

# **Pelagic nutrient profiles and bacterial diversity in Lake Tanganyika**

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## **Objective**

To study the relationship between nutrient availability and bacterial community composition within the water column of Lake Tanganyika.

## **Introduction**

Lake Tanganyika is located in East Africa between four and eight degrees south latitude. It is the largest African rift lake and the second deepest lake in the world. Permanent thermal stratification prevents the lake from fully circulating (Coulter, 1991). The depth and stability of the thermocline vary throughout the year. During the dry season (June-August), strong winds blow from the southeast causing upwelling in the southern part of the lake. The seiche created by these winds then oscillates between the north and south ends of the lake during October and November recycling nutrients from the deep to the surface waters.

Previous research on bacterial communities in the lake has focused on bacterioplankton production in the upper 80m of the water column (Jarvinen et al, 1996; Sarvala et al, 1999). These studies found that bacteria production constitutes 20-25% of the total plankton productivity in pelagic waters. Though we know that they make these contributions, however, we do not know what the bacterial community composition looks like. This project will look for changes in community composition between 16 different depths and compare them to nutrient availability. This abstract focuses on the first part of this project which is to make deep water nutrient profiles for various nitrogen and phosphorus species, oxygen, alkalinity, iron, sulfate and silica as well as physical characteristics of the water such as temperature, pH, conductivity, turbidity and redox.

## **Methods**

Samples were collected from 16 different depths ranging from 0 to >1000m on Friday, July 19, 2002. This was day one of the *R/V Maman Benita* cruise to the Luichi Delta platform (July 19-21, 2002). It was overcast with a wind speed of approximately 10m/s. Lightning was spotted in the distance. We wanted to sample at Climlake's North Station sampling site (5° 05'S, 29° 31'E) because the depth there is approximately 1100m. Four casts were made. The CTD was at the bottom of the first cast. The first cast also obtained samples for depths of 1000, 800, 600, 400 and 350m. The site was located at 5.02088S and 29.51929E. Two 10L-General Oceanic sampling bottles and three 5L-bottles were used. The second cast obtained samples for 300, 250, 200, 175 and 150m. This was done at 5.02567°S, 29.53226°E. The third cast was for 125, 100, 75 and 50m. One of the small sampling bottles broke, so we were only able to sample four depths. This site was located at 5.02947°S, 29.52583°E. The fourth cast was made at 5.01947°S, 29.52972°E and sampled at 125, 25 and 0m. We drifted approximately 3km during each cast. The GPS coordinates listed reflect the final position of the boat when the last sample was taken out of the water.

pH, turbidity, conductivity and redox were measured for each depth immediately using a Hach EC10 pH Meter, a Hach 2100P Turbidimeter, a YSI Model 33 S-C-T Meter and a Hanna Instruments Redox Meter (98201), respectively. A glass dissolved oxygen bottle was also filled. For the 350-1000m samples, 2.5L of water were saved for later testing. For the other depths, 3.5L were saved. Secchi depth was taken with a 20cm diameter disc by five people and averaged.

For each depth, one or two liters of water, for 350-1000m or 0-300m, respectively, were filtered using a 47mm Whatman GF/B filter. This filtered water was frozen and transported back to the lab for testing. The filters for depths 0-300m were placed in capped test tubes, wrapped in aluminum foil and frozen for

chlorophyll analysis. Then, one liter of water was filtered using a 47mm Gelman Sciences 0.2µm filter. The filter was placed in a small, capped, glass test tube and frozen. The filtered water was poured into four dissolved organic matter (DOM) bottles. Finally, 250-300mL of unfiltered water was refrigerated for later analysis.

On Saturday, July 20, 2002, alkalinity titrations were done on board the ship using 100mL of the unfiltered sample from each depth. I used the method described in the Hach Digital Titrator (Model 16900) handbook. It uses sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) as the titrant and Phenolphthalein and Bromocresol Green-Methyl Red as indicators.

Winkler titrations for dissolved oxygen were also performed on July 20 using the method recommended by Stanton, et al. The reagents used for this were made according to the directions in Stanton, et al on July 16, 2002. They include MgSO<sub>4</sub> solution, alkaline iodide solution, and a starch indicator. The alkaline iodide solution contained potassium and sodium salts, however, as opposed to all potassium or all sodium constituents. The sodium thiosulphate solution was made on July 17.

July 22-24, 2002, tests for nitrate, nitrite, ammonia, total phosphorus, reactive phosphorous, total iron, sulfate and silica were performed using a Hach DR/2010 Spectrophotometer. On July 31, 2002 chlorophyll was extracted from the GF/B filters using 90% ethanol. On August 1, chlorophyll readings were taken with a Turner Designs Aquafluor.

The 0.2µm filters from each depth were transported back to the US for bacterial DNA extraction, amplification and sequencing. The sequences from each depth will then be compared to each other and to nutrient concentrations at their particular depth.

## Results

The CTD reached a maximum depth of 1078m. The temperatures recorded decreased with depth and indicated that the thermocline was at 60-70m at the time of sampling (Figure 1). Average temperature for the water column was 23.7 °C. pH ranged from 9.5 at depth to 10.2 at the surface (Figure 2). Conductivity was between 667 and 692 micromhos (Figure 3). There was a peak at 1000 m. Dissolved oxygen ranged from 0.02 mg/L at depth to 6.79 mg/L at the surface (Figure 4). Turbidity ranged from 3.29 to 3.86 nephelometric turbid units [NTU]. The ranges for CTD data are summarized in Table 1.

Nitrate concentrations varied from 0.015 mg/L to 0.110 mg/L (Figure 5). The peak concentration was at 75m. Ammonia concentrations ranged from 0.01 mg/L to 0.105 mg/L (Figure 6). The highest concentration was at 50m. Nitrite ranged from 0.009 mg/L to 0.020 mg/L with peak concentration at 1000m (Figure 7). Total phosphorus peaked at 350m with a concentration of 1.2 mg/L PO<sub>4</sub><sup>3-</sup> (Figure 8) 0.155 mg/L PO<sub>4</sub><sup>3-</sup> was the lowest total phosphate concentration, at 50m. Reactive phosphorus ranged from 0.040 mg/L to 0.585 mg/L (Figure 9). The lowest concentration was at 25m while the highest concentration was found at 600m. Total iron ranged from 0.05 mg/L at 125m, 300m and 400m to 0.16 mg/L at the surface (Figure 10). Sulfate varied from 0.5 mg/L at 100m and 300m to 2.5 mg/L between 150 and 200m, inclusive (Figure 11). Silica increased with depth, from 1.52 mg/L SiO<sub>2</sub> at the surface to 20.4 mg/L at 1000 m depth (Figure 12). Manual pH measurements ranged from 8.46 at depth to 9.11 at the surface (Figure 2). Manual conductivity ranged from 330 to 690 micromhos (Figure 3). The lowest value was measured at 150m and the highest at 1000m. Redox measurements became more negative with depth (Figure 13). At the surface it was 56 mV and at 400m it was -255 mV. Results from the Winkler titrations and dissolved oxygen probe readings were 0.03-9.34 mg/L and 6.92-7.06 mg/L, respectively (Figure 4). Alkalinity ranged from 2.64 mM at 100m to 3 mM at 1000m (Figure 14). Chlorophyll *a* ranged from fluorescence of 3 to 207.9 without the addition of acid (Figure 15). Turbidity ranged from 0.1-0.28 NTU (Figure 16). With acid, it ranged from 2.4 to 145.8. Secchi depth was 13.55m. Ranges for each nutrient or property can be found in Table 2.

## Discussion

The majority of the profiles constructed follow patterns similar to those in earlier studies (Adams et al, 2000; Plisnier et al, 1999). The CTD data used is the downward half of the cast averaged over every 200

data points collected. The temperature profile indicates a typically stratified tropical lake, though it only varies 3°C between surface and bottom. This stratification affects dissolved oxygen and other nutrient concentrations in the water column. The oxycline is around 60-70m, thus inhibiting many oxygen-needing organisms from living on the bottom of the lake. With a lower number of organisms, less nutrients are used. Thus, deep waters tend to be nutrient rich. Total phosphorus, reactive phosphorus and silica all increase with depth. Their concentrations all increase significantly just below the thermo- and oxyclines, probably because there are less organisms there to use them. From previous research, one would also expect ammonia to follow the same decreasing trend. Interestingly, however, ammonia peaks around the oxycline and then decreases. This is probably due to experimental error and faulty reagents for the analysis or because the lower depths (particularly 1000m) were out of range. Nitrate concentration peaked just below the thermo- and oxyclines, and nitrite remained relatively constant throughout the water column. Both nutrient profiles were consistent with Adams et al (2000) and Coulter (1991). Total iron also remained constant. The surface value is high, but the boat used for sampling was rusty, which may have affected the concentration.

Alkalinity is approximately half as great as expected (Wehrli et al, 2002). This is probably due to faulty reagents as we obtained similar low values two weeks before during the Limnology practice lab. High alkalinity levels make Lake Tanganyika a well-buffered lake.

The pH, turbidity and dissolved oxygen probes on the CTD were not calibrated correctly. To calibrate the pH, I compared the manual data to that off the CTD and found a linear relationship (Figure 17). The regression line equation was  $\text{pH}_{\text{meter}} = 0.9982 \text{pH}_{\text{CTD}} - 1.0907$  and  $R^2 = 0.9178$ . The corrected pH range is 8.5 at depth to 9.1 at 25 and 50m. The turbidity data between the CTD and manual measurements did not show a clear relationship (Figure 18),  $R^2 = 0.1245$ . The CTD only measured 3 different turbidities over all the depths, and they were significantly higher than those measured manually. This suggests a malfunction in the turbidimeter on the CTD that is independent of calibration. To correct the dissolved oxygen values, I plotted the results of the Winkler titrations and CTD cast from Climplake's (Wehrli) July 2002 cruise (Figure 19). It yielded a linear relationship with equation  $\text{DO}_{\text{Winkler}} = 1.0184 * \text{DO}_{\text{CTD}} - 0.1568$  and  $R^2 = 0.9862$ . The adjusted CTD dissolved oxygen values range from 0.2 mg/L to 7.01 mg/L. I chose to use Climplake's data to make the calibration curve because they had more data to compare, however, the data from my CTD cast and Winkler titrations are also included in Figure 19. My data yielded a logarithmic relationship.

The data obtained suggest possible changes in bacterial community composition with depth. Between 50 and 75m, I expect to see a significant shift because the oxycline is around 60m. At 125, 150 and 175m, I would expect to see similar community compositions between depths. The results from the chlorophyll *a* analyses at these depths suggest bacterial interference. One would expect fluorescence readings to decrease after the addition of acid, but at these depths the fluorescence increased. A possible explanation is that bacteria are interfering with the readings (Pete McIntyre, personal communication). These depths are also interesting as they are just below the oxycline, where nutrient concentrations, including the phosphorus species, ammonia and sulfate, increase significantly. Aerobic and photosynthetic bacteria would decrease here because of the lack of oxygen and light, but anaerobic bacteria would start to thrive. At 250-400m, I expect sulfur bacteria and iron related bacteria (IRBs) to be particularly abundant (James Scott, personal communication). Because of the shallowness of the oxycline and great depth of the lake, I anticipate a greater diversity of anaerobic bacteria. However, there may not be as many shifts in community composition if the same types of bacteria exist uniformly in anoxic water. One indication of this is that redox remains relatively constant below 150m.

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**Table 1: CTD Data**

Property	Range
Temperature	23.3-26.4 °C
pH	9.5-10.2
Conductivity	667-692 micromohls
Dissolved Oxygen	0.02-6.79 mg/L
Turbidity	3.29-3.86 NTU

**Table 2: Manual Data**

Property	Range
pH	8.46-9.11
Conductivity	330-690 micro-mohs
Dissolved Oxygen	0.03-9.34 mg/L
Nitrate [NO <sub>3</sub> - N]	0.015-0.110 mg/L
Ammonia [NH <sub>3</sub> ]	0.01-0.105 mg/L
Nitrite [NO <sub>2</sub> - N]	0.009-0.020 mg/L
Total Phosphorus [PO <sub>4</sub> 3-]	0.155-1.2 mg/L
Reactive Phosphorus [PO <sub>4</sub> 3-]	0.04-0.585 mg/L
Total Iron [Fe]	0.05-0.16 mg/L
Sulfate [SO <sub>4</sub> 2-]	0.5-2.5 mg/L
Silica [SiO <sub>2</sub> ]	1.52-20.4 mg/L
Redox	-255- +73 mV
Alkalinity	2.64-3 mM
Chlorophyll a	2.323-207.8 units of fluorescence
Turbidity	0.1-0.28 NTU



