Indiana Volunteer Lake Monitoring Report: 2019-2022

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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.

2019-2022 Primary Volunteers by County

BROWN COUNTY

Quinn Hetherington	Cordry Lake
David Jarrett	Sweetwater Lake

CARROLL COUNTY

Shannon O'Farrell	Freeman Lake

ELKHART COUNTY

Dan Ganger	Indiana
Lesa Hershberger	Simonton

FULTON COUNTY

Ray Dausman	Lake Manitou
Mark Koten	Lake Manitou
Robert Zawacki	Town

GIBSON COUNTY

Brad Smith	Long Pond

GREENE COUNTY

William Jones	Airline Lake

JOHNSON COUNTY

Tom Houghman	Lamb Lake
Barbara Spaans	Peoga Lake

KNOX COUNTY

Brad Smith	Washington, Long Pond Anson's, Long Pond Knox, Half Moon

KOSCIUSKO COUNTY

Fran Allen	Syaracuse Lake
Daniel Berkey	Lake Wawasee
Chuck Brinkman	Irish Lake
Ron Chambers	James, Oswego, & Tippecanoe Lake
Kyle Flumbaum	Webster Lake
Debra Hutnick	Palestine Lake
Lisa Llewellyn	Waubee Lake
Dawn Meyer	Webster Lake
Doug Morris	
Jim Nichols	Winona Lake
Diane Tulloh	Lake Papakeechie
Troy Turley	Center Lake
Jerferson Vangundy	Webster
Tina Wielgot	

LAGRANGE COUNTY

Jonathan Barnes	Little Turkey Lake
Don Bonistalli	Witmer Lake
Lynn Bowen	Martin, Olin, & Oliver Lakes
John Chapo	Little Turkey Lake
Tom Henry	Big Turkey Lake
Michael James	South Twin Lake
Richad Kelly	Wall Lake
Christopher Koop	Adams Lake
Don Merton	North Twin & South Twin Lakes
Beth Sholly	Shipshewana
Jim Simish	Wall Lake
Steve Singer	Big Long Lake
Jolyn Strahm	Fish and Royer Lake

LAKE COUNTY

Bill Conaty	Dalecarlia Lake

George Hamnik	Double Tree
Mandy Komorowski	
Mike Talley	Holiday

LAPORTE COUNTY

Don Lode	Hog & Saugany Lakes

MARION COUNTY

Debra Osborn	Lake Clearwater
Toby Stone	Lake Clearwater
Bella Realey	Eagle Creek

MARSHALL COUNTY

Dan Baughman	Lake Maxinkuckee
Margaret Bonen	Cook Lake
William Harris	Lost Lake
Joe Skelton	Flat, Galbraith, & Lake of the Woods
Elizabeth Symon	Flat & Galbraith Lakes
Adam Thada	Flat & Galbraith Lakes

MONROE COUNTY

Michael Chitwood	University Lake
Allison DeVries	Griffy Lake
Richard Harris	Lake Monroe (Upper & Lower)
Rebecca Jania	Griffy Lake
Nathan Smalley	Griffy Lake
Rebecca Swift	Griffy Lake

MONTGOMERY COUNTY

Denise Carnall	Lake Holiday
Roger Dieckmeyer	Lake Holiday

MORGAN COUNTY

Amran Ahmand	Ole Swimming Hole
Tim Street	Ole Swimming Hole
Brigitte Schoner	Whippoorwill Lake

NOBLE COUNTY

Chuck Farris	Crooked Lake
John Klaassen	Sylvan Lake
Ryan Klaassen	Sylvan Lake
Nancy Lough	Skinner Lake
Nick Stranger	Knapp Lake

PORTER COUNTY

Alicai Barber	Flint Lake
Dan Fee	Lake Louise
Robert Minarich	Flint, Long, & Loomis Lake
Mike Talley	Big Bass Lake
Sharon Goodall	

POSEY

Brad Smith	Pitcher, Ribeyre, Greathouse, & Mackey Lake

STARKE COUNTY

Tom Camire	Koontz Lake
Phil Woolery	Bass Lake

STEUBEN COUNTY

Mike Ebersole	Silver Lake
Bridget Harrison	Clear Lake
Peter Hudson	Lake Gage
Amber Kimmel	Lake James
Marjorie Lilley	Ball Lake
Walter Lilley	Ball Lake
Dennis Mahuren	Lake George
Mike Marturello	Snow Lake
Jim Shiffler	Long (Clear) Lake
John Williamson	West Otter Lake

WHITE COUNTY

Shannon O'Farrell	Shafer Lake

WHITLEY COUNTY

Bob Chambers	Little Cedar
Bob Chapman	Big and Little Cedar, Round, & Shriner Lake
Chuck Farris	Little Crooked Lake
Denise Heckman	Goose Lake
Bill MacDonald	Old Lake

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DESCRIPTION OF PROGRAM

The Indiana Volunteer Lake Monitoring Program (VLMP) was created in 1989 as a component of the Indiana Clean Lakes Program (INCLP) administered through the Indiana Department of Environmental Management (IDEM). Indiana University's O'Neill School of Public and Environmental Affairs (O'Neill) implements the program through a grant from IDEM. The INCLP is a comprehensive, statewide public lake monitoring 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 VLMP was created to accomplish four main objectives:

1. Collect water quality data to contribute to the understanding of Indiana lakes;
2. Monitor water quality changes to provide an early warning for in-lake problems;
3. Encourage citizen involvement in protection and management of lakes;
4. Provide a means for Indiana citizens to learn more about lake ecology and management.

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

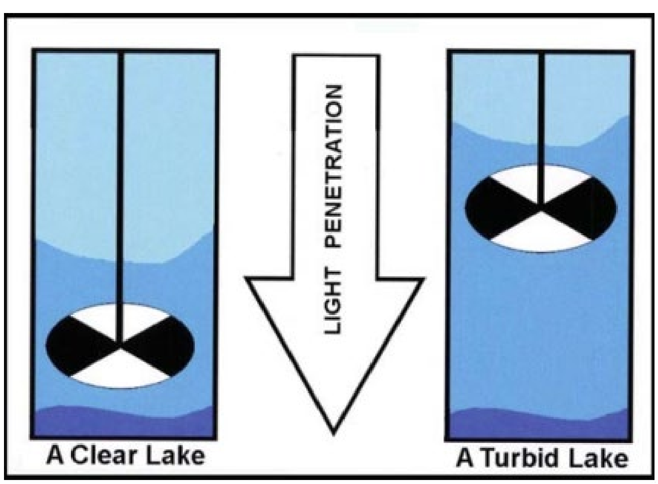


Figure 1 Secchi disk and water quality.

A subset of volunteers collect water samples for total phosphorus, total nitrogen, and chlorophyll *a* analyses through the Expanded Program. Phosphorus is the primary limiting nutrient required for growth by algae and aquatic plants; therefore, most lake management programs measure phosphorus concentrations. Nitrogen is the second most impactful nutrient that is added to lakes through sediment and fertilizer. Chlorophyll *a* is the primary green pigment in algae and is a direct measure of algal production.

Dissolved oxygen and temperature meters are 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 is consumed by the respiration of oxygen-breathing aquatic organisms (fish) and through bacterial decomposition. 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 can affect where aquatic organisms can live in lakes.

Additional efforts are made to educate volunteers and citizens on aquatic invasive species. The addition of aquatic plant monitoring and zebra mussel early detection were added in 2012. Citizen education and engagement has been the primary success of the program.

MATERIALS AND METHODS

All volunteers are given a training manual, access to online data entry, paper data forms, and a Secchi disk with a calibrated measuring tape. Secchi disks are painted and assembled by INCLP staff.

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 Secchi depth measurements, volunteers assign a color to the water. Volunteers choose from a list of: Clear, Clear/Blue, Blue/Green, Blue/Brown, Green, Brown, or Green/Brown. The color selected is the best match to the lake and choices provided. Volunteers qualitatively select a recreational potential and physical appearance of the lake for the day they are monitoring. Data is submitted to INCLP staff electronically or in the form of paper data sheets: https://clp.indiana.edu/.

Volunteers collect temperature and dissolved oxygen data using meters that can be checked out from INCLP or local soil and water conservation district offices. Temperature and dissolved oxygen change with the seasons; volunteers are encouraged to take monthly profile measurements lake.

Volunteers participating in the Expanded Program collect samples for chlorophyll *a*, total nitrogen, 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 provided with a kit, including a PVC 2-meter integrated water column sampler, filters, forceps, a filtering apparatus, hand-held vacuum pump, a pitcher, sample bottles, a storage tote, a Styrofoam mailer, prepaid express mail tags, and an expanded program manual. Phosphorus and nitrogen samples are poured into 125 ml polyethylene bottles and then frozen. A known volume of lake water is filtered through a glass-fiber filter (Whatman GF-F) to trap the algae to analyze for chlorphyll *a*. 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 Limnology lab in Bloomington for analysis by INCLP staff.

Many of the volunteers monitor lake level. This data is shared with the Department of Natural Resources. While INCLP does not provide analysis of this data, it does collect this information.

The aquatic invasive species monitoring program acts as an early detection system for new aquatic invasive plants in Indiana. We train volunteers in workshops lasting 2-3 hours. Volunteers are asked to observe aquatic plants on their lake or in specified areas and report time spent to INCLP staff. In the event that the volunteers find one of the targeted invasive species of concern, including assessment of the zebra mussel artificial substrate, they are encouraged to send it to INCLP staff for positive identification.

VOLUNTEER RECRUITMENT

Volunteers are recruited via statewide news releases, announcements online, word of mouth, information booths at the annual Indiana Lake Management Conference, and the INCLP website (https://clp.indiana.edu/). New volunteers are trained around the state at individual or group training sessions with INCLP staff.

Citizens are critical to the success of the VLMP. 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 lakes as a valuable ecological and recreational asset and share an interest in protecting or improving water quality. Many volunteers are actively involved in lake or conservation associations and participate in lake management decisions. By participating in the VLMP, volunteers become better stewards and spokespersons for lakes.

Program Growth

The VLMP began in 1989 with 41 volunteers taking measurements on 51 lakes. From 2019 to 2022, 1,750 observations were made on 112 lakes in Indiana. From 2019 to 2022, 68 volunteers were trained to monitor lakes. Over the past 4 years we have seen a decrease in the number of lakes reporting and observations made on individual lakes. However, we have had higher community outreach and connection with training more individuals. Retention of volunteers is low at this time. The expanded volunteer monitoring program was at maximum participation during this same time. The decline in Secchi monitoring is primarily from volunteers retiring and not having a replacement or lakes not reporting data. The total number of lakes sampled and observations made in the VLMP 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	438	37	131
2009	93	568	42	158
2010	80	578	40	144
2011	78	537	48	176
2012	85	561	48	182
2013	78	509	44	153
2014	78	617	36	123
2015	73	593	45	158
2016	75	597	48	181
2017	71	483	51	183
2018	75	455	54	191
2019	88	461	53	200
2020	80	394	59	195
2021	57	379	51	194
2022	66	409	57	202

THE LAKES

Lakes can be classified based on how they were formed, where they are located (ecoregion) and physical characteristics (depth, surface area, etc.).

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. Most of these lakes were formed by glacial activity and 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, limestone is prevalent and lakes were formed in basins created by the solution of the 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. Seventy-four of the monitored lakes are natural lakes, thirteen are impoundments, and two are surface mine lakes.

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 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 among these land types and their lakes. Overall, six ecoregions are located within the state of Indiana (Figure 2). Five of these contain lakes sampled in the Volunteer Monitoring Program during the 2019-2022 sampling seasons (Figure 3). Characteristics of Level III ecoregions within Indiana, as described by Omernik and Gallant (1988), are described in Table 2.

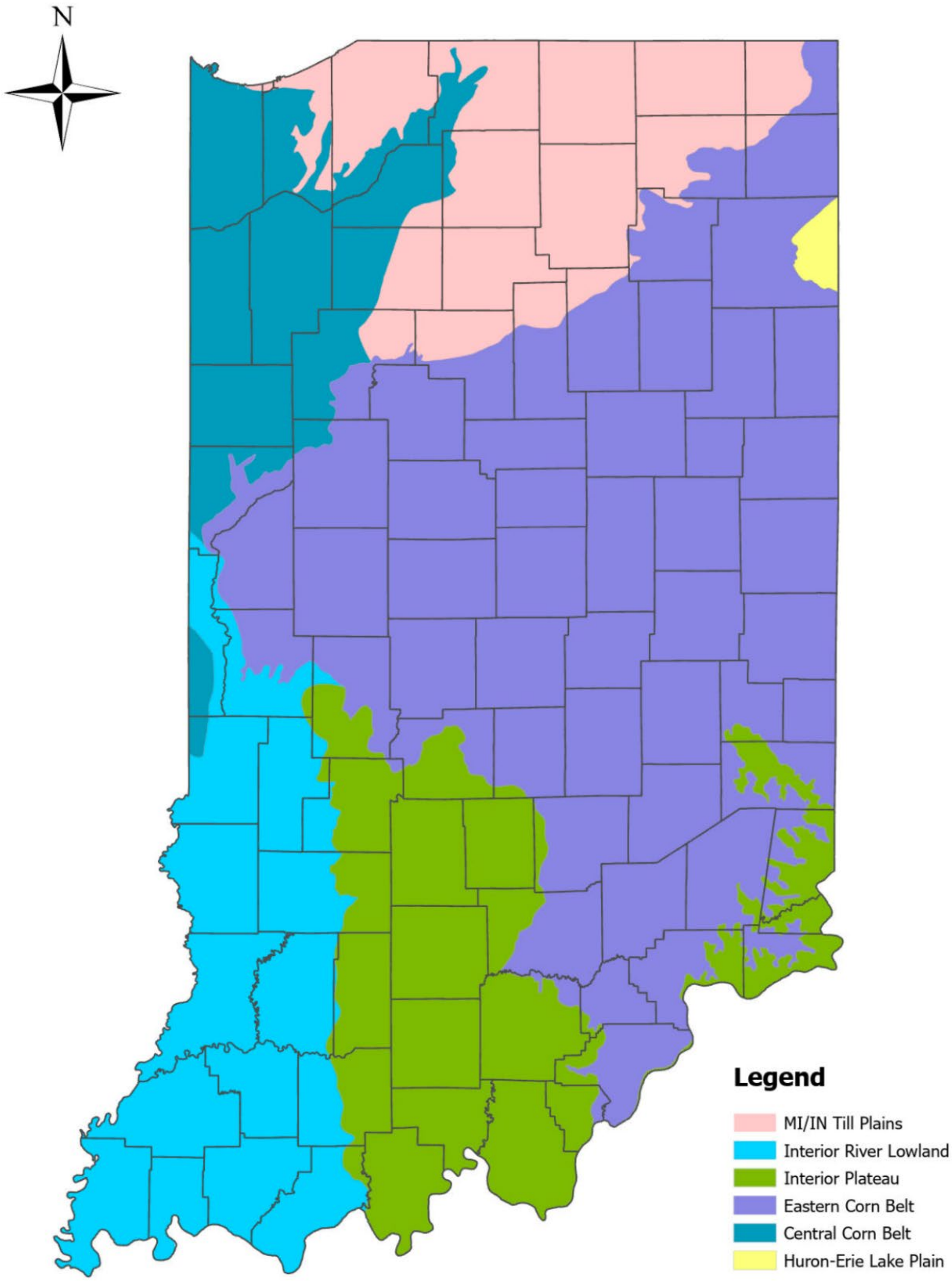


Figure 2. Level III ecoregions in Indiana. After: Omernik and Gallant (1988).

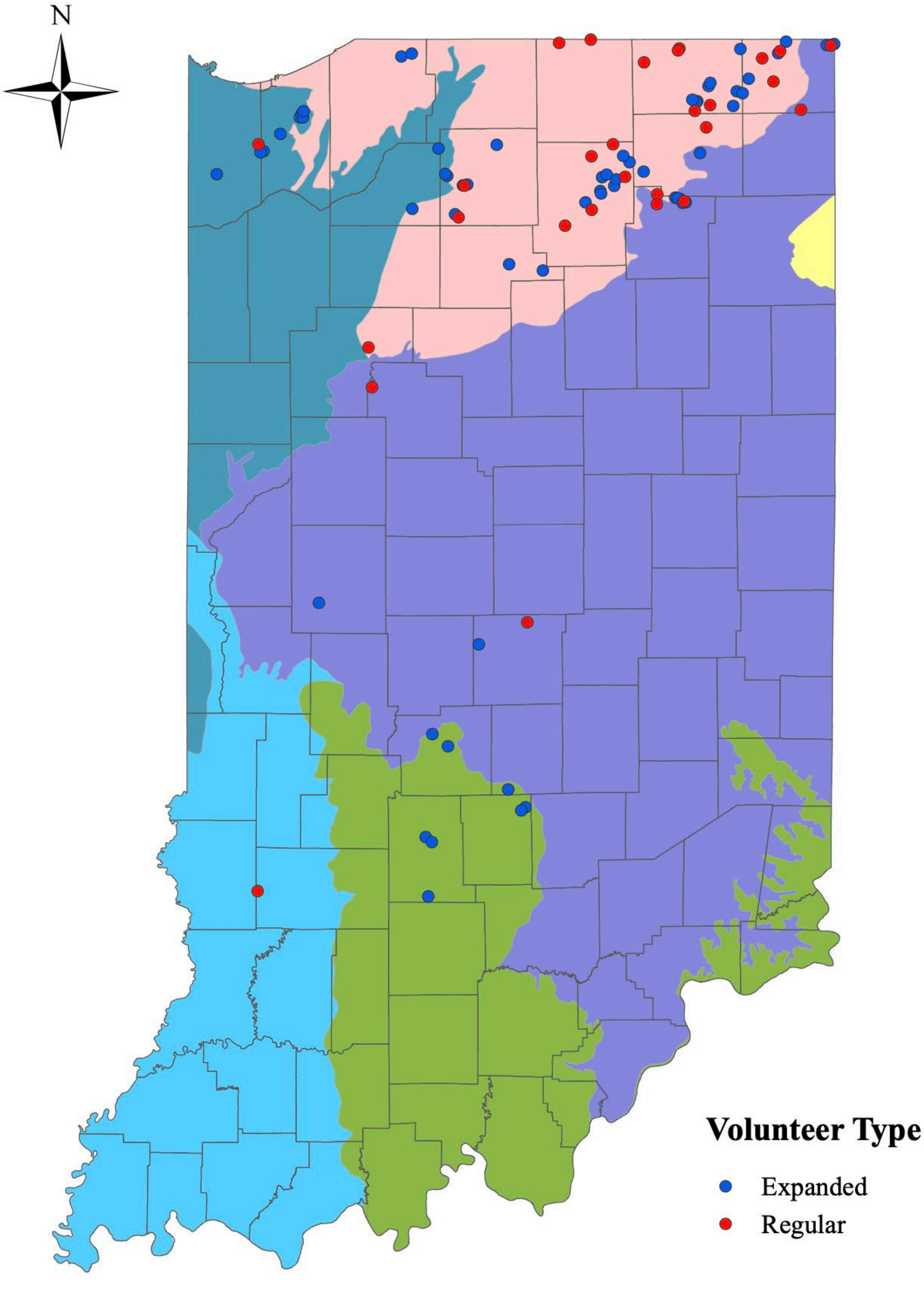


Figure 3. 2022 Volunteer Lakes by Level III Ecoregions in Indiana.

Table 2. Indiana Level III ecoregion characteristics and summary statistics for associated lakes sampled in the 2019-2022 as part of the Indiana Clean Lakes Volunteer Monitoring Program.

54 – Central Corn Belt Plains	
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 (2019-22)	11
Maximum Surface Area	346 acres
Maximum Depth	67 feet
Median Secchi Disk Transparency	3.9 feet
Number of Expanded Lakes	10
Median Total Phosphorus Concentration	40 µg/L
Median Total Nitrogen Concentration	924 µg/L
Median Chlorophyll-a Concentration	13 µg/L

55 – Eastern Corn Belt Plains	
Gently rolling glacial till plain broken by moraines and outwash plains. This ecoregion supports a diverse hardwood forest, and approximately 75% is currently in cropland, primarily corn and soybeans. This ecoregion has few natural lakes or reservoirs.	
Number of Lakes in Program (2019-22)	5
Maximum Surface Area	1547 acres
Maximum Depth	66 feet
Median Secchi Disk Transparency	2.9 feet
Number of Expanded Lakes	2
Median Total Phosphorus Concentration	75 µg/L
Median Total Nitrogen Concentration	1203 µg/L
Median Chlorophyll-a Concentration	42 µg/L

56 – Southern Michigan/Northern Indiana Drift Plains	
25,800 square-mile ecoregion including 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 (2019-22)	65
Maximum Surface Area	2618 acres

Maximum Depth	123 feet
Median Secchi Disk Transparency	7.6 feet
Number of Expanded Lakes	50
Median Total Phosphorus Concentration	22 µg/L
Median Total Nitrogen Concentration	792 µg/L
Median Chlorophyll-a Concentration	7.6 µg/L

57 – Huron/Erie Lake Plains	
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 region is urbanized. There are few lakes or reservoirs in this ecoregion.	
Number of Lakes in Program (2019-22)	0

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 (2019-22)	7
Maximum Surface Area	10750 acres
Maximum Depth	110 feet
Median Secchi Disk Transparency	7.15 feet
Number of Expanded Lakes	7
Median Total Phosphorus Concentration	18 µg/L
Median Total Nitrogen Concentration	403.5 µg/L
Median Chlorophyll-a Concentration	3 µg/L

72 – Interior River Valleys and Hills Ecoregion	
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 (2019-22)	1

Maximum Surface Area	24 acres
Maximum Depth	68 feet
Median Secchi Disk Transparency	20.55 feet
Number of Expanded Lakes	0
Median Total Phosphorus Concentration	NA
Median Total Nitrogen Concentration	NA
Median Chlorophyll-a Concentration	NA

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. Monroe Reservoir in Monroe County had the largest surface area of lakes in the program, 10,750 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 2,617 acres and 1,853 acres respectively. Conversely, the smallest lake, University Lake in Monroe County, at 8 acres is an impoundment. The smallest natural lake is still Little Crooked Lake in Whitley county at 11 acres. The majority of the monitored lakes are less than 500 acres in surface area (Figure 4).

Lake depths spanned an order of magnitude. The deepest monitored lake was Lake Tippecanoe in Kosciusko County at 123 feet, while Lost Lake in Marshall County and Lake Dalecarlia in Lake County were the shallowest lakes at 4.8 feet (Figure 5). Unsurprisingly, the deepest lake, Tippecanoe, is a natural lake. The smallest lakes consisted of an impoundment, Dalecarlia, but also, a natural lake, Lost. This is another example of the expanse of lake types throughout Indiana.

Size of monitored lakes' watersheds also varied greatly. Lake Freeman in Carroll County had the largest watershed, 464,126 hectares. Indiana Lake in Elkhart County had the smallest watershed, 161 hectares. The majority of the lakes in the program have watersheds between 2000 and 5000 hectares in size (Figure 6). This is an increase from the last reporting period where most lakes fell within the 500 to 2000 hectare watershed size.

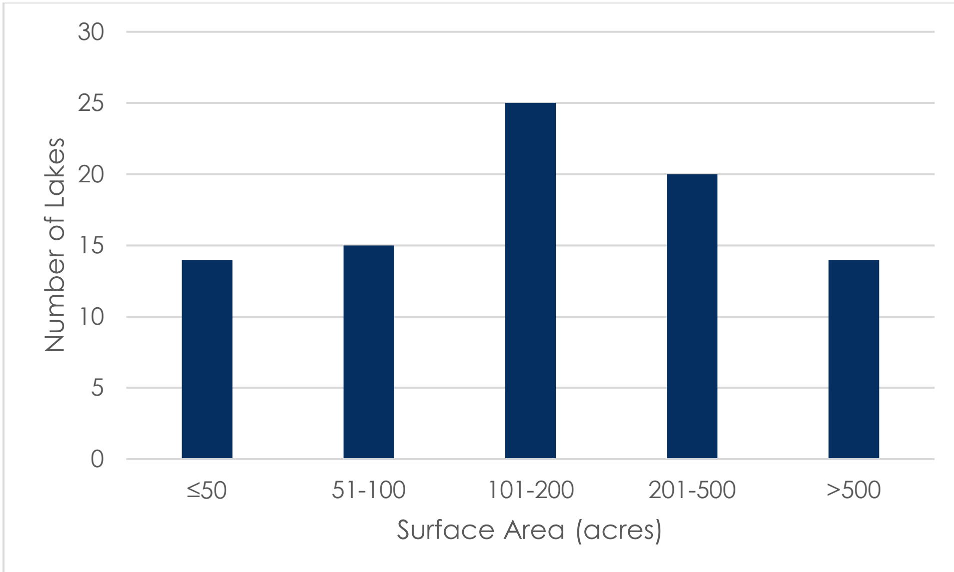


Figure 4. Size distribution of lakes in the Indiana Clean Lakes Volunteer Monitoring Program.

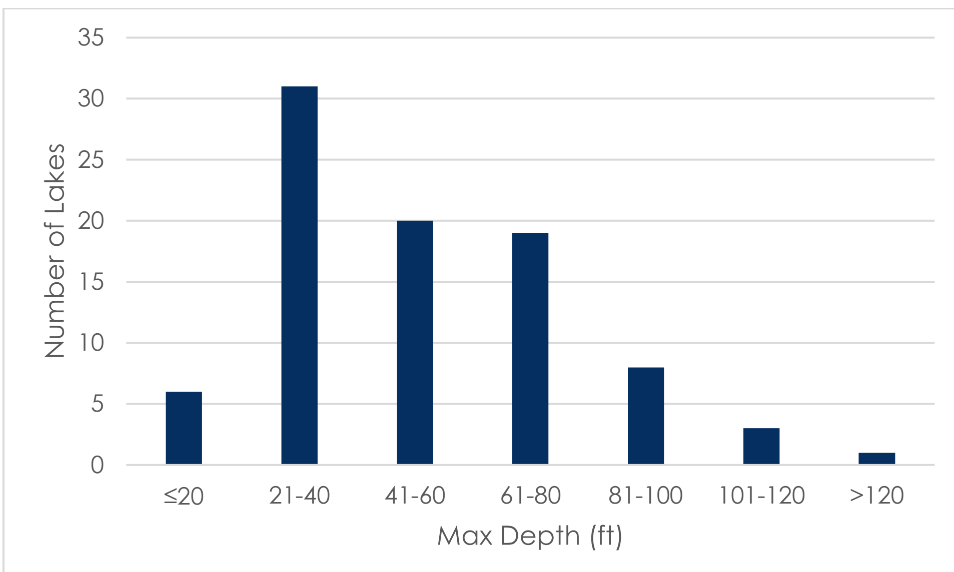


Figure 5. Depth distribution of lakes in the Indiana Clean Lakes Volunteer Monitoring Program.

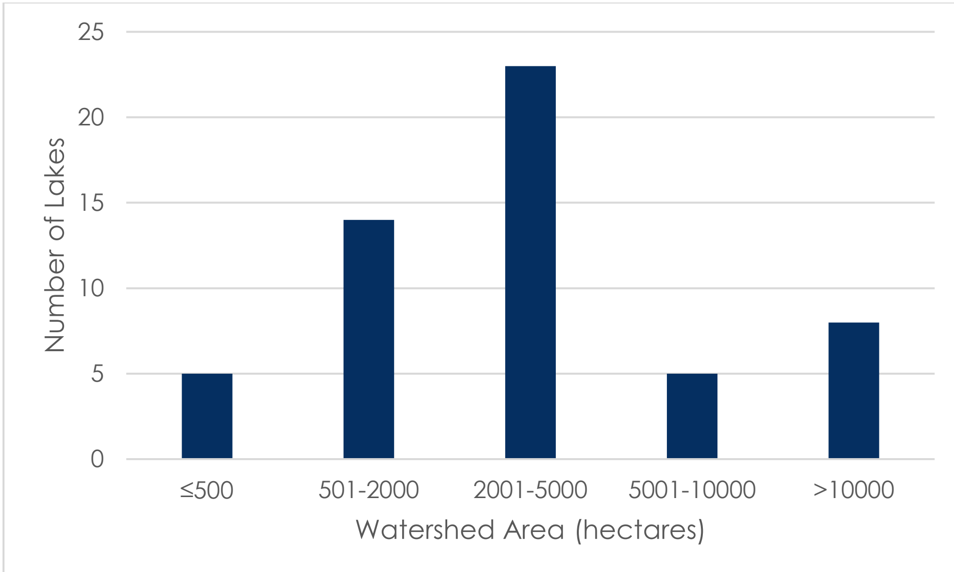


Figure 6. Watershed area distribution for lakes in the Indiana Clean Lakes Volunteer Monitoring Program.

CARLSON'S TROPHIC STATE INDEX

To analyze all the data collected, it is helpful to use an index to normalize the data across many parameters. The most widely used and accepted lake trophic state index (TSI) is Carlson's TSI 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 the basis for the Carlson TSI. Using this method, a TSI score can be generated for each of the three measurements. Carlson TSI scores 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 are used to make predictions on the others.

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 be assessed using the TSI score for one or more parameters (Figure 7).

As an example, 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 7). 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.

It is important to note that the Carlson TSI does not apply equally to all lakes. The relationship between transparency, chlorophyll *a*, and total phosphorus can vary based on factors not observed in Carlson's study lakes. Indiana Lakes are generally more turbid as a result of sediment runoff compared to the lakes Carlson used in his model. High concentrations of suspended sediments will decrease transparency from the predicted value based on total phosphorus and chlorophyll *a* concentrations. Heavy predation of algae by zooplankton can cause chlorophyll *a* values to decrease from the levels that would be expected based on total phosphorus concentrations.

From 2019 to 2022 the lakes monitored were primarily split between mesotrophic and eutrophic lakes. Few lakes were classified as oligotrophic or hypereutrophic. Minimum and maximum TSI scores ranged from 31 to 81 for chlorophyll *a* (Table 3), 26 to 100 for total phosphorus (Table 4), and 32 to 87 for Secchi transparency (Table 5) during the grant period.

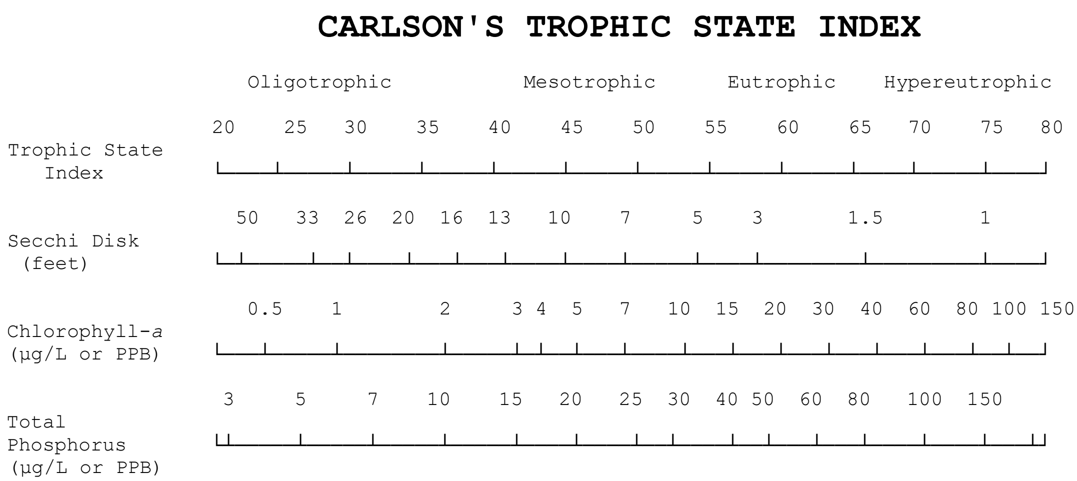


Figure 7. Carlson's Trophic State Index

Table 3. Minimum and maximum Carlson TSI scores for Chlorophyll a from 2019-2022 for lakes in the Indiana Clean Lakes Volunteer Monitoring Program

Chlorophyll a TSI Max or Min	Year	Lake	County	Score
Maximum	2019	Mackey	Posey	81
Minimum	2019	Cordry	Brown	31
Maximum	2020	Town	Fulton	74
Minimum	2020	Cordry	Brown	31
Maximum	2021	Long Pond Gibson	Gibson	77
Minimum	2021	Cordry	Brown	31
Maximum	2022	Dalecarlia	Lake	77
Minimum	2022	Sweetwater	Brown	31

Table 4. Minimum and maximum Carlson TSI scores for Total Phosphorus from 2019-2022 for lakes in the Indiana Clean Lakes Volunteer Monitoring Program

TP TSI Max or Min	Year	Lake	County	Score
Maximum	2019	Washington	Knox	91
Minimum	2019	Indiana	Elkhart	37
Maximum	2020	Holiday	Lake	76
Minimum	2020	Cordry	Brown	26
Maximum	2021	Greathouse	Posey	82
Minimum	2021	Oliver	Lagrange	30
Maximum	2022	Louise	Porter	100
Minimum	2022	Indiana	Elkhart	30

Table 5. Minimum and maximum Carlson TSI scores for Secchi disk transparency from 2019-2022 for lakes in the Indiana Clean Lakes Volunteer Monitoring Program

Secchi TSI Max or Min	Year	Lake	County	Score
Maximum	2019	Half Moon	Knox	87
Minimum	2019	Airline	Greene	33
Maximum	2020	Town	Fulton	71
Minimum	2020	Clearwater	Marion	33
Maximum	2021	Dalecarlia	Lake	76
Minimum	2021	Cordry	Brown	35
Maximum	2022	Bass	Starke	68
Minimum	2022	Clearwater	Marion	32

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. The July/August measurements are used for year-to-year comparisons for consistency. They also represent the “worst-case” scenario for lake conditions as they take into account factors including warm weather, lake stratification, algal blooms and heavy recreational use. Volunteers receive annual summary reports for individual lakes, which include the minimum, maximum, the July/August Secchi depth mean, and Carlson’s TSI. Volunteer monitors also receive an annual summary of all lakes in the program. Summary reports and raw data can be found online at https://clp.indiana.edu/.

The deepest Secchi depth in the 2019-2022 seasons was 32.1 feet at Clearwater Lake in Marion County in 2019. The next deepest measurement, also on Clearwater Lake but in 2020, was 26.7 feet.

Factors Affecting Lake Transparency

Anything that increases the amount of suspended material in the water affects the Secchi depth transparency. Decreased water transparency is related to increases 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. The location of the lakes, surrounding land use, basin morphometry, basin type, watershed size, ecoregion, and time of week when sampled can all influence transparency.

Variation in lake conditions and Secchi depth transparency can occur as a result from long term events or non-seasonal events. Non-seasonal events that can 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.
2. Localized storms, droughts, or other variable weather events.
3. Major lake events that occur only once every few years, for example, weed treatments or channel dredging.

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 2019-2022 help support this premise. Median Secchi depth transparency increases with increasing maximum depth (Figure 8). Potential bias in the data trends may be due to uneven distribution of measurements at lakes with different maximum depths.

Basin Type
Impoundments typically have lower Secchi depth transparencies than natural lakes due to their elongated shape (longer wind fetch), and larger watersheds. This results in greater water and sediment runoff. Median Secchi depths for 2019-2022 were lower for impoundments than natural lakes at 5.1 and 7.6 feet respectively (Figure 9). Surface mine lakes may not follow trends like manmade or natural lakes. The two lakes in this group had the highest median Secchi depth at 22.6 feet of other lake types.

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 10).

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. The median Secchi depth transparency was higher for lakes with a watershed less than 500 hectares (11.3 feet) and lower for those watersheds greater than 10000 hectares (6.2 feet) (Figure 11).

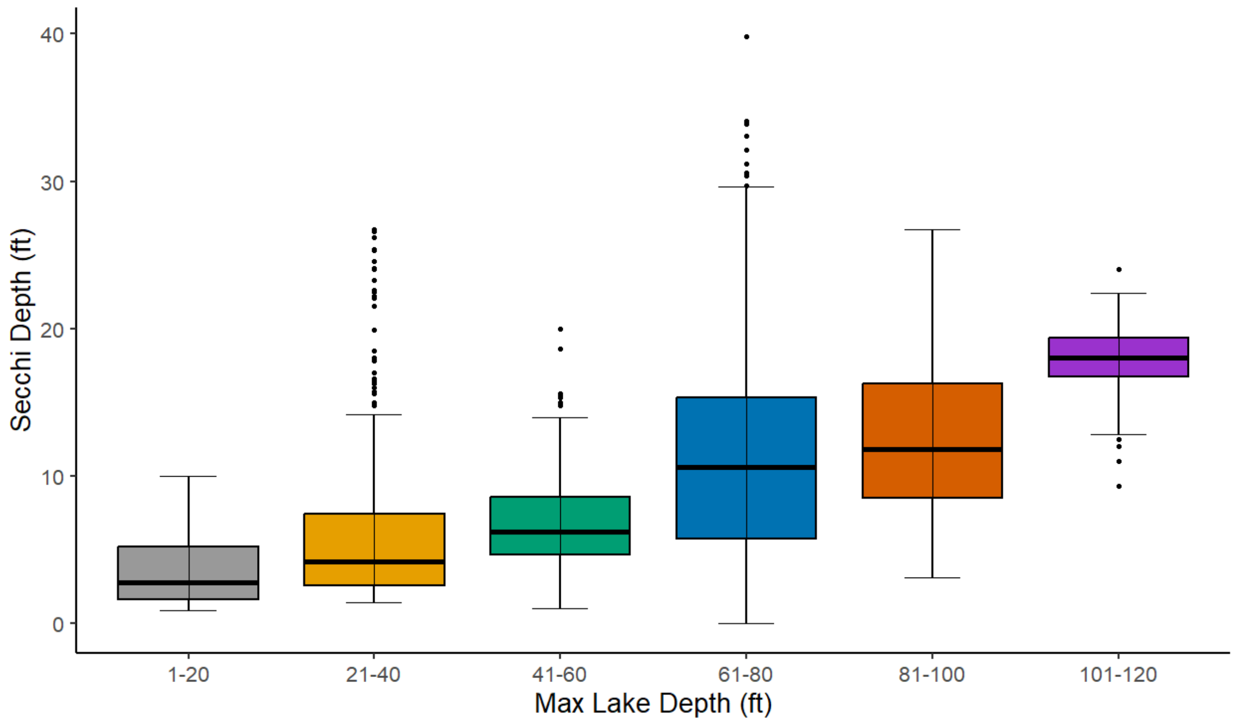


Figure 8. 2019-2022 transparency distribution vs. maximum lake depth for lakes in the Indiana Clean Lakes Volunteer Monitoring Program. Secchi depth is represented by the line inside the boxes, and the error bars show the minimum and maximum values. The dots show outlier values.

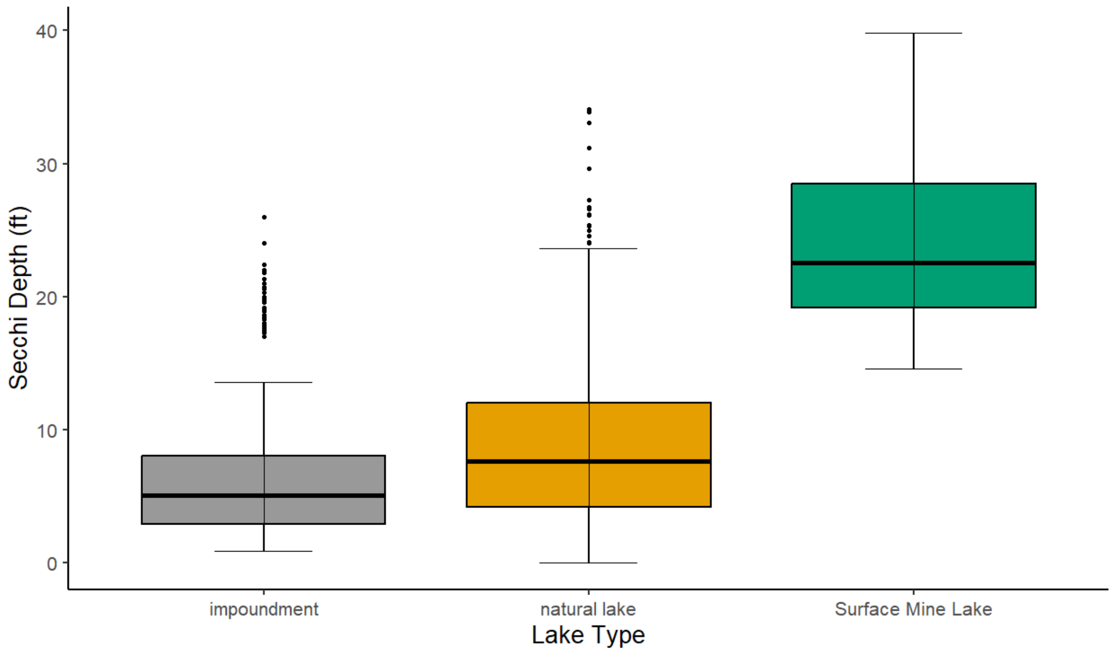


Figure 9. 2019-2022 transparency distribution of natural lakes and manmade lakes in the Indiana Clean Lakes Volunteer Monitoring Program. Median Secchi depth is represented by the line inside the boxes, and the error bars show the minimum and maximum values. The dots show outlier values.

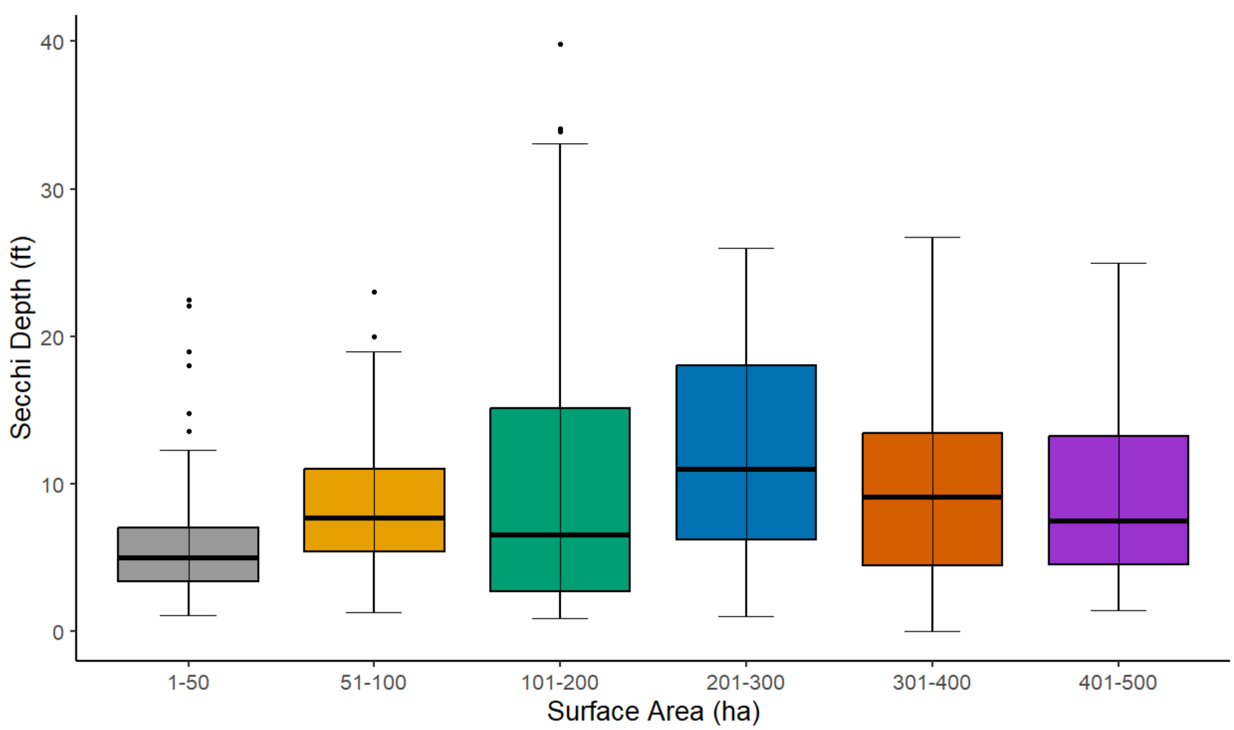


Figure 10. 2019-2022 transparency distribution vs. lake surface area for lakes in the Indiana Clean Lakes Volunteer Monitoring program. Median Secchi depth is represented by the line inside the boxes, and the error bars show the minimum and maximum values. The dots show outlier values.

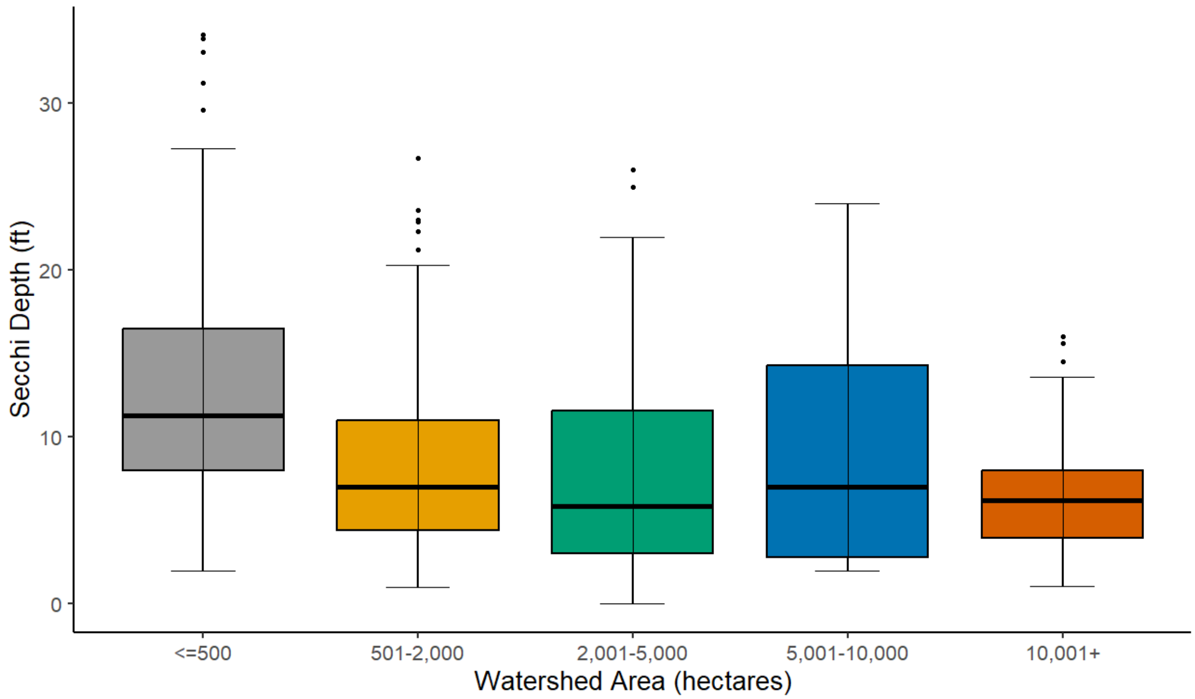


Figure 11. 2019 – 2022 transparency distribution vs. watershed size for lakes in the Indiana Clean Lakes Volunteer Monitoring Program. Median Secchi depth is represented by the line inside the boxes, and the error bars show the minimum and maximum values. The dots show outlier values.

Ecoregion
Secchi disk transparency varies greatly among the ecoregions of Indiana (Figure 12). The median summertime transparency for monitored lakes in the Central Cornbelt Plains (Ecoregion 54) was 3.9 feet. This ecoregion 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).

The Eastern Corn Belt (Ecoregion 55) lakes had the lowest median summertime transparency at 2.9 feet. This region has large amounts of cropland (75%) and few natural lakes or reservoirs.

Monitored lakes in the Southern Michigan/Northern Indiana Drift Plains (Ecoregion 56) had the second highest median Secchi disk transparency of 7.6 feet. This ecoregion contains the majority of the natural, glacial lakes in Indiana. Transparency is expected to be higher in these lakes because they are natural lakes and are deeper than other kinds of lakes.

Monitored lakes in the Interior Plateau (Ecoregion 71) had a median transparency of 7.15 feet. All of the lakes monitored by volunteers in this ecoregion are impoundments and might be assumed to have lower transparency values. However, this region includes lakes located within Hoosier National Forest and several other Indiana State Parks and Forests. The largely forested watersheds provide more protection for the lakes by reducing soil erosion and nutrient loss.

The one monitored lake in the Interior River Valleys and Hills (Ecoregion 72) had a median transparency of 20.55 feet. Land use in this ecoregion varies greatly and includes cropland, livestock, pasture, timber, and coal surface mines. The number of observations at lakes in different ecoregions should be taken into consideration when examining trends and comparing monitored lakes across ecoregions.

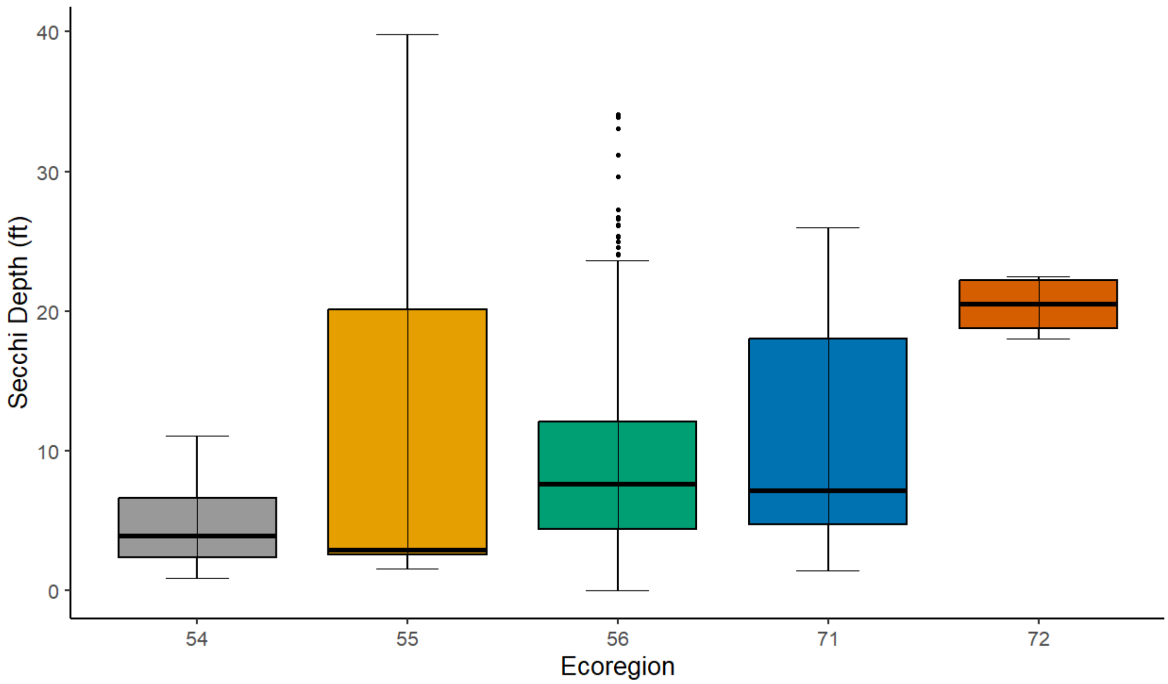


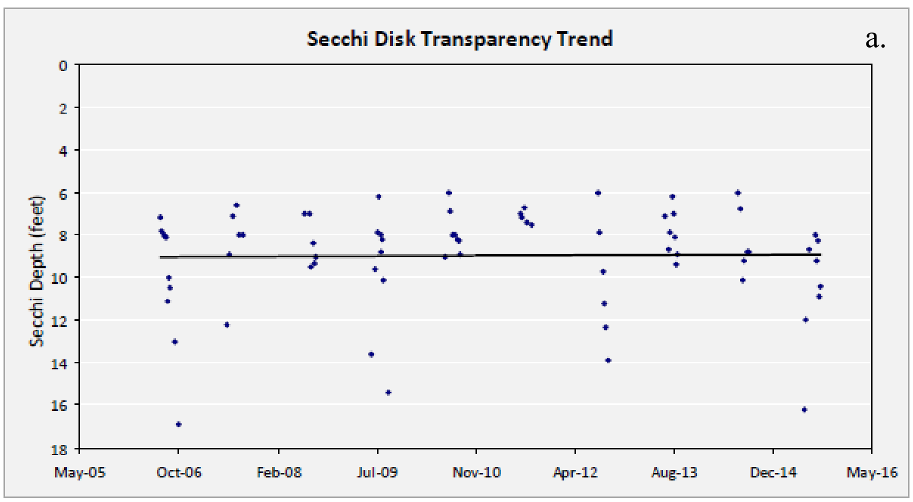
Figure 12. 2019-2022 lake transparency among ecoregions for lakes in the Indiana Clean Lakes Volunteer Monitoring Program. Median Secchi depth is represented by the line inside the boxes, and the error bars show the minimum and maximum values. The dots show outlier values.

Long-Term Trends

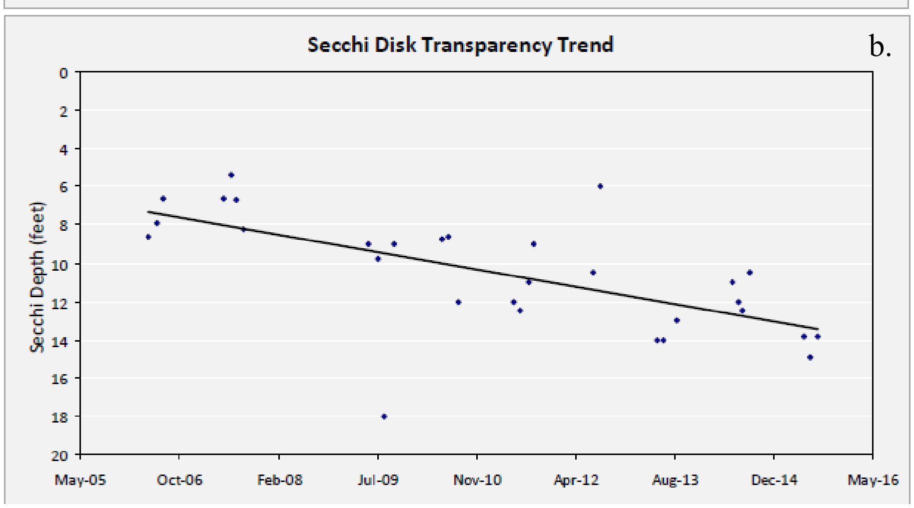
One of the main objectives of the Volunteer Lake Monitoring Program is to establish long-term data on Indiana lakes to assess trends in water quality. Each year volunteers receive a graph of all the measurements taken over the previous 10 years. A computer software program is used to fit a trend-line 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. A line that appears to be horizontal indicates that transparency has not changed much throughout the sampling period (Figure 13a). An upward sloping line indicates decreasing transparency, and a downward sloping line indicates increasing transparency (Figures 13b and c).

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 potentially causing the trend line not to reflect a true trend include the number of samples taken during a sampling season, the distribution of samples, and the time period within the season that the samples were taken. For example, average transparency will be overstated if a majority of samples are taken during periods typically having elevated transparency, e.g. early spring or late fall, and if samples are not taken during July and August, when transparency is usually low (Figure 14). 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.

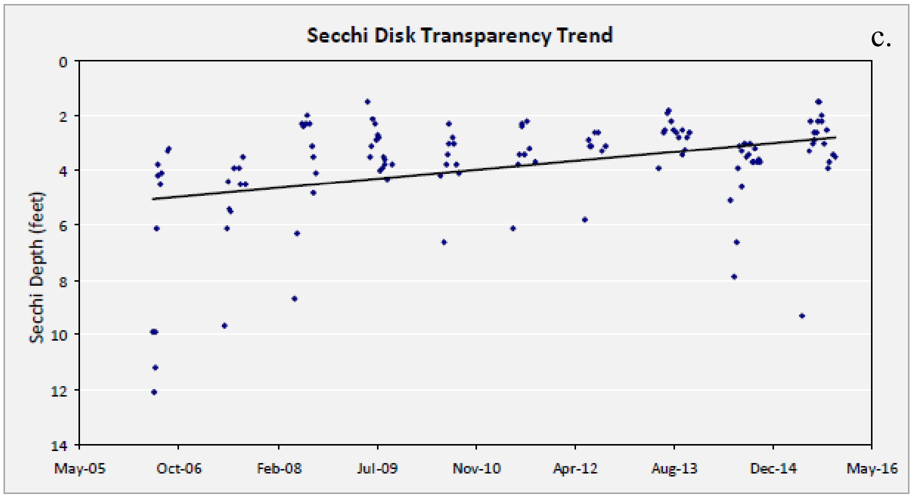
Variation in sample timing among years can also affect data trends. If samples were taken during the spring and fall early in the program, and then taken primarily in July and August in more recent years, it would appear that transparency was decreasing when that may not be the case. The reverse of that sampling pattern would make it appear that transparency is improving when that also may not be accurate.



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



A trend line showing increasing Secchi disk transparency over time.



A trend line showing decreasing Secchi disk transparency over time.

Figures 13a-c. Example of long-term transparency trends.

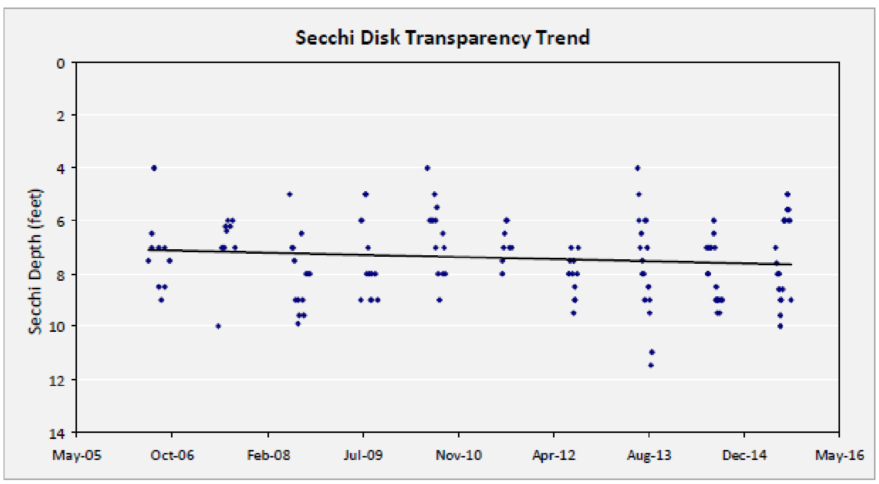


Figure 14. Seasonal variation in Secchi disk transparency

Trophic State Index Analysis

Carlson's TSI provides a means to analyze and compare annual lake data. Long-term trends in TSI values can be a more reliable method of comparison than transparency trends as TSI values are calculated using the July/August means, thereby removing seasonal variations. Based on July/August mean transparency values, the majority of lakes monitored in the program have been mesotrophic or eutrophic (Figure 15). On average less than 10% of lakes were hypereutrophic. A lake's trophic status can vary yearly, but long-term data indicates that for many lakes the trophic state is relatively stable.

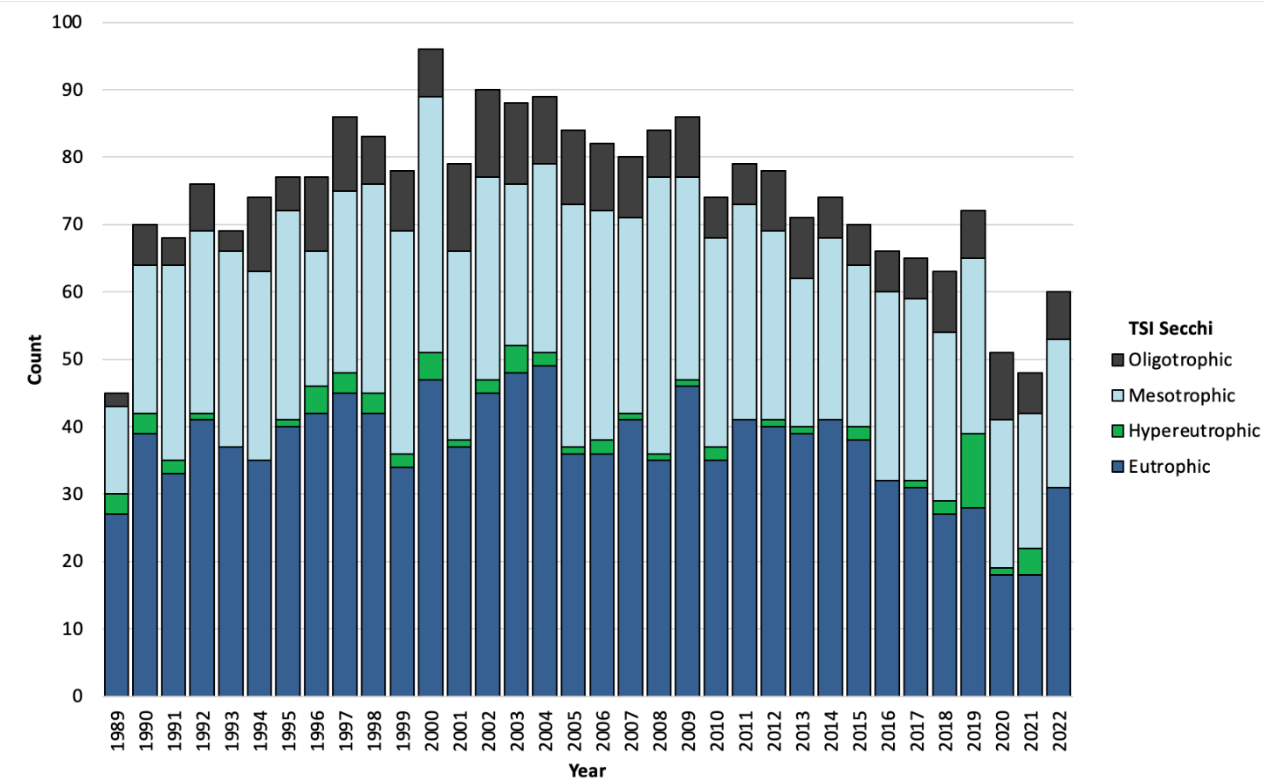


Figure 15. Annual distribution of monitored lakes' trophic classes calculated using July/August summertime means of Secchi depth from 1989-2022.

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 (Figure 16).

User perceptions of water quality vary among regions and lakes. 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.

In our volunteer monitoring program, citizen perceptions of ‘crystal clear’ lakes showed the widest range of responses of the physical appearance categories. What appears to be excellent transparency to volunteers on some lakes is considered poor transparency on others.

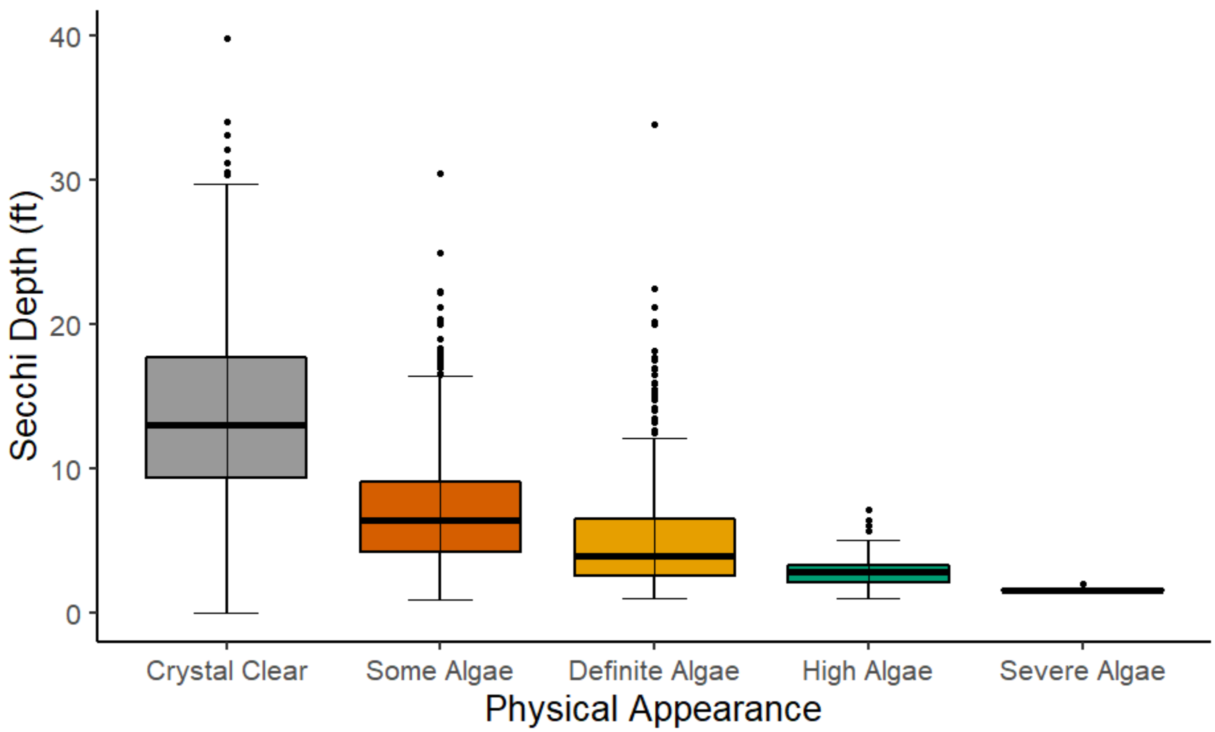


Figure 16. 2019-2022 lake transparency distribution across physical appearance categories. Median Secchi depth is represented by the line inside the boxes, and the error bars show the minimum and maximum values. The dots show outlier values.

Recreation Potential
Volunteers are also asked to rate recreation potential each time they make 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 ratings were correlated with transparency with the exception of the No Swimming rating (Figure 17). Some lakes do not allow swimming or have limited recreation, which can lead to these responses. Similar to physical appearance categories, recreation potential categories varied at different lakes with some overlap between "Beautiful – no impairment" and "Minor Aesthetic Problems".

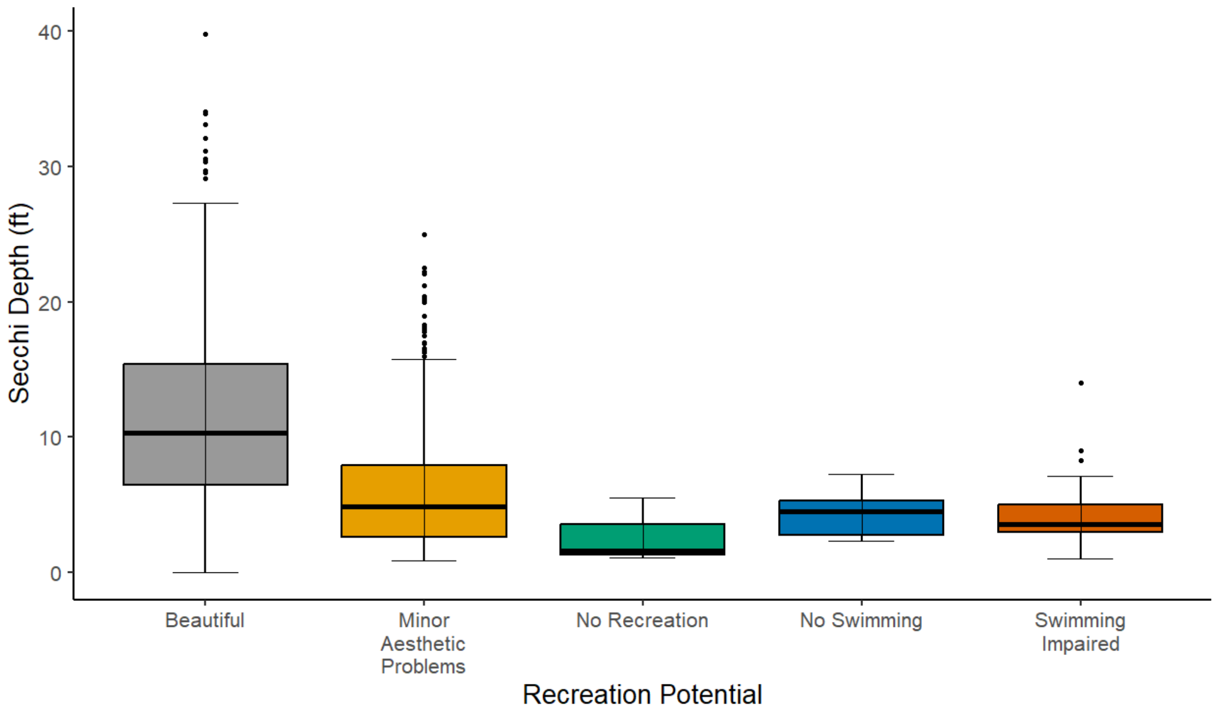


Figure 17. 2019-2022 lake transparency distribution across volunteer recreation potential ratings. Median Secchi depth is represented by the line inside the boxes, and the error bars show the minimum and maximum values. The dots show outlier values.

COLOR RESULTS

Water color can be used as an additional indicator of lake health and to provide insight into the cause of decreasing transparency. Sediment and algae influence the color of a waterbody, with sediments tinting the water brown and algae often causing the water to be various shades of green. Water color can also be a factor of the underlying geology. Limestone over time and through weathering process creates "marl" lakes that have a blue green hue to them.

Volunteers can report one of the following seven color categories:

1. Clear
2. Clear/Blue
3. Blue/Green
4. Green
5. Brown
6. Green/Brown
7. Blue/Brown

This system allows comparison between the colors and the transparency results. Lakes for which the volunteers select "clear blue" have the highest transparency (Figure 18). 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. The lowest median Secchi depth readings are also for the choices of "brown" and "green/brown" (Figure 18). This is likely a result of suspended sediments contributing to the turbidity of the water.

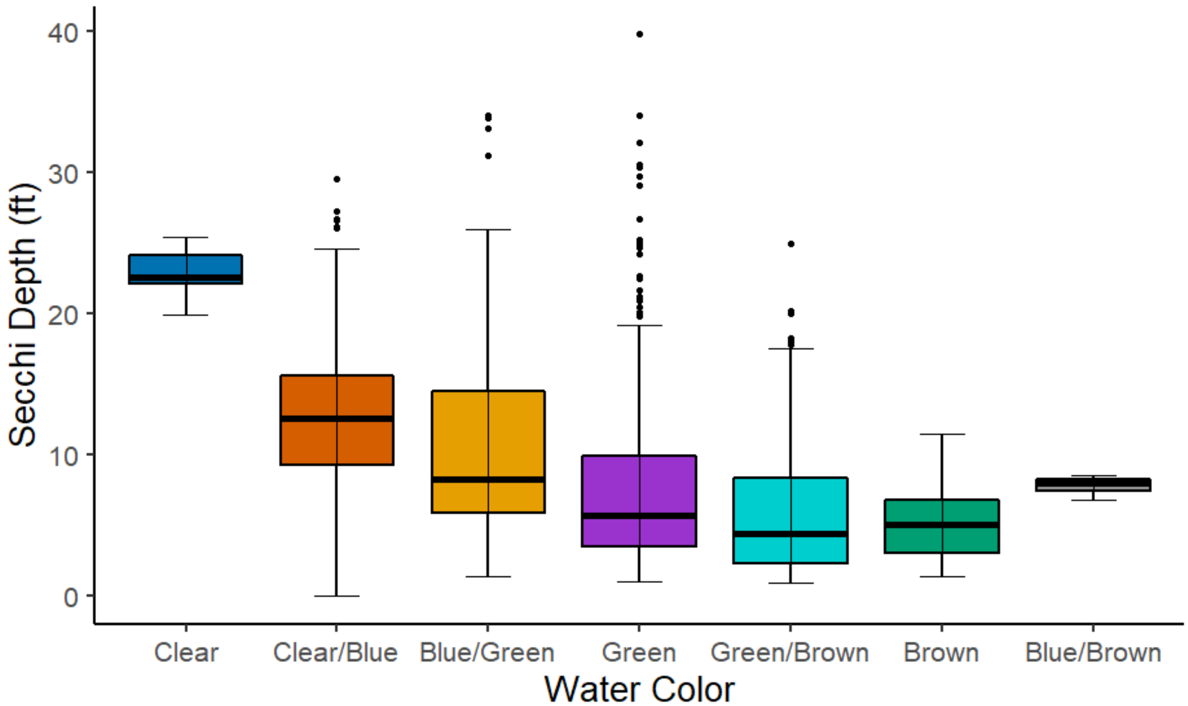


Figure 18. 2019-2022 lake transparency distribution across water color responses. Median Secchi depth is represented by the line inside the boxes, and the error bars show the minimum and maximum values. The dots show outlier values.

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 20).

From 2019-2022, 253 dissolved oxygen and temperature profiles were made on 22 different lakes (Figure 19). In 2022, 87 profile measurements were collected, overtaking the previous highest number in program history in 2016 of 84. 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

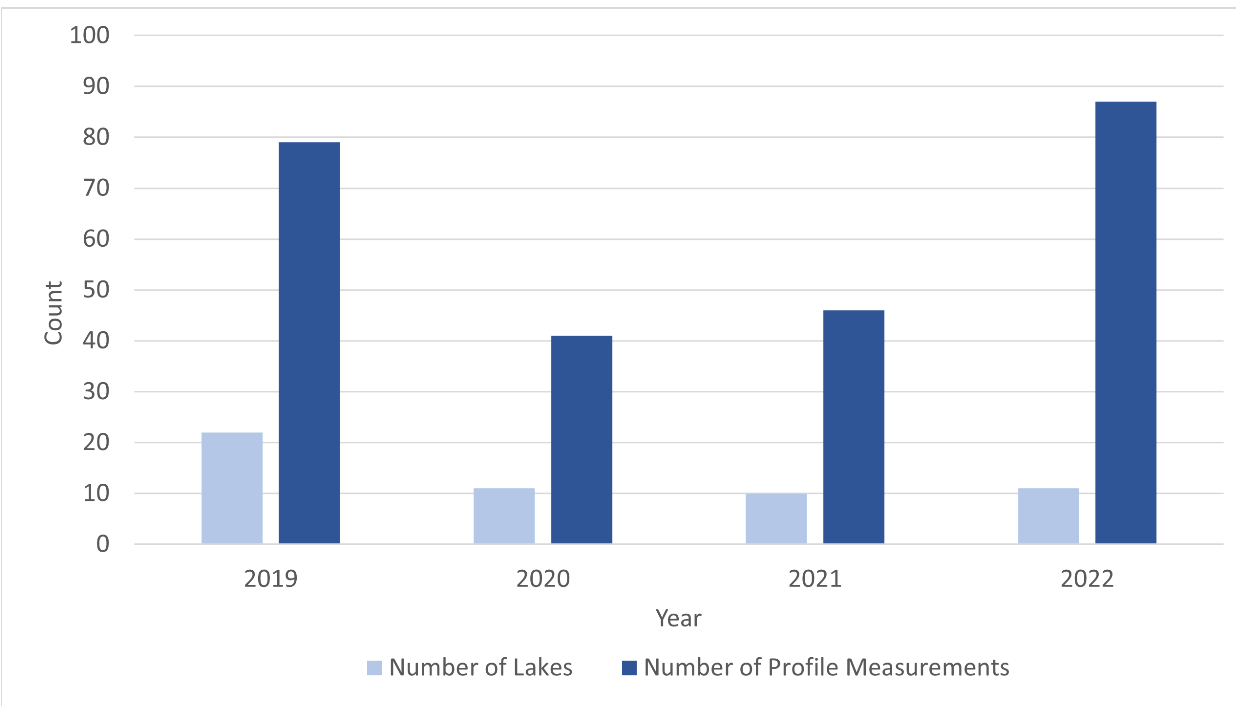


Figure 19. Number of Lakes and profile measurements taken from 2019-2022.

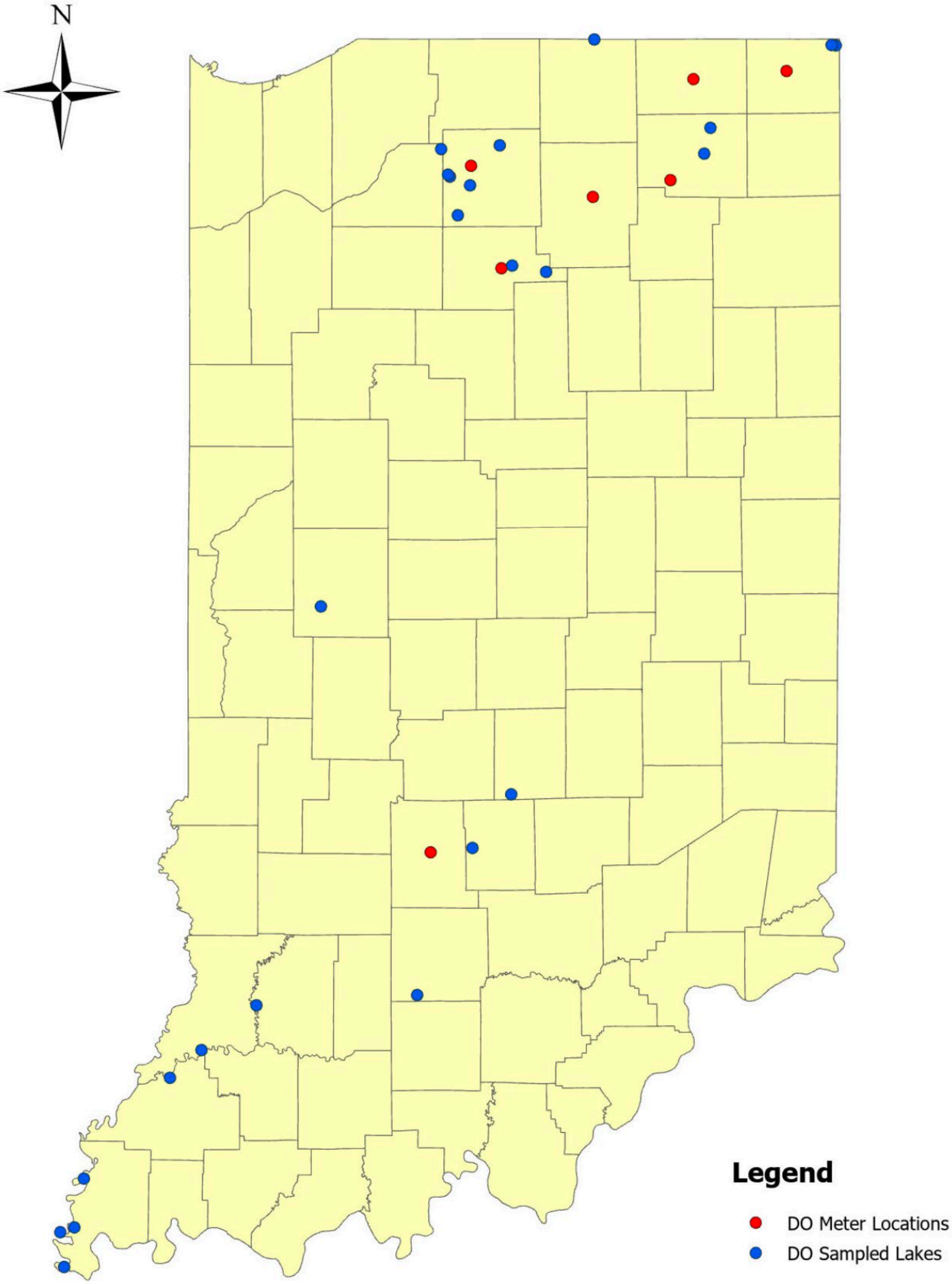


Figure 20. Dissolved oxygen and temperature meter locations and lakes sampled for dissolved oxygen and temperature.

Figures 21 and 22 illustrate an example of changes in a typical temperature and dissolved oxygen profile during the summer season. Long Lake was stratified the entirety of summer 2022. The temperature barrier does not allow the lake to mix (Figure 21). The surface of the water remains much warmer than the lake bottom throughout the summer and finally begins to cool in late September. This temperature difference allows for the dissolved oxygen profile to follow the same pattern. Oxygen from the top layer of the lake cannot mix with the bottom water layers due to this temperature change thus creating hypoxic conditions (Figure 22).

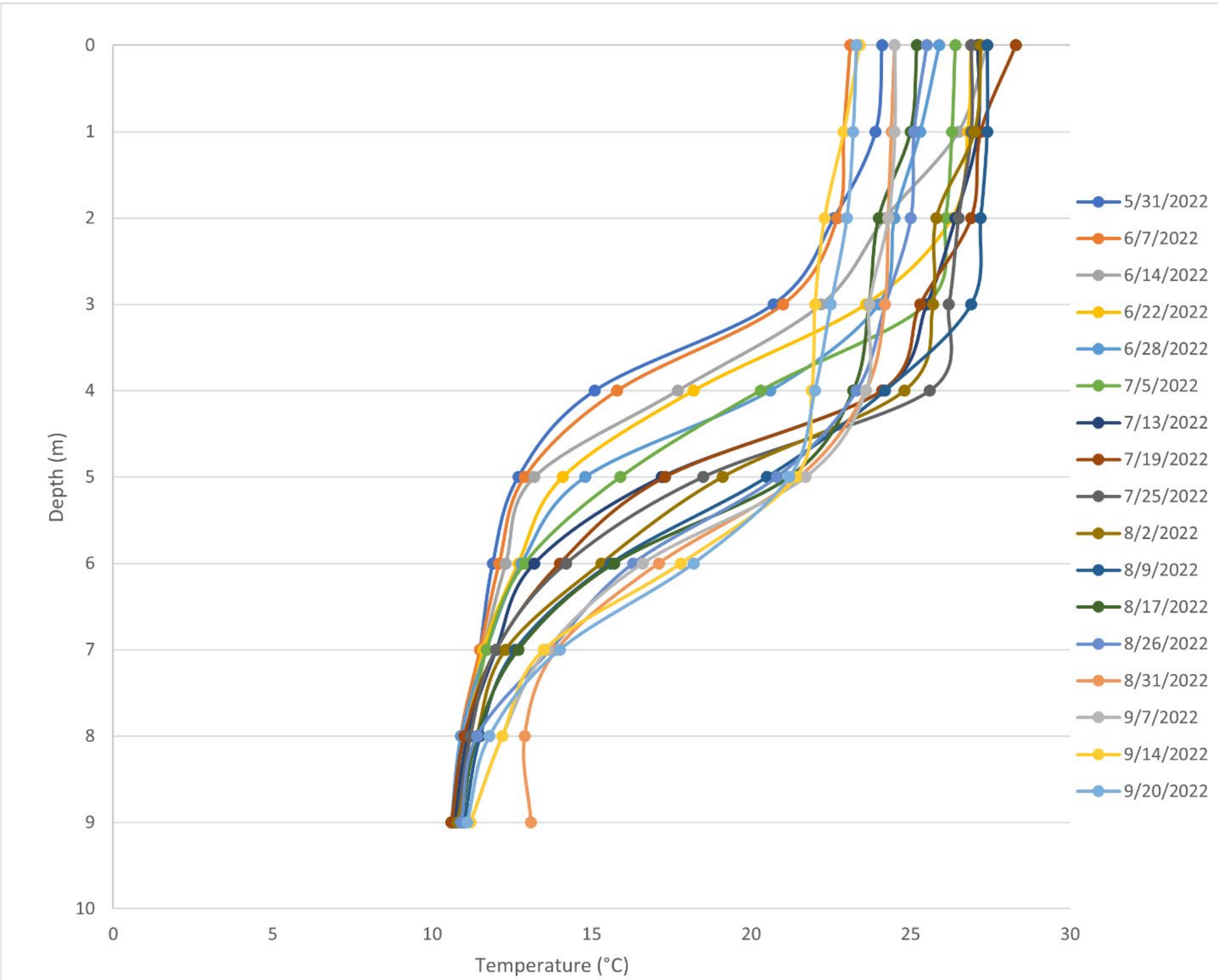


Figure 21. Temperature profile of Long Lake in Steuben County from June through September.

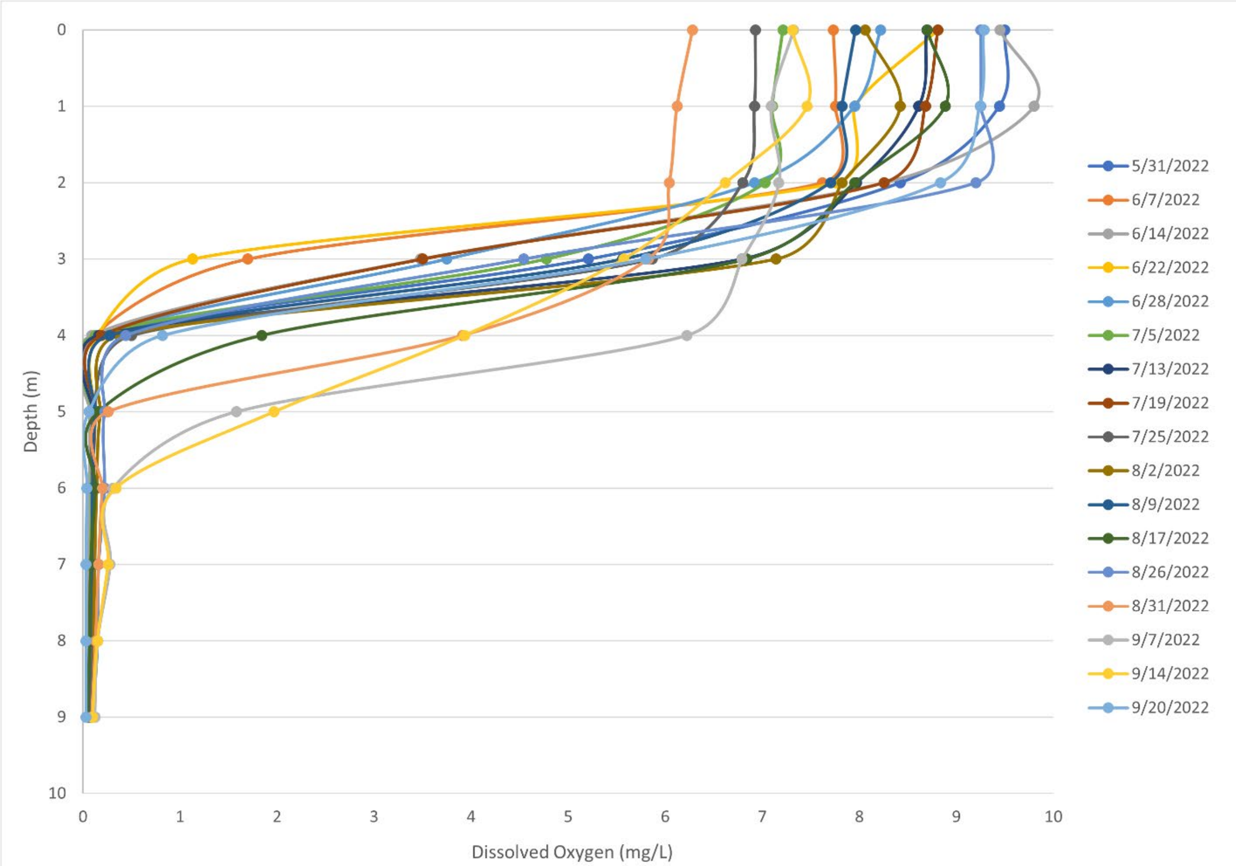


Figure 22. Dissolved oxygen profile of Long Lake in Steuben County from June through September.

EXPANDED PROGRAM RESULTS

From 2019-2022 expanded volunteer monitors collected 791 total phosphorus, total nitrogen, and chlorophyll *a* measurements on 70 lakes. The Expanded Program has grown over the past 4 years. While some lakes have come in and out over that time, we have overall maintained over 50 lakes in all years. The expanded lake locations are shown in Figure 3. They are located throughout the state but are concentrated in the northeast. Annual summary reports that include the minimum, maximum, and July/August mean values for total phosphorus, total nitrogen and chlorophyll *a* from 2019 through 2022 can be found online at https://clp.indiana.edu/.

Variation in size and depth of the expanded lakes is similar to the variation in all lakes in the program. Figure 23 and 24 show the size and depth distribution of lakes in the Expanded Program, respectively. University Lake in Monroe County had the smallest surface area, 8 acres and is one of eight lakes less than 50 acres in size. Lake Wawasee in Kosciusko County, 2,617 acres, had the greatest surface area of natural lakes sampled and one of eleven lakes that had a surface area greater than 500 acres. The majority of expanded program lakes had surface areas between 100 and 200 acres.

Lake Dalecarlia in Lake County was the shallowest lake in the Expanded Program at 4.8 feet. Tippecanoe Lake in Kosciusko County, 123 feet, was the deepest lake. Twenty-five of the 70 lakes sampled from 2019 and 2022 were between 21 and 40 feet deep. Four lakes were greater than 100 feet deep and four lakes were less than 20 feet deep with the remaining lakes distributed throughout the middle depths.

Louise Lake in Porter County (1058 µg/L) had the highest total phosphorus concentration from 2019-2022. Twenty lakes had recorded summertime values below 10 µg/L of total phosphorus. Skinner Lake in Noble County (5238 µg/L) had the highest total nitrogen concentration. Eleven lakes had nitrogen concentrations less than 100 µg/L.

Town Lake in Fulton County had the highest and second highest chlorophyll *a* concentrations from the 2019-2022 sampling period, with 198 and 166 µg/L, respectively. Louise Lake in Porter County had the third highest chlorophyll *a* concentration of 137 µg/L. Thirty-four lakes had summertime chlorophyll *a* concentrations below 2 µg/L.

No relationship was seen between total nitrogen and total phosphorus, as the source of these nutrients can come from different sources and end up in different sinks (Figure 26). However, data from the Expanded Program agree with expected relationships between total phosphorus and chlorophyll *a*—as total phosphorus increases, chlorophyll *a* increases (Figure 27). Another relationship that is seen in Expanded Program data is as chlorophyll *a* increases, Secchi disk transparency decreases logarithmically (Figure 28). 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 29).

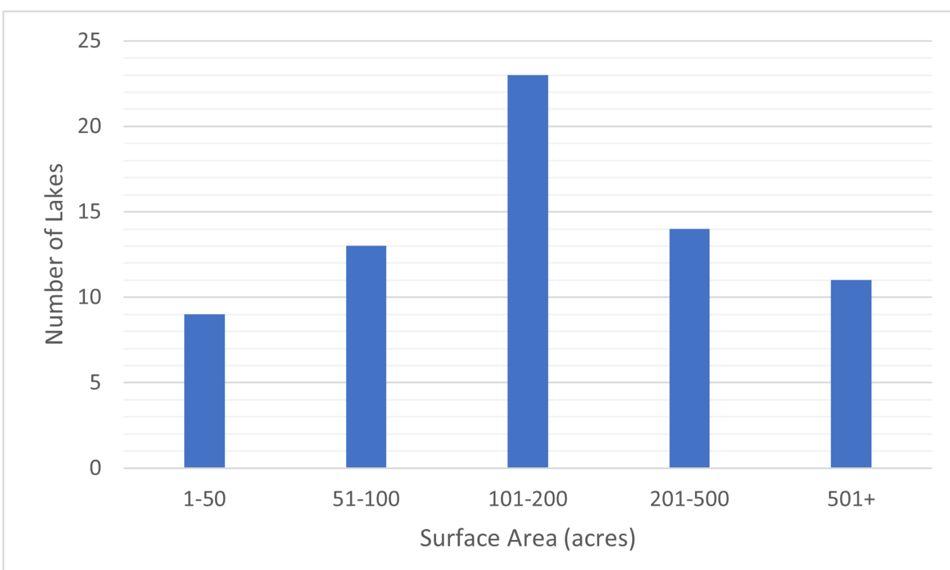


Figure 23. Size distribution of lakes in the Expanded Volunteer Monitoring Program 2019-2022.

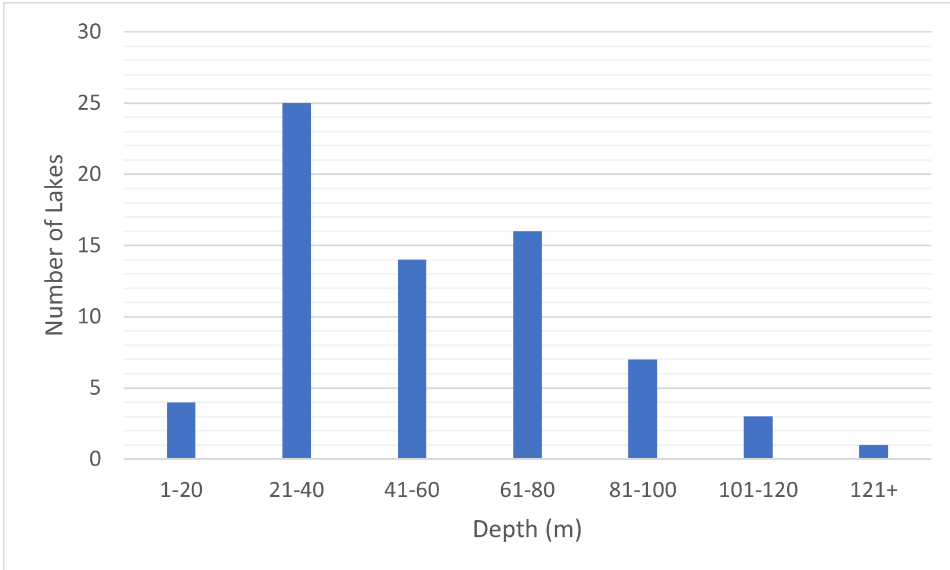


Figure 24. Depth distribution of lakes in the Expanded Volunteer Monitoring Program 2019-2022.

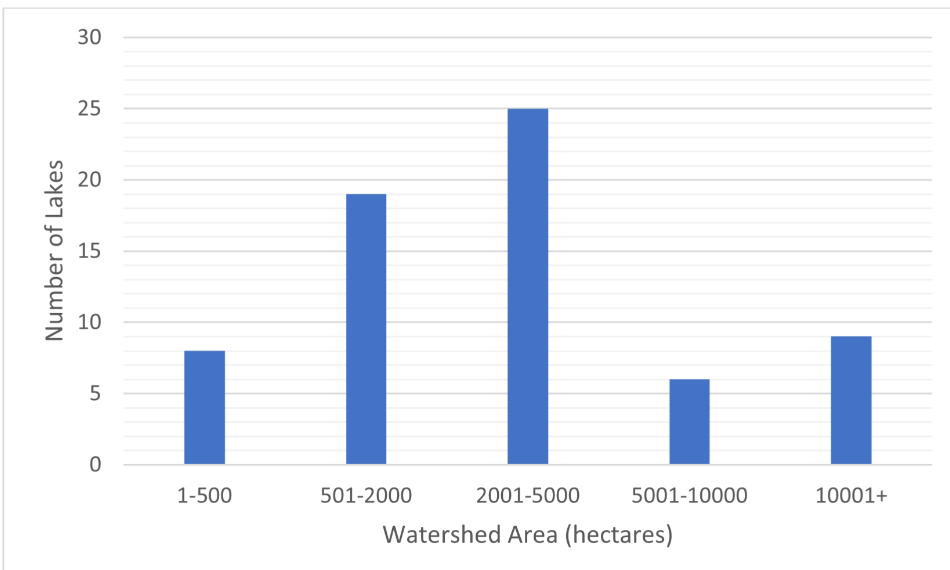


Figure 25. Watershed area distribution of lakes in the Expanded Volunteer Monitoring Program 2019-2022.

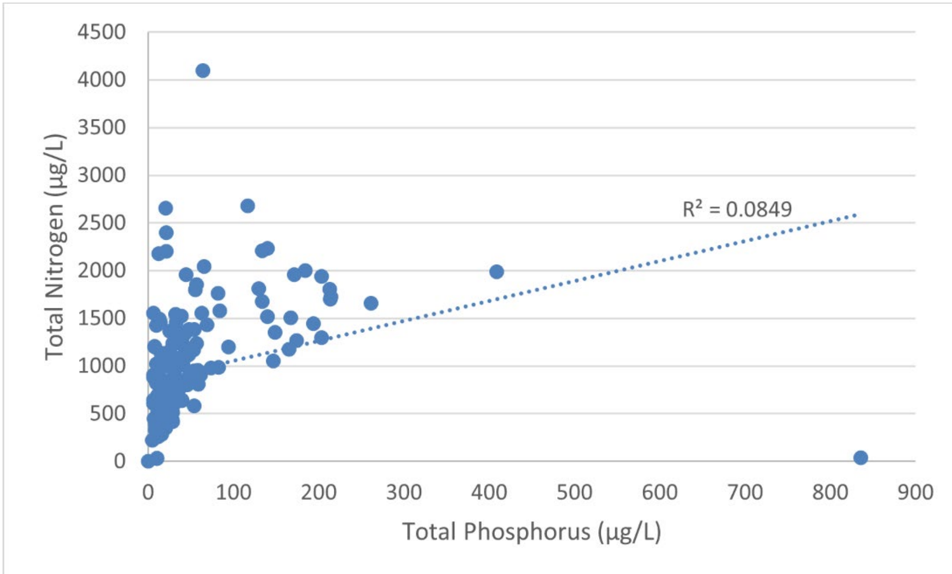


Figure 26. Relationship between total phosphorus and total nitrogen in lakes monitored by volunteers from 2019-2022.

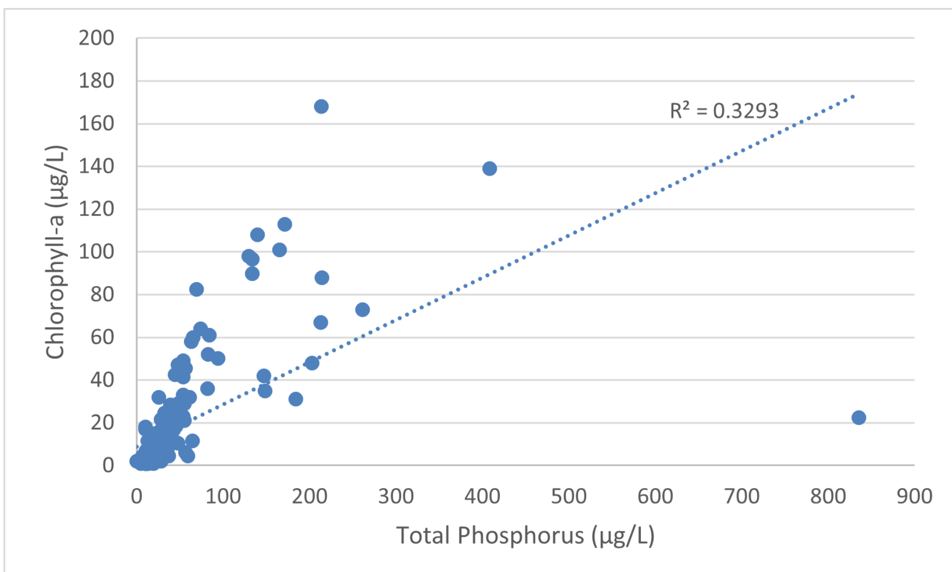


Figure 27. Relationship between total phosphorus and chlorophyll *a* in lakes monitored by volunteers from 2019-2022.

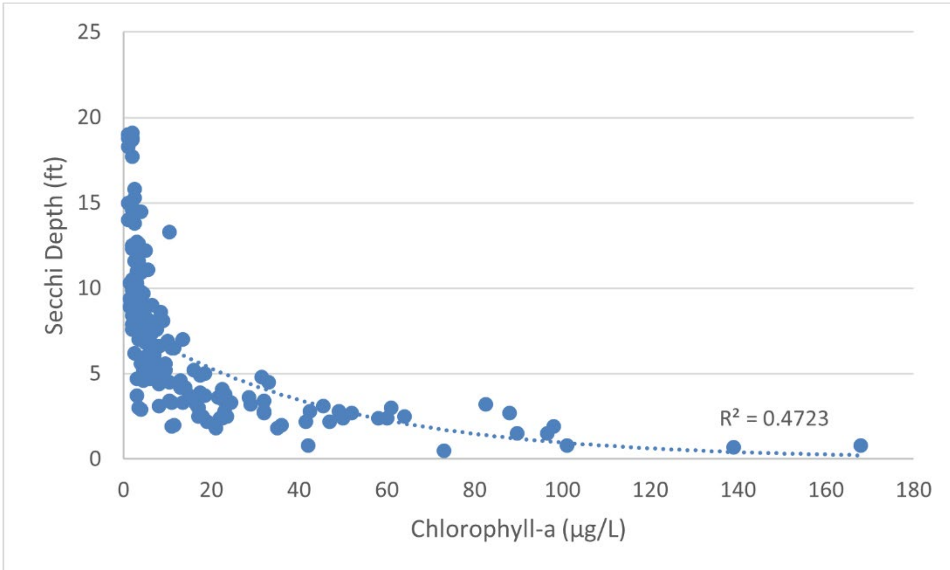


Figure 28. Relationship between transparency and chlorophyll *a* from 2019-2022.

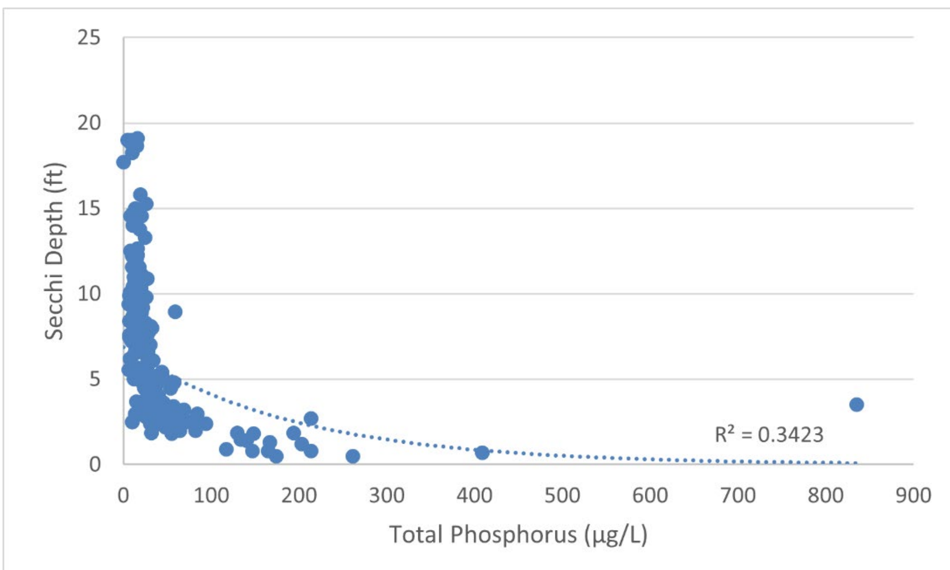


Figure 29. Relationship between transparency and total phosphorus from 2019-2022.

Factors Affecting Phosphorus, Nitrogen, and Chlorophyll *a* Concentrations

Many factors influence total phosphorus and total nitrogen concentrations, which subsequently affect chlorophyll *a* concentrations. Nutrient 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 where agriculture predominates generally have higher phosphorus and nitrogen loads (Novotny, 2003). Watersheds made up of mostly of forests tend to have lower nutrient loads. 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 nutrients to lakes include gardening, fertilizing lawns, some industrial activities, and improperly functioning septic systems or wastewater treatment plants. Once nutrients enter the lake they areutilized by algae and rooted vegetation, and the remaining nutrients settle as particulates. Shallower lakes are more prone to wind resuspension of sediments, resuspending nutrients and releasing them for algal production. Other internal factors that influence nutrient concentrations include sediment disturbance due to recreational use, surface area, and the maximum lake depth.

Chlorophyll concentrations in lakes are influenced by factors that affect algae growth including: nutrient availability, light intensity and penetration, water temperature, and algal predation. An increase in total phosphorus, with all other factors held constant, can 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 *a*.

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. Although the highest concentration was not in the shallowest grouping (Louise Lake at 34 feet), the next twelve highest concentrations all belong to lakes shallower than 21 feet. (Figure 30).

Total nitrogen concentrations had more variation among different depths than total phosphorus (Figure 31). Total nitrogen measures various forms of nitrogen (i.e., nitrate, ammonia, dissolved organic nitrogen, etc.) and can accumulate in different levels of the water column. For instance, a shallow lake might have an abundance of nitrogen runoff from the watershed in its surface waters or a deep lake might have a buildup of ammonia in the hypolimnion due to the lack of oxygen interrupting the nitrogen cycle. We see this variation among Expanded Program lakes, where lakes 41-60 feet deep have a median total nitrogen of 738 μg/L and lakes 81-100 feet deep have a median concentration of 668 μg/L with no clear influence of lake depth alone.

Chlorophyll *a* concentrations mirrored the total phosphorus concentrations based on maximum depth (Figure 32). The highest chlorophyll *a* concentrations were in the shallowest lake group. Median chlorophyll *a* concentration for lakes less than 21 feet deep is 53 μg/L. The lowest median chlorophyll *a* concentrations were found in lakes with a depth greater than 81 feet, with an overall median at these depths of 2 μg/L.

The surface area of monitored lakes had little effect on total phosphorus, total nitrogen, or chlorophyll *a* concentrations (Figures 33, 34, and 35). Median concentrations were slightly higher at the smallest surface area and then leveling off above 50 acres. Once again, smaller surface area lakes might not be mixing as much as larger-sized lakes. Volunteers' samples could be reflecting the presence of non-mixed nutrients from runoff and the algal growth that benefits from this source in these smaller surface area lakes.

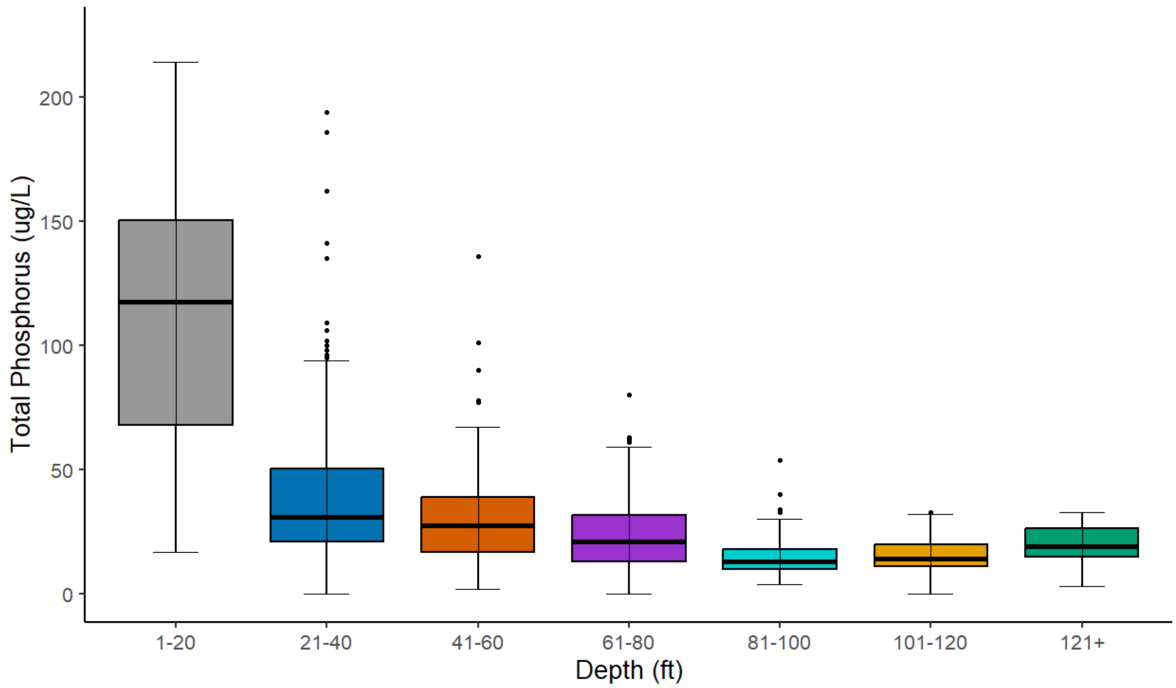


Figure 30. Distribution of summertime total phosphorus concentrations (2019-2022) by depth. The median is the line inside the boxes and the error bars show the minimum and maximum values. The dots show the outlier values.

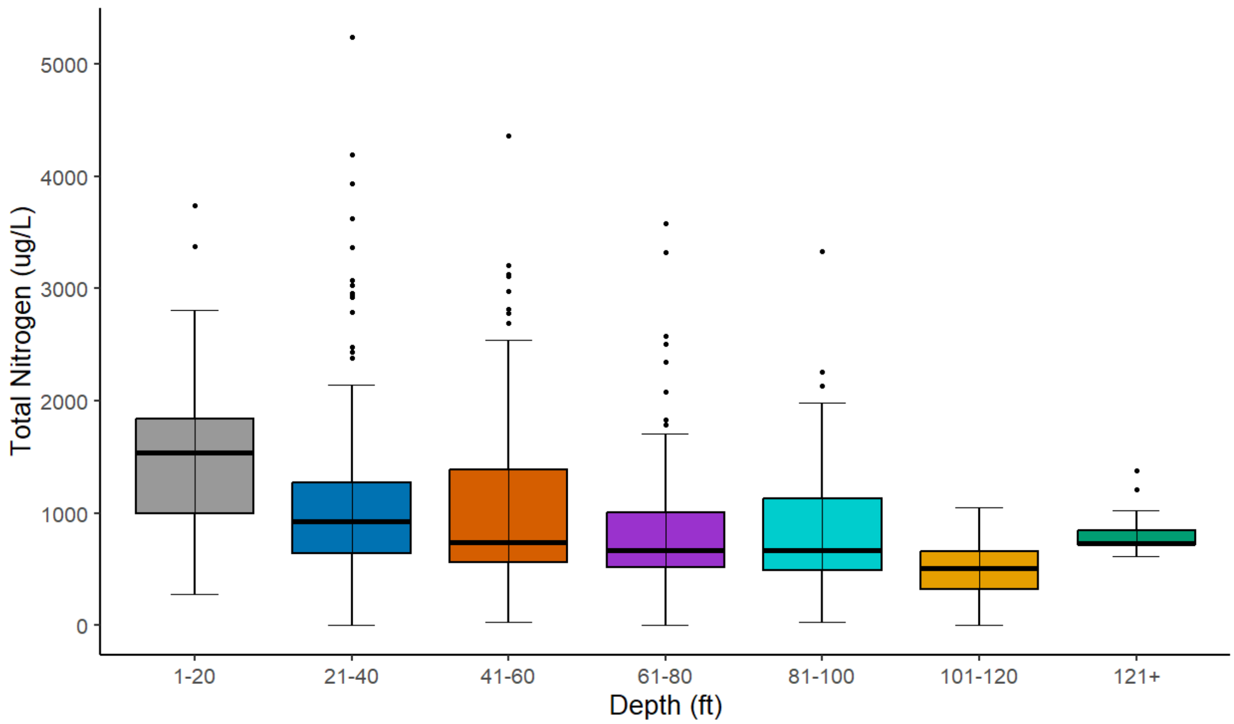


Figure 31. Distribution of summertime total nitrogen concentrations (2019-2022) by depth. The median is the line inside the boxes and the error bars show the minimum and maximum values. The dots show the outlier values.

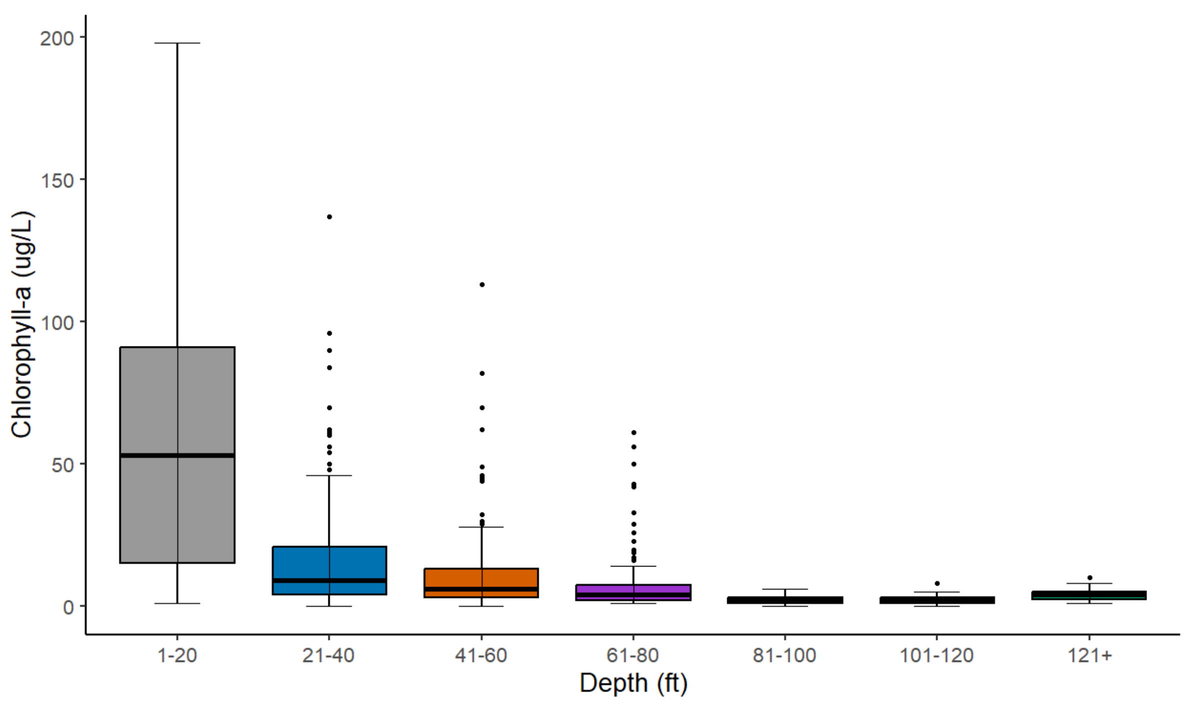


Figure 32. Distribution of summertime chlorophyll *a* concentrations (2019-2022) by depth. The median is the line inside the boxes and the error bars show the minimum and maximum values. The dots show the outlier values.

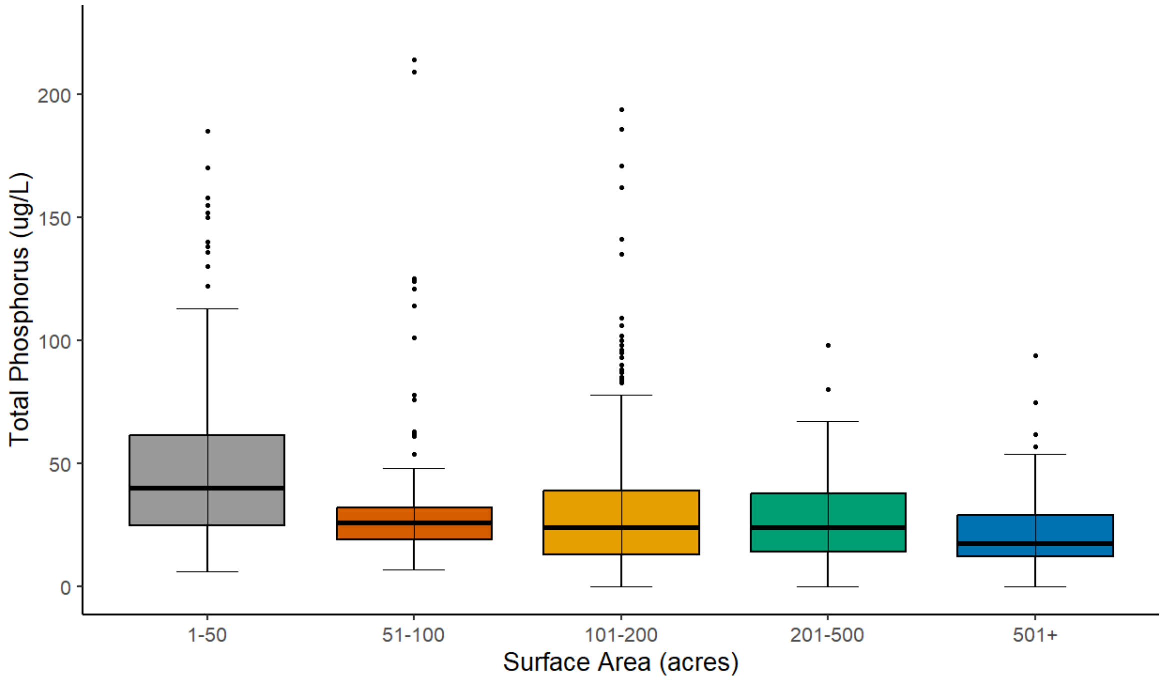


Figure 33. Distribution of summertime total phosphorus concentrations (2019-2022) by basin size. The median is the line inside the boxes and the error bars show the minimum and maximum values. The dots show the outlier values.

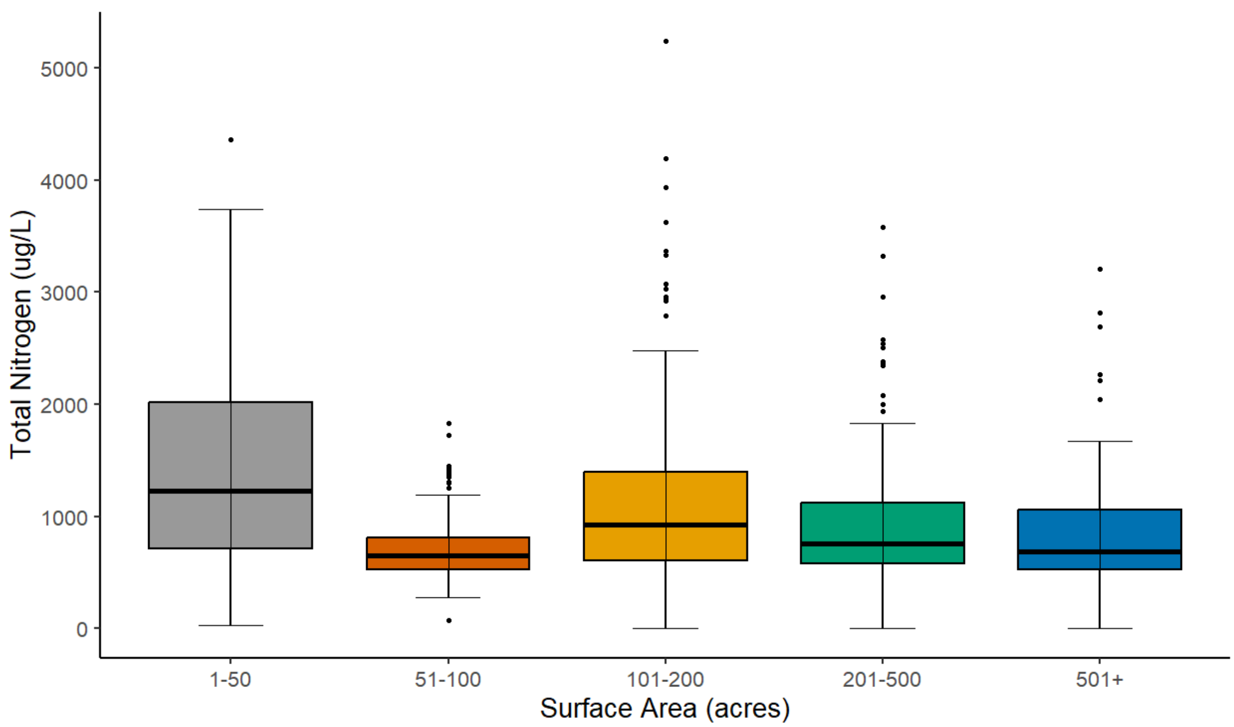


Figure 34. Distribution of summertime total nitrogen concentrations (2019-2022) by basin size. The median is the line inside the boxes and the error bars show the minimum and maximum values. The dots show the outlier values.

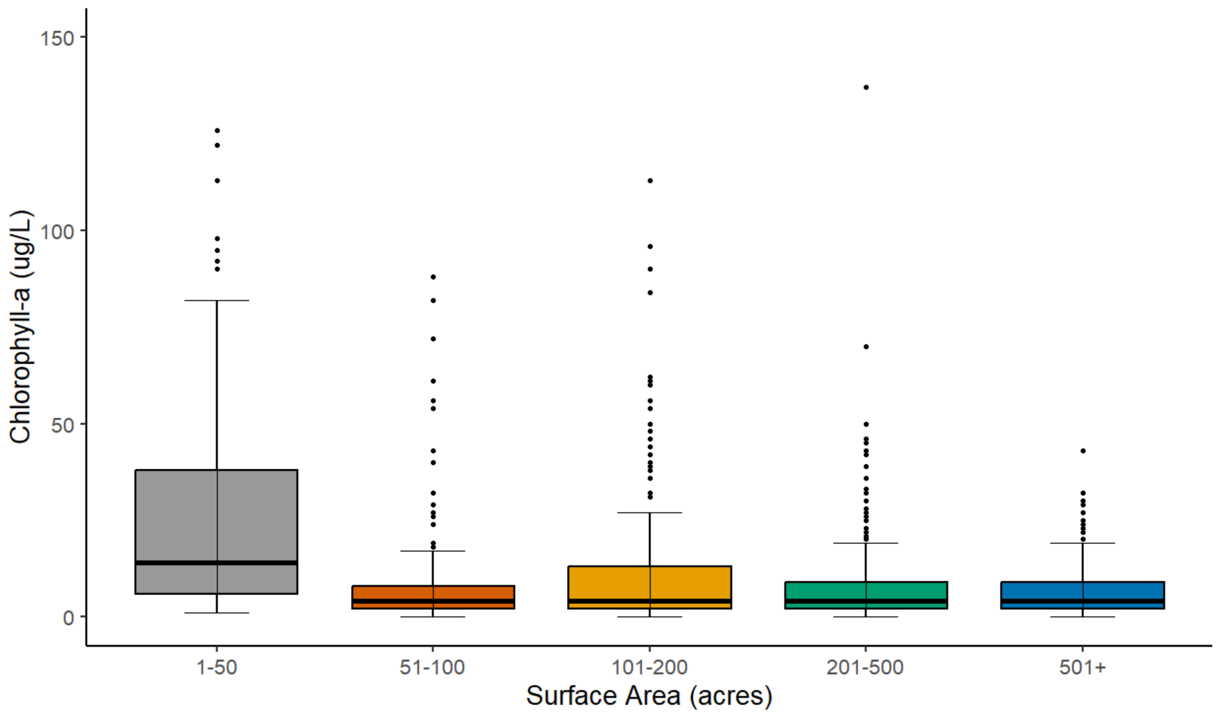


Figure 35. Distribution of summertime chlorophyll *a* concentrations (2019-2022) by basin size. The median is the line inside the boxes and the error bars show the minimum and maximum values. The dots show the outlier values.

Watershed Size

The watershed area of monitored lakes had little effect on total phosphorus, total nitrogen, or chlorophyll *a* concentrations (Figures 36, 37, and 38). The median concentrations varied little between different watershed areas. The Expanded Program may not have a representative amount of lakes to show the relationship between total phosphorus, total nitrogen, and chlorophyll *a* with the lakes' watershed area.

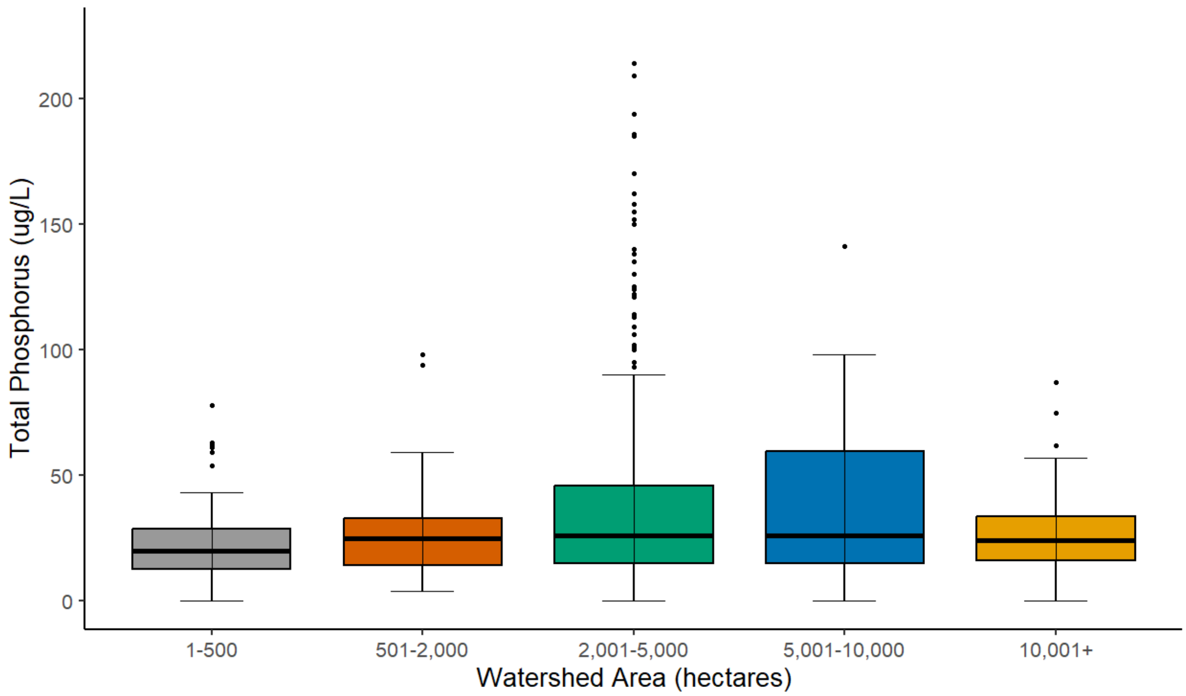


Figure 36. Distribution of total phosphorus concentrations (2019-2022) by watershed size. The median is the line inside the boxes and the error bars show the minimum and maximum values. The dots show the outlier values.

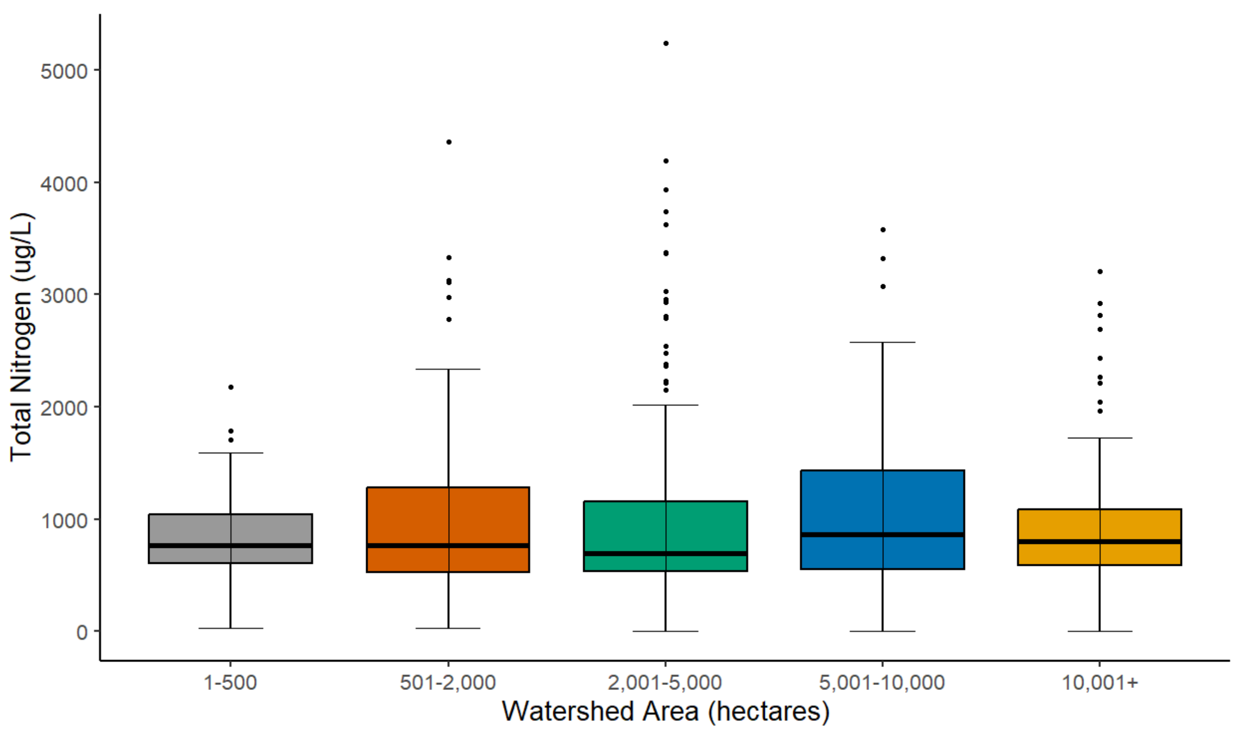


Figure 37. Distribution of total nitrogen concentrations (2019-2022) by watershed size. The median is the line inside the boxes and the error bars show the minimum and maximum values. The dots show the outlier values.

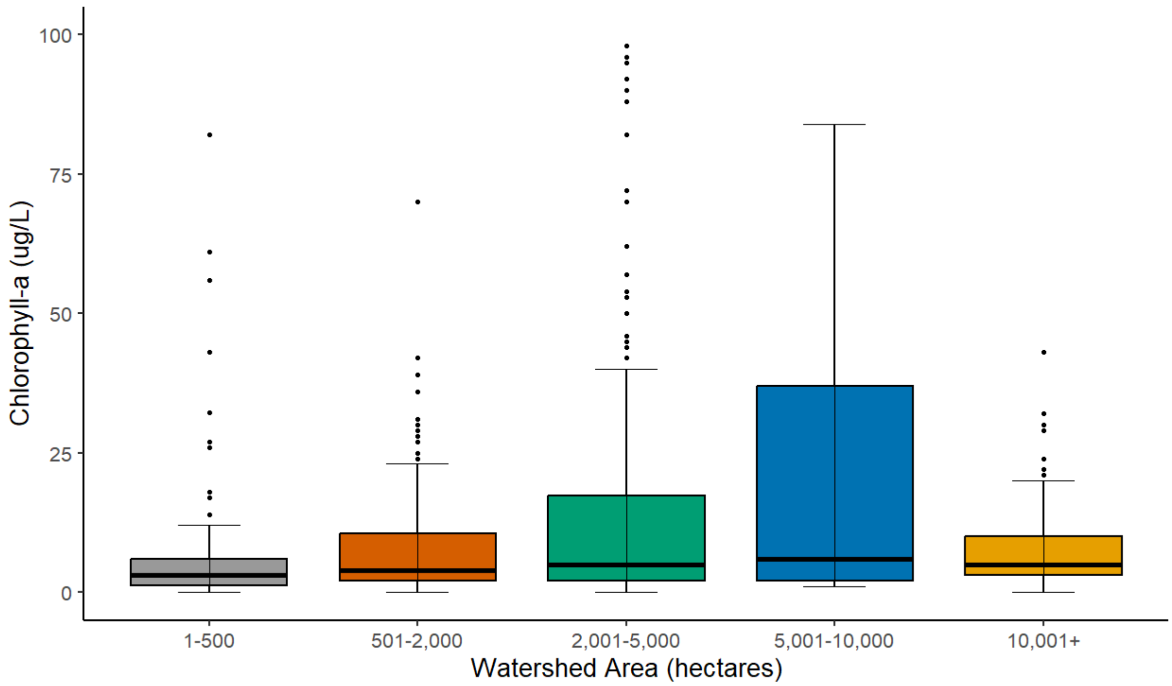


Figure 38. Distribution of chlorophyll *a* concentrations (2019-2022) by watershed size. The median is the line inside the boxes and the error bars show the minimum and maximum values. The dots show the outlier values.

Ecoregion

Total phosphorus and chlorophyll *a* concentrations are expected to vary with ecoregion because land use and type vary among ecoregions (Figure 39). Ecoregion 55 (Eastern Corn Belt) had the highest median total phosphorus concentration, 75 µg/L. The next highest median concentration was in Ecoregion 54, with total phosphorus at 40 µg/L. Lakes in these two regions are surrounded by agriculture which may increase nutrient runoff and cause increased phosphorus loading. The lowest median total phosphorus concentration, 18 µg/L, occurred in Ecoregion 71 (Interior Plateau) followed by Ecoregion 56 (Southern Michigan/Northern Indiana Drift Plains), with a median concentration of 22 µg/L.

Similarly, total nitrogen concentrations followed the total phosphorus pattern of concentration values across ecoregions (Figure 40). Where more land use is allocated to agriculture and thus a greater potential source for nutrients, there was also higher total nitrogen. Ecoregion 55 had median 1203 µg/L and Ecoregion 54 had 924 µg/L total nitrogen. Ecoregion 71 only had median 71 µg/L total nitrogen as this ecoregion contains mostly forested landscapes.

Lastly, chlorophyll *a* concentrations expectantly followed the same patterns as nutrient concentrations across ecoregions (Figure 41). Ecoregion 55 had the highest median chlorophyll *a* concentration, 42 µg/L. Ecoregion 54 had the next highest median chlorophyll at 13 µg/L, then Ecoregion 56 with 4 µg/L and Ecoregion 71 with 3 µg/L.

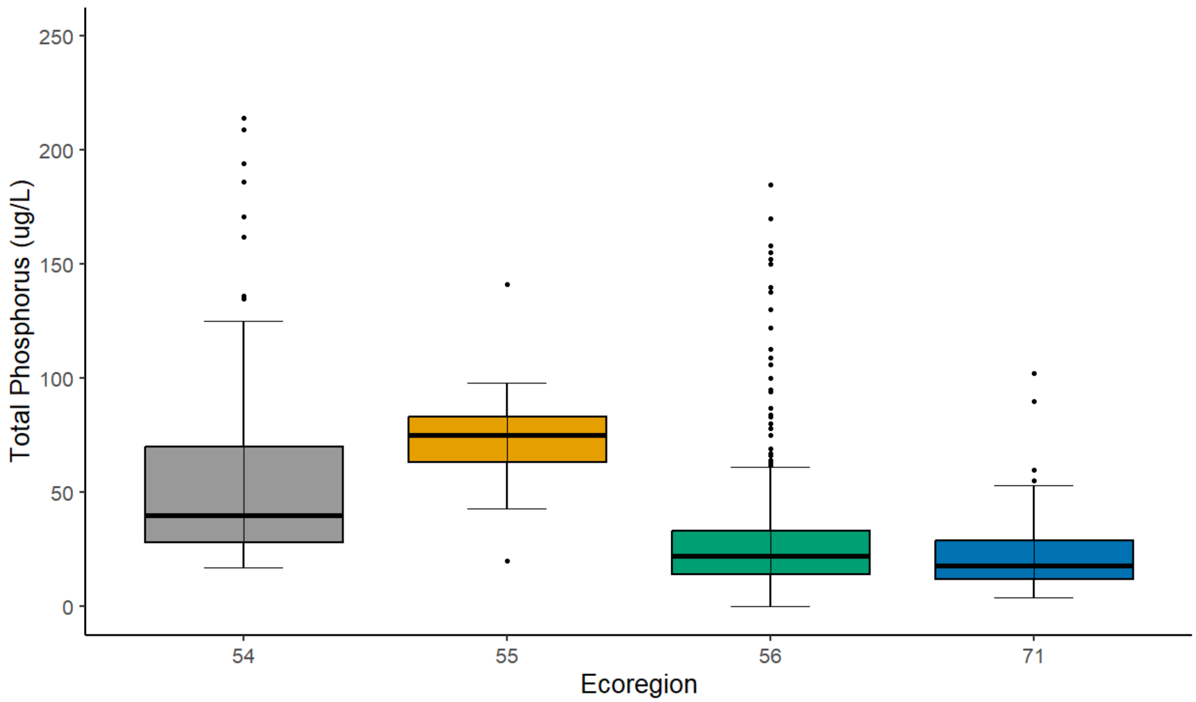


Figure 39. Distribution of total phosphorus concentrations (2019-2022) based on ecoregion. The median is the line inside the boxes and the error bars show the minimum and maximum values. The dots show the outlier values.

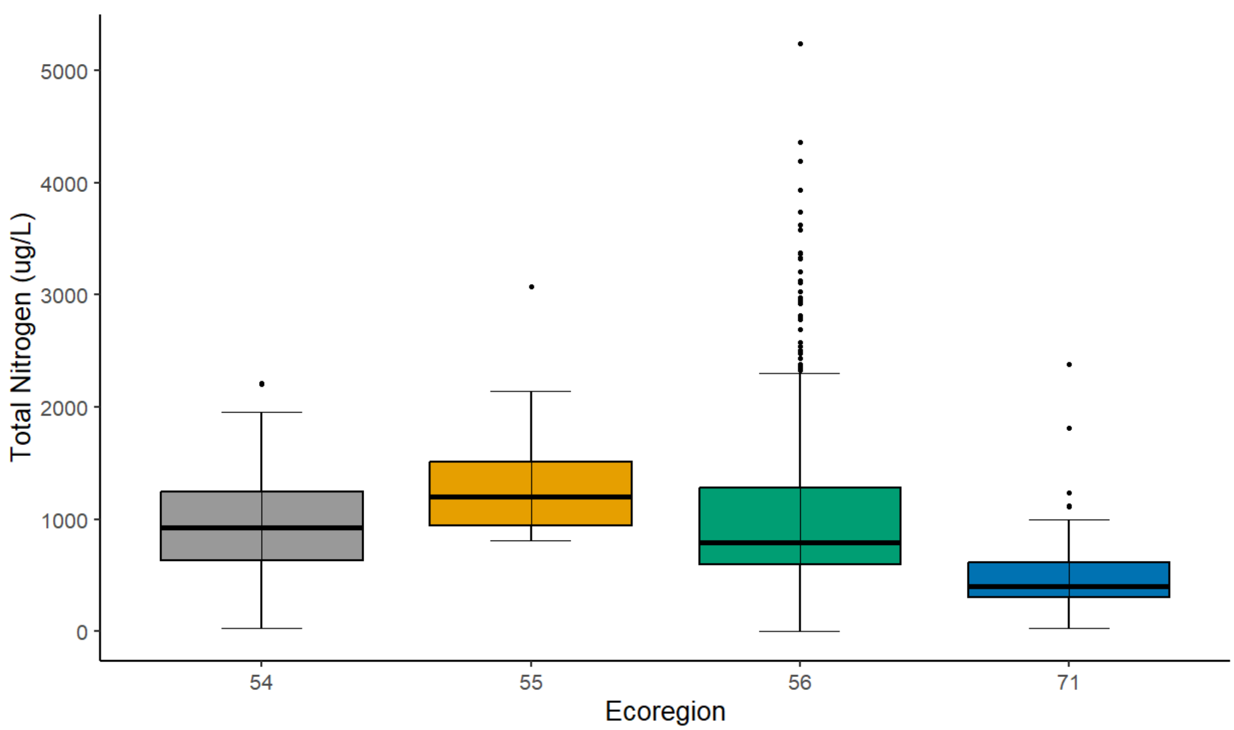


Figure 40. Distribution of total nitrogen concentrations (2019-2022) based on ecoregion. The median is the line inside the boxes and the error bars show the minimum and maximum values. The dots show the outlier values.

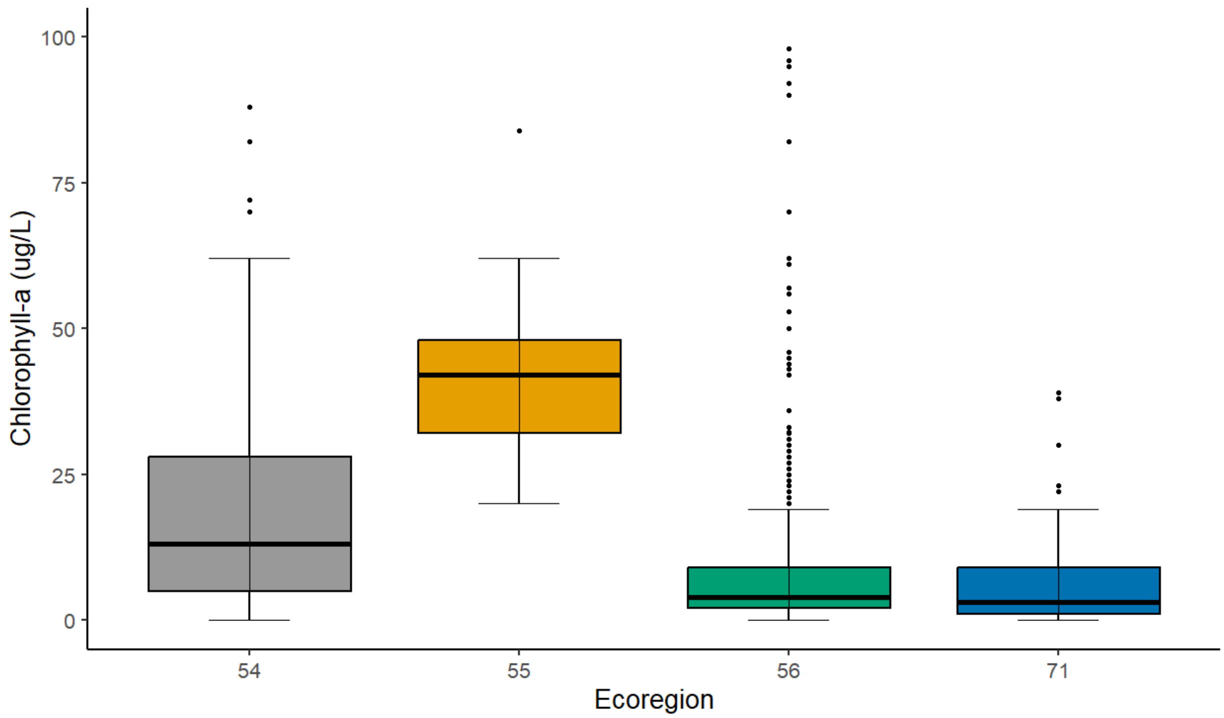


Figure 41. Distribution of chlorophyll *a* concentrations (2019-2022) based on ecoregion. The median is the line inside the boxes and the error bars show the minimum and maximum values. The dots show the outlier values.

Trophic State Index Analysis

Carlson's Trophic State Index is used to normalize total phosphorus, total nitrogen, and chlorophyll *a* as well as transparency (Figure 42). Trophic state is best analyzed using chlorophyll *a* as it is a direct indicator or productivity. For expanded sample analysis, we use only chlorophyll a to classify trophic state in this report. The distribution of lakes in each trophic class did not vary much from year to year. Secchi depth results in a similar trend (Figure 17). The Secchi trophic class predicted mostly mesotrophic and eutrophic conditions in the lakes for the past four years (Figure 42).

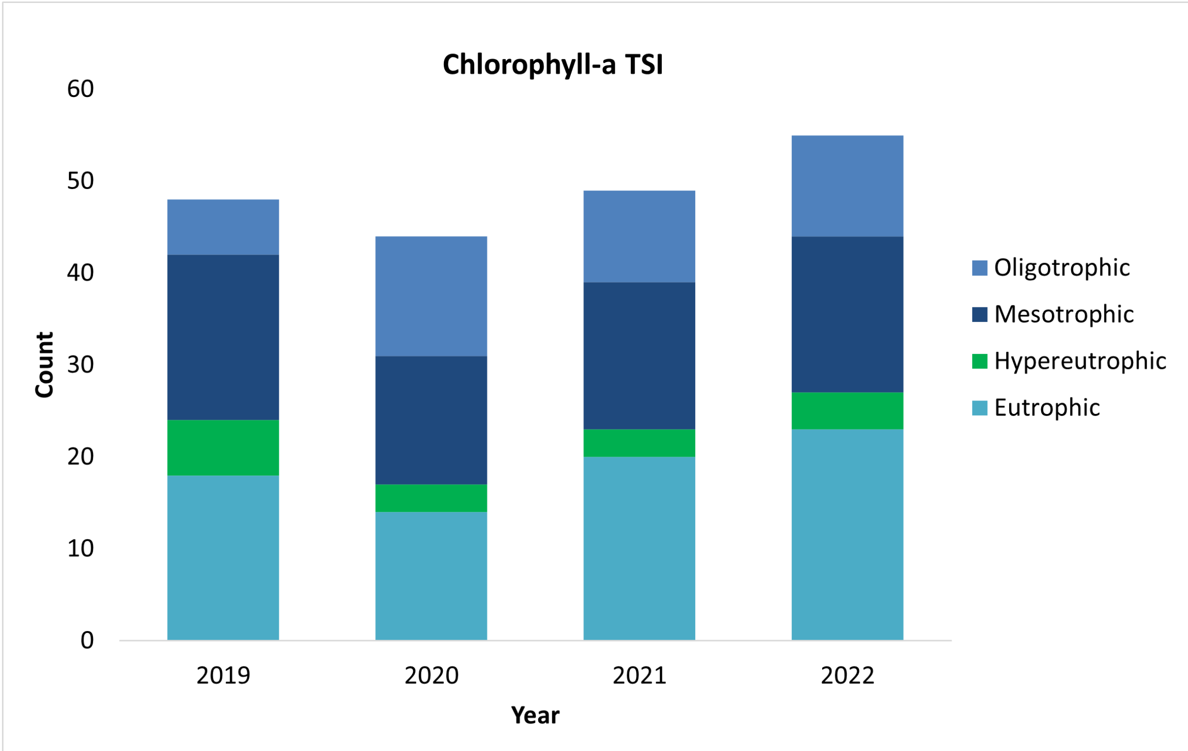


Figure 42. Number of lakes among trophic classes for July/August summertime means of chlorophyll *a*.

Trend Analysis

Volunteer data is best suited for looking at trends on individual lakes. Trend analysis is possible and looking at year to year variation can be helpful (Figures 43, 44, and 45). The data show little change in total phosphorus, total nitrogen, or chlorophyll *a*. There might be a slight decrease in the median concentration values from the start of the reporting period to the most recent year, but there is still high variation in each year's results as seen in the outlier values for each year.

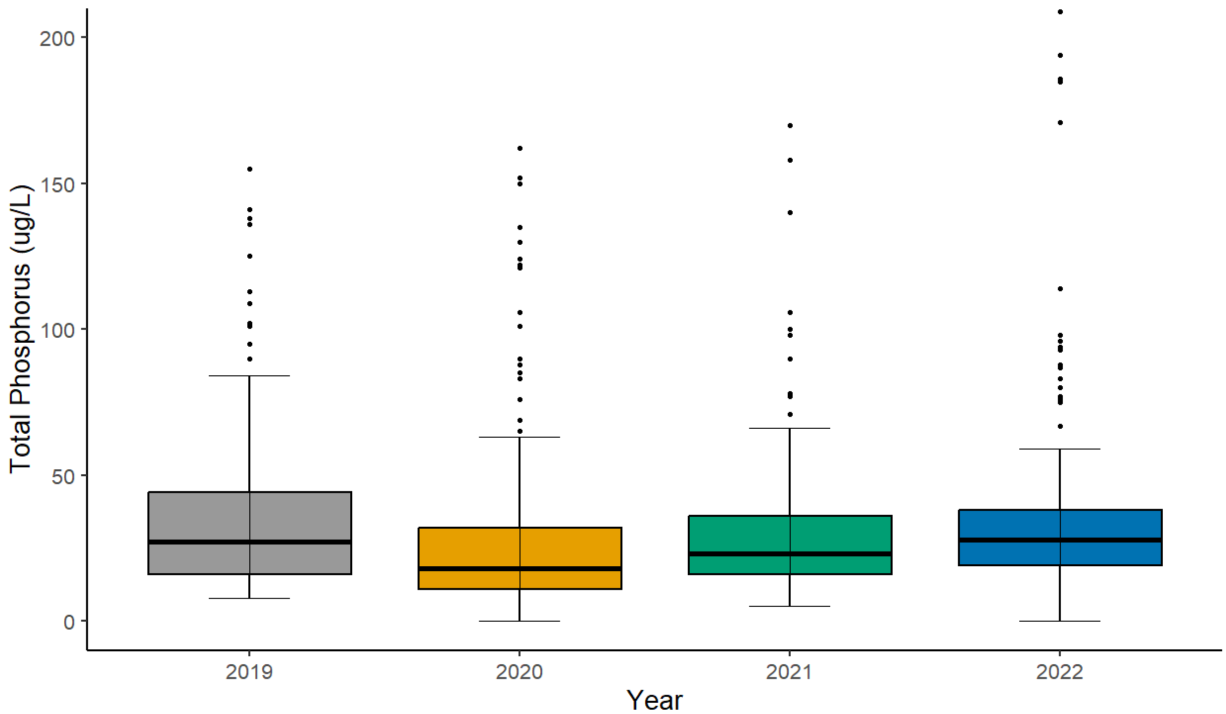


Figure 43. Total phosphorus summertime results categorized by year. The median is the line inside the boxes and the error bars show the minimum and maximum values. The dots show the outlier values.

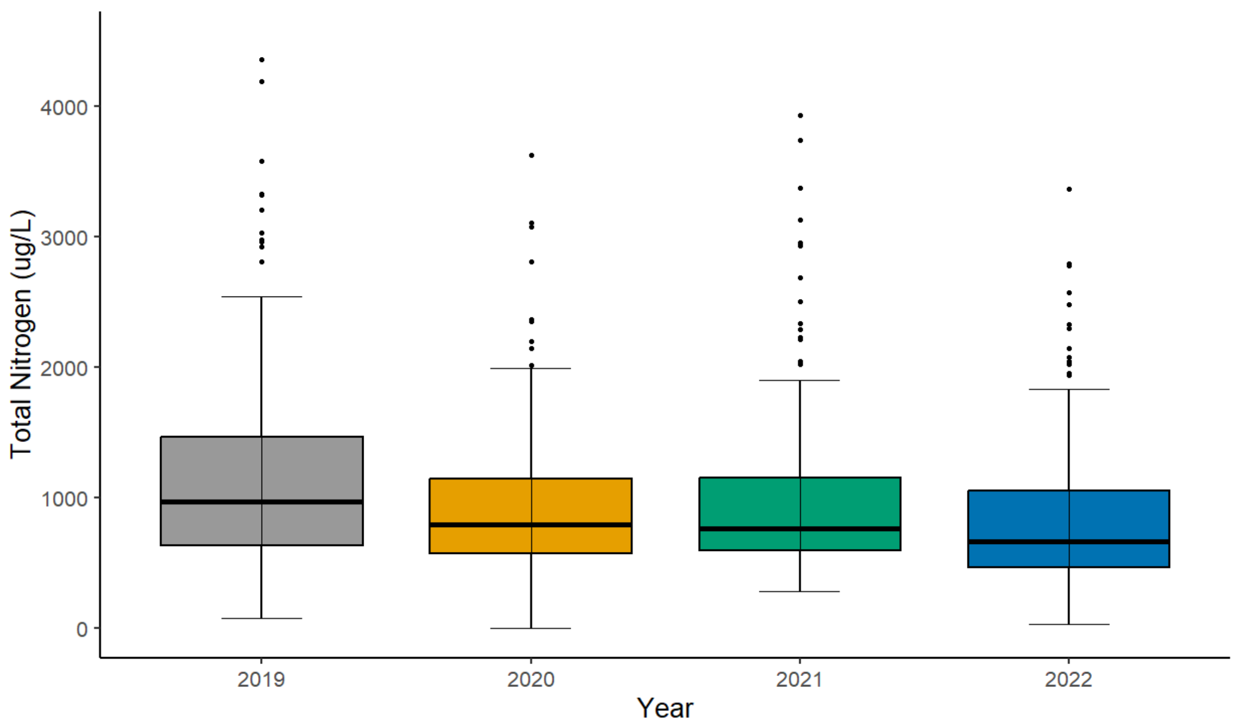


Figure 44. Total nitrogen summertime results categorized by year. The median is the line inside the boxes and the error bars show the minimum and maximum values. The dots show the outlier values.

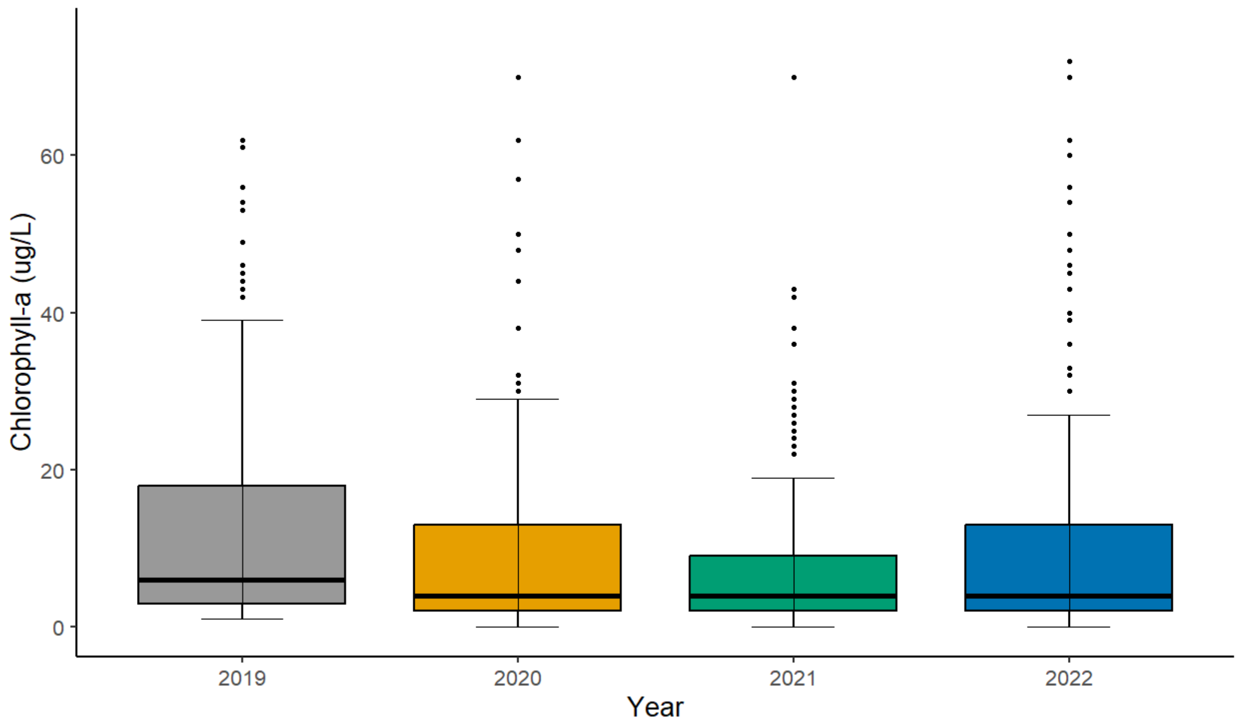


Figure 45. Chlorophyll *a* summertime results categorized by year. The median is the line inside the boxes and the error bars show the minimum and maximum values. The dots show the outlier values.

SURVEY RESULTS

At the end of each sampling season, we request volunteers complete a brief survey concerning their monitoring experience. These questionnaires provide feedback about the program and information on how we can better serve our volunteers and make improvements to the program. The survey also helps us determine how well any new policies and procedures are working for the volunteers.

Each year, respondents are asked "Please rank your concern of the following issues affecting your lake." Algal blooms have been a common concern across survey years, with 27.5% of respondents in 2022 ranking algal blooms as the top issue followed by silt at 24% (Figure 46). In recent years, respondents have become increasingly interested in learning about the management of watercraft, specifically in mitigating their environmental and shoreline impact.

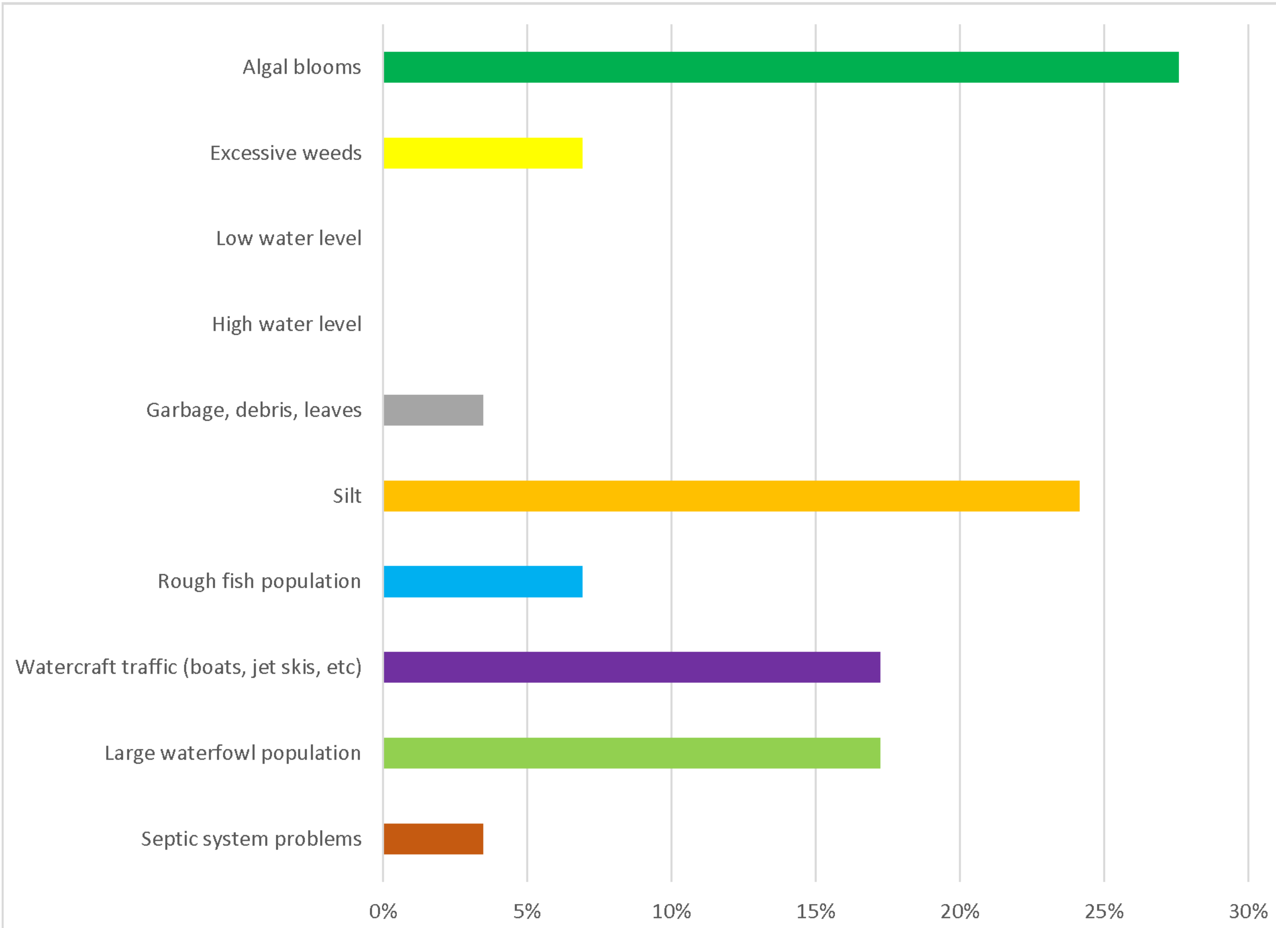


Figure 46. 2022 survey result reporting common issues with monitored lakes.

Many of the questions in the volunteer survey request feedback on the best ways to improve the volunteer lake monitoring program. There continues to be suggestions for improvements to the data entry process after rolling out a new form in 2018. Data entry and accessibility is a high priority in the coming years to improve efficiency and ease of use for the volunteers.

PROGRAM CHANGES

The volunteer monitoring program is taking steps to transition to a digital format wherever possible. The change allows faster response time and will allow volunteers to have access to data in a more timely manner.

Since 2018 volunteer end of the season reports have been sent out digitally as PDFs unless hardcopies were requested. We began an online end of the year survey in 2018 as a result of decreased participation. In some years, we send follow up surveys via mail if volunteers do not respond. We continue to work on the most effective ways to keep volunteers engaged.

INCLP in conjunction with O'Neill is also reformatting and rebuilding the database used to house and access data. Our goal is to make real-time Secchi depth data available online and implement easy to use data visualization tools on the website. While this process has stalled as a result of the pandemic, we hope to get this project back on track in the coming grant cycle.

CONCLUSIONS

The VLMP provides invaluable information on Indiana's lakes. The data collected through this program provide long-term data otherwise unachievable by INCLP. The VLMP has continued to change in the past four years, and we look forward to continued growth and improvement in the years to come. Growth of the program will continue in 2022 that will focus on recruiting volunteers on lakes without current monitors that have been monitored in the past. Overall, the citizen scientists are vital to this program, and we look forward to our continued work with them.

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