

Seasonal Phosphorus and Chlorophyll Levels of the Tri -Lakes, Adams County,  
WI.

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## ABSTRACT

The levels of chlorophyll and phosphorus in the Tri-Lakes area were studied over a three month period in the summer of 2012. Upper and Lower Camelot Lake, Lake Sherwood, and Lake Arrowhead were studied in the Town of Rome in Adams County, Wisconsin. Samples were taken from several different locations on each lake once a month in June, July, and August. The samples were sent to the State Laboratory of Hygiene to be analyzed for phosphorus and chlorophyll. Secchi depth readings were also taken at these locations. Phosphorus and chlorophyll levels between each lake varied as well as at different locations within each lake. The amount of mixing in each lake, land use surrounding each lake, and the amount of adequate shore buffers on each lake influence the levels of chlorophyll and phosphorus at each sampling site and lake.

Lake Sherwood had the highest average observed chlorophyll and phosphorus level of all the lakes. Consequently, it also had the lowest average Secchi depth reading. A strong correlation was shown in a comparison of the mean Secchi depth and mean chlorophyll level for each lake. Phosphorus and Chlorophyll levels are known to positively correlate with each other. High levels of chlorophyll often result in decreased water clarity and increased algal blooms as observed in the Tri-Lakes.

Lake Arrowhead, Lake Sherwood, and the Upper and Lower Camelot lakes are considered phosphorus limited like many lakes in Wisconsin. The amount of phosphorus in a lake determines or limits the aquatic plant algal productivity. Phosphorus has a major impact on the overall quality of lake water.

There are many factors that contribute to variations of phosphorus, chlorophyll, and Secchi depth levels between lakes. The size and form of lakes have an impact on general transport processes such as sedimentation, internal loading, and outflow, which in turn has an impact on many abiotic variables, such as phosphorus and water quality (Hakanson 2004). For northern temperate lakes, the relationship between phosphorus and algal biomass has been found to vary across a wide range of landscape settings (Cheruvilil et. al. 2011). Increasing and decreasing populations of grazing plankton, such as *Daphnia*, that consume algae can also cause changes in the clarity of water. (Carpenter Et al. 1999) Water column stability and mixing may cause variations in chlorophyll, phosphorus, and Secchi depth between sampling sites within a lake.

Phosphorus is a nutrient that plays a major role in the eutrophication of lakes. Eutrophication is the natural process that describes increasing lake productivity, nutrient enrichment, and lake aging. The presence of phosphorus in lakes enables plants to use other nutrients more efficiently, further increasing productivity (Addy and Green 1996.) A study done by John R. Jones and Roger W. Bachman demonstrated there was a strong correlation between the average July-August chlorophyll concentration and the measured

concentrations of total phosphorus (Bachman and Jones 1976). The use of chlorophyll, total phosphorus, and Secchi depth measurement can be used to determine Carlson's Trophic State Index. Higher chlorophyll and total phosphorus concentrations translate into higher TSI values (Addy and Green 1996). The trophic state index scale is used to determine whether the lake is eutrophic, mesotrophic, or oligotrophic. Lake Arrowhead, Upper and Lower Camelot Lakes, and Lake Sherwood are considered mesotrophic to mildly eutrophic lakes (Evans 2007).

The purpose of this research was to identify any significant differences in phosphorus levels, chlorophyll levels, and Secchi depth between Upper and Lower Camelot Lake, Lake Sherwood, and Lake Arrowhead as well as identify any differences between the sampling sites within each lake. The relationship between phosphorus levels and chlorophyll levels in these lakes were analyzed, as well as their relationship to Secchi depth levels.

The study area was a series of lakes called the "Tri-Lakes" in the town of Rome in Adams County, Wisconsin. Upper and Lower Camelot Lakes flow through dams into Sherwood Lake. A dam impounds Fourteen Mile Creek downstream from the dams at Lower and Upper Camelot Lakes and Sherwood Lake, on its way to the Wisconsin River, creating Lake Arrowhead (Evans 2007). These lakes are part of the Fourteen Mile Creek Watershed. The average depths of the lakes ranged from 3-4 meters, and the surface area was between 772,950 square meters to 1,052,183 square meters, with Lake

Arrowhead having the largest surface area and Upper Camelot having the smallest surface area.

## METHODS

There were 3-4 sampling sites on each lake that were sampled every month from June until August for phosphorus, chlorophyll, and Secchi depth. (Figure 1, 2, 3) Samples of lake water were obtained by using a 6-ft integrated water sampler. The integrated water sampler is a six and a half foot PVC pipe that serves as a collection tube. After these samples were obtained, the bottles to be analyzed for phosphorus were preserved with sulfuric acid and sent to the State Laboratory of Hygiene for analysis. Chlorophyll was measured by filtering a known amount of the lake water sample, 200 ml, through a fiber filter. The filter paper itself was used for analysis and was sent to the State Laboratory of Hygiene for analysis. A Secchi depth measurement was performed at each sampling site using a 20 cm black/white disk. A measurement was taken by dropping the Secchi depth into the water until the disk was no longer visible, then bringing the disk slowly back up until it was visible. The two distances from where the disk was visible and no longer visible were marked, and then an average was taken to be used as the depth measurement.

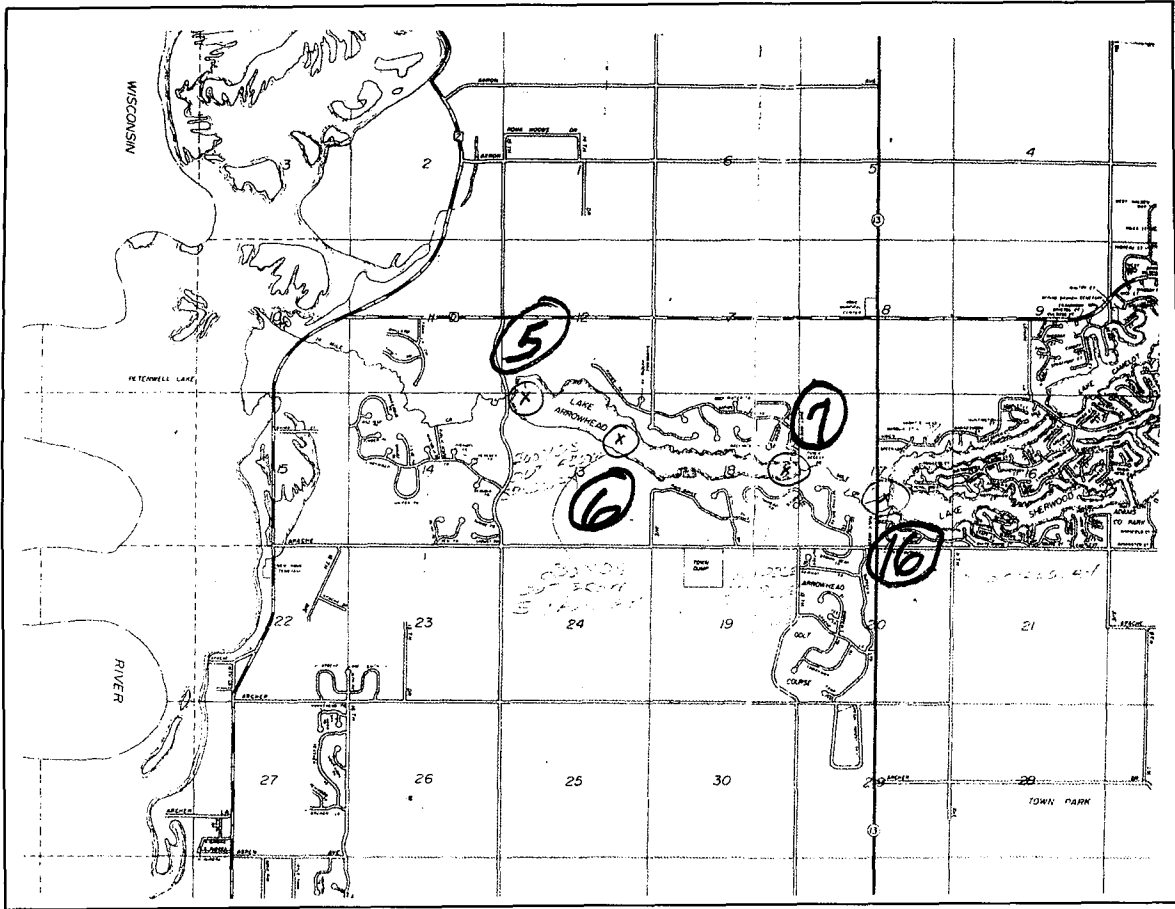


Figure 1. Map of Sampling Sites on Lake Arrowhead, Adams County, WI.

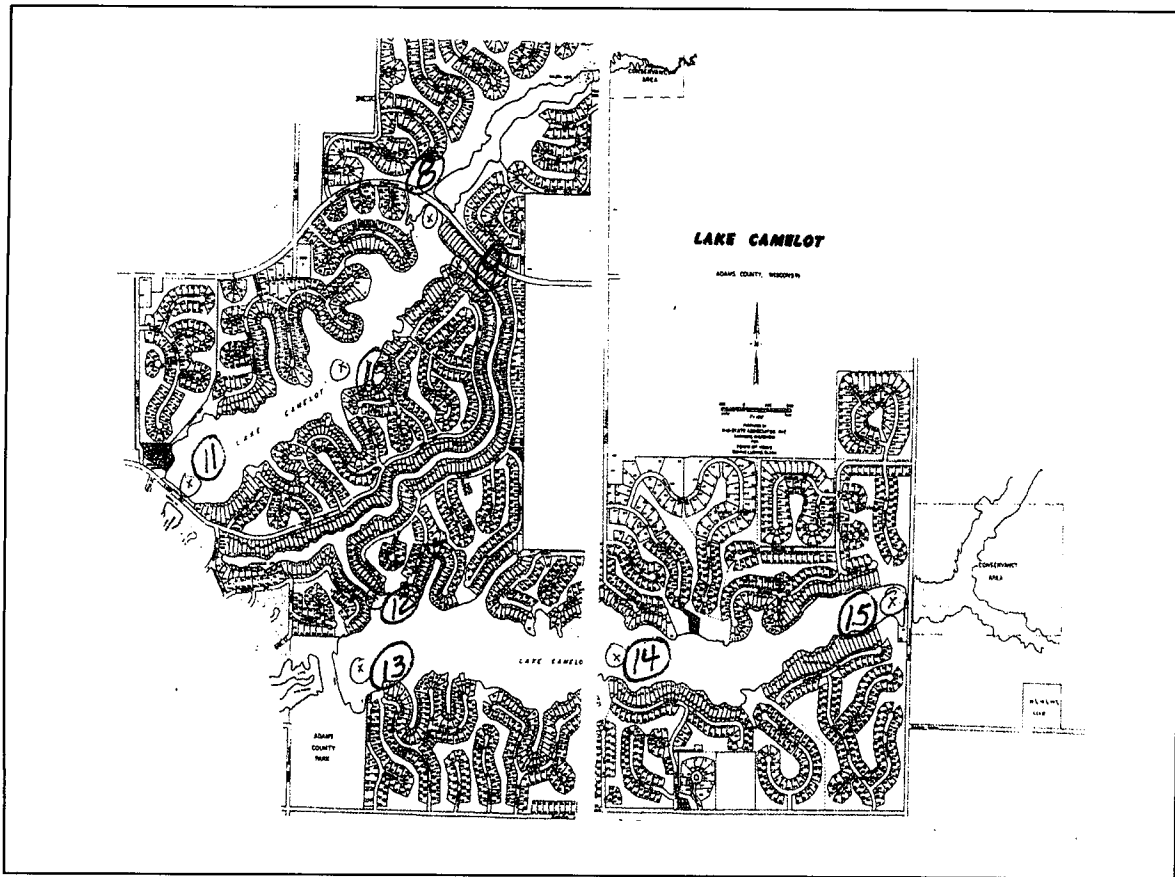


Figure 2. Map of Sampling Sites on Upper and Lower Lake Camelot, Adams County, WI.

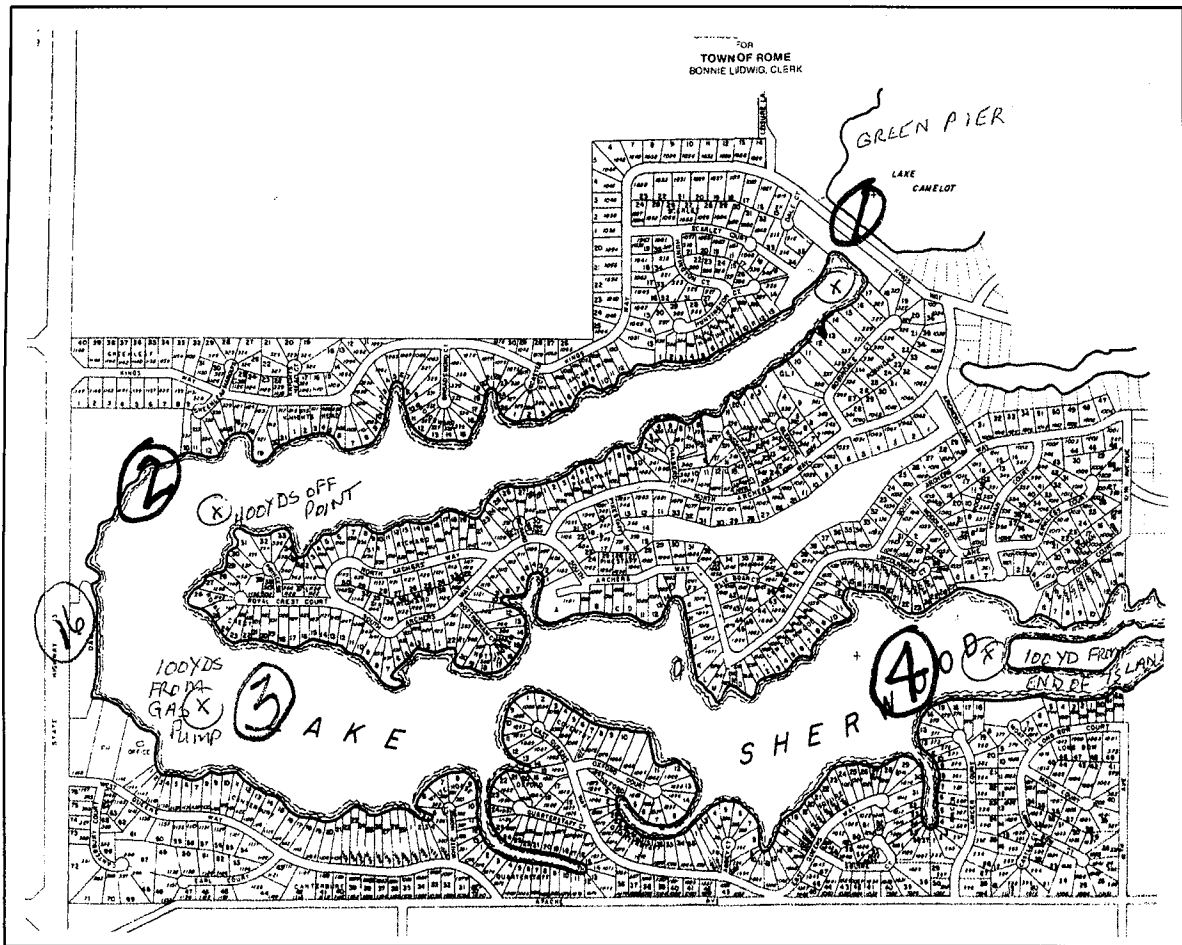


Figure 3. Map of Sampling Sites on Lake Sherwood, Adams County, WI.

## RESULTS AND DISCUSSION

Average seasonal phosphorus, chlorophyll, and Secchi depth measurements were calculated for each lake (Table 1.) The levels varied between each of the lakes. Lake Sherwood had the highest average phosphorus and chlorophyll level of any of the other lakes. Lake Sherwood also had the lowest average Secchi depth reading of all three lakes. In general the mean Secchi depths were highest in June and the lowest in July for all of the lakes. Phosphorus levels of Lake Arrowhead and Sherwood peaked in July, but phosphorus



levels in Upper and Lower Lake Camelot peaked in August. All of the lakes had the lowest average Secchi depth reading in the month of July. Average chlorophyll levels were the highest in July in all of the lakes except for Lake Arrowhead (Table 2). Low Secchi depth readings are expected with high chlorophyll and phosphorus levels. The different sampling sites on each lake had variations in the levels of phosphorus, chlorophyll, and Secchi depth readings. Percent change for each sampling site on each lake was calculated from the average of each lake (Tables 3, 4, 5, 6).

Table 1. Seasonal averages of Chlorophyll, Total Phosphorus, and Secchi Depth Levels for Lake Sherwood, Arrowhead, and Camelot, Adams County, WI.

|                | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) |
|----------------|------------------------|------------------------|--------|
| Lake Arrowhead | 10.41                  | 29.33                  | 2.17   |
| Lake Sherwood  | 15.38                  | 38.33                  | 1.32   |
| Upper Camelot  | 10.91                  | 21.67                  | 1.97   |
| Lower Camelot  | 10.72                  | 30.75                  | 2.01   |

Table 2. Monthly Averages Chlorophyll, Total Phosphorus, and Secchi Depth for Each Lake for June, July, and August.

| Month  | Lake Arrowhead         |                        |        | Lake Sherwood          |                        |        | Upper Lake Camelot     |                        |        | Lower Lake Camelot     |                        |        |
|--------|------------------------|------------------------|--------|------------------------|------------------------|--------|------------------------|------------------------|--------|------------------------|------------------------|--------|
|        | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) |
| June   | 15.35                  | 32.67                  | 2.10   | 13.68                  | 32                     | 1.58   | 5.09                   | 17.25                  | 2.63   | 4.24                   | 22.75                  | 2.78   |
| July   | 10.44                  | 33.00                  | 1.80   | 18.95                  | 44.25                  | 1.13   | 14.65                  | 23.25                  | 1.4    | 18.97                  | 27                     | 1.5    |
| August | 5.45                   | 22.33                  | 2.60   | 13.52                  | 38.75                  | 1.25   | 13                     | 24.5                   | 1.88   | 8.95                   | 42.5                   | 1.75   |

Table 3. Percent change from lake average for Lower Lake Camelot calculated for each site. (Adams County, WI)

|                                      | Lower Lake Camelot ( % change from lake average) |          |          |          |
|--------------------------------------|--|----------|----------|----------|
| Sampling Location                    | Site #12   | Site #13 | Site #14 | Site #15 |
| Chlorophyll( $\mu\text{g/l}$ )       | 4.70   | 1.09     | 11.54    | -17.29   |
| Total Phosphorus ( $\mu\text{g/l}$ ) | -16.53   | -20.87   | 0.81     | 36.59    |
| Secchi Depth (m)                     | 7.79   | 16.25    | -2.16    | -23.71   |

Table 4. Percent change from lake average for Upper Lake Camelot calculated for each site. (Adams County, WI)

|                                      | Upper Lake Camelot ( % change from lake average) |         |          |          |
|--------------------------------------|--|---------|----------|----------|
| Sampling Location                    | Site #8  | Site #9 | Site #10 | Site #11 |
| Chlorophyll( $\mu\text{g/l}$ )       | 20.62  | 24.77   | -15.85   | -29.78   |
| Total Phosphorus ( $\mu\text{g/l}$ ) | 20.00  | 21.54   | -15.38   | -26.15   |
| Secchi Depth (m)                     | -13.71   | -10.32  | 3.21     | 20.14    |

Table 5. Percent change from lake average for Lake Sherwood calculated for each site. (Adams County, WI)

|                                      | Lake Sherwood ( % change from lake average) |         |         |         |
|--------------------------------------|---|---------|---------|---------|
| Sampling Location                    | Site #1                                     | Site #2 | Site #3 | Site #4 |
| Chlorophyll( $\mu\text{g/l}$ )       | -5.74                                       | -11.16  | -5.72   | 22.64   |
| Total Phosphorus ( $\mu\text{g/l}$ ) | -6.09                                       | -14.78  | -22.61  | 43.48   |
| Secchi Depth (m)                     | -16.67                                      | 11.11   | 11.11   | -6.57   |

Table 6. Percent change from lake average for Lake Sherwood calculated for each site. (Adams County, WI)

|                                      | Lake Arrowhead ( % change from lake average) |         |         |
|--------------------------------------|--|---------|---------|
| Sampling Location                    | Site #5                                      | Site #6 | Site #7 |
| Chlorophyll( $\mu\text{g/l}$ )       | -31.12                                       | 18.92   | -14.02  |
| Total Phosphorus ( $\mu\text{g/l}$ ) | -25.00                                       | -12.50  | 37.50   |
| Secchi Depth (m)                     | 6.15   | 10.77   | -12.31  |

Higher chlorophyll levels were associated with higher phosphorus levels shown by an upward trend, but correlation between phosphorus and chlorophyll was not strong with a correlation coefficient of 0.5978 (Figure 4). The lowest average Secchi depth measurement is associated with the highest chlorophyll and phosphorus measurement (Figure 5&6). There was a downward trend between Secchi depth and phosphorus, in general as phosphorus decreased Secchi depth increased (Figure 5). Correlation between Secchi depth and phosphorus wasn't as strong as expected with a correlation coefficient of 0.5448 (Figure 5). Correlation between Secchi depth and chlorophyll was very strong with a correlation coefficient of 0.978 (Figure 6).

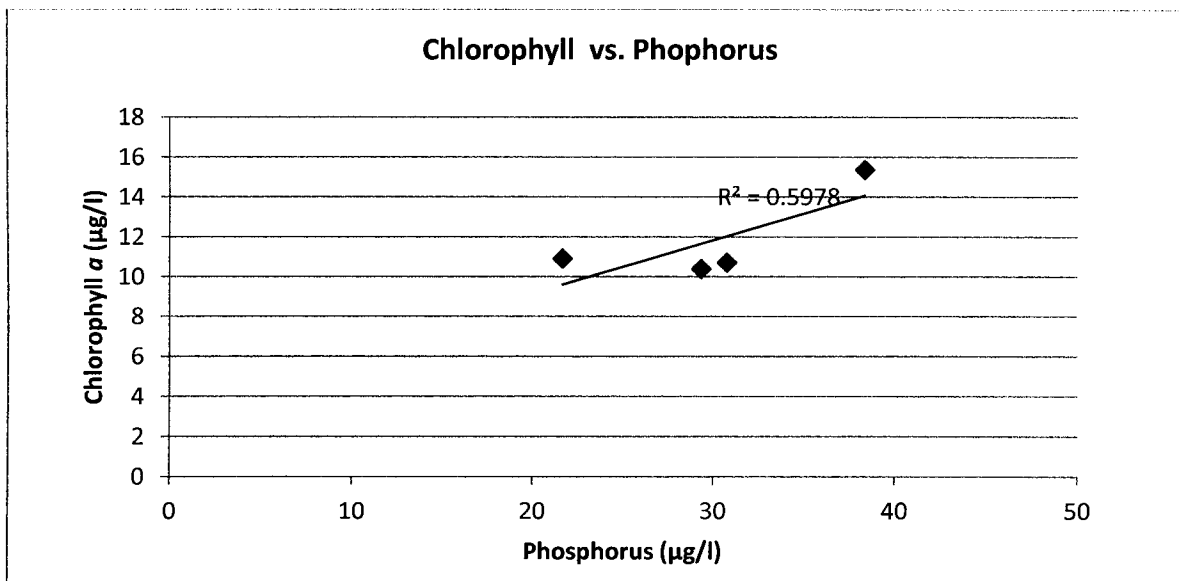


Figure 4. Comparison of the average chlorophyll and phosphorus levels in Lake Sherwood, Lake Arrowhead, and Upper and Lower Camelot Lakes. (Adams County, WI)

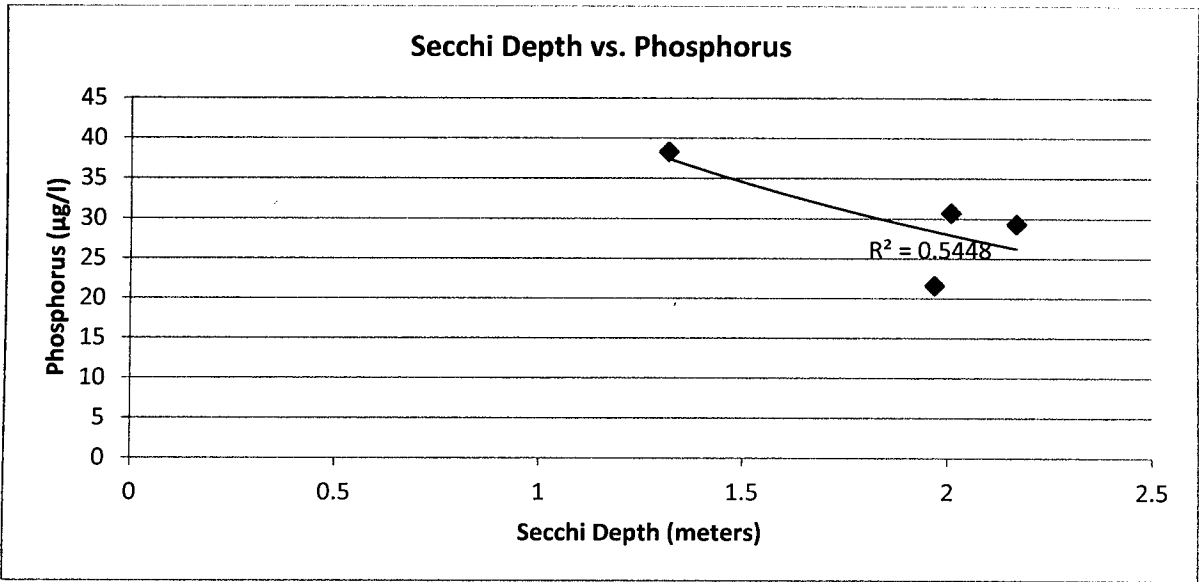


Figure 5. Comparison of the average Secchi depth and phosphorus levels in Lake Sherwood, Lake Arrowhead, and Upper and Lower Camelot Lakes. (Adams County, WI)

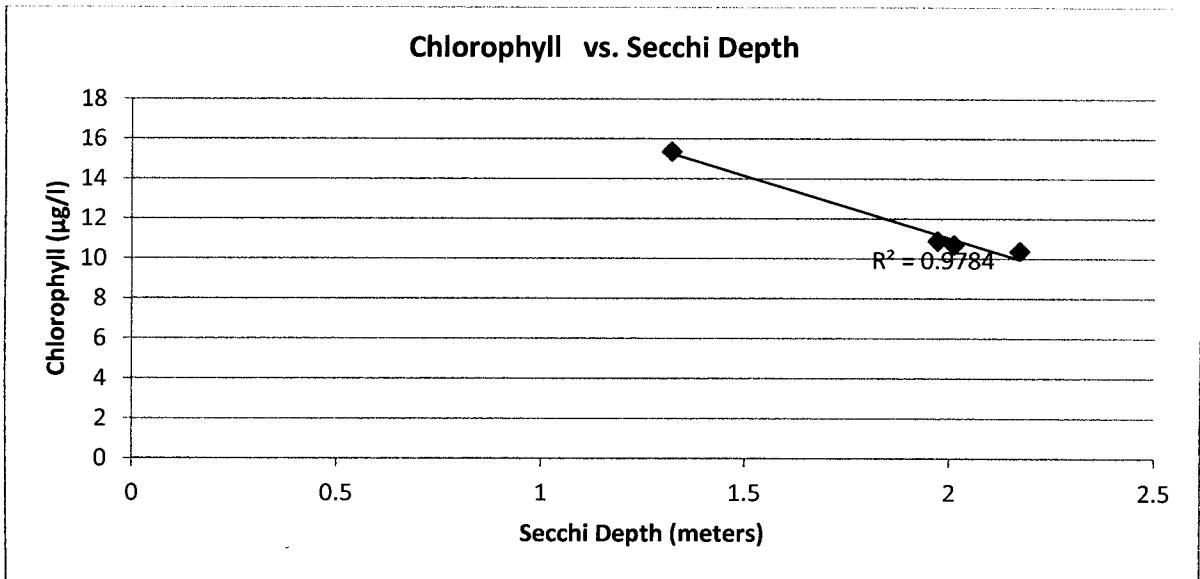


Figure 6. Comparison of the average Secchi depth and chlorophyll levels in Lake Sherwood, Lake Arrowhead, and Upper and Lower Camelot Lakes. (Adams County, WI)

## CONCLUSIONS

The study done by John R. Jones and Roger W. Bachman resulted in a strong correlation found between the average summer chlorophyll and phosphorus levels (Bachman and Jones 1976). This differed from the comparison of chlorophyll and phosphorus in the Tri-Lakes, which resulted in a weak correlation. The differences between the studies could be attributed to the amount of lakes studied and location. This study only took measurements from 4 lakes in Wisconsin, while the study by John R. Jones and Roger W. Bachman took measurements from 16 lakes in Iowa.

The strong correlation between Secchi depth and chlorophyll levels (figure 6) is comparable to the results of a study on summer water clarity responses to phosphorus, *Daphnia* grazing, and internal mixing in Lake Mendota, Wisconsin (Carpenter et.al. 1999). The deepest Secchi depths in their study occurred when phosphorus loading and concentrations were low, and the generally shallower Secchi depths were attributed to blue-green algal blooms. Since chlorophyll levels are used to indicate algal levels, with greater algal growth, water clarity decreases (Addy and Green 1996).

A low correlation coefficient value means there is a high amount of unexplained variance in the data (Figure 5&6). Variation in these levels can be attributed to landscape settings of the lakes, size, and depth of the lakes. The largest land use category for Lake Sherwood and the Camelot lakes area is agriculture, while the largest land use for Lake Arrowhead area is residential which may account for differences in the phosphorus levels

(Evans 2007). The groundwater watershed for Lake Sherwood is small compared to the other lakes, and Upper and Lower Camelot lakes feed into Lake Sherwood which may account for the higher levels of chlorophyll and phosphorus in Lake Sherwood as compared to the other lakes. Buffer areas of native vegetation filter and trap fertilizers, sediments, and runoff before reaching a lake. An inadequate buffer near a sampling location would be likely to result in increased phosphorus loading and higher levels than other areas on the lake. Water clarity can also be reduced by turbidity, which is suspended material such as algae, silt, and dissolved organic chemicals that can color or cloud the water (Evans 2007). Turbidity due to suspended sediment was not taken into account when comparing the Secchi depth values with chlorophyll and phosphorus levels.

Stability of a water column is affected by air temperatures, solar radiation, and frequency of wind events (Carpenter et.al. 1999). Since the summer of 2012 was hotter and dryer than average for Wisconsin, the stability of the water column, plankton biomass populations, and mixing of the lake may have been affected. The stability of the water column, plankton biomass population, and lake mixing are all factors that influence phosphorus and chlorophyll between lakes as well as within a lake.

Appendix 1. Monthly Chlorophyll, Total Phosphorus, and Secchi Depth readings and averages for each sampling site in Adams County, WI.

| Lake Sherwood      |                        |                        |        |                        |                        |        |                        |                        |        |                        |                        |        |
|--------------------|------------------------|------------------------|--------|------------------------|------------------------|--------|------------------------|------------------------|--------|------------------------|------------------------|--------|
| Site #             | 1                      |                        |        | 2                      |                        |        | 3                      |                        |        | 4                      |                        |        |
|                    | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) |
| June               | 11.90                  | 38.00                  | 1.30   | 11.30                  | 32.00                  | 1.80   | 12.80                  | 22.00                  | 1.80   | 18.70                  | 36.00                  | 1.40   |
| July               | 16.10                  | 33.00                  | 1.10   | 18.60                  | 35.00                  | 1.10   | 20.80                  | 35.00                  | 1.10   | 20.30                  | 74.00                  | 1.20   |
| August             | 15.50                  | 37.00                  | 0.90   | 11.10                  | 31.00                  | 1.50   | 9.91                   | 32.00                  | 1.50   | 17.60                  | 55.00                  | 1.10   |
| Average            | 14.50                  | 36.00                  | 1.10   | 13.67                  | 32.67                  | 1.47   | 14.50                  | 29.67                  | 1.47   | 18.87                  | 55.00                  | 1.23   |
| Lake Arrowhead     |                        |                        |        |                        |                        |        |                        |                        |        |                        |                        |        |
| Site #             | 5                      |                        |        | 6                      |                        |        | 7                      |                        |        |                        |                        |        |
|                    | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) |                        |                        |        |
| June               | N/A                    | 21.00                  | 2.10   | 22.50                  | 28.00                  | N/A    | 8.17                   | 49.00                  | 2.10   |                        |                        |        |
| July               | 10.80                  | 25.00                  | 1.80   | 10.70                  | 31.00                  | 1.80   | 9.81                   | 43.00                  | 1.80   |                        |                        |        |
| August             | 3.54                   | 20.00                  | 3.00   | 3.94                   | 18.00                  | 3.00   | 8.87                   | 29.00                  | 1.80   |                        |                        |        |
| Average            | 7.17                   | 22.00                  | 2.30   | 12.38                  | 25.67                  | 2.40   | 8.95                   | 40.33                  | 1.90   |                        |                        |        |
| Upper Lake Camelot |                        |                        |        |                        |                        |        |                        |                        |        |                        |                        |        |
| Site #             | 8                      |                        |        | 9                      |                        |        | 10                     |                        |        | N. Lobe (11)           |                        |        |
|                    | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) |
| June               | 4.39                   | 19.00                  | 2.40   | 4.35                   | 19.00                  | 2.40   | 5.65                   | 15.00                  | 2.70   | 5.98                   | 16.00                  | 3.00   |
| July               | 21.40                  | 32.00                  | 1.20   | 15.50                  | 25.00                  | 1.40   | 11.60                  | 21.00                  | 1.50   | 10.10                  | 15.00                  | 1.50   |
| August             | 13.70                  | 27.00                  | 1.50   | 21.00                  | 35.00                  | 1.50   | 10.30                  | 19.00                  | 1.90   | 6.91                   | 17.00                  | 2.60   |
| Average            | 13.16                  | 26.00                  | 1.70   | 13.62                  | 26.33                  | 1.77   | 9.18                   | 18.33                  | 2.03   | 7.66                   | 16.00                  | 2.37   |
| Lower Lake Camelot |                        |                        |        |                        |                        |        |                        |                        |        |                        |                        |        |
| Site #             | 12                     |                        |        | 13                     |                        |        | S. Lobe (14)           |                        |        | 15                     |                        |        |
|                    | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) | CHL( $\mu\text{g/l}$ ) | TP ( $\mu\text{g/l}$ ) | SD (m) |
| June               | 4.73                   | 20.00                  | 2.90   | 3.19                   | 18.00                  | 3.70   | 2.83                   | 18.00                  | 2.80   | 6.24                   | 35.00                  | 1.70   |
| July               | 22.40                  | 23.00                  | 1.50   | 21.20                  | 24.00                  | 1.60   | 23.50                  | 28.00                  | 1.50   | 8.76                   | 33.00                  | 1.50   |
| August             | 6.54                   | 34.00                  | 2.10   | 8.12                   | 31.00                  | 1.90   | 9.54                   | 47.00                  | 1.60   | 11.60                  | 58.00                  | 1.40   |
| Average            | 11.22                  | 25.67                  | 2.17   | 10.84                  | 24.33                  | 2.40   | 11.96                  | 31.00                  | 1.97   | 8.87                   | 42.00                  | 1.53   |

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