Technical Memorandum for Square Lake Monitoring Research (2013)

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Summary

This memorandum reports on monitoring research for the first year of a three-year moratorium period (2013-2015) during which the Minnesota Department of Natural Resources (MDNR) will not stock rainbow trout (RBT) to Square Lake (Washington County, MN). Prior to this moratorium, RBT had been stocked to Square Lake each year since 1980 (usually 5000 yearling RBT per year). Findings of the 'Square Lake Implementation Plan Refinement' Clean Water Partnership (CWP) study completed in 2010 identified predation by rainbow trout on large-bodied *Daphnia* (*Daphnia pulicaria*) to be the most likely cause for the trend of declining water transparency in Square Lake over the past several decades. The three-year rainbow trout stocking moratorium initiated in the fall of 2012 will enable data to be collected and compared with historical data to assess whether or not the cessation of trout stocking results in an increased abundance of large-bodied *Daphnia* (*D. pulicaria*) and improvements in the lake's water quality (e.g., increased clarity, decreased levels of algal biomass, decreased oxygen depletion in deep water). This memorandum contains a summary of the data collected in 2013 and a preliminary comparison of those data to two recent years (2010 and 2012) when rainbow trout were stocked to the lake by the MDNR. Preliminary results from the first year of the trout-stocking moratorium show significantly greater abundance of large-bodied *Daphnia*, during the summer stratification period. In addition, water clarity increased, levels of algae decreased, and there was less oxygen depletion in deep water. However, trends for the water quality variables (water clarity, algae levels, oxygen levels in deep water) were not statistically significant.

Methods

Square Lake was sampled once a month from January to March, and twice a month from May to October during 2013. For the January-March sampling dates when there was ice cover, whole water column zooplankton net tows were taken from 3 locations in the lake: site W (West), site C (Central), and site E (East) (Fig. 1). For the May-October dates, incremental samples were taken from four different depths in the water column at the location in the deepest part of the lake (site C in Fig. 1), in addition to the whole water column net tows at the 3 sites. The purpose of taking incremental samples was to evaluate how the taxonomic composition and abundance of zooplankton varied among different depths. Duplicate samples were collected and analyzed in all cases.

Temperature and dissolved oxygen profile data were collected at the deepest sampling location on all dates. In addition, on the open-water season sampling dates (May-

October), secchi depth measurements were taken, and water samples were collected for the analysis of Chlorophyll a (algal biomass), total phosphorus (TP), and total nitrogen (Total Kjeldahl Nitrogen: TKN) concentrations. Temperature and oxygen data provide information about the stratification pattern in the lake and the size of the *Daphnia pulicaria* habitat/refuge zone at different times of year.

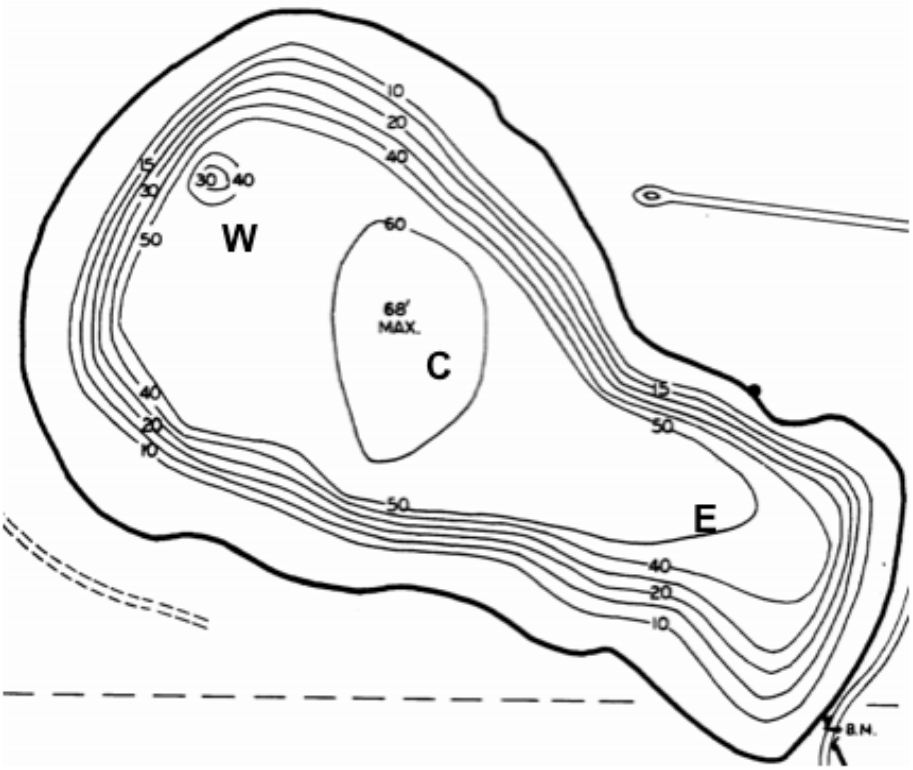

Figure 1. Bathymetric map of Square Lake showing the three sampling locations (W, C, and E).

Results

Temperature & Dissolved Oxygen

During the winter of 2013, dissolved oxygen levels were < 1 mg/L below 16 m on the January 6 and February 14 sampling dates, and by the March 7 sampling date the region with dissolved oxygen levels< 1 mg/L had increased to depths below 14 m (Fig. 2).

Ice out was very late in 2013 (May 3). When sampled on May 5, the lake was ice-free and nearly uniform in temperature (6.4 ^{o}C at the surface and 4.8 ^{o}C at the bottom), but it had not yet mixed (oxygen levels at depths below 14 m were still < 1 mg/L). By the second sampling date in May (May 20), the water column was thermally stratified (Fig. 2, top panel) with surface waters (0-2 m) at ~ 15 ^{o}C, a thermocline extending from 2 m to 9 m, and hypolimnetic waters extending from 9 m to the bottom where temperatures ranged from 5-7 ^{o}C. Some mixing had occurred between the May 5 and May 20 sampling dates, but oxygen levels below 16 m were still very low (< 1 mg/L). These data indicate that the abbreviated spring in 2013 resulted in incomplete mixing during the

spring and prevented the deep water in Square Lake from becoming full oxygenated before the onset of summer stratification.

For the remainder of the summer stratification period in 2013, the surface mixed layer (epilimnion) gradually deepened from a depth of 0-4 m on June 7 to 0-11 m on October 25 (Fig. 2, top panel). During this same period, the region of hypoxia (oxygen levels < 1 mg/L) in Square Lake gradually increased from depths below 14 m on June 7 to depths below 10 m on October 14 (see the red-shaded area in the oxygen contour plot in Fig. 2, bottom panel). On the last sampling date in 2013 (October 25), the water column had begun to destratify and the upper bound of the hypoxic region (< 1 mg/L) was at 13 m.

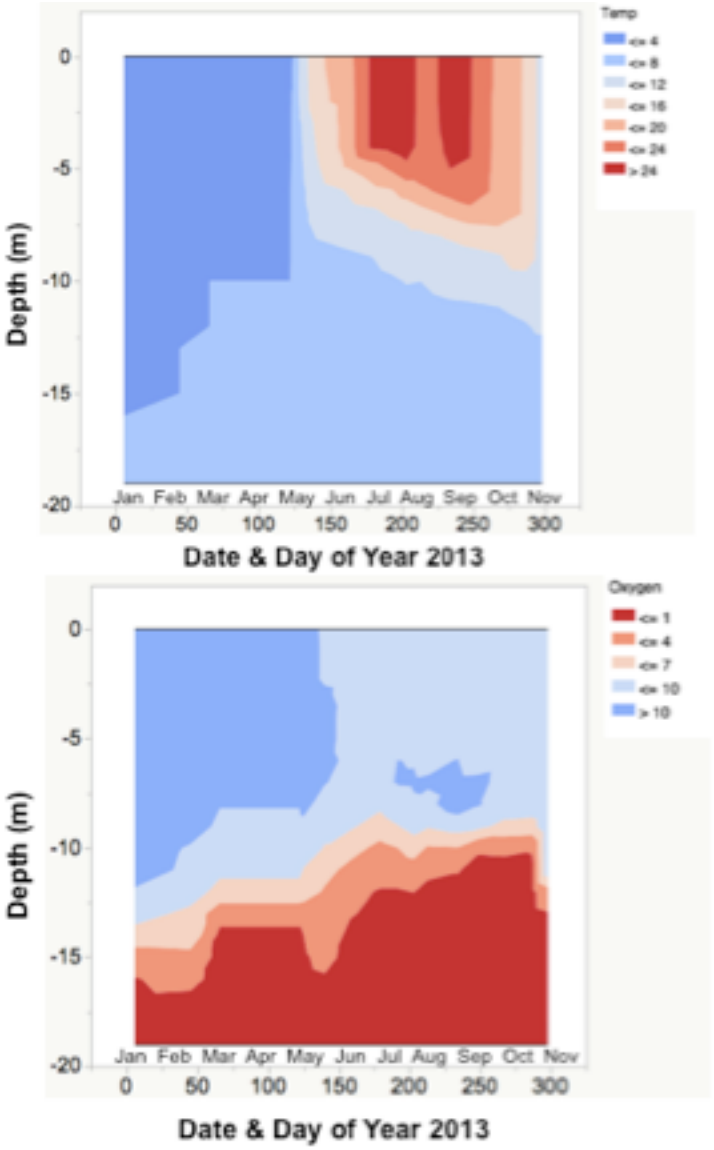

Figure 2. Contour plots of water temperature (top panel) and dissolved oxygen concentration (bottom panel) at different depths from 6 January through 25 October 2013. Contour lines are labeled in ^{o}C for temperature and mg/L for dissolved oxygen. See Appendixes II and III for data used to generate these plots. **Note:** Ice out in 2013 was on May 3.

Water Clarity (secchi depth) and Algal Biomass (Chl a)

The water clarity (secchi depth) of Square Lake was very high (8.1 m) on the second sampling date in May (May 20) when the lake had become strongly stratified (see Fig. 3). The secchi clarity was consistently close to 5 m from June to September, and decreased slightly in October to ~ 4.5 m. The overall average (+/- SE) summer (mid-May through August) secchi clarity was 5.46 +/- 0.44 m.

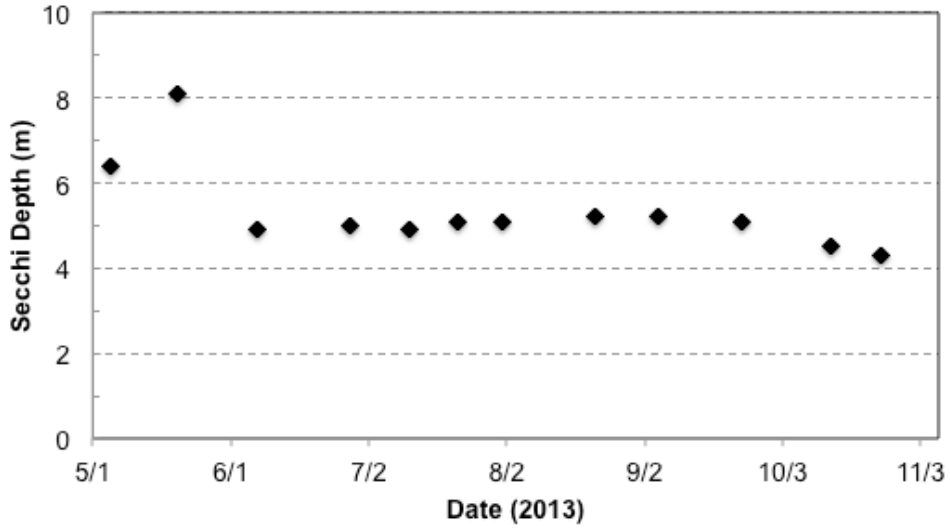

Figure 3. Secchi depth measurements on open-water dates (May-October) in 2013.

Levels of algal biomass (Chl a) in the surface water varied from 1 µg/L to 9 µg/L, with a summer (mid-May through August) average (+/- SE) of 1.66 +/- 0.34 µg/L (Fig. 4).

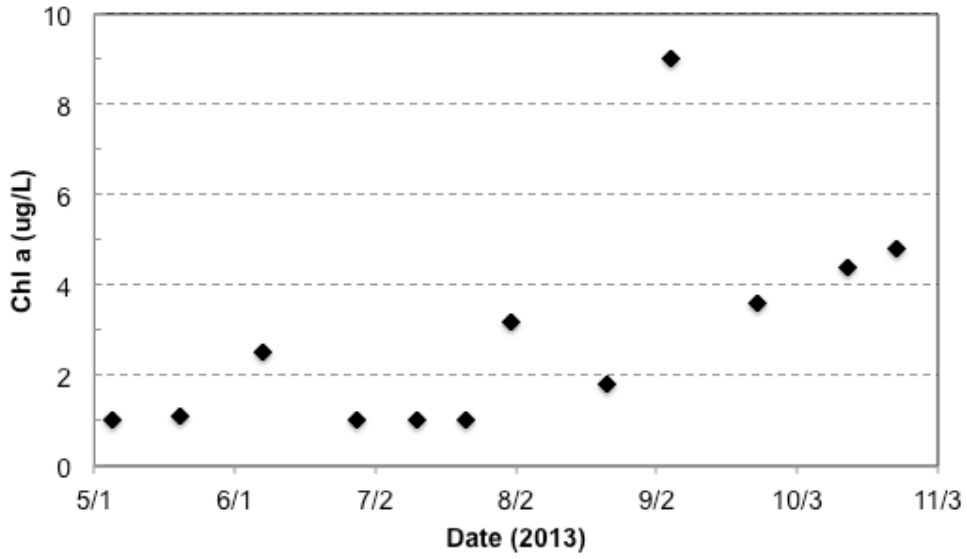

Figure 4. Surface water phytoplankton biomass (Chl a, ug/L) from open-water dates (May-October) in 2013.

Daphnia pulicaria population dynamics

Water column densities of the large-bodied *Daphnia* species (*D. pulicaria*) ranged between 1-2 animals per liter during the winter. Population densities were greatest on the late May and early June sampling dates (~ 4 per liter), and remained above or near 2 per liter until late August. From late August to late October, *D. pulicaria* gradually declined to a minimum of 0.44 per liter on October 25 (Fig. 5).

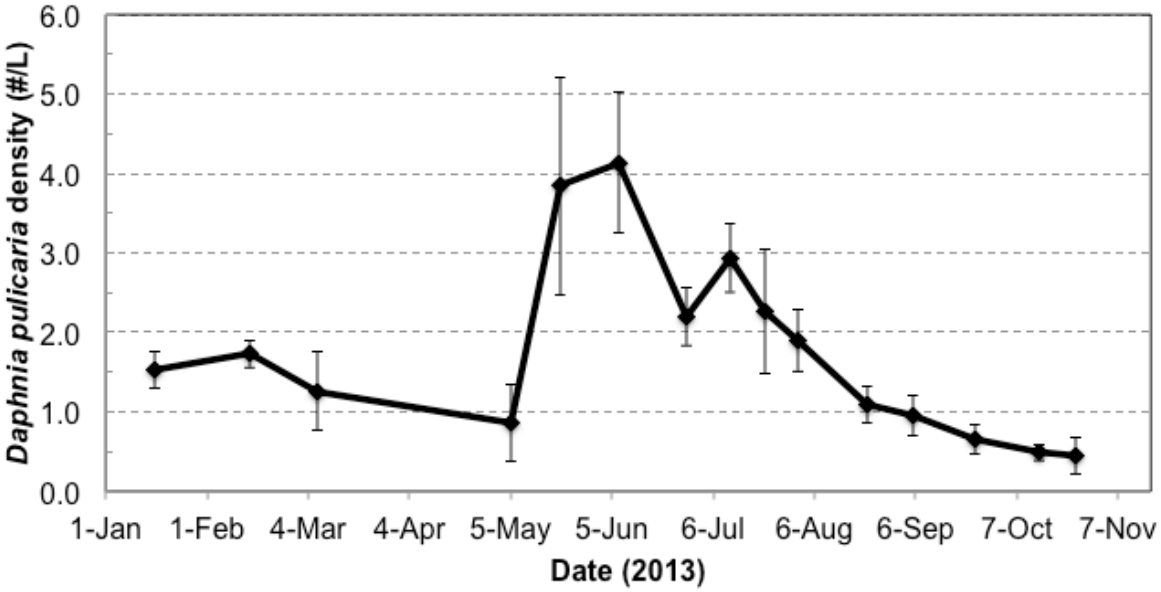

Figure 5. Population dynamics for *Daphnia pulicaria* in 2013. Values are means (+/- SE) calculated from water column net tows from the three sampling locations.

Zooplankton Community Composition

The zooplankton community of Square Lake continues to be dominated by two species of *Daphnia* (*D. pulicaria* and *D. mendotae*), and calanoid and cyclopoid copepods. Densities of these common taxa and all others from whole water column and incremental depth samples can be found in Appendix I.

Preliminary Assessment of Trout Stocking Moratorium

The fundamental expectation for the trout-stocking moratorium in Square Lake is that the absence of size-selective predation by rainbow trout will enable the population of large-bodied *Daphnia* (*D. pulicaria*) to increase in abundance. An increased density of these highly effective grazers of phytoplankton (algae) would then be expected to result in a decrease in abundance of phytoplankton and clearer water. Additionally, greater grazing intensity by *D. pulicaria* on phytoplankton should result in less settling of organic matter (i.e., dead algae) to the sediments and subsequently less oxygen depletion in the hypolimnion during summer stratification (as a result of less microbial decomposition of organic matter). A smaller anoxic region of the hypolimnion would provide more habitat for *D. pulicaria* at depths below the habitat of their fish predators and could enable the

population to persist at higher densities later into the summer stratification period than in recent years.

Results of a preliminary analysis comparing zooplankton and water quality data between 2013 (the first year of the moratorium) and data from two recent trout stocking years (2010 & 2012) support these expectations (though not always in a statistically significant manner). There was a clear difference in the abundance of the *Daphnia pulicaria* in 2013 compared to the two pre-moratorium years.

The general pattern of population dynamics for *D. pulicaria* was similar among the three years. Population sizes differed significantly among months (ANOVA $p < 0.001$) with largest population sizes in May-June that declined into mid- to late summer. While the pattern of population dynamics was similar among years, population densities of *D. pulicaria* during May-September were markedly more abundant in 2013 (ANOVA $p < 0.001$) than in 2012 or 2010 (Fig. 6).

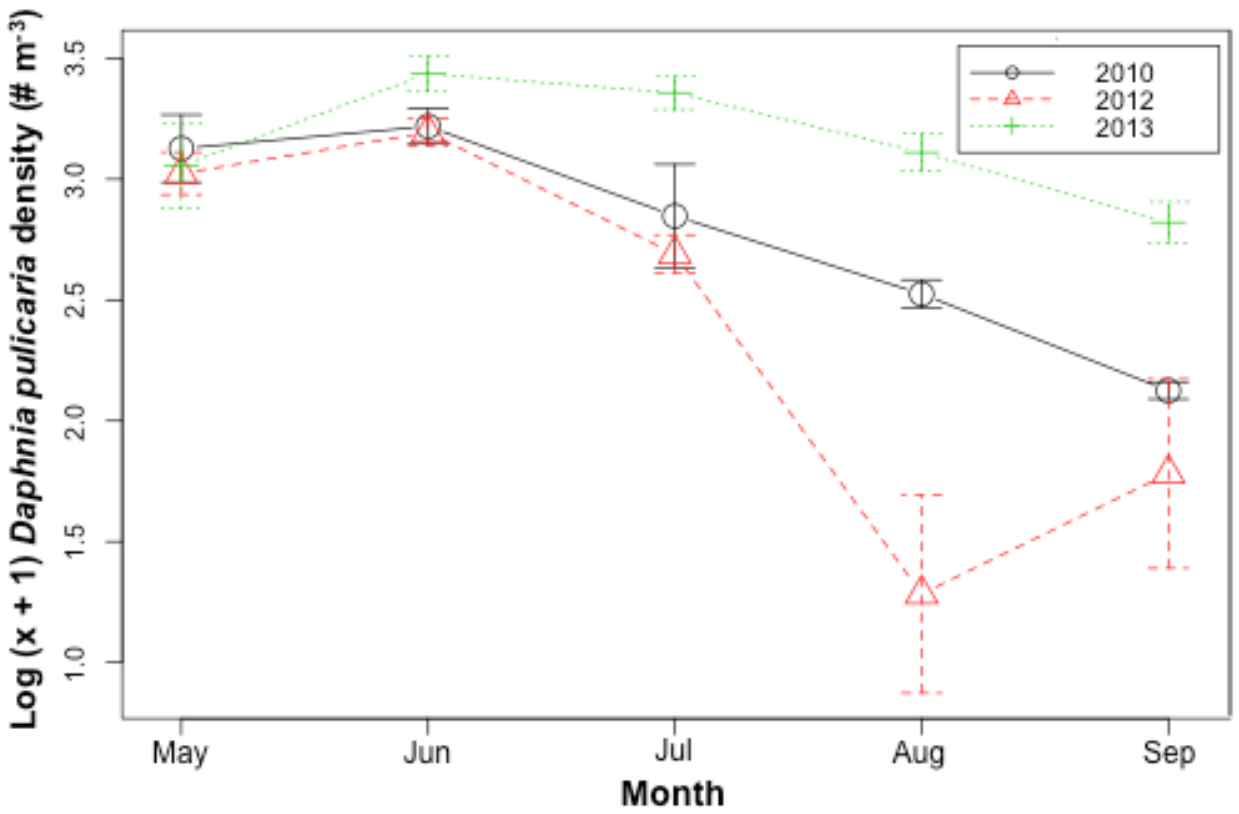

Figure 6. Mean densities (Log (x+1) transformed) of *D. pulicaria* from whole water column net tows during May-September in 2010, 2012, and 2013. Error bars represent +/- 1 SE. An ANOVA test evaluating the factors of year and month shows that there are statistically significant ($p < 0.001$) effects of both factors.

In addition to the *Daphnia* results that were consistent with expectations, there was some improvement in the trophic state indicators (i.e., secchi clarity & Chl a concentration) in the summer of 2013 compared to the recent pre-moratorium years. The average water clarity (secchi depth) from mid-May through August was greater in

2013 compared to 2012 and 2010 (Fig. 8), and levels of surface water phytoplankton biomass were lower in 2013 compared to 2012 and 2010 (Fig. 9). However, in both cases the differences were not statistically significant (One-way ANOVA for secchi clarity: $F_{2,24} = 1.14$, $p = 0.33$; One-way ANOVA for Chl a: $F_{2,20} = 2.39$, $p = 0.12$).

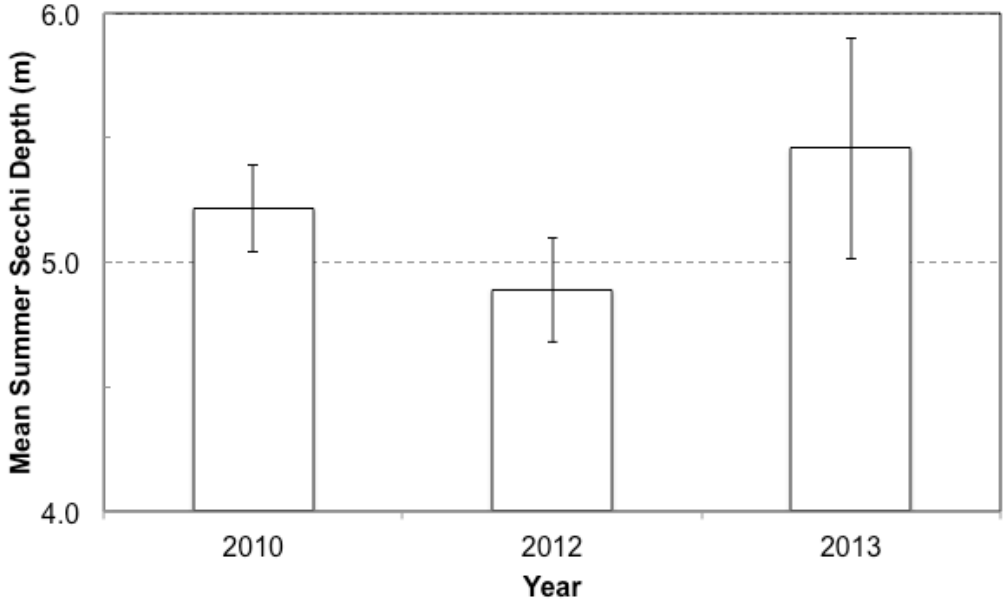

Figure 8. Mean (+/- SE) summer (mid-May through August) Secchi depths for Square Lake in 2010, 2012, and 2013. 2013 was the first year of the trout-stocking moratorium.

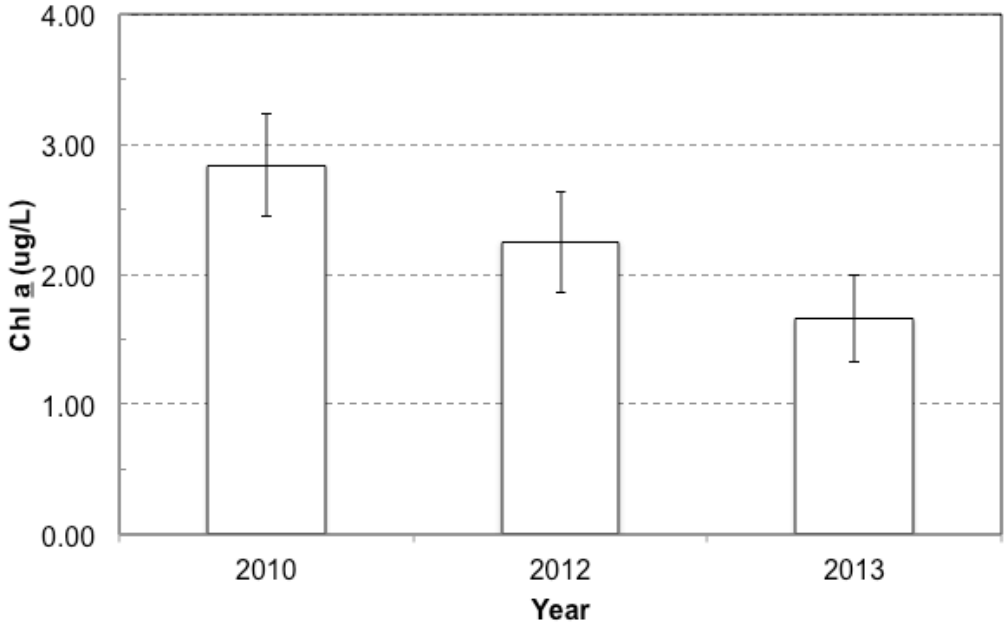

Figure 9. Mean (+/- SE) summer (mid-May through August) levels of surface water phytoplankton biomass (Chl a) for Square Lake in 2010, 2012, and 2013. 2013 was the first year of the trout-stocking moratorium.

Lastly, there is some support for the expectation that the absence of rainbow trout in the lake would result in less hypolimnetic oxygen depletion. A comparison of the oxygen data between 2013 and 2012 (the last year in which trout were stocked in Square Lake) shows that the extent of hypoxia in 2013 was somewhat less than it was in 2012, despite the lack of complete re-oxygenation of the bottom waters in the spring due to the late ice out!. In July, depths below 12 m were hypoxic (oxygen levels < 1 mg/L) in 2013 versus depths below 11 m in 2012. For August, the difference was even greater: depths below 11 m were hypoxic in 2013, versus depths below 9 m in 2012. Oxygen data from the next two years of the moratorium (2014 and 2015) will enable us to better evaluate if this is a consistent outcome when trout are not stocked to the lake.