Hydrobiologia 157: 47–55 (1988)

Some limnological observations on two Ethiopian hydroelectric reservoirs: Koka (Shewa administrative district) and Finchaa (Welega administrative district)

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Received 16 June 1986; in revised form 1 October 1986; accepted 28 December 1986

Key words: benthos, dams, Ethiopia, fish, plankton, reservoirs

Abstract

Koka Reservoir in the Ethiopian Rift Valley (altitude about 1600 m) appears to be similar to natural lakes in the region. Its water is turbid because of suspended inorganic material. At the time of measurement it was supersaturated with oxygen to a depth of about 8 m, and displayed a pronounced conductivity stratification, due probably to the incomplete mixing of two inflows. The phytoplankton was dominated by *Microcystis*. The zooplankton was of low diversity but abundant. There was a large population of benthic invertebrates.

Finchaa Reservoir in west central Ethiopia (altitude about 2200 m) is very different. It covers the former Ch'omen Swamp and so contains many floating islands and large quantities of decomposing vegetation, causing undersaturation with oxygen even at the surface. The water is somewhat turbid owing to the presence of organic debris, of low conductivity, slightly acidic, and apparently calcium-dominated. A species of *Microcystis* was the most abundant phytoplankter. The zooplankton was sparse and of very low diversity. There were almost no benthic invertebrates.

Introduction

Considerable information exists on the limnology of the natural lakes of Ethiopia but little is known about the country's reservoirs. Since hydroelectric power plays an increasingly important part in the economy of Ethiopia, this lack of information could pose problems for water and fishery management because reservoirs differ from natural lakes in a number of ways (see e.g. Baxter, 1985).

In February 1985, through the kindness of the Ethiopian Water Resources Development Authority, we were able to visit two important reservoirs, Koka and Finchaa, collect samples, and make certain measurements and observations. The results of these are presented here.

Description of the sites

Koka Reservoir (called Lake Galilea on some maps, e.g. Belay & Wood, 1984) was formed by the construction of a concrete dam on the Awash River in the Ethiopian Rift Valley, 80–100 km southeast of Addis Ababa. Filling began about 1959 and flooded a considerable area of relatively flat acacia savannah (Fig. 1). Large numbers of dead standing trees were visible in the years after the dam was closed, and

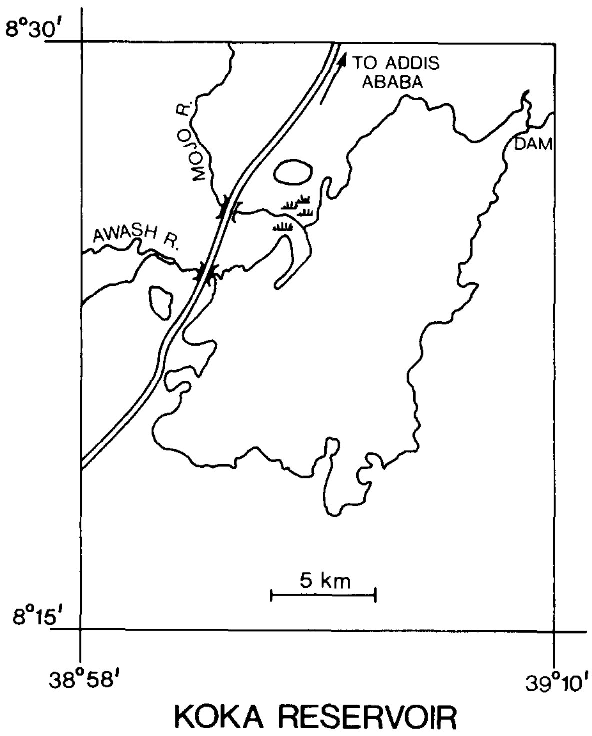

Fig. 1. Outline map of Koka Reservoir.

probably stumps remain beneath the surface. Besides the Awash River, the main source of water to the reservoir is the Mojo River.

The altitude of the lake surface is given as 1 589 m on the official map (Series EMA3, Sheet NC37-14 Edition 1. Date of information 1969). There is no indication of whether this refers to the maximum, the minimum, or some intermediate level.

A few kilometers downstream from Koka Dam are two other installations with concrete dams, Awash II and III, completed about 1975. These do not impound much water and appear to operate essentially on the run of the river as controlled by Koka Dam.

Finchaa Reservoir was formed in about 1972 by the construction of a rock-fill dam on the Mita Stream, shortly above the point where it plunges into the gorge of the Finchaa River, a tributary of the Abay River (Blue Nile) (Tikubet & Gemetchu, 1984). Existing maps are based on information obtained before the dam was closed, but the general form of the reservoir can be inferred from Fig. 2. Damming the Mita stream flooded the Ch'omen Swamp forming a relatively shallow lake comparable in area with the natural lakes of the Ethiopian Rift Valley. The water level was 2218 m at the time of our visit, as shown by a gauge on the dam. The highest level shown on the gauge was 2223 m.

The reservoir contains many floating islands of vegetation some tends of meters across. These appeared to float downstream in the latter part of the day, necessitating the presence of a boom constructed of oil drums to protect the intake to the turbines, and to be driven upstream by light winds the following morning. Presumably, many of these become stranded when the reservoir is drawn down and float up again when the water level rises, and will persist for many years.

Water hyacinth (*Eichhornia crassipes*) occurs in the Awash reservoirs and has caused concern because of the possibility of blockage of the intakes to the turbines, especially in Awash II and III. No *Eichhornia* was observed in Finachaa.

The principal fish species in both reservoirs is probably Tilapia (*Oreochromis niloticus*). Barbs (*Barbus*), Catfish (*Clarias*) and Common Carp (*Cyprinus carpio*) are also present in Koka. Silver Carp (*Hydrophthalmichthys molitrix*) and Grass Carp (*Ctenopharyngodon idella*) were introduced into Finchaa in 1975 (Tedla & Haile Meskel, 1981). It is not known if any of these established breeding populations.

Sampling and measurements in Finchaa Reservoir were carried out on February 17, 1985 and in Koka Reservoir on February 19, 1985.

Methods

Chemical analyses were carried out using a Hach portable analysis kit. Chlorophyll *a* was measured spectrophotometrically using hot 90% methanol as the extracting agent (Talling & Driver, 1963). Oxygen and temperature measurements were made with a YSI Model 57 oxygen meter. Conductivity measurements were made with a YSI Model 33 conductivity meter. Phytoplankton and zooplankton samples were collected with a 15 μ and a 64 μ mesh net respectively. Zooplankton was collected by taking four vertical hauls from a depth of 8 m in each lake.

Two benthic samples were taken at each of three

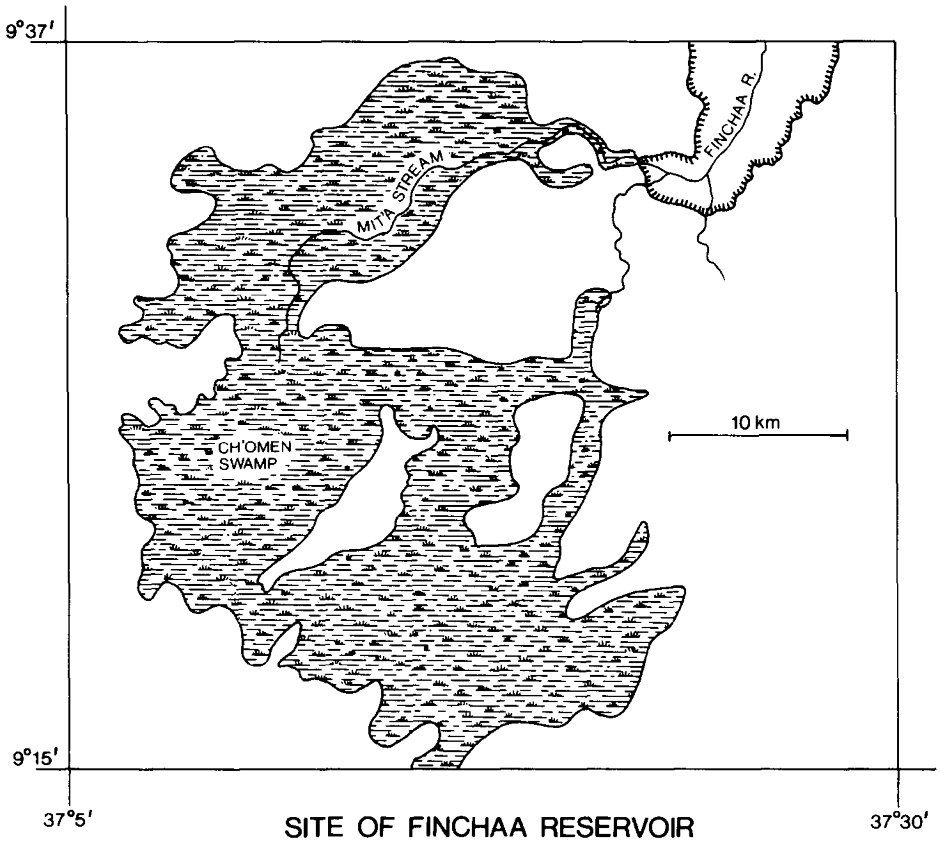

Fig. 2. Map of the site of Finchaa Reservoir and surrounding area.

different depths in each lake using a 225 cm^2 Ekman type grab. The samples were washed through a 0.2 mm mesh net and hand-sorted in the laboratory under dissecting microscope.

In addition, one Ekman grab sample was collected at each station and three subsamples from each were taken for measuring the total organic content in the sediments. Each subsample was dried in the oven at 105 °C and the organic content was determined by loss on ignition at 550 °C.

Results and discussion

The stations at which measurements were made were a few hundred meters above the dams. In Finchaa Reservoir this was in a comparatively narrow portion (Fig. 2), so the results obtained may not be representative of conditions in the reservoir as a whole, and the upstream drift of floating islands necessitated frequent changes of station.

Except for superficial warming, neither reservoir displayed any significant thermal stratification (Fig. 3). In spite of its greater altitude, Finchaa was about 1.5 °C warmer than Koka, perhaps because of a longer retention time in a shallow basin.

The oxygen profiles for the two reservoirs were quite different (Fig. 4). Concentrations in Finchaa declined with depth, reaching zero about a meter above the bottom. In Koka, the concentration remained fairly constant with depth below the upper few centimeters down to about 8 m and did not reach zero even at the bottom.

Percent saturations for the temperatures and altitudes of the two lakes were calculated according to Golterman *et al.* (1978). Finchaa was only about 65% saturated even at the surface. Koka was supersaturated by about 30% at the surface, and main-

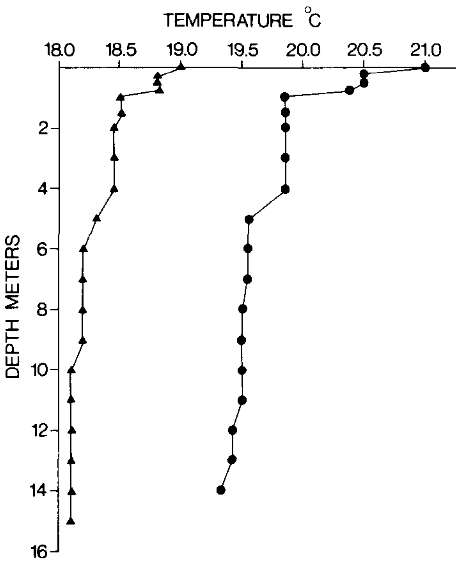

Fig. 3. Temperature profiles of Finchaa Reservoir (circles) and Koka Reservoir (triangles), February 1985.

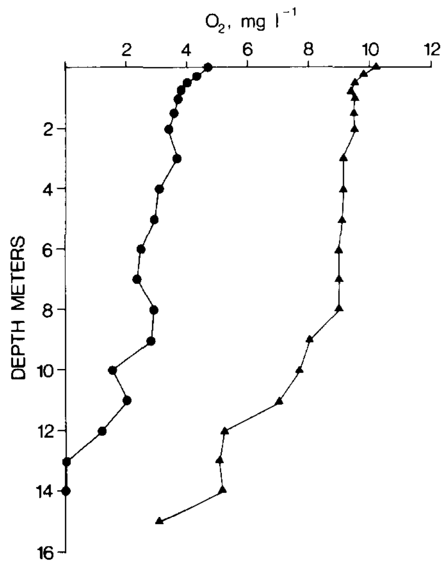

Fig. 4. Oxygen profiles of Finchaa Reservoir (circles) and Koka Reservoir (triangles), February 1985.

tained about 20% supersaturation until the concentration began to decline at 8 m.

Undersaturation in oxygen at the surface during the day is unusual in Ethiopian lakes, although certain highly productive lakes can become undersaturated or even deoxygenated at night (Talling *et al.*, 1973). In Finchaa it can probably be attributed to a high biochemical oxygen demand due to organic matter combined with a relatively low level of primary productivity.

Both lakes were of relatively low transparency, but for different reasons. Finchaa gave a Secchi disc reading of about 1.5 m. The principal light-absorbing material here was probably suspended organic material. Koka gave a Secchi disc reading of 28 cm and contained suspended silt. The water somewhat resembled that of Lake Langano (Wood *et al.*, 1978), but in Langano the silt is in stable suspension and does not precipitate unless the salt concentration of the water is altered (Belay & Wood, 1984), whereas the material in Koka water settles out on standing.

A few chemical analyses were carried out and a more extensive analysis of a sample from Lake Koka was performed in the Earth Sciences Department of the University of Waterloo. This sample was collected about March 15, 1986 near the point where the Awash River enters the reservoir. All these results are presented in Table 1, along with some previously published values for Lake Koka (Water Resources Development Authority Ethiopia, 1984). The general composition of Lake Koka water is similar to that of other waters from the Ethiopia Rift Valley (Talling & Talling, 1965; Von Damm & Edmond, 1984). The ratio of total divalent cations to total monovalent cations is fairly high. This is not uncommon in African waters which have not undergone sufficient evaporation to bring about the precipitation of calcium (Talling & Talling, 1965; Von Damm & Edmond, 1984).

The water of Lake Finchaa is one of the most dilute ever reported from Ethiopia, comparable only to certain lakes and tarns in the Bale mountains (Löffler, 1978; Baxter & Golobitsh, 1981). It is also unusual in having a pH value of less than 7. Calcium is probably the predominant cation.

The electrical conductivity profiles of the lakes are shown in Fig. 5. The electrical conductivity of Lake Finchaa water does not vary much throughout the water column. In Lake Koka, however, the conductivity increased sharply with depth below about 8 m. This is the same depth as that at which the oxygen concentration began to decline. Apparently there was a layer of slightly heavier, partially deoxygenat-

Table 1. Some chemical characteristics of Lake Koka and Lake Finchaa.

	Koka February 1985	Koka June – July 1984 (WRDA)	Koka March 1986	Finchaa February 1985
Surface conductivity $\mu S\ cm^{-1}$	200	320	380	75
Surface pH	8.40	8.3	-	6.45
Na^+, $meql^{-1}$	-	-	1.40	-
K^+, $meql^{-1}$	-	-	0.21	-
Ca^{++}, $meql^{-1}$	1.28	1.40	0.86	0.58
Mg^{++}, $meql^{-1}$	0.42	-	0.31	0.20
Total cations	-	-	2.78	-
HCO_3^-, $meql^{-1}$	-	2.89	2.59	-
$SO_4^=$, $meql^{-1}$	-	NIL	0.14	-
Cl^-, $meql^{-1}$	0.25	0.28	0.49	0.03
Total anions	-	-	3.22	-
Chlorophyll *a* μgl^{-1}	22.4	-	-	5.56

ed water underlying a lighter, oxygen-supersaturated layer and isothermal with it. Earlier analyses on samples taken in late June or early July, 1984, at an unspecified station, showed a conductivity (presumably in surface water) of 320 μS (Water Resources Development Authority Ethiopia, 1984) i.e. the same as we found in the lower water. A sample taken about a year later at the upper end of the reservoir was similar. Our station was below the point where the Mojo River enters the lake. It seems likely that the pattern observed was due to the presence of a relatively dilute, well-oxygenated overflow from the Mojo River above a more concentrated water mass mostly derived from the Awash River.

The chlorophyll value for Lake Finchaa is perhaps misleading. Microscopic examination of samples revealed the presence of considerable greenish plant debris, so some of the chlorophyll may be derived from this and not from photosynthetically-active organisms.

The value for Lake Koka is within the range of those found for natural Rift Valley Lakes (Belay & Wood, 1984).

The percentage organic content values in the sediments of Lake Finchaa were much higher than in those of Lake Koka (Table 2). This is probably due to large amounts of decomposing roots and stalks. The samples contained large quantities of vegetal debris as well as undecomposed plant fragments.

In Lake Koka, the sediment is very fine, easily washable through a 200 μ mesh net, and contains no undecomposed material. The organic content is

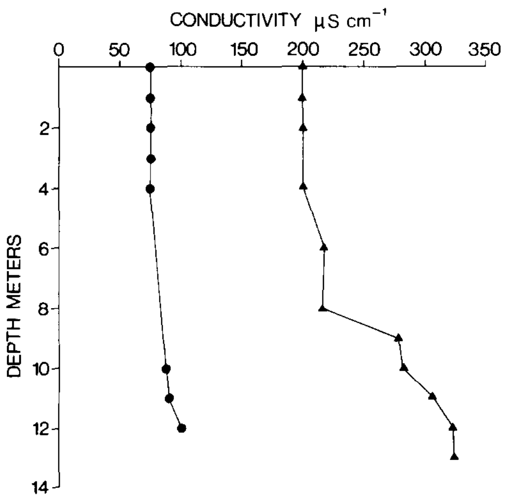

Fig. 5. Conductivity profiles of Finchaa Reservoir (circles) and Koka Resevoir (triangles), February 1985.

Table 2. Percentage of organic matter in sediments of Lakes Finchaa and Koka, February 1985.

	Depth of water at station (m)				
	1	2.5	6	8	13
Lake Finchaa	18.33	-	-	42.30	41.77
Lake Koka	-	7.36	11.53	11.15	-

somewhat high in comparison with certain other tropical African lakes (McLachland, 1974) but is comparable with the values found in other Ethiopian Rift Valley Lakes (Tudorancea, unpublished data).

Biological limnology

Phytoplankton

The genera of planktonic algae identified in the two lakes are listed in Table 3. The predominant planktonic alga in both lakes was a species of *Microcystis*; this genus is widely distributed in Ethiopian lakes.

Table 3. Genera of phytoplankton found in net samples from Finchaa and Koka Reservoirs, February 1985.

	Finchaa	Koka
Cyanophyta	*Microcystis*	*Anabaena*
	Merismopedia	*Merismopedia*
	Rhaphidiopsis	*Microcystis*
Chlorophyta	*Ankistrodesmus*	*Chlamydomonas*
	Cladophora	*Coelastrum*
	Cosmarium	*Mougeotia*
	Desmidium	*Oedogonium*
	Gonatozygon	*Scenedesmus*
	Micrasterias	*Staurastrum*
	Pediastrum	
	Scenedesmus	
	Selenastrum	
	Spirogyra	
	Staurastrum	
Chrysophyta		*Chromulina*
Pyrrophyta	*Cystodinium*	
	Peridinium	
Euglenophyta	*Phacus*	
Bacillariophyta	*Neidium*	*Cyclotella*
		Navicula

Zooplankton

The species of zooplankton found in the two reservoirs are listed in Table 4. As in other Ethiopian lakes (Wodajo & Belay, 1984) and tropical lakes generally (Fernando, 1980) the diversity was low.

The zooplankton of the two lakes was very different both in composition and abundance. Lake Koka, at the time of sampling, was dominated by the calanoid *Tropodiaptomus processifer* and the cladoceran *Daphnia barbata*. The cladoceran *Moina*

Table 4. Zooplankton species found in net samples from Koka and Finchaa Reservoirs, February 1985.

	Koka	Finchaa
Rotifera		
Filina opaliensis	x	0
Keratella tropica	xx	x
Conochilus sp.	x	0
Polyarthra vulgaris	x	0
Gastropus hyptopus	x	0
Trichocerca similis	0	x
Trichocerca chattoni	0	x
Anuraeopsis coelata	0	x
Auraeopsis fissa	0	x
Hexarthra mira	0	xx
Ascomorpha soltans	0	xx
	0	x
Cladocera		
Bosmina longirostris	x	0
Ceriodaphnia reticulata	0	xx
Chydorus pubescens	0	x
Daphnia barbata	xxx	0
Diaphanosoma excisum	x	x
Moina micrura	xx	0
Copepoda		
Mesocyclops aequatorialis similis	xx	0
Mesocyclops sp. (copepodites)	0	x
Metadiaptomus colonialis	xx	0
Thermocyclops decipiens	x	0
Thermocyclops oblongatus	x	xx
Tropodiaptomus processifer	xxxx	0
Nauplii	0	x

xxxx = very abundant; xxx = abundant; xx = less abundant; x = rare; 0 = absent.

micrura and the rotifer *Keratella tropica* were also present but in smaller numbers.

The much sparser zooplankton in Lake Finchaa was dominated by the cyclopoid *Thermocyclops oblongatus*, the cladoceran *Ceriodaphnia reticulata*, and the rotifers *Anuraeopsis fissa* and *Hexarthra mira*. Rotifers often constitute a substantial part of the zooplankton in reservoirs in temperate regions (see e.g. Pinel-Alloul *et al.*, 1982; Potter & Meyer, 1982). No calanoids were found.

Benthic fauna

The benthic fauna is very different in the two reservoirs, probably as a result of differences in total organic matter and dissolved oxygen.

Except for three larvae and one pupa of *Chaoborus* cf. *ceratopogones* (Chaoborinae) caught at a depth of 8 m, there were no benthic organisms in any of the samples from Lake Finchaa. Even in the marshy area around the edge of the reservoir, only very few ostracods, chironomids and oligochaetes were collected by using a hand net.

The absence of Oligochaeta, particularly Tubificidae, in this lake seems unusual. The Tubificidae occur in large numbers in many Ethiopian Rift Valley lakes, including the very saline lakes Shala and Abijata (Tudorancea & Harrison, in press). It is well known that some tubificids such as *Tubifex* and *Limnodrilus* can tolerate a high organic content in sediments and considerable oxygen depletion. It seems that the presence of acids which inhibit the growth of the bacteria on which the worms feed, may

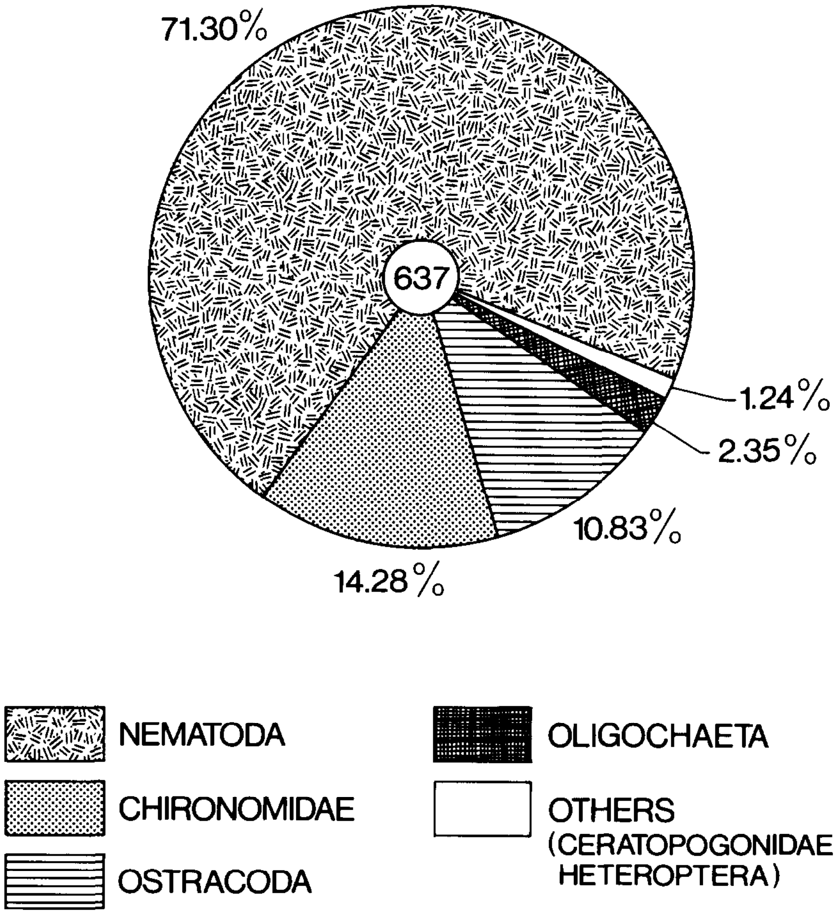

Fig. 6. Percentage abundances of benthic organisms in Lake Koka in February, 1985. The total number of organisms is shown in the middle of the circle.

be responsible for the absence or scarcity of oligochaetes (Brinkhurst & Cook, 1974).

By contrast, the benthic fauna in Lake Koka is composed of the same major taxonomic groups as that of other Ethiopian Rift Valley lakes. The numerically dominant group is Nematoda followed by Chironomidae and Ostracoda (Fig. 6). Oligochaetes represented a relatively small proportion in comparison with their proportions in natural lakes of the Rift Valley (Tudorancea, unpublished data).

Table 5 shows the densities of the major taxonomic groups in Lake Koka sediments. Except for oligochaetes, which occur in low densities at all three depths studied, densities were generally higher at the two deeper water stations than at the nearshore station, perhaps because of the sandy and relatively hard bottom near shore. Two groups of insects, Ceratopogonidae larvae and Heteroptera, occurred only at one station and at relatively low densities.

These two reservoirs provide an interesting contrast. Lake Koka appears to have become very similar to the other lakes of the Ethiopian Rift Valley. The small proportion of oligochaetes in the benthos of this lake compared with that in natural lakes of the region suggests that the ecosystem may not yet be fully mature. The conductivity stratification which we observed appears to be of a type often observed in reservoirs and associated with the particular morphological and hydraulic characteristics which tend to differentiate reservoirs from natural lakes (Kennedy *et al.*, 1985).

Lake Finchaa is very different, partly because of its greater altitude and the quality of its feedwater, but mainly because its basin was originally a swamp rather than open savanna. This led to a very large initial input of organic matter and an additional loading each year as refilling drowns new growth on the draw-down zone. Oxidative and fermentative degradation of this material is probably responsible for the partial deoxygenation and acidification of the water (Gunnison *et al.*, 1985) which in turn have adversely affected both the planktonic and the benthic communities. It seems likely that this state of affairs will continue almost indefinitely.

Table 5. Densities of benthic taxa (individuals/m^2) at various depths in Lake Koka, February 1985.

	Depth of water at station (m)		
	2.5	6.0	8.0
Nematoda	244	9333	341
Oligochaeta	133	67	89
Ostracoda	22	756	533
Chironomidae*	178	600	830
Ceratopogonidae	-	89	-
Heteroptera	-	111	-

*These included the following: *Harnischia* sp. (common at 2 m station); *Microchironomus* sp. (common at 6 and 8 m stations); *Procladius* sp., *Clinotanypus* sp.

Although both these reservoirs were constructed for the generation of electricity, it would be desirable if they could be used in other ways, particularly for the maintenance of commercial fisheries. Koka is already used for this purpose to some extent, and could probably yield a greater return if it were not for the presence of submerged trees which interfere with the use of nets (Feyissa, 1983).

Finchaa appears less promising, if the conditions we observed are representative of the reservoir as a whole throughout the year. The low chlorophyll *a* concentration in our sample suggests that primary productivity is low, and the undersaturation in oxygen and the almost total absence of benthic invertebrates and paucity of zooplankton make it appear somewhat unpromising as a habitat for fish.

Acknowledgements

We are grateful to the Water Resources Development Authority, and particularly to Ato Bekele Desta and to driver Ato Abraham Woldemichael, for providing accommodation and logistic support.

We thank Dr. A. Sarnita, Dr. Ranjani Rajapaksa, Dr. Danielle Defaye, Dr. B. Dussart, Dr. A. D. Harrison and Dr. J. Green for identifying specimens, and R. Kellerman for chemical analyses.

This work was done in the course of a joint project in limnology and freshwater biology between Waterloo University and Addis Ababa University, funded by the Canadian International Development Agency (CIDA). RMB was on a leave of absence from the National Water Research Institute. We thank all these institutions for their support.

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