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 Weile 2016). The two metrics often are highly correlated in lakes (Wetzel and Likens 2000). Our goals in this study were 1) to examine spatial distributions of chl α annually and seasonally in KY Lake, and 2) to 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 in Land-Between-the-Lakes Recreation Area (Fig. 1). Total nitrogen (TN) and total phosphorus (TP) data from the same time period were used to describe the nutrients at both embayments.

Chl α (APHA 2005)

- Water samples were collected using a Kemmerer sampler at 1-meter depth at both sites.
- Samples are vacuum-filtered through GFF filters (0.5-0.7 µm pore size), ground, and acetone-extracted in test tubes.
- Test tubes were centrifuged, acetone blanks and samples were measured by spectrophotometry before and after acidification for phaeophytin correction. Measurements are calculated in µg/L.
- Geospatial hotspots of Chl α were identified using ARCMAP GIS software and data from several monitoring sites in Kentucky Lake.

PP (Wetzel and Likens 2000)

- Integrated water samples were collected from 0-2 meter depths at each site, inoculated with 0.15 mL of ^{14}C, and incubated shipboard for two hours at *in situ* temperatures.
- Samples were filtered through GFC or GFF filters and dried at room temp for 24 hours.
- Filters were placed into scintillation vials with 2 mL of ®Scintifluor; depurations/min counted by scintillation counter
- ^{14}C uptake calculated as µgC/L/hr.

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

Statistical Analyses (SYSTAT 13.0, Excel 2013)

- Excel 2013 was used to explore raw 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 a at several 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 all years (Figs. 4 and 5) for each embayment and using regression-correlation analysis we showed that there's a strong correlation between chl α and PP. Although the r^2 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.

Seasonal analyses showed a significate positive correlation of chl α and PP during the winter, spring, and fall (p<0.01 for Ledbetter and p<0.02 for Panther; Figs. 6 and 7). The correlations break down during summer at both embayments (Figs. 6c and 7c). The greatest positive correlation between chl α and PP occur during the spring at Ledbetter and during the winter at Panther.

Further analysis using ANOVA and multiple comparison procedures differentiate which seasons have significantly different chl α concentrations and PP (Figs. 8 and 9). Chl α at Ledbetter embayment is higher in summer than spring and winter (but not fall) (Fig. 8). PP is significantly higher in spring, summer, and fall than in winter at Ledbetter. At Panther (Fig. 9) there are no significant differences in chl α by season. However, there are significant difference in PP occurring between fall and summer and fall and winter.

Although N:P ratios were not significantly different between embayments, they were significantly different among all seasons except during winter and summer at Ledbetter and winter and spring at Panther (Fig. 10; ANOVA, p<0.05).

Acknowledgments

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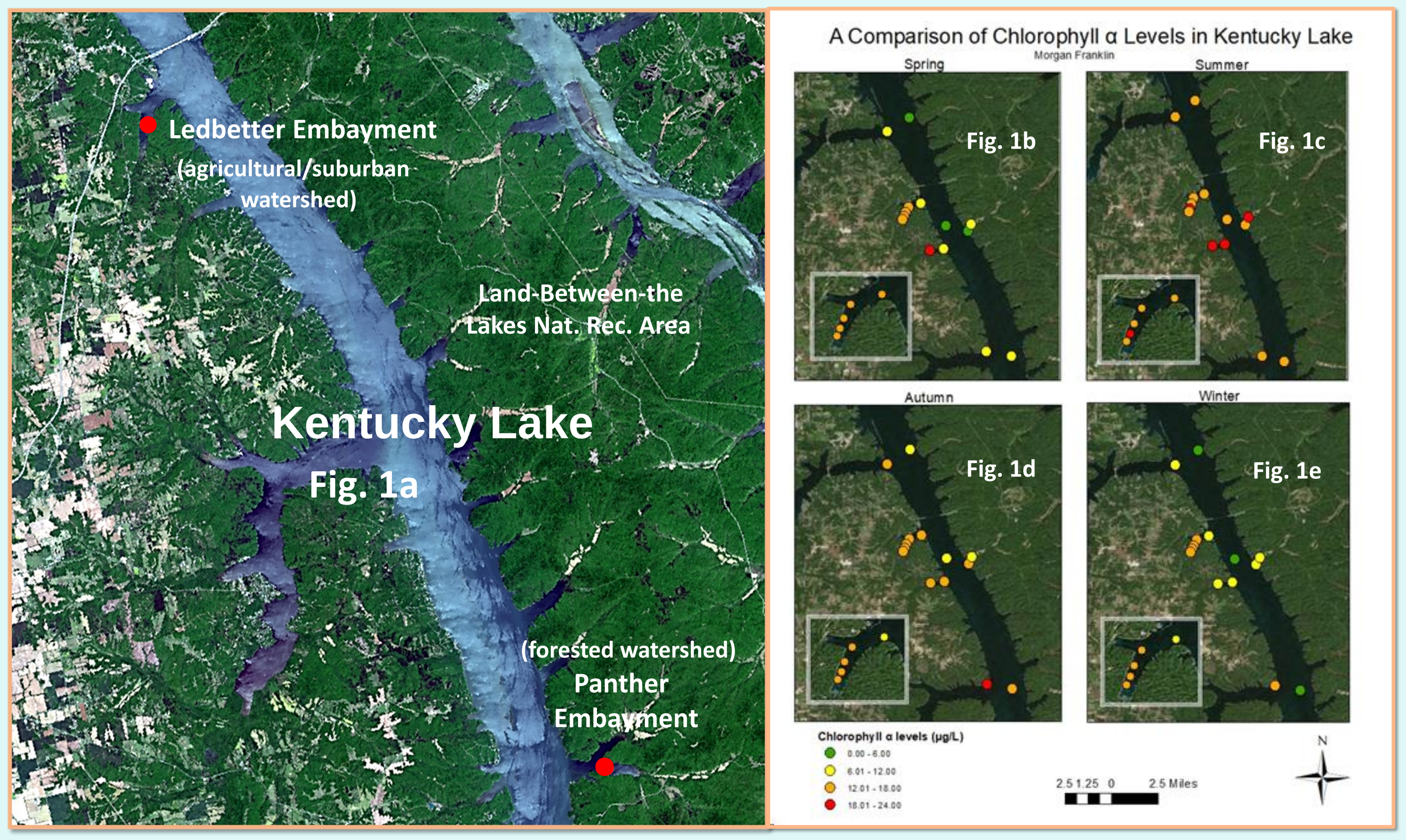


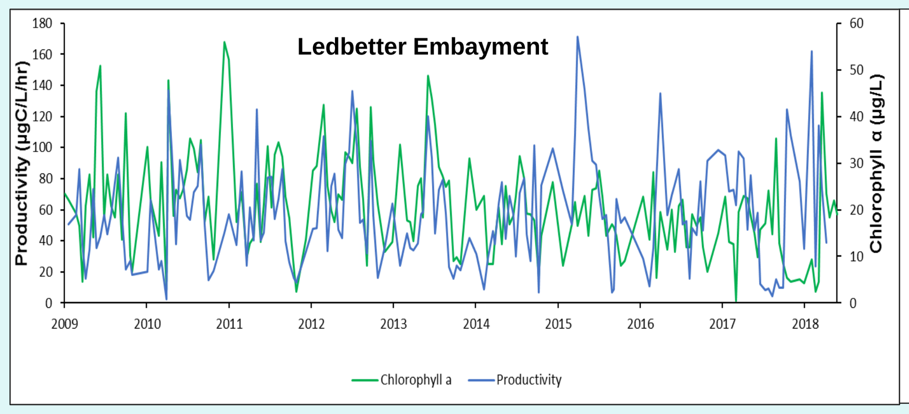


Fig. 2. Time series of annual variation in Chl α and PP at Ledbetter embayment, 2009-2018.

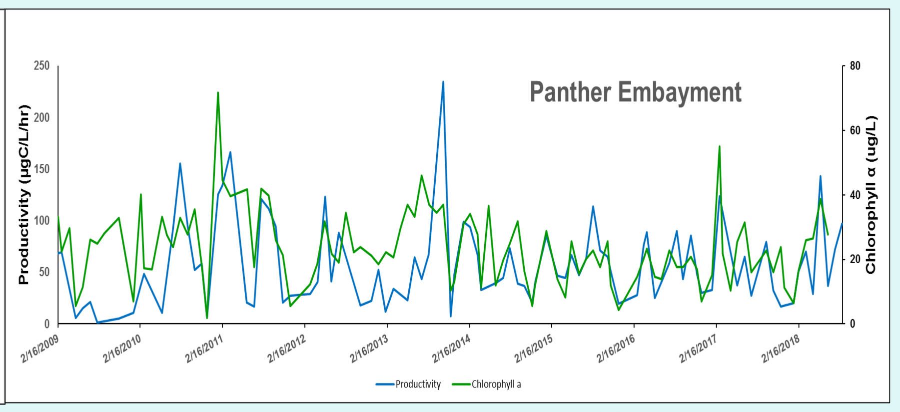


Fig. 3. Time series of annual variation in Chl α and PP at Panther embayment, 2009-2018.

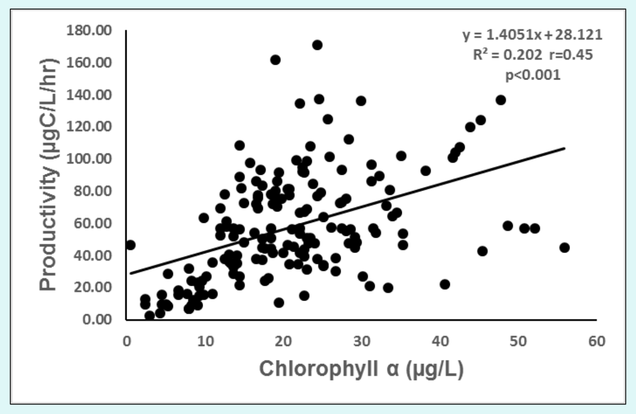


Fig. 4. Regression-correlation analyses of chl α and PP at Ledbetter embayment (all seasons, all years).

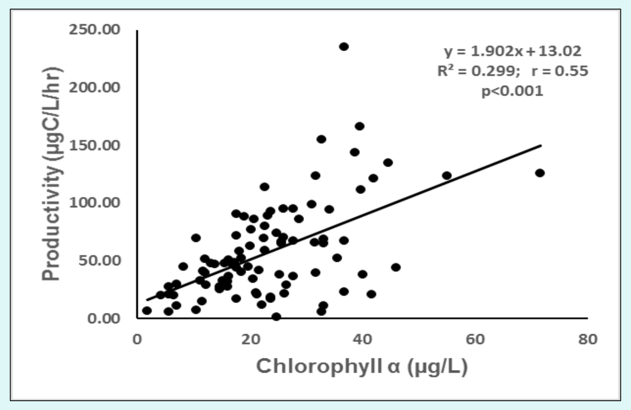
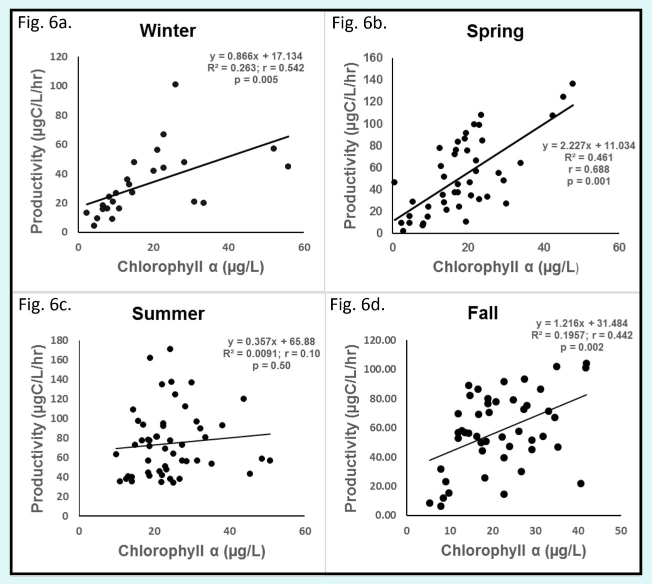
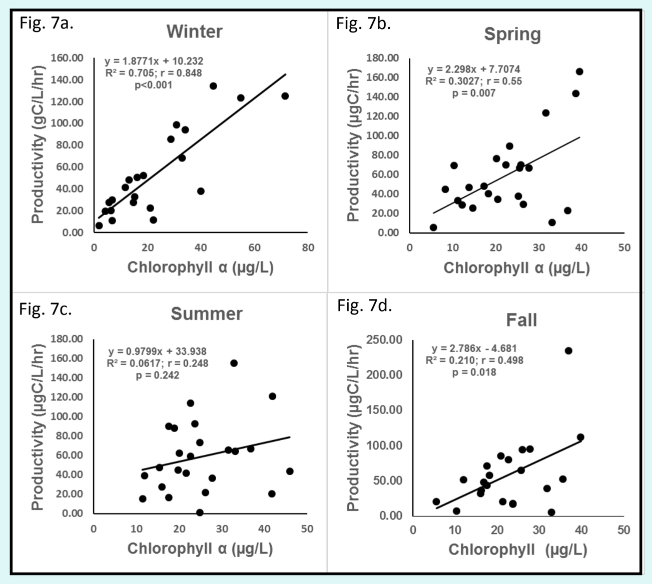


Fig. 5. Regression-correlation analyses of chl α and PP at Panther embayment (all seasons, all years).





Ledbetter Embayment

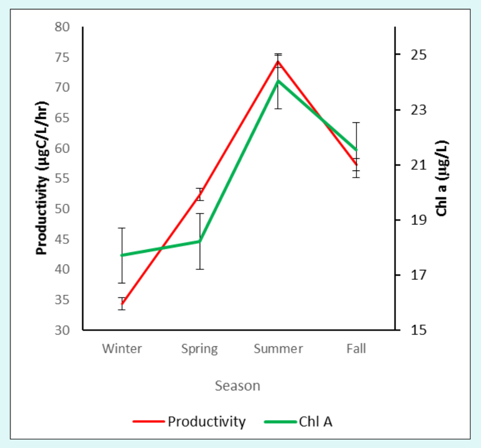


Fig. 8. ANOVA Tukey's multiple comparison of chl α (green line) and PP (red line) at Ledbetter embayment. Significant differences among seasons include the following at α = 0.05. For Chl α: Spring-Summer and Summer-Winter; for PP: all are different except Fall-Spring.

Panther Embayment

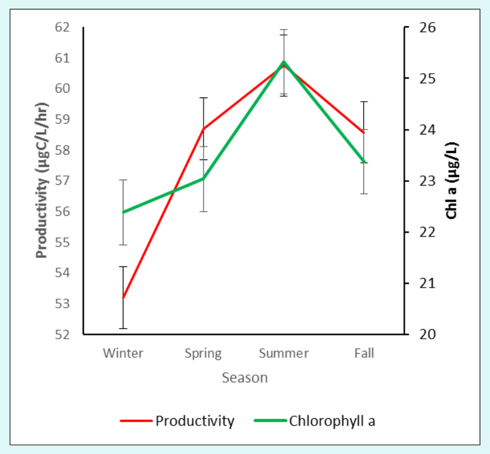


Fig. 9. ANOVA Tukey's multiple comparison of chl α (green line) and PP (red line) at Panther embayment. Significant differences among the seasons include the following at α = 0.05. For Chl α: no differences; for PP: Fall-Summer and Fall-Winter.

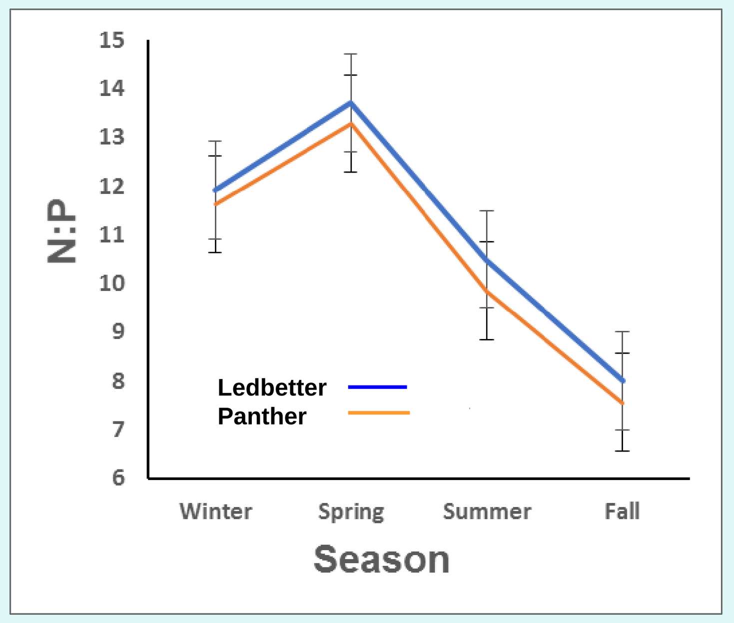


Fig. 10. Seasonal N:P ratios at Ledbetter (blue line) and Panther (orange line) embayments. ANOVA indicated no significant difference between the two sites. Tukey's multiple comparison of N:P ratios within sites were all significantly different (p<0.05) except for Winter-Summer at Ledbetter and Winter-Spring at Panther.

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 was 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 a-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 or PP trends (Yang and Yang 2011). Others have also suggested that grazing by zooplankton (Steele and Baird, 1961; Yang and Yang, 2011) and bivalves (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 Irish Seas have been suggested by Bot and Colijn (1996) and Steele and Baird (1961).

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 and PP relationship. During summer, chl α may not be 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 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 hypoxia and habitat degredation. This could lead to fish kills and toxin production by dying algae which may impair drinking water supplies and pose other management issues.

Literature Cited

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