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Title: Nitrogen or Phosphorous Limitation in Nearshore and Pelagic Waters of Kigoma Bay, Lake Tanganyika - East Africa

Abstract

Low concentrations of nutrients and strong spatial and seasonal dynamics in Lake Tanganyika have been problematic for determining the limiting factor for primary productivity. We attempted to determine a limiting factor by measuring phytoplankton growth response to nutrient addition. Ambient lake-water nutrient levels of Kigoma Bay, Lake Tanganyika were measured from 23 June 98 to 26 June 98. Following the sampling period, water from both the littoral zone and pelagic zone of Kigoma Bay was collected and phytoplankton growth response to nitrogen and phosphorus addition was measured. Opposite results were obtained for the different zones; addition of nitrogen failed to increase algal biomass in the treatments obtained from the littoral zone, while addition of phosphorus failed to increase algal biomass in the treatments from the pelagic. Results suggest that further work is needed on both nutrient dynamics and alga community dynamics in Lake Tanganyika.

Introduction

Lake Tanganyika, the deepest of the African Great Lakes, has been widely noted for low ambient nutrient levels (Coulter 1991, Edmond et al. 1993). Nitrite (NO_2) and phosphorus, both total and $\text{PO}_4\text{-P}$, have been particularly difficult to measure and are often too low to determine accurately. Nitrate (NO_3) and ammonium (NH_4) have been found at higher levels, though the seasonal average is still relatively low (Plisnier et al. 1996). Establishing a limiting factor in Lake Tanganyika has thus been difficult given the low levels of nutrients. Although it has long been argued that the lake is most likely nitrogen limited (Talling and Talling 1965, Moss 1969, Edmond et al. 1993), recent long-term research has found Lake Tanganyika to be seasonally dynamic in nutrient composition (Plisnier et al. 1996). Both Coulter et al. (1991) and Hecky and Kling (1981) have suggested that the lake may switch between nitrogen and phosphorus limitation based on the season. In Kigoma Bay, Tanzania ambient soluble reactive phosphorus ($\text{PO}_4\text{-P}$) levels have ranged from 0.8 mg/L to 0.0 mg/L and nitrate levels have ranged from 0.222 mg/L to 0.0 mg/L over a single year (Plisnier et al. 1996).

Nutrient levels have also been found to vary greatly over short periods of time (Plisnier, personal communication), suggesting that the physical features of the lake driving the dynamics of the lake can potentially operate over relatively short periods of time. Little is known about these processes or the levels of scale upon which they operate. Similarly,

physical processes may have a profound effect on ambient nutrient levels over relatively small spatial scales. Upwelling processes, driven by the lake's catabatic and onshore winds, may raise nutrients to coastal regions of the lake early in the morning. Similarly, different planktonic communities in the littoral and pelagic zones may respond differently to available nutrients. In the summer months, the Kigoma Bay pelagic region has been dominated by cyanophyta, especially *anabaena* (Hecky et al. 1978). Although primary productivity is thought to be higher in the littoral zone (Plisnier et al. 1996), little research is available on the algal community. A combination of biological and physical effects have been invoked to help explain the nutrient patterns of Lake Tanganyika; Coulter (1991) suggests that nitrogen is primarily fixed in the mixolimnion with little eddy diffusion from below while phosphorus is brought into the mixolimnion almost entirely from mixing with deeper waters.

We investigated possible differences in nutrient availability and growth responses of phytoplankton to nutrient enrichment between the pelagic and littoral zones in Kigoma Bay, Tanzania during the summer dry season. We tested the hypothesis that the lake is nitrogen limited by measuring ambient lake-water nutrients in the morning and evening and by evaluating growth responses of phytoplankton to the addition of both nitrate and phosphorus.

Methodology

Water samples were taken at 5 m depth in the littoral zone and 5 m, 30 m and 60 m depth in the pelagic zone on alternating evenings and mornings from we June 98 to 26 June 98 (Appendix A, Table 1). Samples were 2.0 L in volume and analyzed for ammonia, nitrate, nitrite and total phosphorus with a Hach Co. DR/2010 spectrophotometer. All analysis methods are USEPA approved for water analysis.

Phytoplankton growth response experiments were conducted following Lehman and Branstrator (1994). Water was collected from one littoral and one pelagic site near Kigoma Bay, Tanzania (Appendix A, Table 1). Light intensity was measured with a LI-COR LI-1000 light meter and water was drawn at 20% surface water light intensity at each site. Treatment water was hand pumped from the determined depth and filtered with 100 μM mesh and transported in a closed cooler to the laboratory. Bath water for incubation was taken at surface depth and also transported in a closed cooler. Phytoplankton were incubated in 2 quart volume transparent polyethylene enclosures (Zip-Lock bags). Treatments were 2350 mL volume, enriched with either 10 μM nitrogen (NH_4NO_3), 1 μM phosphorous (Na_2HPO_4) or both in combination. Enclosures were incubated in bath at ambient lake-water temperature for 48 hr. Neutral density screen filters were used to reduce the ambient surface intensity of the sunlight to measured lake-water levels. Concentrations of

Chl *a* were obtained by performing overnight extraction in 94.1% methanol and measuring with spectrophotometer. Final values were determined by the following equation:

$$\text{Chl } a \text{ (ug/L)} = ([665 \text{ nm}] - [750 \text{ nm}]) * \{(13.9 * v) / (V * 0.40 \text{ cm})\}$$

where *v* is the volume of extract, *V* is the total volume filtered, 13.9 is the Chl *a* coefficient and 0.40cm is the path length of the spectrophotometer.

Results

The water used for treatment from the littoral zone was more nitrate rich than the pelagic, though nitrite and SRP levels were the same (Appendix A, Table 2). Ammonia was not present in the water drawn from the pelagic and data was not available for the littoral zone.

Week long data indicate that nitrate generally varies more than SRP and was frequently absent from the water column, suggesting that it may be a limiting factor in both zones (Appendix A, Tables 3 and 4). Phosphorus and nitrite were similar at both sites and present in low concentrations. Ammonia was not present in the samples though often it is only found in the deeper waters below the thermocline (Plisnier et al. 1996).

Results from the nutrient enrichment were not conclusive (Appendix A, Figures 1 and 2). Algal biomass did not increase in the littoral zone with addition of nitrogen. Phosphorus addition greatly increased algal biomass in one treatment, and just slightly above the control in the second. Because the second Chl *a* measurement was taken from the combination of two treatments of 2350 mL each, there were only two measurements to compare. The nitrogen addition failed to increase algal biomass beyond the control. Addition of both nitrogen and phosphorus in combination obtained a growth response similar to the control.

In the pelagic zone, the opposite results were obtained. Algal biomass did not increase with addition of phosphorus. No two replicates were combined for Chl *a* measurement so that three replicates could be obtained for each treatment. However, one of the nitrogen additions broke open during incubation, reducing the number of replicates to two. One nitrogen addition underwent a very large growth response and the other did only slightly better than the control. The phosphorus addition failed to obtain an algal biomass higher than the control, and the nitrogen and phosphorus in combination yielded an algal biomass similar to the control.

Discussion and Conclusion

While preliminary analysis suggests that the littoral zone was phosphorus limited and the pelagic zone was nitrogen limited, the large standard deviation in treatments where a growth response was invoked beyond the control suggests a larger number of replicates is required.

However, a similar experiment performed with pelagic water from the middle of the lake had yielded similar results (Jarvinen et al. 1996). Although they found the greatest algal response was to a combination of carbon, nitrogen and phosphorus, phosphorus showed a large standard deviation among treatments for increased growth response and the nitrogen addition failed to surpass the control in algal biomass.

The responses we found may be a result of a difference in phytoplankton communities. A large amount of cyanophyta was observed in the shallows of Kigoma Bay. If they are forming heterocysts, the nearshore waters may obtain a stronger growth response from phosphorus. Similarly, if the offshore community is dominated by diatoms or green algae, a larger response to nitrogen may be observed. Continuing research both on nutrient fluxes in Lake Tanganyika and its algal communities are necessary to gain a better understanding of the seasonal and spatial differences in limiting factors to primary productivity.

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