Impact of Dominant Primary Producer on Shallow Lake Stratification and Dissolved Oxygen Levels

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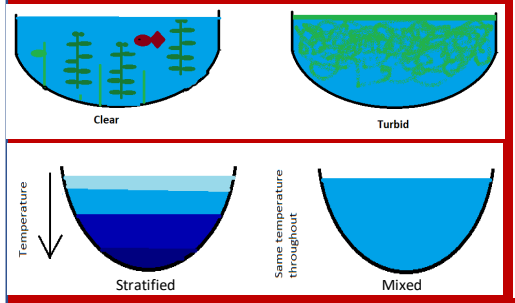
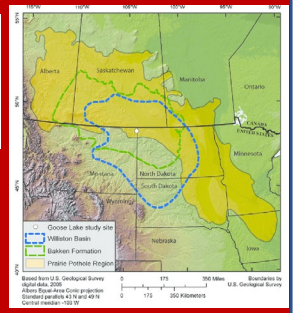
Background

The Prairie pothole region is a 715,000 square kilometer area in North America encompassing thousands of shallow lakes formed by melted glaciers. Previous research has found that these lakes exhibit two stable states, one dominated by macrophytes (clear) and another dominated by phytoplankton (turbid) (Zimmer et al. 2006). Later studies found that the lake state strongly influences nutrient stoichiometry, with clear lakes showing higher rates of denitrification (Ginger et. al. 2017). Others have found significant diel fluctuations in dissolved gas concentrations in these shallow lakes when they are clear, as plants help to stabilize and stratify the water column during the day against mechanical forces of mixing, while allowing nocturnal convective mixing (Andersen et al. 2017). In comparing the dissolved oxygen concentrations in these lakes, previous researchers found that turbid lakes tended to be more stratified with increasing depth, while clear lakes tended to stratify more frequently despite shallower depths. These temperature stratifications also correlated with stratification in the level of dissolved oxygen between the surface and deep waters (Domine, 2011).





Figures 1, 2, and 3. Top displays the two stable lake systems characterized by the dominant primary producer. Bottom shows the differing temperature gradient between stratified and mixed lakes. Right shows map of pothole lakes region shaded in yellow (Preston, 2012)

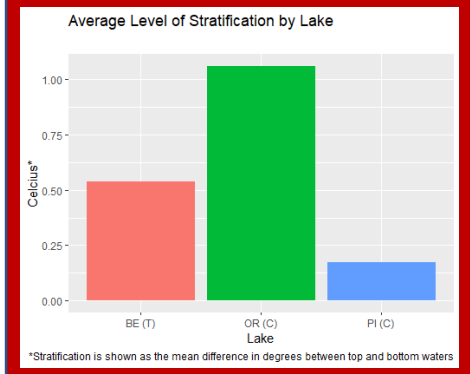
Methods

Three shallow Minnesota lakes, either clear or turbid, were sampled over three years to determine their stratification status and measure the level of dissolved oxygen in their water columns. Levels of dissolved oxygen were measured with an optical sensor on a SONDE made by Hydrolab. The averages for each of these variables was then calculated, and ANOVAs were run to determine whether lake type affected the average stratification of the lake, and whether this stratification or lake type was correlated with a difference in average dissolved oxygen.

Hypothesis

It was hypothesized that the stabilizing effect of macrophytes in the clear lakes would lead to relatively higher levels of stratification compared to the turbid lakes, and that the increased photosynthetic biomass in the clear lakes would lead to a higher average level of dissolved oxygen.

Results

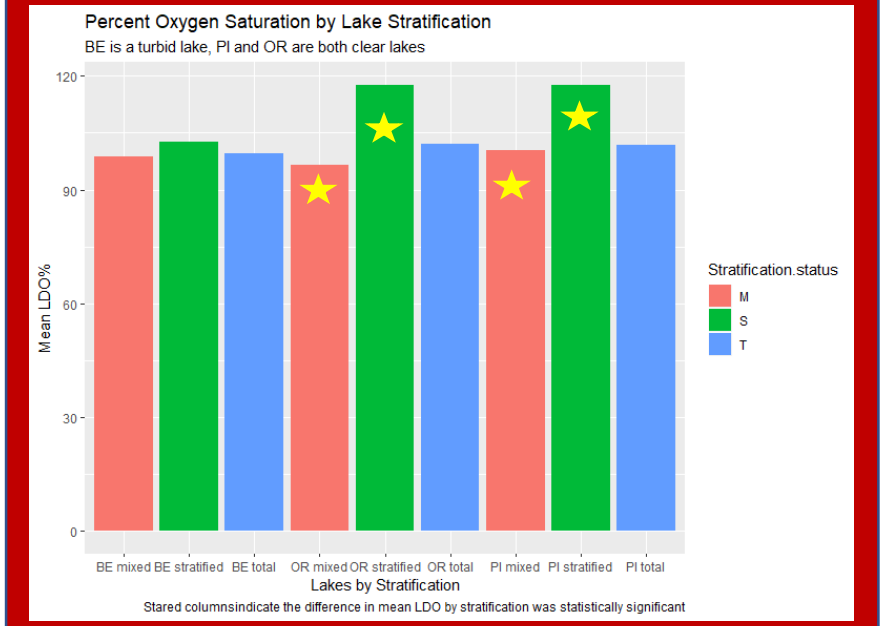


Lake Type and Stratification

There was statistically significant variability in how much each lake stratified compared to one another. The clear lakes had average stratification both higher and lower than the turbid lake, indicating that whether the lake was clear or not did not predictably affect how much each lake stratified. OR, with the greatest stratification was also the deepest lake, and PI, with the least average stratification was also the shallowest

Impact on Dissolved Oxygen

The clear lakes, PI and OR, had significantly higher dissolved oxygen concentrations when they stratified compared to when they mixed. There was less variability in dissolved oxygen concentration by stratification in the turbid lake, BE. Both lake types tended to have dissolved oxygen levels closest to the mixed state overall as shown by the blue total dissolved concentration for each lake.



Discussion

Lake Type and Stratification

There was significant variation in the degree to which the lakes stratified, even among lakes of the same type. Hence, there was not a clear pattern in stratification by lake type. The clear lakes had both higher and lower average stratification compared to the turbid lake. This finding is likely due to the small sample size. Because depth has previously been cited as an important factor in the stratification of turbid lakes, more needs to be considered to gain a more complete understanding of how lake type impacts stratification.

Dissolved Oxygen

Stratification was correlated with an increased level of dissolved oxygen in the clear lakes, but not the turbid lake. Though lake type did not have a direct correlation with the absolute level of dissolved oxygen in the lake, these results suggest that there may be a difference in the levels of dissolved oxygen between clear and turbid lakes when they stratify that is not obvious from total measurements. While the difference in average level of dissolved oxygen by stratification status was not significant in the turbid lake, it was in the clear lakes. This finding follows earlier research that showed that daytime stratification and nocturnal convection allows shallow lakes to mix dissolved gasses leading to higher average levels of dissolved oxygen concentrations when they stratify.

Relevance

Much of the current literature on dissolved oxygen in freshwater systems focuses on the ways in which short term hypoxia in lakes can be detrimental to the variety and abundance of life at all trophic levels (Weinke,2018). The water quality benefits that clear states offer in addition to their tendency to increase the level of dissolved oxygen in the water are why the Department of Natural Resources currently manages for these lakes (Pennsylvania Department of Environmental Protection, 2015). These results suggest that selecting for the clear state might also mean selecting for its impact on dissolved oxygen concentrations by stratification. In sum, these results did not suggest that there were differences in the amount of production in lakes by state, but the dissolved oxygen results may suggest differences by lake type in where this production is distributed in the water column.

References

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