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Chlorophyll α and Primary Production Dynamics in Kentucky Lake: 2009-2018

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Introduction

Chlorophyll α (chl α) can be used as a proxy for phytoplankton biomass while primary productivity (PP), the rate at which carbon is fixed into phytoplankton cells, is an indicator of how quickly carbon is turned over within the phytoplankton community (Cole and Welle 2016). The two metrics are often highly correlated in lakes (Wetzel and Likens 2000). Our goals in this study were to 1) examine spatial distributions of chl α annually and seasonally in KY Lake, and 2) examine the relationship between chl α and PP in two embayments of contrasting land use. The hypothesis is that there is a positive correlation between chl α and PP.

Methods and Data

The data used in this study are from the Kentucky Lake Long-term Monitoring Program (KLMP), 2009-2018. Chl α and PP samples are collected every 16 days during monitoring cruises on Kentucky Lake. The monitoring data analyzed in this study are from Ledbetter Embayment, an agricultural watershed on the west side of KY Lake and Panther Embayment, a forested watershed on the east side inLedbetter and Panther Embayments. The two metrics are often highly correlated in lakes (Wetzel and Likens 2000). Our goals in this study were to 1) examine spatial distributions of chl α annually and seasonally in KY Lake, and 2) examine the relationship between chl α and PP in two embayments of contrasting land use. The hypothesis is that there is a positive correlation between chl α and PP.

Chl α (APHA 2005)

• Water samples were collected using a Kemmer sampler at 1-meter depth at both sites.
• Samples are vacuum extracted in light filtered syringes (0.5-0.7 μm pore size).
• Chl α was determined in light filtered syringes (0.5-0.7 μm pore size) and measured by spectrophotometry at 800 nm after addition of a 0.5% (w/v) solution of NaOH.

PP (Wetzel and Likens 2000)

• Integrated water samples were collected from 0.2 meter depth at each site, inoculated with 0.15 mL of 14C, and incubated in the dark for 12 hours at both sites.
• Samples were filtered through GF/F filters and dried at room temp for 24 hours.
• Filters were placed into scintillation vials with 2 mL of Scintifluor and counted in a scintillation counter.

TN and TP (APHA 2005) modified for Lachat Instruments, Milwaukee, WI

Statistical Analyses (SYSTAT 13.0, Excel 2013)

• Excel 2013 was used to explore data for potential trends and to inform other analyses. Graphs were created in Excel.
• Linear regression and ANOVA with Tukey’s multiple comparison for seasonal effects were carried out in SYSTAT 13.0.

Results

Figs. 1b-1e show the results of the GIS mapping of "hotspots" of chl α at all sites in Kentucky Lake. Figs. 2 and 3 illustrate annual variability of chl α and PP at Ledbetter and Panther embayments over the ten year study. By plotting all data for five years (Figs. 4 and 5) for each embayment and using regression-correlation analysis we showed that there is a strong correlation between chl α and PP. Although the r² values explain only 20% and 30% of the variation for Ledbetter and Panther embayments, respectively, the analysis indicates a significant relationship (p<0.001). However, based on Figs. 2 and 3, a strong seasonal dynamic emerged which lead us to separate the data by season for further analysis.

Fig. 1e shows the results of the GIS mapping of "hotspots" of chl α at all sites in Kentucky Lake. Figs. 2 and 3 illustrate annual variability of chl α and PP at Ledbetter and Panther embayments over the ten year study. By plotting all data for five years (Figs. 4 and 5) for each embayment and using regression-correlation analysis we showed that there is a strong correlation between chl α and PP. Although the r² values explain only 20% and 30% of the variation for Ledbetter and Panther embayments, respectively, the analysis indicates a significant relationship (p<0.001). However, based on Figs. 2 and 3, a strong seasonal dynamic emerged which lead us to separate the data by season for further analysis.

Discussion and Conclusion

From the GIS results, we showed "hotspots" of chl α occurring mostly in the shallower embayments on the west side of Kentucky Lake during summer and fall (Figs. 1b-1e). This lead to broader questions about the effects on chl α distributions with respect to watershed nutrient inputs and the relationship between chl α and primary productivity. In general, a positive relationship between chl α and PP occurred in both embayments over the 10-year study. In Ledbetter and Panther embayments, as chl α increased, an increase in PP also observed. But seasonal effects carry much more weight in the relationship between chl α and PP than any site effects. An exception occurs, however, during the summer where the relationship breaks down in both embayments. Although N:P ratios were not significantly different between embayments, they were significantly different among most seasons except during winter and summer at Ledbetter and winter and spring at Panther. The highest N:P ratio occurs in the spring when a pulse of nitrogen enters via runoff, a rapid drop off in N:P occurs during summer and fall. We can only hypothesize that the rapid decrease may contribute to the breakdown in the chl α:PP relationship during summer.

Variables that commonly change seasonally such as nutrient decreases, light, and temperature may contribute to much variability in the strength of the relationship between chl α and PP. Other studies have found that while N:P ratios had increased over time, the addition of excess nutrients did not disrupt chl α:PP trends (Yang and Yang 2011). Others have also suggested that grazing by zooplankton (Steble and Baird, 1981) and herbivores (Yang and Yang 2011) instead may have played a role in altering phytoplankton standing stock and PP. Seasonal effects of irradiance and depth of light penetration on the chl α:PP relationship in the North and South embayments have been suggested by Bot and Colijn (1989) and Steele and Baird (1981).

To answer our initial question: can chl α be used to predict PP, we can give a cautionary “yes,” but must consider seasonal effects on the chl α:PP relationship. During summer, chl α may be not a good predictor of PP due to a decoupling between the biomass and the rate at which carbon is taken up by the cells.

Knowing this we can say that Kentucky Lake is similar to other water bodies where stronger relationships between chl α and PP have been found. High levels of chl α in which can be visible to the eye may also indicate high levels of PP which may lead to rapid die off and result in areas of hypoxic and habitat degradation. This could lead to fish kills and toxin production by dying algae which may impair drinking water supplies and pose other management issues.

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Literature Cited