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LIMNOLOGY PROJECT AT MAHAWELI RESERVOIRS; II A Limnological study at Kotmale, Victoria and Randenigala reservoirs.

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Abstract

The objective of this study was to collect basic data to ascertain status of Kotmale, Victoria and Randenigala reservoirs and to understand the trophic evolution of the reservoirs. The transparency values changed with the reservoirs. The highest frequency percentage of secchi depth observed at each reservoir are; Victoria 1.21—1.61m, Randenigala 2.51—3.01m and Kotmale 2.10—2.30 indicating highest value at Randenigala and the lowest value at Victoria. All three reservoirs are thermally stratified and the highest differences in temperature gradients were observed from surface to about 25m depth. In the deeper layers the temperature gradient is distinctly low. The highest conductivity values were observed closer to the dams of the three reservoirs indicating accumulation of dissolved ions towards the dams. In all three reservoirs the pH gradient was higher at the surface compared to the values bellow 10m depths. The high dissolved Oxygen concentrations are closely linked with the euphotic zones. Oxygen concentrations were markedly low below the depth of 20m. However there is no completely deoxygenated layers at the bottom of the reservoirs.

Data on chemical substances also proves the development of a strong chemocline below 20m depth level. Water hardness values are high when water retention levels of the reservoirs are low. High levels of Hydrogen Sulfide concentrations have been observed at the bottom layers of Randenigala reservoir from time to time. Sulfide concentration increased with the increasing depth of the reservoirs. The range of Nitrite concentrations recorded for Victoria is 0.005—0.1 ppm and for Randenigala 0.01—0.08 ppm. Ammonia was recorded only in deeper layers below the 45m level at Randenigala.

The zooplankton community of the three reservoirs consists of Copepods, Rotifers and Cladocerans.

The phytoplankton community of the three reservoirs consist mainly of green and blue green algae.

Key Words: Mahaweli Reservoirs, Thermally stratified, chemodine, Zooplank ton, Phytoplankon.

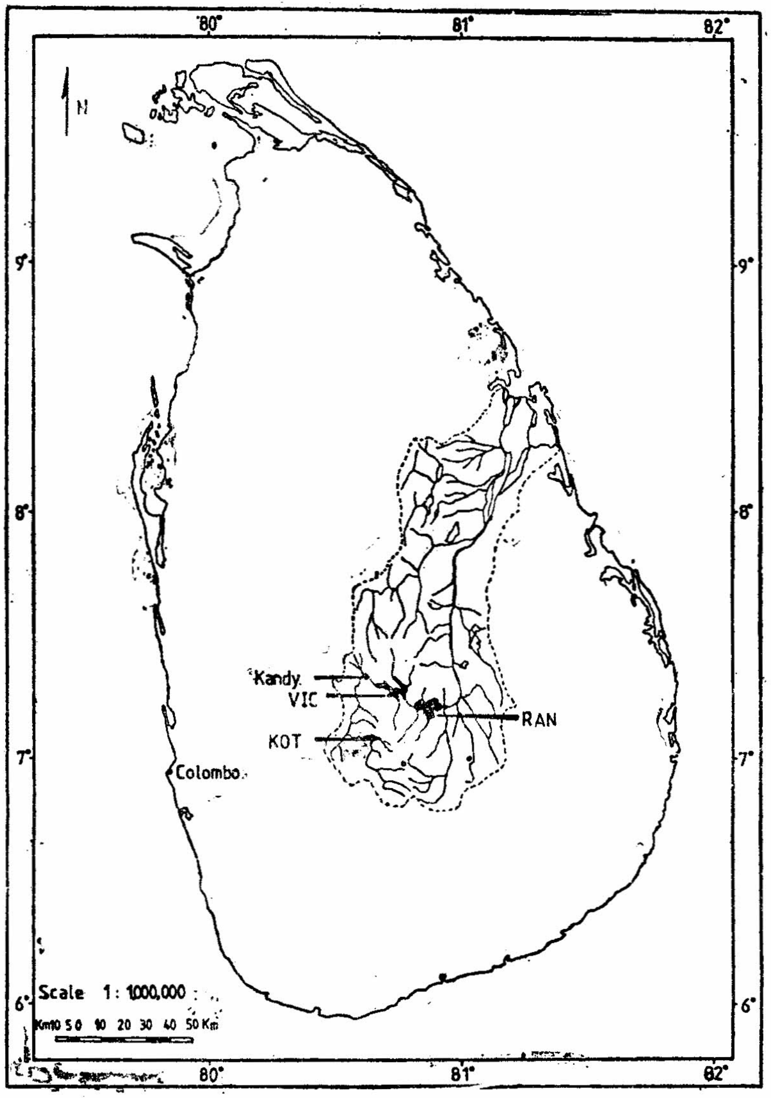

Fig. 1. Catchment area of river Mahaweli and the location of the three reservoirs, Kotmale (KOT), Victoria (VIC) and Randenigala (RAN) under investigation.

1. Introduction

Kotmale, Victoria and Randenigala are the three major deep reservoirs resulted from the accelerated Mahaweli Project. These reservoirs originated due to damming of the Mahaweli river (Fig.1) for the purposes of hydroelectric power generation and irrigation.

The morphometric and hydrological data of the three reservoirs are summarized in Piyasiri 1991. Fig. 2 illustrates the capacity and area curves of the three reservoirs.

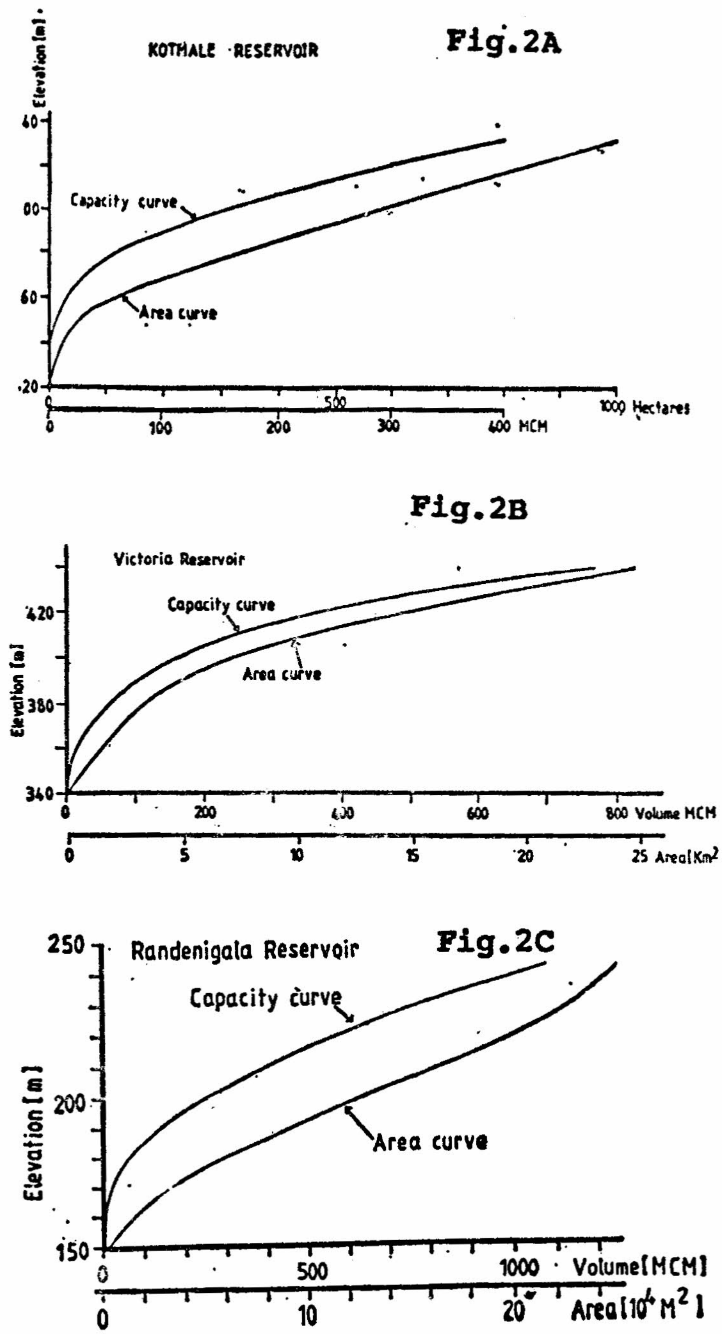

Fig. 2. Capacity and area curves of (2A) Kotmale, (2B) Victoria and (2C) Randenigala reservoirs.

A complete and continuing limnological survey of the Mahaweli reservoirs is a necessity in order to protect the water bodies from the dangers of eutrophication and pollution.

Objective of the present paper is to summarize some of the limnological observations of the three reservoirs in terms of physico-chemical and biological properties. Results of this paper is based on the preliminary investigation carried out from March 1987 to February 1988.

2. Materials and Methods

Sampling was done in order to obtain adequate data for characterizing the water bodies. Water samples were collected from three major stations and from several substations at each reservoir using a RUTTNER'S sampler (1 L capacity) operated from a boat and attached to a winch and an integrated depth meter. For locations of major and substations see Piyasiri 1991. At each major stations, samples were collected from the bottom to the top at 5 m intervals whereas at sub stations the samples were taken only on the surface and at 10m depths. This sampling procedure was used in order to study the vertical and horizontal distributions of the parameters. Sampling was carried out once a month at Kotmale and Randenigala and every fortnight at Victoria. Secchi depth measurements were taken at each sampling station. Water temperature, conductivity, pH values and dissolved Oxygen concentration were measured in each water sample collected using a thermometer, a type 300 Chemtrix Oxygen meter, a type 300 conductivity meter (automatically corrected to 20^0 C by internal thermister network in probe) and a pH meter (model 3070 Jenway) respectively. Ammonium, nitrate and nitrite were measured using MERCK—Aquant test kits.

Chlorophyll—a concentrations were measured using a spectrophoto metric method. Plankton samples were collected using a closing type net (20 μ — 30 μ net sizes) for investigations on phytoplankton and zooplankton. Samples collected were transferred into plastic bottles and fixed in formalin. Further analysis of the samples for plankton studies were done in the zoology laboratory at University of Sri Jayawardenepura.

Results

3. Light Penetration

Diagrams published in Piyasiri 1991 illustrate the percentage frequency distribution of Secchi depth values in the three reservoirs. Size classes of the Secchi depth for the highest frequency percentages of such measurements recorded from each reservoir are as follows; Victoria 1.21 m—1.61 m, Randenigala 2.51 m — 3.01 m and Kotmale 2.10 m — 2.30 m indicating that the highest transparency values at Randenigala and the lowest at Victoria.

In general the highest transparency values were observed during January, February and March in all three reservoirs. The chlorophyll density measured at Victoria reservoir during the investigations showed that the transparency is influenced by the Chlorophyll—a density to a certain extent during some months (Fig. 3).

The mean euphotic limits calculated from mean Secchi depth values for the three reservoirs are 5.10 m$\pm$0.39 for Kotmale, 5.00$\pm$0.30 m at Victoria and 6.25$\pm$0.59 at Randenigala respectively. Below this compensation level primary productivity is considered to be nil.

Water Temperature

Accordng to the classification of Hutchinson & Loffler 1956, the three reservoirs under investigation belongs to the category of Oligomictic lakes where temperature are well above 4^0 C with a rare circulation.

The thermal behavior are identical for all three reservoirs. Unlike in the reservoirs in the temperate countries, vertical heterogeneity occurs throughout the year in the reservoirs under observation. The mean epilimnetic water temperatures are around 26^0C at Kotmale, 27^0C at Victoria and 28^0C at Randenigala during the investigation period. However, the epilimnetic water temperatures may often vary due to weather conditions such as wind action and rain. Below 20 m the temperature gradient for all three reservoirs are below 0.03^0C/m thus causing formation of a strong thermocline. The daily density changes in the upper 15—20 m strata of waters of the reservoirs cause relocation of these strata even during windless days, but such changes in the epilimnion do not disturb the firmly established thermocline. However, due to hydroelectric power generation and the run-off of water at the bottom layers, the upper Oxygenated water layers get mixed with the bottom layers periodically.

Thermal stratification has a pronounced influence on the distribution and concentration of several elements, primarily Oxygen. Due to thermal stratification, Oxygen concentrations near the bottom starts to decrease. (Piyasiri 1991).

Dissolved Oxygen

Oxygen stratification follows a similar pattern of variation in the three reservoirs. Oxygen concentration closer to the bottom of the reservoirs decreased resulting in a clinograde Oxygen curve.

However there is no evidence of complete deoxygenated layers at the bottom of any reservoir under observation.

The high Oxygen concentrations are closely linked with the euphotic zones of the three reservoirs where photosynthetic activity is high. The mean oxygen concentrations calculated for the surface waters closer to the dams are 7.5 ± 1.76 mg/l at Kotmale 6.5 ± 1.06 mg/l at Victoria and 6.4 ± 1.03 mg/l at Randenigala. The mean Oxgen concentration at 5 m depths are 6.6 ± 1.33 mg/l at Kotmale, 5.5 ± 2.04 mg/l at Victoria and 5.2 ± 2.20 mg/l at Randenigala.

Oxygen depletion is markedly observed below the depth of 20 m in all three reservoirs where mixing of surface waters with the deeper layers are limited. Chemical data also show the development of a strong chemocline below the 20 m level.

Conductivity

There is a marked seasonal fluctuation of conductivity values in the three reservoirs. The lowest conductivity values recorded from Randenigala are from December to March. During this period, the recorded mean conductivity values fall within the range of 110—116 μs/cm.

The low conductivity ranges of 98—116 μs/cm at Victoria occurred during December to March. The lowest value of 30 μs/cm occurred at Kotmale reservoir in February 1987.

The highest conductivity values are recorded for waters closer to the dams of the three reservoirs indicating an accumulation of dissolved ions towards the dams. The mean conductivity values of the vertical profiles of the waters recorded from the three reservoirs fall into the ranges of 30—87 μs/cm at Kotmale, 85 — 139 μs/cm at Victoria and 110—188 μs/cm at Randenigala. The highest range is observed from Randenigala, the lowest at Kotmale with an intermediate value at Victoria.

pH Values

The pH vary between 6.07—8.36 at Kotmale, 6.20—8.32 at Victoria and 6.88—6.69 at Randenigala during this investigation period. Mean pH values above 7 have been recorded during June, September, November of 1987 and January and March of 1988 in Victoria, in October December 1987, and February 1988 at Randenigala and in November 1987, January and in March 1988 at Kotmale.

In all three reservoirs the pH gradient is steeper above 10 m depths whereas below this depth pH remained more or less constant. However, in all three reservoirs pH values are generally higher at the surface compared to the values below the 10 m level.

Chemical Parameters

Water hardness—

The high mean hardness values around 1 m.mol/l have been observed for Victoria in March and June, in August, September, October, at Randenigala respectively. From Nov. 1987—March 1988, the hardness values were below 0.5 m.mol/l. There is a significant correlation between the water hardness and the water retention levels of the reservoirs.

It has been observed that high hardness values are often correlated with the low water retention levels of the reservoirs and decrease of hardness with the increasing water level. (refer to the diagram in Piyasiri 1987).

Sulfate

According to the analysis made during the preliminary investigation period the sulfate concentration of the three reservoirs showed a tendency to increase with increasing depth. For instance at Victoria, the sulfate concentration increased upto about 6.5 ppm at 80 m, at Randenigala up to 4.7 at 60 m and at Kotmale up to 3.4 ppm at 65 m (Piyasiri 1987).

However, when the water retention levels of the reservoirs become low; like for instance at Victoria, in July 1988, and at Randenigala in August and October 1987 the Sulfate concentration decreased down to about 1 ppm. Out of the three reservoirs, the highest mean Sulfate concentrations are recorded from Victoria and the lowest from Kotmale closer to the dams.

Hydrogen Sulfide

Detectable levels of Hydrogen Sulfide was found mostly at the deeper layers of Randenigala and rarely at the Victoria and Kotmale reservoirs. The recent diurnal investigations of Randenigala (in July 1988) revealed concentrations upto about 0.5 ppm in the bottom 15m. The presence of Hydrogen Sulfide is closely associated with the depletion of Oxygen and low pH values.

Orthophosphate

The orthophosphate concentrations were at undetectable levels below 5 ug/l in all three reservoirs. The highest concentrations were recorded in the months of October and December 1987 at Victoria reservoir whereas comparatively low levels were recorded from Randenigala and Kotmale during this period

Nitrogen Compounds

Nitrite concentrations increased with increasing depth in all three reservoirs. The range of nitrite concentrations recorded from Victoria are between 0.005—0.1 ppm and at Randenigala betwen 0.01—0.08 ppm. Nitrate concentrations recorded from Victoria are in the range of 10—40 ppm.

Ammonia was recorded only in the deep layers of waters below 45 m at Randenigala. On two occasions 0.9 ppm. Ammonia were recorded from Randenigala at the major station 2 at 45 m and 50 m depths and at station 3 at 50 m and 55 m depths.

Plankton

Zooplankton

Among the species identified in the monthly samples collected, many typically limnetic species such as *Brachionus caudatus. Asplancha Brightwelli, Trichocerca* sp. *Keratella tropica. Lecane* (rotifera); *Diaphamosoma exisum, Ceriodaphnia cornuta. Moina. Bosminopsis Alona*— (Cladocera), *Meocyclops leukarti. Thermocyclops* and *Eudiaptomus* (copepoda) were found.

Some of these species mentioned occurred in most of the samples examined. These are *Brachionus caudatus. Trichocerca. Keratella tropica Diaphanosoma* sp, *Ceriodaphnia, Bosminopsis* and *Calanoids.* During some periods large number of copepod eggs and nauplii stages were observed.

Seasonal changes and population dynamics of these zooplankton will be discussed in Piyasiri and Jayakody 1991.

Phytoplankton

The taxonomic group represented by the most algal species were the blue green algae. The great variability in cell sizes, colony from and development of gas vacuoles in the *Microcystis species* were striking. The predominant species of blue greens consisted of *Microcystis* and that of diatoms consisted of *Melosera granulata* at all sampling depths. Among greens the predominant species were Cosmarium sp and *Trochischia* ap.

4. Discussion

Limnological studies in water bodies of Sri Lanka are rare. However, there is a case study on Limnology of Parakrama Samudra (Schiemer 1983) which summarize various limnological aspects of the lake. Present investigation is to identify the status of the reservoirs in terms of physico-chemical and biological parameters. Very few work has been conducted on these reservoirs, Dharmawardhana (1985). Tams, New York Anon. 1986 (Nov. 1981) and work of a group of German Scientists (Anon 1986).

No published information available on the light penetration of the three reservoirs. According to the present observations Victoria reservoir is the least transparent one. Low transparency values may not only caused by the algae but also by wind caused resuspension of sedimented particles decrease the transparency. The transparency minima (Fig. 3) in Feb. March, April, May and June 1988 coincide with Chlorophyll—a peaks indicating the resuspension of sedimented algae. Similar sedimentation has been reported in lake Tjeukemeer in Netherlands (Haan 1982). Thermal stratification observed in the three reservoirs is a known phenomena in tropical lakes and in lakes of temperate zones during summer. For instance similar stratification has been observed in lake Parakrama Samudra in Sri Lanka (Schiemer 1983) and lake Vechten in Netherlands (Steenbergin & Vedow 1982).

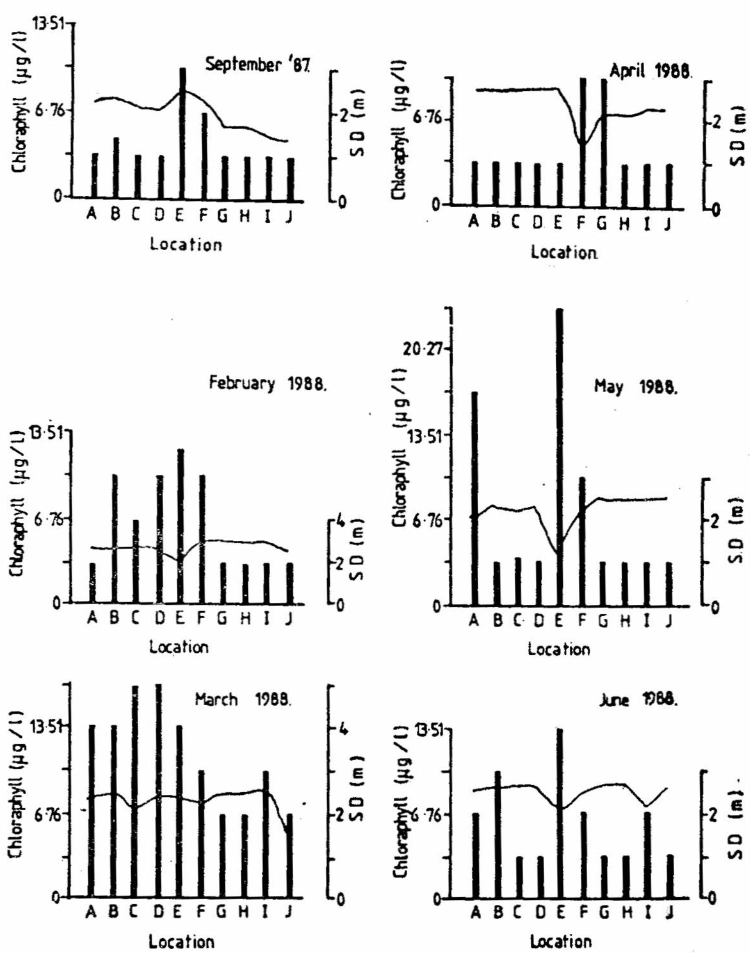

Fig. 3. Chloraphyll-a density (Black bars) measured at different substations (A–J) at Victoria reservoir. The horizontal line drawn across the black bars indica.e the Secchi depth values (SDm) observed at each substation.

Dissolved Oxygen concentrations of the three reservoirs show spatial and temporal variations. spatial variation is striking along the vertical profile of the reservoirs rather than along the length and the breadth. Temporal variations were observed during day and night and seasonally. In this type of large reservoirs (surface waters) the dynamics of the dissolved Oxygen concentration reflects the metabolism of the free water only, as against the shallow waters where it is reflection of total metabolism (also see Veenigen 1982). The variations in Dissolved Oxygen is further effected by the climatic conditions as solar radiation and temperature.

Conductivity is a measure of total dissolved salts in the reservoirs. Increase in conductivity values show a close relationship to decreasing altitude. The high conductivity values closer to the dams indicate discharge of more dissolved salts in to the reservoirs situated in low altitudes.

pH values of the three reservoirs indicate more alkaline conditions in the surface waters and slightly acidic conditions in the bottom. Low pH values in the bottom indicate the decomposition processes of the bottom waters. This is often correlated with the accumulated phytomass left at the bottom part of the reservoirs due to removal of trees during construction of reservoirs. Similar results has been reported for Randenigala in Anon 1986.

Water hardness values observed for the three reservoirs indicate comparatively low $Ca^{2}+$ and $HCO_{3}-$ ion concentrations in the three reservoirs.

Juday et al (1935) studied 234 lakes and recorded 0.75 to 7.86 mg Sulfate per litre. The mean content being 4.0 mg/l and the modal class containing 3.0—3.9 mg/l. In the reservoirs under present investigation, highest values observed are 3.4—6.4 ppm. (at the bottom regions of the reservoirs). However, in general, sulfate concentrations of the three reservoirs belong to the modal class (during present investigation period).

According to the experiments of Mortimer (1941—1942) increase in Sulfate with depth would likely to occur during stagnation, at least if stratification is maintained for a long enough period similar to the situation occur in the present reservoirs under investigation. Increase in Sulfate concentration with increasing depth, decreasing Oxygen concentration and decreasing temperature in the vertical profiles of the three reservoirs is very clear. This type of marked stratification in sulfur compounds is provided by the Grosses Sager Meer at the end of summer stagnation (Ohle 1955 a).

The Hydrogen Sulfide concentrations found at the bottom of the reservoirs are fairly low. However, at Randenigala, significantly high values have been observed in the bottom time to time. This may be due to the decomposition of accumulated phytomass at the bottom. In the tropical lakes of Indonesia the odor of Hydrogen Sulfide frequently indicated the presence of small amounts of the gas in the deep Oxygen deficient waters (Ruttner 1931).

The nitrite concentrations found in Victoria and Randenigala are less than 1 ppm. Minute amounts of nitrite are some times found in unpolluted surface has long been regarded as a warning of sewage contamination. Juday et al (1938) examining 504 surface samples collected during summer months from 307 lakes in north eastern Wisconsin also found presence of small quantities of nitrite in surface waters.

Ammonia is the major nitrogenous endproduct of the bacterial decomposition. The Ammonia concentration recorded from the bottom of Randenigala reservoir indicates the highest decomposition processes taking place in the bottom of the reservoir.

The zooplankton found in this survey consist of a typical tropical forms. The rotifera are characterized by the dominance of the genus Brachionus and *Keratella tropica.* These species were found in all most all the samples. Distinctly dominant species found in the limnetic region are *Ceriodaphnia cornuta. Diaphanosoma exisum* & *Bosminopsis* species. These species are tropicopolitan and atrophic which occur throughout the tropics and dominating limnetic zooplankton. The dominant cyclopids found were *Thermocyclops* sp. and *Mesocyclops leukarti.* They are also eurytropic.

Investigations on phytoplankton of the present survey is confined to the compositon of the algae. Details on algal periodicity and population dynamics will be discussed elsewhere.

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