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Ecological changes in two Ethiopian lakes caused by contrasting human intervention

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Abstract

Alemaya and Hora-Kilole are small lakes found in central and southeastern parts of Ethiopia at similar altitudes. These lakes are exposed to contrasting human interventions. From Lake Alemaya water is withdrawn, while water is added to Lake Hora-Kilole because agricultural experts diverted flow from an adjacent river by constructing a weir. As a result, Lake Alemaya is continually shrinking due to uncontrolled water withdrawal for irrigation and municipal uses but Lake Hora-Kilole, now a reservoir, has increased in volume. Such uncontrolled contrasting anthropogenic intervention has caused ecological changes as observed from various limnological parameters. The problems of conserving these two tropical African lakes and the plankton contained in them are noted. Based on the present scenario, suggestions are forwarded as to what should be done with these lakes and similar situations elsewhere in the tropics.

Key words: Ethiopian lakes – Lake Alemaya – Lake Hora-Kilole – water use and conservation

Introduction

Alemaya and Hora-Kilole are small lakes found in the central and southeastern parts of Ethiopia at similar altitudes.

Lake Alemaya was formed due to marine transgression in the region from Late Triassic to Early Cretaceous time ~225–100 million years ago (BROOK LEMMA 1995). Although small, it provides freshwater for drinking, irrigation, fishing (*Oreochromis niloticus* and *Clarias gariepinus*), animal watering, general municipal uses and recreation to over 120,000 people of the region.

Lake Hora-Kilole was formed due to volcanic action ~7000 years ago (MOHR 1961). This lake is located in a remote area with low population density. Up until 1989, the original water of this crater lake was not potable for people or animals due to its high salinity (conductivity 6720 $\mu S\ cm^{-1}$) (TALLING & TALLING 1965; WOOD & TALLING 1988). In late 1989 a weir was constructed on the nearby River Mojo and water was diverted into Hora-Kilole in an attempt to convert it into a reservoir. The purpose of the diversion was to irrigate the south and eastern low-lying plains of about 3000 hectares of farmland by gravitational flow [personal commun. of Mr. ABEBAW TEZERA, Hora-Kilole (Hidi) Irrigation Project Leader]. It was further emphasized that the planned water harvest was over $16 \times 10^6\ m^3$ per year during the heavy rains of July, August and September and the light rains of March. The canal between River Mojo and Lake Hora-Kilole should have discharged 10–15 m^3 per second. Depending on the amount of rainfall, the discharge of the canal varies from year to year but, despite this variability, it was planned to use at least $10 \times 10^6\ m^3$ per year for irrigation.

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However, an unforeseen water loss of about $9 \times 10^6 m^3$ per year, mainly through leakage (see also Sally Agency 1990), resulted in there being insufficient water available for gravitational irrigation. Furthermore, the water level of the River Mojo was too low during the dry months to continue diverting it into the lake although dry season flow in the river is essential to provide for at least three tanneries and for the highly populated communities downstream.

The irrigation scheme envisaged evidently failed due to not being able to harvest the planned volume of water as a result of the unexpectedly high water loss. However, the changes transformed Lake Hora-Kilole into a dilute freshwater system with a drastic lowering of its water conductivity (BROOK LEMMA 1994; ZINABU GEBRE-MARIAM 1994) bringing the salinity of the lake to tolerable ranges for human and animal use.

Limnological investigations were made at both lakes after they began to change under the influence of human interference. Previous data from Lake Alemay were collected about 14 years ago (BROOK LEMMA 1995) and 10 years ago from Lake Hora-Kilole (BROOK LEMMA 1994). The topic of this paper are the ecological changes caused by the contrasting scenarios at Lakes Alemaya and Hora-Kilole in regard to human water requirements. Another aim of this study is to describe the status of the lakes in 2000.

Materials and Methods

Study sites

Lake Alemaya is located in the Southeastern Ethiopian Plateau margin bordering the Southern Afar, at 2000 m

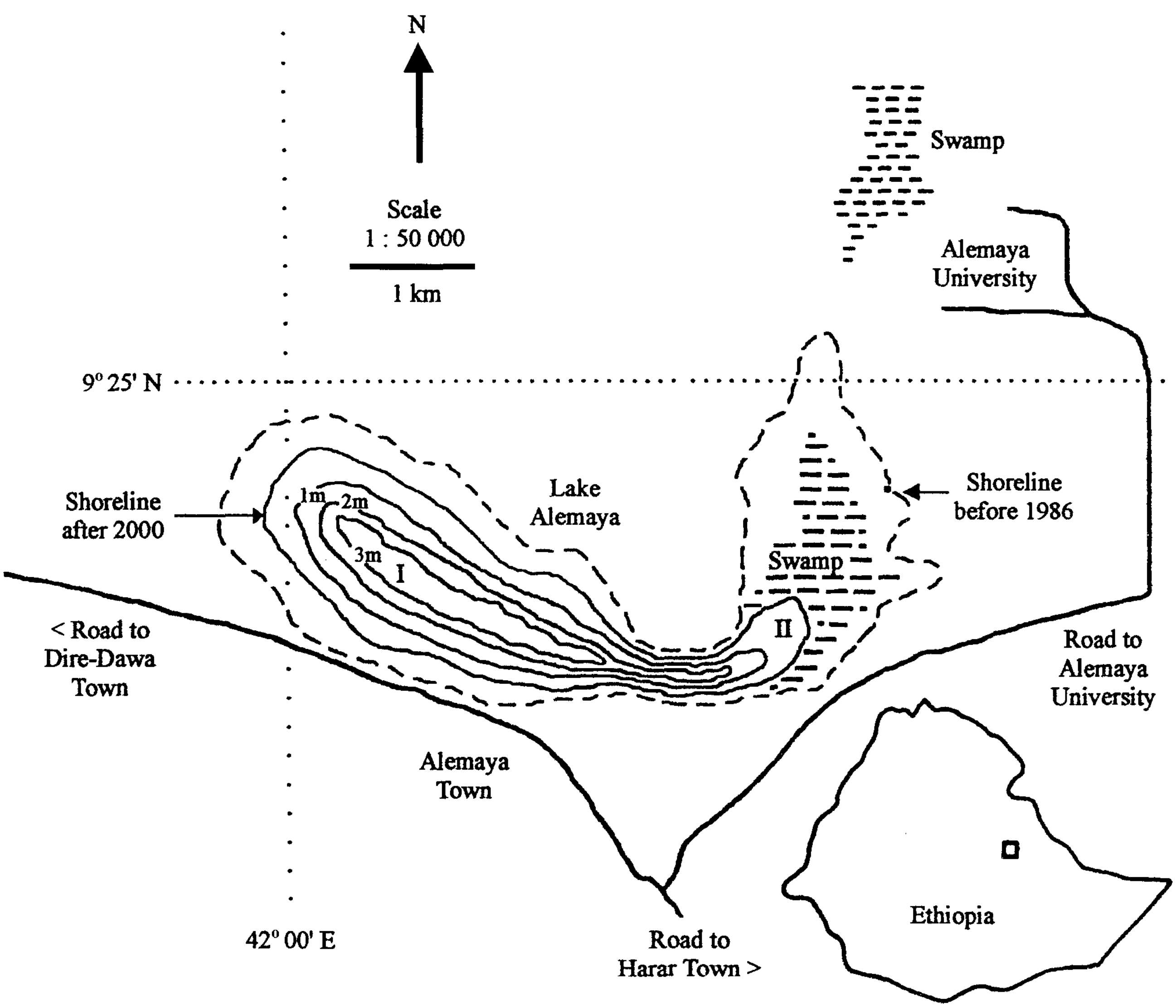

Fig. 1. Map of Lake Alemaya. The inset in the map of Ethiopia is the enlarged Lake Alemaya area. Symbols I and II represent the sampling stations.

above sea level, between 41°40′ and 42°02′E, and 9°22′ and 9°21′N (Fig. 1). Lake Hora-Kilole is found in the Central Ethiopian Plateau at 1920 m above sea level, 39°5′ E and 8°48′N (Fig. 2). The lakes are thus at similar altitudes of 2000 m and exposed to similar current climatic changes in the tropics.

Lake Hora-Kilole is a roughly circular lake with a cone-shaped basin with comparatively clear water in the dry months and turbid water in the rainy months. During the rains, silt and plant debris are brought into the lake by runoff and inflow from River Mojo. The lake has no visible outlets.

Sampling was done at two sampling stations in Lake Alemaya (Fig. 1) and one in Lake Hora-Kilole (Fig. 2). Morphometric data for the lakes before and after the changes due to the contrasting scenarios in human water requirements were obtained (Tables 1 and 4).

Sampling and measurements

The different parameters were measured and samples taken at central positions in the lakes (see stations in Figs. 1 and 2). Basic limnological data of the lakes were collected using combined temperature/dissolved oxygen/conductivity meters (Yellow Spring Instruments – YSI). Depths were assessed by sounding, and water transparency was measured using a standard Secchi disc with 20 cm diameter.

Phytoplankton samples were collected monthly with a Van Dorn water sampler: from Lake Alemaya in the years 1986, 1987, 1999 and 2000 and from Lake Hora-Kilole in the years 1990, 1999 and 2000. Phytoplankton identification and biomass assessment were made by double strip counting in Sedgwick Rafter Cell under a binocular microscope (100x magnification) (Lind 1979; Wetzel & Likens 1979).

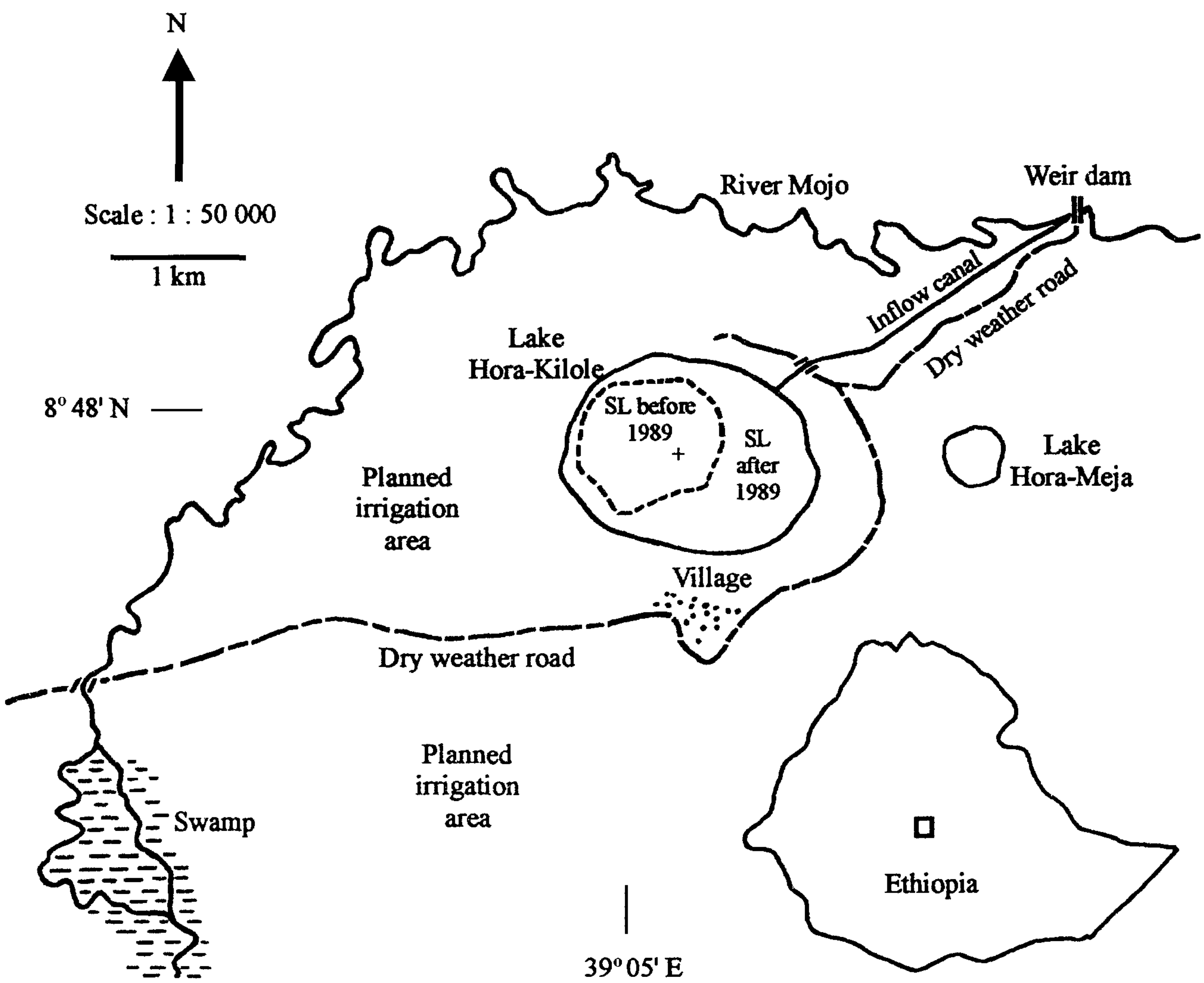

Fig. 2. Map of Lake Hora-Kilole and the adjacently flowing River Mojo. The inset in the map of Ethiopia is the enlarged Lake Hora-Kilole area (a locality also known as Hidi). The symbol "+" shows the sampling station and "SL" represents the shoreline.

Zooplankton samples were collected using 55 µm mesh size net. Counting and identification of zooplankton was made according to the methods described in BROOK LEMMA (1994, 1995). The total counts for the phytoplankton and zooplankton were changed into percent for the periods specified in the figures to fit into pie charts.

Results

To show the climatic changes that the lakes have undergone, meteorological data for Lake Alemaya area for the years 1960 to 2000 were used from the weather station of Alemaya University and for Lake Hora-Kilole area

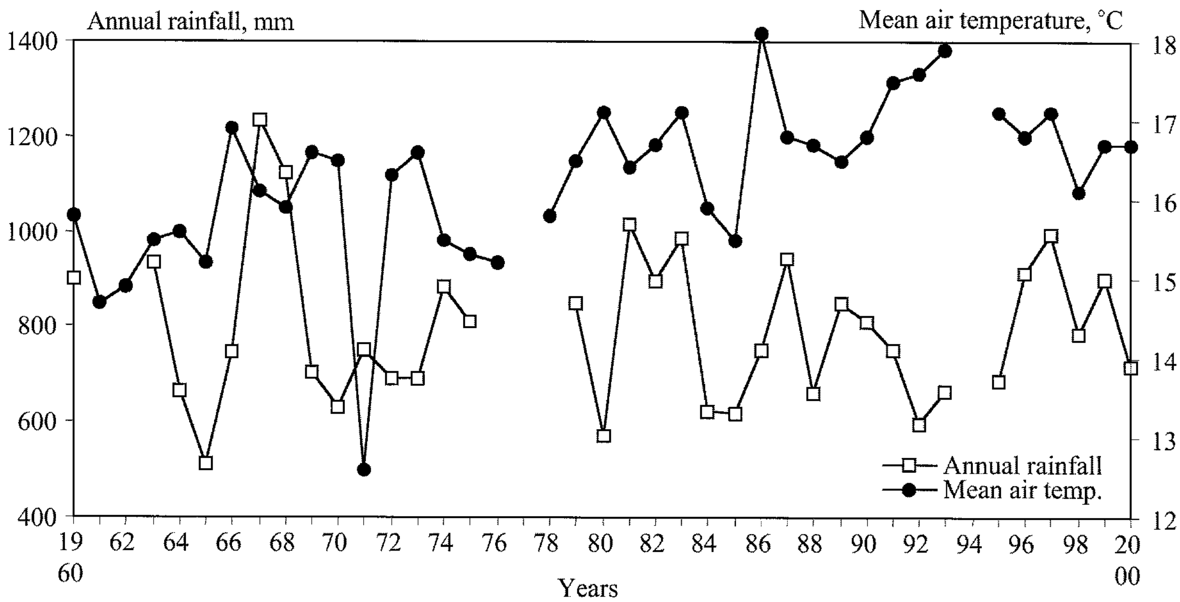

Fig. 3. Annual rainfall and mean air temperatures of Lake Alemaya area, 1960–2000.

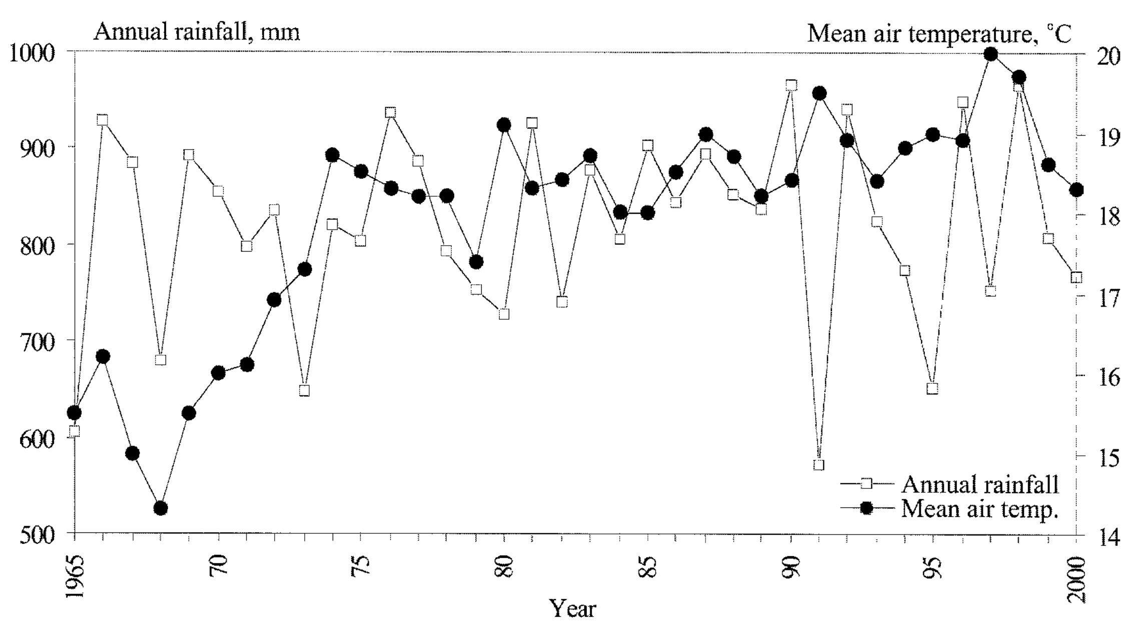

Fig. 4. Annual rainfall and mean air temperatures of Lake Hora-Kilole area, 1965–2000.

for the years 1965 to 2000 from the Debre-Zeyt Agricultural Research Center, located very close to the lake.

Climatic data are presented in Figs. 3 and 4.

Lake Alemaya

Some basic limnological characteristics of Lake Alemaya for 1986, 1987, 1999 and 2000 are shown in Table 1. The mid-day surface water temperature ranged between 19.1 °C and 23 °C in 1986 and 1987, and 19.3 and 24.0 °C in 1999 and 2000. Diurnal stratification and nocturnal mixing occur because the lake is shallow (depth 3.0–3.5 m). Dissolved oxygen in surface water ranged between 3.0 and 5.0 mg $O_2 L^{-1}$ in 1986 and 1987 and 6.0 and 8.5 mg $O_2 L^{-1}$ in 1999 and 2000. Although dissolved oxygen stratification was observed in Lake Alemaya (BROOK LEMMA 1995), the difference of dissolved oxygen concentrations with depth was very small. Electrical conductivity ranged between 960 and 1180 µS cm^{-1} in 1986 and 1987 and 990 and 1200 µS cm^{-1} in 1999 and 2000. The lakewater remained alkaline with pH values at the surface ranging between 7.4 and 8.8 in 1986 and 1987 and 8.0 and 9.2 in 1999 and 2000. The Secchi disc transparency varied from 0.98 to 1.81 m in 1986 and 1987 and 0.8 m to 0.9 m in 1999 and 2000 (Table 1).

Table 1. Comparison of some limnological parameters in Lake Alemaya between the periods 1986–1987 and 1999–2000.

Parameters	1986 and 1987	1999 and 2000
Altitude	2000 m a.s.l.	2000 m a.s.l.
Surface area	4.72 km^2	2.17 km^2
Maximum depth	7.0–8.5 m (at dry and wet seasons)	3.0–3.5 m
Mean depth	3.13 m	1.33 m
Volume	0.15 km^3	0.005 km^3
Secchi depth	0.98–1.81 m	0.8–0.9 m
Water temperature	19.0–23.0 °C	19.3–24.0 °C
pH	7.4–8.8	8.0–9.2
Dissolved oxygen	3.0–5.0 mg $O_2 L^{-1}$	6.0–10.0 mg $O_2 L^{-1}$
Conductivity	960–1180 µS cm^{-1}	990–1200 µS cm^{-1}

Table 2. Dominant phytoplankton species identified in the years 1986, 1987, 1999 and 2000 in Lake Alemaya.

Dinophyceae	*Peridinium* sp.
Chlorophyceae	*Cosmarium* sp. *Pediastrum* sp. *Staurastrum* sp.
Bacillariophyceae	*Nitzschia* sp. *Navicula* sp. *Synedra* sp.
Cyanophyceae	*Merismopedia* sp. *Anabaena* sp.

Table 3. Zooplankton species identified in the years 1986, 1987, 1999 and 2000 in Lake Alemaya.

Cladocera	*Diaphanosoma mongolianum* *Ceriodaphnia* sp. *Moina micrura dubia*
Copepoda	*Thermocyclops decipiens* *T. oblongatus*
Rotifera	*Brachionus calyciflorus* *B. dimidiatus* *B. angularis* *B. urceolaris* *B. quadridentatus* *B. caudatus* *Pompholyx sulcata* *Filinia longiseta* *F. opoliensis* *Asplanchna priodonta* *Polyarthra* sp. *Hexarthra mira* *Lecane luna* *L. bulla* *L. lunaris* *Trichocerca* sp.

Among the phytoplankton species, *Navicula* sp. (cell number 2–9%) showed an increase between 1986 and 1999 but *Cosmarium* sp. (cell number 64–43%) and *Merismopedia* sp. (cell number 28–13%) showed their highest abundances at the beginning of the investigation, continuously decreasing towards the end of the study period at stations I and II. Dinophyceae, represented by *Peridinium* sp., were persistently present in increasing numbers throughout the study period (station I: 14–31%; station II: 13–34%) (Fig. 5).

Table 2 presents an overview of phytoplankton species identified in Lake Alemaya, and a list of the zooplankton species of this lake is given in Table 3. During the study period, Rotifera (station I: 14–19%; station II: 7–10%) and Copepoda (station I: 56–67%; station II: 81–83%) have continuously increased, while Cladocera (station I: 30–14%; station II: 12–7%) showed considerable decrease (see Fig. 6).

Lake Hora-Kilole

Some basic limnological parameters of Lake Hora-Kilole are given in Table 4. These data allow a comparison of the situation before the water of the River Mojo was discharged in the lake (1989) and the features of the years 1990, 1999 and 2000. Due to the filling up of the crater of Lake Hora-Kilole by diverting River Mojo, the water surface was raised to approximately 1914 m a.s.l. in the dry months of March to June. The maximum level reached was about 1920 m during the heavy rains from July to September (Table 4).

The water of the lake was clear in the dry months and turbid in the rainy season. At this time, silt and plant debris are brought into Lake Hora-Kilole by runoff and the inflow from River Mojo. The Secchi depth was measured as 0.15 m before 1989 and ranged between 0.37 m and 1.80 m in the years 1990, 1999 and 2000. The maximum transparency of 1.80 m was reached in the dry seasons when runoff and entry of silt into the lake were re-

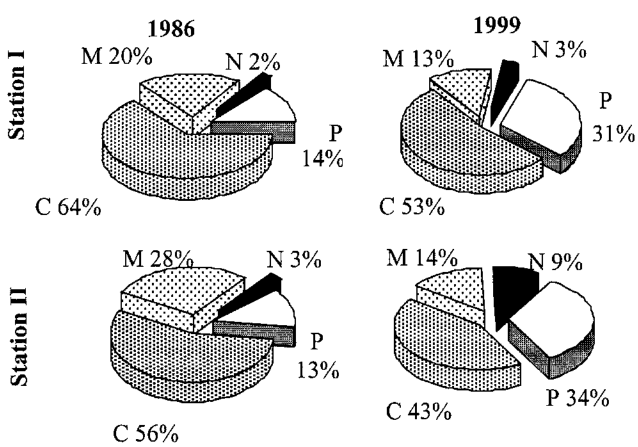

Fig 5. Abundance of phytoplankton species at stations I and II in Lake Alemaya in the years 1986 and 1999.
Legend: C – *Cosmarium* sp.; P – *Peridinium* sp.; N – *Navicula* sp.; M – *Merismopedia* sp.

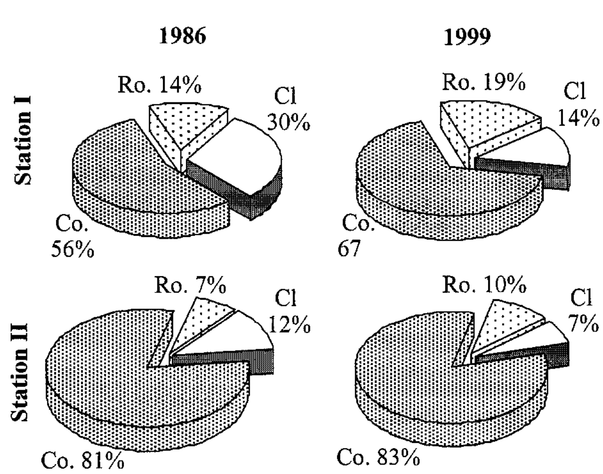

Fig. 6. Abundance of zooplankton species at stations I and II in Lake Alemaya in the years 1986 and 1999.
Legend: Ro – Rotifera; Co – Copepoda; Cl – Cladocera.

Table 4. Comparison of some limnologial parameters in Lake Hora-Kilole before the inflow of River Mojo in the year 1989 and in the years 1990, 1999 and 2000.

Parameters	Before 1989*	1990, 1999 and 2000
Altitude	2000 m a.s.l.	1920 m a.s.l.**
Surface area	0.77 km^2	1.18 km^2
Maximum depth	6.4 m	29 m
Mean depth	2.6 m	1.69 m
Volume	0.002 km^3	0.023 km^3
Secchi depth	0.15 m	0.37–1.80 m
Water temperature	19.0–23.0 °C	19.3–24.0 °C
pH	9.6	7.4–9.2
Dissolved oxygen	1.0–12.0 mg O_2 L^{-1}	3.4–10.6 mg O_2 L^{-1}
Conductivity	5930 µS cm^{-1}	239–339 µS cm^{-1}

* Data recorded at various periods before 1989 from Elizabeth Kebede et al. (1986), Green (1986), Talling et al. (1973) and Wood et al. (1984).
** Altitude was overestimated by previous authors. The data for the year 2000 were given from the Ethiopian Mapping Agency in sheet No. 0839 A1 (1975).

Table 5. Dominant phytoplankton species identified before 1989 and in the years 1990, 1999 and 2000 in Lake Hora-Kilole.

Before 1989*	1990, 1999 and 2000
Cyanophyceae	**Cyanophyceae**
Chroococcus minutus	*Anabaena* sp.
Spirulina sp.	
	Chlorophyceae
	Cosmarium sp.
	Pediastrum simplex
	Staurastrum sp.
	Scendesmus quadricuadata
	S. bijuga
	Dictyosphaerium pulchellum
	Coelastrum reticulatum
	Dinophyceae
	Peridinium sp.
	Ceratium hirundinella
	Bacillariophyceae
	Nitzschia sp.
	Anlacoseira granulata
	Fragilaria ulna
	Cyclostephanos dubius
	Cyclotella sp.
	Chrysophyceae
	Chrysocapsa paludosa

* Data recorded at various periods before 1989 from Elizabeth Kebede et al. (1986), Green (1986), Talling et al. (1973) and Wood et al. (1984).

duced. Surface water temperature varied from 19.3 to 23.0 °C before 1989 and between 19.3 and 24 °C in 1990, 1999 and 2000. Dissolved oxygen concentration at the water surface ranged between 1.0 and 12.0 mg $O_2 L^{-1}$ before 1989 and between 3.4 and 10.6 mg $O_2 L^{-1}$ in the years after the inflow of River Mojo. The surface pH varied between 7.4 and 9.2. In the water column of the lake, the pH before 1989 was 9.6, and it varied between 7.4 and 9.2 in 1990, 1999 and 2000. Electrical conductivity of Lake Hora-Kilole before the dilution by water of the river was 5930 µS cm^{-1}, but in 1990, 1999 and 2000 it ranged between 239 and 339 µS cm^{-1} (Table 4).

All phytoplankton species identified in Lake Hora-Kilole are shown in Table 5. The dominant phytoplankton species that prevailed in the years 1990, 1999 and 2000 in the lake were *Peridinium* sp. (54, 77 and 96%, respectively), *Cosmarium* sp. (12, 20 and 2%), *Staurastrum* sp. (33, 2 and 1%) and *Nitzschia* sp. (1% in the whole study period) (Fig. 7).

Among zooplankton species, rotifers showed an abundance of 2, 7 and 9%, copepods were represented by 5, 71 and 84% and cladocerans by 93, 22 and 7%, in the years 1990, 1999 and 2000, respectively (Fig. 7). In general, it was observed that after the inflow of the River Mojo the dominant rotifer was *Filinia* sp. Among the Cladocera the dominant species was *Daphnia barbata*, and among the Copepoda it was *Thermocyclops decipiens* (compare Table 6).

Table 6. Zooplankton species identified before 1989 and in the years 1990, 1999 and 2000 in Lake Hora-Kilole.

Before 1989*	1990, 1999 and 2000
Copepoda	**Copepoda**
Paradiaptomus africanus	*Thermocyclops decipiens*
(Lovenula africana)	*Mesocyclops aequatorialis similis*
Anuraeopsis coelata	
Rotifera	**Rotifera**
Ascomorpha saltans	*Filinia opoliensis*
Filinia opoliensis	*F. longiseta*
	Brachionurus urceolaris
	B. angularis
	Lecane (Monostyla) bulla
	Keratella cochlearis
	K. cochlearis tecta
	Asplanchna sp.
	Pompholyx sulcata
	Polyarthra dolichoptera
	Synchaeta pectinata
	Cladocera
	Daphnia barbata
	Moina micrura dubia

* Data recorded at various periods before 1989 from Elizabeth Kebede et al. (1986), Green (1986), Talling et al. (1973) and Wood et al. (1984).

Discussion

Climatic patterns in the study areas

The climatic pattern in Lake Alemaya area shows a steady rise in air temperature. The minimum of the mean air temperature was measured in 1971 with 12.6 °C and the maximum in 1986 with 18.1 °C (difference = 5.5 °C). In the year 2000 the mean air temperature was 16.7 °C (difference = 4.1 °C). Rainfall does not seem to show much change although it appears to be highly erratic in this area, indicating that this is one of the reasons for the variability of the volume of the lake.

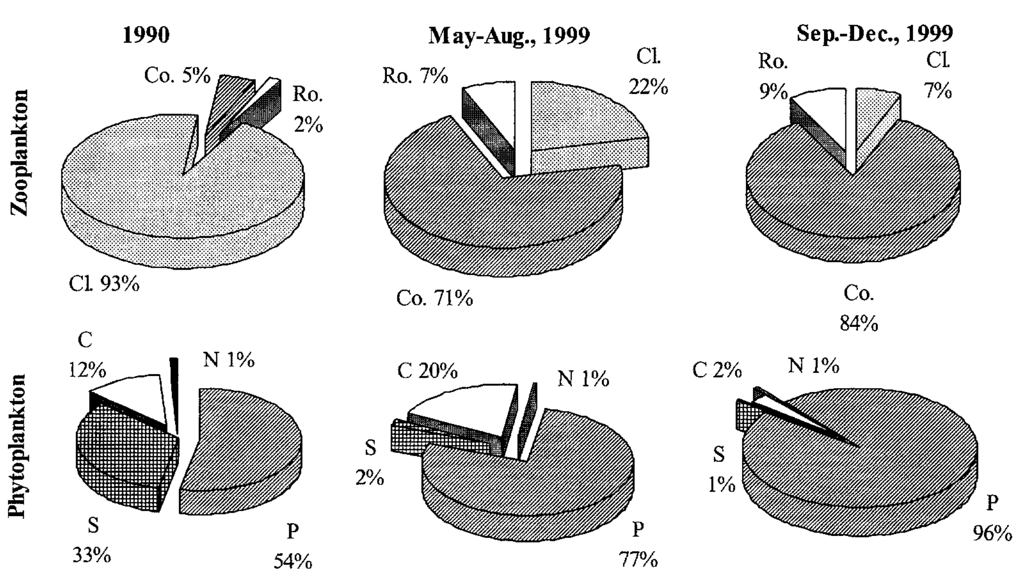

Fig. 7. Abundance of zooplankton and phytoplankton species in Lake Hora-Kilole in the years 1990 and 1999.
Legend: Ro – Rotifera; Co – Copepoda; Cl – Cladocera; C – *Cosmarium* sp.; N – *Nitzschia* sp.; S – *Staurastrum* sp.; P – *Peridinium* sp.

In Lake Hora-Kilole area, similar patterns of temperature and rainfall changes are observed as in Lake Alemaya area. The minimum of the mean air temperature was measured in 1968 with 14.3 °C and the maximum in 1997 with 20 °C (difference = 5.7 °C). In the year 2000 a mean air temperature of 18.3 °C (difference = 4 °C) was recorded in Lake Hora-Kilole area. Rainfall remained highly erratic in this area, with similar consequences on the volume of Lake Hora-Kilole.

Lake Alemaya

The morphometry of Lake Alemaya has changed drastically since the 1980s (Table 1). By 2000, the maximum depth has decreased to 3.0–3.5 m, less than half of the wet season depth of 8.5 m measured 14 years ago. The volume of the lake and the size of the surface area show a corresponding decrease. Secchi depth has become shallower, water temperature showed a slight increase and the pH value increased to a maximum of 9.2 in the year 2000. Together with the decrease in volume and the increasing concentration of dissolved solids, conductivity has slightly increased in the course of the last 14 years. Also the concentration of dissolved oxygen has increased, probably due to the shallowness of the lake, which allowed more effective mixing by wind.

The phytoplankton community of Lake Alemaya is dominated by four groups of algae, namely Chlorophyceae, Dinophyceae, Bacillariophyceae and Cyanophyceae. Chlorophyceae (mainly *Cosmarium* sp.) and Dinophyceae, largely represented by *Peridinium* sp., have shown persistently high abundance followed by Bacillariophyceae. The occurrence of phytoflagellates such as *Peridinium* sp. is usually associated with the inflow of organic matter (NAKAMOTO 1975; WOOD & TALLING 1988; BROOK LEMMA 1994, 1995), in our study due to human interferences of improper sewage disposal, overcrowding in the watershed and excessive removal of vegetation cover for the cultivation of cultivated farmland. Among the Cyanophyceae, *Merismopedia* sp. was found to be the major species.

The zooplankton community in Lake Alemaya showed a broad diversity of rotifers and a high population density of copepods during the study period. The cladoceran population shows a continuous decrease, in favor of rotifers and copepods. Total zooplankton population has risen from fewer than 20×10^3 individuals m^{-3} at the beginning of the study to between 60 and 100×10^3 individuals m^{-3} at the end of the study. The cladoceran population has generally decreased from about 20×10^3 individuals m^{-3} to more or less stable conditions of 5×10^3 individuals m^{-3}. These values have been turned into percent abundance to show the relative dominance of each group.

These multiple changes, especially the continuous shrinking of Lake Alemaya, is leading to a risk of habitat loss for birds and fish (*Oreochromis niloticus* and *Clarias gariepinus*), diverse phytoplankton and zooplankton associations and other invertebrate assemblages. The values of these species in sustaining the food web and their genetic potentials for future generations are in serious danger of disappearance.

In general, Lake Alemaya has changed its morphometry, it is continuously shrinking. Up to 1999, tropical Lake Alemaya has changed to a shallow oligotrophic lake with a moderate altitude and wide variety of plankton populations, but with relatively low productivity. In the year 2000, this lake which is highly important for the people of the region, faces a strong water budget deficiency and hence continuous shrinkage. This is due to

- an excessive withdrawal of water for municipal and household uses by the people within and outside of the watershed area
- changing climatic conditions; a marked rise of air temperature in the region is contributing to an increased loss of water by evapo-transpiration
- the adverse effects of deforestation and irrigation practices, namely lowering of the water table due to erosion and transportation of the topsoil in the lake; there the silk will be accumulated (BROOK LEMMA 1995).

Also the quality of the water of Lake Alemaya has drastically deteriorated, for instance due to poor sanitary facilities of the growing population of the watershed area. As a result, the people living in the watershed of Lake Alemaya and in the town Harar are advised by the Regional Office of the Ministry of Public Health not to drink tap water drawn from the lake without boiling. In the future the people will eventually lose their water supply without any substitution. Also the erratic nature of the rainfall has made people more and more insecure. Additionally, the various agro-chemicals (pesticides, herbicides, and fertilizers) applied in the irrigated fields of the watershed should be taken into consideration as a main source of pollution. This may lead to even greater deterioration of water quality.

This scenario implies the potential loss of aquatic life in this highly important aquatic natural resource, just because there is no sustainable action plan of water use by the community. There are currently no conservation activities taking place to counter balance the pressures on this lake from increasing human population and the changing climatic conditions. If this complex scenario continues, it is possible that Lake Alemaya will disappear in a short period of time. It is necessary that the municipalities of the consumer towns, farmers and all other concerned groups make urgent and concerted efforts.

Lake Hora-Kilole

Lake Hora-Kilole was once grouped among the unique saline lakes of Africa, such as the lakes Arenguade, Chitu, Nakuru, Abijata (Abiata) and Shala (ELIZABETH KEBEDE et al. 1986; GREEN 1986, 1993; PROSSER et al. 1968; TALLING et al. 1973; TUDORANCEA et al. 1999; WOOD & TALLING 1988; WOOD et al. 1984; VARESCHI 1982). This lake was also well known for its rich *Spirulina* sp. assemblage and bird fauna. As described above, the planned use of the lake as a reservoir to irrigate the south and eastern fields of about 3000 hectares was not achieved, because the water level did not reach the desired elevation for gravitational irrigation.

But the diversion of River Mojo into Lake Hora-Kilole has caused substantial changes in the morphometric, biological and physico-chemical characteristics of the lake. Now, the lake has drastically increased in volume, and the lakewater has been diluted due to the inflow from River Mojo. This increase in volume has occurred despite progressive rise in annual air temperature and erratic patterns of rainfall over the past 35 years. The addition of river water into Lake Hora-Kilole bypassed the effects of evapo-transpiration many times and has thus altered the water salinity.

Presently, the changes in morphometry and thermal relations in the lake have caused a stable stratification in temperature, dissolved oxygen and other dissolved substances (BROOK LEMMA 1994). Unlike pre-1989 periods of polymixis, at present anoxic situations exist in Lake Hora-Kilole at depths below 10 m when the lake is thermally stratified (BROOK LEMMA 1994).

The tropical, volcanic Lake Hora-Kilole is no longer a shallow, polymictic lake with high conductivity and high primary production as previously (PROSSER et al. 1968; TALLING et al. 1973; WOOD & TALLING 1988), but it is now a relatively deep and warm oligotrophic freshwater lake with low conductivity (BROOK LEMMA 1995).

The chemical changes associated with the dilution of the lakewater have together with the increase of the lake volume brought a lot of changes to the phytoplankton and zooplankton assemblages and other invertebrates.

For instance, drastic changes of the plankton community could be observed. The previous dominant phytoplankton species *Spirulina* sp. has been very rapidly replaced by *Peridinium* sp., *Cosmarium* sp., *Staurastrum* sp. and *Nitzschia* sp. Caused by the excessive deforestation, erosion of the topsoil and siltation of Lake Hora-Kilole, high volumes of organic matter and silt flow into the lake and have caused proliferation of Dinoflagellates, for instance *Peridinium* sp. The previous unique plankton community has been lost without realization of its potential, particularly the commercial exploitation of *Spirulina* sp., which is known for its rich and unique protein content (CANTER-LUND & LUND 1995). The main factor for the changes in the algal community in Lake Hora-Kilole may be the reduction of the conductivity.

The changes in the zooplankton community are also associated with the conversion of the lake into a reservoir, making it possible for more freshwater species to prevail.

The diversion of River Mojo into Lake Hora-Kilole has also resulted in the introduction of at least three basically riverine *Barbus* spp. (BROOK LEMMA 1994). The influx of these fishes has depressed the abundance of the only fish previously present, *O. niloticus*. As a result of the high predation pressure from the currently dominant juvenile *Barbus* spp., the large cladoceran population has decreased and has been replaced by small rotifers.

Conclusions

The study of these contrasting anthropogenically induced limnological transformations is interesting and important, because the ecological changes observed in the types and numbers of plankton associations, the production cycles, the water quality and other physico-chemical factors can contribute to a general limnological understanding, conservation and rational exploitation of natural resources in the tropics, where continuous climatic changes can be observed. Finally, it may be suggested that the examples of Lake Alemaya and Lake Hora-Kilole warrant that any future use or harvest of water from tropical lakes deserve closer interdisciplinary study, concerted decision making, adequate water budgeting and conservation plans for the sake of sustainability before embarking into such projects.

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