

LRMD Board Handout for 4/18/09 Meeting

NOTE: *The following is a small excerpt taken from the 'water quality description' section of the draft management plan. It includes a summary of long-term monitoring results related to water clarity, phosphorus and chlorophyll. Analysis of these three variables should provide a good, big-picture perspective on lake health trends from a strictly water-quality perspective. Other measures of water quality—such as temperature, dissolved oxygen concentrations, pH, and bacteria counts—are or will be addressed in the plan, but were not included in this excerpt.*

Lake Trophic Status

Lakes are routinely characterized and evaluated according to their trophic status. Trophic status describes the level of nutrient enrichment (or fertility) and primary productivity (plant and algae growth) in a lake. It is determined by assessing water clarity, phosphorus and chlorophyll-a data. Carlson's Trophic State Index (TSI) is a continuum scale of 0 to 100, corresponding with the clearest and most nutrient-poor lake possible, to the murkiest and presumably most nutrient-rich lake possible.

Lakes undergo a natural aging process, called eutrophication, as sedimentation and decay increase fertility and cause lakes to fill in over thousands of years. This process moves a lake's trophic status toward higher points along the index. Human activities that increase the rate of nutrient enrichment can compress the eutrophication timeframe to only a few years or decades. Water bodies that receive excessive amounts of nutrients like phosphorus from their watersheds are most likely to become eutrophic.

Lakes can be divided into four nutrient-enrichment categories: oligotrophic (TSI 0-40), mesotrophic (TSI 40-50), eutrophic (TSI 50-70) or hypereutrophic (TSI 70-100). Oligotrophic lakes are generally clear, deep and free of weeds or large algae blooms. They are low in nutrients, well oxygenated, and not capable of supporting large fish populations. However, these lakes often develop a food chain that can sustain a very desirable fishery with large game fish. Mesotrophic lakes lie between the oligotrophic and eutrophic stages. They have moderately clear water and may become devoid of oxygen in their bottom waters, causing phosphorus release from the sediment. Eutrophic lakes have poor water clarity, are high in nutrients, and support a large biomass of aquatic plants and animals. They are usually either weedy or subject to frequent algae blooms, or both. Although capable of supporting large fish populations, these lakes are also more susceptible to oxygen depletion. Rough fish like carp are commonly found in eutrophic lakes. Finally, hypereutrophic lakes are those that are super-enriched with problematic nutrients like phosphorus. These lakes experience heavy algae blooms throughout the summer, and may even experience fish kills. Rough fish dominate in hypereutrophic lakes. It is important to recognize that lakes can shift between trophic states. This shift can be in a negative or positive direction, depending on watershed condition and the level of management intervention.

Lakes dominated by aquatic plants tend to have high amounts of phosphorus tied up in the bottom sediments, and relatively low phosphorus in the water column. Conversely, lakes that produce mostly algae have high phosphorus concentrations in the water. Most lakes have a fairly

stable ratio of aquatic plants to algae. TSI values only represent the portion of nutrients (phosphorus) that are found in the water column, as evidenced by the amount of algae growth. Therefore, if most of the available nutrients are held in the sediments of a lake with heavy plant growth, its true nutrient status cannot be accurately measured using TSI calculations.

Lake Ripley is best described as meso-eutrophic. It fluctuates between mesotrophic and eutrophic conditions with a summer mean TSI of about 50. A similar lake left undisturbed might be expected to maintain a TSI value of about 40. [Need to correlate historic climatic patterns to observed TP, chlorophyll and Secchi to demonstrate range of runoff and lake-response possibilities] The trophic status of Wisconsin lakes based on chlorophyll-*a* concentration, water clarity (Secchi-disk depth), and total phosphorus concentration is presented in Table 8 below.

Table 8: Trophic classification of Wisconsin lakes based on total phosphorus, chlorophyll-*a*, and Secchi depth values.¹ (Carlson, 1977, and modified by Lillie and others, 1993)

Trophic Class	Trophic State Index (TSI)	Total Phosphorus (µg/l)	Chlorophyll- <i>a</i> (µg/l)	Secchi Depth (ft)
100				
Hyper-eutrophic	-----70-----	-----96.0-----	-----56.0-----	-----1.6-----
Eutrophic				
	-----50-----	-----24.0-----	-----7.3-----	-----6.5-----
Mesotrophic				
	-----40-----	-----12.0-----	-----2.6-----	-----13.1-----
Oligotrophic	0			

Phosphorus as Limiting Nutrient

Phosphorus (P) and nitrogen (N) are the two nutrients that most directly influence aquatic plant and algae growth; the extent of which depends on the relative abundance and availability of each nutrient. These often problematic nutrients typically enter lakes in the form of polluted runoff that may contain eroded soil, manure, pet waste, chemical fertilizers, and organic debris, among other material. The erosion of stream banks, construction sites, shorelines and farmland all contribute sediment and fertile runoff to downstream lakes. Failing septic systems around smaller, unsewered lakes can also contribute significantly to nutrient-loading problems.

Plants need phosphorus and nitrogen to grow. However, phosphorus reduction is often the focus of lake-rehabilitation programs because it is: (1) in short supply relative to other critical nutrients and therefore dictates the rate of algae growth, and (2) it is easiest to manipulate since the element has no gaseous component in its biogeochemical cycle. N:P ratios are used to determine

¹ Lillie, R.A., S. Graham and P. Rasmussen. May 1993. Trophic State Index Equations and Regional Predictive Equations for Wisconsin Lakes. Wisconsin Department of Natural Resources. Research Management Findings #35 technical bulletin.

which nutrient most “limits” or controls algae productivity by comparing the relative availability of each nutrient within the water column. Because the essential nutrient is in short supply, it effectively limits the amount of primary productivity the lake is capable of supporting. A N:P ratio greater than 15:1 near the water surface is indicative of a lake that is phosphorus limited. A ratio from 10:1 to 15:1 indicates a transition situation, and a ratio less than 10:1 usually indicates nitrogen limitation. Lakes with intermediate ratios can be limited from time to time by either element, but by reducing phosphorus availability, this element can be made the limiting factor.

The limiting nutrient for algae growth in Lake Ripley is phosphorus, with typical N:P ratios in excess of 27:1. This is not surprising since phosphorus is the key nutrient affecting the amount of algae growth in over 95% of Wisconsin’s lakes (Lily & Mason, 1983). According to the 1994 Water Resources Appraisal, phosphorus sources to the lake include watershed inflow (83%), direct precipitation (9%), and groundwater inflow (8%). The lake bottom may also be a significant source of phosphorus. It is commonly released from nutrient-rich bottom sediment due to physical disturbance, high pH levels, or anoxic conditions. Algae blooms could then result, especially when phosphorus enters the water column during the summer growing season.

Summer mean total phosphorus concentrations and associated TSI values from 1986-2008 are illustrated in [Figures 10 and 11](#) below. Surface total phosphorus concentrations for Lake Ripley during the summer months are generally indicative of a meso-eutrophic system, with an average value of 20.1 µg/l. Most recorded values were clustered in the range of 10-25 µg/l, but with a relatively big spike in 1990 following a drought year when phosphorus release from anoxic sediments may have been a factor. There does not appear to be a strong trend toward increasing or decreasing total phosphorus concentrations over the 22-year monitoring period.

When phosphorus concentrations exceed 25 µg/l at the time of spring turnover in natural lakes and impoundments, these water bodies may occasionally experience nuisance levels of algal growth (>10 µg/l = mild blooms; >30 = severe; >60 = very severe). In hard water lakes like Lake Ripley where limestone is dissolved in the water, marl (calcium carbonate) precipitates and falls to the bottom. These marl formations absorb phosphorus, reducing its overall concentration as well as algae growth. Hard water lakes often have clear water, but may be weedy since rooted aquatic plants can still get phosphorus from the sediments.

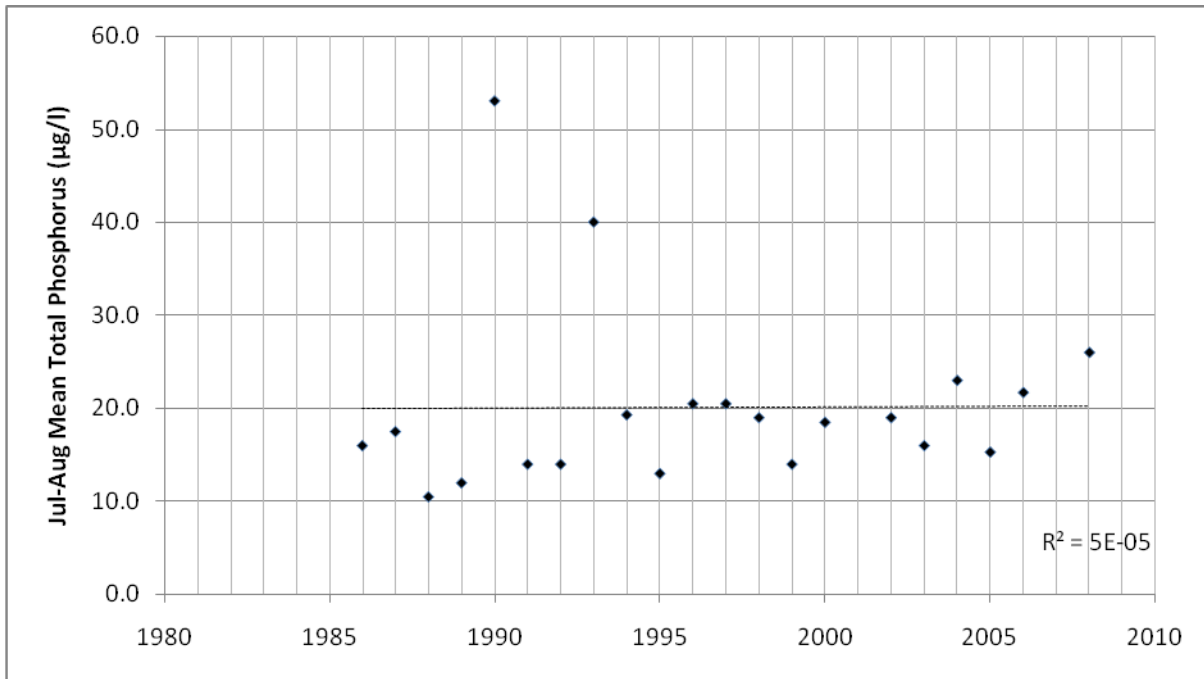


Figure 10: July-August Mean Total Phosphorus Measurements (1986-2008)

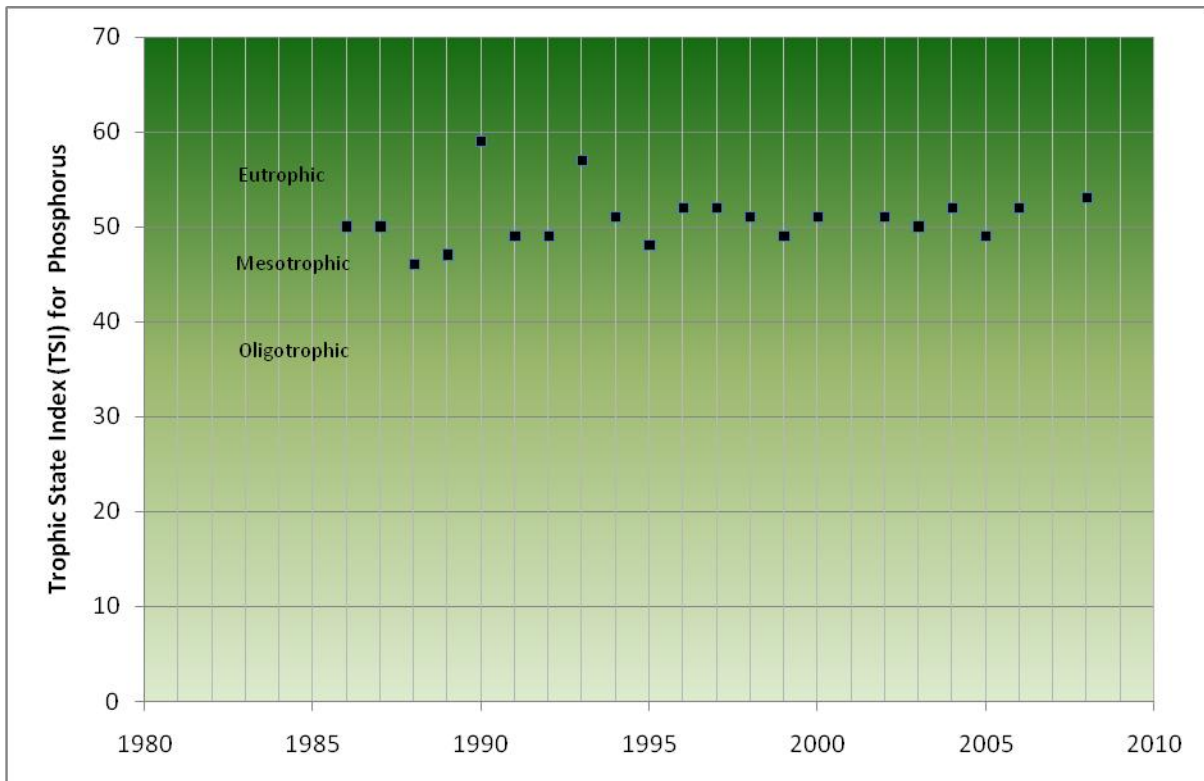


Figure 11: TSI Based on Corresponding Total Phosphorus Readings (1986-2008)

Algae (Phytoplankton)

Phytoplankton is a term used to describe free-floating, microscopic plant life, more commonly known as algae. Algae are the primary producers that form the base of the aquatic food chain. The amount of sunlight and nutrients that are available in a lake, among other factors, will dictate algae abundance. In eutrophic lakes, high nutrient fertility can cause nuisance algae blooms that make the water appear very green and murky. Blue green algae (cyanobacteria) are even known to produce a floating green scum thick enough to shade out aquatic plants. High concentrations of wind-blown algae may accumulate on shorelines where they die and decompose, causing noxious odors, unsightly conditions and oxygen depletion.

Controlling nuisance algae populations in lakes is a difficult undertaking. Because algae are microscopic plants that are free-floating and even free-swimming in the water column, managing the whole lake rather than just the problem areas is necessary. Since algae populations are caused by high nutrient concentrations, attempting to eliminate algae by attacking it directly with algicides (chemical herbicides) is a short-term solution that may become a costly management approach over the long run. The best way to manage excessive algae is to both reduce the supply of nutrients (especially phosphorus) into the lake, and then control the availability of nutrients that are already contained within the lake. This represents a “bottom-up” approach to algae control.

A supplementary “top-down” approach, called biomanipulation, uses food-web manipulations to help manage algae problems. By influencing predator-prey relationships, such as through the stocking of gamefish or removal of rough fish, conditions can be made more or less favorable to algal growth. For example, as the number of top predators (like bass and walleye) increase, the number of planktivorous fish (like bluegill and perch) should decrease, resulting in less predation on algae-consuming zooplankton. This, in turn, means higher populations of zooplankton that can graze on problem algae. Zooplankton populations can also be enhanced through the availability of sufficient plant cover where these tiny animals can escape fish predation.

Chlorophyll-*a*, the green pigment found in all photosynthesizing organisms, is commonly used as an indicator of algal biomass in lakes. Chlorophyll-*a* values for Lake Ripley during the summer months are generally indicative of a meso-eutrophic system, with an average value of 8.5 µg/l. Chlorophyll-*a* concentrations and associated TSI values from 1986-2008 are illustrated in [Figures 12 and 13](#) below. There does not appear to be any strong trends toward increasing or decreasing chlorophyll-*a* concentrations over the 22-year monitoring period.

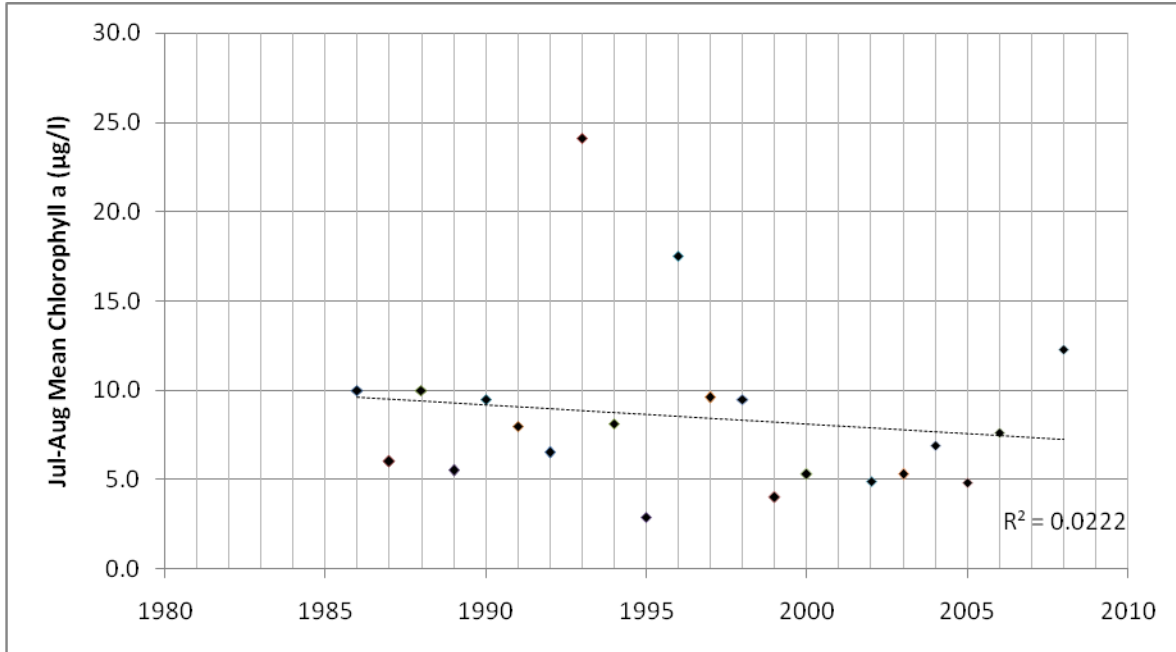


Figure 12: Chlorophyll-*a* Measurements (1986-1999)

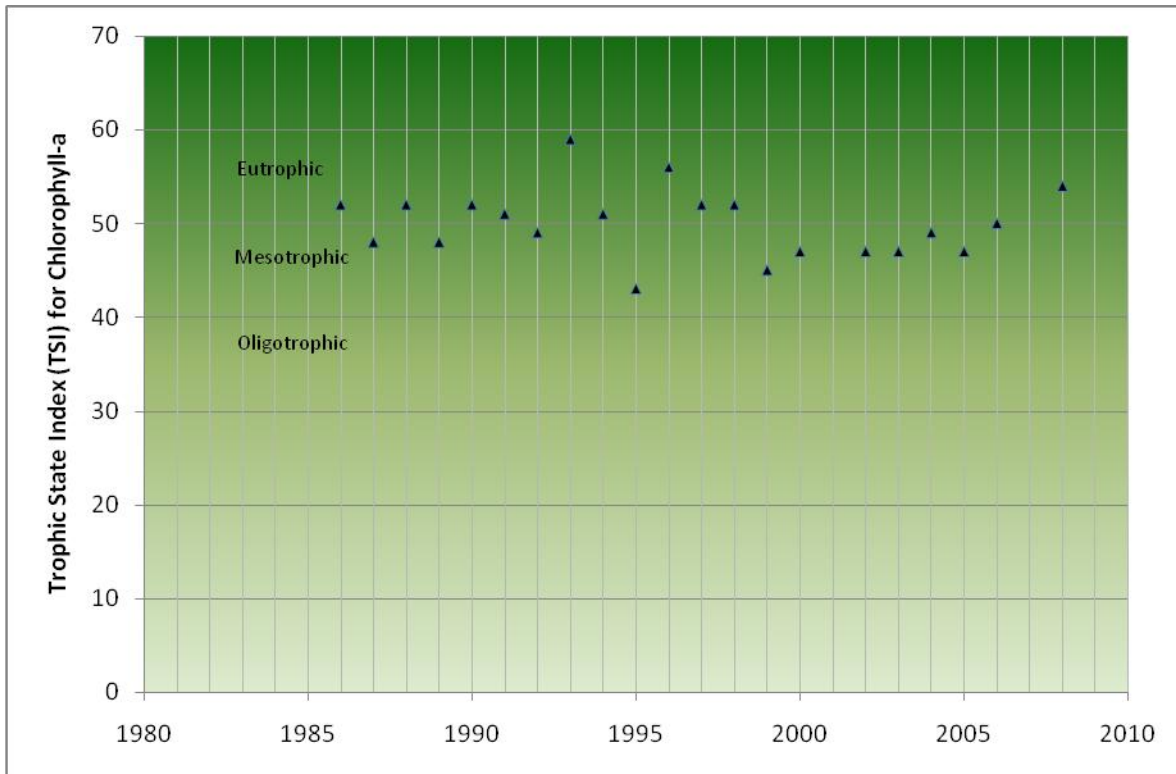


Figure 13: TSI Based on Corresponding Chlorophyll-*a* Readings (1986-2008)

Water Clarity

Water transparency measurements are taken with a device known as a Secchi disc, which is used to evaluate the clarity of a lake's water column. A Secchi disc is an eight-inch-diameter, black-and-white patterned plate that is lowered into the water until it reaches a depth at which it is no longer visible from the water surface. The recorded depth can be compared to values from other lakes and used as an indicator of overall water clarity.

Generally, sunlight can penetrate to a depth equal to 1.7 times the Secchi depth. The depth to which light is able to penetrate, the photic zone, roughly coincides with the depth where there is enough oxygen to support fish and other aquatic life. Transparency may be affected by factors such as turbidity (suspended sediment and particulate matter), water color, and free-floating algae cells. Secchi depth measurements are often used in conjunction with chlorophyll-*a* and total phosphorus concentrations to determine a lake's trophic status and overall water quality condition.

Lake Ripley summer mean Secchi-depth measurements and associated TSI values from 1973-2007 are illustrated in [Figures 14 and 15](#) below. Over this timeframe, individual Secchi measurements ranged from 2.5 to 9.5 feet during the July-August period, with an average of 5.9 feet. These values generally reflect a meso-eutrophic system, with an average TSI of 52. There is a slightly evident trend toward increasing water clarity conditions over the roughly 34-year monitoring period.

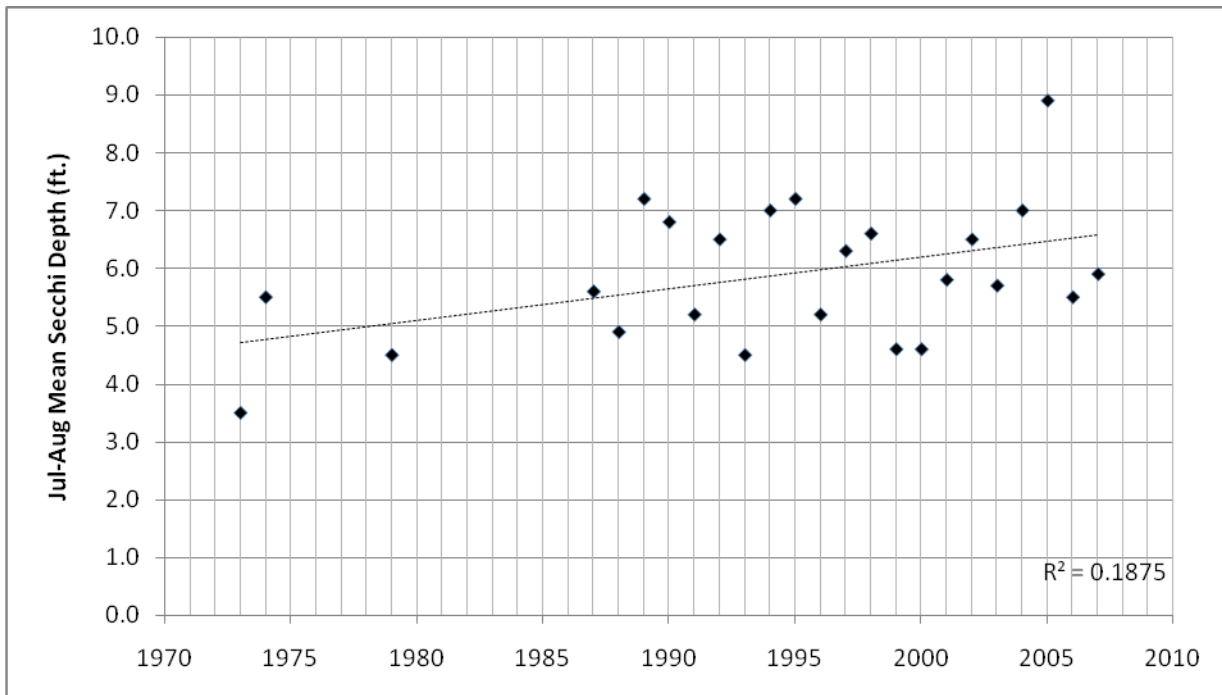


Figure 14: Secchi Depth Measurements (1973-2007)

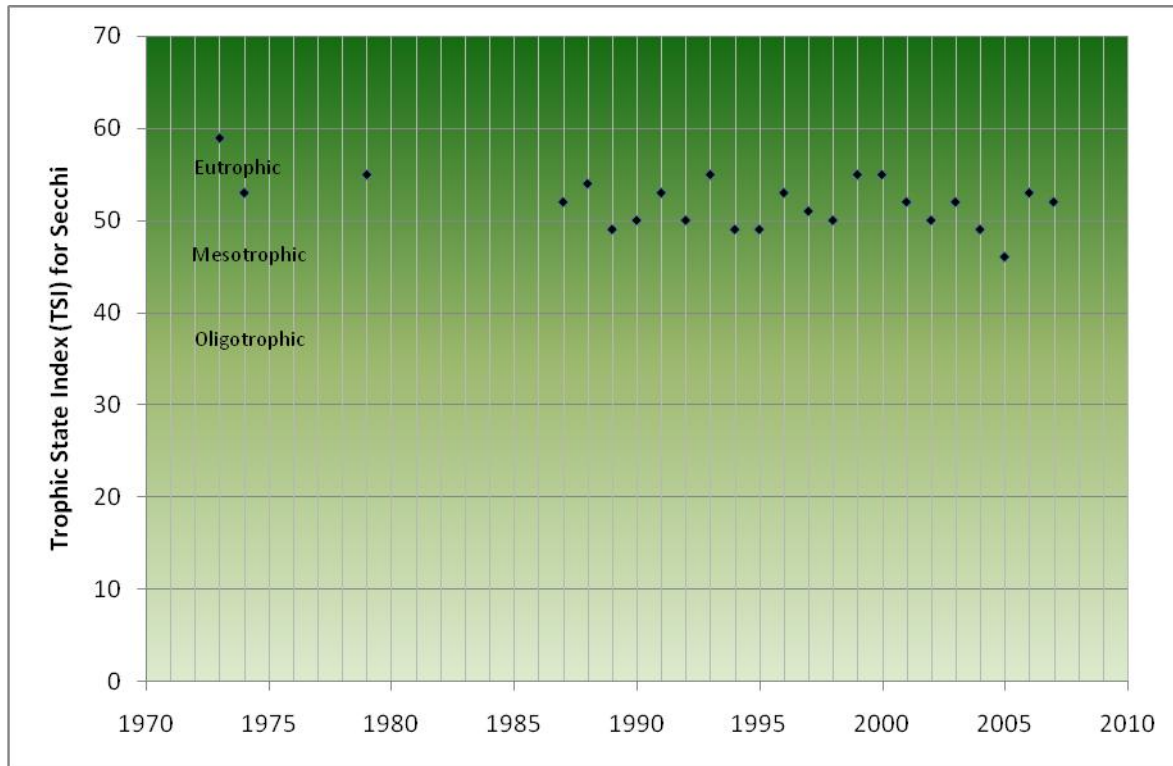


Figure 15: TSI Based on Corresponding Secchi Depth Readings (1986-2008)

Carlson's Trophic State Index is mostly intended as a predictor of algal biomass. Consequently, TSI for chlorophyll-*a* is a better predictor than either of the other two indices. However, useful insights can be gained by evaluating the interrelationships among all three indices, such as the identification of other environmental factors that may influence algal biomass. For example, when TSI for chlorophyll-*a* is greater than TSI for Secchi depth, large particulate algae may dominate in the lake. In contrast, when TSI for Secchi depth and total phosphorus are both greater than TSI for chlorophyll-*a*, light attenuation may be due to water color or turbidity, rather than algae. The interrelationships of the three indices are shown in Figure 16 below. The data plot suggests that large-particulate algae likely dominated in 1990, 1993, 1994, 1996 and 1998, while suspended sediment may have played a dominant role in 1987, 1995, 1999, 2000, 2002, 2003 and 2006.

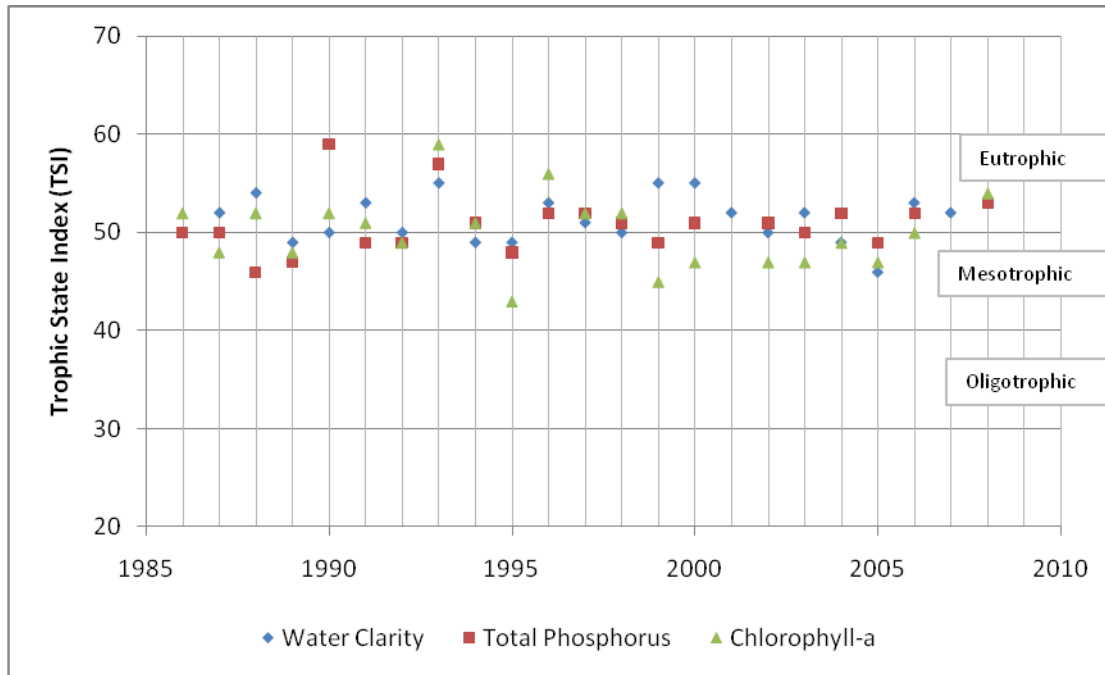


Figure 16: TSI Chart of Combined Secchi Depth, Total Phosphorus and Chlorophyll-a Readings (1986-2008)

Water Quality Index

Lillie and Mason (1983) classified all Wisconsin lakes using a random data set collected in the months of July and August. The water-quality index that was developed is based on surface total-phosphorus and chlorophyll-a concentrations and Secchi depths. Applying the water-quality index to Lake Ripley, total-phosphorus and chlorophyll-a concentrations were on average indicative of “good” water quality, while Secchi depths were on average indicative of “fair” water quality. Table 9 shows the total phosphorus, chlorophyll-a and Secchi depth ranges that correspond with each water quality ranking. Typical value ranges for Lake Ripley are highlighted.

Table 9: Water quality index for Wisconsin lakes based on total phosphorus, chlorophyll-a and Secchi depth values. (Adapted from Lillie and Mason, 1983)

Water Quality Index	Total Phosphorus (µg/l)	Chlorophyll-a (µg/l)	Secchi Depth (ft)
Excellent	<1.0	<1.0	>20.0
Very good	1.0-10.0	1.0-5.0	10.0-20.0
Good	10.0-30.0	5.0-10.0	6.5-10.0
Fair	30.0-50.0	10.0-15.0	5.0-6.5
Poor	50.0-150.0	15.0-30.0	3.3-5.0
Very poor	>150.0	>30.0	<3.3