Interpreting Lake Data

Indiana Clean Lakes Program • Factsheet 08-01

Indiana Clean Lakes Program

The Indiana Clean Lakes Program was created in 1989 as a program within the Indiana Department of Environmental Management's (IDEM) Office of Water Management. The program is administered through a grant to Indiana University's School of Public and Environmental Affairs (SPEA) in Bloomington. The Indiana Clean Lakes Program is a comprehensive, statewide public lake management program having five components:

1. Public information and education
2. Technical assistance
3. Volunteer lake monitoring
4. Lake water quality assessment
5. Coordination with other state and federal lake programs.

Lake Water Quality Assessment

The goals of the lake water quality assessment component include: (a) identifying water quality trends in individual lakes, (b) identifying lakes that need special management, and (c) tracking water quality improvements due to industrial discharge and runoff reduction programs (Jones 1996).

Public lakes are defined as those that have navigable inlets or outlets or those that exist on or adjacent to public land. Only public lakes that have boat trailer access from a public right-of-way are generally sampled in this program. Sampling occurs in July and August of each year to coincide with the period of thermal stratification and the period of poorest annual water quality in lakes. Approximately 80 lakes are assessed each summer proceeding geographically through the state to minimize travel costs.

Sampling generally occurs at one site on each lake and is positioned over the deepest part of the lake. Profile measurements of dissolved oxygen (D.O.) and temperature are taken at 1 meter intervals from the surface to the bottom of the lake. Water samples for chemical analyses are collected from one meter below the water surface and from 1-2 meters above the lake bottom.

Sampling one site at each lake every 5 years is not the ideal frequency for data gathering. However, this protocol allows for gathering data from as many lakes as possible within a reasonable time frame and financial budget. The current protocol also reduces seasonal variability in sampling.

Water Quality Parameters Included in Lake Assessments

Monitoring lakes requires many different parameters to be sampled. The parameters analyzed in this assessment include:

Phosphorus: Phosphorus is an essential plant nutrient and most often controls aquatic plant (algae and macrophyte) growth in freshwater. It is found in fertilizers, human and animal wastes, and yard waste. There is no atmospheric (vapor) form of phosphorus. Because there are few natural sources of phosphorus and the lack of an atmospheric cycle, phosphorus is often a ***limiting nutrient*** in aquatic systems. This means that the relative scarcity of phosphorus may limit the ultimate growth and production of algae and rooted aquatic plants. Therefore, management efforts often focus on reducing phosphorus input to a receiving waterway because: (a) it can be managed, and (b) reducing phosphorus can reduce algae production. Two common forms of phosphorus are:

> ***Soluble reactive phosphorus (SRP)* –** SRP is dissolved phosphorus readily usable by algae. SRP is often found in very low concentrations in phosphorus-limited systems where the phosphorus is tied up in the algae and cycled very rapidly. Sources of SRP include fertilizers, animal wastes, and septic systems.
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> ***Total phosphorus (TP)* –** TP includes dissolved and particulate forms of phosphorus. TP concentrations greater than 0.03 mg/L (or 30μg/L) can cause algal blooms in lakes and reservoirs.

Nitrogen: Nitrogen is an essential plant nutrient found in fertilizers, human and animal wastes, yard waste, and the air. About 80% of the atmosphere is nitrogen gas. Nitrogen gas diffuses into water where it can be "fixed" (converted) by blue-green algae to ammonia for algal use. Nitrogen can also enter lakes and streams as inorganic nitrogen and ammonia. Because nitrogen can enter aquatic systems in many forms, there is an abundant supply of available nitrogen in these systems. The three common forms of nitrogen are:

> ***Nitrate (NO_3^-)* –** Nitrate is an oxidized form of dissolved nitrogen that is converted to ammonia by algae under anoxic (low or no oxygen) conditions. It is found in streams and runoff when dissolved oxygen is present, usually in the surface waters.
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> ***Ammonia (NH_4^+)* –** Ammonia is a form of dissolved nitrogen that is readily used by algae. It is the reduced form of nitrogen and is found in water where dissolved oxygen is lacking such as in a eutrophic hypolimnion. Important sources of ammonia include fertilizers and animal manure. In addition, ammonia is produced as a by-product by bacteria as dead plant and animal matter are decomposed.
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> ***Organic Nitrogen (Org N)* –** Organic nitrogen includes nitrogen found in plant and animal materials and may be in dissolved or particulate form. In the analytical procedures, total Kjeldahl nitrogen (TKN) was determined. Organic nitrogen is TKN minus ammonia.

Light Transmission: This measurement uses a light meter (photocell) to determine the rate at which light transmission is diminished in the upper portion of the lake's water column. Another important light transmission measurement is determination of the 1% light level. The 1% light level is the water depth to which one percent of the surface light penetrates. The 1% light level is considered the lower limit of algal growth in lakes and this area and above is referred to as the *photic zone*.

Dissolved Oxygen (D.O): D.O. is the dissolved gaseous form of oxygen. It is essential for respiration of fish and other aquatic organisms. D.O. enters water by diffusion from the atmosphere and as a by-product of photosynthesis by algae and plants. Epilimnetic waters continually equilibrate with the concentration of atmospheric oxygen. Excessive algae growth can over-saturate (greater than 100% saturation) the water with D.O when rate of photosynthesis production is greater than the rate of oxygen diffusion to the atmosphere. Hypolimnetic D.O. concentration is typically low as there is no mechanism to replace oxygen that is consumed by respiration and decomposition. Fish need at least 3-5 mg/L of D.O. to survive.

Secchi Disk Transparency: Secchi disk transparency refers to the depth to which the black and white Secchi disk can be seen in the lake water. Water clarity, as determined by a Secchi disk, is affected by two primary factors: algae and suspended particulate matter. Particulates (soil or dead leaves) may be introduced into the water by either runoff or sediments already on the bottom of the lake. Erosion from construction sites, agricultural lands, and riverbanks all lead to increased runoff. Bottom sediments may be resuspended by bottom-feeding fish such as carp, or by motorboats or strong winds in shallow lakes.

Plankton: Plankton are important members of the aquatic food web. Plankton includes algae (microscopic plants) and zooplankton (tiny shrimp-like animals that eat algae). Plankton are collected with a 2 meter integrated sampler. Plankton are then concentrated and enumerated. Blue-green algae are those that most often form nuisance blooms and their dominance in lakes may indicate poor water conditions. Plankton data densities are expressed as cells per milliliter of lake water. Plankton data were historically expressed in Natural Units per liter. A Natural Unit is one organism that may have a single cell or may be a colony of multiple cells. In 2010 we changed to cell counting to be consistent with the World Health Organizations (WHO) standards.

Chlorophyll *a*: The plant pigments of algae consist of the chlorophylls (green color) and carotenoids (yellow color). Chlorophyll *a* is the most dominant chlorophyll pigment. Thus, chlorophyll *a* is often used as a direct estimate of algal biomass.

<u>How Much Nitrogen and Phosphorus is Too Much?</u>

Phosphorus is often a *limiting nutrient* in lakes. This means that an addition of phosphorus to most lakes will result in increased growth of algae. Therefore, lake management efforts often focus on reducing phosphorus inputs to lakes because: (a) it <u>can</u> be managed since there is no phosphorus gas that can enter lakes from the atmosphere like there is for nitrogen, and (b) reducing phosphorus can reduce algae production.

Results of studies conducted by Richard Vollenweider in the 1970's are often used as guidelines for evaluating concentrations of water quality parameters. His results are given in the table below. Vollenweider relates the concentrations of selected water quality parameters to a lake's *trophic state*. The trophic state of a lake refers to its overall level of nutrition or biological productivity. Trophic categories include: *oligotrophic, mesotrophic, eutrophic* and *hypereutrophic*. Lake conditions typically associated with these trophic states are:

Oligotrophic - lack of plant nutrients keep productivity low, lake contains oxygen at all depths, clear water, deeper lakes can support trout.

Mesotrophic - moderate plant productivity, hypolimnion may lack oxygen in summer, moderately clear water, warm water fisheries only - bass and perch may dominate.

Eutrophic - contains excess nutrients, blue-green algae dominate during summer, algae scums are probable at times, hypolimnion lacks oxygen in summer, poor transparency, rooted macrophyte problems may be evident.

Hypereutrophic - algal scums dominate in summer, few macrophytes, no oxygen in hypolimnion, fish kills possible in summer and under winter ice.

The units in the table are either milligrams per liter (mg/L) or micrograms per liter (µg/L). One mg/L is equivalent to one part per million (PPM) while one microgram per liter is equivalent to one part per billion (PPB). Remember that these are only guidelines; similar concentrations in your lake may not cause problems if something else is limiting the growth of algae or rooted plants.

TABLE 1. Mean values of some water quality parameters and their relationship to lake production. (after Vollenweider, 1979)

PARAMETER	Oligotrophic	Mesotrophic	Eutrophic	Hypereutrophic
Total Phosphorus (µg/L or PPB)	8	27	84	>750
Total Nitrogen (mg/L or PPM)	0.661	0.753	1.875	-
Chlorophyll *a* (µg/L or PPB)	1.7	4.7	14.3	-

Expected Values for Water Quality Parameters

A wide variety of conditions, including geography, morphometry (lake depth, area, shoreline length, etc.), time of year, and watershed characteristics, can influence the water quality of lakes. Thus, it is difficult to predict and even explain the reasons for the water quality of a given lake. To help you place your lake data into perspective, consider the following data for 456 Indiana lakes collected during July and August 1998-2004 under the Indiana Clean Lakes Program. The set of data summarized in the table represents the mean of the epilimnetic and hypolimnetic samples for each of the 456 lakes.

	Secchi Disk (ft)	NO_3 (mg/L)	NH_4 (mg/L)	TKN (mg/L)	SRP (mg/L)	TP (mg/L)	Chl *a* (µg/L)	Plankton (NU/L)
Median	6.9	0.275	0.818	1.66	0.12	0.17	12.9	35570
Max.	32.8	9.4	22.5	27.05	2.84	2.81	380.4	753170
Min.	0.3	0.013	0.018	0.230	0.01	0.01	0.013	39

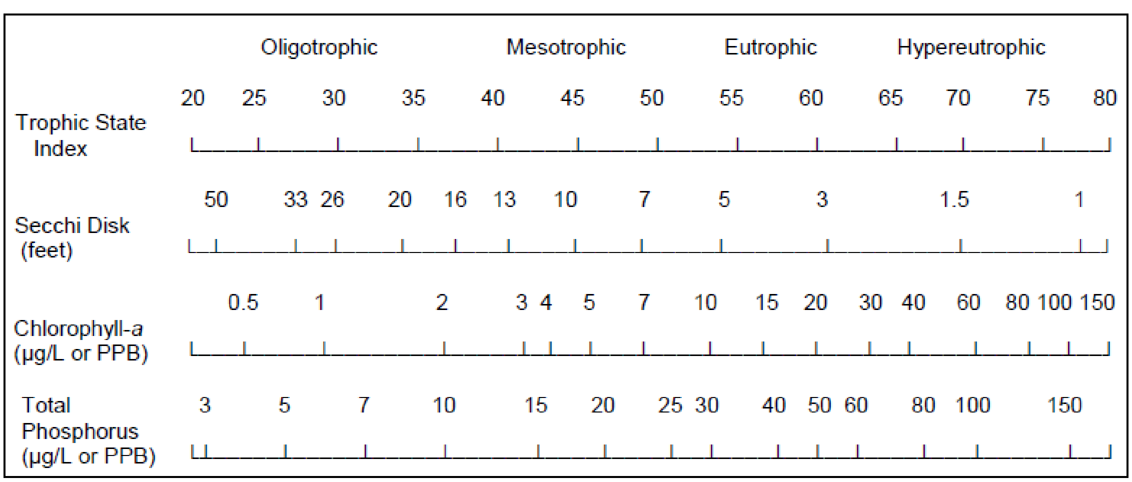
<u>What is a Trophic State Index?</u>

The large amount of water quality data collected during lake water quality assessments can be confusing to evaluate. Because of this, Indiana and many other states use a trophic state index (TSI) to help evaluate water quality data. A TSI condenses water quality data into a single, numerical index. Different index (or eutrophy) points are assigned for various water quality concentrations. The index total, or TSI, is the sum of individual eutrophy points for a lake. Until 2010 we used both the Indiana TSI and the Carlson TSI to analyze our data. In 2010, in order to be consistent with new standard methodology, we switched to the use of only the Carlson TSI to analyze Indiana's lakes.

<u>The Carlson TSI</u>

The most widely used and accepted TSI in the U.S. is one developed by Bob Carlson called the Carlson TSI. Carlson analyzed summertime total phosphorus, chlorophyll *a*, and Secchi disk transparency data for numerous lakes and found statistically significant relationships among the three parameters. He developed mathematical equations for these relationships and these for the basis for the Carlson TSI. Using this index, a TSI value can be generated by one of three measurements: Secchi disk transparency, chlorophyll *a* or total phosphorus. Data for one parameter can also be used to predict a value for another. The TSI values range from 0 to 100. Each major TSI division (10, 20, 30, etc.) represents a doubling in algal biomass.

CARLSON'S TROPHIC STATE INDEX



As a further aid in interpreting TSI results, Carlson's scale is divided into four lake productivity categories: oligotrophic (least productive), mesotrophic (moderately productive); eutrophic (very productive) and hypereutrophic (extremely productive).

Using Carlson's index, a lake with summertime Secchi disk depth of 3 feet would have a TSI of 61 points (located in a vertical line with the 3 feet). This lake would be in the eutrophic category. Because the index was constructed using relationships among transparency, chlorophyll, and total phosphorus, a lake having a Secchi disk depth of 3 feet would also be expected to have about 20 µg/L chlorophyll and about 50 µg/L total phosphorus.

Not all lakes have the same relationship between transparency, chlorophyll and total phosphorus as Carlson's lakes do. Other factors such as high suspended sediments or heavy predation of algae by zooplankton may keep chlorophyll concentrations lower than might be otherwise expected from the total phosphorus or chlorophyll concentrations. High suspended sediments would also make transparency worse than otherwise predicted by Carlson's index.

It is also useful to compare the actual trophic state points for a particular lake from one year to the next to detect any trends in changing water quality. While climate and other natural events will cause some variation in water quality over time (possibly 5-10 trophic points), larger point changes may indicate important changes in lake quality.

The Indiana TSI

The Indiana TSI ranges from 0 to 75 total points. The TSI totals are grouped into the following three lake quality classifications:

TSI Total	Water Quality Classification
0-15	highest quality (oligotrophic)
16-30	intermediate quality (mesotrophic)
31-45	low quality (eutrophic)
46-60	lowest quality (hypereutrophic)

A rising TSI score for a particular lake from one year to the next indicates that water quality is worsening while a lower TSI score indicates improved conditions. However, natural factors such as climate variation can cause changes in TSI score that do not necessarily indicate a long-term change in lake condition. Parameters and values used to calculate the Indiana TSI are given in the table following.

THE INDIANA TROPHIC STATE INDEX

Parameter and Range			Eutrophy Points
I.	Total Phosphorus (μg/L)		
	A.	At least 30	1
	B.	40 to 50	2
	C.	60 to 190	3
	D.	200 to 990	4
	E.	1000 or more	5
II.	Soluble Phosphorus (μg/L)		
	A.	At least 30	1
	B.	40 to 50	2
	C.	60 to 190	3
	D.	200 to 990	4
	E.	1000 or more	5
III.	Organic Nitrogen (mg/L)		
	A.	At least 0.5	1
	B.	0.6 to 0.8	2
	C.	0.9 to 1.9	3
	D.	2.0 or more	4
IV.	Nitrate (mg/L)		
	A.	At least 0.3	1
	B.	0.4 to 0.8	2
	C.	0.9 to 1.9	3
	D.	2.0 or more	4

Indiana Trophic State Index (continued)

V.	Ammonia (mg/L)		
	A.	At least 0.3	1
	B.	0.4 to 0.5	2
	C.	0.6 to 0.9	3
	D.	1.0 or more	4
VI.	Dissolved Oxygen: Percent Saturation at 5 feet from surface		
	A.	114% or less	0
	B.	115% 50 119%	1
	C.	120% to 129%	2
	D.	130% to 149%	3
	E.	150% or more	4

VII. Dissolved Oxygen: Percent of measured water column with at least 0.1 ppm dissolved oxygen

A.	28% or less	4
B.	29% to 49%	3
C.	50% to 65%	2
D.	66% to 75%	1
E.	76% 100%	0

VIII. Light Penetration (Secchi Disk)

A.	Five feet or under	6

IX. Light Transmission (Photocell): Percent of light transmission at a depth of 3 feet

A.	0 to 30%	4
B.	31% to 50%	3
C.	51% to 70%	2
D.	71% and up	0

X. Total Plankton per liter of water sampled from a single vertical tow between the 1% light level and the surface:

A.	less than 3,000 organisms/L	0
B.	3,000 - 6,000 organisms/L	1
C.	6,001 - 16,000 organisms/L	2
D.	16,001 - 26,000 organisms/L	3
E.	26,001 - 36,000 organisms/L	4
F.	36,001 - 60,000 organisms/L	5
G.	60,001 - 95,000 organisms/L	10
H.	95,001 - 150,000 organisms/L	15
I.	150,001 - 5000,000 organisms/L	20
J.	greater than 500,000 organisms/L	25
K.	Blue-Green Dominance: additional points	10

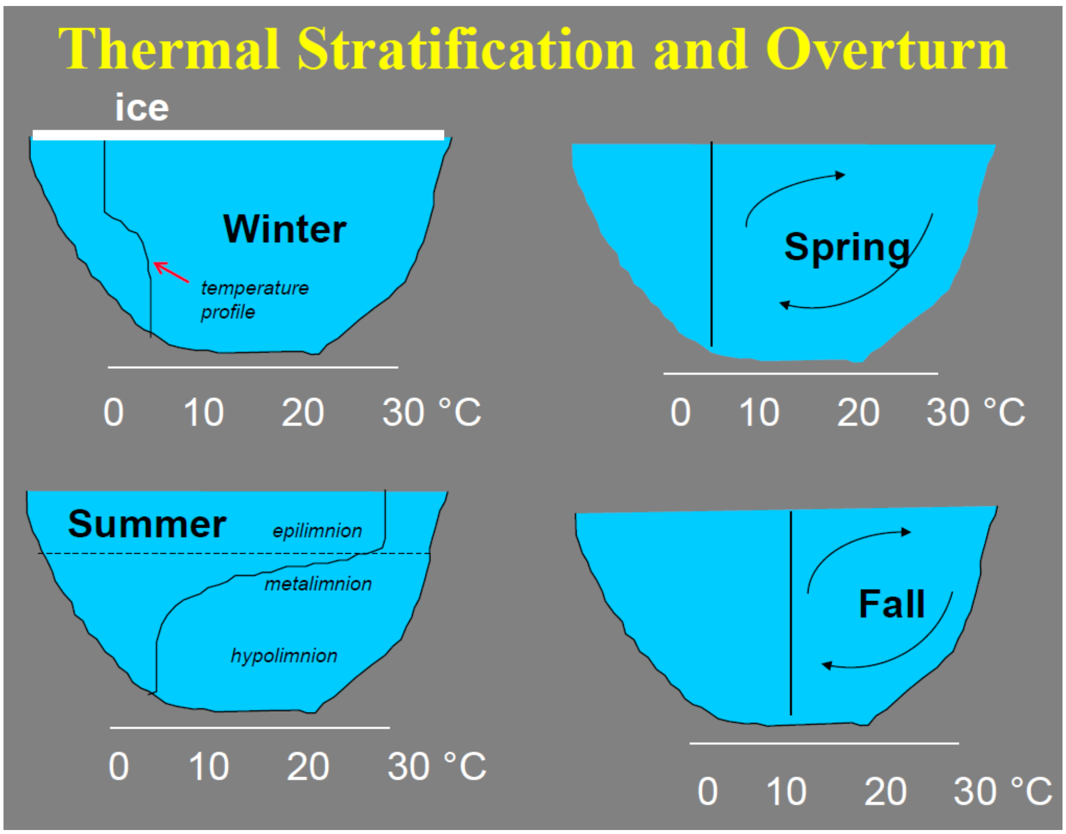
HOW YOUR LAKE CHANGES WITH THE SEASONS

As the spring sun rises higher in the sky and air temperatures become warmer, the surface water of lakes warms as well. This warm water is less dense than the cold, heavy water on the lake bottom. The wind does not have enough energy to overcome these density differences and completely mix the lake; so only the surface water (***epilimnion*)** is mixed during the summer in deeper lakes (more than 16-23 feet deep). Thus, the bottom waters in the ***hypolimnion*** are isolated from the air at the surface. This temperature and density layering in lakes is called ***stratification***.

Dissolved oxygen in the hypolimnion is consumed by bacteria decomposing organic matter (dead algae, leaves, etc.) on the sediments. This lost oxygen is not replaced during stratification because the hypolimnion is not in contact with the atmosphere and photosynthesis (which produces oxygen as a by-product) cannot take place in the dark waters. As a result, oxygen concentrations are often lower in the hypolimnion of stratified lakes - the lower the hypolimnetic oxygen concentration, the more productive (***eutrophic***) the lake is. Low oxygen in the hypolimnion can also allow phosphorus to separate from compounds in the sediments and re-dissolve in the water. Ammonia can also accumulate in the hypolimnion as a result of bacterial decomposition of organic material in the sediments.

In the fall, cooler air temperatures gradually cool the lake's surface water until it is nearly the same temperature as the bottom water. Because all the water now has similar density, a light wind can cause the lake to mix completely down to the bottom. This is called ***fall overturn***. Any increased nutrients in the hypolimnion can now mix with the surface water and this may cause a fall algae bloom in some lakes.

Seasonal Variation in Lake Temperatures



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