LIMNOLOGICAL STUDIES OF THE PELAGIC ZONE OF LAKE TANGANYIKA AT KIGOMA, TANZANIA.

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ABSTRACT

Some limnological parameters and chlorophyll a were determined for twelve months at a pelagic station near Kigoma. Temperatures ranged between 25.7 ºC and 27.3 ºC at the surface, and 24.1 ºC and 24.7 ºC at100 m. Thermal stratification persisted throughout the year with the thermocline oscillating between 15 m in October and 60 m in May. Dissolved oxygen concentrations were high at the surface, ranging between 6.59 mg l^{-1} and 8.15 mg l^{-1}, while at 100 m the concentrations ranged from less than 0.20 mg l^{-1} to 1.94 mg l^{-1}. Nitrate-nitrogen concentrations in surface water ranged between 26 µg N l^{-1} in May and 74 µg N l^{-1}in December. Nitrate -nitrogen concentrations generally increased with depth to 80 m, after which they decreased. Soluble reactive phosphorus concentrations in the photosynthetic zone were always very low, ranging between 0.30 µg P l^{-1} and 4.0 µg P l^{-1}. The concentrations increased with depth. Total phosphorus concentrations in the surface water were also low, ranging between 2.0 µg P l^{-1} in March and 12.0 µg P l^{-1} in August. The concentrations increased with depth. Chlorophyll a concentrations were generally low throughout the year, except for October and April-May when high concentrations were found. In October the mean concentration was 4.52 µg Chl a l^{-1}, while January had the lowest concentrations with a mean of 0.36 µg Chl a l^{-1}. Chlorophyll a concentrations decreased with depth.

INTRODUCTION

Lake Tanganyika is the deepest lake in Africa and contains the second largest volume of anoxic water after the Black Sea (Hecky 1991). The lake lies between 3^0 31' and 8^0 50' S and 29^0 05' and 31^0 15' E (Plisner *et al.* 1999). It is about 650 km long, with an average width of 50 km, lying at an elevation of 773 m asl. (Edmond *et al*. 1993).

In the mixolimnion, the water does not mix completely but there is a stable stratification in the pelagic zone (Coulter 1963). In the northern basin around Kigoma, vertical mixing is confined above the thermocline at 50 to 80 m (Coulter & Spigel 1991). It has been shown that in Lake Tanganyika, most of the nutrients are found in the deep monimolimnion (Hecky *et al.* 1991) and their upward transport occurs mainly during the dry season when maximum circulation takes place (Hecky 1991). Strong south easterly winds blow over the lake between May and September, causing upwelling in the southern end of the lake (Coulter 163, Hecky op. cit., Coulter & Spigel op. cit.). However, rainfall is reported to contribute more than 50 % of total dissolved fixed nitrogen in the lake (Edmond *et al.* 1993; Hecky op. cit.). Hecky and Kling (1981) also reported that nitrogen fixation by *Anabaena* spp. is likely to be a very important process in the lake.

Chale (2004) reported minimum secchi disc readings and very high chlorophyll *a* levels in the offshore water around Kigoma in October. The low secchi disc visibility and high chlorophyll *a* had been shown to be a result of *Anabaena* spp. blooms which take place during that period (Hecky and Fee 1981, Plisnier *et al.* 1999).

Phytoplankton biomass expressed as chlorophyll *a* has been reported to be generally low (Hecky and Kling 1981), with the exception of Octber-November when very high concentrations have been found (Chale 2004). These high levels have been attributed to the heterocystous cyanobacteria *Anabeana* spp. which bloom during that period (Hecky and Fee 1981, Salonen *et al.* 1999, Hecky 1991).

Kurki *et al.* (1999) reported cyclopoid copepods to dominate the zooplankton in the pelagic zone throughout the year with peaks in October-November and at the end of the wet season in April and May. The zooplankton could have a negative effect on the phytoplankton due to grazing.

In the following, profiles of monthly limnological data and chlorophyll *a* in the offshore water of L. Tanganyika near Kigoma are presented. The study was conducted between July, 1998 and June, 1999.

MATERIALS AND METHODS

The study was carried out at an offshore station about 5 km from shore where the depth was more than 500 m (Chitamwebwa 1999). Sampling was conducted in the mixolimnion to the depth of 100 m. In order to minimize changes in the water characteristics, sampling was always carried out between 9:30 am an 10:30 am.

Water temperature and dissolved oxygen were determined at 5 m intervals using a Yellow Springs Incorporated, Model 50B Dissolved Oxygen Meter with a cord length of 80 m. Temperature and dissolved oxygen values between 85 m and 100 m depths were obtained on samples brought on deck the vessel.

Samples nutrients and chlorophyll a were collected at 20 m intervals using a 7.4 litre capacity (Limnos, Finland) water sampler.

Sample treatments for nitrate-nitrogen, soluble reactive phosphorus and chlorophyll *a* were carried out as described in Chale (2004).

All sample analyses were carried out in triplicate.

RESULTS

Surface water temperatures were always high, ranging between 25.7 ^{o}C in August and 27.3 ^{o}C in February (Fig. 1). Bottom water temperatures did not differ much throughout the study period, with values between 24.1 ^{o}C in October and 24.7 ^{o}C in April and May. Thermal stratification was observed throughout the year, though the depths at which the thermocline occurred differed from month to month.

Dissolved oxygen concentrations in the surface water ranged between 6.59 mg l-1 and 8.15 mg l^{-1} in August and April, respectively (Fig. 2). There was always oxygen at 100 m, though the concentrations differed during the different months. In November, April and May, the oxygen concentrations were 1.94 mg l^{-1}, 1.07 mg l^{-1} and 1.60 mg l^{-1}, respectively at 100 m. Low oxygen was found in October from the depth of 20 m. At 20 m the concentration was only 3.03 mg l^{-1}.

Nitrate-nitrogen concentrations in surface water ranged between 26 µg l^{-1} in May and 66 µg l^{-1} in December (Fig. 3). From the surface to 40 m, NO_3-N concentrations generally increased slightly. But after 40 m steep increases to 80 m were observed. For example, the mean NO_3-N concentration was 61 µg N l^{-1}, while at 60 m it was 118 µg N l^{-1} and at 80 m it was 218 µg N l^{-1}. After 80 m, the concentrations generally decreased.

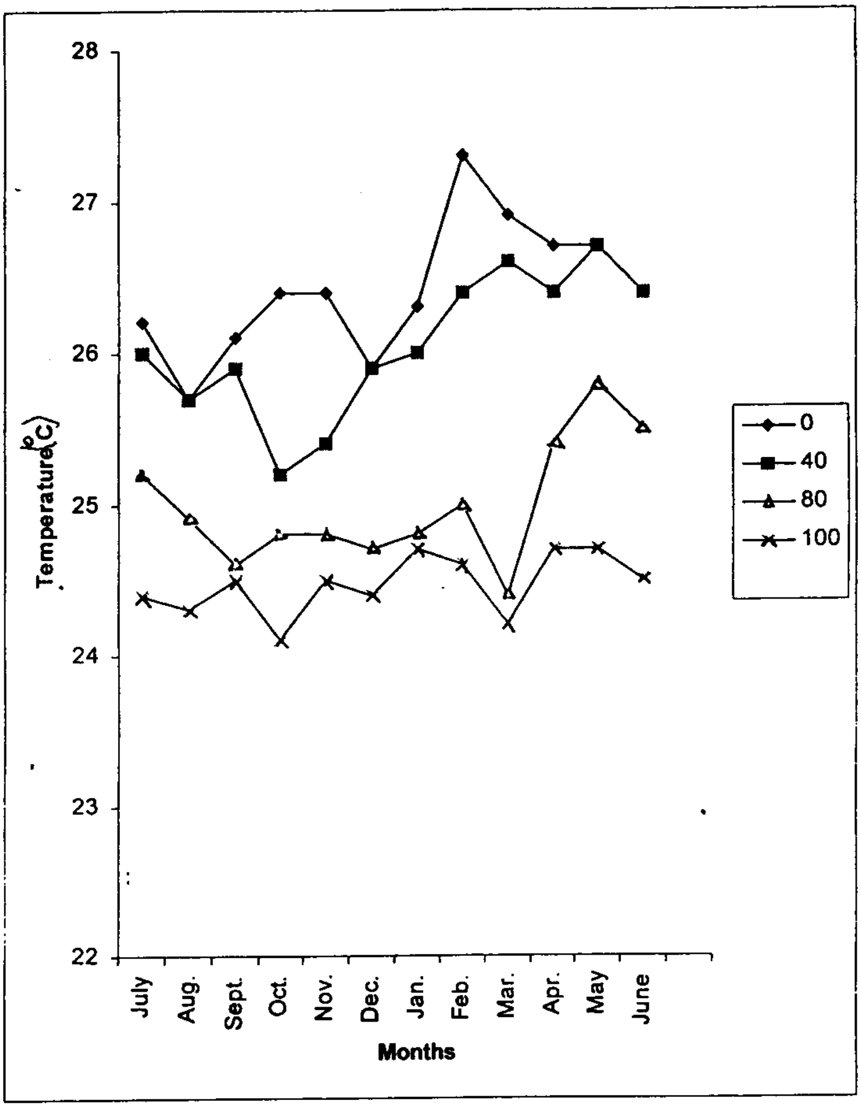

Figure 1: Monthly Temperature (°C) Profiles at Various Depths.

Soluble reactive phosphorus (SRP) concentrations in the euphotic zone were usually very low (Fig. 4). The lowest values were obtained in August, December, January and March, when the concentrations were close to the limit of detection (0.25 µg P l^{-1} with a 4 cm cell). The mean SRP in the euphotic zone was 1.75 µg P l^{-1}.

Chlorophyll *a* concentrations are presented in Fig. 5. In July, February and March, peak levels were obtained at 40 m. October had the highest levels throughout the water column with a mean concentration of 4.52 µg Chl *a* l^{-1} (range 3.2 and 5.11 µg Chl *a* l^{-1}).

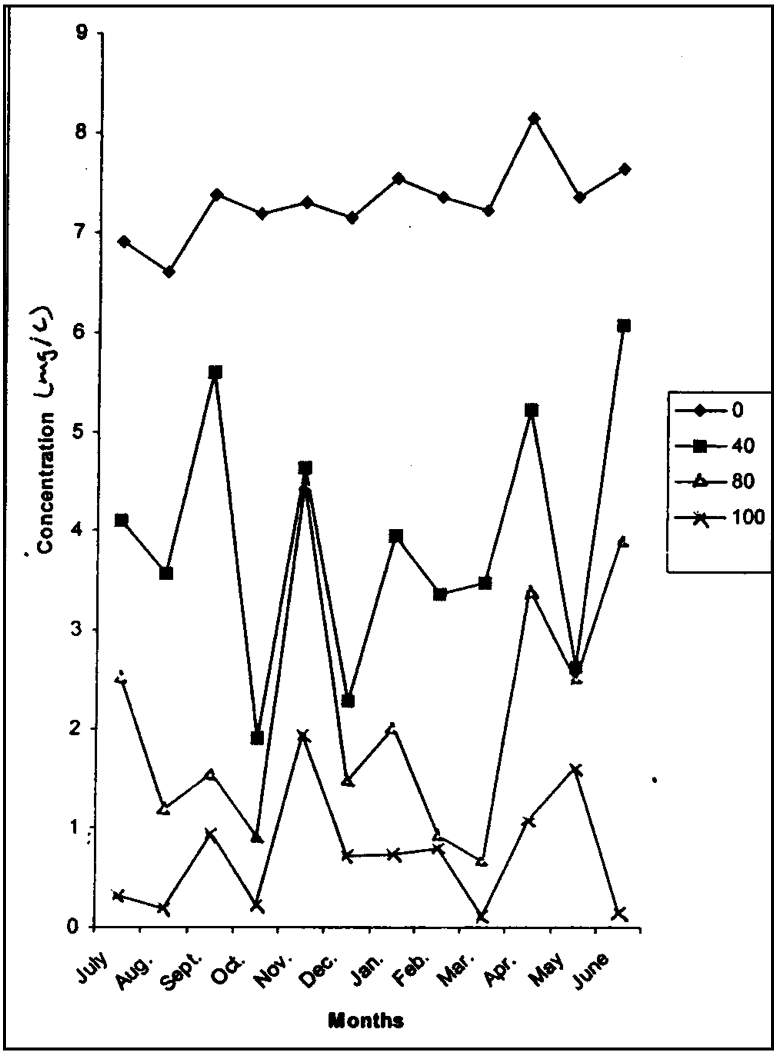

Figure 2: Monthly Dissolved Oxygen Concentrations (mg l^{-1}) with Depth.

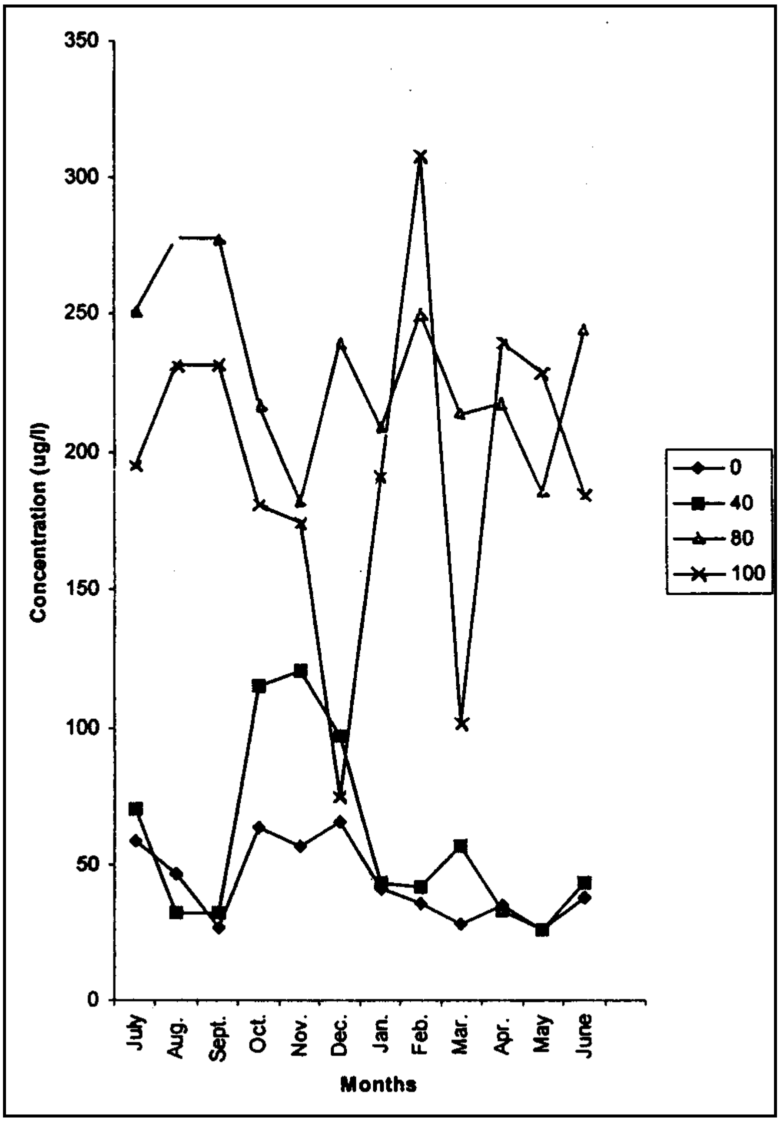

Figure 3: Nitrate- nitrogen ($\mu g\ l^{-1}$) with Depth at Sampling Location.

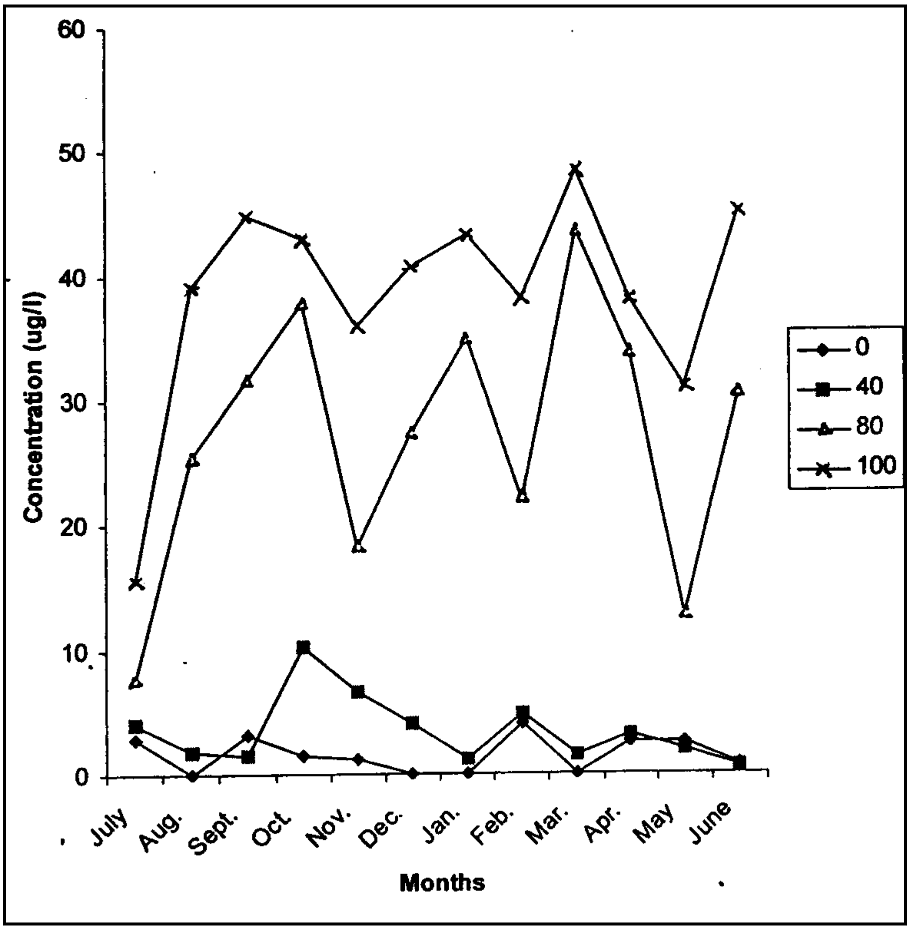

Figure 4: Monthly Soluble Reactive Phosphorus Concentrations (µg ll^{-1}) at Sampling Location.

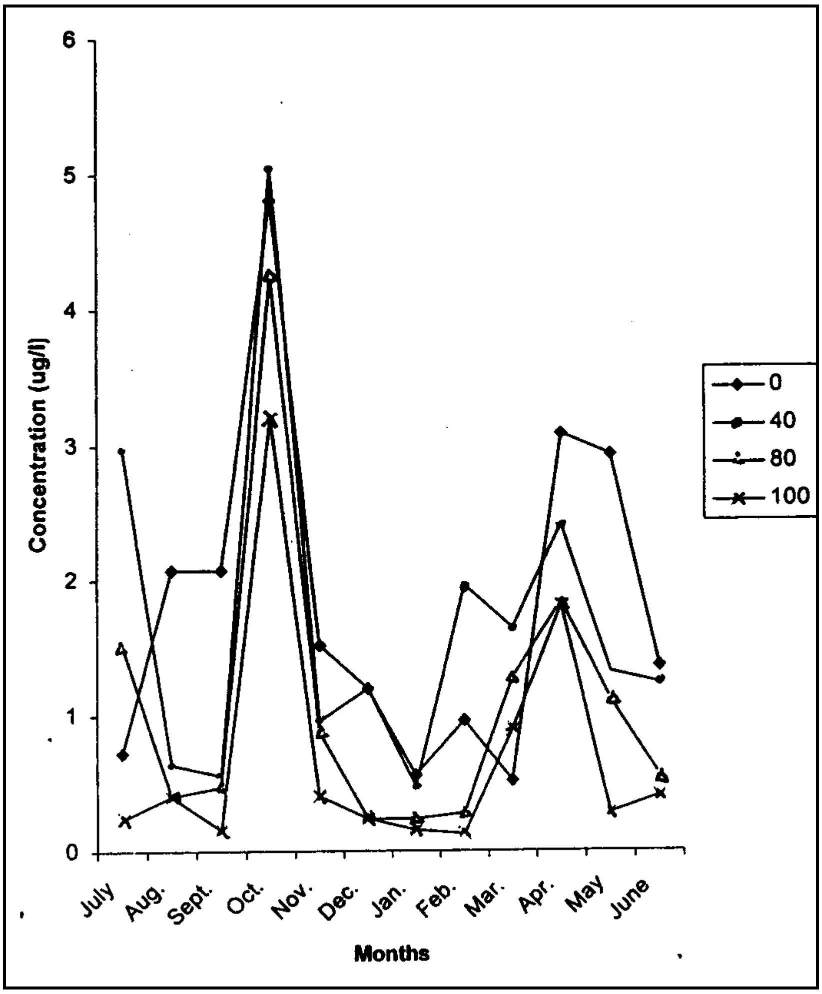

Figure 5: Chlorophyll *a* Levels (μg l^{-1}) at Sampling Location.

DISCUSSION

Thermal stratification was observed to persist throughout the year, with maximum depth during the dry season in May and July and also in December. The permanency of the thermocline in the northern basin has also been reported (Coulter 1963, Coulter and Spigel 1991, Chitamwebwa 1999, Plisnier *et al.* 1999). Coulter and Spigel (op. cit.) stated that stratification was at its maximum during the rainy season. However, Plisnier *et al.* (op. cit.) observed deepening of the thermocline at Kigoma between November and June. This covered the wet season and part of the dry season. In the present study, the deepening of the thermocline was observed during both periods as reported by Plisnier *et al.* (1999). The highest surface temperature (27.3 °C) was recorded in February, while the lowest was recorded in August. A similar situation was reported by Coulter and Spigel(1991) for Kigoma. At 100 m, the temperature ranged between 24.1 °C and 24.7 °C, a range which had been reported before (Chitamwebwa 1999, Edmond *et al.* 1993).

In the present study, the thermocline was observed to oscillate between 15 m and 60 m.

Oxygen was present throughout the study period from surface to 100 m, though the bottom water had very low concentrations. The occurrence of oxygen below the thermocline has also been reported by Coulter (1963). The deeper penetration of oxygen may have been due to ventilation of the metalimnion (Hecky *et al.* 1991). The low oxygen concentrations found in October from the depth of 20 m may have been a result of advection of deep water into the metalimnion (Plisnier *et al.* 1999, Coulter 1963) and also decomposition of dead organic matter. In October, heavy scums of *Anabaena* spp. were observed in the study area (Hecky and Kling 1981).

Nitrate-nitrogen concentrations in the euphotic zone ranged between 26 µg N l^{-1} in may and 74 µg N l^{-1} in December. hecky and Kling (1981) reported mean concentrations of total dissolved fixed nitrogen ranging between 49 and 84 µg N l^{-1} in the euphotic zone. In the present study high NO_3-N concentrations were found between 60 m and 80 m (Fig.3). The mean nitrate levels at those depths were 118 µg N l^{-1} and 218 µg N l^{-1}, respectively. Plisnier *et al.* (1999) reported maximum NO_3-N concentrations between 60 m and 80 m in the north of the lake, while Jarvinen et al. (1999) found higher nitrate levels between 40 m and 60 m at Kigoma. In the present study, maximum nitrate concentration was found at 100 m in February, when the value was 308 µg N l^{-1}. Edmond et al. (1993) reported a maximum NO_3-N concentration of 154 µg N l^{-1} at 96 m in April at Kigoma. In Lake Tanganyika, rainfall is reported to contribute at least 50 % of total dissolved fixed nitrogen (Hecky 1991, Hecky et al. 1991, Edmond et al. op. cit.). The high levels between October and december could be a result of fixation by *Anabaena* spp. and rainfall (Edmond et al. op. cit. Hecky op. cit.). The generally low concentrations in the photosynthetic zone may be due to uptake by phytoplankton (Hecky and Kling 1981; Hecky *et al.* 1991).

In L. Tanganyika, most of the nutrients are in the monimolimnion and their supply to the mixolimnion depends on vertical mixing (Coulter 1963, Hecky *et al.* op. cit., Edmond *et al.* 1993, Plisnier *et al.* 1999). The general decline of nitrate after 80 m could be due to denitrification processes (Edmond *et al.* 1993). The low levels of dissolved phosphorus in the epilimnion have been stated to be a result of phytoplankton uptake (Hecky and Kling op. cit., Hecky *et al.* 1981).

October had the highest concentrations of chlorophyll *a* throughout the mixolimnion. Peak chlorophyll *a* levels in the euphotic zone were obtained in October and a small peak in April-May (Chale 2004). Similar observations were reported by hecky and Fee (1981). The high concentration of chlorophyll *a* in October could have been due to *Anabaena* spp. which were found to bloom during that period. Hecky and Kling (1981) reported similar observations at Kigoma.In April-May, chrysophytes have been shown to dominate the phytoplankton and Kigoma (Hecky and Kling op. cit.), whose population maximum could be a result of secondary upwelling (Plisnier *et al.* 1999, Chale 2004). The role of zooplankton to phytoplankton populations in the lake is not well known. Kurki *et al.* (1999) reported the dominance of cyclopoid copepods in the zooplankton during October-November and April-May. The zooplankton would underestimate phytoplankton biomass through selective grazing.

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