FIELD ALGAE MEASUREMENTS USING EMPIRICAL CORRELATIONS AT DEER CREEK RESERVOIR

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ABSTRACT

Deer Creek Reservoir in Utah has a history of high algae concentrations and despite recent nutrient reduction efforts, seasonal algae blooms continue. Cost effective, accurate, and comprehensive monitoring is important to understand the algal processes driving this problem. Current laboratory methods for accurately measuring algae are expensive and time consuming. In addition, laboratory methods require point samples, which do not describe the complex spatial, especially vertical, trends, in the algal data because of the limited number of samples taken. In situ probes are able to measure chlorophyll and provide a less expensive alternative for measuring chlorophyll than laboratory methods while also providing high resolution vertical profile measurements. They also measure data quickly which allows denser horizontal sampling. To use the probe data, good correlations between in situ probe chlorophyll measurements and laboratory algae measurements are important, but these correlations are reservoir and time dependant as reservoir conditions change. This study reports on efforts to develop these correlations and provide a general description of the dynamic reservoir algal processes at Deer Creek Reservoir.

INTRODUCTION

Deer Creek Reservoir in Utah has a history of high algal concentrations which affects the drinking water treatment and quality in the Utah and Salt Lake valleys. Mitigation practices to limit phosphorus and other nutrient loading in the reservoir are currently in place. This has lowered the amount of nutrients and algae in the reservoir, but seasonal algal blooms continue to be a problem. . Cost effective, accurate, and comprehensive monitoring is important to understand the algal processes driving this problem. Current laboratory methods for accurately measuring algae are expensive and time consuming. In addition, laboratory methods require point samples, which do not describe the complex spatial, especially vertical, trends, in the algal data because of the limited number of samples taken. In situ probes are able to measure chlorophyll and provide a less expensive alternative for measuring chlorophyll than laboratory methods while also providing high resolution vertical profile measurements. They also measure data quickly which allows denser horizontal sampling. To use the probe data, good correlations between in situ probe chlorophyll measurements and laboratory algae measurements are important, but these correlations are reservoir and time dependent as reservoir conditions change. This study reports on efforts to develop these correlations and provide a general description of the dynamic reservoir algal processes at Deer Creek Reservoir.

Chlorophyll-a is a key indicator of the presence of algae and can be used as a field measurement of algae mass. Several methods are currently in use to measure chlorophyll-a concentrations including chlorophyll extraction in a laboratory, in situ fluorometry, algal cell counting, high performance liquid chromatography, and other optical methods. The chlorophyll-a measurements are used as a quantitative index of the amount of algae in the water.

This study focuses on efforts at Deer Creek Reservoir to develop empirical correlations between chlorophyll-a concentrations using in situ optical sensor measurements and algae concentrations measured by cell counting methods in the laboratory. Based on probe measurements, We found the algae exhibited interesting diurnal patterns in vertical migration and also large diurnal wind driven migrations from the dam to the head of the reservoir, almost 5 miles. These processes are important to capture in models and may not be apparent from the limited traditional algae sampling methods.

Deer Creek Reservoir was constructed between 1938 and 1941 as part of the Provo River Project (David Eckhoff, Alane Boyd et al. 2002; Bell 2009). It is located in Wasatch County, Utah on the Provo River providing drinking and irrigation water as well as recreation to residents of Utah, Wasatch, Summit, and Salt Lake Counties. The watershed drainage area for Deer Creek is 171,663 acres, not including the drainage area for Jordanelle Reservoir (David Eckhoff, Alane Boyd et al. 2002). The reservoir's capacity is 152,700 acre-feet (Bell 2009) . Figure 1 shows a photo of the reservoir.


Figure 1. Deer Creek Reservoir

In 1974 Deer Creek was classified as eutrophic based on the Carlson's Trophic State Index. This classification was given due to anaerobic conditions caused by low dissolved oxygen levels and high total phosphorus loadings. In 1984 Utah Governor Scott Matheson issued the 1984 Water Quality Management Plan in an effort to improve the water quality of Deer Creek. The purpose of this plan was to control the total phosphorus loadings into the reservoir. In order to accomplish its goals several projects and controls were implemented including the construction of Jordanelle Reservoir, the Provo River Restoration Project, controls set on nearby water treatment plants, agricultural practices, animal feeding practices, and controls set for nearby fish hatcheries (David Eckhoff, Alane Boyd et al. 2002). Current controls were put in place as a result of a total maximum daily load (TMDL) study on Deer Creek done in 2002. This study showed that after the earlier controls for phosphorus and other nutrients were implemented, the nutrient levels found in the reservoir showed a decrease in their concentration.

Although the nutrient levels decreased, seasonal algae blooms continued to occur. The TMDL study reported annual goals for algal biomass measurements as 5.1ug/L chlorophyll-a, $6.5x10^7$ um^3/ml biomass, and $3.3x10^7$ um^3/ml cyanophyta (David Eckhoff, Alane Boyd et al. 2002).

The TMDL study cited an incident involving algae blooms in the reservoir in 2001. The high concentration of algae caused taste and odor problems in the drinking water for the Orem and Salt Lake Valley areas. The Orem Water Treatment Plant used activated carbon to remove the taste and odor from the water (David Eckhoff, Alane Boyd et al. 2002). In order to avoid this problem again, the current additional controls on nutrient loading into Deer Creek Reservoir were put into place.

To evaluate the impact of these controls and help support future management decisions, accurate and efficient methods to measure algae concentrations in the field are required. Several studies have developed correlations between algae biomass and chlorophyll-a measurements including those done by Kenneth H. Nicholls and Peter J. Dillon, Daniel E. Canfield, Jr., Stephens B. Linda, and Lynn M. Hodgson, and Blanka Desortova (Nicholls and Dillon 1978; Desortová 1981; Canfield Jr, Linda et al. 1985). These studies showed strong correlations between algal biomass and chlorophyll-a and also evaluated traditional testing methods such as microscopic cell counting to determine algal biomass and using spectrophotometry to measure chlorophyll-a concentrations in chlorophyll extractions.

Although the correlations are strong, the procedures for measuring chlorophyll-a and biomass using spectrophotometry and microscopic determination are tedious and costly. All of the data used in the reviewed literature were collected using water samples taken in the field and then analyzed in the laboratory. The cost, time, and difficulty of taking numerous samples results in an incomplete understanding of the algae vertical profile in the water column.

A high-resolution, low-cost measurement method for either chlorophyll-aor biomass is needed to better understand the spatial distribution of algae in Deer Creek Reservoir. In the past few years a number of field probes that use optical methods to measure chlorophyll have become available. Since these probes use optical methods, they are influenced by turbidity, algae cell walls, and other factors. The goal of this study was to develop correlations between field measurement techniques using probes and traditional laboratory measurement methods.

METHODS

The field chlorophyll-a and laboratory algae data from Deer Creek Reservoir used in this study were provided by the Central Utah Water Conservancy District. These data were collected monthly between April and November from 2005 to 2010 as the weather conditions on Deer Creek permitted in a sampling location just upstream of the dam.

Water samples for algae analysis were taken at the same location and time as the chlorophyll-a measurements using accepted standard methods. These water samples were 2 liters in volume and taken at three different zones in the water column: the upper euphotic zone, the lower euphotic zone, and near the reservoir bottom. To create the two-liter samples in the upper two zones, two separate one-liter samples were collected and mixed. To represent the upper euphotic zone, a one-liter sample was taken at the surface and another taken at the secchi depth and mixed in a 2-liter bottle. To represent the lower euphotic zone, a one-liter water sample was taken at the secchi depth and another taken at 3 times the secchi and mixed in a 2-liter bottle. A single 2-liter water sample was taken near the reservoir bottom to represent the bottom zone. All three water samples were sent Rushforth Phycology to determine the amount of algae in the water as biovolume by using microscopy cell counting methods. The laboratory results provided algae biovolume in micrometers per milliliter for total phytoplankton subdivided into algal taxon and species. In this study we only analyzed the correlation between the total phytoplankton biovolume measurements and the field chlorophyll measurements. We used the biovolume measurement as an index for biomass (Canfield Jr, Linda et al. 1985).

Field chlorophyll measurements were taken every meter from the water surface to the reservoir bottom using an optical sensor attached to a Hach Hydro Lab sonde. The measurements were stored on a handheld data collector and uploaded to a spreadsheet.

To compare algae biovolume to field-measured chlorophyll-a, we estimated the average chlorophyll-a concentrations, based on the sensor data, for the upper and lower euphotic zones based on the secchi depth. The average for the bottom zone was computed using the two lowest probe measurements.

Monthly average measurements of algae biovolume and chlorophyll for each zone were then calculated. Regression analysis was done for each zone with field-measured chlorophyll-a as the independent variable and laboratory-measured algae biovolume as the dependent variable. Only linear fits for each data set were evaluated. Statistical Discovery Software JMP was used in this study to help manage and find the best fit for the data. In order to better observe trends in the data, biovolume and chlorophyll were both plotted against the month for each sample zone.

RESULTS

The results from the analysis show positive correlations between algal biovolume and chlorophyll-a for the three zones. Figures 2, 3 and 4 show the results from the regression analysis for the lower euphotic zone, the upper lower euphotic zone, and the bottom zone, respectively.

None of the zones show very strong relationships between laboratory-measured total biovolume and field-measured chlorophyll-a. By inspection, one or two outliers exist in each of the three data sets that increase the variance and reduce the correlation between the two measurement methods.

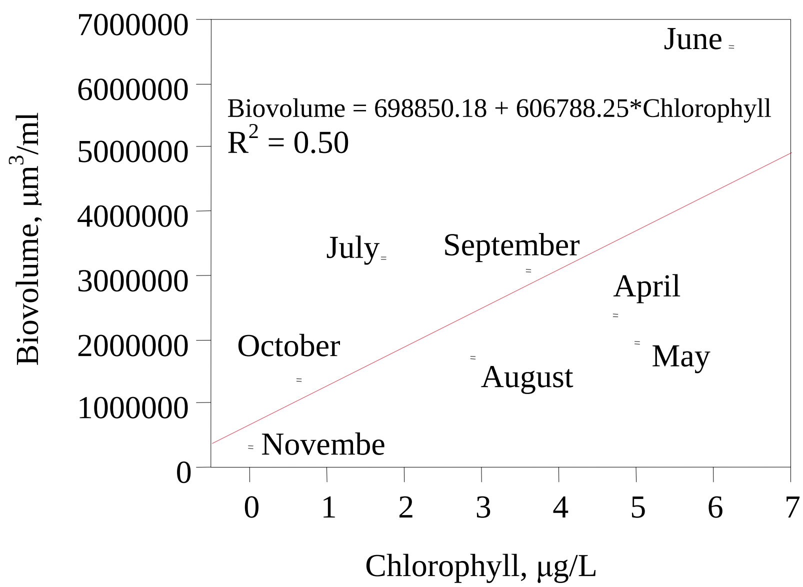

Figure 2. Correlation between Biovolume and Chlorophyll for the lower euphotic zone

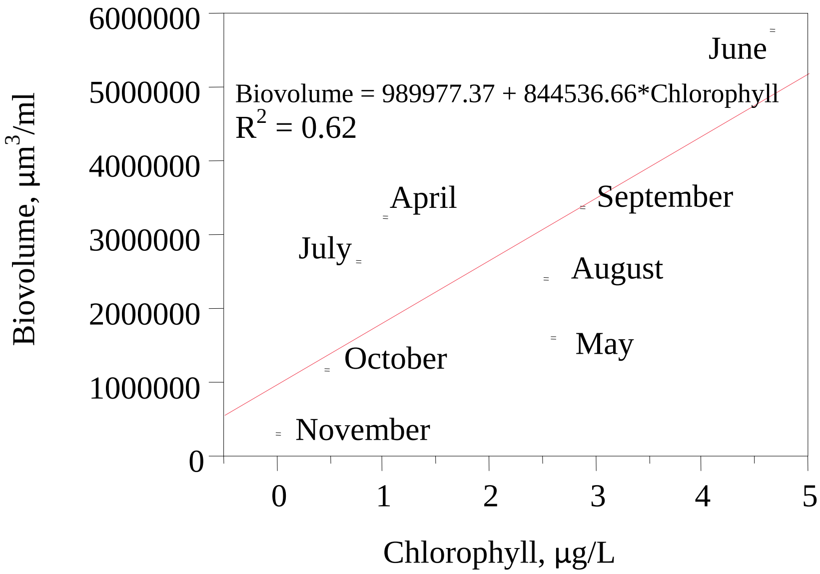

Figure 3. Correlation between Biovolume and Chlorophyll for the upper euphotic zone

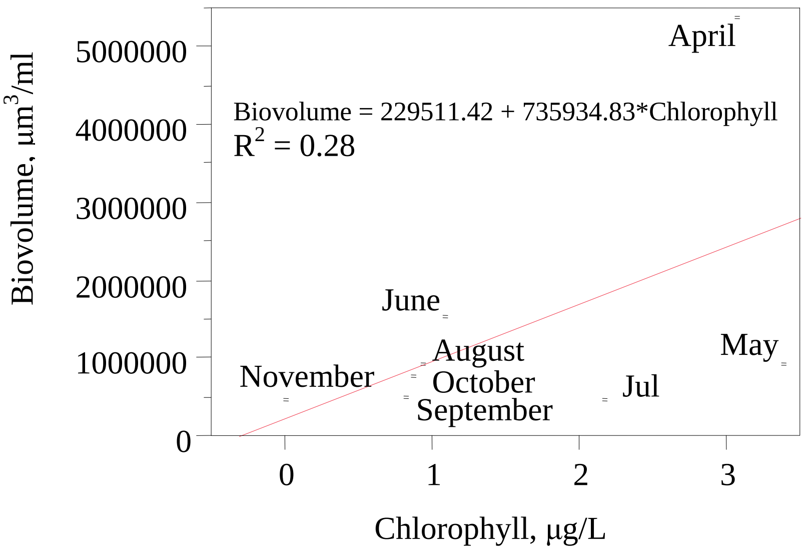

Figure 4. Correlation between Biovolume and Chlorophyll for the bottom zone

Figures 5, 6, and 7 show biovolume and chlorophyll plotted against time for the lower euphotic zone, the upper euphotic zone, and the bottom zone, respectively. From these plots we were able to visually evaluate the general trends between the laboratory and field measurements over time. The two measurements follow similar trends for the bottom of the water column (Figure 7) but do not exhibit similar trends in the upper and lower euphotic zones.

We hypothesize that this lack of correlation is due to the fact that we used total phytoplankton as the master variable. The different taxa have different sensitivities for the field-measurements. For example, diatoms, because of their thick carbonate shells have a different response from the field-probe as it measures observable chlorophyll-a. We expect that further study using individual taxa as the master variable will result in better correlations.

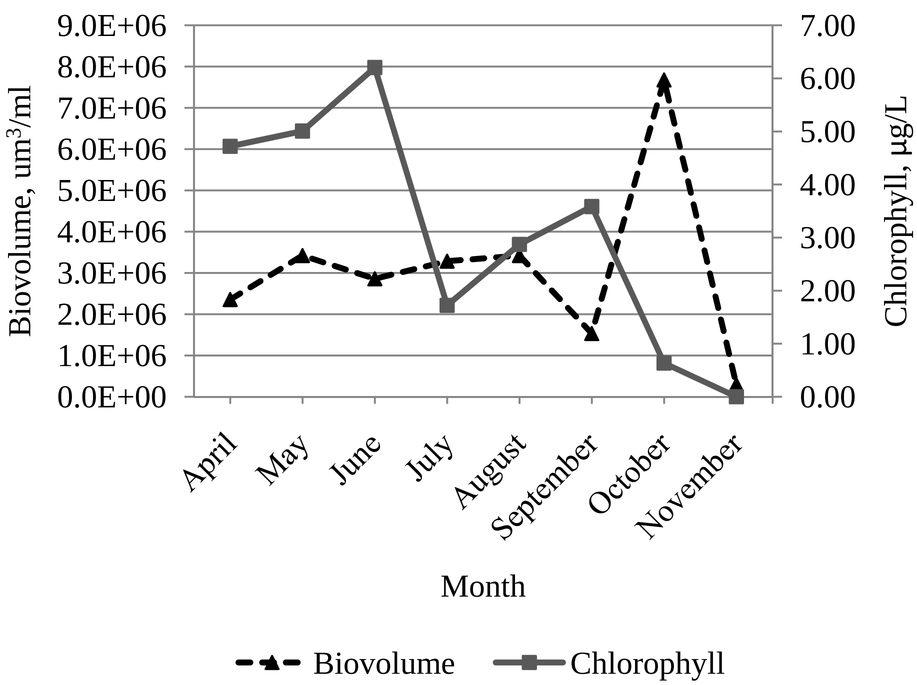

Figure 5. Average biovolume and chlorophyll trends over time in the lower euphotic zone

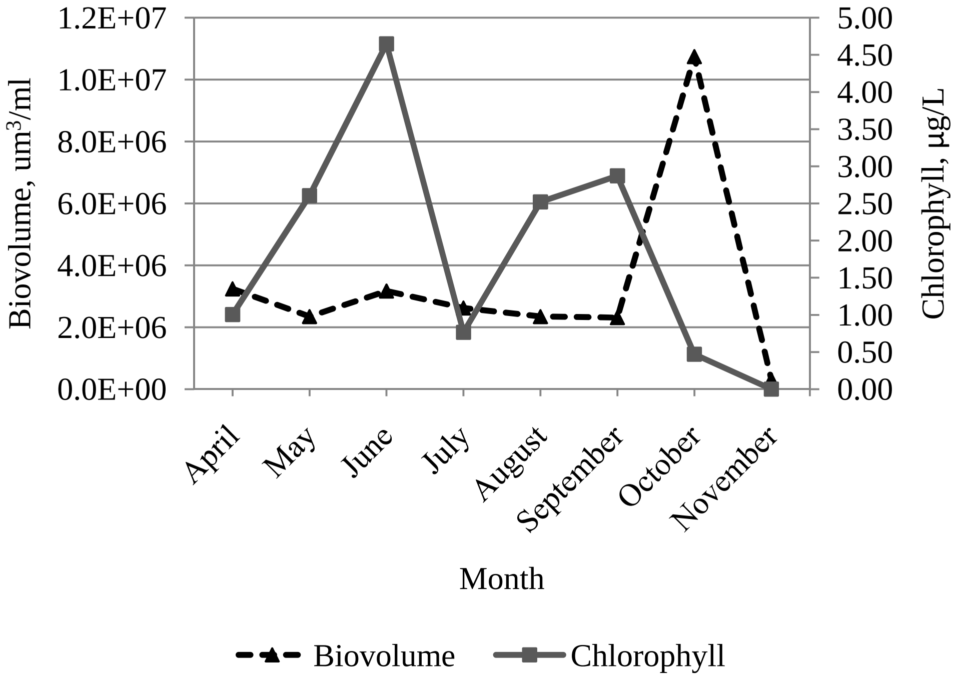

Figure 6. Average biovolume and chlorophyll trends over time in the upper euphotic zone

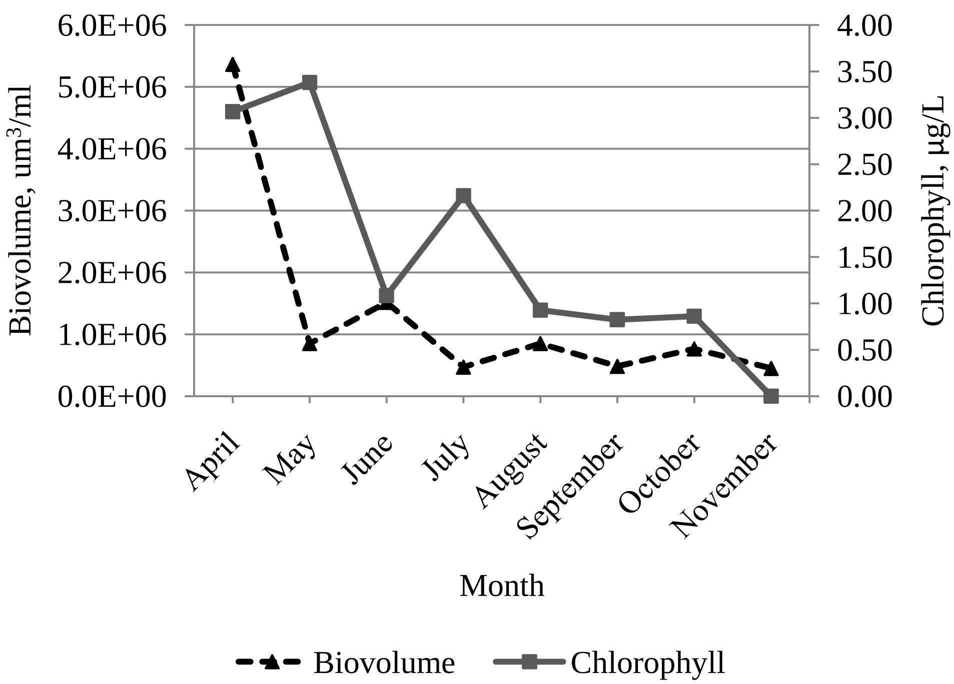

Figure 7. Average biovolume and chlorophyll trends over time at the bottom of the water column

CONCLUSIONS

The results from the regression analysis show that there is some correlation between total phytoplankton biovolume and chlorophyll-a concentrations in Deer Creek Reservoir with the best correlations in the lower reservoir zone. The upper zones exhibited less correlation between the two measurements. We developed linear final regression equations between the laboratory-measured biovolume and the field-measured and chlorophyll-a data based on monthly values that were averaged over 6 years. The data were also averaged spatially for the three separate vertical water column zones.

High-resolution, low-cost field measurements can provide significantly more information on the spatial and temporal aspects of reservoir processes. Although these initial results do not exhibit high correlations, even approximate data can provide information on these spatial and temporal trends.

To be useful, better correlations or measurement methods are required. We expect that looking at subdivisions of the data and not performing the temporal averaging may result in better empirical estimates. We think that the low correlations could be the result of different types of algae present in the various months, each with a different correlation between the field and laboratory measurements.

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