EUTROPHICATION OF KIGOMA BAY, LAKE TANGANYIKA, TANZANIA

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ABSTRACT

Studies carried out in Kigoma bay (Tanzania) and at a deep water offshore station in lakeTanganyika showed marked differences in the water characteristics at the two locations. At the pelagic station, the water was more transparent (mean 11.47 m) and poor in phosphorus (mean 6.46 µg p/1 and 2.23 p/1 total and soluble reactive p, respectively). The mean transparency value for the bay was 4.05 m, and the levels of total and soluble reactive phosphorus were 14.75 µg p/1 and 4.34 µg p/1, respectively. The high water transparency coupled with low phosphorus levels in the pelagic zone indicate that the pelagic region is oligotrophic, while the values for the bay show that it is meso – eutrophic. Nitrogen levels in the bay were also much higher (mean 61 µg n/1) than in the open waters (44 µg n/1). Phytoplankton biomass, expressed as chlorophyll a, was higher in the bay (mean 2.42 µg /1) than in the pelagic region (mean 1.55 µg /1). The high nutrient levels in the bay may have caused the high chlorophyll a values in there. During October 1998, very high chlorophyll a values (4.80 µg /1) and low transparency (7.70 m) were obtained at the offshore station. High chlorophyll a levels and low water transparency in the pelagic zone of the lake during October has also been reported by other workers. The high chlorophyll a levels are believed to result from Anabaena spp. blooms that occur during this period. High levels of nitrogen levels have also been observed during October.

Key words: *Lake Tanganyika, Kigoma bay, eutrophication, nutrients, chorophyll a.*

INTRODUCTION

Lake Tanganyika is a large rift valley meromictic lake with a maximum depth of 1470 m (Coulter & Spigel 1991). The pelagic zone of the lake is considered to be oligotrophic with high water transparency and low phosphorus levels (Coulter 1963, Hecky *et al.*, 1991, Edmond *et al.* 1993). Hecky and Kling (1981) showed that phytoplankton biomass expressed as chlorophyll a was usually low (mean 0.50 µg /1) for the central portion (off Kigoma) of the lake. High concentrations of chlorophyll a (mean 1.20 µg/1) have been obtained during October – November and attributed to *Anabaena* sP. blooms (Hecky & Fee 1981 Hecky & Kling 1981 Hecky 1991).

Kigoma Bay (Fig. 1) is about 4 km long and 3 km across and is surrounded by Kigoma town which has an estimated population of about ninety thousand. The bay is shallow with a maximum depth of less than 25 m and is the source of the town's domestic water supply. Some untreated domestic wastewater and oil from an electricity generating plant drain into the bay. These may not only be of concern to public health, but also they can affect the biodiversity in the bay. Run off from the surrounding area also enters the bay during the rainy season.

In order to find the impact of human activities at the bay, studies were conducted within the bay and at an off shore station that was about 500 m deep (Chitamwebwa 1999) and about 4 km off Nondwa Point in the pelagic zone. Samples were collected twice per month in the bay and monthly at the off shore station between July 1998 and June 1999.

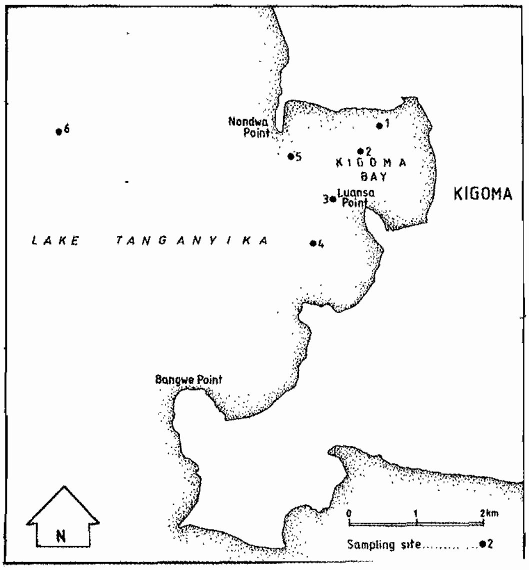

Figure 1: Map of Kigoma Bay showing the Sampling stations, 1-6.

MATERIALS AND METHODS

Integrated water samples were collected to depths of 10 m using a 2.5 cm internal diameter flexible plastic pipe weighted at the bottom. After lowering the pipe to the desired depth, the upper open end was stoppered with a rubber bung and the pipe hauled using a 2 mm diameter nylon string. The samples were then transferred to plastic buckets which had previously been rinsed with aliquots of the collected water. Two litre and one litre capacity plastic bottles were then filled with the samples, stoppered tightly and immediately stored under ice. The two litre samples were later used in chlorophyll a determinations, while one litre samples were used for nutrient analyses. Sample pH and temperature were determined in the field on aliquots of the collected water immediately after collection using a Model HI 9023 microcomputer pH meter. Conductivity values were obtained with a Model HI 8033 Portable Multi-Range Conductivity/TDS meter manufactured by Hanna Instruments, Italy. Conductivity values were then converted to specific conductance at 25 ½C. The pH meter was always standardized using pH 4.01 and pH 7.01 buffers. The above determinations were carried out in the field.

Transparency was obtained with a 20 cm diameter secchi disc. Samples for dissolved oxygen determinations were collected at the surface and at 10 m depths using a two (2) litre capacity van Dorn water sampler. The samples were fixed in the field for subsequent later determinations of dissolved oxygen using the modified Winkler method (Anon. 1980).

In the laboratory, 500 ml aliquots of the one litre bottle samples were filtered through pre-washed 0.45 m Whatman GF/C filter papers for soluble reactive nutrient determinations. In most cases, the filtered samples were analyzed on the day of sample collection. When it was not possible to carry out the analyses on the day of sampling, the samples were ice frozen and analyzed the following day. The unfiltered portions of the samples were used for total phosphorus determinations.

Soluble reactive phosphorus was determined as orthophosphate using the ascorbic acid method (Anon. 1980) on 50 ml aliquots. Nitrate-nitrogen was determined as the nitrite ion using the sulphanilamide method (Wetzel & Likens 1991) after reducing the nitrate ion through a copper-cadmium column (Mackereth *et al.* 1989). Initial determinations of ammonia and nitrite showed the absence of the two ions, and hence they were not analyzed further. Silica was determined on filtered samples using the molybdosilicate method (Anon. 1980).

Total phosphorus was determined on unfiltered samples by the ascorbic acid method, after digestion with 5% w/v potassium persulphate solution (Wetzel & Likens 1991). Sample digestion with a mixture of potassium persulphate and concentrated Sulphuric acid, as described in the Standard Methods (Anon 1980), was consistently found to give erroneous results and hence was abandoned although chemistry of the water in the lake might have been the cause. The water has high magnesium (35 mg/1), calcium (12.3 mg/1), carbonate (190 mg/1) and chloride (28.1 mg/1) contents (present study).

All the nutrient levels were determined using a Jenway 6300 spectrophotometer. Initially phosphorus was determined using the 1 cm cell, but the results showed the absence of soluble reactive phosphorus in the water. Later when a 4 cm cell was used, it was possible to get some values. For phosphorus, the limit of detection with the 1 cm cell was found to be 2.50 μg P/1.

Chlorophyll a determinations were carried out by extraction with 90% aqueous methanol. Two-litre water samples were filtered through 0.45 m Whatman GF/C filter papers. After filtration the filters were folded and put in 50 ml capacity tubes containing 10 ml of the aqueous methanol. The tubes were then capped and wrapped in dark cloth and left overnight in the refrigerator. All nutrient level and chlorophyll a determinations were carried out in duplicate.

RESULTS

Apart from a few parameters, such as pH, dissolved oxygen and silica that were of about equal magnitudes in the bay and outer station, most of the values different between the two locations (Table 1). The pelagic waters were about 2.83 times more transparent than at the bay, and the mean annual water temperatures for the latter were 2 ½C warmer than the at former. The mean conductivity value in the bay was lower (629 μS/cm) than in the open waters (639 μS/cm of dilution of the bay, during the rainy season, through run-off from the surrounding area. Both nitrogen (61.0 g N/1) and phosphorus (14.70 μg P/1) levels were much higher than in the open waters (44.0 μg N/1 and 6.47 g P/1). This could mean that nutrient input into the bay from external sources was important. The high chlorophyll a values in the bay (mean 2.20 μg/1) compared to these in the open waters (mean 1.55 μg/1) suggest for higher phytoplankton populations per unit volume in the bay relative to the open water.

Table 1: Parameter values (mean +/- SD) obtained in Kigoma Bay and Offshore station, Lake Tanganyika 1948/1999.

Parameter	Kigoma Bay	Offshore Station
Transparency (m)	4.05 (1.48)	11.47 (2.47)
Temperature (½C)	28.40 (1.06)	26.40 (0.44)
pH	9.07 (0.06)	9.05 (0.08)
Conductivity (mS/cm)	629.0 (21)	639.0 (11)
Dissolved Oxygen (mg/1)	7.20 (0.85)	7.30 (0.39)
NO_3-N (m g /1)	61.0 (24)	44.0 (15)
PO4-P (m /1)	4.34 (3.22)	2.23 (1.14)
Total P (mg/1)	14.7 (5.90)	6.46 (3.33)
Silica (mg/1)	1.56 (0.23)	1.56 (0.34)
Chlorophyll a (m g /1)	2.42 (1.17)	1.55 (0.90)

Water transparency in Kigoma Bay was lower than at the off shore station throughout the sampling period (Fig. 2). It is observed that, with the exception of October 1998 when chlorophyll a levels reached 4.80 µg/1 at the outer station, phytoplankton biomass was always lower than in the bay (Fig. 2). Chlorophyll a levels were very low during the rainy season in January 1999 at the outer station and in the bay (0.56 µg/1 and 0.75 µg/1 respectively). After a very low phytoplankton biomass in March 1999 at the off shore station, the population increased rapidly to reach a value of 3.08 µg/l chlorophyll a in April 1999. An inverse relationship was observed between water transparency and chlorophyll a amounts.

Total phosphorus concentrations were always lower at the off shore station than in the bay (Fig. 3). Very low values were obtained at the off shore station in September 1998 (12.0 µg P/1) and March 1999 (1.90 µg P/1). High phosphorus concentrations were observed in August 1998 and January 1999 (12.0 µg P/1 and 11.70 ug P/1, respectively). In the bay, very high total phosphorus values were obtained in July 1998 (32.0 µg P/1); the levels then progressively declined to reach a minimum in November 1998 (6.30 µg P/1). The levels increased to 14.50 µg P/1 in December 1998 and to 18.0 µg P/1 in February 1999. After that, total phosphorus decreased to 6.0 µg P/1 in May and then increased slightly to 9.80 µg P/1 in June 1999.

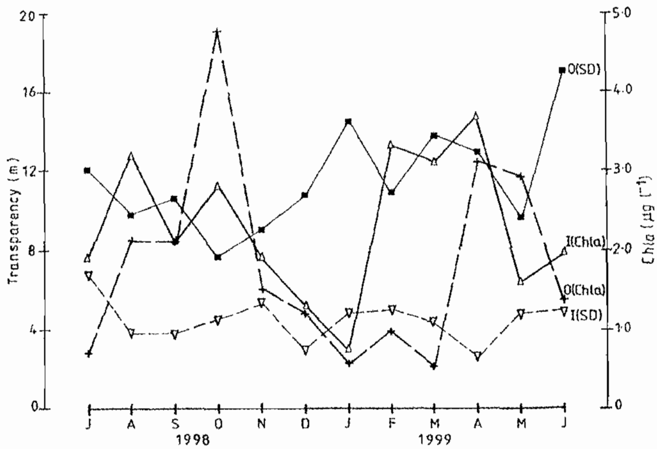

Figure 2: Mean Transparency and Chlorophyll a levels at inshore (I) and offshore (O) stations at Kigoma Bay, Lake Tanganyika, Tanzania.

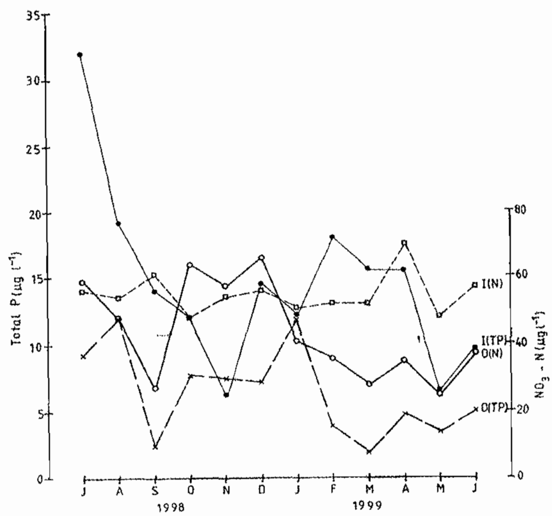

Fig. 3: Mean Total phosphorus and Nitrate nitrogen at inshore (I) and offshore (O) stations at Kigoma Bay, Lake Tanganyika, Tanzania.

Nitrate concentrations did not fluctuate much in the bay throughout the sampling period (Fig. 3). Exceptions were observed in September 1998 and April 1999 when the values were 61 µg N/1 and 70 µg N/1, respectively. At the open water station, the levels ranged between a low of 26 µg N/1 in May 1999 and a high of 66 µg N/1 in December 1998.

Silica levels were high in both the bay and open water throughout the twelve month sampling period (Table 2). Between July and December 1998, silica was higher in the bay (range 1.54 – 1.84 mg Sio4/1) than in the open water (range 1.20 – 1.50 mg Sio4/1), after that, silica concentrations at the pelagic stations were higher (range 1.40 – 1.82 mg Sio4/1) than in the bay (range 1.32 – 1.66 mg Sio4/1).

Table 2: Monthly silica concentrations (mg/l) at sampling locations

Years	**1998**						**1999**					
Month	J	A	S	O	N	D	J	F	M	A	M	J
Inshore	1.55	1.53	1.85	1.65	1.55	1.64	1.40	1.32	1.36	1.66	1.66	1.65
Offshore	2.50	1.20	1.25	1.50	1.39	1.49	1.46	1.40	1.46	1.62	1.83	1.62

DISCUSSION

The present data shows marked differences in the water characteristics of Kigoma Bay and the off shore waters. High water transparency in the open waters had previously been observed by others (Coulter 1963, Hecky & Fee 1981, Hecky & Kling, 1981, Edmond *et* al. 1993). High transparency coupled with low phosphorus levels in the pelagic zone suggest that the pelagic zone might be oligotrophic (Beauchamp 1939; Coulter, 1963, Hecky & Kling 1981). During October 1998, when the transparency was the lowest at the outer station (7.70 m), chlorophyll a values were the for the whole of during the study period (4.80 µg/1). A low transparency in October had also been reported earlier (Coulter 1963, Hecky & Fee 1981, Hecky & Kling 1981, Hecky 1991). The authors stated that the decline in transparency was a result of *Anabaena* spp. blooms that occurred during that period. In the bay where chlorophyll a values were usually high, the secchi disc readings were low (Fig. 2). Although no phytoplankton counts were made at the sampling locations, it may be assumed that the low transparency was also caused by high phytoplankton populations.

Nutrient levels in the bay were usually higher than in the open waters (Fig. 3). Edmond *et al.* (1993) and Hecky *et al.* (1991) reported low phosphorus concentrations in the surface waters of the pelagic region of the lake. Phosphorus replenishment in the pelagic zone was mostly likely effected by water mixing and nitrogen through fixation of atmospheric nitrogen by *Anabaena* spp. (Heck, 1991, Hecky & Kling 1981). Nitrogen fixation by *Anabaena* spp. has also been reported for the North American Great Lakes (Megard 1972).

The high chlorophyll a values in the bay may have been caused by the high nutrient levels in the bay (Schindler 1978). The bay receives untreated domestic wastewater and run-off from the surrounding area. Increase in nutrient levels and corresponding increases in algal populations have also been reported for the Bay of Bujumbura in Burundi (Caljon 1992).

Silica concentrations were very high in the bay and open waters (Table 2). It can therefore be assumed that silica cannot be the main cause in the differences of the productivities of the two locations.

According to the Wetzel's (Table 12-1) ranking of lake productivity levels, Kigoma Bay, with a mean total phosphorus concentration of 14.70 µg/P/1, is considered to be meso-eutrophic, while the open waters with a mean total phosphorus concentration of 6.46 µg P/1 is oligotrophic (Wetzel 1975).

CONCLUSION

The water characteristics of kigoma bay are markedly different from those of the pelagic waters. The bay is becoming enriched with plant nutrients, leading to high phytoplankton biomass. Untreated domestic sewage from kigoma town may be responsible for the high phosphorus and nitrate concentrations in the bay. Since the bay is also the source of the town's domestic water supplies, the discharge of untreated sewage effluents may also constitute a health hazard. In order to minimize the danger of the bay becoming eutrophic, sewage effluents should not be allowed to freely drain into the bay.

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