Secchi Depth

As you know, the Secchi Disc depth is used to measure the water clarity of a lake. Three factors may affect secchi disc depth: planktonic algae, suspended sediment and stained water color.

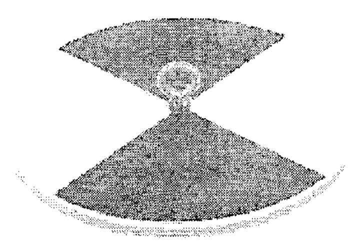
Measuring secchi depth helps determine if algae are present in low numbers, or if a bloom is occurring. Algal blooms are generally considered to decrease the aesthetic appeal of a lake because people prefer clearer water to swim in and look at. Algae are always present in a balanced lake ecosystem. They are the photosynthetic basis of the food web. Algae are eaten by zooplankton, which are in turn eaten by fish. You will know algae are causing reduced Secchi depth if the water generally appears green when you assess the color against the white background of the secchi disc.

Suspended sediment (also referred to as turbidity) refers to tiny particles of soil or organic matter that are suspended in the water. Water clarity is severly limited if suspended sediments are high. Shallow lakes are often turbid because wind stirs up sediment from the bottom. High suspended sediments are often found in flowages and impoundments where precipitation runoff from the watershed transports solids via an incoming stream. Suspended sediments make the water look, to some degree, opaque and brown, like mud shaken up in a jar with water.

In addition to algae and suspended sediment, stained water color can influence Secchi depth. Stain in lakes is caused by a brown pigment from organic matter, called tannins. Tannins are natural and not a result of pollution. Tannins can be distinguished from suspended sediment because the water, even though its brown, it looks clear, like tea. Though tannins are not harmful per se, they are often not perceived as aesthetically pleasing as clear water. Tannins can also be important for decreasing light penetration into the water and decreasing algal growth.

Water Quality Index Based On Secchi Depth

Clarity	Secchi Depth
Excellent	> 20 Feet
Very Good	10 - 20 Feet
Good	6.5 - 10 Feet
Fair	5 - 6.5 Feet
Poor	3.25 - 5 Feet
Very Poor	< 3.25 Feet



Even if the clarity is rated as poor or very poor, perceptions of what makes a high quality lake will vary according to individuals. An extremely clear lake is valued highly by swimmers, but a weedy lake is favored by anglers since more fish might be present. The water clarity that can be expected of a lake also varies widely depending on the location, the lake type, and historical conditions. Regardless of clarity, lakes are often the most valuable asset a community has in terms of its recreational potential and aesthetic value.

Phosphorus

Phosphorus is a nutrient that plants and algae need to grow. Phosphorus (as well as chlorophyll) is measured in micrograms per liter (ug/L), which is equivalent to parts per million (ppm). The samples that you collected were analyzed at the State Laboratory of Hygiene in Madison. The results of the test enable you to answer the question, "Is my lake potentially susceptible to algae blooms?" Your samples were measured for total phosphorus. Phosphorus may appear in water in various forms and may not always be in a form available for biological productivity. Therefore, total phosphorus shows the potential productivity of the lake. Lakes that have more than 20 micrograms per liter (ug/L or parts per million), and impoundments that have more than 30 micrograms per liter of total phosphorus may experience noticeable algae blooms.

Water Quality Index Based on Total Phosphorus

Description	Total P (ug/L)
Excellent	< 1
Very good	1-10
Good	10-30
Fair	30 - 50
Poor	50 - 150
Very Poor	> 150

It should be noted that 4 ug/L is the lowest concentration that our laboratory can measure. There for the highest rating a lake could obtain is "very good." Several lakes obtained results of "Below Level of Detection", or less than 4 ug/L, meaning the actual concentration may have been better than very good. It helps t imagine how small one microgram per liter is (or one part per million) is to realize that the lab is already capable of analyzing very minute quantities. One part per million is equivalent to one second in 35 years!

Chlorophyll

Chlorophyll is a pigment that makes plants (and algae) green. When you filtered water during each sampling episode last summer, you were extracting algae from the water. We analyzed the samples at our laboratory to quantify how much algae was in the water. If the chlorophyll levels show that there was little algae in the water, but the Secchi depth on the same day indicated poor water clarity, the poor clarity was probably caused either by suspended sediments or tannins (see above). Conversely, if the chlorophyll level was high, and the Secchi depth shows very good water clarity, we would suspect that some error was made with either sample collection, analysis or recording the results.

Water Quality Index Based on Chlorophyll

Description	Chlorophyll (ug/L)
Excellent	< 1
Very good	1-5
Good	5-10
Fair	10-15
Poor	15-30
Very Poor	> 30

Trophic State Index

The Secchi depth results, along with phosphorus and chlorophyll data if available, allow us to determine the trophic status (or level of nutrient enrichment) of the lake. Trophic state index is a continuum scale of 0 to 100, corresponding with the clearest (and most nutrient poor) lake possible, to the least clear (and presumably, most nutrient rich) lake possible. Lakes can be divided into three main levels of nutrient enrichment categories. The first is oligotrophic (TSI 0-40), or nutrient poor. These lakes are characterized by very high Secchi depths (very clear water), plenty of oxygen even in deep water, and they may have cold-water fish species living in them.

Oxygen concentrations may be low if the lake is closer to the next category, called mesotrophic (TSI 40-60). Mesotrophic lakes fall in the middle of the continuum from nutrient-poor to nutrient-rich. They have moderately clear water, and may experience low to no oxygen concentrations in bottom waters.

Lakes that are nutrient-rich are called eutrophic (TSI > 50). They have decreased Secchi disc readings and experience low to no oxygen in the bottom waters during the summer. These lakes would only be habitable to warm water fish. They may also experience blue-green algae blooms. Lakes that are super-enriched fall into a fourth category termed hypereutrophic (TSI >70). These lakes experience heavy algae blooms throughout the summer, and may even experience fish kills. Rough fish dominate in hypereutrophic lake systems.

We label trophic states for the purposes of discussion, but remember that the categories actually make smooth transitions into each other. Date from one date may show a lake as being eutrophic, and the next date as being mesotrophic. (If the general tendency for the lake is eutrophic, we refer to the lake as eutrophic).

A note on aquatic plants: If your lake has many rooted aquatic plant and otherwise clear water for the most part, the Trophic State Index could be a mischaracterization of the true nutrient status of the lake. Lakes dominated by aquatic plants tend to have high amounts of phosphorus in the bottom sediments and relatively low phosphorus in the water column. Lakes that grow mostly algae, on the other hand, have high phosphorus in the water. Most lakes have a fairly stable ratio of aquatic plants to algae. Trophic Status Index only measures the portion of nutrients that are found in the water column, as evidenced by the amount of algae. So if most of the nutrients are held in the sediments and the lake is loaded with aquatic plants, the true, total nutrient status cannot be accurately measured using the Trophic Status Index.

Trophic State Index Scale:

TSI < 30	Classical oligotrophy: clear water, many algal species, oxygen throughout the year in bottom water, cold water, oxygen-sensitive fish species in deep lakes.
TSI 30-40	Deeper lakes still oligotrophic, but bottom water of some shallower lakes will become oxygen-depleted during the summer.
TSI 40-50	Water moderately clear, but increasing chance of low dissolved oxygen in deep water during the summer.
TSI 50-60	Lakes becoming eutrophic: decreased clarity, fewer algal species, oxygen-depleted bottom waters during the summer, plant overgrowth evident, warm-water fisheries (pike, perch, bass, etc.) only.
TSI 60-70	Blue-green algae become dominant and algal scums are possible, extensive plant overgrowth problems possible.
TSI 70-80	Becoming very eutrophic. Heavy algal blooms possible throughout summer, dense plant beds, but extent limited by light penetration (blue-green algae block sunlight).
TSI > 80	Algal scums, summer fishkills, few plants, rough fish dominant.

Dissolved Oxygen

The amount of dissolved oxygen available in a lake, particularly in the deeper parts of the lake is critical to its overall health. The amount of dissolved oxygen in the water is determined by water temperature (cold water holds more oxygen than warm water), atmospheric pressure (which increases with depth) and biological productivity. Plants and algae are important for producing oxygen in the water, but when they die, the situation is reversed when bacteria associated with decomposing plants (or animals) consume oxygen. In general, cold-water fish, such as trout, need at least 5 parts per million of oxygen to survive, as well as cold temperatures. In contrast, warm-water fish which are more common to the majority of lakes in Wisconsin, need at least 3 parts per million of oxygen. If the amount of oxygen falls below these levels, the fish species that cannot tolerate low levels suffocate and die.

Temperature

Temperature is another critical factor in understanding a lake. Just as trout need lots of oxygen to survive, they also need cold water temperatures, generally less than 72 degrees F. If the water gets too warm, or oxygen is not available, a fishkill may result. On the other hand, most fish can tolerate warmer temperatures; bluegills, for example, can survive in water as warm as 80 F.

Temperature profile data will show whether or not the lake mixes or stratifies. Shallow lakes typically mix almost constantly through normal wind and wave action, allowing water that had been at the bottom to move to the top and vice versa. Because of this mixing, temperature and dissolved oxygen remain about the same form the surface to the bottom.

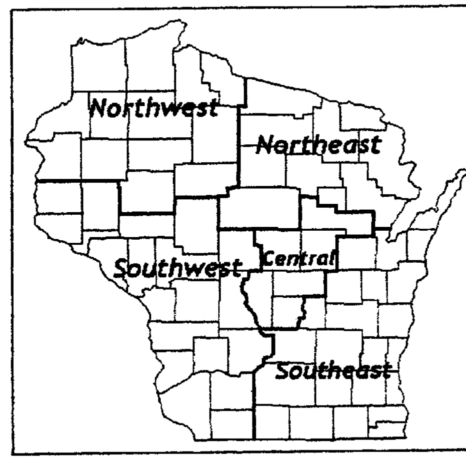
In contrast, deep lakes usually stratify or divide into distinct temperature layers during the summer months. The warm water stays at the top and the cold water stays at the bottom. The zone at which the temperature changes most abruptly is called the thermocline. Water below the thermocline is usually much colder and it doesn't mix with the water at the top of the lake because cold water is much denser and heavier than warm water. The reason you must take the temperature of water at regular intervals is so you don't miss the thermocline.

Deep lakes normally stratify during the summer months and mix in the spring and fall. As the air temperature starts declining at the end of the summer and early fall, the surface of the water cools. The cooler, denser water begins to sink, destroying the stratification and initiating complete circulation of the water column. The lake will have almost uniform temperature during the winter, when its frozen surface prevents much circulation of the water column. Once the ice melts in the spring, the water is once again exposed to wind action, and begins circulating again. The spring overturn will continue until the lake stratifies on a calm, warm day in the summer.

The dissolved oxygen and temperature are related. If you see that there is a thermocline, you know that the lake stratifies. Once you determine where the thermocline is, you can usually predict that the dissolved oxygen concentration will decline at the same point. This is typical for deep lakes. If the dissolved oxygen concentration declines to the point where there is none, chemical reactions can take place that would otherwise not occur in an oxygen-rich environment. Specifically, in an anoxic (zero oxygen) environment, phosphorus that had been chemically bound to bottom sediments can now be released into the colder layers of the water column. This may result in algae blooms in the lake after the next mixing.

In shallow lakes, there is usually no thermocline, and usually the dissolved oxygen concentration of the lake stays fairly high. However, shallow lakes that are constantly mixing may be more sensitive to nutrient loading from the watershed. These loadings can come from nonpoint sources of pollution, such as agricultural runoff from farm fields or barnyards, or from urban runoff from streets or constructions sites. When nutrients are added to a shallow lake, they may be constantly available to feed weeds or algae. In a deep lake, the nutrients may become isolated in the deep, cold water (the hypolimnion), where they are unavailable to be taken up by algae until the lake mixes.

Lake Georegions



Wisconsin's lake "georegions" originated from a grouping of lakes made in the early 1980s by DNR senior limnologists. The groupings are based on the best professional judgement of the scientists most familiar with Wisconsin's lake resources. The georegions roughly reflect "hydro-chemical lake regions" which are based on the state's bedrock geology, glacial geology and soil type, and more recently described "ecoregions" which are based on geological characteristics as well as dominant vegetation.

Northwest Georegion

The northwest georegion is lake-rich. Most of the lakes found here are relatively small (< 100 acres), natural lakes and many have extensive wetlands. Many "stained" (brown with organic matter) lakes are found in this georegion. In general, the majority of lakes in this georegion have relatively low phosphorus levels and are relatively free of sediment. However, Polk, St. Croix, and Barron Counties tend to be shallow and more eutrophic. Chlorophyll concentrations and water clarity varies considerably in northwest georegion lakes.

Central Georegion

The central georegion forms a distinct lake group. In a large part of this georegion, lakes are scarce due to the nature of the underlying soil and bedrock. Most central georegion lakes are small (< 100 acres) and tend to have small watersheds. Most have low phosphorus, low chlorophyll concentrations and high water clarity.

Northeast Georegion

Thirty seven percent of Wisconsin's lakes are found in the northeast georegion. Most (93%) are natural lakes -- a higher percentage than any other georegion. Northeastern lakes tend to be clustered with extensive wetlands. Many are "stained" (brown with organic matter). Lake size varies considerably. Lakes in this georegion tend to be deeper than other georegions As a group, northeastern lakes have low phosphorus and chlorophyll and the greatest water clarity of the five georegions.

Southwest Georegion

Large, shallow, eutrophic lakes and impoundments are found in the southwest georegion. Natural lakes are scarce because of the topography and geological history (much of this georegion lies in the Driftless Area). Most lakes in this georegion are shallow and don't stratify. Southwestern lakes tend to have high phosphorus, high chlorophyll and low water clarity.

Southeast Georegion

Lakes and bogs are common in the southeast georegion. This georegion has more large lakes (>1000 acres) than other georegions and many shallow lakes. Southeastern lakes tend to have relatively high phosphorus, high chlorophyll and low water clarity.

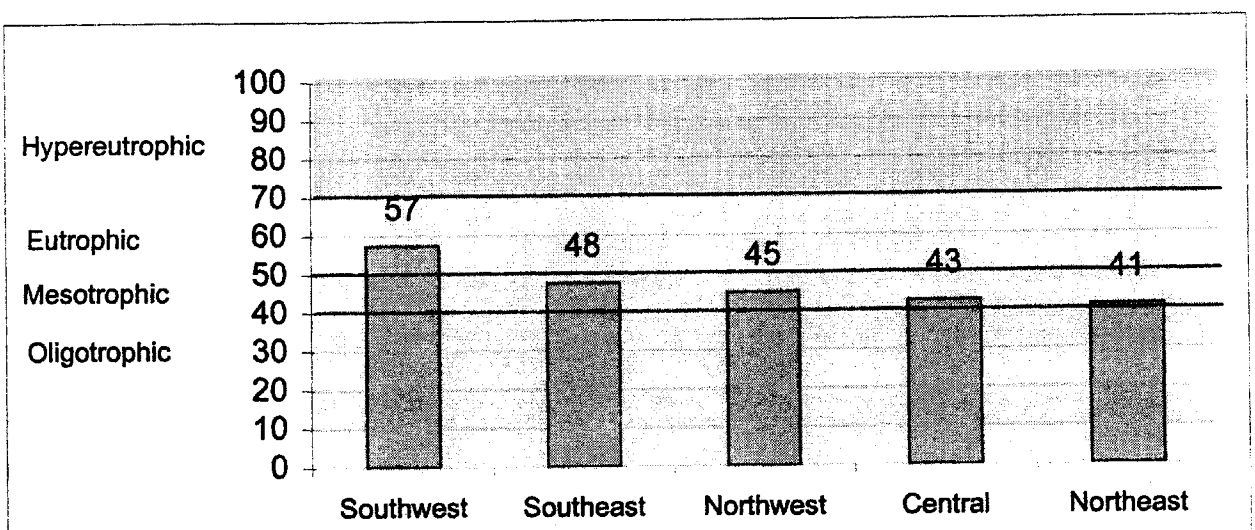


Figure 1. 2001 Average Summer (June, July, August) Trophic State Index (Secchi) values for each Georegion.

Lake Types

Physical characteristics of lakes can greatly influence water quality. Two factors are especially important: the primary source of the lake's water and it's flushing rate and whether or not the lake water "stratified" (divides into distinct temperature zones) in the summer months. Your lake's type is on your Annual Report.

Seepage Lakes

Seepage lakes are fed mainly by precipitation and runoff, supplemented by groundwater from the immediate drainage area. These lakes do not have an inlet or permanent outlet. Seepage lakes are the most common lake type in Wisconsin. Many seepage lakes are low in nutrients, acidic and susceptible to acid rain. These lakes have small watersheds.

Drainage Lakes

Drainage lakes are fed by streams, groundwater, precipitation and runoff. These lakes have an inlet and an outlet and the main water source is stream drainage. Most major rivers in Wisconsin have drainage lakes along their course. Water quality in Drainage Lakes can be highly variable. These lakes often have large watersheds.

Drained Lakes

Drained lakes have no inlet, but like spring lakes, have a continuously flowing outlet. Drained lakes are not groundwater fed. Their primary source of water is from precipitation and direct drainage from the surrounding land. Frequently, the water levels in drained lakes will fluctuate depending on the supply of water. Under severe conditions the outlets from drained lakes may become intermittent. Drained lakes are the least common lake type found in Wisconsin.

Spring Lakes

Spring lakes are fed by groundwater, precipitation, and limited runoff. Spring lakes have a permanent outlet, but no inlet. The primary source of water for spring lakes is groundwater flowing into the bottom of the lake from inside and outside the immediate surface drainage area. Spring lakes are the headwaters of many streams and are a fairly common type of lake in northern Wisconsin. These lakes are usually well buffered against acid rain and contain low to moderate amounts of nutrients. These lakes have small watersheds.

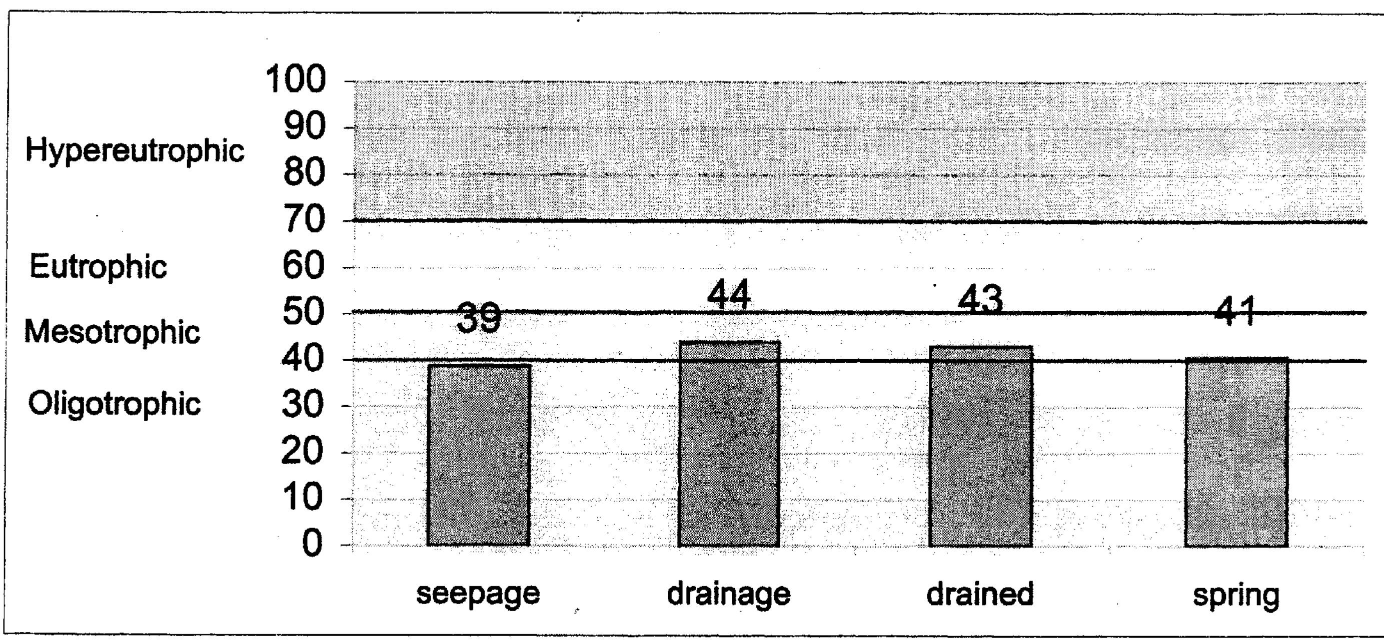


Figure 2. 2001 Summer (June, July, August) Trophic State Index (Secchi) averages for different Lake Types in the NORTHEAST GEOREGION.

Stratified vs. Mixed

In addition to the four lake types, some lakes thermally stratify (divide into distinct temperature layers) in the summer months, and other lakes do not. Stratifying can influence a lake's trophic condition by preventing mixing of phosphorus from the lake's bottom waters to the surface. When phosphorus becomes trapped at the lake bottom, it is unavailable to floating algae (which also need sunlight) in the lake's upper water. Stratification is influenced by a lake's shape and it's depth. A good rule of thumb is that lakes less than 20 feet deep seldom strafity while those over 20 feet in depth usually do.

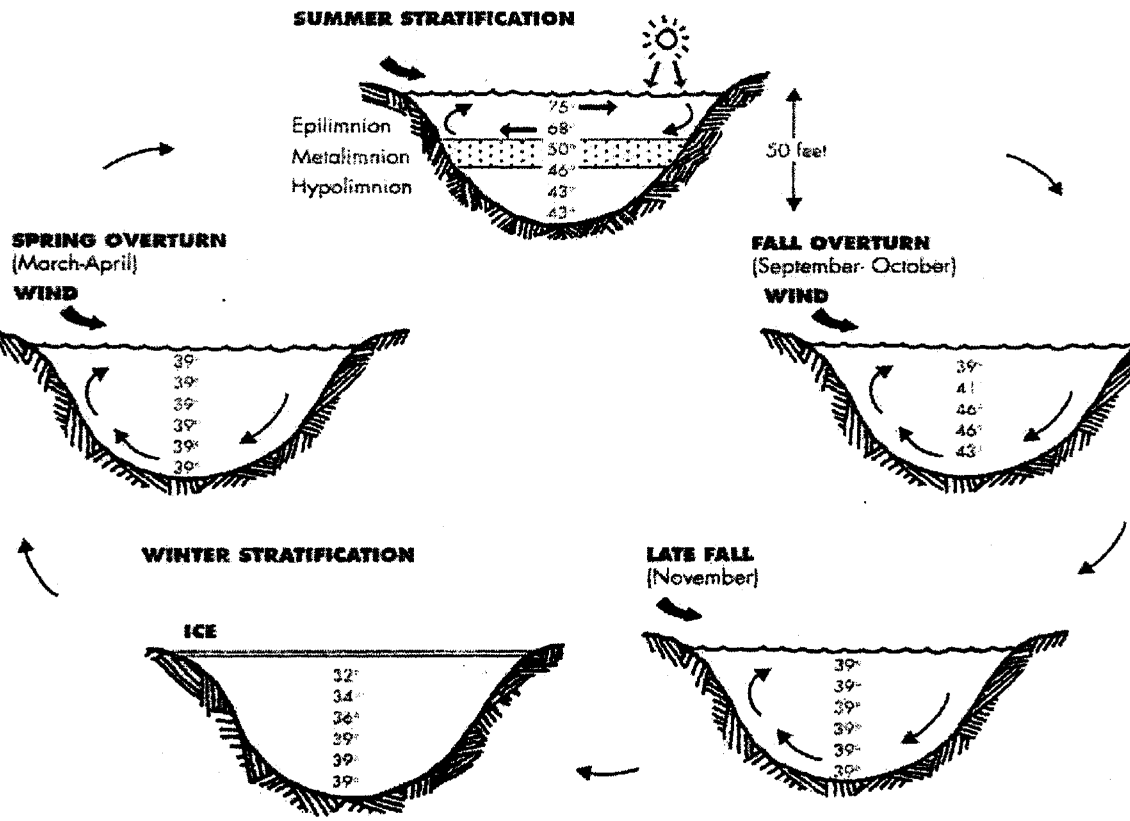


Figure 3. Annual temperature cycles in stratified lakes - from the booklet *Understanding Your Lake Data.* Contact your Region Coordinator or Central Office to request a copy, or visit http://www.dnr.state.wi.us/org/water/fhp/lakes/under/index.htm

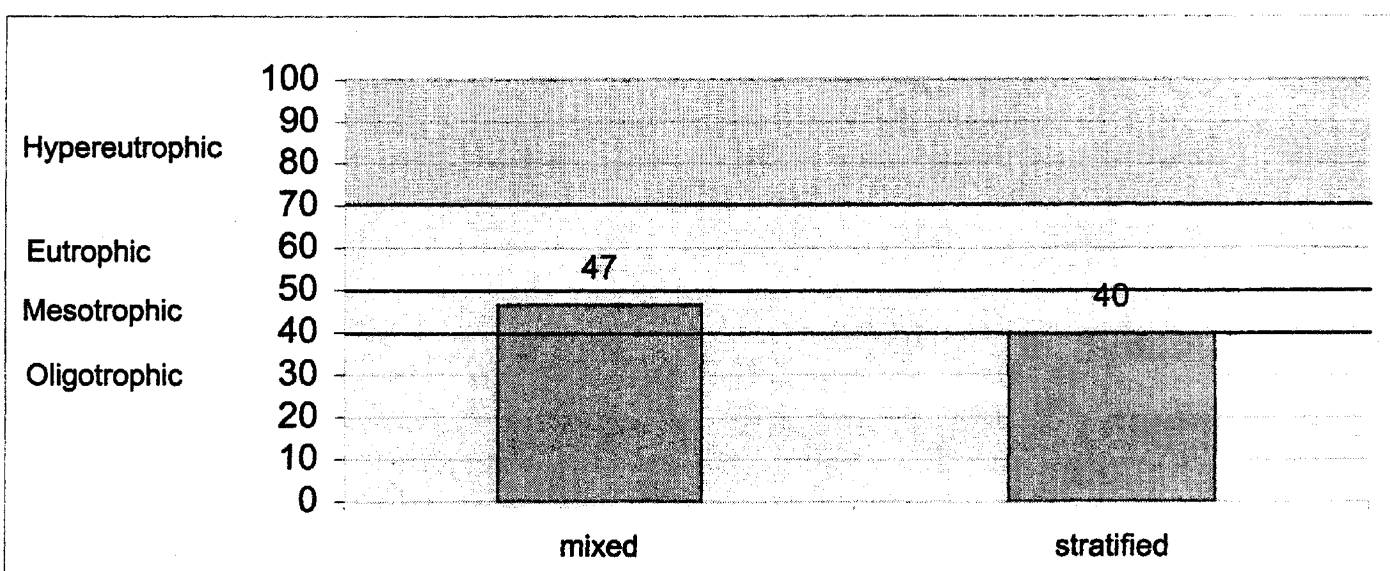


Figure 4. Summer 2001 (June, July, August) Trophic State Index (Secchi) values for mixed lakes vs. stratified in the NORTHEAST GEOREGION.