Indiana Volunteer Lake Monitoring Report:

2009-2011

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ACKNOWLEDGEMENTS

The chemical analysis of water samples is a labor-intensive process. The total phosphorus and chlorophyll *a* results in this report would not have been possible were it not for the capable help and skills of many SPEA graduate research assistants who conducted the analyses. Julia Bond provided GIS graphics assistance as well as much needed support with training this past year. Julia has also put in countless hours updating the volunteer portion of our website to make it much more user friendly.

Funds for this program were provided by Section 319 Lake Water Quality Assessment Grants from the U.S. Environmental Protection Agency. Laura Bieberich of the Indiana Department of Environmental Management was the Project Officers.

Most importantly, THANK YOU to all our volunteer lake monitors! Your hard work and dedication contribute greatly to the understanding and sound management of Indiana's lakes.

2009-2011 Volunteers by County

BROWN COUNTY	
Quinn Hetherington	Cordry Lake
David Jarrett	Sweetwater Lake
Buzz Settles	Sweetwater Lake
ELKHART COUNTY	
Gordon Mills	Heaton
Larry Lehman	Indiana
FRANKLIN COUNTY	
Tag Nobbe	Brookville
Reservoir	
FULTON COUNTY	
Dennis Grossnickle	Lake Manitou
Jerry Caylor	Nyona Lake
HARRISON COUNTY	
Guy Silva	Pinestone Lake
JOHNSON COUNTY	
Tom Houghman	Lamb Lake
KOSCIUSKO COUNTY	
Kathy Hiatt	Banning & Little Barbee Lake
Donald Hagan	Big Barbee & Kuhn Lake
Len Draving	Big & Little Chapman Lake
Jack Carr	Bonar Lake
Troy Turley	Center Lake
John Bender	Diamond Lake
Sandra Buhrt	Elizabeth Lake
Chuck Brinkman	Irish Lake
Jeff & Pam Thornburgh	James, Oswego, & Tippecanoe Lake
Debra Hutnick	Palestine Lake
Sandra Buhrt	Rachel Lake
Toney Owsley	Ridinger Lake
Kathy Hiatt	Sawmill Lake
Ron Hill	Sechrist Lake
Dean Schwalm	Syracuse Lake
Mike West	Waubee Lake
Daniel Berkey	Lake Wawasee
Don & Dawn Meyer	Webster Lake
Chris Cummins	Winona Lake
Chris Rankin	Winona Lake
Dave Patterson	Yellow Creek Lake
LAGRANGE COUNTY	
Joe Kraft	Adams Lake
Howard Pratt	Big Long Lake
Tom Henry	Big Turkey Lake
Tom Mackin	Lake of the Woods
Randy Furniss	Little Turkey Lake
Lynn Bowen	Martin, Olin, & Oliver Lake
Terry Gust	Martin, Olin, & Oliver Lake

Donna Moran	Martin, Olin, & Oliver Lake
Vanessa Eash	Pretty Lake
Robert Christen	Witmer Lake

LAKE COUNTY

Brongiel Frank	Cedar Lake
Paul Borkowski	Holiday Lake
Ed Spanopoulos	Holiday Lake

LAPORTE COUNTY

Paul and Joy Kamradt	Clear Lake

MARION COUNTY

Joan Baltz	Spirit Lake

MARSHALL COUNTY

Jerry Wall	Cook Lake
Joe Skelton	Flat, Galbraith, & Lake of the Woods
Peter Gyerko	Holem Lake
Bill & Allie Harris	Lost Lake
Dan Baughman	Lake Maxinkuckee
Kathy Clark	Lake Maxinkuckee
Andrew Plaia	Lake Millpond
John Guyse	Myers Lake
Louis Wenino	Pretty Lake
Joseph Coury	Pretty Lake

MONROE COUNTY

Heather Robbins	Griffy Lake
Elizabeth Tompkins	Griffy Lake
Adam Casey	Lake Lemon

MONTGOMERY COUNTY

Robert Ginger	Lake Holiday

MORGAN COUNTY

Les Smith	Nebo & Painted Hills Lake
John winters	Ole Swimming Hole
Brigitte schooner	Whippoorwill Lake

NOBLE COUNTY

Jane Litwiller	Bear Lake
Michael Martin	Big Lake
Tom York	Crooked Lake
Chuck Farris	Crooked Lake
Jane Litwiller	High Lake
Nick Stranger	Knapp Lake
Jean Cook	Little Long Lake
Nancy Lough	Skinner Lake
John Fitzpatric	Skinner Lake
Colin Tipton	Upper Long Lake

PORTER COUNTY

Paul Borkowski	Big Bass Lake
Ed Spanopoulos	Big Bass Lake
Robert Minarich	Flint, Long, & Loomis Lake
Christian Anderson	Louise Lake

PUTNAM COUNTY

Brian Waldman	Heritage Lake

ST. JOSEPH COUNTY

Mike Squint	Tawny Lake

STARKE COUNTY

Tom Camire	Koontz Lake

STEUBEN COUNTY

Peg Zeis	Lake Anne
Paul Oakes	Ball Lake
Joe Geiger Jr.	Barton Lake
Pam Manee	Big Otter Lake
Michael Frederick	Clear Lake
Joann Stanley	Clear Lake
Andrew Hosey	Crooked Lake
Allen Lefevre	Lake Gage
Scott MacDonald	Lake Gage
Jim Aikman	Hogback Lake
James Clary	Lake James
Pam Manee	Little Otter Lake
Paul Marki	McClish Lake
Joseph Peck	Silver Lake
Mike Marturello	Snow Lake
James Weber	Syl-Van Lake
John Williamson	West Otter Lake

WABASH COUNTY

Leslie Patterson	Salamonie Lake

WHITLEY COUNTY

Gregory Hunter	Big Cedar Lake
Denise Heckman	Goose Lake
Chuck Lewton	Little Cedar Lake
Tom York	Little Crooked Lake
Chuck Farris	Little Crooked Lake

Rick Miller	Loon Lake	Mauro Garcia	Shriner Lake
Jeanne Rethlake	Old Lake		
Myron Green	Round Lake		
Dave Byers	Shriner Lake		

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DESCRIPTION OF PROGRAM

The Indiana Volunteer Lake Monitoring Program was created in 1989 as a component of the Indiana Clean Lakes Program (CLP) administered through the Indiana Department of Environmental Management (IDEM). Indiana University's School of Public and Environmental Affairs (SPEA) implements the program through a grant from IDEM. The Indiana Clean Lakes Program is a comprehensive, statewide public lake management program with five components: public information and education, technical assistance, volunteer lake monitoring, lake water quality assessment, and coordination with other state and federal lake programs

The Volunteer Lake Monitoring Program component of the Clean Lakes Program was created to accomplish four main objectives:

1. Collect water quality data that will contribute to the understanding of how Indiana lakes function;
2. Monitor water quality changes to provide an early warning for problems that may be occurring in lakes;
3. Encourage citizen involvement in the protection and management of their lakes;
4. Provide the means whereby Indiana citizens can learn more about lake ecology and management.

All volunteers in the Program take Secchi disk transparency measurements on their lakes. The Secchi disk is one of the oldest and most basic tools used by limnologists. Secchi disks are used as an indicator of water quality by measuring the transparency of water (Figure 1). Secchi disk measurements can be used as a first, simple check for eutrophication. Water clarity is affected by two main factors: algae and suspended sediments. Color observations are also made with the Secchi depth to differentiate between these two factors. Algae are a main element in determining trophic status. Sediment may be introduced to lakes via runoff from construction sites, agricultural lands, and river banks. Shallow lakes are especially susceptible to sediment resuspension from motor boats, personal watercraft, or strong winds.

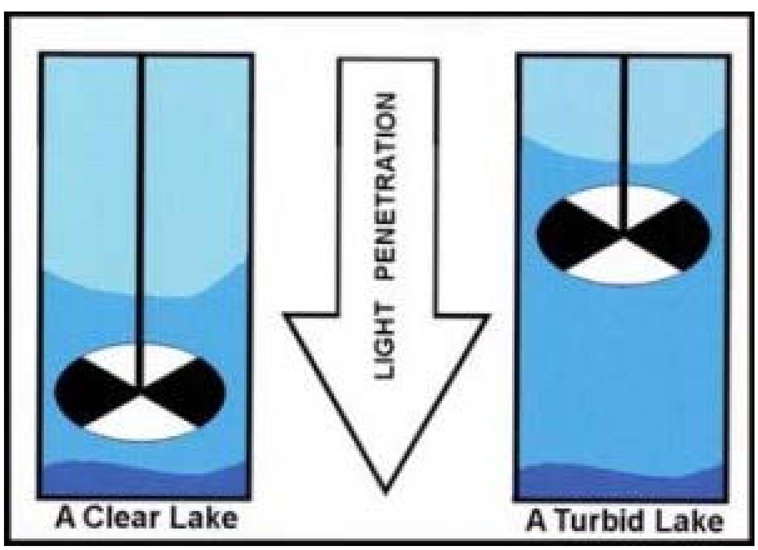


Figure 1. Secchi disk and water quality.

A subset of volunteers also collects water samples for total phosphorus and chlorophyll *a* analyses through our Expanded Program. Phosphorus is the primary limiting nutrient required for growth by algae and aquatic plants; therefore most lake management programs measure phosphorus concentrations. Chlorophyll *a* is the primary green pigment in algae and is a direct measure of algal production.

Dissolved oxygen and temperature meters are also available to volunteers throughout the state. Dissolved oxygen enters water via two pathways: diffusion into water from the atmosphere and production by algae and aquatic plants as a by-product of photosynthesis. Oxygen, in turn, is consumed by the respiration of fish and other oxygen-breathing aquatic organisms and by bacterial decomposition processes. The quantity and distribution of dissolved oxygen in lakes helps determine the importance of these processes, and defines where fish and other aquatic life may survive. Lake zones with extremely low concentrations of dissolved oxygen may not support aquatic life and may instead promote chemical conditions whereby nutrients are released into the water from sediment storage. Temperature also has an effect on what aquatic organisms can live in certain areas of a lake.

In 2008 volunteers began taking lake level readings to help support the Department of Natural Resources. The volunteers are taking lake level readings at various locations throughout the state. In 2008 after the start of the program, 6 volunteer monitors turned in 23 lake level readings. From 2009 to 2011 volunteers made 497 lake level observations on 52 lakes.

MATERIALS AND METHODS

All volunteers are given a training manual, postage paid data cards, and a Secchi disk with a calibrated measuring tape. Secchi disks are painted and assembled by CLP staff at SPEA.

Volunteers need access to a boat once every two weeks. Secchi disk measurements are taken on sunny, calm days between the hours of 10:00 a.m. and 4:00 p.m. Measurements are taken at the same site each time, generally over the deepest part of the lake. In addition to the Secchi depth measurement, volunteers also assign a color to the water. Volunteers choose from a list of: Clear/Blue, Blue/Green, Green, Brown, or Green/Brown. They choose a color that best matches the color of the lake water. Volunteers also evaluate the recreational potential and physical appearance of the lake. Volunteers submit these data to SPEA via pre-paid postage cards or they can enter their data electronically on the CLP website: http://www.indiana.edu/~clp/.

Volunteers are able to use a temperature and dissolved oxygen meter that can be checked out from SPEA or local soil and water conservation district offices. Both temperature and dissolved oxygen change with the seasons, volunteers are encouraged to take several profile measurements of their lake, ideally once per month.

Volunteers participating in the Expanded Program collect samples for chlorophyll *a* and total phosphorus at the same location as their Secchi disk measurement. Expanded Program samples are collected once a month during the summer, typically May through August.

The Expanded Program volunteers are given a kit, assembled by CLP staff, including a PVC 2-meter integrated water column sampler, filters, tweezers, a filtering apparatus, a hand-held vacuum pump, a pitcher to transfer collected water, sample bottles, a five gallon bucket for equipment storage, a Styrofoam mailer, prepaid express mail tags, and an expanded program manual. Phosphorus water samples are poured into 125 ml polyethylene bottles and frozen. To collect chlorophyll *a*, a known quantity of lake water is filtered through a glass-fiber filter (Whatman GF-F), which traps the algae. Filters are folded, placed in a 30 ml opaque bottle, and frozen. Once two months of samples are collected, they are shipped overnight to the SPEA lab in Bloomington for analysis by CLP staff.

Many of the volunteers are also monitoring lake levels. The CLP staff is in the process of corresponding with volunteers and the Indiana Department of Natural Resources to find the locations of the lake level gauges or to have new ones installed. This will help incorporate more information and involvement for the volunteer monitors.

VOLUNTEER RECRUITMENT

Volunteers have contributed essential lake data since Indiana Volunteer Monitoring Program was created in 1989. Volunteer monitoring data provides information for volunteers, lake organizations, the Indiana Department of Environmental Management, and others interested in obtaining lake information.

Volunteers are recruited via statewide news releases, local newspaper articles, announcements in the quarterly *Water Column* newsletter, word of mouth, information booths at the annual Indiana Lake Management Conference and Northern Indiana Lakes Festival, and the CLP website (www.indiana.edu/~clp). New volunteers are trained around the state at individual or group training sessions with CLP staff.

Citizens are critical to the success of the Indiana Volunteer Lake Monitoring Program. Their participation allows IDEM to monitor long term lake water quality and to gather data on many more lakes than would be possible without this program. While volunteers come from a wide variety of backgrounds and have varying interests, they all recognize the importance of their lakes as a valuable ecological and recreational asset, and share an interest in protecting or improving its water quality. Many volunteers are actively involved in lake or conservation associations, and participate in lake management decisions. By participating in the Indiana Volunteer Lake Monitoring Program, volunteers become better stewards and spokespersons for their lakes.

Program Growth

The Volunteer Monitoring Program began in 1989 with 41 volunteers taking measurements on 51 lakes. From 2009 to 2001, 1,710 observations were made on 106 lakes in Indiana. From

2009 to 2011 28 new volunteers were trained to monitor their lakes. Over the past 3 years we have seen a decrease in the number of lakes reporting, but an overall increase in the number of observations made on individual lakes. The expanded volunteer monitoring program has also grown in the past 3 years from 42 expanded lakes in 2009 to 48 lakes in 2011. In 2011 we increased the participation in the expanded monitoring program by 8 volunteers and will continue to increase the number of volunteers in the expanded program in 2012. The total number of lakes sampled and observations made in the Volunteer Monitoring Program since its inception are listed in Table 1.

TABLE 1. Summary of Lakes Monitored with Total Annual Observations.

	Secchi Disk Program		Expanded Program	
Year	Lakes Monitored	Total Observations	Lakes Monitored	Total Observations
1989	51	370	n/a	n/a
1990	73	535	n/a	n/a
1991	74	523	n/a	n/a
1992	85	537	30	90
1993	75	514	31	95
1994	75	677	28	116
1995	85	644	27	130
1996	81	563	27	100
1997	91	668	31	92
1998	87	548	31	111
1999	90	537	31	104
2000	104	618	34	120
2001	84	583	39	132
2002	93	569	41	136
2003	91	611	40	124
2004	94	590	39	132
2005	95	589	40	146
2006	83	514	45	157
2007	91	536	42	149
2008	81	414	37	131
2009	93	568	42	158
2010	80	578	40	144
2011	78	537	48	176

THE LAKES

A variety of attempts have been made to classify lakes. Lakes can be classified based on how they were formed, physical characteristics (depth, surface area, etc.), and where they are located (ecoregion).

Lake Formation

Hutchinson (1957) classified lakes based on how they were formed. Most lakes in Indiana were formed by glacial activity, solution, river channel migration, or by human activity (damming).

The majority of lakes sampled by the Volunteer Monitoring Program are natural lakes located in northern Indiana (Figure 2).Most of these lakes were formed by glacial activity. These lakes are mainly "ice block" or kettle lakes, formed by the large blocks of ice deposited in the glacial outwash plain. In the southern portion of Indiana, where limestone is prevalent, lakes were formed in basins caused by the solution of limestone. River channel migration also forms lakes. As a river shifts course, the former channel becomes cut off from the new active channel and can form oxbow lakes. Finally, impoundments have been created by human activity through all parts of Indiana, including farm ponds, millponds, quarry holes, and reservoirs. Eighty-two of the monitored lakes were natural lakes and thirteen were impoundments.

Physical Characteristics

Lakes can also be classified based on their physical characteristics such as surface area, depth, and watershed area. Monitored lakes varied greatly in surface area and depth. Brookville Reservoir in Franklin County had the largest surface area of lakes in the program, 5258 acres respectively. Lake Wawasee in Kosciusko County and Lake Maxinkuckee in Marshall County were the largest natural lakes in the program with surface areas of 2617 acres and 1853 acres respectively. Conversely, Pinestone Lake in Harrison County and Little Cedar Lake in Whitley County had the smallest surface areas, 1 acres and 10 acres respectively. Nineteen lakes have a surface area less than 50 acres, 18 lakes are between 50-100 acres, 26 lakes are between 101-200 acres, 21 lakes are between 201-500 acres, and 12 lakes are greater than 500 acres (Figure 3).

The deepest monitored lake was Lake Tippecanoe in Kosciusko County at 123 feet, while Lost Lake in Marshall County was the shallowest natural lake at 4 feet. Four of the monitored lakes were less than 20 feet deep, thirty-eight lakes were between 21-40 feet, twenty-two lakes were between 41-60 feet, seventeen were between 61-80 feet, eight were between 81-100 feet, and four were greater than 100 feet (Figure 4).

Monitored lakes also varied in the size of the watershed. Salamonie Reservoir in Wabash County has the largest watershed, 355,831 acres. Banning Lake has the smallest watershed, 306 acres. Four lakes had a watershed area less than 500 acres, 10 watersheds were between 501-2000 acres, 19 watersheds were between 2001-5000 acres, 11 watersheds were between 5001-10,000 acres, and 24 watersheds were greater than 10,000 acres (Figure 5).

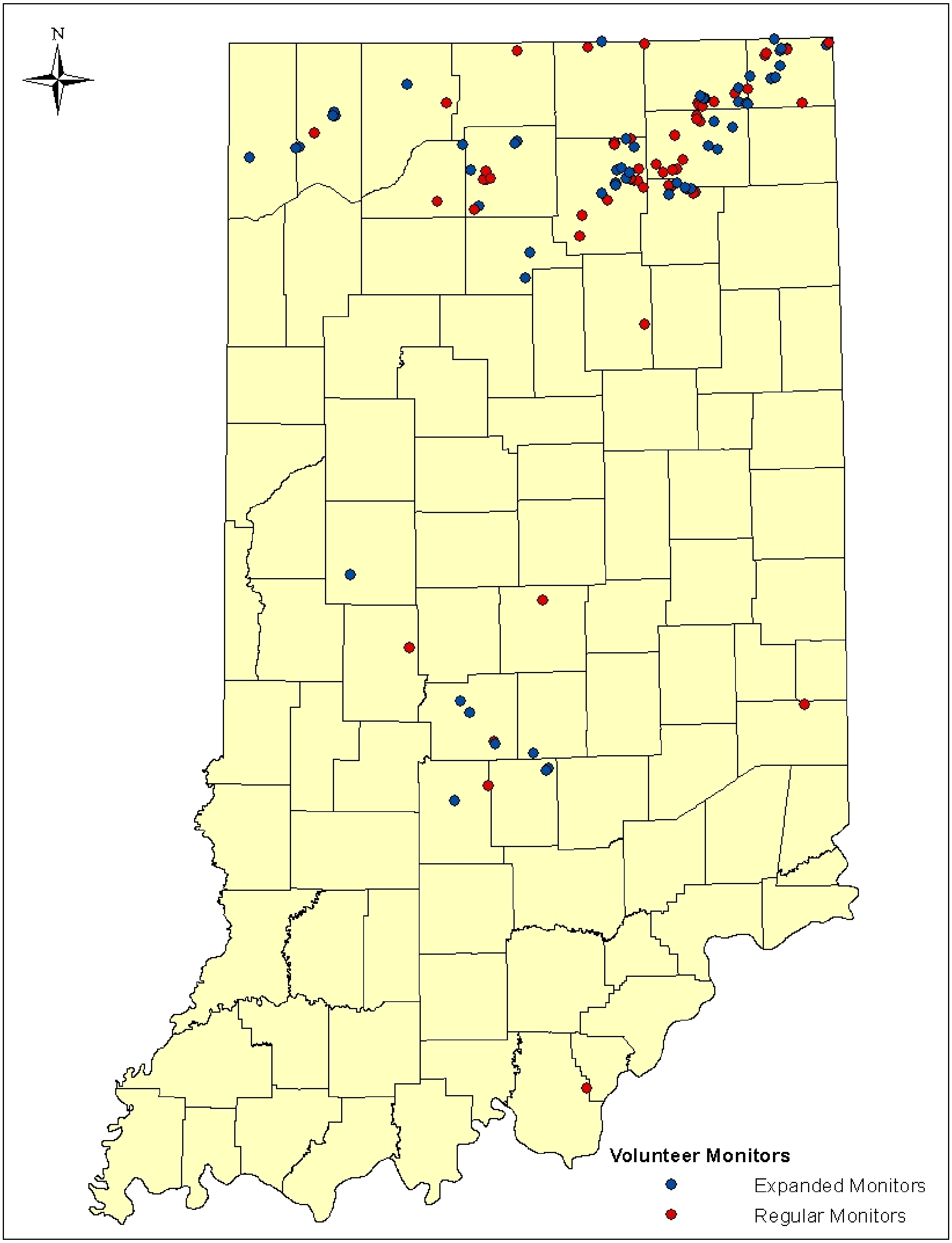


Figure 2. Lakes in the Volunteer Monitoring Program from 2009-2011.

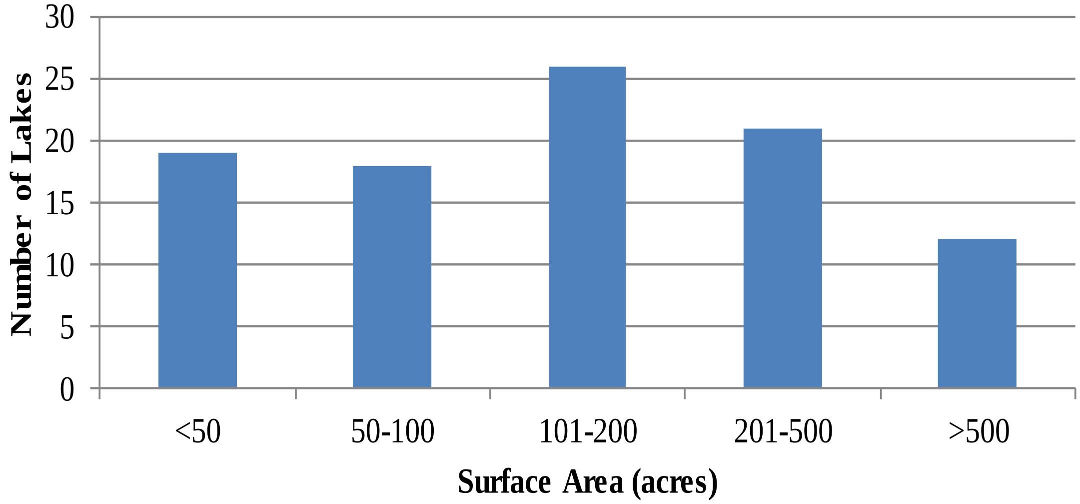


Figure 3. Size distribution of lakes in the Volunteer Monitoring Program.

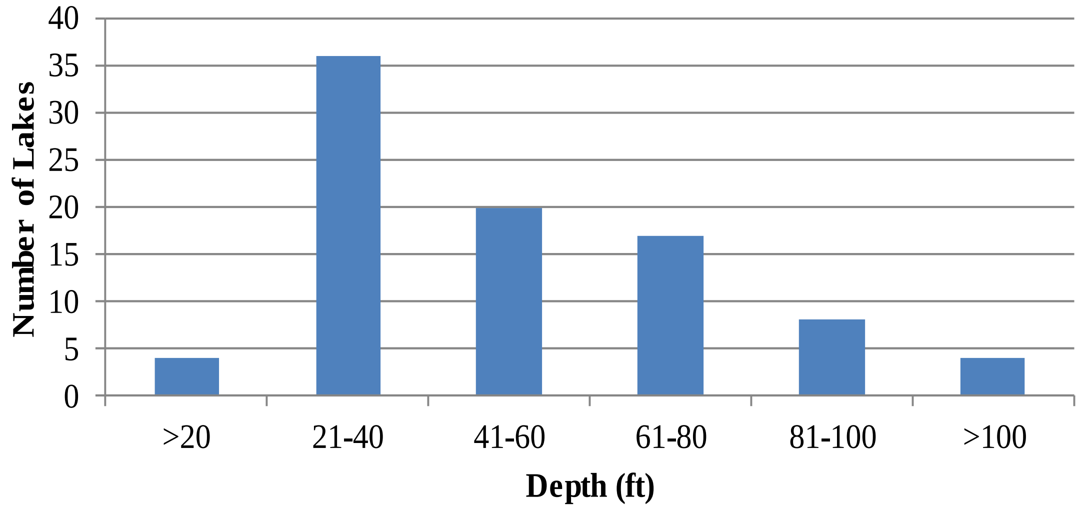


Figure 4. Depth distribution of lakes in the Volunteer Monitoring Program.

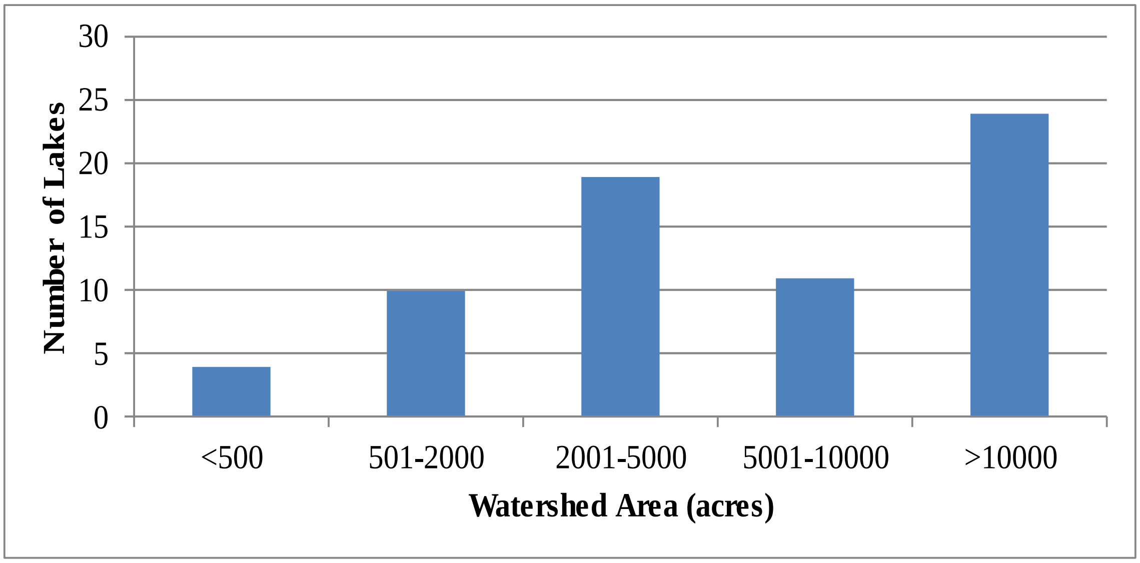


Figure 5. Watershed area distribution for lakes in the Volunteer Monitoring Program.

Ecoregion

Ecoregions were delineated in the late 1980's to provide a geographic framework for more efficient management of ecosystems and their components (Omernik, 1987). This concept recognizes that land features such as bedrock geology, topography, soil type, vegetation, land use and human impacts interact to form specific ecological regions or ecoregions. The relative importance of individual factors and the complexity with which these factors interact varies from one ecoregion to another.

Indiana is a state composed of many different land types. The northern portion of the state is relatively flat, while the southern portion of the state is hilly. Land use ranges from row crop agriculture in the northern and central portion of the state to large areas of forest in the south to coal mines in the southwest. The use of ecoregions can help explain the differences between these different land types. Overall, six ecoregions are located within the state of Indiana (Figure 6). Five of these contain lakes sampled in the Volunteer Monitoring Program during the 2011 sampling season. Characteristics of Level III ecoregions within Indiana, as described by Omernik and Gallant (1988) are described in Figures 7, 8, 9, 10, 11, and 12.

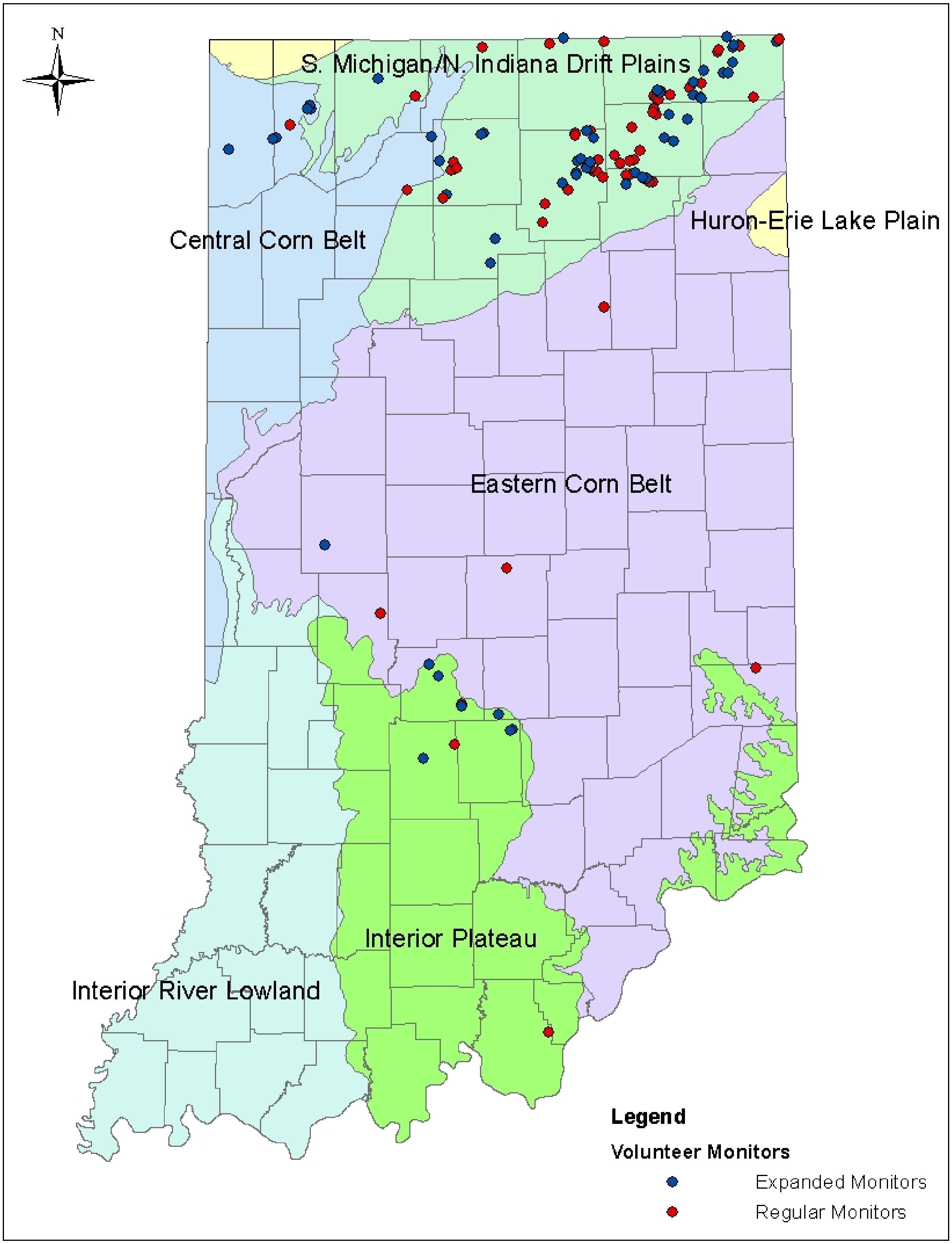


Figure 6. VolunteerlLakes by Level III Ecoregions in Indiana. After: Omernik and Gallant (1988).

54 – Central Corn Belt Plains Ecoregion The Central Corn Belt Plains ecoregion consists of a dissected glacial till plain mantled with loess. Historically, this region was mostly low relief and soils originally developed in tall-grass prairie and oak/hickory forests. Today, almost all of this ecoregion is cultivated for feed crops (corn, soybeans, feed grains and some forage) for livestock. Only 5% of the land remains in woodland. Non-point source pollution in the Central Corn Belt Plains is derived from crop and livestock production.

Number of Lakes in Program During 2009-2011: 8
Maximum Surface Area: 781 acres
Maximum Depth: 68 feet
Median Secchi Disk Transparency: 3.9 feet
Number of Expanded Lakes: 7
Median Total Phosphorus Concentration: 31.7 µg/L
Median Chlorophyll a Concentration: 27.3 µg/L

Figure 7. Ecoregion 54.

55 – Eastern Corn Belt Plains Ecoregion

The Eastern Corn Belt Plains ecoregion is a gently rolling glacial till plain broken by moraines and outwash plains. It supports a diverse hardwood forest and approximately 75% is currently is in cropland, primarily corn and soybeans. This ecoregion has few natural lakes or reservoirs.

Number of Lakes in Program During 2009-2011: 4
Maximum Surface Area: 5258 acres
Maximum Depth: 96 feet
Median Secchi Disk Transparency: 2.8 feet
Number of Expanded Lakes: 1
Median Total Phosphorus Concentration: 60.7 µg/L
Median Chlorophyll a Concentration: 36.9 µg/L

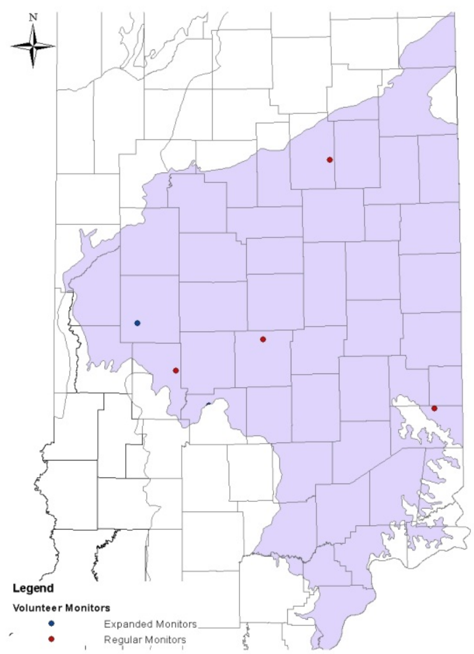
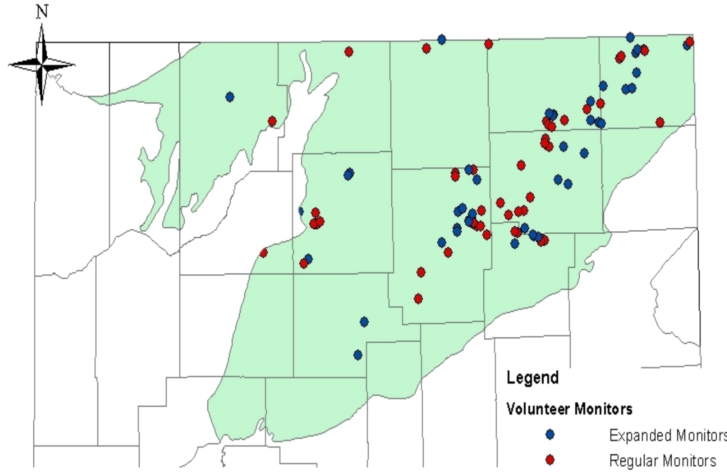


Figure 8. Ecoregion 55.

56 – Southern Michigan/Northern Indiana Drift Plains Ecoregion

This 25,800 square-mile ecoregion includes a broad, nearly flat to rolling glaciated plain, deeply mantled by glacial till and outwash, sandy and gravelly beach ridges and flats, belts of morainal hills, and boggy kettle depressions. Land is managed for cropland, livestock, forest and woodland, and urban use. Approximately 25% of the region is urbanized. Lakes are common in some areas; however many depressions are filled with peat deposits or dark mineral soils.



Number of Lakes in Program During 2009-2011: 82
Maximum Surface Area: 2619 acres
Maximum Depth: 123 feet
Median Secchi Disk Transparency: 5.9 feet
Number of Expanded Lakes: 35
Median Total Phosphorus Concentration: 15.5µg/L
Median Chlorophyll a Concentration: 2.8 µg/L

Figure 9. Ecoregion 56.

57 – Huron/Erie Lake Plains Ecoregion

This ecoregion consists of a broad, nearly level lake plain crossed by beach ridges and low moraines. Most of the area was originally covered by forested wetlands. Local relief is generally only a few feet. The ecoregion covers 11,000 square miles of Indiana, Ohio and Michigan. Cash crop farming is the primary land use in the Huron/Erie lake Plain and soils are often poorly drained. Approximately one-tenth of the regionis urbanized. There are few lakes or reservoirs in this ecoregion.

Number of Lakes in Program during 2009-2011: 0

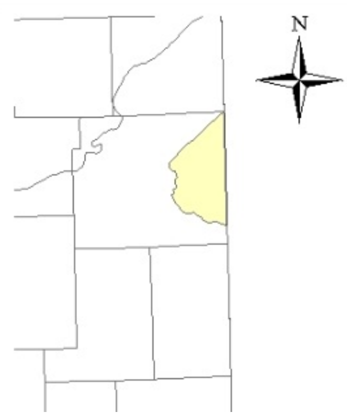


Figure 10. Ecoregion 57.

71 – Interior Plateau Ecoregion

The Interior Plateau includes a till plain of low topographic relief formed from Illinoisan glacial drift materials, rolling to moderately dissected basin terrain, and rolling to deeply dissected plateaus. Layers of limestone, sandstone, siltstone and shale underlie much of this region. Acreage in this ecoregion is managed for cropland, livestock, pasture, woodland and forest. There are numerous quarries and some coal surface mines; natural lakes are few.

Number of Lakes in Program During 2009-2011: 10
Maximum Surface Area: 1648 acres
Maximum Depth: 110 feet
Median Secchi Disk Transparency: 6.0 feet
Number of Expanded Lakes: 5
Median Total Phosphorus Concentration: 39.6 µg/L
Median Chlorophyll a Concentration: 3.7 µg/L

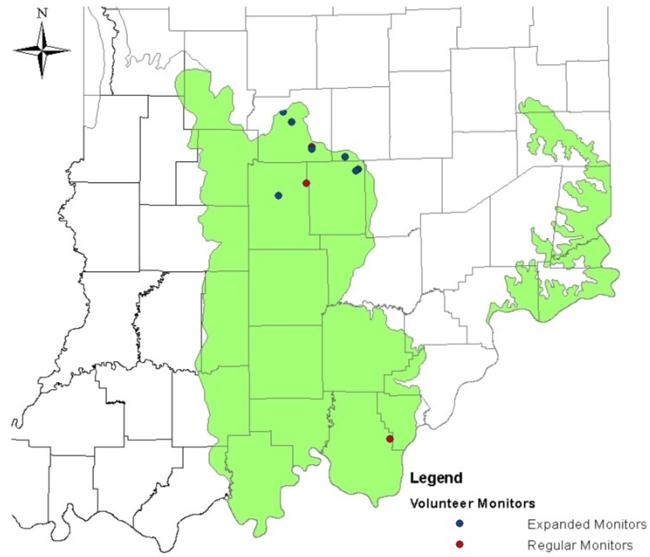


Figure 11. Ecoregion 71.

72 – Interior River Valleys and Hills Ecoregion

The Interior River Valley and Hills is comprised of a dissected glacial till plain, rolling narrow ridge tops, and hilly to steep ridge slopes and valley sides. Land uses are varied: cropland, livestock, pasture, timber and coal surface mines. About one-third of the region is forested, primarily in oak and hickory. Lakes, reservoirs and numerous ponds are scattered throughout the ecoregion. The greatest land use impacts on stream water quality in the region result from crop and livestock production and surface mining.

Number of Lakes in Program During 2009-2011: 0

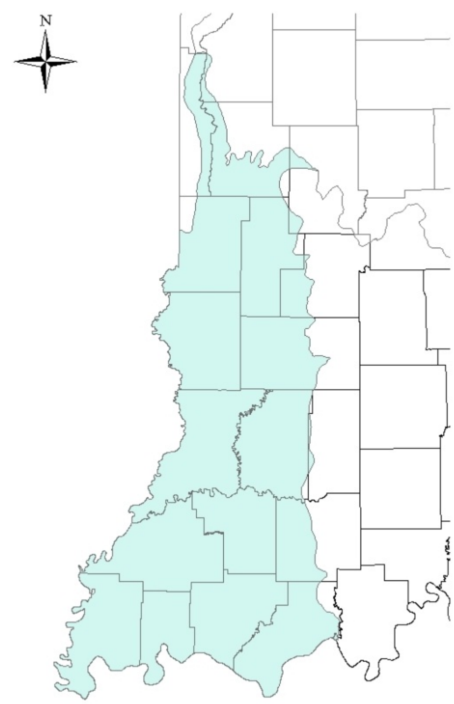


Figure 12. Ecoregion 72.

CARLSON'S TROPHIC STATE INDEX

In order to analyze all of the data collected it is helpful to use a trophic state index (TSI). A TSI condenses large amounts of water quality data into a single, numerical index. Different values of the index are assigned to different concentrations or values of water quality parameters.

The most widely used and accepted TSI, called the Carlson TSI, was developed by Bob Carlson (1977). Carlson found statistically significant relationships between summertime total phosphorus, chlorophyll *a*, and Secchi disk transparency for numerous lakes. He then developed mathematical equations to describe the relationships between these three parameters, which are then the basis for the Carlson TSI. Using this method a TSI score can be generated by just one of the three measurements. Carlson TSI values range from 0 to 100. Each increase of 10 TSI points (10, 20, 30, etc.) represents a doubling in algal biomass. Data for one parameter can also be used to predict the value of another.

The Carlson TSI is divided into four main lake productivity categories: *oligotrophic* (least productive), *mesotrophic* (moderately productive), *eutrophic* (very productive), and *hypereutrophic* (extremely productive). The productivity of a lake can therefore be assessed with ease using the TSI score for one or more parameters (Figure 13). Mesotrophic lakes, for example, generally have a good balance between water quality and algae/fish production. Eutrophic lakes have less desirable water quality and an overabundance of algae or fish.

Using the Carlson TSI index, a lake with a mean July/August Secchi disk depth of 7 feet would have a TSI score of 49 points (located in line with the 7 feet) (Figure 13). This lake would be in the mesotrophic productivity category. It would also be expected to have a chlorophyll *a* concentration of 7 µg/L and a total phosphorus concentration of 25 µg/L based on the relationships between these parameters.

The Carlson TSI does not apply to all lakes. The relationship between transparency, chlorophyll *a*, and total phosphorus can vary based on factors not observed in Carlson's study lakes. High concentrations of suspended sediments will cause a decrease in transparency from the predicted value based on total phosphorus and chlorophyll *a* concentrations. Heavy predation of algae by zooplankton will cause chlorophyll *a* values to decrease from the expected levels based on total phosphorus concentrations.

In 2011 the highest (most eutrophic) TSI score was sixty-nine for Big Bass Lake in Porter County and the lowest score of thirty-three was for Sweetwater Lake in Brown County. Big Bass Lake in Porter County consistently had the highest TSI score from 2009-2011. Sweetwater Lake was consistently on the lower end with TSI scores in the mid-thirties. In 2009, 2010, and 2011 the lakes monitored were primarily split between mesotrophic and eutrophic lakes. No lakes were classified as oligotrophic and only two lakes were classified as hypereutrophic.

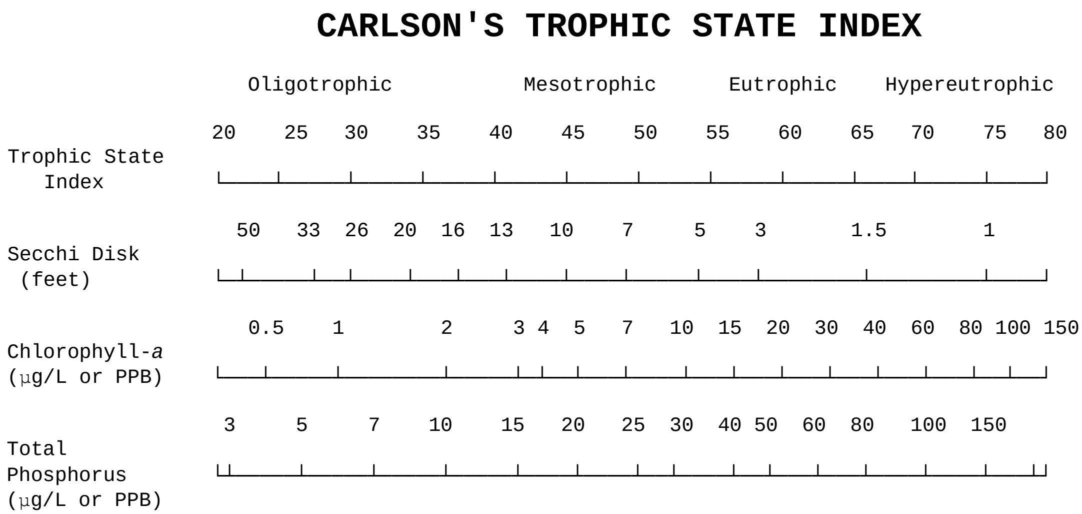


Figure 13. Carlson's index is the most widely-used TSI in the world.

TRANSPARENCY RESULTS

Secchi disk transparency can vary on individual lakes in as little as a day. It is best to look at transparency results through the summer average rather than one-time measurements. Figure 14 shows the average Secchi disk transparency for the summer of 2011. Many of the lakes monitored in the program are located in northern Indiana as this is where most of the lakes are located. In the past three years since the last volunteer report there have been more lakes added in the central part of the state. Tables 2, 3, and 4 in Appendix A provide summary results for the individual lakes, including the minimum, maximum, and the July/August mean. Raw data can be found online at www.indiana.edu/~clp. The July/August measurements are used for year-to-year comparisons for consistency and to represent the "worst-case" scenario for lake conditions. The July/August means take into account factors such as warm weather, lake stratification, algal blooms and heavy recreational use.

Volunteer lake monitors also receive a copy of the annual summary that include the minimum, maximum, July/August mean Secchi depth measurement, and the Carlson's TSI index value based on the July/August mean for each lake. The deepest Secchi depth for the 2009-2011 reporting time was 30 feet, and was recorded at Indiana Lake in Elkhart County. The measurement was taken in May of 2010 and was early in the season. The next deepest measurement on a different lake was on Lake James in Steuben County in May of 2009. The shallowest Secchi depth transparency for the three reporting years was 0.9 feet on Big Bass Lake in Porter County in August of 2009 and 2010. The next shallowest reading was 1 foot on Salmonie Lake in Wabash County in May of 2009.

The deepest July/August mean values for 2011 were found at Sweetwater Lake in Brown County at 21 feet and Cordry Lake in Brown County at 20.0 feet. Both of these lakes are impoundments and surrounded by forest and karst topography. The shallowest July/August mean values for 2011 were found at Big Bass Lake in Porter County (1.7 feet) and Little Turkey Lake in LaGrange County (2.0 feet). These natural lakes are surrounded by farm lands. The location of the lakes and the surrounding land use can greatly affect the water transparency.

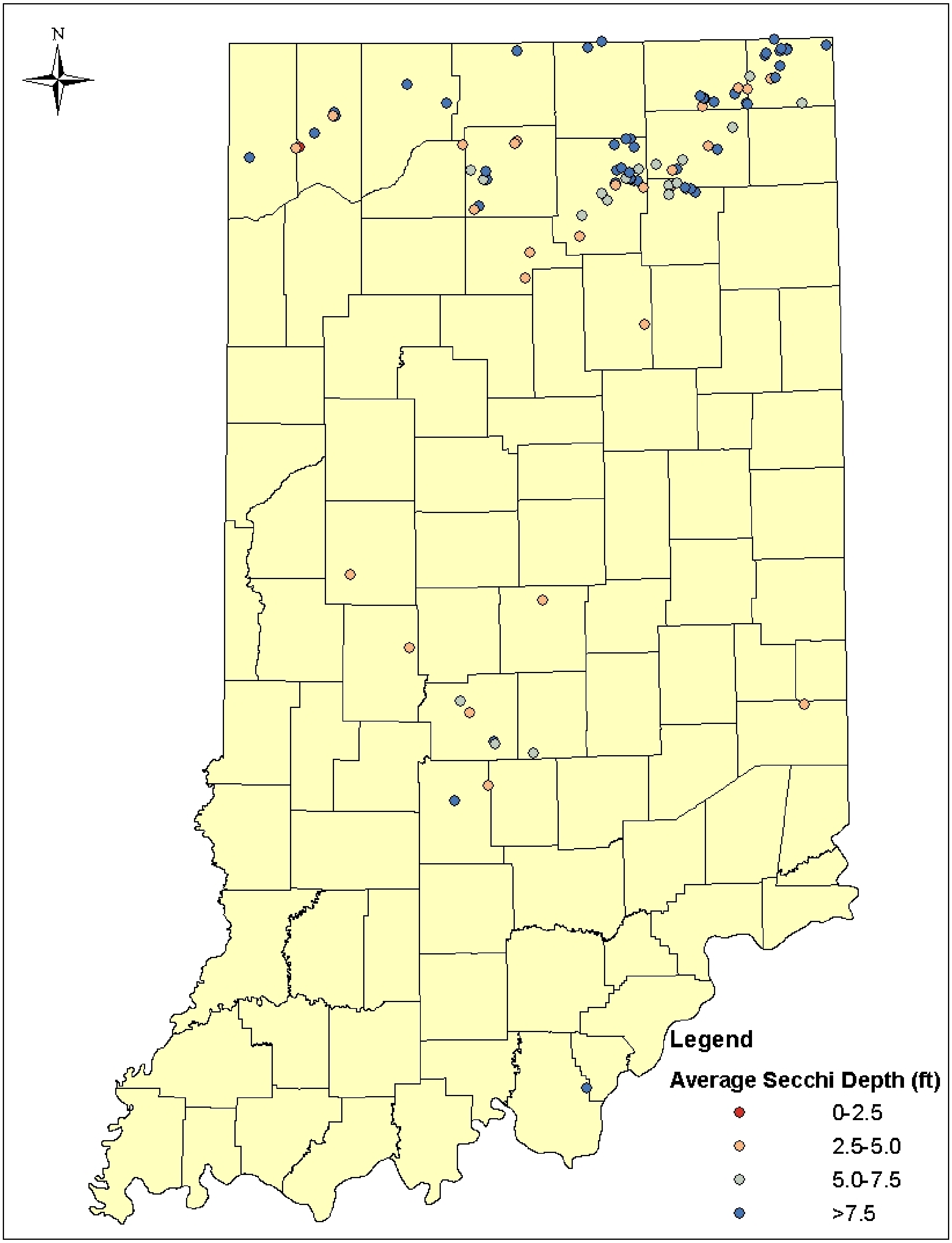


Figure 14. Secchi disk transparency July/August mean results for 2011.

Factors Affecting Lake Transparency

Anything that increases the amount of suspended material in the water affects the Secchi disk transparency. Decreased water transparency is generally related to either an increase in sediment or algae in the water column. Sediment enters the water column as a result of runoff from the landscape or is resuspended from the lake bed. Algal growth is directly related to nutrient enrichment of a lake. Therefore increases in nitrogen or phosphorus in the water leads to more algal growth and a decrease in transparency. The basin morphometry, basin type, watershed size, ecoregion, and time of week when sampled can all influence on transparency.

Basin Morphometry

The physical characteristics of a lake (known as *morphometry*) influence many lake processes. Larger lakes have a greater volume of water to dilute watershed non-point sources. Shallow lakes tend to be more productive than deeper lakes due to the large sediment area to water volume ratio. Sediment resuspension from wind mixing and turbulence caused by boats and personal watercraft are more prevalent in shallow lakes and can lead to a decrease in transparency. Data from 2009-2011 help support this premise. As the maximum depth of a lake increases, the mean Secchi depth transparency also increases (Figure 15). The mean Secchi depth is represented by the square in the figure and as the lake depth increases so does the Secchi depth. Lakes having a maximum depth greater than 100 feet had the only median Secchi depth transparency over 10 feet.

Basin Type

Impoundments typically have lower Secchi depth transparencies than natural lakes due to their elongate shape (longer wind fetch), and larger watersheds; resulting in greater water and sediment runoff. These conditions are observed in Indiana as impoundments have a median transparency of 3 feet, while natural lakes have a transparency of 6 feet (Figure 16).

Surface Area

The surface area of a lake has little effect on the transparency of a lake. Surface area does not help explain much about the volume of the water, the watershed, or the morphometry of the lakes surface. Larger lakes tend to have a greater wind fetch. This allows for more mixing of the surface water of the lake. The Secchi depth results support this finding as no correlation occurs between the lake transparency and the surface area (Figure 17).

Watershed Size

An increase in watershed size means that more land area drains into a lake and this can result in more sediment delivery to the lake. Along with sediment, a larger watershed size also leads to more nutrients entering the lake, which can stimulate algal growth thereby decreasing transparency further. Thus, we'd expect lakes with larger watersheds would have reduced Secchi depth transparency. Data from the Volunteer Lake Monitoring Program supports these relationships (Figure 18). The median Secchi depth transparency was higher for lakes with a watershed less than 5000 ha (6.5 feet) and lower for those watersheds greater than 5000 ha (3.5 feet).

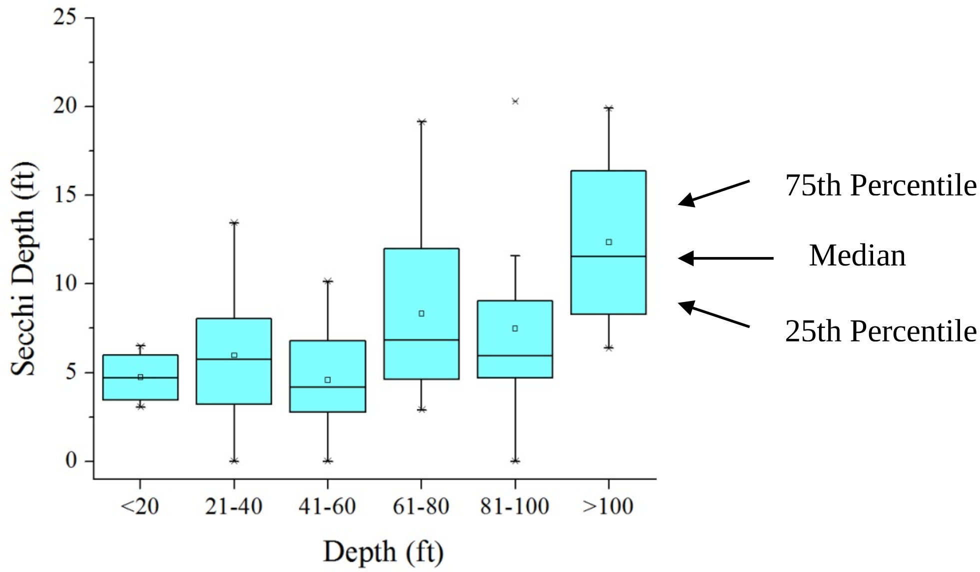


Figure 15. Transparency distribution vs. maximum lake depth. The squares represent the mean. The median is the line inside the boxes and the error bars show the minimum and maximum values. The asterisks show the outlier values.

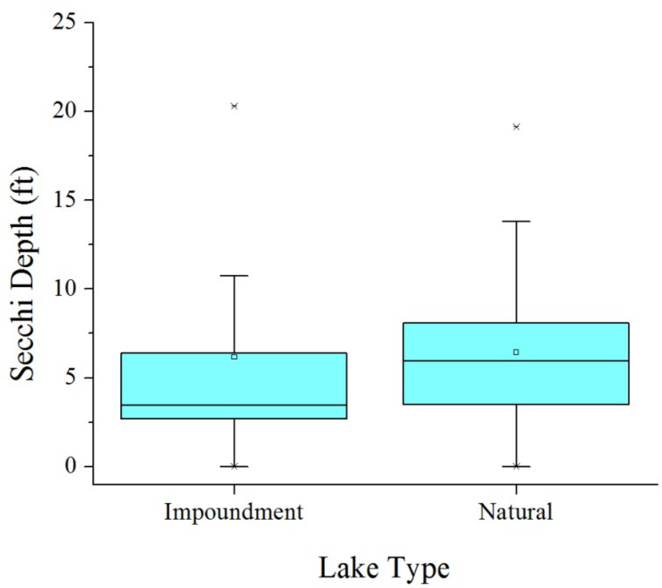


Figure 16. Transparency distribution of natural lakes and impoundments. The squares represent the mean. The median is the line inside the boxes and the error bars show the minimum and maximum values. The asterisks show the outlier values.

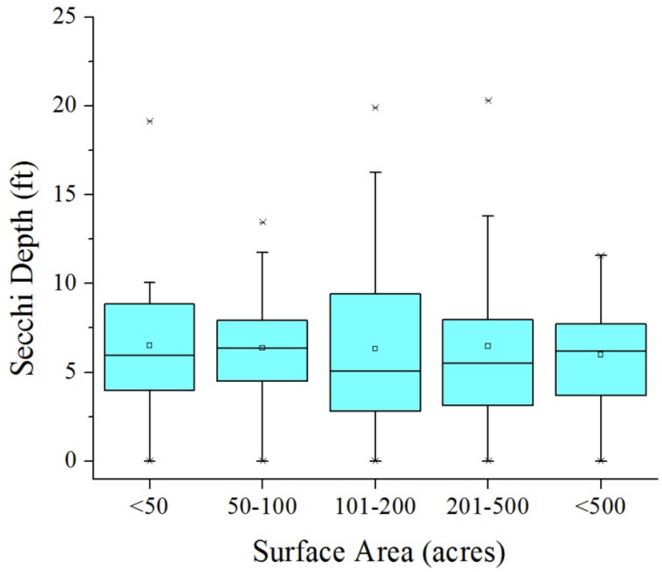


Figure 17. Transparency distribution vs. lake surface area. The squares represent the mean. The median is the line inside the boxes and the error bars show the minimum and maximum values. The asterisks show the outlier values.

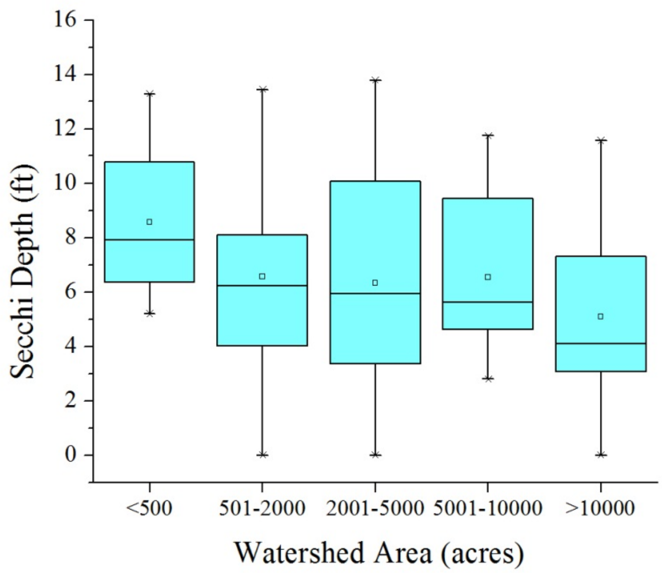


Figure 18. Transparency distribution vs. watershed size. The squares represent the mean. The median is the line inside the boxes and the error bars show the minimum and maximum values. The asterisks show the outlier values.

Ecoregion

Median Secchi disk transparency varies greatly among the ecoregions of Indiana (Figure 19). The Central Corn Belt (Ecoregion 54) had the lowest mean summertime transparency measurement of 1.3 feet.

The Ecoregion 54 had a median transparency of 4.5 feet. This region has a limited number of shallow lakes that are subject to resuspension of sediments. The majority of land in this region is cultivated for feed crops (corn, soybeans, feed grains), leading to increased nutrient and sediment inputs to these lakes.

The Southern Michigan/Northern Indiana Drift Plains (Ecoregion 56) had the second highest median Secchi disk transparency, 5.9 feet. This ecoregion contains the majority of the natural, glacial lakes in Indiana, and the highest number of volunteer-monitored lakes in our program. Transparency is expected to be higher in these lakes because they are natural lakes and are deeper than other lakes.

The Eastern Corn Belt (Ecoregion 55) also has large amounts of cropland (75%). This influences the lakes of that region leading to the lowest median transparency, 4 feet.

The Interior Plateau (Ecoregion 71) has a median transparency, 6 feet. All of the lakes monitored by volunteers in this ecoregion are impoundments. These would be expected to have lower transparencies because they are impoundments, but these lakes include those located within Hoosier National Forest and in several Indiana State Parks and Forests. The largely forested watersheds provide more protection for the lakes by reducing soil erosion and nutrient loss.

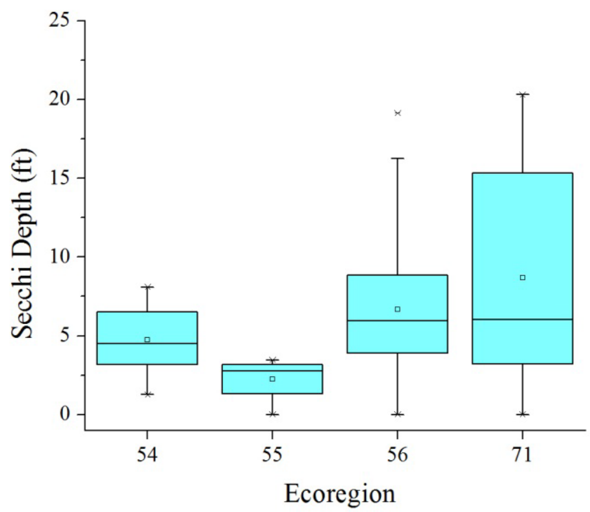


Figure 19. Distribution of mean lake transparency of monitored lakes (2009-2011) among ecoregions. The squares represent the mean. The median is the line inside the boxes and the error bars show the minimum and maximum values. The asterisks show the outlier values.

Long-Term Trends

One of the main objectives of the Volunteer Lake Monitoring Program is to obtain long-term data on Indiana lakes to assess trends in water quality. Each year volunteers receive a graph of all the measurements taken over the previous 10 years. A computer software program is used to fit a trend-line to the points. This trend line gives information on how the lake has changed over time. The graph is displayed with the lake surface at the top and increasing depth down the vertical axis. Therefore, a downward sloping line indicates increasing transparency (Figure 20b). An upward sloping line indicates decreasing transparency. A line that appears to be horizontal indicates that transparency has not changed much throughout the sampling period (Figure 20a).

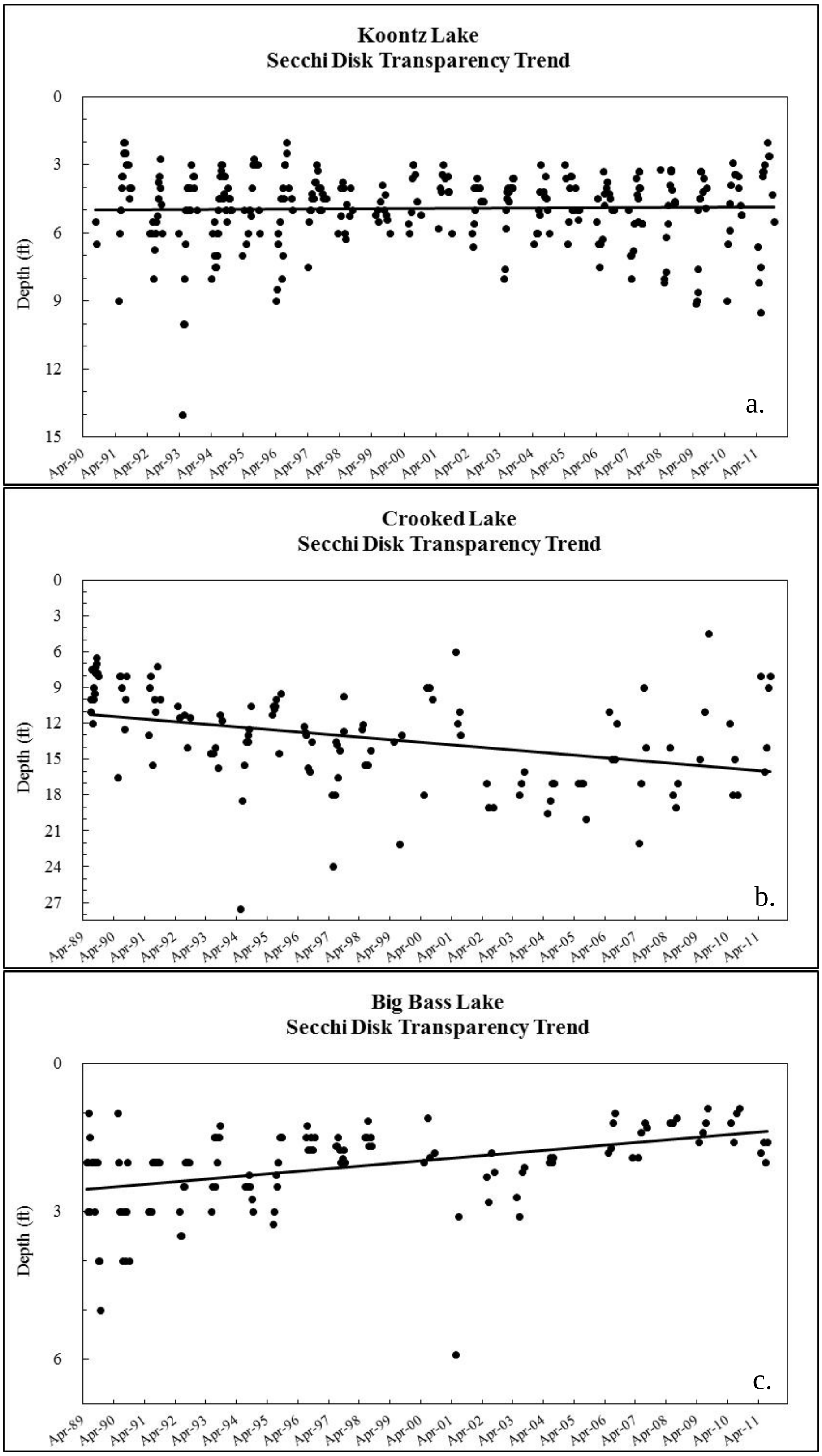
Caution should be used when analyzing these trend data because they have not been normalized. As a result, trend lines might not be indicative of a true trend in the condition of the lake. Factors that may cause the trend line to not reflect a true trend include the number of samples taken during a sampling season, the distribution of those samples, and the time period within the season that the samples were taken. If a majority of samples are taken during periods that typically have higher transparency, such as early spring or late fall and samples are not taken during July and August, when transparency is usually low, average transparency will be overstated (Figure 21).

Conversely if the majority of samples were taken during July and August and none were taken during the spring and fall, average annual transparency will be underestimated. Variation in when samples are taken between years can also affect the trends seen in the data. If samples were taken during the spring and fall early in the program and samples were then taken in July and August in more recent years it would appear that transparency was worsening when that may not be the case. Likewise if samples were taken in July and August in the first years of participation in the program and then were taken only in the spring and fall in more recent years it would appear that transparency was improving when that may not be accurate.

When we visually inspected the trend plots made for volunteers in 2011, there were 29 lakes with long-term trends suggesting improving transparency, 25 lakes with a visual trend of decreasing transparency, and 25 lakes with little or no change in transparency.

Variation in lake conditions and Secchi disk transparency may simply occur as a result of events that span long time periods or as a result of non-seasonal events. Non seasonal events that may affect transparency include but are not limited to:

1. Major watershed changes that may occur in one year, but not others, for example, clear cutting or large construction projects.
3. Localized storms, droughts or other variable weather events.
4. Major lake events that occur only once every few years, for example, weed treatments or channel dredging.



A trend line showing virtually no change in Secchi disk transparency overtime.

A trend line showing improving Secchi disk transparency overtime.

A trend line showing decreasing Secchi disk transparency overtime.

Figure 20. Long-term transparency trends.

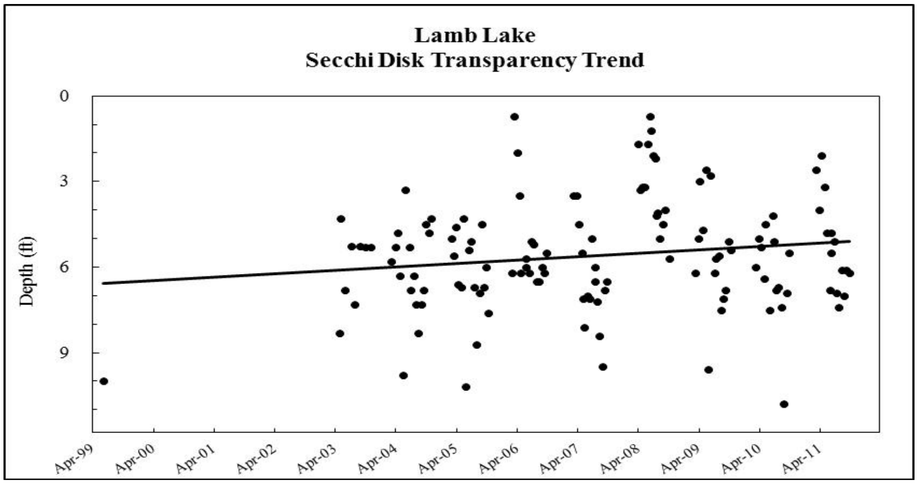


Figure 21. Seasonal variation in Secchi disk transparency

Trophic State Index Analysis

Carlson's TSI provides a means to analyze and compare annual lake data. Observation of long-term trends in TSI values can be a more reliable method of comparison as TSI values are calculated using the July/August means thereby removing seasonal variations. From 2009-2011 the majority of lakes were mesotrophic or eutrophic (Figure 22). On average about 1% of lakes were hypereutrophic. The percentage of hypereutrophic lakes have decreased over the years with no lakes being hypereutrophic in in 2011. The decrease in the amount of hypereutrophic lakes may indicate an improving trend in lake water quality. A lake's trophic status can however, vary yearly, but long-term data indicates that for many lakes the trophic state is very stable.

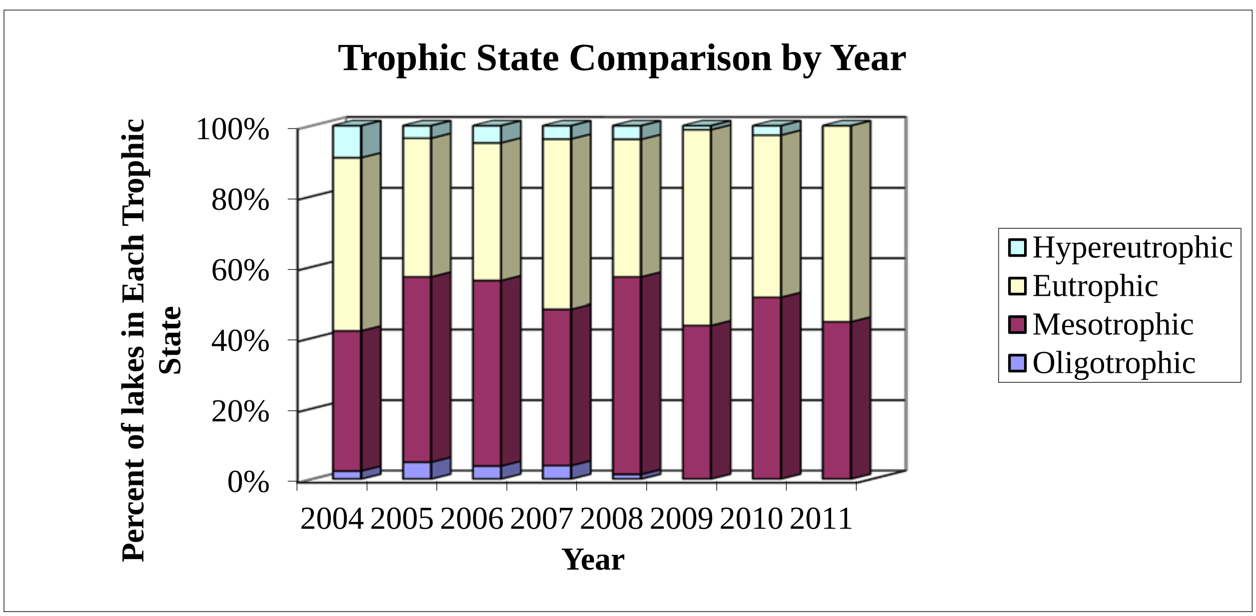


Figure 22. Annual distribution of lakes among trophic classes for July/August summertime means of Secchi depth from 2004-2011.

PHYSICAL APPEARANCE & RECREATION POTENTIAL RESULTS

Volunteers, assessments of physical appearance and recreation potential of lakes provide additional useful information. Hoyer, Brown and Canfield (2004) found significant relationships between lake users perceptions of physical condition of water and associated lake trophic state water chemistry variables. They also found a relationship between recreational or aesthetic value and trophic state.

Physical Appearance

Volunteers are asked to rate the physical appearance of their lake each time they measure transparency. Volunteers rate the lake's physical appearance using the following categories:

1. Crystal Clear
2. Some Algae
3. Definite Algae
4. High Algae
5. Severe Algae

A rating of 1 or 2 indicates enhanced physical appearance. Decreasing transparency generally leads to values of 3, 4, or 5 for physical appearance because sediment and algae that reduce transparency also cause the appearance of the lake to be less desirable. In general, lower transparency is correlated with higher algal levels and therefore more impaired physical appearance.

User perceptions of water quality vary among ecoregions. Smeltzer and Heiskary (1990) found that expectations of lake users also vary by region. Users in regions of Minnesota and Vermont develop different water quality expectations based upon regional water quality. Areas where mesotrophic lakes predominate generate higher expectations than regions where eutrophic or hypereutrophic lakes predominate.

Citizen perceptions of 'crystal clear' lakes showed the greatest differences among ecoregions (Figure 23). For example, a transparency of approximately 6 feet in the Central Corn Belt (Region 54) received a rating of crystal clear, while the same transparency in all other regions is rated as definite algae or worse. What appears to be excellent transparency to volunteers in this ecoregion is considered poor transparency in all other ecoregions. Lake users in the Interior Plateau (Region 71) had the highest perception of their lakes compared to other regions. Lakes in this region have primarily forested watersheds, which leads to reduced sediment and nutrient inputs. Differences among ecoregions decrease as water quality worsens. Citizen perceptions of 'definite algae', 'high algae', and 'severe algae' correspond to similar transparency values (Figure 23).

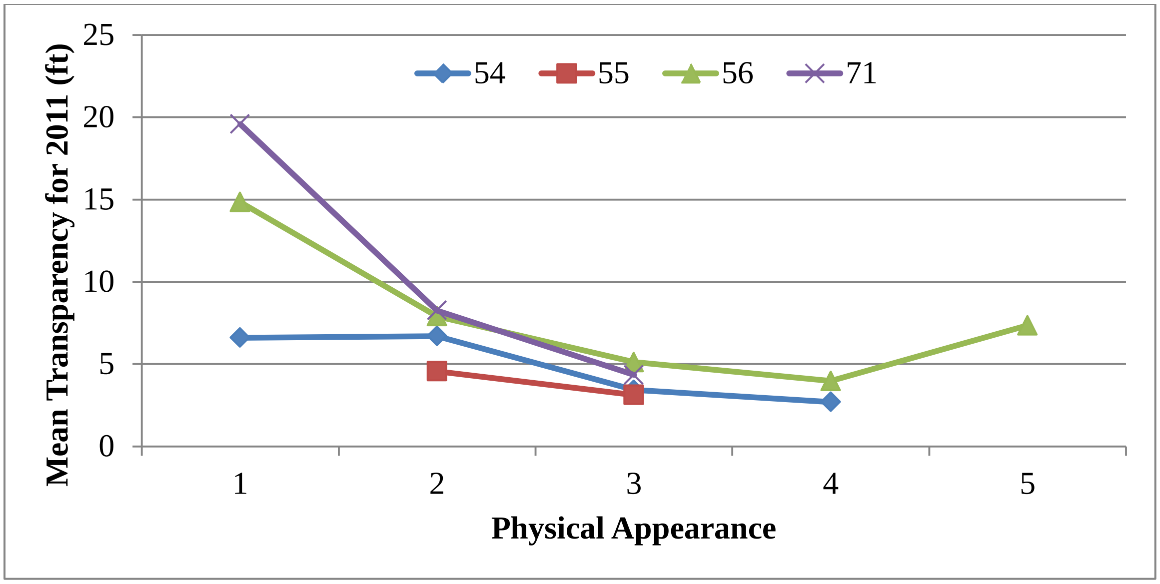


Figure 23. 2011 Mean transparency for each physical appearance categorized by ecoregion.

Recreation Potential

Recreation potential is also rated each time a volunteer makes a transparency measurement. Volunteer monitors rate recreation potential based on the following five categories;

1. Beautiful – no impairment
2. Minor Aesthetic Problems
3. Swimming Impaired
4. No Swimming
5. No Recreation

Recreation potential was correlated with transparency but not to the same degree as physical appearance. Additional factors relating to recreation potential such as leaf litter, bacteria, or water temperature do not influence transparency. In addition, some lakes do not allow swimming or have limited recreation, which can cause the recreation to be rated as no swimming or recreation.

Recreational potential varies with ecoregions similarly to physical appearance. A transparency of 6 feet in the Central Corn Belt (Region 54) is classified as 'beautiful-no impairment', while the same transparency in other regions is classified as 'minor aesthetic problems' (Figure 24).

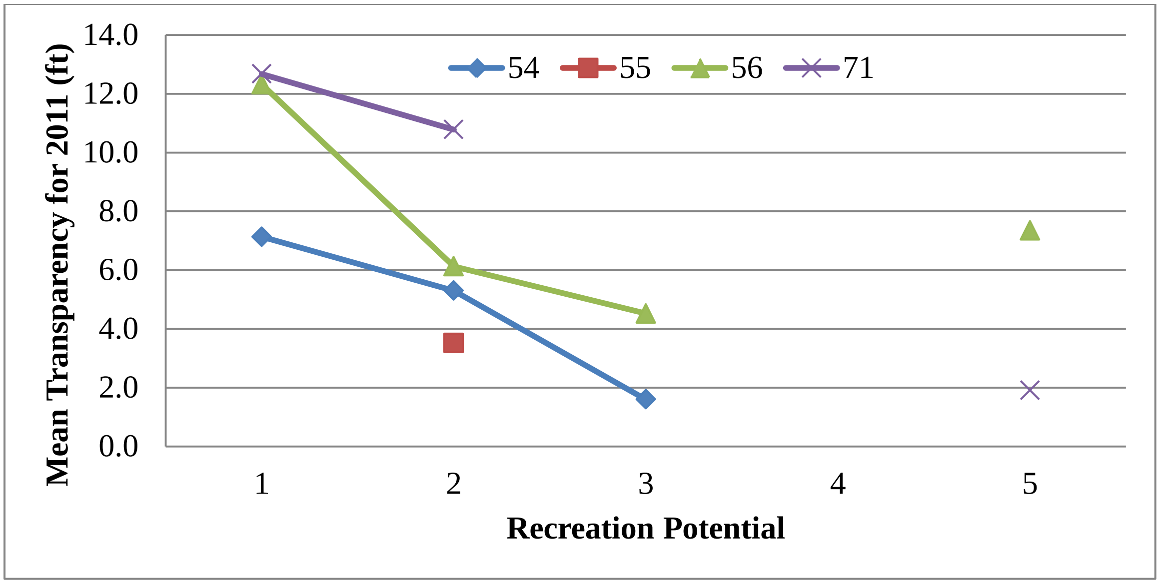


Figure 24. 2011 mean transparency for each recreational potential categorized by ecoregion.

Limitations

Although this information is interesting it is difficult to interpret at this scale. The 2011 data lead us to believe that users in different ecoregions value there lakes differently, but when we look more closely we see that the number of individual responses may also be a factor (Figure 25 and 26). Ecoregions help explain relationships in the data, however it may be more effective to look for other explanations.

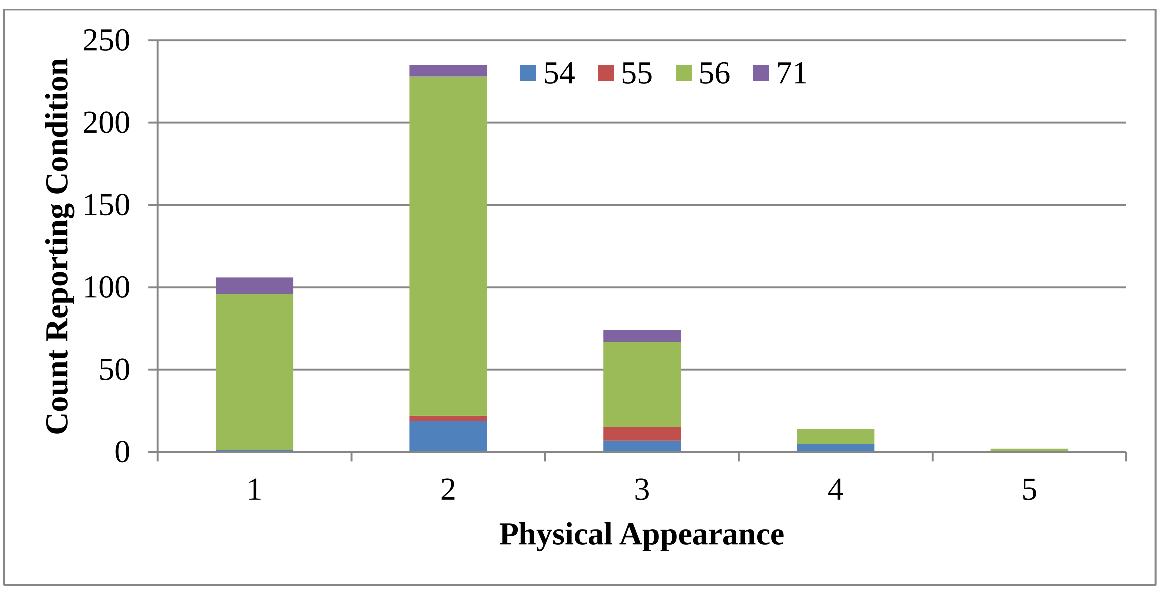


Figure 25. Number of individual observations of physical appearance categorized by ecoregion in 2011.

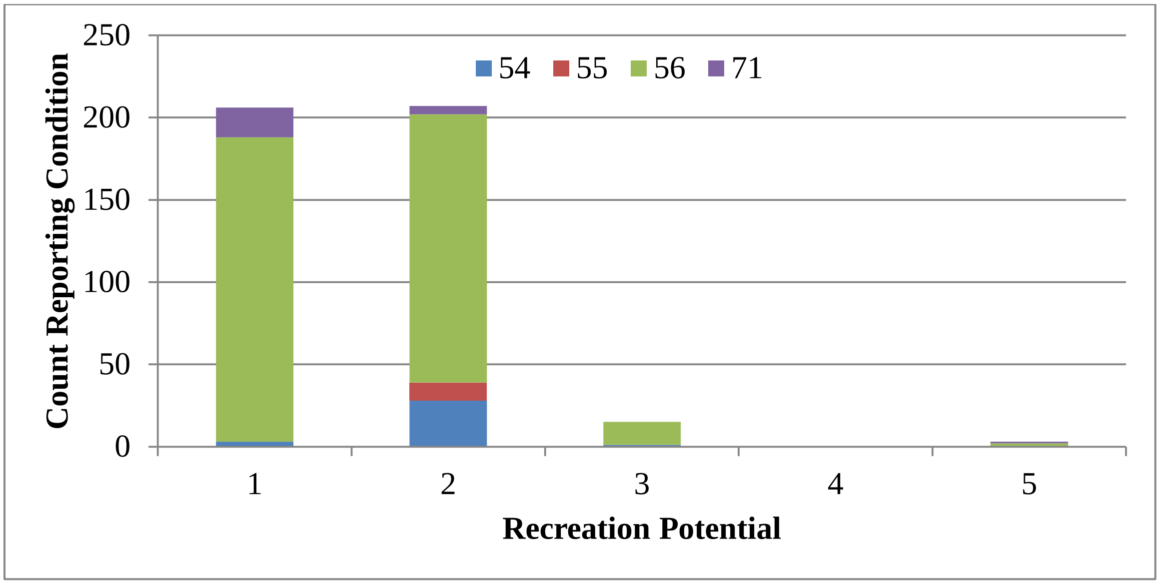


Figure 26. Number of individual observations of recreation potential categorized by ecoregion in 2011.

COLOR RESULTS

Water color can be used as an additional indicator of lake health and it can also be used to provide insight into what is causing decreases in transparency. Sediment and algae influence the color of a waterbody. Sediments tint the water towards brown colors and algae tend to cause the water to be various shades of green. Water color can also be a factor of the underlying geology. Limestone overtime and through weathering process creates "marl" lakes that have a blue green hue to them.

Volunteers can have five choices when selecting a water color to report: Clear Blue, Blue/Green, Green, Brown, and Green/Brown. This simplistic system allows comparison between the colors and the transparency results. Lakes for which the volunteers select "clear blue" have the highest transparency, although it also has the lowest number of individuals reporting that color (Figure 27). This only makes sense that the clear lakes will have the highest transparency. It is interesting to see that the lakes with "brown" and "green/brown" have lower transparency than the lakes reported as "green".

Volunteers that report "clear/blue" as the color of the lake have the highest transparency and also have a smaller spread of Secchi depth readings (Figure 28). The greatest spread of data is for the color choice of "green". This could be explained by the variation in the density of algal growth that would contribute to the green coloration of the water. The more dense the algal growth the more turbid the water would appear to be resulting in a lower transparency. The greater variation in these results could also be linked to the greater number of measurements being reported for the color "green". The lowest median Secchi depth readings are also for the choices of "brown" and "green/brown" as are the means (Figure 27). This is likely a result of suspended sediments contributing to the turbidity of the water.

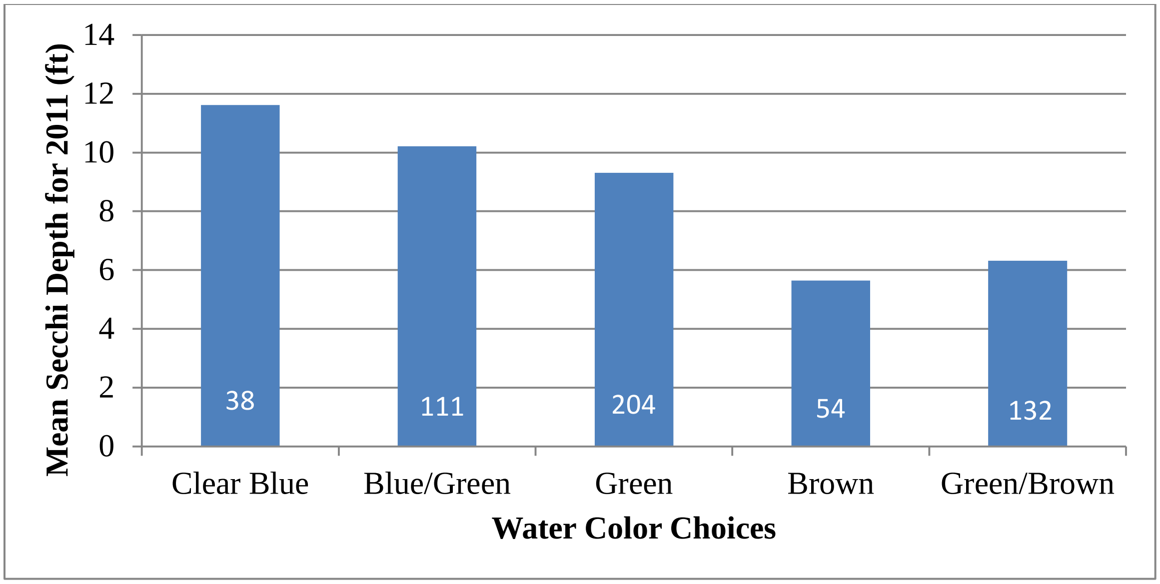


Figure 27. 2011 Secchi depth transparency categorized by water color (numbers indicate number of measurements).

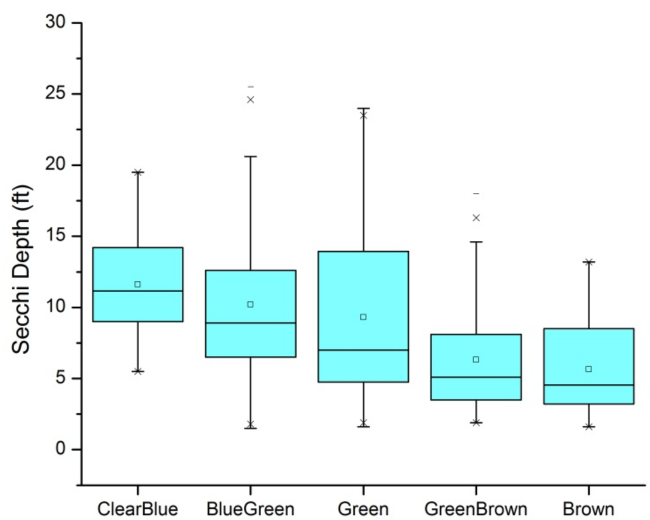


Figure 28. Box and whisker plot displaying 2011 Secchi disk transparency categorized by water color. The squares represent the mean. The median is the line inside the boxes and the error bars show the minimum and maximum values. The asterisks show the outlier values.

TEMPERATURE AND DISSOLVED OXYGEN RESULTS

Volunteers are able to check out temperature and dissolved oxygen meters from the School of Public and Environmental Affairs in Bloomington, Soil and Water Conservation District offices in Elkhart, Fulton, Kosciusko, LaGrange, Marshall, and Steuben Counties, and Merry Lea Environmental Learning Center (Figure 30). Volunteer use of the meters has increased over the past three years since the replacement of all of the old meters.

From 2009-2011, 118 dissolved oxygen and temperature profile were made on 21 different lakes (Figure 29). From 2005-2008, the program only had 51 profiles taken on 7 lakes. In the last year alone we had 65 profile measurements. The recent increase in measurements is likely due to the strong push we have been making to get more volunteers involved in this part of the program. Dissolved oxygen and temperature profiles can yield very useful information and can indicate:

1. If the lake is thermally stratified or mixing (unstratified)
2. If stratified, the depth of the hypolimnion
3. The position of the metalimnion
4. How much of the lake has sufficient oxygen for fish
5. If the hypolimnion has no oxygen
6. the potential for nutrient release from the bottom sediments

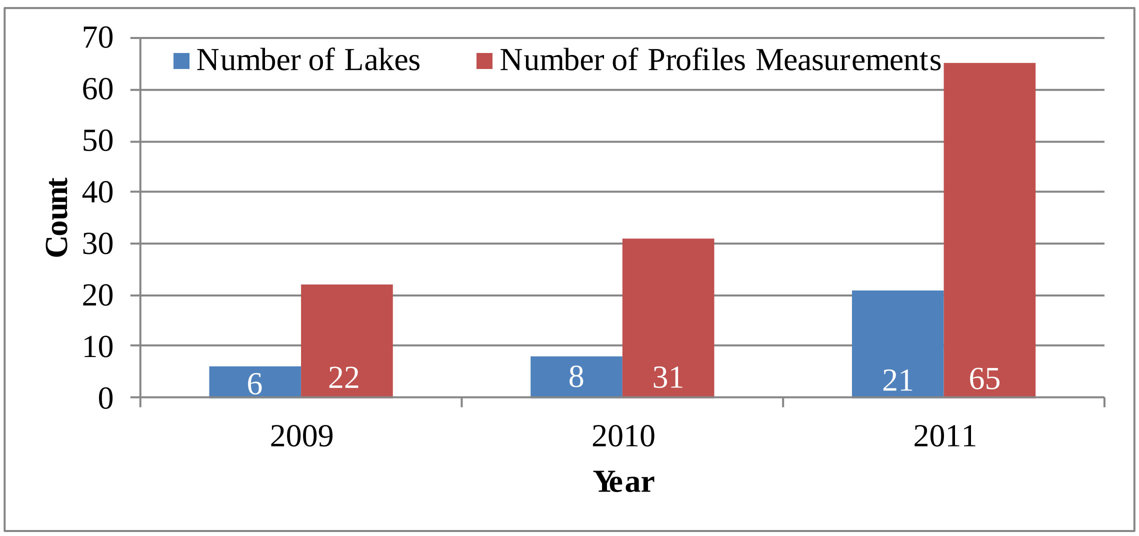


Figure 29. Number of Lakes and profile measurements taken from 2009-2011.

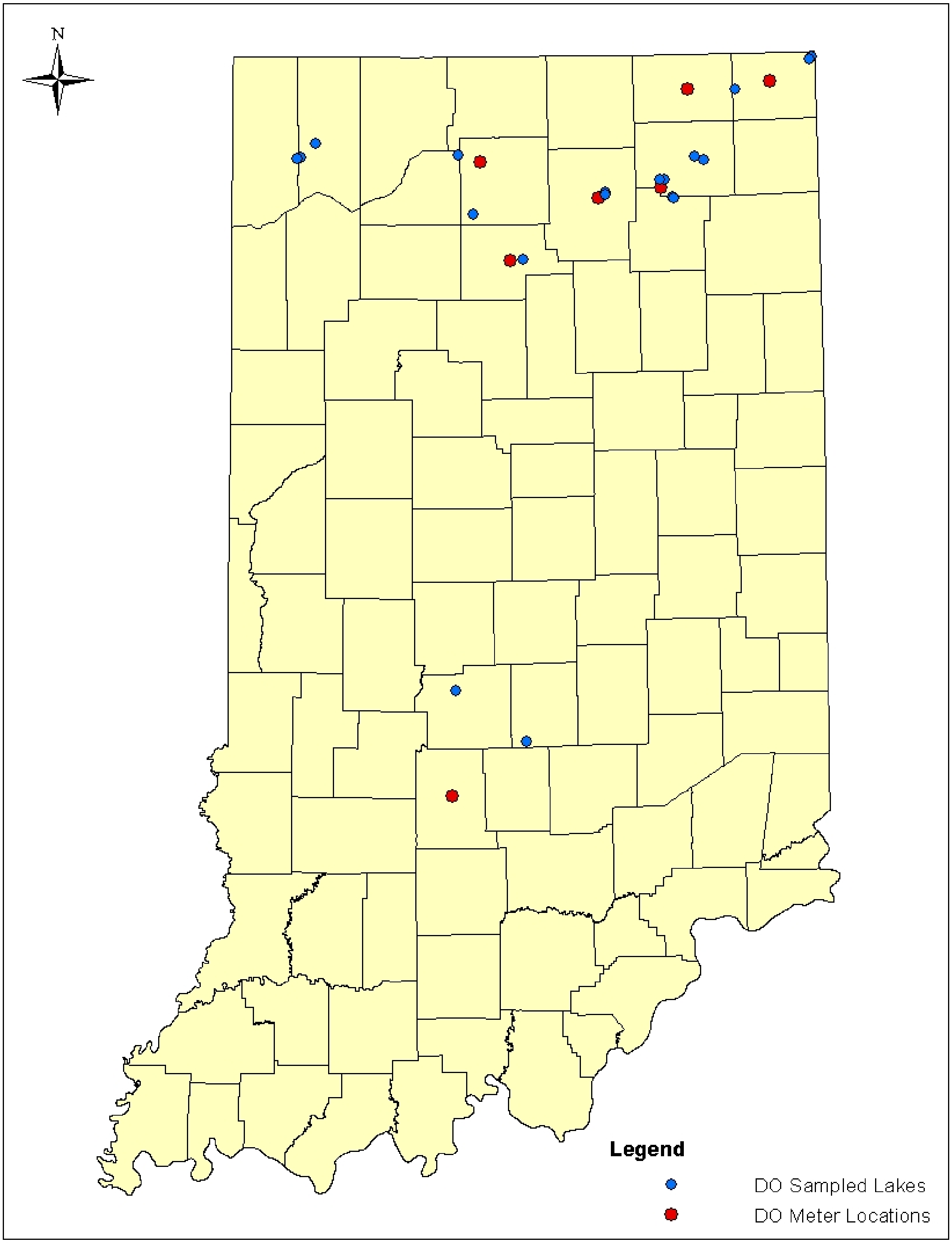


Figure 30. **Dissolved oxygen and temperature meter locations and lakes sampled for dissolved oxygen and temperature.**

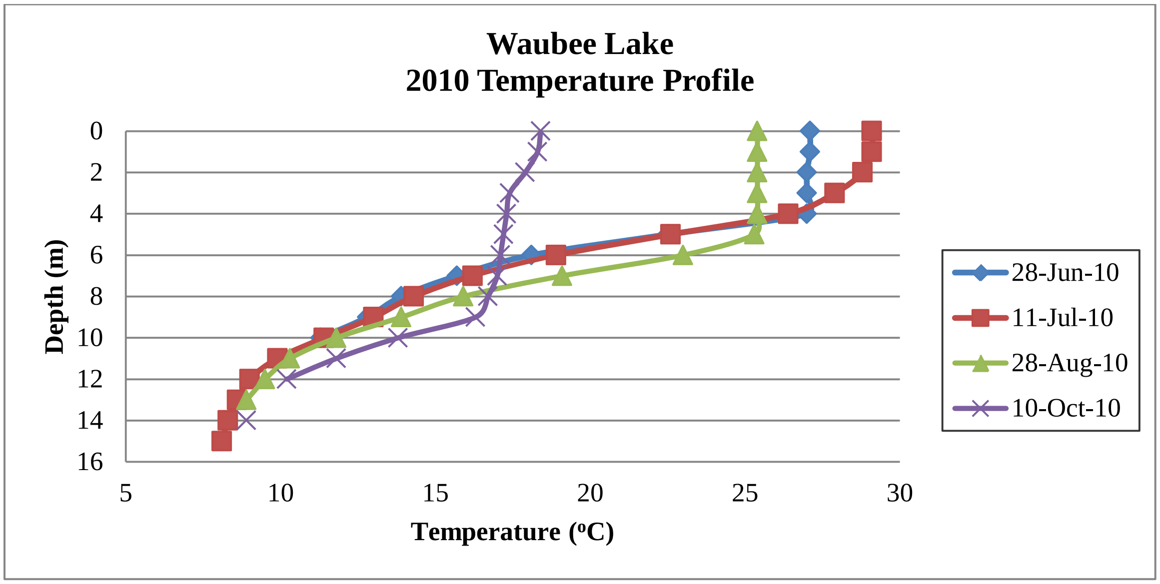


Figure 31. Temperature profile of Waubee Lake from June through October of 2010.

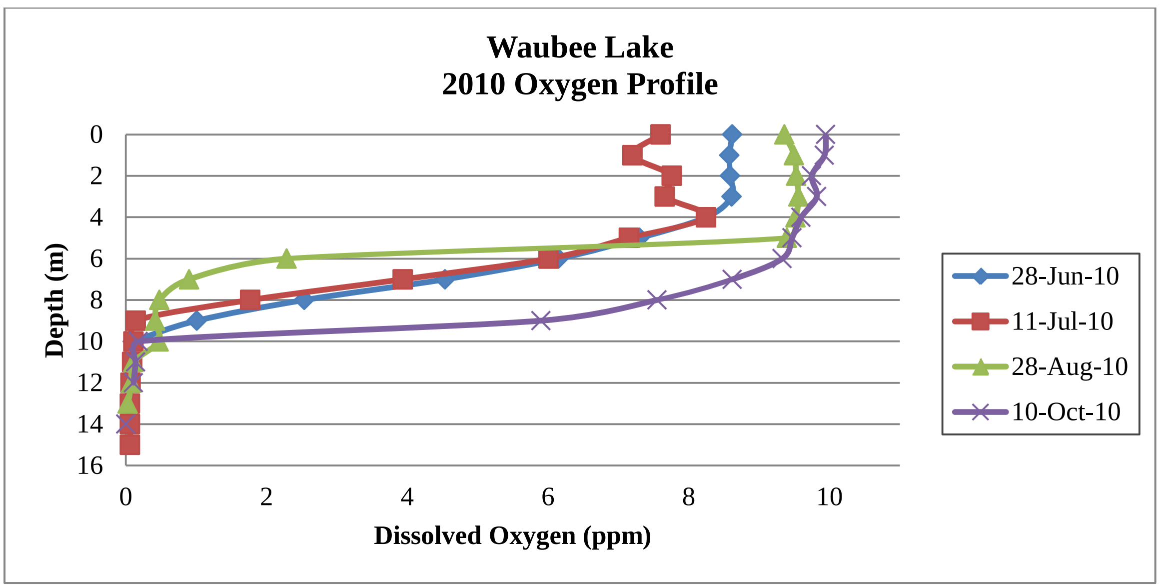


Figure 32. Dissolved oxygen profile of Waubee Lake from June through October of 2010.

Figures 31 and 32 illustrate an example of changes in a typical temperature and dissolved oxygen profile during the 2010 summer season. Waubee Lake in Kosciusko County was strongly stratified from June to August according to the profiles. The strong temperature barrier does not allow the lake to mix completely (Figure 31). In October the surface of the water is beginning to cool and will likely experience turnover (complete mixing). This temperature difference allows for the dissolved oxygen profile to follow the same pattern. The temperature change does not allow oxygen from the top layer of the lake to mix into the bottom creating hypoxic conditions (Figure 32). A full report that we send to our volunteer monitors who collect this data can be found in Appendix C.

EXPANDED PROGRAM RESULTS

In 2011, expanded volunteer monitors collected 172 total phosphorus and chlorophyll *a* measurements on 47 lakes. From the last report in 2008 we have grown the Expanded Program by 10 lakes, which accounts for approximately 40 more samples a season. The expanded lake locations are shown in Figure 2. They are located throughout the state, but are concentrated in the northeast.

Variation in size and depth of the expanded lakes is similar to the variation in all lakes in the program. Figure 33 and 34 show the size and depth distribution of lakes in the Expanded Program, respectively. Little Crooked Lake in Whitley County had the smallest surface area, 15 acres and is one six lakes less than 50 acres in size. Lake Wawasee in Kosciusko County, 2617 acres, had the greatest surface area of the lakes sampled and one of eight lakes that had a surface area greater than 500 acres. The majority of Expanded Program lakes (36) had surface areas between 50 and 500 acres. Cedar Lake in Lake County was the shallowest lake in the Expanded Program, 14.1 feet. Tippecanoe Lake in Kosciusko County, 123 feet, was the deepest lake. Twenty of the 51 lakes sampled between 2009 and 2011 were between 21 and 40 feet deep. Four lakes were greater than 100 feet deep, while only two were less than 20 feet deep. The remaining lakes were distributed fairly evenly among the remaining classifications; 41-60 feet, 61-80 feet, and 81-100 feet.

Tables 5, 6, and 7 in APPENDIX B contain the minimum, maximum, and July/August mean values for total phosphorus and chlorophyll *a* from 2009 through 2011, respectively. Big Bass Lake in Porter County (256 μg/L) and Cedar Lake in Lake County (177 μg/L) had the highest mean total phosphorus concentrations from 2009-2011 and were the only lakes having concentrations greater than 100 μg/L. These numbers are consistent with those reported in the previous report from 2008. The mean summertime total phosphorus concentrations have increased for both lakes from 207 μg/L and 152 μg/L, respectively. Cordry Lake in Brown County and Lake of the Woods in LaGrange County had the lowest mean total phosphorus concentrations, 8.6 μg/L and 9.4 μg/L, respectively. The lakes with the lowest total phosphorus have changed since 2008. In 2008 Yellowood Lake had the lowest concentration of total phosphorus and it is no longer monitored. Griffy Lake had the second lowest with a concentration of 11.7 μg/L in 2008 and it has increased to 47.8 μg/L in 2011. This is likely due to dam issues at the reservoir.

Cedar Lake in Lake County had the highest mean chlorophyll *a* concentration of 72.6 μg/L, from the 2009-2011 sampling period. Big Bass Lake in Porter County had a mean chlorophyll *a* concentration of 57.3 μg/L. Both of these lakes also had the highest chlorophyll *a* concentrations from the 2008 summary report. The total phosphorus and chlorophyll *a* concentrations for these lakes have increased over the past three years. Two lakes had chlorophyll *a* concentrations less than 1 μg/L; McClish Lake in Steuben County (0.92 μg/L) and Gage Lake in Steuben County (0.92 μg/L). In 2008 there were 5 lakes with summertime means below 1 μg/L.

The data from the Expanded Program agree with expected relationships between total phosphorus and chlorophyll *a*. Figure 35 shows that as total phosphorus increases, chlorophyll *a* increases. Another relationship that is seen in Expanded Program data is that as chlorophyll *a* increases, Secchi disk transparency decreases logarithmically (Figure 36). More chlorophyll *a* indicates increased algal biomass that interferes with light penetration and decreases transparency. Secchi disk transparency also decreases exponentially as total phosphorus increases (Figure 37). The relationship between the transparency and total phosphorus is likely explained by suspended sediment and particles that have phosphorus attached to them. It could also be explained by the relationship of chlorophyll *a* to total phosphorus.

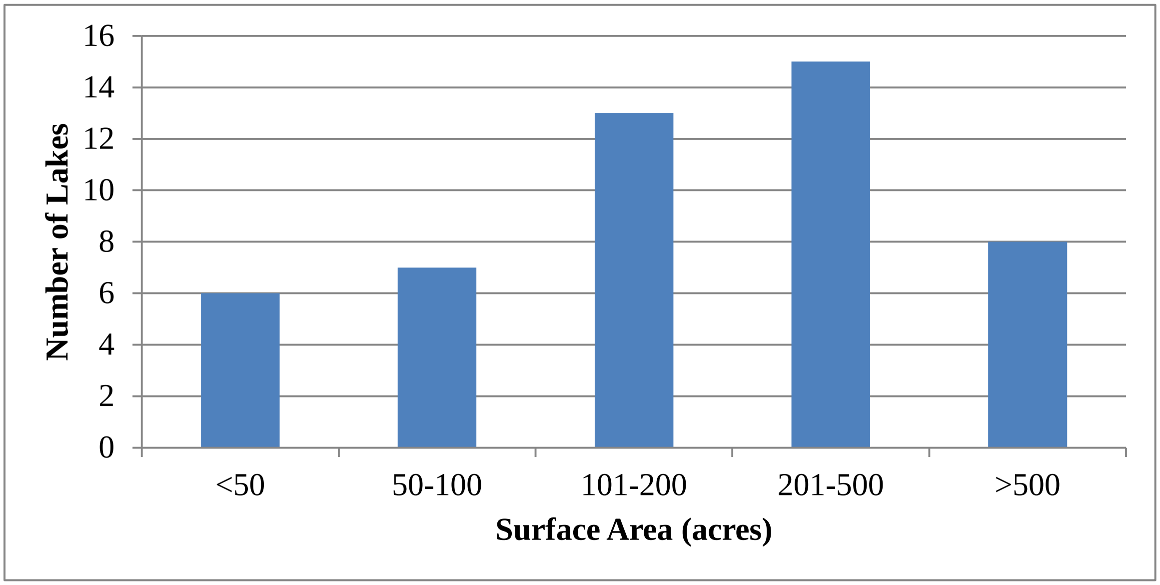


Figure 33. **Size distribution of lakes in the Expanded Volunteer Monitoring Program 2009-2011.**

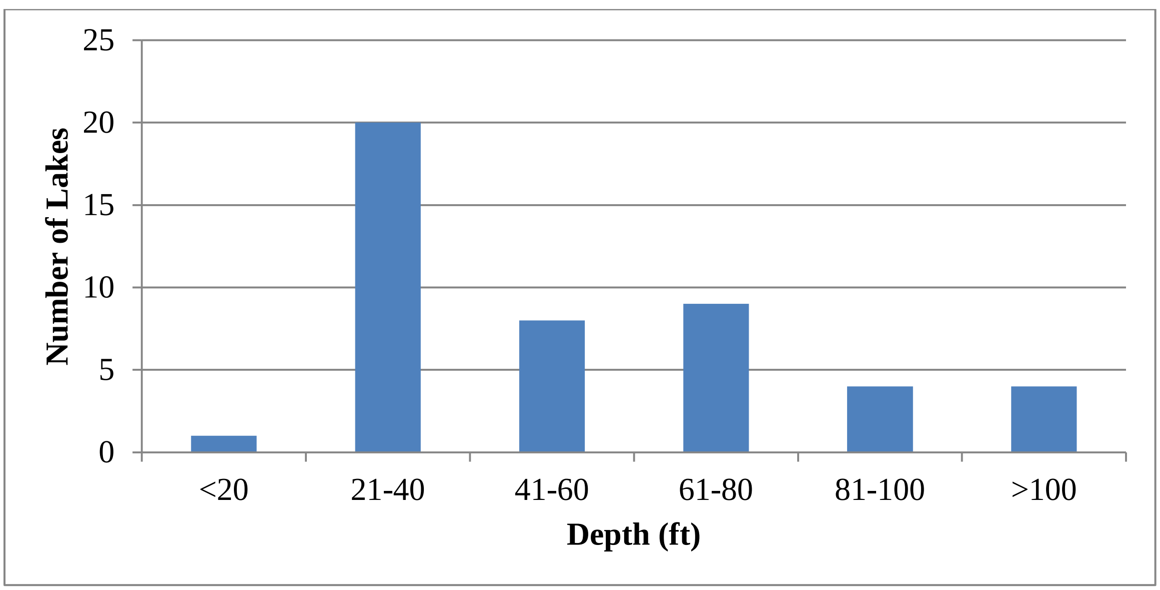


Figure 34. Depth distribution of lakes in the Expanded Volunteer Monitoring Program 2009-2011.

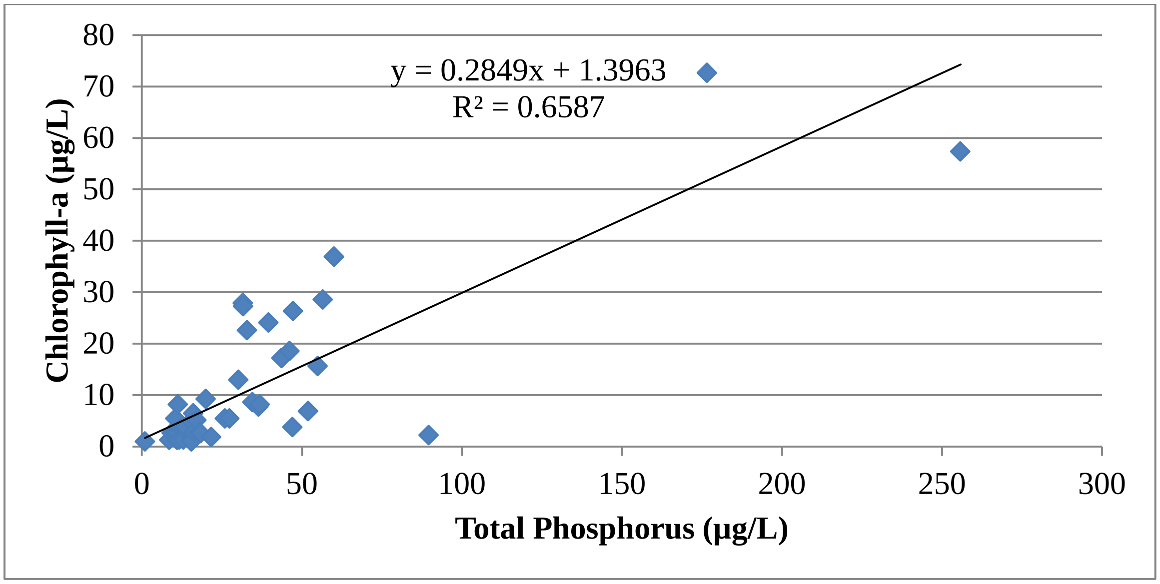


Figure 35. Relationship between July/August summertime means of total phosphorus and chlorophyll *a* in lakes monitored by volunteers.

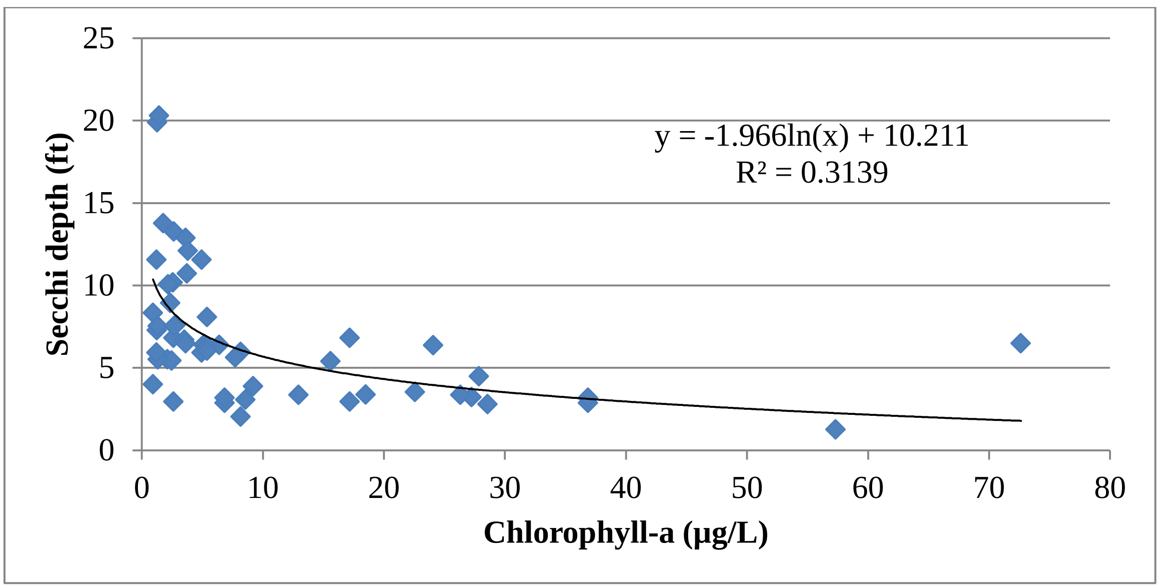


Figure 36. Relationship between July/August summertime means of transparency and chlorophyll *a*.

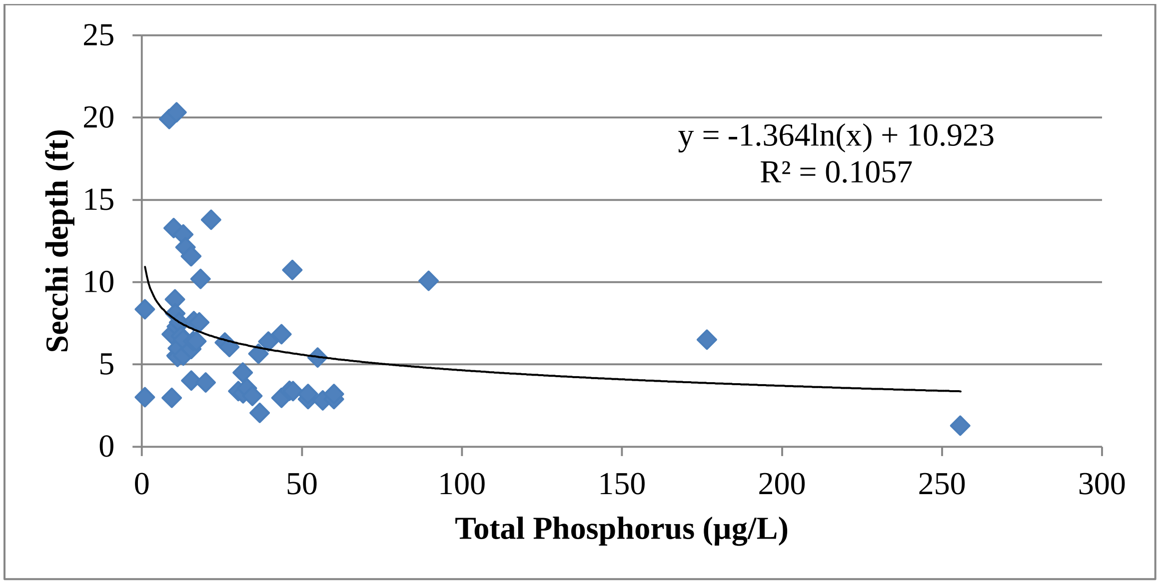


Figure 37. Relationship between July/August summertime means of transparency and total phosphorus.

Factors Affecting Phosphorus and Chlorophyll *a* Concentrations

Many factors influence total phosphorus concentrations, which subsequently affect chlorophyll *a* concentrations. Phosphorus concentrations are affected by both external and internal factors. Watershed land use is one factor that can be used as a predictor of water quality. Watersheds in which agriculture predominates will generally have higher phosphorus loads (Novotny, 2003). Watersheds comprised mostly of forests will generally have lower phosphorus loads; therefore the phosphorus concentration in the lake will be lower. Human activities that remove vegetation from land, such as row crop agriculture and construction practices, can increase runoff and nutrient additions to lakes. Other human activities that add phosphorus to lakes include: gardening, fertilizing lawns, some industrial activities, and improperly functioning septic systems or wastewater treatment plants. Once phosphorus enters the lake the dissolved portion is utilized by algae and rooted vegetation, the suspended portion settles attached to sediment particles. Shallower lakes are more prone to wind resuspension of sediments, thereby resuspending phosphorus as well, making it available for algal production. Other internal factors that influence phosphorus concentrations include sediment disturbance due to recreational use, surface area and the maximum depth.

Chlorophyll concentrations in lakes are influenced by factors that affect algae growth including: phosphorus availability, light intensity and penetration, water temperature, and algal predation. An increase in total phosphorus, with all other factors held constant, will often cause an increase in algae and result in an increase in chlorophyll *a*. Factors that increase turbidity such as heavy runoff or boating may cause chlorophyll *a* concentrations to remain low even when total phosphorus increases because the increased turbidity decreases light availability. A robust zooplankton population may prey on algae sufficiently to reduce algal biomass and thus, chlorophyll.

Characteristics of lakes such as basin morphometry, watershed size, and ecoregion can be used to describe these relationships in Indiana's lakes. Basin morphometry can determine the importance of resuspension of sediments and the availability of light in lakes. Watershed size can provide information about nutrient and sediment delivery while ecoregions help explain land use and human impacts on lakes.

Basin Morphometry

Total phosphorus concentrations are often greater in shallow lakes because bottom sediments, rich in phosphorus, may be resuspended into the water by motorboats or wind activity. Shallow lakes also have less water volume per unit surface area, meaning there is less dilution of phosphorus. The Cedar Lake (Lake County) was the shallowest lake sampled (14 feet) and had the highest mean total phosphorus concentration, 177 μg/L, while lakes with a maximum depth greater than 100 feet had the lowest median total phosphorus concentrations, 11 μg/L (Figure 38).

Chlorophyll *a* concentrations mirrored the total phosphorus concentrations based on maximum depth (Figure 39). The mean chlorophyll *a* concentrations was highest for Cedar Lake (Lake County) as well (72.6 μg/L). The lowest median chlorophyll *a* concentraitions were found in lakes with a depth greater than 81 feet (1.8 μg/L). Higher concentrations of phosphorus in shallow lakes contribute to greater algal production. Shallow lakes may also have more of the water volume available for photosynthetic activity so they will likely be more productive.

The surface area of monitored lakes had little effect on total phosphorus or chlorophyll *a* concentrations (Figures 40 and 41). The median concentrations varied little between different surface areas.

Watershed Size

Lakes with larger watersheds are expected to have higher total phosphorus and chlorophyll *a* concentrations as they likely have more runoff. Median total phosphorus concentration were highest in lakes with a watershed between 5,000-10,000 acres (45.4 μg/L) and lowest in lakes with a watershed less than 2000 acres (13.1 μg/L) (Figure 42). The median chlorophyll *a* concentration was highest in lakes with a watershed between 5,000-10,000 acres (12.5 μg/L) but was lowest in lakes with a watershed area of less than 500 acres (2.65 μg/L) (Figure 43).

The data do not show the expected relationship but many other factors may be affecting the results. Figure 41 shows little relationship between phosphorus concetnration and the watershed area. The reason for this is likely because we are using the July/August means for these comparisons as it helps to normalize the data for comparison. Normalizing the data removes our May and June samples from the analysis. We would expect to see more rain in May and June that would contribute to the runoff, therefor reducing the relationship we see.

In figure 42 and 43 we see that the median concentration does increase with increased size, but we see the greatest concentrations in the 5,000-10,000 acre range. It is likely that we see this relationship because the lakes in this range are of natural origin so the turbidity of the water is more likely contributed by algal production, whereas the lakes with the largest watersheds are typically reservoirs and the turbidity is most likely due to suspended sediments rather than higher algal production. The higher turbidity due to runoff may even inhibit algal production that affects chlorophyll *a* concentration.

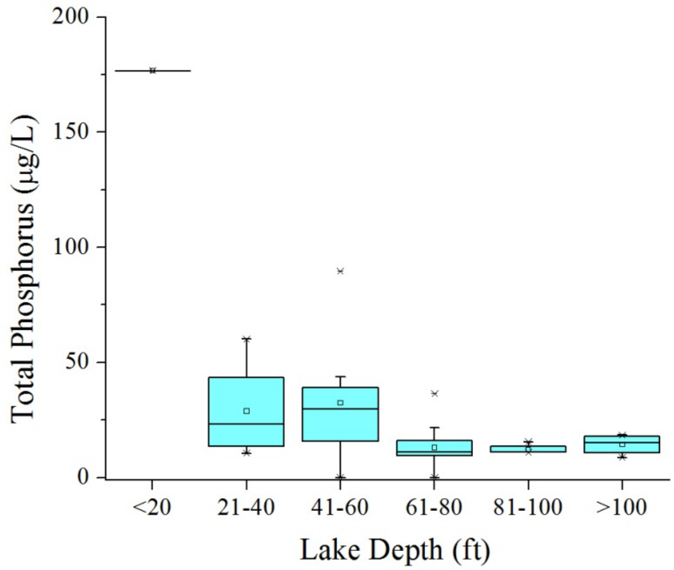


Figure 38. Distribution of July/August summertime mean total phosphorus concentrations (2009-2011) by depth. The squares represent the mean. The median is the line inside the boxes and the error bars show the minimum and maximum values. The asterisks show the outlier values.

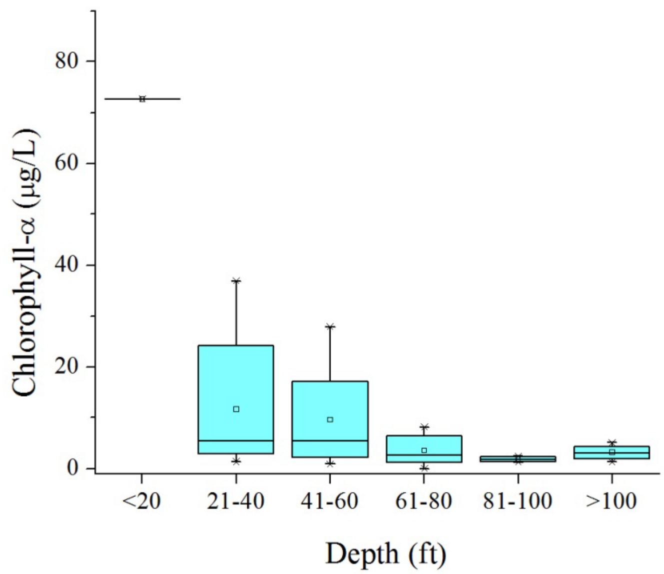


Figure 39. Distribution of July/August summertime mean chlorophyll *a* concentrations (2009-2011) by depth. The squares represent the mean. The median is the line inside the boxes and the error bars show the minimum and maximum values. The asterisks show the outlier values.

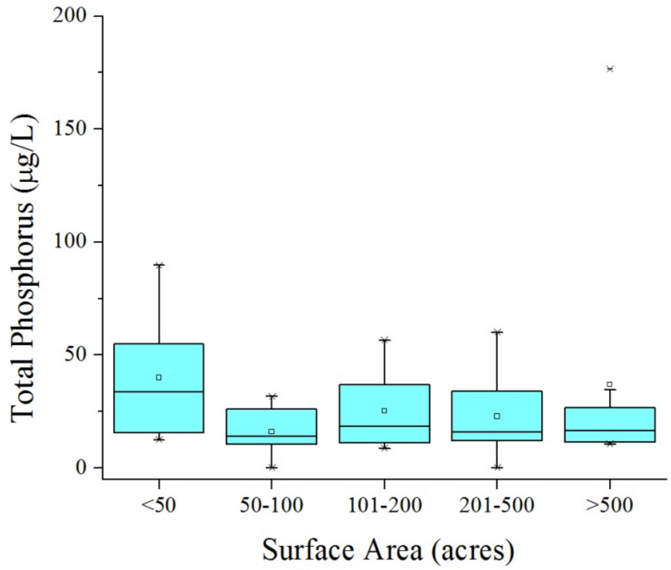


Figure 40. **Distribution of July/August summertime mean total phosphorus concentrations (2009-2011) by basin size.** The squares represent the mean. The median is the line inside the boxes and the error bars show the minimum and maximum values. The asterisks show the outlier values.

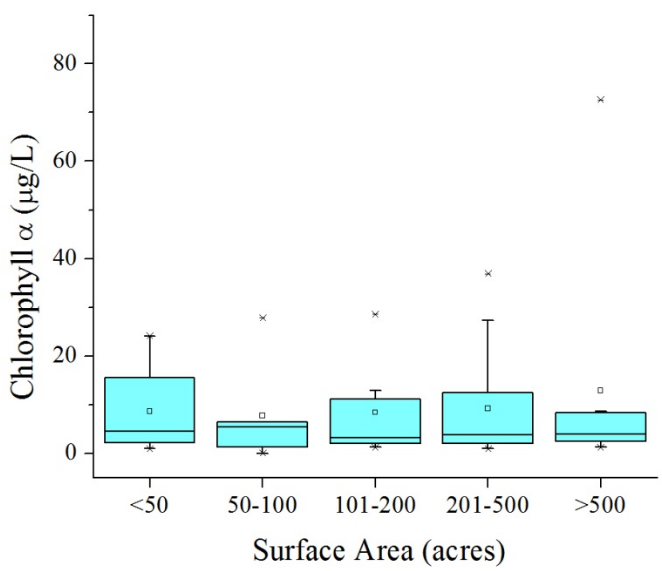


Figure 41. Distribution of July/August summertime mean chlorophyll *a* concentrations (2009-2011) by basin size. The squares represent the mean. The median is the line inside the boxes and the error bars show the minimum and maximum values. The asterisks show the outlier values.

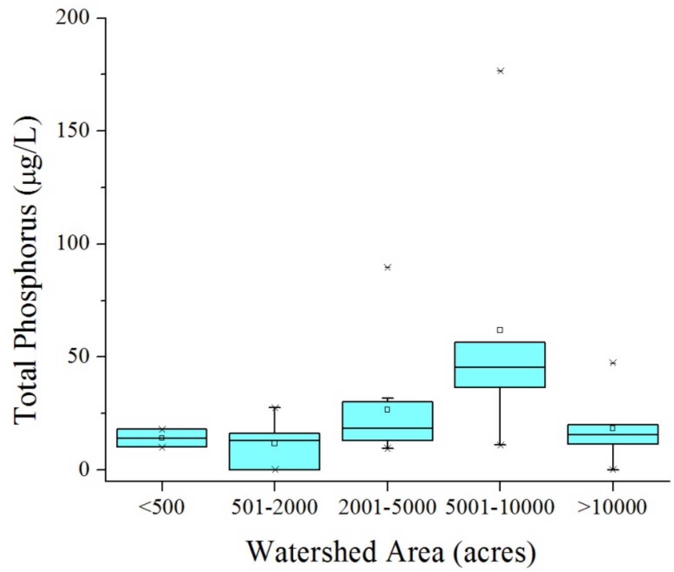


Figure 42. Distribution of mean total phosphorus concentrations (2009-2011) by watershed size. The squares represent the mean. The median is the line inside the boxes and the error bars show the minimum and maximum values. The asterisks show the outlier values.

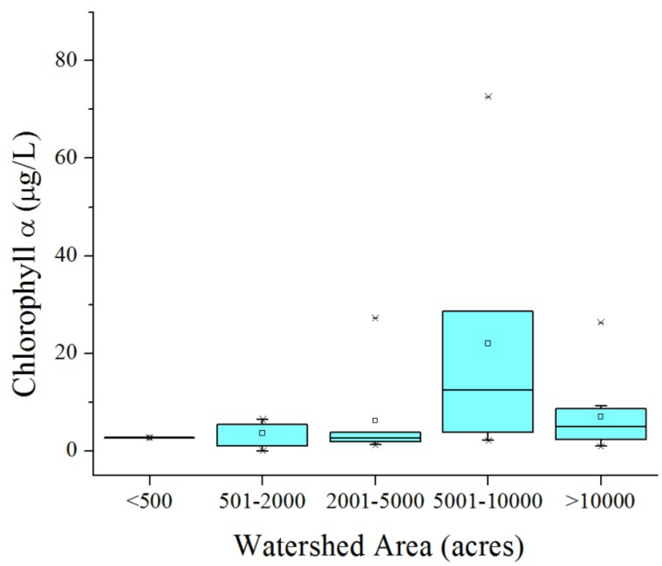


Figure 43. Distribution of mean chlorophyll *a* concentrations (2009-2011) by watershed size. The squares represent the mean. The median is the line inside the boxes and the error bars show the minimum and maximum values. The asterisks show the outlier values.

Ecoregion

Total phosphorus and chlorophyll *a* concentrations are expected to vary with ecoregion because land use and type vary among ecoregions. Ecoregion 55 (Eastern Corn Belt) had the highest median total phosphorus concentration, 60.0 μg/L, but only one lake was represented in this ecoregion (Figure 44). Lakes in this region are surrounded by agriculture which may increase nutrient runoff. The lowest median total phosphorus concentration, 15.4 μg/L, occurred in Ecoregion 56 (Southern Michigan/Northern Indiana Drift Plains). The lakes in Ecoregion 56 are surrounded by agriculture, but there are also 35 lakes in this region so there is a better representation of these lakes.

Chlorophyll *a* concentrations also vary with ecoregion in a similar manner to total phosphorus as expected (Figure 45). Ecoregion 55 (Eastern Corn Belt) had the highest median chlorophyll *a* concentration, 36.9 μg/L. The next highest was 27.3 μg/L in Ecoregion 54 (Central Corn Belt). The lowest median chlorophyll *a* concentration, 2.82 μg/L, was in Ecoregion 56.

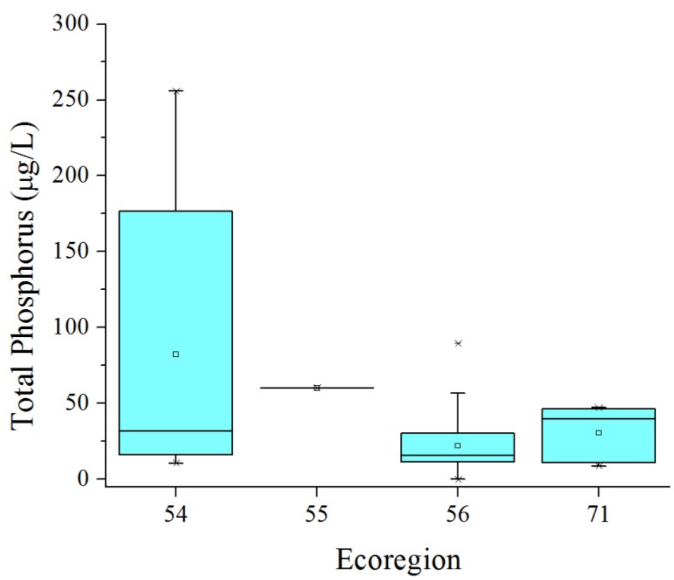


Figure 44. Distribution of mean total phosphorus concentrations (2009-2011) based on ecoregion. The squares represent the mean. The median is the line inside the boxes and the error bars show the minimum and maximum values. The asterisks show the outlier values.

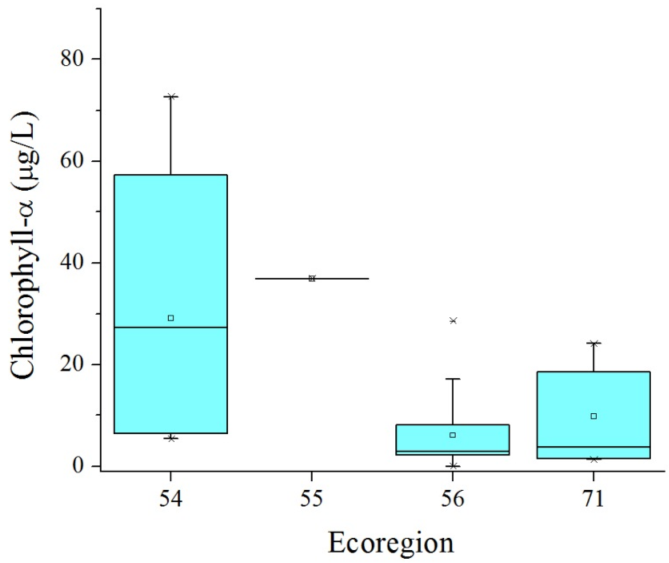


Figure 45. Distribution of mean chlorophyll *a* concentrations (2009-2011) based on ecoregion. The squares represent the mean. The median is the line inside the boxes and the error bars show the minimum and maximum values. The asterisks show the outlier values.

Trophic State Index Analysis

Carlson's Trophic State Index is calculated for total phosphorus and chlorophyll a as well as transparency. Figure 46 and 47 show the number of lakes in each trophic class for 2009, 2010, and 2011. The number of lakes in each trophic class did not vary much from year to year; however, it is interesting to see that the two parameters result in different trophic classifications for the same lakes. The trophic states of the same lakes for total phosphorus predict the lakes being more eurtrophic than the chlorophyll a trophic state. This could be a result of phosphorus being bound to other particles in the water rather than algal biomass. The result is less chlorophyll *a* than we would expect. Figure 22 (from the Transparency section) shows that we also do not see the same trends with Secchi transparency results for trophic state. The Secchi trophic states predict mostly mesothrophic and eutrophic conditions in the lakes for the past three years.

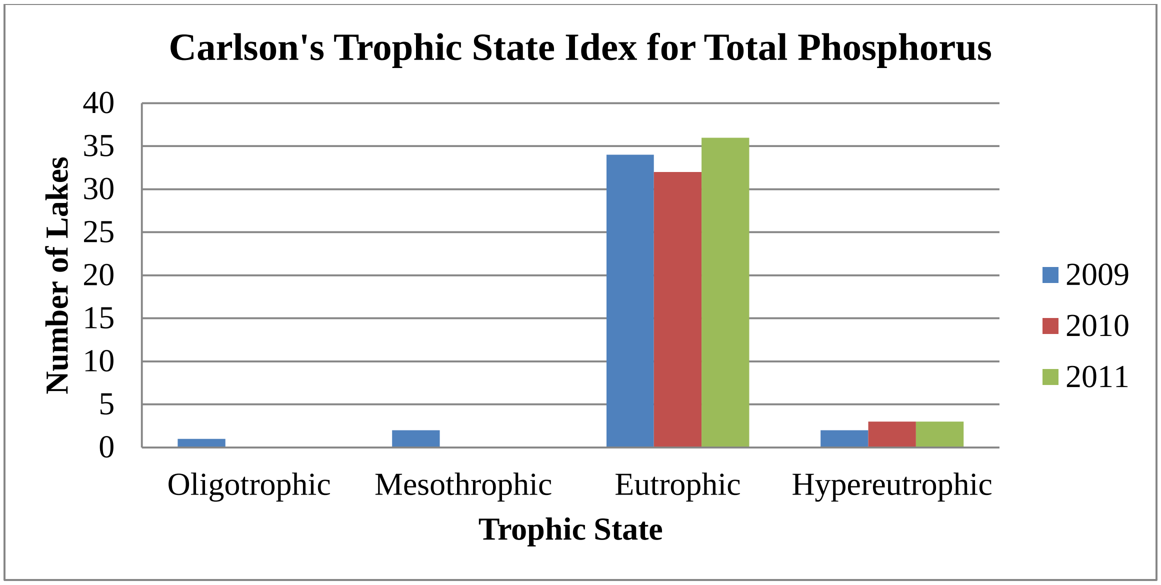


Figure 46. Number of lakes among trophic classes for July/August summertime means of total phosphorus.

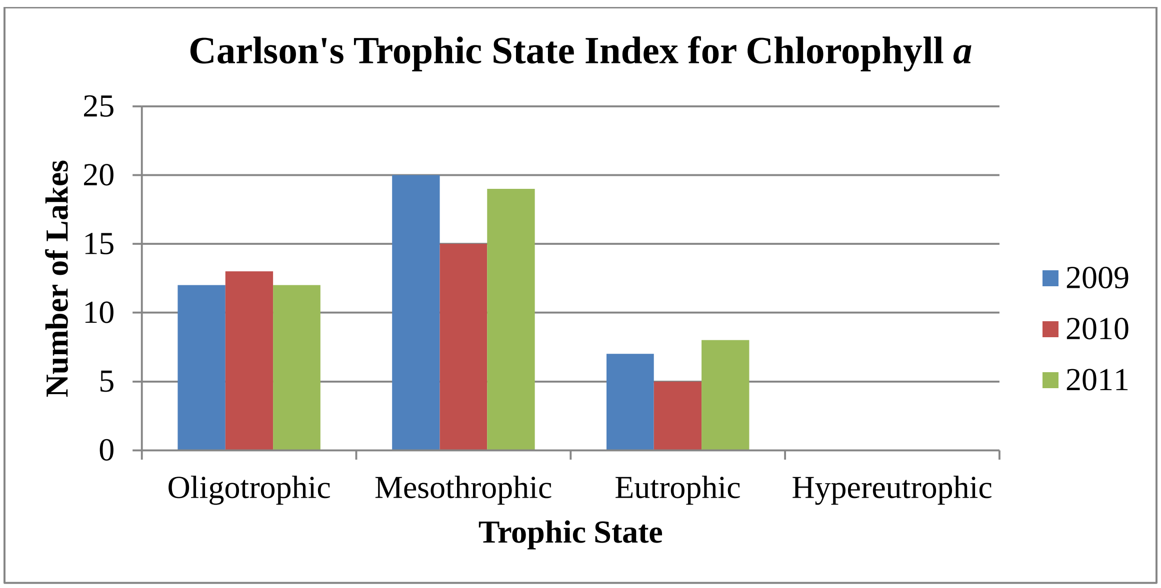


Figure 47. Number of lakes among trophic classes for July/August summertime means of chlorophyll *a*.

Trend Analysis

Volunteer data is best suited for looking at trends on individual lakes. However, by removing the lakes that have changed over the past 3 years and only including those that collected samples for all three years we can attempt to identify trends in the dataset. Figure 48 and 49 show that the mean total phosphorus and chlorophyll *a* have shown little variation over the past three years. The median also shows little change, which is good for Indiana's lakes.

The outlier values for both total phosphorus and chlorophyll *a* are Big Bass Lake (Porter County) and Cedar Lake (Lake County). These two lakes have been consistently high in the past as well (see Table 2, 3, and 4). While Cedar Lake has been known to suffer from internal phosphorus loading issues (phosphorus being released from the sediment into the water column) it is more difficult to understand why Big Bass Lake is eutrophic.

Big Bass Lake had the lowest Secchi transparency in 2009 and 2010 and had the highest Carlson's TSI score for Secchi transparency all three years. Figure 20 (c) also shows that the transparency of the lake has been getting worse over the years as well. I can only speculate as to why this lake has such high concentrations of total phosphorus and chlorophyll *a*, but it is likely do in part to it being within an agriculturally dominated watershed (Ecoregion 54, Central Corn Belt). The lake is 39 feet deep and has a surface area of 512 acres neither of these factors helps explain the high values. It would be interesting to look at this lake more closely to see if we could identify more direct causes of the high chlorophyll *a* and total phosphorus concentrations.

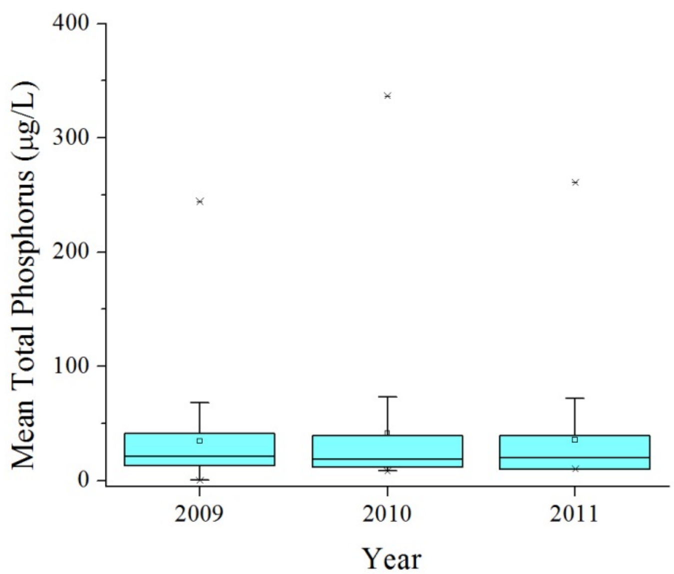


Figure 48. Total phosphorus July/August summertime mean categorized by year. The squares represent the mean. The median is the line inside the boxes and the error bars show the minimum and maximum values. The asterisks show the outlier values.

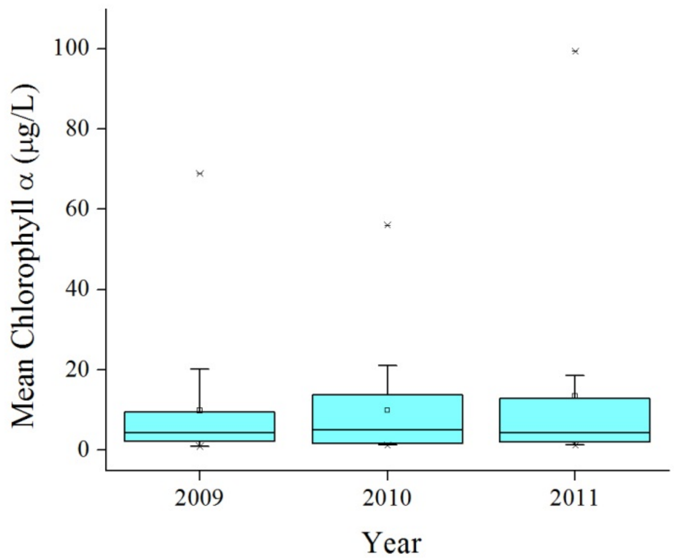


Figure 49. Chlorophyll *a* July/August summertime means categorized by year. The squares represent the mean. The median is the line inside the boxes and the error bars show the minimum and maximum values. The asterisks show the outlier values.

SURVEY RESULTS

Each year volunteers receive a brief survey following the sampling season. These questionnaires provide feedback about the program and information on how we can better serve our volunteers to improve the program. The survey also helps us find out what changes we need to make as well as how well any new policies and procedures are working for the volunteers. Survey results for 2011 are not available yet.

In 2009 and 2010 volunteers were asked to indicate the biggest problems affecting their use and enjoyment of their lake. The 2008 data have been included for comparison to previous years. In 2008 through 2010 volunteers indicted that the algal blooms where the greatest problem affecting enjoyment and use of their lakes. Excessive weeds have been one of the greatest issues volunteers have had in the past as well as large waterfowl populations. Silt and water levels continue to be an issue as well. Results from 2008-2010 are shown in Figure 50 with the percentage of respondents reporting problems.

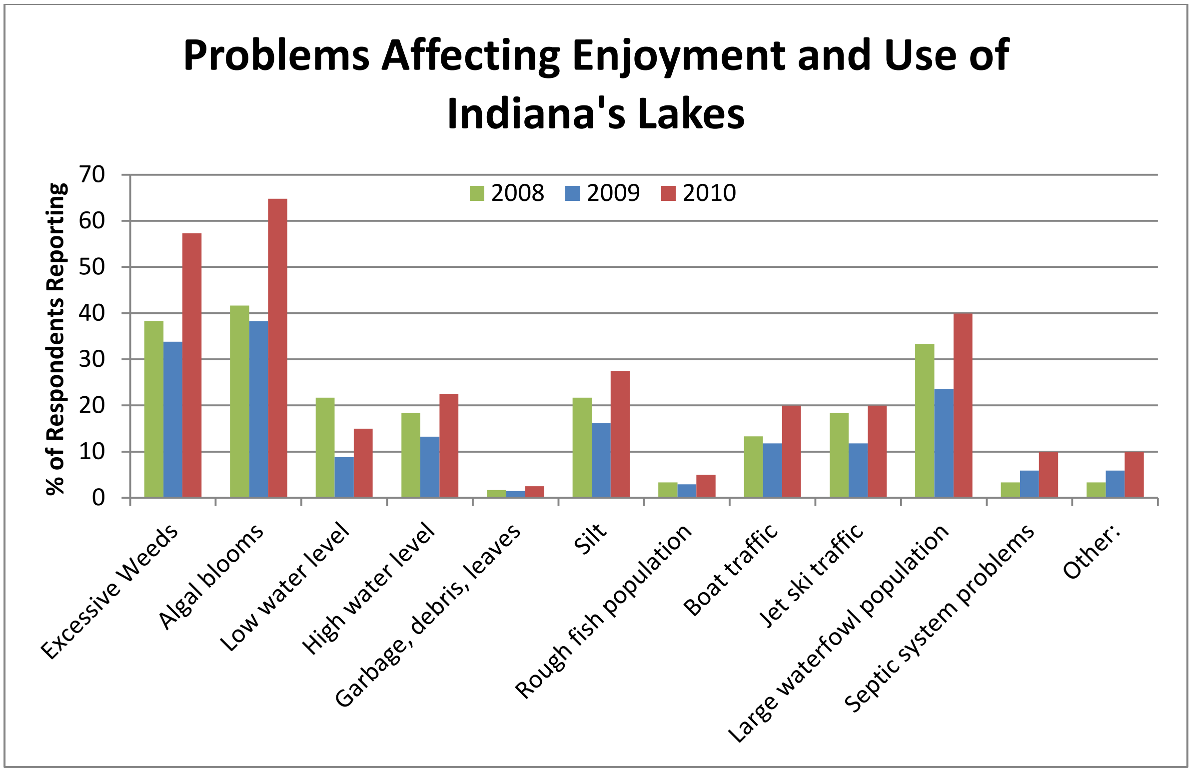


Figure 50. 2008-2010 survey result reporting common issues with monitored lakes.

In 2010 the volunteer survey was altered to include questions about the likelihood of taking dissolved oxygen and temperature readings on their lakes (Figure 51). The survey results were mixed, with 41% of those reporting saying they are very likely to take these measurements and 38% saying they are not likely. Volunteers were also asked how far they would travel to check out a meter to use to take dissolved oxygen and temperature readings (Figure 51). Results show that people are most likely to travel 0-15 minutes to check out a meter, with 44% of respondents saying they would travel that distance. The second highest response was 15-30 minutes with 30% of respondents saying they would travel that distance to check out a meter. This suggests that it would be best if the meters where within 15-30 minutes from volunteers in order to maximize use. Volunteers were finally asked if they would attend workshops hosted by CLP staff, 48% responded that they are likely to attend workshops (Figure 51). We will use this information to determine future direction for the volunteer monitoring program and assessment of future needs.

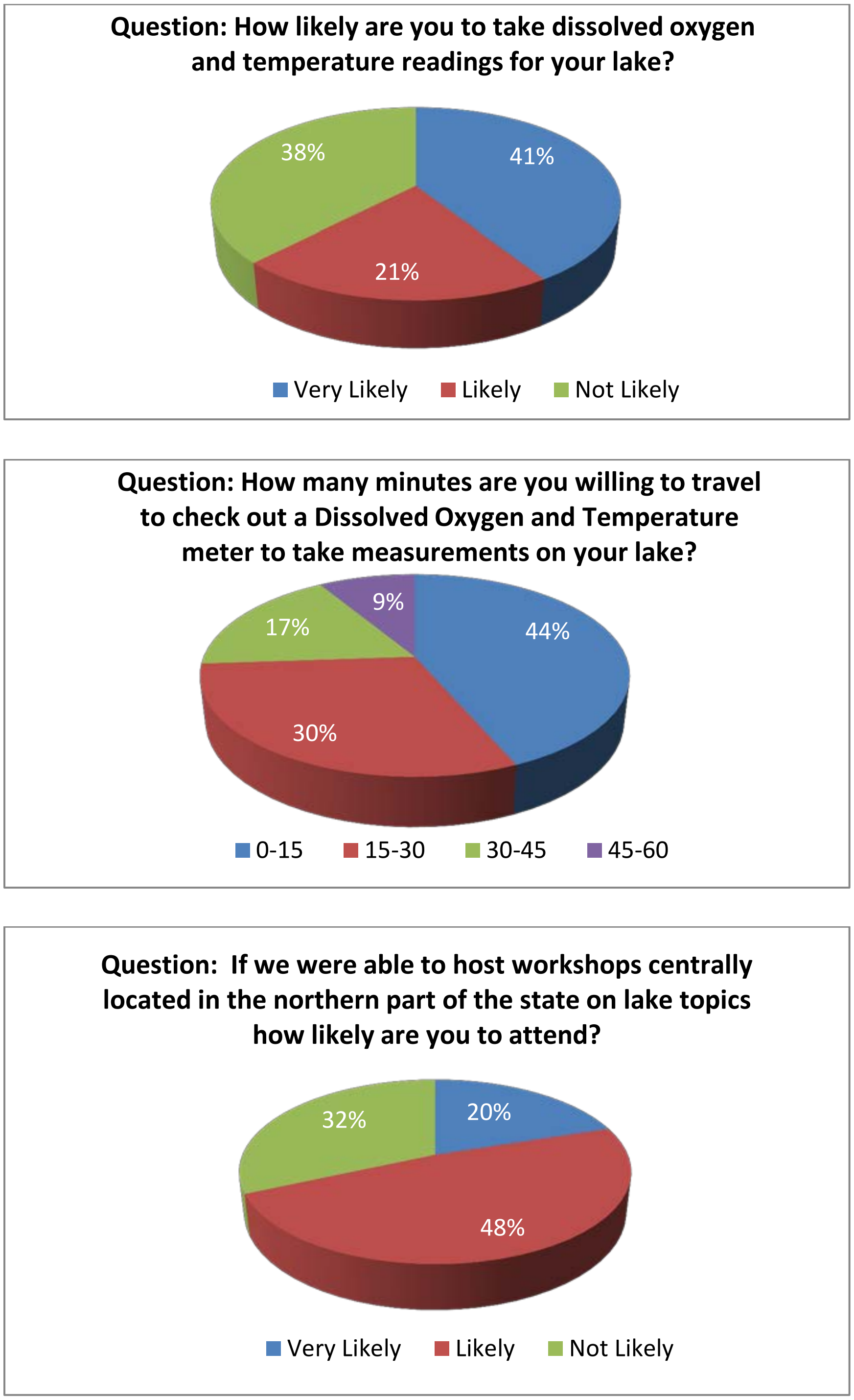


Figure 51. **Survey results from 2010, 61 respondents.**

CONCLUSIONS

The volunteer lake monitoring program provides invaluable information on Indiana's lakes. The data collected through this program provide consistent long-term data. The efforts of the volunteer lake monitors allow for continuous monitoring of Indiana's lakes at a substantially reduced cost. The volunteer program has continued to grow and change in the past three years and we hope to see these efforts continue in the future. Growth of the expanded monitoring program will continue in 2012 as well as the addition of more monitors to the program. The volunteers are vital to this program and we look forward to our continued work with them.

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APPENDIX A:

Secchi Disk Transparency Summaries for Lakes by Year for 2009-2011

Table 2. Secchi Disk Transparency Summary Data for 2009.

Lake Name	County	Surface Area (acres)	Max Depth (feet)	Yearly Min (feet)	Yearly Max (feet)	July/Aug Mean (feet)	Carlson's TSI (for Jul/Aug mean)	# of Obs.
Adams	LaGrange	308	93	5.4	14.8	6.0	51	6
Ball	Steuben	87	66	4.0	7.8	4.5	56	4
Banning	Kosciusko	17	17	5.2	5.2	5.2	53	1
Barton	Steuben	94	44	8.7	11.8	8.7	46	3
Big	Noble	304	45	3.3	8.0	4.9	54	6
Big Barbee	Kosciusko	97	12	2.8	6.2	3.5	59	10
Big Bass	Porter	512	39	0.9	1.6	1.0	77	4
Big Cedar	Whitley	144	75	12.5	17.6	16.2	37	4
Big Chapman	Kosciusko	366	82	5.2	11.9	7.7	48	8
Big Long	LaGrange	450	65	15.7	19.6	17.2	36	8
Big Otter	Steuben	69	38	6.8	10.4	7.9	47	4
Bonar	Kosciusko	40	26	10.7	11.0	0.0	n/a	2
Cedar	Lake	781	16	9.0	12.0	9.0	45	3
Center	Kosciusko	120	42	2.2	7.9	7.4	48	4
Clear	Porter-Laporte	17	33	6.6	11.3	7.7	48	7
Cook	Marshall	93	52	4.6	7.1	5.3	53	5
Cordry	Brown	169	110	16.2	21.7	19.3	n/a	8
Crooked	Steuben	117	43	6.5	11.3	6.5	50	4
Crooked	Noble	828	78	4.5	15.0	11.0	43	3
Diamond	Kosciusko	79	39	4.5	5.7	0.0	n/a	2
Elizabeth	Kosciusko			15.6	21.0	17.7	36	4
Flat	Marshall	26	31	3.7	6.2	5.3	53	4
Flint	Porter	89	67	5.3	13.8	6.7	50	4
Gage	Steuben	327	70	8.0	20.6	10.0	44	9
Galbraith	Marshall	35	41	1.9	4.9	3.9	58	5
Goose	Whitley	84	69	3.0	15.0	3.0	61	6
Griffy	Monroe	130	36	9.8	16.0	11.5	42	6
Heaton	Elkhart	87	22	9.0	18.0	13.3	40	4
Heritage	Putnam	330	43	2.7	3.9	3.0	61	5
Hogback	Steuben	146	26	3.0	5.3	4.3	56	7
Holem	Marshall	40	29	3.6	9.8	7.6	48	7
Holiday	Montgomery	180	22	2.7	6.0	3.1	61	16
Holiday	Lake	327	90	3.7	7.4	3.7	58	4

Lake Name	County	Surface Area (acres)	Max Depth (feet)	Yearly Min (feet)	Yearly Max (feet)	July/Aug Mean (feet)	Carlson's TSI (for Jul/Aug mean)	# of Obs.
Indiana	Elkhart	122	68	8.0	18.0	9.1	45	18
Irish	Kosciusko	187	34	4.0	5.5	4.8	55	4
James	Steuben	282	63	8.6	26.3	10.8	43	6
James	Kosciusko	1034	86	5.7	12.5	6.5	50	9
Knapp	Noble	88	59	3.8	7.4	4.8	55	8
Koontz	Starke	346	31	3.3	9.1	3.8	58	14
Kuhn	Kosciusko	118	27	7.1	13.4	8.1	47	10
Lake of the Woods	LaGrange	136	84	6.4	11.3	8.5	46	3
Lake of the Woods	Marshall	416	48	2.4	5.2	2.4	64	4
Lamb	Johnson	95	42	2.6	9.6	6.2	51	15
Little Barbee	Kosciusko	68	26	2.0	3.5	2.6	63	2
Little Cedar	Whitley	45	75	5.2	10.2	5.8	52	5
Little Chapman	Kosciusko	177	31	2.5	7.4	3.3	60	8
Little Crooked	Whitley	11		4.0	9.0	6.0	51	4
Little Long	Noble	71	65	5.3	11.5	7.7	48	6
Little Otter	Steuben	34	37	7.0	12.2	9.1	45	4
Loon	Whitley	222	92	3.6	7.3	4.1	57	3
Lost	Marshall	416	48	3.2	4.0	3.7	58	3
Lower Fish	LaPorte	134	16	5.5	9.6	5.5	53	2
Manitou	Fulton	713	44	1.5	4.3	3.5	59	15
Martin	LaGrange	26	56	2.9	15.8	12.0	41	11
Maxinkuckee	Marshall	1854	88	0.0	21.8	0.0	n/a	4
McClish	Steuben	509	71	9.1	14.3	0.0	n/a	2
Millpond	Marshall	168	16	5.4	6.7	0.0	n/a	4
Myers	Marshall	96	54	20.0	20.0	0.0	n/a	1
Nebo	Morgan			10.5	11.3	0.0	n/a	2
Nyona	Fulton	104	32	2.6	4.0	2.7	63	5
Old	Whitley	32	42	2.0	7.0	5.9	51	5
Ole Swimming Hole	Morgan	110	27	2.7	6.5	3.5	59	11
Olin	LaGrange	103	82	5.5	16.1	8.5	46	13
Oliver	LaGrange	371	91	4.2	14.7	5.8	52	13
Oswego	Kosciusko	83	36	5.0	11.3	6.3	51	9
Painted Hills	Morgan			5.8	5.8	0.0	n/a	1

Lake Name	County	Surface Area (acres)	Max Depth (feet)	Yearly Min (feet)	Yearly Max (feet)	July/Aug Mean (feet)	Carlson's TSI (for Jul/Aug mean)	# of Obs.
Pinestone	Harrison			8.0	13.0	11.0	43	5
Pretty	Marshall	97	40	7.4	17.6	13.8	39	3
Pretty	LaGrange	184	84	12.0	15.0	12.0	41	3
Rachel	Kosciusko			12.0	13.2	12.0	41	4
Round	Whitley	131	63	6.2	11.5	10.1	44	6
Salamonie	Wabash	2860	76	1.0	4.0	3.1	61	16
Sawmill	Kosciusko	27	26	2.2	4.3	3.1	61	2
Sechrist	Kosciusko	99	59	7.6	13.4	8.8	46	7
Shriner	Whitley	120	74	7.6	20.6	19.8	34	6
Silver	Steuben	238	38	9.4	15.4	15.4	38	2
Skinner	Noble	40	32	1.3	3.6	3.1	61	9
Snow	Steuben	422	84	6.2	15.4	8.9	46	10
Spirit	Marion			4.2	4.2	4.2	56	1
Sweetwater	Brown	275	100	15.7	22.0	17.5	36	10
Syracuse	Kosciusko	564	35	9.0	14.9	10.3	44	6
Tawny	St. Joseph			6.7	16.3	9.5	45	5
Tippecanoe	Kosciusko	707	123	4.7	15.0	5.6	52	9
Upper Long	Noble	86	54	5.0	9.0	7.1	49	13
Waubee	Kosciusko	117	51	7.0	24.0	9.0	46	8
Wawasee	Kosciusko	2618	77	4.0	12.0	5.1	54	4
Webster	Kosciusko	774	45	5.2	16.2	6.6	50	7
West Otter	Steuben	118	31	2.4	5.6	4.3	56	6
Whippoor-will	Morgan	8.5	12	4.3	8.6	5.6	52	9
Winona	Kosciusko	478	80	5.8	6.0	5.9	52	2
Witmer	LaGrange	204	54	3.0	8.5	3.1	61	4
Yellow Creek	Kosciusko	61	19	2.7	2.7	2.7	63	2
*** No Data**	**Totals**			**n/a**	**n/a**	**n/a**		560
	2009 Min			0.0	1.6	0.0	34.1	1.0
	2009 Max			20.0	26.3	19.8	76.6	18.0
	2009 Average			5.8	11.2	6.7	50.7	6.1

Table 3. Secchi Disk Transparency Summary Data for 2010.

Lake Name	County	Surface Area (acres)	Max Depth (feet)	Yearly Min (feet)	Yearly Max (feet)	July/Aug Mean (feet)	Carlson's TSI (for Jul/Aug mean)	# of Obs.
Adams	LaGrange	308	93	5.4	13.3	6.7	50	9
Ball	Steuben	87	66	4.1	6.1	4.8	55	4
Barton	Steuben	94	44	10.0	10.9	0.0	n/a	2
Big	Noble	304	45	2.5	8.5	3.6	59	7
Big Barbee	Kosciusko	97	12	3.4	3.6	3.5	59	3
Big Bass	Porter	512	39	0.9	1.6	0.9	78	4
Big Chapman	Kosciusko	366	82	6.5	11.4	7.6	48	12
Big Long	LaGrange	450	65	11.4	23.2	12.8	40	9
Big Turkey	LaGrange	40	26	2.5	6.4	3.2	60	13
Bonar	Kosciusko	40	26	8.8	17.0	0.0	n/a	3
Brookville	Franklin	5260	100	4.0	4.0	0.0	n/a	1
Cedar	Lake	781	16	1.0	1.0	1.0	77	2
Center	Kosciusko	120	42	4.8	10.8	9.2	45	5
Clear	LaPorte	17	33	6.1	8.7	7.5	48	4
Cook	Marshall	93	52	8.2	9.6	8.7	46	5
Cordry	Brown	169	110	16.8	23.5	20.4	34	9
Crooked	Noble	117	43	12.0	18.0	16.4	37	4
Elizabeth	Kosciusko			14.7	21.3	18.2	35	5
Flat	Marshall	26	31	4.4	7.8	7.2	49	5
Flint	Porter	89	67	6.5	13.2	7.0	49	4
Gage	Steuben	327	70	5.2	12.8	7.6	48	7
Galbraith	Marshall	35	41	1.7	5.1	3.9	57	4
Griffy	Monroe	130	36	7.0	20.6	10.3	44	6
Heaton	Elkhart	87	22	8.6	12.0	12.0	41	3
Heritage	Putnam	330	43	2.3	2.4	2.4	65	2
Hogback	Steuben	146	26	3.0	4.0	3.5	59	5
Holem	Marshall	40	29	6.0	12.4	11.4	42	6
Holiday	Lake	180	22	1.4	6.9	2.5	64	4
Holiday	Montgomery	327	90	2.6	5.2	2.8	62	7
Indiana	Elkhart	122	68	8.0	30.0	13.2	40	65
Irish	Kosciusko	187	34	3.7	11.0	3.7	58	6
James	Kosciusko	282	63	5.0	15.4	5.1	54	7
James	Steuben	1034	86	8.5	24.1	12.3	41	6
Knapp	Noble	88	59	4.9	11.6	6.4	50	14
Koontz	Starke	346	31	2.9	9.0	3.2	60	13
Kuhn	Kosciusko	118	27	6.4	8.5	6.6	50	3
Lake of the Woods	LaGrange	136	84	4.0	11.8	4.6	55	4

Lake Name	County	Surface Area (acres)	Max Depth (feet)	Yearly Min (feet)	Yearly Max (feet)	July/Aug Mean (feet)	Carlson's TSI (for Jul/Aug mean)	# of Obs.
Lake of the Woods	Marshall	416	48	2.6	7.4	3.4	60	4
Lamb	Johnson	95	42	4.2	10.8	6.4	50	14
Little Cedar	Whitley	45	75	8.1	10.1	9.0	45	3
Little Chapman	Kosciusko	177	31	1.6	5.7	3.4	60	15
Little Crooked	Whitley	11		3.0	9.0	8.5	46	4
Little Long	Noble	71	65	4.6	4.6	4.6	55	1
Little Turkey	LaGrange	135	30	3.3	7.3	3.3	60	2
Loon	Whitley	222	92	2.7	4.8	3.9	58	6
Manitou	Fulton	713	44	2.3	6.6	3.1	61	10
Martin	LaGrange	26	56	4.5	11.3	9.1	45	10
Maxinkuckee	Marshall	1854	88	8.3	12.1	10.1	44	6
McClish	Steuben	509	71	10.1	14.6	0.0	n/a	2
Nyona	Fulton	104	32	3.3	4.5	0.0	n/a	2
Old	Whitley	32	42	4.0	7.0	5.9	52	5
Ole Swimming Hole	Morgan	110	27	1.5	5.0	3.2	60	11
Olin	LaGrange	103	82	4.3	10.2	6.1	51	10
Oliver	LaGrange	371	91	4.4	9.1	5.3	53	10
Oswego	Kosciusko	83	36	7.0	15.4	8.0	47	7
Pinestone	Harrison			6.0	8.0	6.0	51	2
Pretty	Marshall	97	40	10.0	14.5	14.0	39	4
Rachel	Kosciusko			9.0	13.6	9.9	44	5
Ridinger	Kosciusko	55	12	4.0	4.4	4.4	56	2
Salamonie	Wabash	2860	76	1.5	4.0	3.1	61	14
Sechrist	Kosciusko	99	59	7.0	13.6	7.3	48	5
Silver	Steuben	238	38	9.4	10.9	10.8	43	4
Skinner	Noble	40	32	2.1	5.8	2.8	62	9
Snow	Steuben	422	84	6.0	9.0	7.8	47	10
Spirit	Marion			5.4	6.6	6.2	51	15
Sweetwater	Brown	275	100	18.0	26.0	22.4	32	12
Syl-Van	Steuben	14	47	9.0	10.5	9.6	45	4
Syracuse	Kosciusko	564	35	8.2	10.2	9.1	45	4
Tawny	St. Joseph			5.6	12.4	7.4	48	8
Tippecanoe	Kosciusko	707	123	7.5	13.8	7.6	48	8
Upper Long	Noble	86	54	4.0	9.0	6.6	50	15
Waubee	Kosciusko	117	51	7.9	12.5	9.9	44	6
Wawasee	Kosciusko	2618	77	7.7	10.7	7.8	47	4
Webster	Kosciusko	774	45	3.3	7.0	4.0	57	7

Lake Name	County	Surface Area (acres)	Max Depth (feet)	Yearly Min (feet)	Yearly Max (feet)	July/Aug Mean (feet)	Carlson's TSI (for Jul/Aug mean)	# of Obs.
West Otter	Steuben	118	31	5.0	12.7	6.2	51	21
Whippoorwill	Morgan	8.5	12	3.4	14.3	8.3	47	17
Winona	Kosciusko	478	80	2.8	2.8	2.8	62	1
Yellow Creek	Kosciusko	61	19	3.4	4.4	3.6	59	3
*** No Data**	**Totals**			**n/a**	**n/a**	**n/a**		574
	2010 Min			0.9	1.0	0.0	32.3	1.0
	2010 Max			18.0	30.0	22.4	77.9	65.0
	2010 Avg			5.7	10.4	6.7	51.3	7.4

Table 4. Secchi Disk Transparency Summary Data for 2011.

Lake Name	County	Surface Area (acres)	Max Depth (feet)	Yearly Min (feet)	Yearly Max (feet)	July/Aug Mean (feet)	Carlson's TSI (Jul/Aug mean)	# of Obs.
Adams	LaGrange	308	93	4.2	18.0	6.4	50	10
Anne	Steuben	15	30	2.0	10.5	8.9	46	6
Barton	Steuben	94	44	9.0	14.2	13.8	39	3
Bear	Noble	136	59	9.4	9.4	0.0	n/a	1
Big	Noble	228	70	3.6	11.1	8.3	47	6
Big Bass	Porter	97	12	1.6	2.0	1.8	69	4
Big Chapman	Kosciusko	512	39	5.1	10.8	7.6	48	12
Big Long	LaGrange	366	82	10.8	19.5	11.4	42	6
Big Turkey	LaGrange	450	65	3.1	7.9	3.8	58	15
Bonar	Kosciusko	40	26	8.5	15.0	8.5	46	4
Cedar	Lake	781	16	9.0	16.0	9.5	45	3
Center	Kosciusko	120	42	5.7	11.1	6.0	51	4
Clear	LaPorte	800	107	7.0	8.5	7.6	48	4
Clear	Steuben	17	33	8.7	21.8	10.2	44	20
Cook	Marshall	93	52	3.9	8.1	6.6	50	4
Cordry	Brown	169	110	15.0	24.6	20.0	34	8
Crooked	Noble	117	43	8.0	16.0	11.2	42	5
Elizabeth	Kosciusko			8.6	16.2	12.4	41	5
Flat	Marshall	26	31	3.7	4.5	4.0	57	4
Flint	Porter	89	67	4.0	7.5	5.5	53	3
Gage	Steuben	327	70	6.2	13.2	7.4	48	6
Galbraith	Marshall	35	41	1.9	3.0	2.8	62	3
Griffy	Monroe	130	36	8.0	11.0	11.0	43	2
Heaton	Elkhart	87	22	9.0	12.5	9.9	44	4
High	Noble	206	108	2.4	4.6	4.6	55	3
Hogback	Steuben	146	26	1.9	3.5	2.4	65	3
Holiday	Lake	180	22	3.0	5.3	3.3	60	4
Holiday	Montgomery	327	90	2.4	5.8	2.8	63	11
Indiana	Elkhart	122	68	9.5	24.0	17.5	36	52
Irish	Kosciusko	187	34	2.9	9.3	3.2	60	6
James	Kosciusko	282	63	5.1	7.6	6.2	51	4
James	Steuben	1034	86	11.3	13.9	13.5	40	3
Knapp	Noble	88	59	4.3	14.2	6.7	50	11
Koontz	Starke	346	31	2.0	9.5	2.7	63	13
Lake of the Woods	LaGrange	136	84	4.2	13.0	7.4	48	4
Lake of the Woods	Marshall	416	48	3.0	5.6	3.0	61	4

Lake Name	County	Surface Area (acres)	Max Depth (feet)	Yearly Min (feet)	Yearly Max (feet)	July/Aug Mean (feet)	Carlson's TSI (Jul/Aug mean)	# of Obs.
Lamb	Johnson	95	42	2.1	7.4	6.3	51	15
Little Cedar	Whitley	45	75	7.9	11.1	9.3	45	5
Little Chapman	Kosciusko	177	31	3.0	4.6	3.6	58	11
Little Crooked	Whitley	11		3.0	7.0	3.7	58	5
Little Long	Noble	71	65	4.9	7.5	0.0	n/a	2
Little Turkey	LaGrange	135	30	2.0	5.0	2.0	67	2
Long	Porter	65	27	7.6	8.8	8.1	47	3
Loomis	Porter	62	55	4.5	5.0	4.5	55	2
Lost	Marshall	416	48	3.9	4.2	4.0	57	2
Louise	Porter	228	34	12.3	12.3	0.0	n/a	1
Manitou	Fulton	713	44	2.2	6.1	2.7	63	9
Martin	LaGrange	26	56	4.7	13.2	9.1	45	12
Maxinkuckee	Marshall	1854	88	6.0	12.5	6.2	51	5
McClish	Steuben	509	71	6.7	16.4	12.0	41	4
Nyona	Fulton	104	32	3.4	6.0	3.4	59	2
Ole Swimming Hole	Morgan	110	27	1.9	6.6	3.4	60	10
Olin	LaGrange	103	82	4.3	13.9	7.3	49	12
Oliver	LaGrange	371	91	4.2	17.3	5.5	53	12
Oswego	Kosciusko	83	36	4.9	9.2	5.8	52	4
Palestine	Kosciusko	230	23	2.6	11.4	4.7	55	7
Pinestone	Harrison			4.1	8.0	5.0	54	7
Pretty	Marshall	97	40	12.5	16.0	12.5	41	3
Rachel	Kosciusko			7.7	13.6	9.5	45	5
Ridinger	Kosciusko	55	12	3.0	7.0	4.2	56	3
Sechrist	Kosciusko	99	59	8.6	9.2	8.8	46	8
Shriner	Whitley	120	74	7.1	25.5	18.5	35	12
Silver	Steuben	238	38	8.5	10.3	10.0	44	4
Skinner	Noble	125	32	1.9	6.7	2.5	64	12
Snow	Steuben	422	84	6.7	7.5	7.2	49	5
Spirit	Marion			3.0	3.3	0.0	n/a	4
Sweetwater	Brown	275	100	16.0	22.0	21.0	33	4
Syracuse	Kosciusko	564	35	6.6	8.3	7.4	48	4
Tawny	St. Joseph			8.1	12.2	12.2	41	5
Tippecanoe	Kosciusko	707	123	5.2	9.3	5.9	51	4
Upper Long	Noble	86	54	6.0	8.0	6.7	50	9
Waubee	Kosciusko	117	51	7.5	10.8	9.4	45	4
Wawasee	Kosciusko	2618	77	4.0	21.0	5.0	54	4
Webster	Kosciusko	774	45	2.0	3.0	2.4	65	6

Lake Name	County	Surface Area (acres)	Max Depth (feet)	Yearly Min (feet)	Yearly Max (feet)	July/Aug Mean (feet)	Carlson's TSI (Jul/Aug mean)	# of Obs.
West Otter	Steuben	118	31	3.8	10.5	6.1	51	18
Whippoorwill	Morgan	25	25	2.9	10.8	5.3	53	25
Winona	Kosciusko	478	80	7.0	7.0	0.0	n/a	1
Witmer	LaGrange	204	54	1.5	8.0	3.2	61	4
Yellow Creek	Kosciusko	158	70	1.6	3.2	2.0	67	4
*** No Data**	**Totals**			**n/a**	**n/a**	**n/a**		540
	2010 Min	11	12	1.5	2.0	0.0	33.3	1.0
	2010 Max	2618	123	16.0	25.5	21.0	68.7	52.0
	2010 Avg	286	54	5.5	10.6	6.8	51.0	6.8

APPENDIX B:

Chlorophyll *a* and Total Phosphorus Summaries for Lakes by Year for 2009-2011

Table 5. Chlorophyll *a* and Total Phosphorus Summary Data 2009.

		Chlorophyll - *a*				Total Phosphorus			
Lake Name	County	Min (ug/L)	Max (ug/L)	July/ Aug Mean (ug/L)	Carlson's Chl-*a* TSI	Min (ug/L)	Max (ug/L)	July/ Aug Mean (ug/L)	Carlson's Phos. TSI
Barton	Steuben	1.8	2.7	2.4	30	13	25	18.0	59
Big	Noble	6.3	31.0	12.2	46	11	52	42.1	65
Big Bass	Porter	5.0	101.7	68.9	64	94	265	244.2	77
Big Chapman	Kosciusko	2.2	3.1	2.6	31	15	22	19.9	60
Big Long	LaGrange	1.2	2.6	1.7	27	15	25	21.2	60
Cedar	Lake	23.9	62.5	62.5	63	86	152	152.0	74
Center	Kosciusko	2.5	5.2	3.3	33	22	25	25.0	61
Clear	Porter-Laporte	1.7	7.6	2.2	29	15	35	22.9	61
Cordry	Brown	0.8	1.6	1.2	23	4	7	7.0	53
Crooked	Noble	1.5	6.5	4.9	37	13	32	13.0	57
Flat	Marshall	1.3	11.4	7.7	42	63	86	67.8	68
Flint	Porter	2.5	11.4	6.1	39	13	26	15.7	58
Gage	Steuben	0.6	1.3	0.9	20	0.01	0.01	0.0	8
Galbraith	Marshall	1.9	21.7	19.4	51	29	86	38.5	64
Goose	Whitley	5.3	35.5	0.0	n/a	27	42	0.0	n/a
Griffy	Monroe	0.4	4.0	3.0	32	1.34	31	4.2	49
Hogback	Steuben	2.7	29.4	25.6	54	37	65	60.9	68
Holiday	Lake	2.2	8.3	5.4	38	22	36	34.5	64
Holiday	Montgomery	6.8	31.2	25.5	54	27	64	60.4	67
Indiana	Elkhart	1.4	2.2	1.5	25	7	11	8.8	54
James	Steuben	1.9	9.1	6.4	40	11	29	13.0	57
James	Kosciusko	0.9	1.7	1.0	21	18	22	19.0	60
Koontz	Starke	4.5	13.4	9.1	43	27	38	34.9	64
Lake of the Woods	Marshall	2.5	8.2	2.6	31	41	75	52.2	66

Lake Name	County	Chlorophyll - *a* Min (ug/L)	Chlorophyll - *a* Max (ug/L)	Chlorophyll - *a* July/ Aug Mean (ug/L)	Chlorophyll - *a* Carlson's Chl-*a* TSI	Total Phosphorus Min (ug/L)	Total Phosphorus Max (ug/L)	Total Phosphorus July/ Aug Mean (ug/L)	Total Phosphorus Carlson's Phos. TSI
Lake of the Woods	LaGrange	4.1	23.1	20.8	52	10	49	0.3	32
Little Chapman	Kosciusko	7.4	39.2	20.3	51	26	64	60.4	67
Little Crooked	Whitley	2.5	17.3	7.9	42	19	39	24.0	61
Manitou	Fulton	4.5	24.6	7.6	42	35	77	36.0	64
Martin	LaGrange	1.7	7.8	3.6	34	7	36	15.9	58
Maxinkuckee	Marshall	1.1	4.4	2.4	30	11	15	15.0	58
McClish	Steuben	0.2	1.6	1.4	25	11	25	25.0	61
Nyona	Fulton	8.4	38.8	9.5	44	51	165	57.1	67
Ole Swimming Hole	Morgan	0.7	16.7	15.8	49	22	67	41.1	65
Olin	LaGrange	0.6	2.3	1.8	27	7	15	11.0	56
Oliver	LaGrange	0.5	5.2	4.3	36	7	15	12.8	57
Oswego	Kosciusko	0.8	6.7	3.4	34	13	26	15.7	58
Silver	Steuben	0.6	3.8	1.5	25	12	15	13.4	57
Sweetwater	Brown	1.1	2.1	1.6	26	11	15	12.8	57
Syracuse	Kosciusko	1.5	5.1	2.1	29	10	19	0.2	29
Tippecanoe	Kosciusko	0.7	8.6	5.5	38	15	38	26.9	62
Wawasee	Kosciusko	2.5	7.2	2.9	32	4	26	5.7	51
*** no data**	**Totals**								
	2009 Minimum	0.2	1.3	0.0	20.5	0.0	0.0	0.0	8.3
	2009 Maximum	23.9	101.7	68.9	63.6	94.0	265.0	244.2	77.0
	2009 Average	2.9	15.3	9.5	37.2	21.5	47.7	32.9	58.5

Table 6. Chlorophyll *a* and Total Phosphorus Summary Data 2010.

		Chlorophyll - *a*				Total Phosphorus			
Lake Name	County	Min (ug/L)	Max (ug/L)	July/ Aug Mean (ug/L)	Carlson's Chl-*a* TSI	Min (ug/L)	Max (ug/L)	July/ Aug Mean (ug/L)	Carlson's Phos. TSI
Barton	Steuben	1.3	1.3	*	n/a	10	16		n/a
Big	Noble	3.4	12.6	8.5	43	29	56	40.3	65
Big Bass	Porter	16.0	73.7	45.7	60	120	426	336.6	79
Big Chapman	Kosciusko	1.9	4.4	2.3	30	16	362	19.2	60
Big Long	LaGrange	1.3	2.4	1.8	27	13.5	23	23.0	61
Cedar	Lake	36.3	56.1	56.1	62	117	164	117.0	72
Center	Kosciusko	1.3	3.5	2.0	28	14	23	15.0	58
Clear	LaPorte	1.3	49.3	7.0	41	24	127	29.4	63
Cordry	Brown	1.3	1.4	1.3	24	7	13	8.8	54
Crooked	Noble	1.3	1.9	1.6	26	10	26	13.0	57
Flat	Marshall	2.3	34.5	9.3	44	30.5	88	64.0	68
Flint	Porter	1.6	5.2	2.9	32	12	29	13.9	57
Galbraith	Marshall	15.5	39.5	18.6	51	20	81	27.2	62
Griffy	Monroe	1.3	5.0	5.0	37	5.02	20	10.0	55
Hogback	Steuben	3.6	25.5	14.2	n/a	39	65	39.0	n/a
Holiday	Montgomery	6.4	47.8	43.0	59	36	125	73.3	69
Holiday	Lake	2.1	14.1	5.4	38	44	75	47.8	66
Indiana	Elkhart	1.3	1.6	1.5	25	10	13	11.4	56
James	Kosciusko	2.2	5.2	3.3	33	17	27.5	17.5	59
James	Steuben	1.3	1.3	1.3	24	10	14	11.8	56
Koontz	Starke	11.6	16.6	13.8	48	37	42	38.5	64
Lake of the Woods	Marshall	6.9	45.6	17.8	50	33	81	39.4	65
Lake of the Woods	LaGrange	1.3	3.1	2.0	28	12	23	12.0	56
Little Chapman	Kosciusko	8.0	14.2	10.4	45	8.74	123	10.4	55
Little Crooked	Whitley	4.5	55.5	5.2	38	28	227	30.9	63
Little Turkey	LaGrange	*	*	*	n/a	10	20	10.0	55
Manitou	Fulton	3.2	6.9	5.8	39	27	31	28.5	62
Martin	LaGrange	1.5	4.8	1.6	26	12	243	243.0	77

Lake Name	County	Chlorophyll - *a* Min (ug/L)	Max (ug/L)	July/ Aug Mean (ug/L)	Carlson 's Chl-*a* TSI	Total Phosphorus Min (ug/L)	Max (ug/L)	July/ Aug Mean (ug/L)	Carlso n's Phos. TSI
Maxinkuckee	Marshall	1.3	2.0	1.7	26	7	13	8.8	54
McClish	Steuben	1.3	1.3	0.0	n/a	13	26	0.0	n/a
Nyona	Fulton	14.2	20.6	0.0	n/a	49	55	*	n/a
Ole Swimming Hole	Morgan	5.1	25.6	21.1	52	29	57	53.9	67
Olin	LaGrange	1.3	1.3	*	n/a	6	12	12.0	56
Oliver	LaGrange	1.9	2.7	*	n/a	9.5	18.5	10.0	55
Oswego	Kosciusko	1.3	1.8	1.5	26	8	34	11.3	56
Silver	Steuben	1.3	29.9	7.5	41	13	19	14.9	58
Sweetwater	Brown	1.3	1.3	1.3	24	7	16	8.4	54
Syracuse	Kosciusko	1.4	2.0	1.5	26	16	23	19.8	60
Tippecanoe	Kosciusko	1.3	7.6	3.2	33	12.5	26	12.7	57
Wawasee	Kosciusko	1.3	38.7	14.1	48	16	20	18.4	59
*** no data**	**Totals**								
	2010 Minimum	1.3	1.3	0.0	24.1	5.0	12.0	0.0	54.0
	2010 Maximum	36.3	73.7	56.1	61.6	120.0	426.0	336.6	79.2
	2010 Average	4.5	17.1	9.4	37.3	23.4	72.1	39.5	60.9

Table 7. Chlorophyll *a* and Total Phosphorus Summary Data 2011.

Lake Name	County	Chlorophyll - *a* Min (ug/L)	Chlorophyll - *a* Max (ug/L)	Chlorophyll - *a* July/ Aug Mean (ug/L)	Chlorophyll - *a* Carlson's Chl-*a* TSI	Total Phosphorus Min (ug/L)	Total Phosphorus Max (ug/L)	Total Phosphorus July/ Aug Mean (ug/L)	Total Phosphorus Carlson's Phos. TSI
Barton	Steuben	1.5	1.9	1.6	26	14	24	17.1	59
Big	Noble	2.5	15.3	2.5	30	27	27	27.0	62
Big Bass	Porter	17.5	86.8	57.3	62	80	201	186.5	75
Big Chapman	Kosciusko	2.8	4.1	3.5	34	10	36	10.0	55
Big Long	LaGrange	1.3	4.5	1.8	27	21	37	21.0	60
Cedar	Lake	89.0	110.2	99.3	67	117	267	260.9	77
Center	Kosciusko	1.6	6.0	2.7	31	11	27	14.1	58
Clear	LaPorte	5.3	6.9	6.0	39	20	25	22.4	61
Clear	Steuben	1.3	3.7	2.6	31	13	26	18.4	59
Cordry	Brown	1.3	7.9	1.3	24	10	20	10.0	55
Crooked	Noble	2.1	5.2	4.4	36	13	38	13.0	57
Flat	Marshall	8.7	38.6	29.7	55	33	90	33.0	63
Flint	Porter	5.3	19.6	10.2	45	11	33	18.8	60
Galbraith	Marshall	22.9	66.8	29.7	55	33	155	33.0	63
Griffy	Monroe	2.0	3.2	3.2	33	10	127	127.0	73
Hogback	Steuben	25.6	60.1	39.2	58	32	55	42.0	65
Holiday	Lake	1.3	14.9	9.7	44	37	54	48.2	66
Holiday	Montgomery	2.8	45.8	42.1	59	72	83	72.0	69
Indiana	Elkhart	1.3	1.7	1.6	26	10	26	10.0	55
Irish	Kosciusko	4.6	18.3	9.2	43	16	33	20.0	60
James	Kosciusko	3.0	15.6	5.2	38	10	38	10.0	55
James	Steuben	1.3	2.3	1.4	24	10	22	21.5	60
Koontz	Starke	2.8	77.0	58.9	62	20	40	21.6	60
Lake of the Woods	LaGrange	2.3	4.6	3.3	33	13	76	16.0	58

Lake Name	County	Chlorophyll - *a* Min (ug/L)	Max (ug/L)	July/ Aug Mean (ug/L)	Carlson's Chl-*a* TSI	Total Phosphorus Min (ug/L)	Max (ug/L)	July/ Aug Mean (ug/L)	Carlson's Phos. TSI
Lake of the Woods	Marshall	7.5	23.1	13.0	47	36	60	39.3	65
Lamb	Johnson	4.1	6.3	5.4	38	26	33	26.0	62
Little Chapman	Kosciusko	7.7	25.6	8.2	42	18	89	19.9	60
Little Crooked	Whitley	3.2	16.3	3.2	33	21	48	27.5	62
Little Turkey	LaGrange	*	*	*	n/a	27	34	27.0	62
Long	Porter	2.6	7.6	5.4	38	10	13	10.5	56
Loomis	Porter	17.2	31.0	27.9	55	25	40	31.6	63
Manitou	Fulton	8.1	16.9	12.3	46	36	85	39.3	65
Martin	LaGrange	1.3	6.3	1.3	24	10	33	10.0	55
Maxinkuckee	Marshall	2.1	4.6	3.3	33	10	28	10.0	55
McClish	Steuben	1.3	13.9	1.3	24	13	73	21.6	60
Nyona	Fulton	6.7	55.9	15.0	48	47	100	53.5	67
Ole Swimming Hole	Morgan	3.2	29.4	18.7	51	30	48	43.5	65
Olin	LaGrange	1.3	2.8	2.0	28	10	24	10.0	55
Oliver	LaGrange	1.3	9.5	2.1	29	10	13	10.0	55
Oswego	Kosciusko	2.4	13.1	5.6	39	10	27	10.0	55
Silver	Steuben	1.4	4.0	2.4	30	13	30	13.0	57
Skinner	Noble	6.4	44.9	28.6	55	48	64	56.6	67
Sweetwater	Brown	1.3	2.8	1.4	25	10	23	11.4	56

Lake Name	County	Chlorophyll - *a*				Total Phosphorus			
		Min (ug/L)	Max (ug/L)	July/ Aug Mean (ug/L)	Carlson 's Chl-*a* TSI	Min (ug/L)	Max (ug/L)	July/ Aug Mean (ug/L)	Carlso n's Phos. TSI
Syracuse	Kosciusko	2.6	8.6	3.5	34	10	20	11.4	56
Tippecanoe	Kosciusko	3.1	14.4	6.7	40	10	24	11.8	56
Wawasee	Kosciusko	1.3	9.5	7.5	41	10	30	10.0	55
West Otter	Steuben	1.3	1.3	1.3	24	13	13	13.0	57
Whippoorwil l	Morgan	12.8	45.3	24.1	53	20	54	39.6	65
*** no data**	**Totals**								
	2010 Minimum	1.3	1.3	1.3	24.1	10.0	13.0	10.0	55.2
	2010 Maximum	89.0	110.2	99.3	67.3	117.0	267.0	260.9	77.4
	2010 Average	6.6	21.6	13.3	39.6	23.3	53.5	34.0	60.8

APPENDIX C:

Example Dissolved Oxygen and Temperature Report Sent to Volunteer Lake Monitors

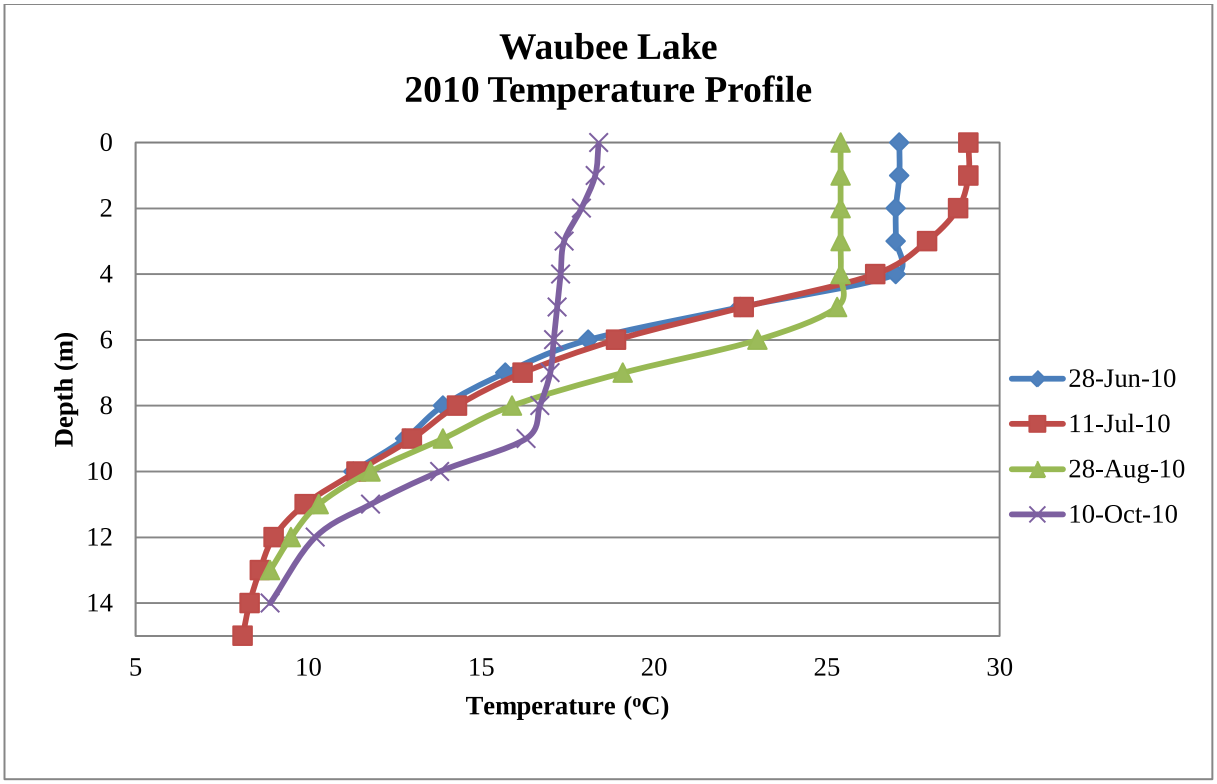
Waubee Lake, Kosciusko County - 2010
Mike West

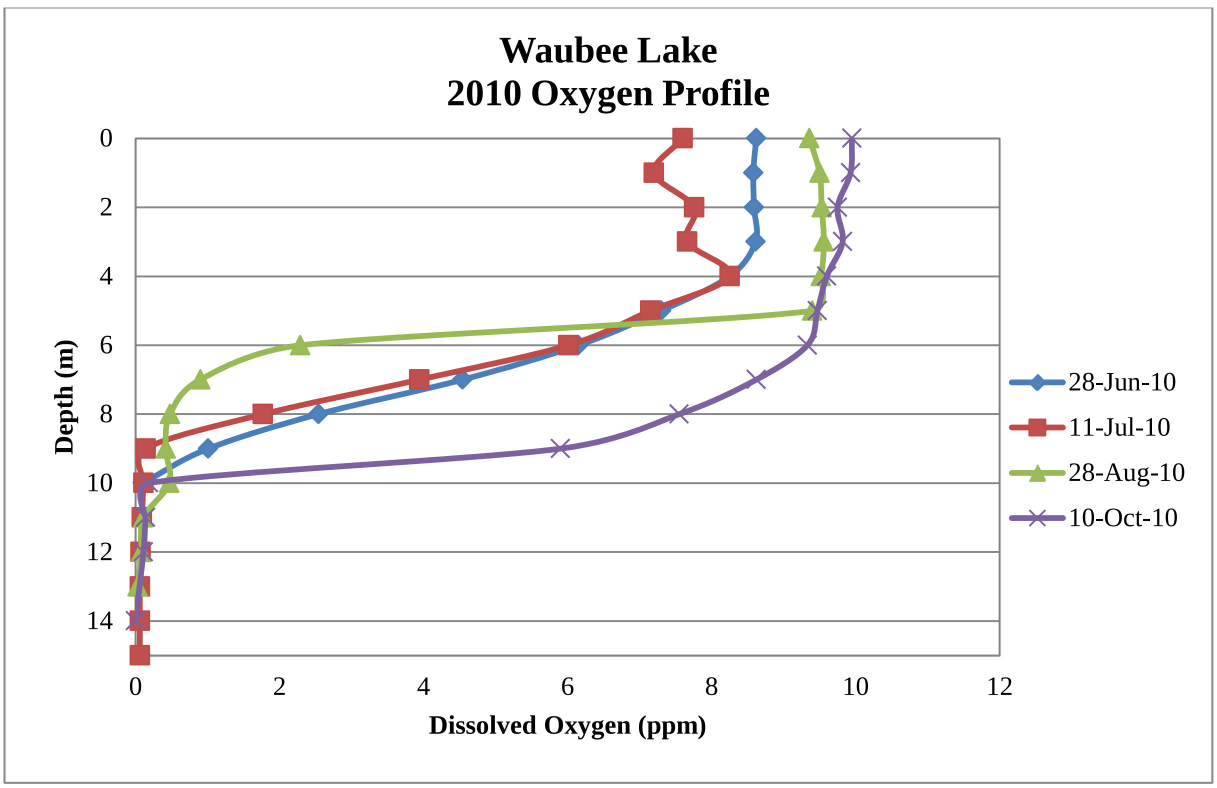
	28-Jun-10		11-Jul-10		28-Aug-10		10-Oct-10	
Depth (m)	Temp (°C)	D.O. (ppm)	Temp (°C)	D.O. (ppm)	Temp (°C)	D.O. (ppm)	Temp (°C)	D.O. (ppm)
Surface	27.1	8.62	29.1	7.6	25.4	9.36	18.4	9.95
1	27.1	8.58	29.1	7.2	25.4	9.5	18.3	9.93
2	27	8.59	28.8	7.76	25.4	9.53	17.9	9.75
3	27	8.61	27.9	7.66	25.4	9.56	17.4	9.82
4	27	8.25	26.4	8.25	25.4	9.52	17.3	9.6
5	22.5	7.3	22.6	7.15	25.3	9.4	17.2	9.47
6	18.1	6.15	18.9	6.01	23	2.29	17.1	9.33
7	15.7	4.54	16.2	3.94	19.1	0.9	17	8.62
8	13.9	2.54	14.3	1.77	15.9	0.48	16.7	7.55
9	12.8	1.01	13	0.14	13.9	0.42	16.3	5.9
10	11.3	0.1	11.4	0.11	11.8	0.47	13.8	0.18
11	--	--	9.9	0.09	10.3	0.11	11.8	0.14
12	--	--	9	0.07	9.5	0.08	10.2	0.11
13	--	--	8.6	0.06	8.9	0.03	--	--
14	--	--	8.3	0.06	--	--	14	0
15	--	--	8.1	0.06	--	--	--	--

Waubee Lake (Kosciusko)

TEMPERATURE: Waubee Lake exhibited signs of thermal stratification from June 28th through August 28th, which is demonstrated by the three semi-distinct layers (epilimnion, metalimnion, and hypolimnion). The metalimnion (middle layer) represents a barrier to mixing between the top and bottom layers due to density differences of the water at different temperatures. The October temperature profile indicated that Waubee Lake is beginning to turnover as the upper 9 m are almost 10°C cooler than the late August readings.

DISSOLVED OXYGEN: The oxygen levels in Waubee Lake also suggest that the lake is stratified. The epilimnion remained oxygenated from June through October, however, the concentration of dissolved oxygen declined into the hypolimnion. Oxygen in the epilimnion is produced by algal photosynthesis and diffusion by the air. Hypoxic conditions occur when the dissolved oxygen concentration is depleted to below 2 to 3 parts per million (ppm). The hypolimnion of Waubee Lake was hypoxic from June through October. Most organisms cannot live under these conditions. The hypoxic area is, in part, a result of the bacteria in the hypolimnion consuming oxygen to decompose the organic material (algae, fish, leaves, etc) that has fallen to the bottom of the lake. Further, the lack of light at greater depths prevents algae from photosynthesizing (and producing more oxygen). The initial stages of fall turnover are seen in the oxygen profile: as the depth increases, the concentration of dissolved oxygen does not decline as rapidly.


Waubee Lake
2010 Temperature Profile
Depth (m)
0
2
4
6
8
10
12
14
5
10
15
20
25
30
Temperature (ºC)
28-Jun-10
11-Jul-10
28-Aug-10
10-Oct-10


Waubee Lake
2010 Oxygen Profile
Depth (m)
0
2
4
6
8
10
12
14
0
2
4
6
8
10
12
Dissolved Oxygen (ppm)
28-Jun-10
11-Jul-10
28-Aug-10
10-Oct-10