A COMPARISON OF TOTAL PHOSPHORUS LEVELS IN LAKES IN KALKASKA COUNTY, MICHIGAN AND RELATION TO TROPHIC STATE INDEX

By

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ABSTRACT

Phosphorus has been determined to be the limiting nutrient in many lakes in Michigan. The amount of phosphorus in a lake can be affected by several factors, including the morphometry of the lake, more specifically, the lake's depth. The amount of phosphorus in mid-summer in 10 lakes of distinctly different morphometry in Kalkaska County, Michigan was measured, in conjunction with several other physical and chemical measurements. Carlson's Trophic State Index was used to classify each lake. Statistical analysis revealed the correlation between mean total phosphorus and these factors was very low. However, within these results, it was observed that the correlation between the mean total phosphorus and Secchi depth was the strongest (R^2 = 0.059), while that of total depth (R^2 = 0.289) was weak and the number of houses (R^2 = 0.028) had the weakest correlation with mean total phosphorus.

INTRODUCTION

A lake is a water-filled hollow in the earth's surface, inland from the ocean. It is different from a pond in that it is generally deeper and larger (Burgis and Morris 1987). The origins and characteristics of lakes have been a subject of research for many limnologists. According to Wetzel (1983), "the origins of lakes and their morphometry are of much more importance than casual interest." The origins of lakes and their morphometry play an important role in the productivity of lakes and their physical, chemical and biological characteristics, within the limits of the climatic condition of their location (Wetzel 1983). The process in which a lake is formed often determines the lake's morphometry (depth). Lakes arise from mostly geological processes (Cole 1983). Some natural forces that form lakes include volcanic eruptions, glacial activity, and tectonic forces (Kalff 2002). The study of the morphological features of a lake system allows us to identify its environmental status (Moses et al. 2011*b*).

Eutrophication is the biological reaction of aquatic systems to nutrient enrichment, the eventual consequence of which is the development of increased primary production (Marsden 1989). There are four main physical factors that affect biological production in a lake, and therefore, the eutrophication process in lakes. These are radiant energy input, nutrient input and loss, oxygen supply and interactions of morphometry and motion (Mortimer 340). These factors are interdependent, as they both cause and are the effects of each other. Lakes are more susceptible, than rivers or streams, to eutrophication because they are largely lentic bodies of water. Rivers and streams being lotic (moving) environments are able to move the nutrients quicker than lakes (Lau and Lane 2001).

Lakes usually rely on ground water or a stream to move nutrients in and out. Eutrophication is predominantly associated with shallow lakes because of the ease with which nutrients from the benthic zone (bottom region of the lake) are mixed throughout the lake (Wetzel 1983). Excessive levels of nutrients within a lake often result from anthropogenic influences, such as the addition of fertilizers, runoff and sewage disposal (Morrice et al 2007).

Phosphorus has been determined experimentally to be the limiting factor in most fresh water lakes; thus, eutrophication of lakes is usually linked to an abundance of phosphorus (Haggard et al. 1999). Phosphorus is the nutrient that is most responsible for increasing lake productivity in Michigan lakes (Cooperative Lakes Monitoring Program 2011). The trophic state of a lake gives the status of the lake in terms of algal productivity. Every lake fits into a particular trophic state according to its degree of eutrophication, and a lake's trophic status may change over time (Moses 2011*a*). Increased phosphorus input stimulates phytoplankton abundance, leading to an increase in chlorophyll *a*, which then results in lowered Secchi transparency (Carlson 1977, Haggard et al. 1999). The phosphorus index is useful because phosphorus levels remain relatively constant year-round and can therefore provide a representative measure of the amount of nutrient in the lake annually and is a predictor of potential algal biomass (Carlson 1977).

The trophic state index (TSI) condenses water quality data into a manageable single numerical index for ascertaining the trophic status of a lake (Moses 2011*a*). TSI expresses lake productivity on a continuous numerical scale from 0 to 100, with increasing numbers indicating more eutrophic conditions (Cooperative Lakes Monitoring

Program 2011). Measurements of any of the trophic criteria (phosphorus, Secchi depth or chlorophyll a) can be used to determine trophic status.

The 10 lakes that were sampled for this research are located in Kalkaska County, Michigan (Fig. 1). All are glacial kettle lakes; basins left from the melting of large blocks of ice (Kalff 2002). These lakes were selected because of their similar origins or natural history, proximity to each other and comparable vegetation. Lake morphometry was used to differentiate the lakes by depth. As lakes become larger and shallower, it has been shown that lake water quality and morphometry become more significant, with deeper lakes having higher water transparency and lower concentrations of nutrients, organic matter and chlorophyll (Noges 2009).

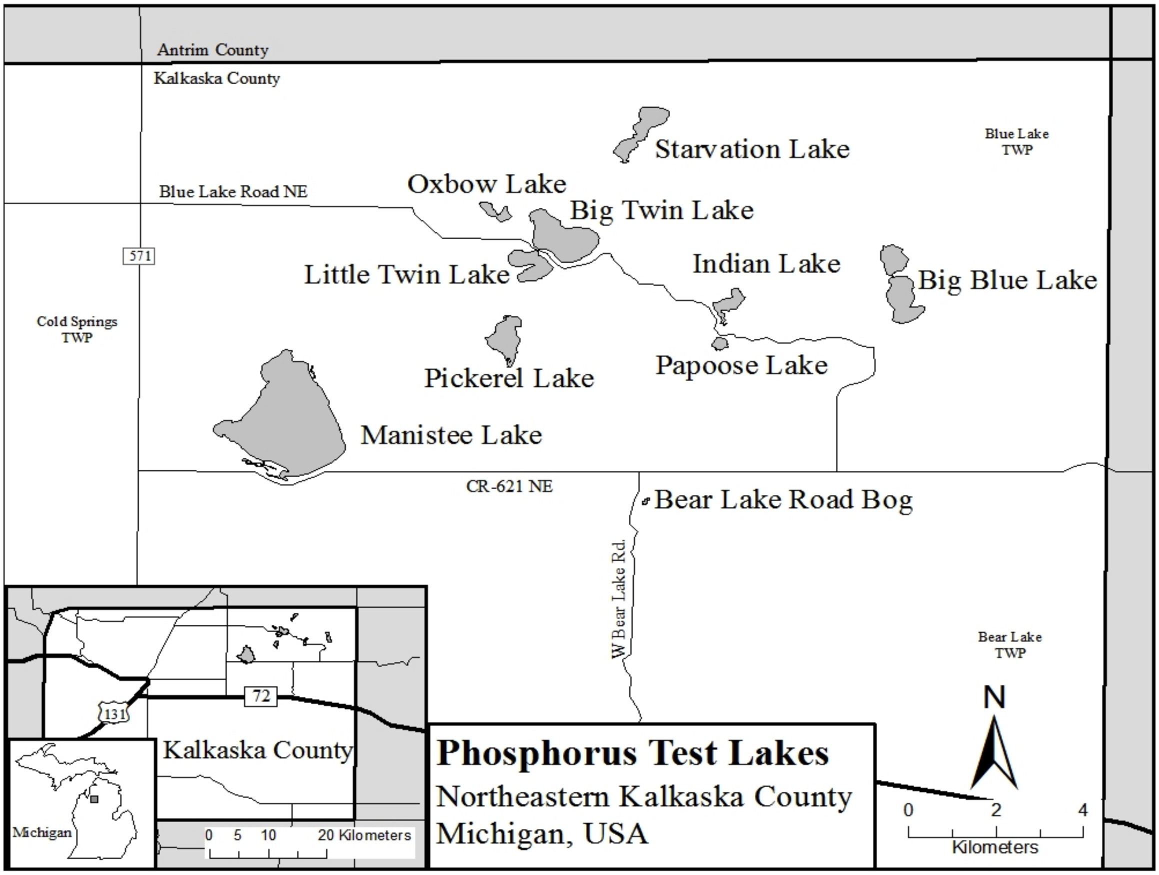

Figure 1. Map of northeastern Kalkaska County, Michigan, showing he locations of the 10 lakes sampled (data sources include ArcGIS Online and the Michigan Center for Geographic Information)

The morphometry of lake basins has been shown to affect the amount of total phosphorus present in the lake (Noges 2009). For this study, it is hypothesized that deep lakes, greater than 13.7 m in maximum depth, will have lower phosphorus levels than shallow lakes because of their depths when the phosphorus levels in the epilimnion and hypolimnion of selected lakes are compared. It is also hypothesized that the Carlson Trophic index for total phosphorus should be lower in deep lakes than in shallow lakes and that the number of houses around a lake will affect the amount of total phosphorus in that lake.

RESULTS

The mean total phosphorus for the top and bottom (epilimnion and hypolimnion) of the 10 lakes that were sampled along with the other factors was calculated (Table 1). We also determined the Carlson trophic state classification for each lake that was sampled (Table 2).

Table 1. Physical and Chemical parameters for 10 lakes in Kalkaska County, Michigan obtained from June 29 – July 19 2012

Lake	Mean Top Total P (μg/L)	Mean Bottom Total P (μg/L)	Mean Total P (μg/L)	Secchi depth (m)	Depth (m)	Houses
Starvation	37.74	47.68	42.71	5.00	14.10	115.00
Indian	49.51	49.02	49.26	3.50	5.40	34.00
Oxbow	40.58	45.57	43.08	4.50	9.60	1.00
Papoose	46.63	46.24	46.43	3.00	5.10	1.00
Little Twin	18.94	50.21	34.57	4.50	9.30	70.00
Big Blue	34.64	31.76	33.20	9.00	25.80	83.00
Big Twin	40.34	49.61	44.98	7.00	24.00	121.00
Pickerel	43.01	49.33	46.17	5.50	21.00	62.00
Manistee	49.68	43.78	46.73	2.50	5.40	
Bear Lake Road Bog	69.29	55.31	62.30	0.50	3.00	0.00

Table 2. Mean total phosphorus (µg/L), total phosphorus and Secchi depth and Carlson Trophic State Index for 10 lakes in Kalkaska County, Michigan

Lake	Mean Total P (µg/L)	TSI (TP)	TSI (SD)	Carlson TSI
Starvation	42.71	58.31	36.78	Mesotrophic
Indian	49.26	60.37	41.93	Mesotrophic
Oxbow	43.08	58.44	38.30	Mesotrophic
Papoose	46.43	59.52	44.15	Mesotrophic
Little Twin	34.57	55.27	38.30	Oligotrophic
Big Blue	33.20	54.68	28.30	Oligotrophic
Big Twin	44.98	59.06	31.93	Mesotrophic
Pickerel	46.17	59.44	35.41	Mesotrophic
Manistee	46.73	59.61	46.78	Mesotrophic
Bear Lake Road Bog	62.30	63.76	70.00	Dystrophic

Analysis of the mean total phosphorus content of the 10 lakes showed no significant correlation between the mean total phosphorus of the lakes and maximum depth ($R^2 = 0.289$, $n = 10$, 95% CI) (Fig. 2).

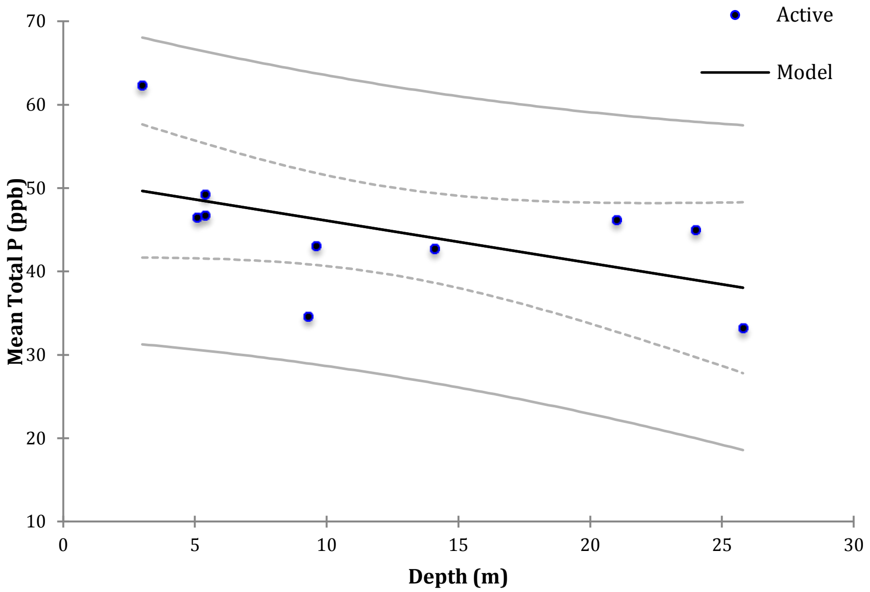

Figure 2. Linear regression showing the relationship (R^2 = 0.289, *n* = 10, 95% CI) between mean total Phosphorus (µg/L) and depth (m) of 10 lakes in Kalkaska County, Michigan

Analysis of the mean total phosphorus and the Secchi depth (R^2 = 0.590, *n* = 10, 95% CI) showed a stronger correlation between the mean total phosphorus and Secchi depth than total depth (Fig. 3). There was a negative correlation between these two factors.

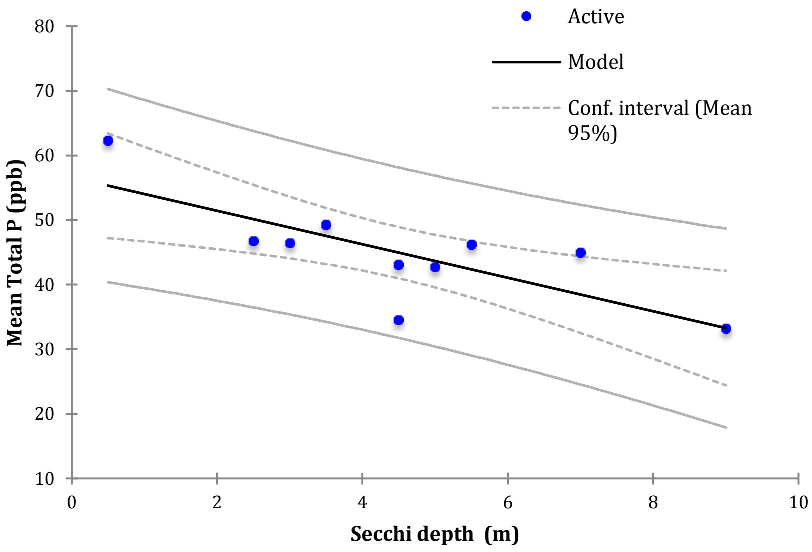

Figure 3. Linear Regression showing the relationship ($R^2 = 0.590$, $n = 10$, 95% CI) between mean total phosphorus (µg/L) and Secchi depth (m) of ten lakes in Kalkaska County, Michigan.

Analysis of the relationship between the mean total phosphorus and the number of houses ($R^2 = 0.028$, $n = 10$, 95% CI) around each lake showed minimal correlation than the other two factors (Fig. 4).

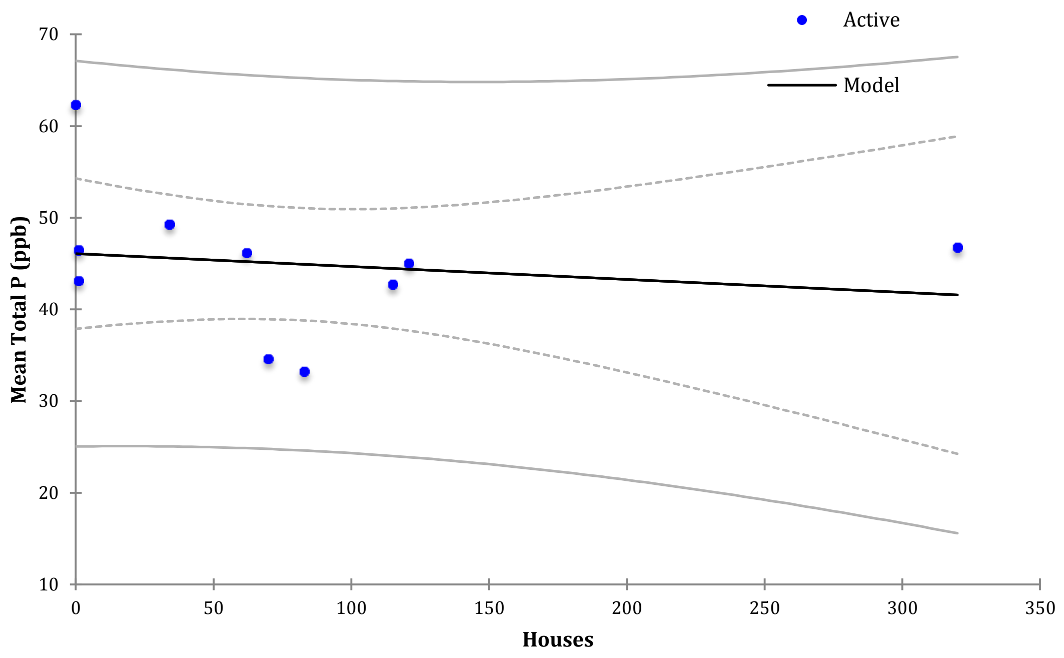

Figure 4. Linear regression showing the relationship (R^2 = 0.028, *n* = 10, 95% CI) between mean total phosphorus (µg/L) and number of houses around 9 lakes and 1 bog in Kalkaska County, Michigan.

When Manistee Lake was removed from the analysis, there was a greater correlation between the number of houses and mean total phosphorus (R^2 = 0.253, *n* = 10, 95% CI) (Fig. 5).

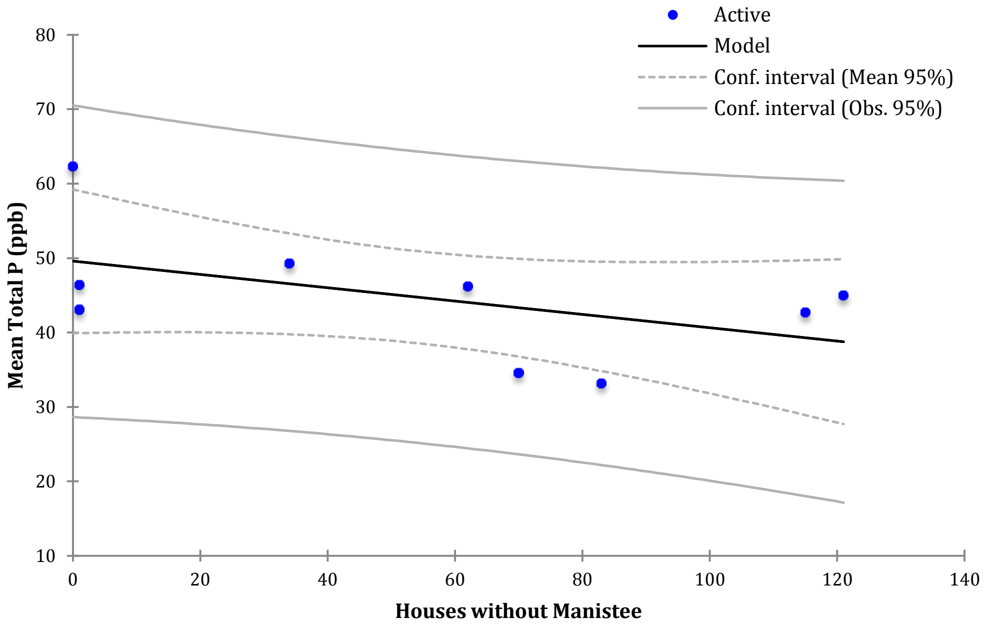

Figure 5. Linear regression showing the relationship ($R^2 = 0.253$, $n = 10$, 95% CI) between mean total phosphorus (μg/L) and number of houses (without Manistee Lake) around 8 houses and 1 bog in Kalkaska County, Michigan.

DISCUSSION

The results of the statistical analysis of the mean total phosphorus and depth show that there is no real correlation between the two parameters. This result is inconsistent with the original hypothesis that the Trophic State Index would be smaller for deeper lakes than for shallow lakes. The TSI results for total phosphorus are comparable among all the lakes in the area as there is no significant difference between the lakes. This result is different from one other study that showed that lake depth is indeed significantly correlated to total phosphorus (Dalkiran et. al 2006).

The results also show that Secchi depth is somewhat correlated with mean total phosphorus. This correlation is also stronger than the mean total phosphorus and total depth correlation. The correlation is expected, as the amount of phosphorus will affect the turbidity of the lake because phosphorus is the main limiting nutrient in these aquatic systems. The correlation is a negative one, showing that about 59% of the time, the mean total phosphorus is less when Secchi depth readings are more for the lakes sampled.

The weakest correlation is between mean total phosphorus and the number of houses on the lakes. It was expected that the number of houses around the lake would increase the amount of phosphorus in the lakes because anthropogenic factors tend to increase the amount of nutrients in a lake. However, the depth of the lake can also be factored into this comparison, as deeper lakes are capable of 'hiding' the phosphorus in their sediments, while shallow lakes would not. Manistee Lake was factored out of the regression analysis the number of houses is so great compared to other lakes sampled. The correlation between the number of houses and the mean total phosphorus given by the R^2 value increased from 0.028 to 0.253 in the absence of the Manistee house count.

The results show most of the lakes in the area are mesotrophic (Big Twin, Manistee, Pickerel, Starvation, Indian, Papoose, Oxbow lakes), while some are oligotrophic (Big Blue, Little Twin lakes) and Bear Lake Road Bog is dystrophic. It should be noted that the trophic status of each lake as given by its TSI is not a description of its water quality, it just an index (Carlson 1977). A similar project done on Minnesota lakes found that TSI values for secchi depth were lower than the values for total phosphorus (Carlson 1977). The greatest correlation between the TSI values was found in August and September, citing springtime crashes in algal populations in May and June for the difference in these two values (Carlson 1977). The TSI for phosphorus can only be used as an indicator of a more broadly defined concept, as the best indicator of lake quality may vary from lake to lake and with seasons (Carlson 1977). The chlorophyll a index would have given a better comparison of the quality of the lakes sampled.

The research may have been limited by the time the laboratory analysis was done. The analysis was started 28 days after the first sampling was done, there was no filtration done on the samples, and sulfuric acid was not used in the samples immediately after they were taken. Kopshy (2010) showed that when phosphorus samples are held for up to 28 days before analysis, the mean total phosphorus concentration calculated is larger than ± 10% of the mean calculated if analysis is done <48 hours after sampling. For future studies, it would be advised that samples be analyzed no later than two days after collection, that they also be filtered and that sulfuric acid be added to preserve them.

Although the hypotheses were not supported, it should be noted that lake behavior would be sensitive to the state in which the lake is in, therefore, small inputs of nutrients such as phosphorus may affect different lakes differently even though they are equally shallow or deep (Lau and Lane 2001). The flushing rate of each lake as well as the watershed around that lake also have to be put into consideration when trying to understand the nutrient levels in each lake and compare them. The addition of nutrients might be minimal, however, the equilibrium of that system is shifting no matter how little the addition.

FURTHER RESEARCH

For further research into the relationship between the amount of phosphorus in lakes in this area and their depths (morphometry), the volume of each lake can be put into consideration. Also, the extent of land use around each lake, for example, gardens and farmlands should be noted.

EXPERIMENTAL

Field Sampling

Sampling was conducted from 29 June 2012 to 19 July 2012. Total lake depth was obtained from the Michigan 98 lakes map book (Michigan 98 lakes). Sampling was conducted at the deepest point in each lake. We also measured dissolved oxygen (DO) (ppm) and temperature (°C) every 1 m from the lake surface to the bottom using a YSI Model 50B DO meter.

Incident solar radiation and amount of light at 1 m depth intervals from the surface to the bottom were measured using a Protomatic underwater photometer (foot-candles). Relative transparency of the lake water was measured using a 20-cm diameter Secchi disc. The Secchi disc was lowered twice and the average taken as the Secchi depth (m).

At the surface of the lake and 1 m into the hypolimnion (1 m from the bottom of the lake for shallow lakes), we also tested the pH using a pH meter (LaMotte wide precision range pH). Hardness was measured for samples collected from both the lake surface and 1m into the hypolimnion the bottom using the LaMotte hardness kit (LaMotte hardness tablet version). We used a Van Dorn sampler to collect water samples for the pH, hardness and phosphorus tests. Water for the pH and hardness tests was collected in glass jars. Triplicate samples were collected and labeled in Whirl Paks® for the phosphorus test, preserved in a cooler with ice while out in the field, and then kept in a freezer until testing was done.

The number of houses around each lake was determined by personal communication with members of the lake homeowners’ associations.

Laboratory Methods

Laboratory analysis was done for all the lakes on July 26, 2012. For phosphorus, we used method 2 from Vernier, which uses multiple standards and a colorimeter to measure concentration (Johnson et al 2007). We prepared standards of concentrations 2 ppb, 10 ppb, 20 ppb, 50 ppb, 100 ppb and 200 ppb. The standards were then digested and their absorbances were measured. We prepared the standards by adding potassium persulfate and 2.63 M sulfuric acid to each flask. They were then digested on a hot plate for 30 minutes. After digestion, 5.0 M sodium hydroxide and PhosVer 3 paks were added to each flask. The standards were then transferred into the 10-cm sample holder. The absorbance of each standard was then read from the Spectronic-21 spectrophotometer.

The samples were removed from the freezer the night before testing to allow thawing. Triplicate samples for each depth were analyzed together using the digestion protocol above. The mean of the top and bottom absorbances were used for the analysis.

We calculated the Carlson Trophic State Index (CTSI) for each lake based on the amount of phosphorus and Secchi depth using the following formulas:

$$\text{TSI (SD)} = 10\left(6 - \frac{lnSD}{ln\,2}\right)$$

$$\text{TSI (TP)} = 10\left(6 - \frac{ln\frac{48}{TP}}{\ln 2}\right)$$

where SD = Secchi Depth (m), and TP = Total Phosphorus (μg/L).

The Trophic State of the lakes was determined from the values obtained from the above formulas. We compared the results of the Secchi depth calculation to the mean total phosphorus results to determine the trophic status of the lakes using a trophic state index template (Fig. 6) (Cooperative Lakes Monitoring program 2010).

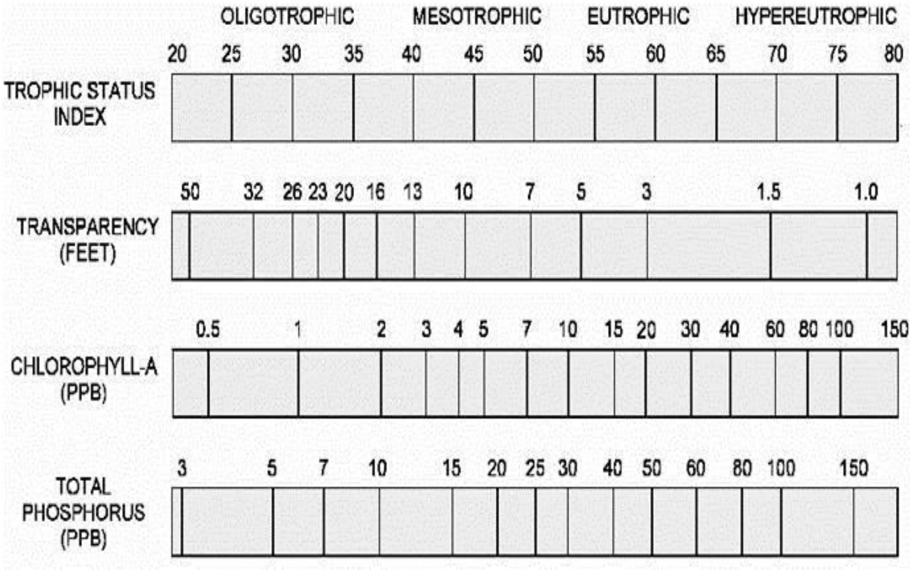

Figure 6. Carlson's Trophic State Index template (Cooperative Lakes Monitoring Program).

Statistical Analysis

We used linear regression analysis to test for a relationship between the morphometry (depth) of the lakes and the amount of phosphorus in the lake. The relationship between the mean total phosphorus and the number of houses around the lake, and the Secchi depth was also determined using linear regression analysis. The dependent variable for our research was the mean total phosphorus in each lake while the independent variable was the lake depth. The trophic state of each lake was determined using the Carlson Trophic state index for secchi depth and phosphorus.

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APPENDICES

APPENDIX I. Limnological data collected from 10 lakes in Kalkaska County from June 29 – July 19, 2012.

A. Chemical and Physical data collected from Lakes in Kalkaska County, Michigan, from June 29 – July 19, 2012.

Starvation Lake					
Depth (m)	Temp.	Oxygen (ppm)	Light (ft-candles)	Hardness	pH
1	26.7	7.97	1500	66	8.0
2	26.8	7.78	800		
3	26.7	7.85	600		
4	25.8	8.19	320		
5	24.9	9.04	180		
6	23.3	10.08	120		
7	21.3	11.23	60		
8	19.6	12.46	0		
9	17.3	11.51			
10	15.8	7.88			
11	14.8	6.20		63	8.0
12	14.4	0.67			

Indian Lake					
Depth (m)	Temp.	Oxygen (ppm)	Light (ft-candles)	Hardness	pH
1	25.2	9.6	5000	70	8.0
2	25.1	9.9	800		
3	24.7	10.7	600		
4	24.2	10.3	370		
5	20.7	7.9	0	69	8.0
6	20.5	0.5			

Oxbow Lake					
Depth (m)	Temp.	Oxygen (ppm)	Light (ft-candles)	Hardness	pH
1	28.3	11.6	2000	94	8.5
2	26.5	12.0	1400		
3	25.7	12.9	1100		
4	24.5	14.5	700		
5	22.9	15.2	480		
6	21.1	11.9	260		
7	20.1	8.5	0.1	110	8
8	19.1	2.3	0		
9	18.6	0.3			

Papoose Lake					
Depth (m)	Temp.	Oxygen (ppm)	Light (ft-candles)	Hardness	pH
1	26.8	8.3	560	16	7.0
2	26.5	8.2	350		
3	26.3	7.5	210		
4	25.6	3.5	0	14	7.0
5	25.1	0.5			

Little Twin Lake					
Depth (m)	Temp.	Oxygen (ppm)	Light (ft-candles)	Hardness	pH
1	27.4	9.0	2000	73	8.0
2	27.2	9.0	1000		
3	27.0	9.3	1400		
4	26.6	9.0	1400		
5	26.5	9.3	1200		
6	25.7	15.3	1000		
7	24.6	14.3	730		
8	23.4	6.8	330	92	7.5
9	23.0	0.5	0		

Big Blue					
Depth (m)	Temp.	Oxygen (ppm)	Light (ft-candles)	Hardness	pH
1	26.4	7.87	2100	135	8.0
2	26.5	7.92	1300		
3	26.1	7.93	900		
4	25.5	8.19	560		
5	24.4	8.58	340		
6	22.1	9.83	210		
7	19.2	11.8	120		
8	15.6	12.7	66		
9	14.1	13.1	37		
10	12.6	12.1	19		
11	11.2	11.6	3.2		
12	10.1	10.7	0		
13	9.1	10.9			
14	8.4	10.3			
15	7.9	9.4		137	8.0
16	7.7	9.2			
17	7.5	8.9			
18	7.2	8.5			
19	7.1	8.2			
20	7.0	7.4			

Big Twin					
Depth (m)	Temp.	Oxygen (ppm)	Light (ft-candles)	Hardness	pH
1	27.1	8.9	2500	107	8.5
2	26.1	9.5	2000		
3	25.1	9.8	1500		
4	24.5	10.1	1500		
5	24.1	10.3	1300		
6	23.2	11.2	1000		
7	21.2	12.8	900		
8	18.8	14.4	500		
9	16.2	15.5	450		
10	14.3	14.6	400		
11	13.2	14.4	300		
12	12.1	12.8	250	109	8.0
13	10.8	11.0	190		
14	10.2	6.9	150		
15	9.6	4.8	110		
16	9.2	2.4	92		
17	9.0	1.7	66		
18	8.9	1.1	46		
19	8.7	0.5	36		

Pickerel Lake					
Depth (m)	Temp.	Oxygen (ppm)	Light (ft-candles)	Hardness	pH
1	25.8	8.9	3500	99	8.0
2	25.0	9.4	2000		
3	23.7	9.6	1500		
4	23.3	9.9	1200		
5	22.8	10.0	900		
6	21.1	11.0	700		
7	18.4	12.8	720		
8	16.3	12.5	700		
9	14.5	11.6	400		
10	13.2	10.8	350		
11	12.0	10.3	320		
12	11.2	10.0	160		
13	10.4	9.3	130		
14	9.7	8.4	95		
15	8.9	7.6	100		
16	8.7	5.8	700		
17	8.1	5.3	600		
18	7.8	4.4	400		
19	7.6	2.9	300	115	8.0
20	7.5	2.4	200		

Manistee Lake					
Depth (m)	Temp.	Oxygen (ppm)	Light (ft-candles)	Hardness	pH
0	23.6	7.9	250	90	8.0
1	24.5	7.4	150		
2	25.1	7.0	69		
3	25.3	6.5	44	90	8.0
3.5	25.4	0.2	0		

Bear Lake Road Bog					
Depth (m)	Temp.	Oxygen (ppm)	Light (ft-candles)	Hardness	pH
0	26.3	8.6	240	5	5.5
1	21.4	13.1	29		
2	15.0	0.6	0.2	8	5.5
3	14.3	0.4	0		

B. Triplicate data for absorbance collected on July 26, 2012 using the Spec-21 spectrophotometer for 10 lakes in Kalkaska County, Michigan.

Starvation Lake

Trial	Absorbance (AU)	
	Top	Bottom
A	0.351	0.496
B	0.305	0.648
C	0.597	0.392
Mean	**0.418**	**0.512**

Indian Lake

Trial	Absorbance (AU)	
	Top	Bottom
A	0.768	0.372
B	0.420	0.521
C	0.400	0.681
Mean	**0.529**	**0.525**

Oxbow Lake

Trial	Absorbance (AU)	
	Top	Bottom
A	0.602	0.529
B	0.437	0.464
C	0.295	0.483
Mean	**0.445**	**0.492**

Papoose Lake

Trial	Absorbance (AU)	
	Top	Bottom
A	0.587	0.404
B	0.396	0.641
C	0.523	0.450
Mean	**0.502**	**0.498**

Little Twin Lake

Trial	Absorbance (AU)	
	Top	Bottom
A	0.359	0.489
B	0.147	0.721
C	0.212	0.398
Mean	**0.239**	**0.536**

Big Blue Lake

Trial	Absorbance (AU)	
	Top	Bottom
A	0.292	0.348
B	0.454	0.405
C	0.419	0.330
Mean	**0.388**	**0.361**

Big Twin Lake

Trial	Absorbance (AU)	
	Top	Bottom
A	0.517	0.461
B	0.475	0.619
C	0.335	0.511
Mean	**0.442**	**0.530**

Pickerel Lake

Trial	Absorbance (AU)	
	Top	Bottom
A	0.536	0.470
B	0.438	0.357
C	0.429	0.756
Mean	**0.468**	**0.528**

Manistee Lake

Trial	Absorbance (AU)	
	Top	Bottom
A	0.383	0.352
B	0.574	0.573
C	0.636	0.500
Mean	**0.531**	**0.475**

Bear Lake Road Bog

Trial	Absorbance (AU)	
	Top	Bottom
A	0.688	0.552
B	0.785	0.625
C	0.678	0.576
Mean	**0.717**	**0.584**

CHRISTIAN WORLDVIEW AND PERSONAL THESIS

During my time at Au Sable where I conducted my research, I was encouraged to think about my purpose as a Christian researcher. Research was an opportunity for me to understand better the workings of a part of the world and to share my findings with others. My research is not for me alone, and understanding this put my work into perspective for me.

As a Christian, I understand that God created the world and all that is in it. He also put value into His creation and even though humanity is higher than plant and animal life, there is an intrinsic value that every thing in the Universe has. This understanding that God places value on everything is something that I believe should persuade Christians to place value on the world around them and seek to take care of it. Obedience to God's mandate in Genesis 1 would not lead to a careless domination of the earth, rather, it would lead to a loving care for creation while we use it to benefit our lives.

As stewards of the earth, we have a responsibility to take care of creation, and what better way to care for it than to understand it first? Hence, the birth of my senior research project. I embarked on this project with the aim of understanding how the depth of lakes affects the amount of nutrients, particularly phosphorus, in them. I also wanted to understand how the number of people who lived around the lakes affected the amount of nutrients in these lakes.

As the research progressed, I began to understand that this quest for knowledge was not only for me. From the mistakes and the observations I made, I was able to understand that the knowledge I was amassing was not only for me, it could benefit others. From the program at Au Sable to the homeowners on the different lakes, everyone could stand to benefit from this research.

A scientific researcher is one who tries to understand better an area of life by using the scientific method of observing, asking questions, formulating hypothesis, testing the hypothesis and proposing theories based on the tests and hypotheses. This method leads to new discoveries that expand the knowledge of other people, enabling better methods of doing things to be invented. A Christian researcher knows that this process is done because a better understanding of creation results in better care for creation, which is in accordance with God’s commands. There is also a sense of purpose in knowing that research is a calling that is not just for oneself, but also for the good of all.