Preliminary investigation of the effects of some limnological parameters on vertical, horizontal, and temporal changes in ash-free biomass of pelagic plankton.

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Introduction

The food web of Lake Tanganyika, as in all ecosystems, has its base in its primary producers and their primary consumers. This means that the spectacularly diverse organisms in this lake, as well as the human populations that inhabit the top of the food chain, are dependent upon the plankton in its waters for their survival.

The term "plankton" refers to the small organisms, (ranging from a few micrometers up to 2mm in length), which inhabit the water columns of aquatic ecosystems. Phytoplankton are microscopic plants - gaining their energy through photosynthesis. They are the primary producers of most aquatic ecosystems. In contrast, the other major class of plankton - zooplankton - consume other organisms in order to gain the energy needed for life.

Together, these two types of microorganisms form the lower levels of the aquatic food web. The phytoplankton, which are the primary producers, are eaten by zooplankton which, in turn, are eaten by small fish. The main predators of the pelagic zooplankton stock in Lake Tanganyika are the two endemic clupeid species: Limnothrissa miodon and Stolothrissa tanganicae. These two species account for a large proportion of the catch of fisheries on the lake - as well as being the primary food source for the larger fish, such as Lates stappersi, which make up the other large segment of the catch.

With this study, I've attempted to correlate vertical, horizontal, and temporal differences in plankton ash-free biomass to differences in the physical and chemical environments the plankton have encountered. The limiting factor, (or factors), for the size and reproduction rate of a given population in a given environment can often be hard to pinpoint. This is because ecosystems are complex, and rather than any one limiting factor, populations are often controlled by complex interactions of numerous factors. In order to better understand the planktonic communities in this lake, I have measured a number of physical and chemical factors of the limnology and have attempted to correlate changes in these factors with changes in the planktonic populations.

There is a large amount of work in the literature regarding the observed vertical migration of zooplankton on a diurnal basis. There is a well-documented migration up into the upper 15 meters of the water column during the night and down into deeper waters during the day. The predominant theory as to the cause of this movement is escape from predators, such as clupeids. Clupeids, which feed on the zooplankton, are visual predators - so it is dangerous for the plankton to be in the shallower waters, where phytoplankton grazing is best, during the daylight hours. They ascend at night to feed, and return to deeper waters, (where the clupeids can't see them or follow due to their higher oxygen requirements), by day. Little work has been done, however, regarding what factors influence the total mass of plankton at various locations in the water column from area to area and from day to day. In order to better understand plankton populations, this is an important question to answer.

Objectives

The goal of this study is to contribute to our overall understanding of the plankton populations in Lake Tanganyika and of their responses to various changes in their environment. My hope is that this type of work, in concert with other research, can be of assistance in future efforts to understand, and possibly to model, factors within the ecosystem of the lake. Such efforts might be employed in attempt to reduce human impacts on the system, avoid losses of biodiversity, or better utilize the resources such as fish populations.
Methodology

I collected all data either during - or from samples taken during - six sampling trips conducted between July 16\textsuperscript{th} and August 2\textsuperscript{nd}, 2001. Sampling trips left from the Tanzanian Fisheries Research Institute station in Kigoma Harbor on the morning of every sampling day and began work at Site 1 by 9:30 am. Site 2 was sampled later in the day – at approximately 1:00pm – but with the timing more variable based upon lake conditions encountered during the morning.

At each site, myself and a team of four other student limnologists, measured a variety of limnological parameters. We constructed temperature and dissolved oxygen profiles of the upper 100m of the water column, (using a YSI 58 probe), and measured light attenuation at 10m intervals through the upper 40m of the water column, (using LI-COR underwater sensors and a LI-1000 data logger). Water samples, taken (using a Van Dorn type sampling bottle) at 10m intervals in the upper 40m of the water column and then at twenty meter intervals down to 100m were analyzed in the field for turbidity, pH, and conductivity (using a Hach turbidimeter 2100A, an Orion pH meter 210A, and a Cole/Parmer conductivity meter 19820-00, respectively). We also stored further samples in a cooler for later laboratory chemical analysis (with a Hach 2010 spectrophotometer).

I conducted plankton hauls at each site throughout the upper 90m of the water column in 15m increments using a 53µm closing plankton net with an top opening ring of 32cm diameter. These factors mean that each sample contains the plankton, (greater than 53µm in size), from 1.2m\textsuperscript{3} of water. The collected samples were then stored in 150mL sample bottles, which were kept in a cooler until I was able to filter them, (no more than four hours).

Upon return to shore, I filtered the samples onto pre-burned and pre-weighed glass fiber filters, which were then put into an oven to be dried at 60\textdegreeC for at least 40 hours. This drying time was determined, through pilot tests, to be sufficient to drive all water from the wet samples. Dry sample weights were then recorded, and samples put into a Neycraft muffle furnace at 550\textdegreeC for three hours to burn off all organic matter. I then re-wetted the samples to restore water to any clay minerals that might have had their associated water content driven off through the burning process and then dried them again before the ash weight was recorded. In this manner, ash-free dry mass was determined for each of the samples (as per APHA 1998). My intent, in obtaining the ash-free dry mass, rather than some other mass measurement, was to remove from my measurements the mass of all other material, such as suspended solids, which might have confounded measurements of biomass. I also decided that the important factor for the purposes of this study was how much mass of biologically available material – material which might contribute to the food web, was present in the samples. In obtaining ash-free dry mass, the masses of planktonic hard parts such as, chitinous or silicious exoskeletons were also removed from measurement.

Results

The vertical distribution of plankton was generally found to follow a bimodal trend. The first peak in mass was found in the upper 30 meters of the water column, while the second was deeper – around 50-70 meters (Figure 1).

The single parameter found to have the most significant effect on the distribution of plankton at my sample sites and times was nutrient levels. I found that nutrients, especially nitrate and phosphorus have an effect both on vertical and horizontal/temporal plankton distribution. On a horizontal level, on nearly all sampling days, the one of my two sites that had the higher average level of nitrate and phosphorus was also found to have the higher ash-free biomass (Figure 2).

This brought up the question of where in the water column this effect is most important. I examined the correlations between levels of each of these nutrients and mass of plankton found in the upper and lower 45m of my sampled water column. In this analysis, I found that the nutrient fluxes were well correlated to upper-column biomass fluctuations, \((r=0.5 \text{ to } 0.8)\), and either not correlated or negatively correlated to mass changes in the lower 45m (Figure 3).
In nearly all cases, the site with the higher concentrations on both Nitrate and Phosphorus also showed the higher overall plankton ash-free mass.
The mean depth of planktonic mass proved to have a strong inverse correlation with the levels of various nutrients—especially nitrate. The mass of plankton in the water column was influenced most strongly in the upper 45m of the water column. These figures relate the masses found in the upper and lower portions of my hauls on the different days with the average concentration of nutrients present.

**Site 1 - Nitrate**

<table>
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<tr>
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<th>July, 26</th>
<th>July, 30</th>
<th>August, 2</th>
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<td>0.004</td>
<td>0.006</td>
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**Site 1 - Phosphorus**

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<th>July, 30</th>
<th>August, 2</th>
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<tbody>
<tr>
<td>Phos</td>
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<td>0.05</td>
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**Site 2 - Nitrate**

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<th>July, 30</th>
<th>August, 2</th>
</tr>
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<tbody>
<tr>
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**Site 2 - Phosphorus**

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<th>July, 26</th>
<th>July, 30</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Phos</td>
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<td>0.02</td>
<td>0.04</td>
<td>0.06</td>
<td>0.08</td>
</tr>
</tbody>
</table>

**Site 1**

- Depth: July, 19: 30; July, 24: 30; July, 26: 30; July, 30: 30; August, 2: 30
- Nitrate: July, 19: 0.035; July, 24: 0.03; July, 26: 0.025; July, 30: 0.02; August, 2: 0.015

**Site 2**

- Depth: July, 19: 30; July, 24: 30; July, 26: 30; July, 30: 30; August, 2: 30
- Nitrate: July, 19: 0.0245; July, 24: 0.0225; July, 26: 0.0205; July, 30: 0.0185; August, 2: 0.0165
In terms of vertical changes in mass profile, I found that the mean depth of plankton biomass was also tied to nutrient levels. Days in which nitrate concentrations were low in the upper levels of the water column also had deeper mean biomass depth ($r=0.7$ to $1.0$) (Figure 4).

**Discussion**

There appears to be a strong correlation between nutrient levels, and temporal/spatial changes in zooplankton ash-free mass. There is also evidence that nutrient levels (especially nitrate and phosphorus) are particularly important in the upper levels of the water column. This makes sense, as nutrients are present in significantly higher quantities deeper in the lake (below the nutricline). These nutrients can move up into the lower epilimnion through diffusion and small-scale turbulence. In the upper levels of the water column, these nutrients seem to be an important limiting factor for plankton abundance.

The first peak in the vertical plankton mass distribution was found in the upper 30 meters of the water column and is probably nutrient limited. The fact that the upper layers show a peak rather than simply a decrease with depth is probably due to the plankton having a maximum light tolerance. This photoinhibition means that they can't survive effectively in the upper meters of the water column. The upper mass peak is at the depth at which light has attenuated to the degree that it is no longer inhibitive, but is instead at an ideal level for phytoplankton growth, (and therefore, also, for their zooplankton grazers). The second peak is deeper in the water column, where nutrients can be expected (and were found), to be more abundant. It is probable that light is the limiting factor for this second peak. However, due to the complex interaction between various factors, (including climatic conditions), responsible for light penetration, my data are inconclusive on this subject.

Although the mass of plankton is spread out along the water column, there are fluctuations in the mean depth of plankton biomass. I found these changes to be very strongly correlated to nutrient levels (especially nitrate). As the nitrate concentration in the upper water column fell, so did the mean depth of the plankton in the water. This is because there are more nutrients at lower depths, so as nutrients become more scarce, plankton are forced to move lower in the water column in order to attain the necessary concentrations.

My data set is flawed in a number of ways. The most significant flaw is size - as the sample size is not large enough to have much predictive power. Another flaw is the fact that the study was carried out in one general location at one time in the year. This has meant that the limnology of the lake, as it was measured, didn’t present much variability. These systems are not perfect and so planktonic responses to changes in their environment cannot be expected to follow a perfect curve. The “noise” that these effectively chaotic differences provide is compounded by the fact that the range of conditions encountered during this study was relatively small. This means that real trends may be lost or may not produce statistically significant results. The data I’ve collected point to some of these conditions that may well prove important. The next step is to sample at places and times where one can expect to encounter a greater range of the particular condition being explored. This would make the planktonic response more clear.

**Future Work**

With further knowledge of plankton populations, we hope to be able to better predict, and manage fish populations as well. Utilization of energy by consumers is far from perfectly efficient and there is a "loss" of energy and of biomass as it moves up the trophic levels. The current belief is that in this system, 15% of phytoplankton biomass is converted to zooplankton biomass, which is then converted to fish biomass with approximately 60% efficiency. Unlike most other systems, however, this does not mean that there is simply more plankton biomass than fish biomass. The grazing and predation in this lake are so efficient that the “standing stock” of fish biomass is actually larger than the “standing stock” of plankton biomass.

Further work must be done before the planktonic response to the changes in their environment will be fully understood. This should be followed by work correlating changes within planktonic populations to changes in fisheries intake. Some work has been done in this realm, (Blikshteyn Nyanza 2000 & and Mwakosya 2001), but such short term studies of the catches taken in by small-scale fishermen are hard to use for any
predictive purposes due to the complex variability of fishermen’s hauls. I suggest that work be done looking at planktonic fluctuations and their impacts on larger scale fisheries – whether through commercial fisheries or through the hauls taken by a representative sample of the population.

With further work of this sort, we may be able to model how limnological changes might impact fish populations. This knowledge would be a valuable tool in managing fisheries such that they may be maximally efficient in their use of this vital resource.

Acknowledgements

I would like to extend my thanks to the team that worked so well together and turned out so much good science - Jake “Kicha” Allgeier, Ishmael “Baba” Kimerei, Pascal “Congoman” Ishumbisho Mwapu, Willy “The Mayor” Mbemba, and Jackson “Dirty Old Man” Raini. I would also like to acknowledge our mentor Pierre-Denis Plisnier for his assistance.

References