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How 5-day Weather Patterns and Buoyancy Regulation Impact Algal Community Assemblage

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5-day weather patterns and buoyancy regulation impact algal community assemblage

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Abstract

The purpose of this study is to model how 5-day weather patterns and algal buoyancy regulation influence the competition between two bloom forming cyanobacteria species in Upper Klamath Lake, Oregon. Sudden changes in weather patterns can quickly impact lake thermal structure, which can rapidly influence the competition between buoyancy regulating cyanobacteria. By modeling competition, I hope to address how altered climate would shift the competitive advantage to toxin forming cyanobacteria. I plan on accomplishing this by coupling a one-dimensional hydrodynamic and algal competition model, with lake specific physiological parameters. A sensitivity test of the model could reveal dramatic shifts in algal competition under future climate change scenarios, which could have implications in how Upper Klamath Lake is managed and how restoration efforts are implemented.

Introduction

Vertical mixing and reaction-diffusion equations have been incorporated into biological-physical models to describe phytoplankton community dynamics, and structure and competition between species (Jöhnk et al 2008; Huisman et al 2002 & 2004). All phytoplankton are impacted by the availability of light, but buoyant species have the ability to regulate their position in the water column, and thus influence the light environment of the water column via shading (Huisman et al 2004). However, the underlying mechanisms that give one buoyant species a competitive edge over another buoyant species are poorly understood. This lab proposes an algal physiological approach to investigating competition between species. Plankton physiological adaptions could have profound effects on restoration efforts, especially when taking into consideration ecosystem response to climate change. Thus, it is important to consider future ecological stressors in order to develop a meaningful long-term restoration plan for a degraded ecosystem.

I am investigating the sensitivity of lake thermal regimes to climate change scenarios, and how this can reassemble algal community structure and influence the competition for light between different species of phytoplankton. I plan to accomplish this by building a coupled biological-physical model (Jöhnk et al 2008) in STELLA to investigate how competition for light is affected by different lake turbulence structures. To increase accuracy of model physiological parameters, I measured *Aphanizomenon flos-aquae* (AFA) buoyancy rates from in-lake specimens.

Research Aims

Cyanobacteria species have differing buoyancy rates and this can confer distinct advantages or disadvantages under certain mixing regimens. To elucidate the advantages one species can have over another during competition, I aim to:

1. From direct observations, measure the velocities of cyanobacteria from UKL. This buoyancy parameter will be used in the model.
2. Create and run a sensitivity analysis on a model which simulates vertical heat transfer through a lake, and investigate how different cyanobacteria buoyancy rates impact species concentration within a lake on days with distinct weather patterns (hot and calm, windy and cold, etc.).

Phytoplankton of Concern

Aphanizomenon flos-aquae (AFA) and *Microcystis aeruginosa* (MSAE) are two buoyant cyanobacteria that are present in Upper Klamath Lake (UKL). AFA dominates the UKL system, but MSAE has been known to bloom. MSAE produces harmful toxins, which is of concern to lake managers because of the health implications for humans and animals (Paerl 2001).

Study Site

UKL is a large (250 km^2), shallow (~4m), and hypereutrophic lake (Johnson et al 1985). This natural lake is located in a sizeable Watershed (9,415 km^2), and a dam down river controls the Height of the lake. All Cyanobacteria samples were taken from the sites listed to the left.

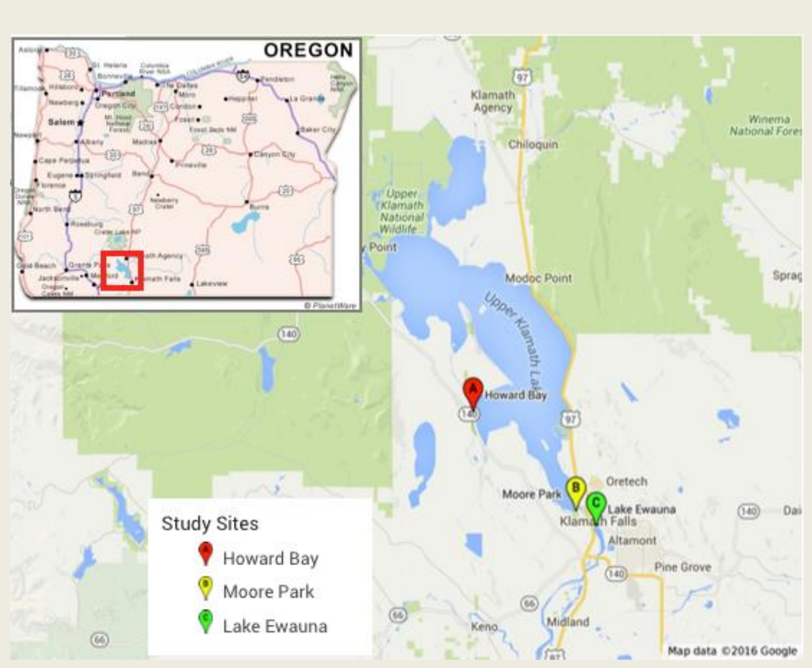

Figure 1: Map of Upper Klamath Lake and algae sample sites.

Methods

Measuring cyanobacteria buoyancy rates

Cyanobacteria samples were collected from UKL, incubated in a dark container for 1-5 hours, and movement was video recorded for 10 minutes. Individual AFA raft buoyancy rates were tracked using Logger Pro® software. Cuvettes were divided into ten subsections. One raft was selected from each subsection. Each raft was tracked for one random minute. All ten subsections were averaged to get one buoyancy rate for each sample (33 samples in total).

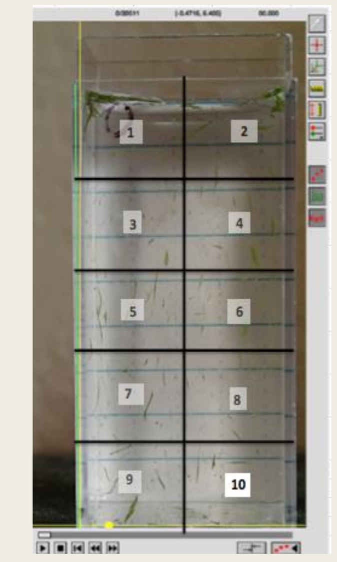

Figure 2: Cuvette and AFA sample

1D Competition Model

Direct lake temperature was collected from UKL via data loggers (in 10 cm intervals) to help recreate heat transfer simulations in a one-dimensional hydrodynamic competition model. The model takes into account meteorological variables (temperature, light gradient) as well as algal physiological variables (specific growth rates, loss rates, light attenuation coefficients, buoyancy rates, optimal growth rates). See Figure 3 for a conceptual diagram.

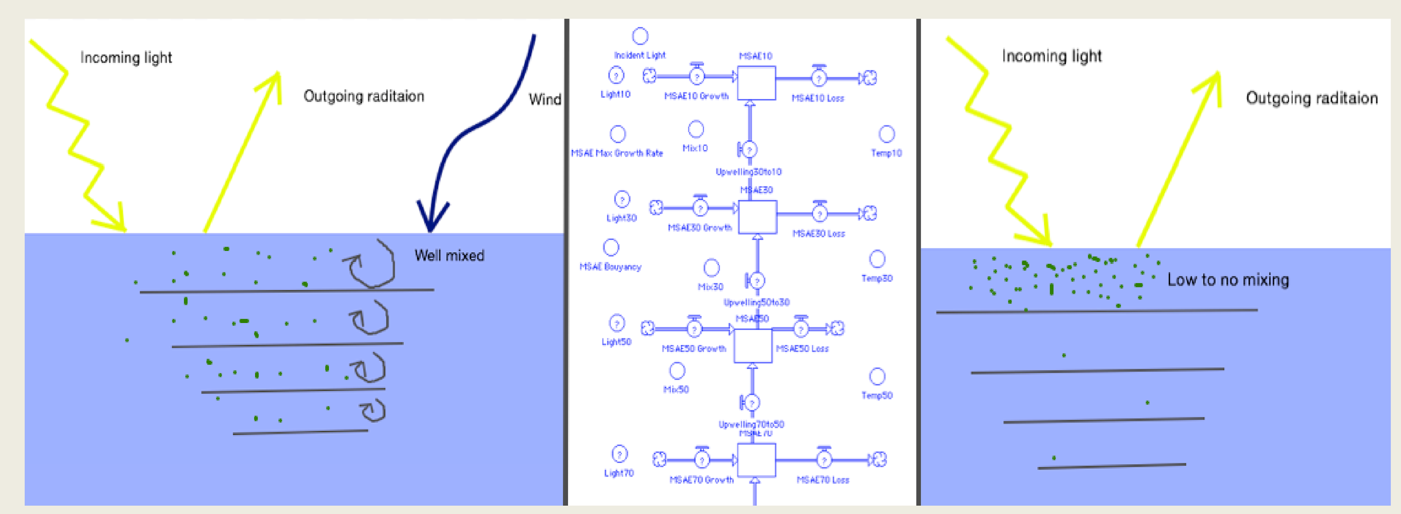

Figure 3: Conceptual diagram of lake thermal structure and algae distribution pattern

Measuring of weather variables

A weather station was placed on the lakeshore and meteorological variables were recorded (PAR, air temperature, humidity, wind etc.). The purpose was to characterize days as hot and calm, or windy and cold when running the sensitivity analysis. Figure 4 shows the in-lake temperature logger data. Figure 5 depicts a windrose, which visualizes wind speed, direction and duration from September 24 to 29, 2015.

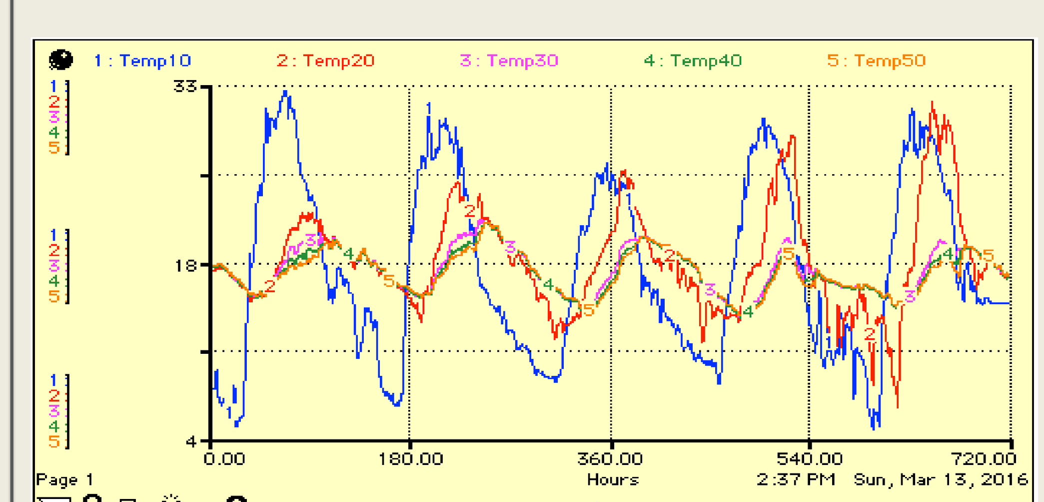

Figure 4: In-lake water temperature for various depths.

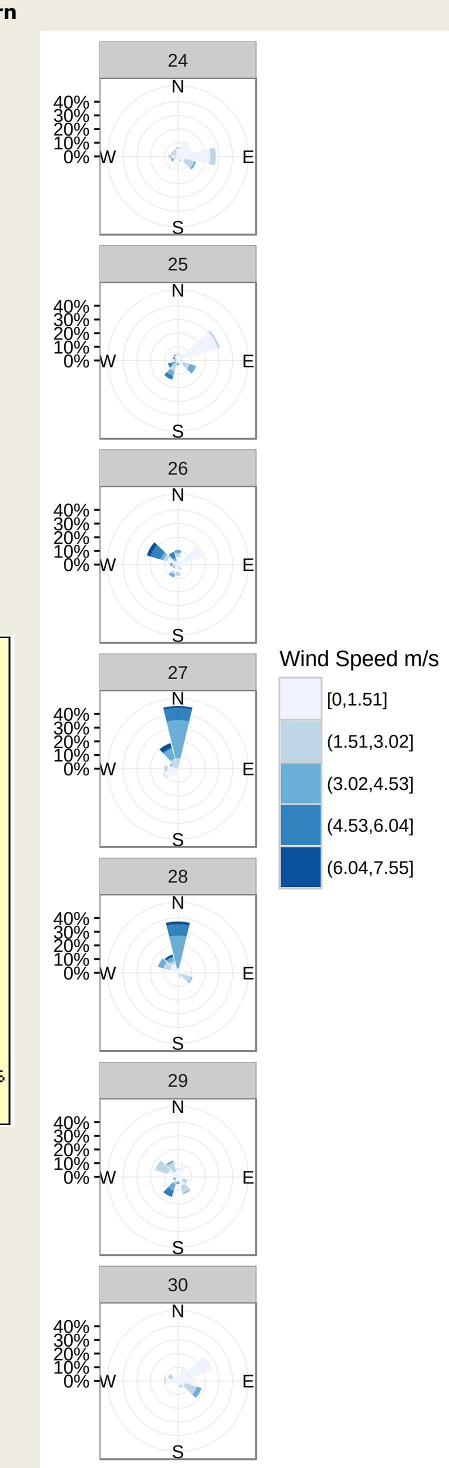

Figure 5: Windrose depicts wind direction, speed and duration.

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Preliminary Results

1D Competition Model

The model currently accounts for temperature gradient, and algal growth parameters. Figure 6 shows the current status of the model.

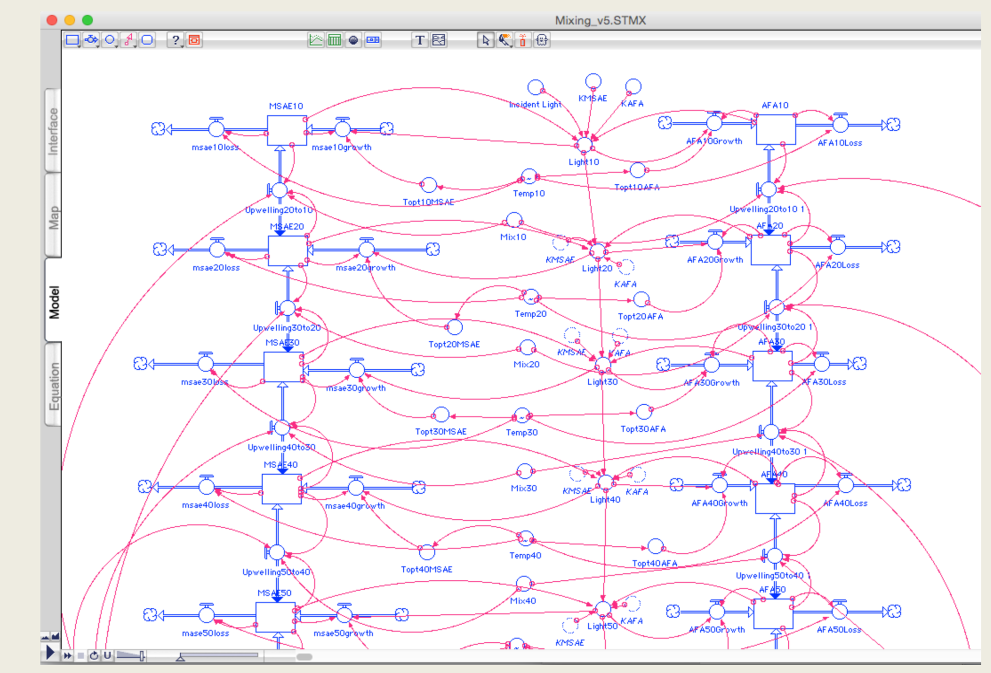

Figure 6: Current configuration of competition model

Buoyancy Rates

The average calculated buoyancy rate for UKL AFA samples is 2.5 x 10^{-4} ms^{-1}. This is the same as the published literature value of 2.5 x 10^{-4} ms^{-1} (Walsby et al 1995). Samples were checked for variance between sample sites, and there was not a statistically significant difference detected (ANOVA, F-value= 2.2, df = 2, p-value = 0.12).

Future Expected Results

By modifying and combining two existing models by Huisman and Jöhnk I hope to better fit the ecological system at Upper Klamath Lake. Huisman and co-workers developed an algal competition model, which incorporates vertical velocities of floating and sinking species. The model was able to predict the outcome of competition for light and estimate critical water column depth and critical turbulent diffusion at which no algal blooms occur (see Figure 7). Jöhnk coupled Huisman's competition model with a one-dimensional meteorologically driven hydrodynamic model. With calibration, Jöhnk's model was able to predict the impact of water temperature on algal specific growth rates, and thus competition (See Figure 8).

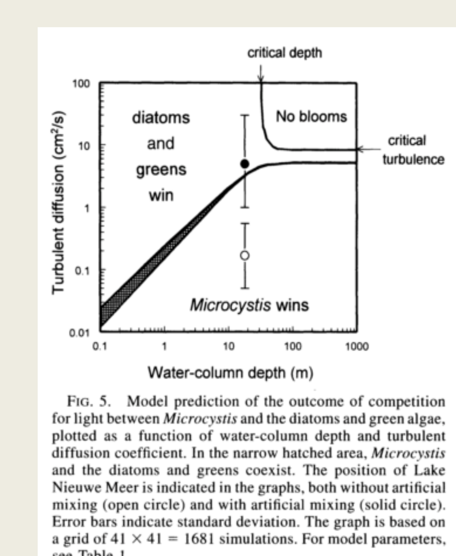

Figure 7: Huisman et al 2004.

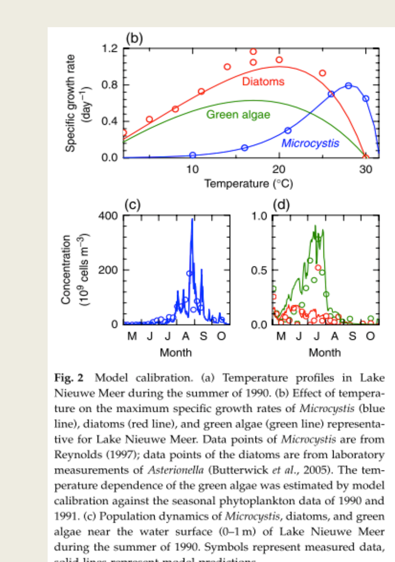

Figure 7: Jöhnk et al 2008.

UKL's ecological system is unique in that it is swallow (reference models are for deeper lakes), hypereutrophic, and hosts a year-around high biovolume of phytoplankton. UKL is also home to two different species of buoyant cyanobacteria (MSAE and AFA). My expected results are:

1. To model the outcome of competition between MSAE and AFA under different lake mixing regimes and weather patterns.
2. Model 5-day weather patterns that create lake turbulence regimens that select for one species of algae over another.

This tool aims to look at short 3-5 day timeframes and at the local scale. By focusing on this scale, a bloom can be contained, but not controlled. The ambition is to shift the management paradigm from creating a clear lake, to more realistic expectation of reducing harm cause by blooms and crashes in UKL.

Next Steps

- The 1D model calibration
- Sensitivity analysis needs completion
- AFA buoyancy rates need finalizing