years.However, there were slight variationin mean values of all parameters (Fig 4) between the two years. As compared to 2021/22, some variables, including pH, temperature (°C), turbidity (NTU), TDS (mg.L^{-1}), and conductivity (s/cm), slightly rose in 2022/23. The lake's Depth (Ft) and DO (mg/L-1) both slightly declined in the later year.

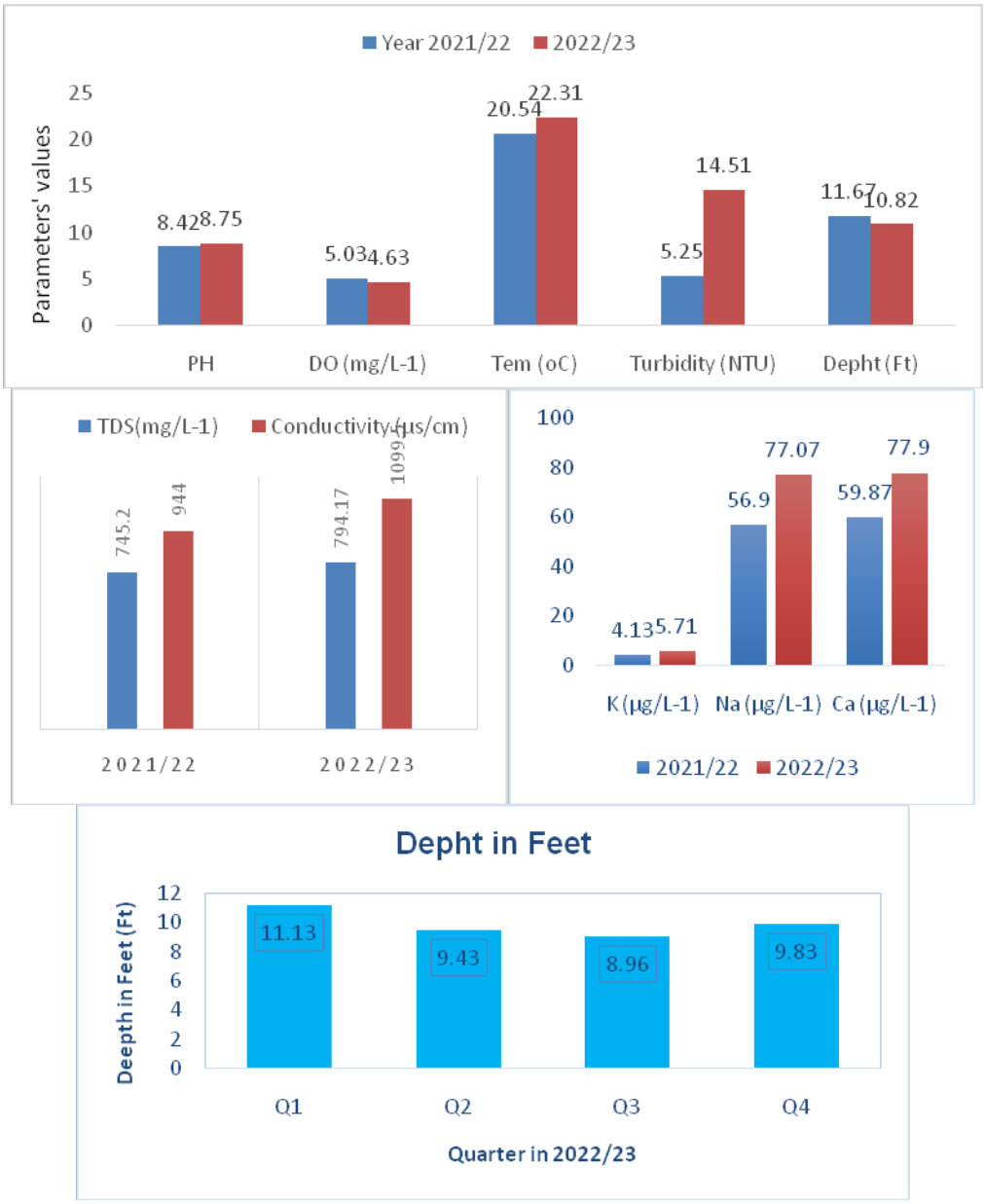

Fig 4: Selected Average physico-chemical parameters of Lake Haramaya in 2021/22 and 2022/23 and Depth meter in Quarter in the year 2022/23

When compared to the previous studies, the current pH value was almost similar with a value recorded for Lake Adele (the neighboring lake situated at few km distance) by Haile Arefayne (2018) and slightly greater than a value recorded for Lake Haramaya by Zinabu Tebeje (2012). The current nitrate value of Lake Haramaya was also agreed with the previous finding of the same lake recorded by Zinabu Tebeje (2012) and the nitrite value of the lake was similar with a value recorded for Lake Adele. Other parameters like Na,Ca and K were less than a value recorded for Lake Adele (Table 5). The current value of electrolytes (Na, Ca, and K) was in $\mu g.L^{-1}$ where as it was in mg/L in previous studies and when converted to the same unit the the current values were lower than previous. The differences may be due to the differences in pressure of irrigation activities between the two lakes (Adele and Haramaya).

Table 5: Mean and SD of some chemical parameters of L.Haramaya and L.Adele(ZinabuTebeje, 2012*; Haile Arefayne,2018**)

Parameters	Values		Author/s
	L.Haramaya	L.Adele	
Nitrate (mg/L)	17.6 ± 4.4	1.81±0.00	*, **
pH	6.86-7.65	8.17±0.01	*, **
K (mg/L)	-	1 ±0.00	**
NO2- (mg/L)	-	0.67±1.89	**
Na (mg/L)	-	185.7 ±0.2	**
Ca (mg/L)	-	11.15 ±1.5	**

Biological parameters

Phytoplankton determination

Plankton is made up of unicellular, filamentous, or colonial organisms that may have prokaryotic or eukaryotic cell structures in many water bodies throughout the world. These creatures play a crucial role in the development of many food chains, fix carbon dioxide, produce oxygen, and play a significant ecological role.

From the current result, Lake Haramaya was full of phytoplankton dominated by Chlorophyta specially cosmarium species. Generally maximum algal density was obtained in October, but there is consistent productivity and diversity throughout the year. The algal species in water samples from Lake Haramaya was listed in table 5. When compared with previous studies, the current value was different from the finding of Brook Lemma (2003) that the current value dominated by Chlorophyta, specially cosmarium species while his finding showed that, Dinophyceae, represented by Peridinium sp., were persistently present in increasing numbers throughout the study period during 1990 and 2000 while cosmarium first increased and then gradually decreased.

Table 5: Major algal division, general future and species found in Lake Haramaya.

Division of algae	General future of the division	Species	Over all % of occurrence
Euglenophyta	❖ **It is a** division of typically unicellular protists, sometimes regarded as algae, sometimes as protozoa (class phytomastigophora) and characterized by the possession of a single flagellum.	● Phacus spp. ● Euglinae	16.67
Chlorophyta	❖ Chlorophyta are a division of green algae, which are either free-floating or anchored on the shore rocks, or are present in large aggregations on stagnant water, such as ponds and lakes.	● Scenedesmus ● Cosmarium ● Crucigenia ● Euastrium ● Monoraphidium ● Staurastrum ● Tetrastrum ● volvox	66.67

Chrysophyta	❖ The Chrysophyceae is a group of fresh water algae characterized mainly by their flagellar structure (although there are also species that are non-motile) and golden color due to the abundance of the pigment fucoxanthin.	● Synura	8.33
Bacillariophyta	❖ **It** is a phylum of algae comprising the diatoms. These marine or freshwater unicellular organisms have cell walls (*frustules*) composed of pectin impregnated with silica and consisting of two halves, one overlapping the other.	● Pinnularia	8.33

The phytoplankton identified from Lake Haramaya was listed in Fig 1 below.

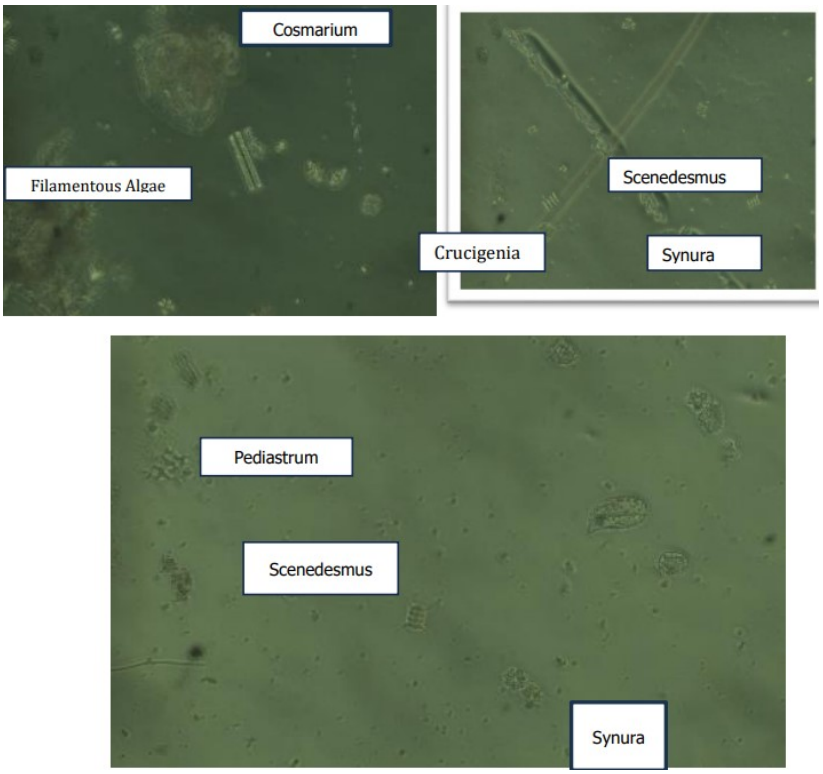

Fig 5:Some identified phytoplankton species from Haramaya Lake

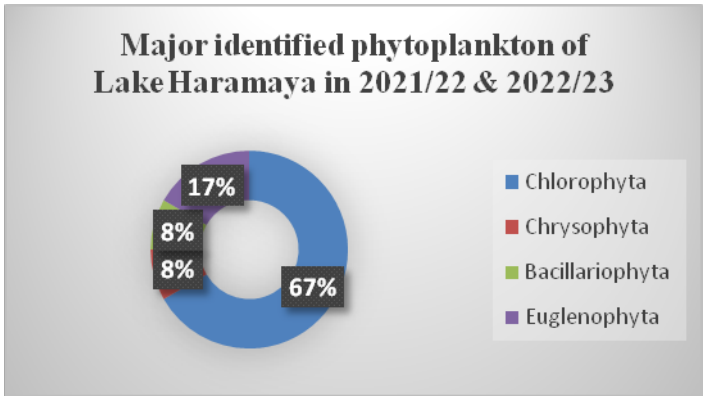

Fig 6: Algal composition of Haramaya Lake

Zooplankton determination

Zooplankton is made up of heterotrophic organisms that eat phytoplankton, particularly consists ofaquatic herbivores and secondary consumers. Zooplankton serves as live food for fish, shrimp, mollusks, and corals in their young phases. They are living things with traits such a high nutritional content, easy digestion, buoyancy, and appealing movement for post-larvae.

From the current study result, Lake Haramaya was full of rotifers, copepods, and daphnia species. When compared with previous findings, the current investigation of rotifers and copepods were similar with a work reported by Brook Lemma (2003) for the same lake. It was dominated by rotifers followed by copepods and daphnia respectively (Fig 7).

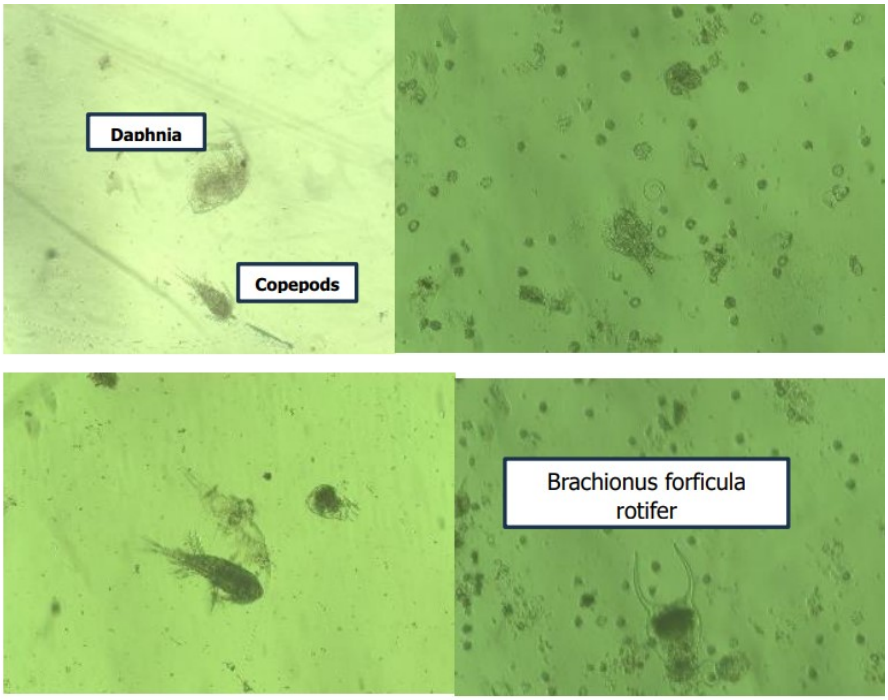

Fig 7: Some zooplankton species identified from Haramaya Lake

Conclusion and recommendations

Physico-chemical and biological parameters are the determining factor for fishery production and productivity in water bodies where there is no supplemental feed for the fish. From the current study result, it can be concluded that studied physico-chemical parameters were not significantly different across all selected sites of Lake Haramaya and are in suitable range for fish production. The volume of the lake and the dissolved oxygen slightly decreased in the year 2022/23 as compared to 2021/22 while values of other parameters slightly increased. The lake was full of planktons that support fish growth and can be concluded that it is possible to increase the fishery production of the lake by introducing appropriate fish species in to the lake if the water volume of the lake remains the same assuming no change on anthropogenic and climatic condition affecting the lake.

As recommendation, there is a need to investigate more about the hydrological consistency or futurity of Lake Haramaya (geological study). Even though there was moderate rain in 2022/23 throughout the year, slight decrease in water volume (depth in feet) observed during the study time. In addition to further water volume investigation in Lake Haramaya, it is also recommend for the government and other stakeholders to take action to minimize the anthropogenic effect of lake Haramaya, especially on economic use of water for irrigation scheme.

Acknowledgments

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References

APHA.(1995). Standard methods for the examination of water and wastewater. American Public Health Association, Washington D.C., U.S.A., 19th Edition.

Brook Lemma (2003). Ecological changes in two Ethiopian lakes caused by contrasting human intervention. *Limnologica* 33, 44-53

Brook Lemma (2011). The impact of climate change and population increase on Lakes Haramaya and Hora-Kilole, Ethiopia (1986–2006).Impacts of Climate Change and Population on Tropical Aquatic Resources, 9.

Cole, G.A. (1983). Textbook of limnology.3rd. edn.C.V. Mosby, Co., 401pp.

EbaMuluneh (2017). Climate Projection Outlook in Lake Haramaya Watershed, Eastern Ethiopia. *Hydrol Current Res*. 8:2 DOI: 10.4172/2157-7587.1000275

Environmental Protection Policy (2018).Background information on water quality measurements using in situ water quality instruments. Monitoring and Sampling Manual.

EPA.(2001). Parameters of Water Quality Interpretation and Standards. Published by the Environmental Protection Agency, Ireland.

Haile Arefayne (2018). Diagnosing the Suitability of Lake Water for Domestic and Agricultural Uses: A Case Study in Eastern Ethiopia. *East African Journal of Sciences*. Volume 12 (*2*) 101-110. ISSN 1993-8195

Melack,J.M. and Kilham ,P.(1974).Photosynthetic activity of phytoplankton in tropical African soda lakes. *Hydrobiologia*, 81:71-85.

Reynolds, C.S. (1994). The long, the short and the stalled: on the attributes of phytoplankton selected by physical mixing in lakes and rivers. *Hydrobiologia*, 89:9-21.

Sitotaw Haile Erena, R. Uttama Reddy & Awol Akmel Yesuf (2022): The drivers for the collapse of Lake Haramaya and proposed integrated rehabilitation strategies, *International Journal of River Basin Management*, DOI: 10.1080/15715124.2022.2047709

Talling, J.F. and Lemoalle, J. (1998).Ecological dynamics of tropical inland waters. Cambridge University Press, Cambridge.

WHO (2011). Guidelines for Drinking-water Quality 4th Edition, New York, USA: UNICEF and the World Health Organization.

ZinabuTebeje (2012). Ground Water Quality Determination of former Lake Haramaya, Haramaya District, Eastern Haranghe Zone, Oroma Regional State, Ethiopia. *J. Appl. Sci. Environ. Manage. Vol. 16 (3) 245 – 252.* JASEM ISSN 1119-8362

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