PhD Dissertation
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Title: Quantifying Mixing at Various Temporal Scales and its Effect on Phytoplankton Development in a Small Suburban Reservoir

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ABSTRACT

Stratification in freshwater lentic systems is generally due to the effect of water temperature on its density. In dimictic lakes, there are two periods of full-lake mixing and two periods of stratification, summer stratification being the one more often studied. During these periods of stratification, according to the classic seasonal model (CSM), the epilimnion, metalimnion, and hypolimnion remain separate entities and do not mix with one another from the onset of stratification in late spring to early summer until the breakdown of stratification in late summer to early fall. However, the CSM addresses only the slow and consistent seasonal temperature and irradiation changes responsible for stable stratification and fails to sufficiently capture more episodic changes which may happen in these stratified bodies of water. These short-term disruptions to stratification, such as mixing and flushing, affect phytoplankton development, which is also not addressed by the CSM.

The subject of this study is Lake Fairfax, a small suburban reservoir in Fairfax County, Virginia built for recreation in 1956. It has a maximum depth of 5 m, a mean depth of 2.5 m, a surface area of 8.7 hectares, and a volume of 220,431 m3 with a large suburban watershed of 1,111 hectares. This study examined a temporally and vertically rich water temperature dataset which allowed for the exploration of the extent to which Lake Fairfax follows the CSM on stratification. From this dataset came numerous findings that are contrary to the CSM. Lake Fairfax has semi-regular cooling events which have both mixing and flushing events associated with them, all of which disrupt water stratification. These events not only have an impact on

thermal stratification but also on vertical profiles of chlorophyll-□, turbidity, TSS, VSS and phytoplankton composition.

Although strong stratification was found through the summer field season in Lake Fairfax only two layers were observed, a 0-2 m upper mixed layer (UL) and a metalimnion-like 2-4 m lower layer (LL) which extends all the way to the bottom of the lake, most likely due to the lake's shallow depth. Both seasonal and weekly patterns of specific conductivity (SpC) fall within what is expect by the CSM. SpC increases with depth and the SpC inflection point deepens along with the temperature inflection point through the summer field season. Patterns of DO also fall within that expected by the CSM, closely related to the balance between photosynthesis and respiration in the upper layer, and increasing through the summer field season. pH values are higher at the surface of the water and decrease with depth as predicted by the CSM as the balance near the bottom leans more towards respiration than photosynthesis. Overall water temperature, SpC, DO, and pH in Lake Fairfax show seasonal patterns in line with the CSM.

However, Lake Fairfax does show many short-term disruptions to stratification which had an impact on the overall strength of lake stratification as well as the thermocline. The disruptions observed included shallowing and deepening of the thermocline as well as partial and complete erosion of the thermocline. No matter the cause, the disruptions to stratification were found to be due initially to changes at the surface which translated into mixing down the water column. The two most observed drivers of stratification disruptions were changes in air temperature and flushing events associated with water cooling events. The events involved in stratification disruption, mainly flushing and mixing associated with external forcing variables impacted chlorophyll-□ values. After the majority of the cooling events associated with these periods of flushing and mixing chlorophyll-□ values decreased below pre-event levels.

Chlorophyll-□, turbidity, TSS, and VSS values indicate the presence of a deep chlorophyll maximum (DCM) in the lower 2 m of the water column, centering at a depth of about 3 m. The DCM is associated with elevated values in turbidity, TSS, and VSS as they may be indirect measures of phytoplankton densities. The average depth for maximum chlorophyll-□ over the study period was 2.57 m with average field season chlorophyll-□ values at 12.7 □g/L in the UL and 51.7 □g/L in the LL. Further evidence of a DCM in Lake Fairfax is the dominance of cyanobacteria at 3 m, and the dominance of Oscillatoria within the cyanobacteria group.