A Beginner's Guide to Water Management — Water Clarity

Information Circular 103


Joe Richard

Florida LAKEWATCH
Department of Fisheries and Aquatic Sciences
Institute of Food and Agricultural Sciences
University of Florida
Gainesville, Florida

September 2001
3rd Edition

UF UNIVERSITY of FLORIDA
IFAS Extension

Florida LAKEWATCH

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Florida
LAKEWATCH

Lake Santa Fe Melrose, FL

Joe Richard

Introduction

Water clarity, the clearness or transparency of water, is one of the most noticeable attributes of a waterbody. It's also something of great importance to many people. The public judges water quality by what they can see, and so their evaluation is often based on this standard. For example, lakes with very clear water may be perceived as good, unpolluted, or pristine, while lakes with limited transparency may be described as undesirable, polluted, or degraded.

Contrary to this popular perception, crystal clear water is NOT the ruler to which all lakes should be compared. It is not true that lakes with lower transparency are necessarily the result of pollution or degradation. In Florida, lakes with a wide range of water clarity occur naturally, even in locations that are unaffected by human impacts. It is also not true that clearer water is safer to swim in or to drink. On the contrary, clear water is just as likely as murky water to harbor pathogens, bacteria, or other contaminants that could be harmful to human health.

In some instances, the standard for water clarity is often influenced by regional values or ideas about how the waterbody is to be used. For example, in Canada, the Canadian government recommends that water should be sufficiently clear so that a Secchi disc is visible at a minimum depth of 1.2 meters (about 4 feet). This recommendation stems from the fact that swimmers want their swimming areas to be clear enough to see underwater obstacles. The 1.2-meter water clarity standard is one reason many of the lakes in Canada, particularly those with an abundance of free-floating algae, do not meet Canadian standards for swimming and are deemed "undesirable." However, it should be understood that many of these lakes have water clarity less than 1.2 meters naturally and have not been impacted by human activity.

Similar conditions exist in Florida, with many people believing that less clear water is undesirable. However, one's preference for clear water is a value judgement, not a scientific measure, and should be based on how people envision using the waterbody. For example, less clear waters typically support abundant populations of fish, plants, birds, or other wildlife — creating opportunities for popular outdoor activities such as fishing, hiking, and nature watching. In fact, some of Florida's best fishing is found in murky, algae-rich waters.

In light of such popular misconceptions surrounding water clarity, one thing is clear — all Florida residents and visitors stand to benefit from a greater understanding of the dynamics and significance of water clarity in Florida lakes. This circular provides a first step by discussing a few important strategies used to manage water clarity. Basic information about water clarity, with an emphasis on its relationship to algal growth in lakes, is provided in the following segments:

1 Measuring Water Clarity
2 What Affects Water Clarity?
3 Water Clarity and Biological Productivity
4 Managing Lakes for Water Clarity

Before you begin however, we encourage you to review the definitions for commonly used scientific terms provided in Appendix A, particularly for ***algae*** and ***chlorophyll.*** More comprehensive information may also be obtained by reading ***A Beginner's Guide to Water Management – The ABCs*** (Circular #101) and ***A Beginner's Guide to Water Management – Nutrients*** (Circular #102). These publications can be downloaded for free from the Florida LAKEWATCH web site: **http://lakewatch.ifas.ufl.edu/LWcirc.html**.

Part 1

Measuring Water Clarity

Milt Putnam/IFAS Communication Services

There are several devices used by scientists to measure turbidity, light extinction, and spectral analysis—all related to water clarity. However, for the purposes of this publication we've decided to focus on use of the Secchi disc, one of the oldest, easiest, and most economical methods for measuring water clarity.

The LAKEWATCH program uses Secchi disc measurements because, aside from the fact that they're easy and inexpensive to use, they provide us with an indirect way to measure the **biological productivity** of a lake – an important component of lake management. But first things first. We'll start with the Secchi disc.

☛ ***For more on*** *biological productivity****, see*** *Section 3 Water Clarity and Biological Productivity* ***on pages 8-11.***

The Secchi Disc

Obtaining a lake's Secchi depth involves the use of a plate-sized device called a Secchi disc (pronounced with several variations, but usually SEH-key disk). Secchi discs of various sizes can be used, but customarily it is an 8-inch diameter disc with alternating black and white quadrants. However, some disks are solid white in color. A line, rope or chain is attached through the center of the Secchi disc and is marked off in intervals like a ruler, usually in feet or meters. To measure a lake's Secchi depth, the disc is lowered into the water to find the depth at which it first vanishes from the observer's sight.[1]

The Secchi disc was named after Pietro Angelo Secchi, a scientific advisor to the Pope and head of the Roman Observatory in the mid 1800s. Commander Cialdi, the commander of the Papal fleet, actually devised the Secchi disc. Secchi was asked by Cialdi to experiment with this disc in the coastal waters of the Mediterranean. The first disc was lowered from the Papal yacht *l'Immacolata Concezione* and used to measure water clarity in the Mediterranean Sea on April 20, 1865. Since that time, Secchi discs have been used to measure water clarity in tens of thousands of waterbodies around the world.

Secchi discs are often colored with alternating black and white quadrants, as shown here. LAKEWATCH uses plain white Secchi discs as seen on the opposite page.

Sandy Fisher

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[1] *On occasion, the Secchi disc can still be seen as it rests on the lake bottom, or it may disappear into thick submerged aquatic macrophyte growth. While the depth at which this happens furnishes some information about the water's clarity, it is not considered to be a measurement of the waterbody's Secchi depth. Also, the word "Secchi" is always capitalized because it refers to the name of the individual who first used it.*

Clear Lake

Gainesville, FL

Joe Richard

To measure a lake's Secchi depth, a Secchi disc is lowered into the water to find the depth at which it first vanishes from the observer's sight.

Part 2

What Affects Water Clarity?

FL Center for Community Design & Research / University of South Florida

Water clarity in Florida lakes ranges between 0.7 feet and 38 feet. Differences in water clarity are primarily caused by the presence (or lack) of dissolved substances and/or suspended particles in the water. However, to fully understand the dynamics of how dissolved substances and/or suspended particles affect water clarity, there are a few things to consider.

Several factors can impact the abundance of dissolved substances and/or particles in the water — consequently impacting water clarity. For example, the abundance of dissolved substances and/or particles in the water can be influenced by the presence of aquatic plants and/or the location of the waterbody. Seasonal variations in climate can also impact water clarity. These factors are discussed in the following section.

Dissolved Substances

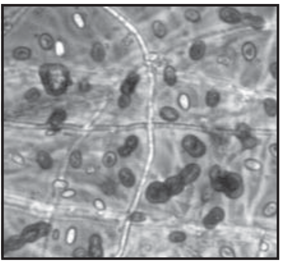
Dissolved organic substances or compounds can come from many types of terrestrial and aquatic plants, and can color the water reddish or brown, sometimes even to the point of appearing black. When there is an abundance of dissolved organic compounds in the water, scientists often refer to the water as being “colored” or sometimes they’ll refer to the waterbody as being a “dark” lake.

There are two types of color that are measured in waterbodies:

♦ ***apparent*** color is the color of a water sample that has NOT had particulates filtered out of the water; and

♦ ***true*** color is the color of a water sample that HAS had all particulates filtered out of the water.

The measurement of true color is the one most commonly used by scientists. To measure true color, the color of a filtered water sample is matched to one from a range of standard colors. Each of the standard colors has been assigned a number on a scale of “platinum-cobalt units” (abbreviated as either “PCU” or “Pt-Co units”). On the PCU scale, a higher value of true color represents water that is more darkly colored. Because dissolved organic compounds (i.e., color) absorb sunlight as the light passes through the water, Secchi depth values decrease as the amount of color in the water increases. Color in Florida lakes ranges from 0 to over 400 PCU.



Mary Cichra

Closterium

Particulates

Particulates include free-floating algae, called phytoplankton, as well as other solids suspended in the water. These include sand, clay, or organic particles stirred up from the bottom, washed in from the shoreline, washed in from the surrounding land, or brought in by the wind and rain. Because particulates absorb and scatter sunlight as the light passes through the water, Secchi depth (water clarity) values decrease as the amount of particulates in the water increases.

While all particles are known to affect water clarity, studies throughout the world have shown that free-floating algae are the dominant particles influencing water clarity in most lakes.

Scientists often estimate the amount of free-floating algae in a lake by measuring the amount of chlorophyll[2] in a water sample, measured in units of micrograms per liter (µg/L). Lakes in the Florida LAKEWATCH database analyzed prior to January 2000 have average chlorophyll concentrations ranging from less than 1 to over 400 µg/L.


Vic Ramey, Center for Aquatic and Invasive Plants

Coontail *(Ceratophyllum demersum)*

Aquatic Macrophytes

The presence or absense of aquatic macrophytes[3] in a waterbody is especially important in understanding water clarity and yet this relationship is sometimes overlooked. It's also a double-edged sword. While water clarity can affect the growth of aquatic macrophytes, the reverse is also true: the presence of large amounts of aquatic macrophytes can influence water clarity.

There are several explanations for this:

One explanation is that submersed macrophytes, or perhaps the algae attached to them, use available nutrients in the water, depriving the phytoplankton (i.e., free-floating algae) of these same nutrients. Consequently, when there is less phytoplankton in the waterbody, water clarity is usually increased.

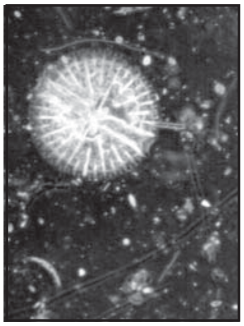
Another explanation for the water clarity/aquatic macrophyte relationship is that submersed macrophytes anchor nutrient-rich bottom sediments in place, buffering the action of waves, and depriving the free-floating algae of nutrients contained in bottom sediments that would otherwise be stirred up.

It's also thought that aquatic macrophytes keep phytoplankton levels down due to the wave buffering action of the plants. As a result, algal cells settle and are prevented from being mixed into the water column.

All three of these mechanisms are probably in action simultaneously, influencing the amount of free-floating algae found in the water column. There's even a formula of sorts that can be used to estimate the impact that aquatic macrophytes may have on whole lake water clarity:

Using the Florida LAKEWATCH database, it's been observed that if aquatic macrophyte coverage is less than 30% of the bottom area of a waterbody, the presence of plants does not greatly influence the amount of free-floating algae in open-water. However, lakes with aquatic macrophyte coverage over 50% or more of the bottom area typically have reduced chlorophyll concentrations and clearer water.

In fact, in a lake with aquatic macrophyte coverage greater than 50%, chlorophyll and nutrient concentrations may become so low and


Mary Cichra

Micrasterias

The size of individual particles, whether algae or other suspended particles, has a strong influence on water clarity. To visualize this effect, consider putting a solid stick of chalk into a bucket of water. Upon putting the chalk stick into the bucket, you will still be able to see through the water to the bottom of the bucket. If, however, the same amount of chalk is ground into fine particles and placed into the water, the water will become so murky that the bottom of the bucket will not be visible. In this manner, when smaller particulates such as small algae dominate an aquatic system, the water clarity is lower than in waterbodies where larger particles dominate — assuming the total amount of particulate matter is the same.

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[2] *Chlorophyll is a green pigment found in all plants and abundant in nearly all algae.*

[3] *Aquatic macrophyte is the scientific term for large aquatic plants. See page 23 of Appendix A for more information.*

the water become so clear that it could mistakenly be described as a biologically unproductive lake. And yet, the presence of such large amounts of macrophytes tells us that the lake is extremely productive. In such an instance, the practice of characterizing a lake based on its water clarity alone becomes inaccurate.

☛ *See* ***Water Clarity*** *and* ***Trophic State*** *in* ***Appendix A***.

Based on these observations, it becomes important for lake managers and /or residents to be aware of the fact that removal of large amounts of aquatic macrophytes can result in reduced water clarity.

For instance, it's been observed that aquatic plant management efforts that reduce a lake's plant coverage from high levels (greater than 50% coverage) to low levels (less than 30%) can result in major increases in chlorophyll concentrations (i.e., phytoplankton) and reduced water clarity.

Based on these observations, it becomes important for lake managers and/or residents to be aware of the fact that removal of large amounts of macrophytes can result in reduced water clarity.

Take Lake Brant in Hillsborough County for example. See below for details on how the introduction of grass carp affected chlorophyll concentrations in the lake and quickly reduced the lake's water clarity.

However, it may be reassuring to note that aquatic plant control efforts conducted on lakes with less than 30% aquatic plant coverage do not produce major increases in chlorophyll concentrations even though they result in the removal of significant amounts of aquatic plants. It should also be noted that planting a fringe of aquatic plants around a lake generally does little to improve water clarity unless the plants grow to cover a major portion of the lake bottom.

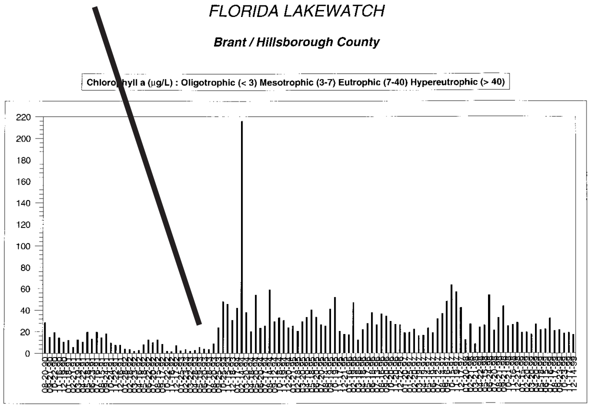
Be careful what you ask for...

Amy Richard

Lake Brant in Hillsborough County provides us with an example of how the removal of large amounts of macrophytes can affect water clarity. The chlorophyll graph shown here tells the story: Grass carp, a herbivorous species of fish, were stocked into the lake to remove (eat) nuisance plants from the lake. The fish did such a good job that within three months a large portion of the plants were gone and chlorophyll concentrations were on the rise. Food for thought, if you're contemplating large-scale aquatic macrophyte removal.

By May 7, 1993 a total of 325 grass carp had been stocked into Lake Brant, a 60-acre lake, to remove large areas of submersed macrophytes. Within three months, chlorophyll concentrations more than doubled, as evident in the bar graph below. Water clarity was reduced by half.

May 7, 1993



Location

The geology and physiography of a lake's watershed influences many characteristics of a lake, including algal levels and the true color of the water. Consequently, the location of a waterbody is strongly linked to its water clarity. Here's how it works:

Water flowing through a watershed to a lake picks up substances such as nutrients (required for algal growth) and humic acids (that color the water). If a lake is located in an area with nutrient-poor or well drained soils, runoff or seepage water percolating up from underneath the lake has little affect on its water clarity. There are simply fewer nutrients and/or dissolved substances being carried into the lake.

Lakes in northwestern Florida (in Washington, Bay, Calhoun, and Jackson counties) provide a good example. LAKEWATCH data collected from this area show that these lakes tend to have chlorophyll concentrations below 3 µg/L, color values generally below 10 PCU, and Secchi depths greater than 10 feet. This is documented in Lake Regions of Florida[4] (EPA/R-97/127).

"Lakes in the New Hope Ridge/Greenhead Slope Lake Region are clear, low in nitrogen and phosphorus, low in chlorophyll, and are among the most oligotrophic lakes in the United States (Canfield 1981)."

In contrast, lakes in the Lakeland/Bone Valley Upland Lake Region in central Florida (Polk and Hillsborough counties) tend to have chlorophyll concentrations above 80 µg/L, color values above 20 PCU, and Secchi depths less than 3 feet. This can be explained by the nutrient-rich and poorly-drained soils of the region documented in Lake Regions of Florida (EPA/R-97/127):

"... the Bone Valley Uplands and the Bartow Embayment, within White's (1970) Polk Upland physiographic region, tend to be more poorly drained flatwoods areas. All of these areas are covered by phosphatic sand or clayey sand from the Miocene-Pliocene Bone Valley Member of the Peace River Formation in the Hawthorn Group (Scott 1992; Scott and MacGill 1981). The region generally encompasses the area of most intensive phosphate mining..."

FL Center for Community Design & Research / University of South Florida

Walden Lake in Hillsborough County is located in the Lakeland/Bone Valley Upland Lake Region in central Florida. Chlorophyll concentrations for this lake are typically high, ranging above 80 µg/L. Water clarity is typically low, with Secchi depths of less than three feet. This can be explained by the highly phosphatic sands the lake is situated upon.

This strong link between location and water clarity suggests there may be natural limits on the level of water clarity that waterbody managers and users can expect in a specific location. Consideration of the lake region in which the lake is situated will provide a useful perspective and help managers and users evaluate the feasibility of different management goals.

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[4] *Lake Regions are geographical areas in which lakes have similar geology, soils, chemistry, hydrology, and biological features. In 1997, using Florida LAKEWATCH data and other information, the United States Environmental Protection Agency designated 47 lake regions in Florida, using these similarities as their criteria. The results of this project were published in a report* ***Lake Regions of Florida****, Griffith, G.E. et al. 1997, U.S. Environmental Protection Agency (EPA/R-97-127). For a copy write: U.S. EPA, 200 SW 35th Street, Corvallis, Oregon 97333. For more information, see Lake Regions in Appendix A. You may also call the LAKEWATCH office for a printout of a specific lake region description (of your lake, for example) or for the LAKEWATCH information pamphlet,* ***Florida Lake Regions Classification System****. Call 1-800-LAKEWATCH (1-800-525-3928).*

Seasonal Variations

Seasonal variations in weather conditions such as temperature, wind, and amount of rainfall are also closely linked with a lake's water clarity. These seasonal changes can affect water clarity by influencing both algal levels and color levels within a lake.

Water Clarity

In Florida, it's been observed that water clarity in individual waterbodies varies in a pattern over the course of several years. For example, the Florida LAKEWATCH database shows that:

♦Water clarity is greatest in lakes from December through February.

♦Water clarity is lowest in lakes from March through May.

It should be noted that although these patterns are well documented, exceptions are common in that maximum or minimum Secchi depths can occur during any month. For more information on patterns in Florida lakes, see Brown et al.[5]

Algal Levels

Similarly, chlorophyll concentrations (algae) in Florida lakes can be highly variable over time and have a direct effect on water clarity. Using the Florida LAKEWATCH database, a general seasonal pattern of chlorophyll can be shown for many Florida lakes. This pattern is described below:

♦ For lakes with low to moderately high chlorophyll levels (oligotrophic to eutrophic), monthly chlorophyll concentrations are typically lower than the annual mean chlorophyll concentration from December to May.

♦ During the months of August thru October, chlorophyll concentrations are typically higher than the annual mean.

Joe Richard

♦ Lakes with high chlorophyll levels (hypereutrophic lakes) tend to have highly fluctuating monthly levels of chlorophyll for most of the year, but tend to have lower levels in December, January, and February.

It's important to note that just like Secchi values, these patterns don't always apply to all lakes; maximum or minimum chlorophyll values in Florida lakes can occur at any time during the year.

Color Levels

Changes in the true color of a waterbody seem to be strongly linked to the amount of seasonal rainfall a watershed receives and the amount of runoff into a waterbody. Runoff is the key factor to remember. During periods of drought, Florida waterbodies tend to be clearer. Even though rainfall may be heavy as the drought abates, water color in the waterbody may not increase until there is substantial runoff. When there is a lot of runoff, true water color can increase quickly and substantially.

Studies of individual Florida lakes also show that increases or decreases in color can significantly influence a lake's water clarity. For example, Grasshopper Lake in Lake County had Secchi depth values greater than 12 feet during dry weather from 1993-1994. Following heavy rains from 1995-1996, the same lake had Secchi depths of less than 3 feet. The corresponding chlorophyll concentrations averaged 1 µg/L during 1993-1994 and 4 µg/L during 1995-1996.

Although these data show an increase in chlorophyll concentrations, the increase is not enough to account for such a drastic change in water clarity. So how to explain such a drastic change in water clarity?

The difference in water clarity was related to the additional color that washed into Grasshopper Lake during the rainy years. Color concentrations in the lake changed from 0 PCU to an observed tea colored water (approximately 40-60 PCU). With the return of dry weather, water clarity increased as color values fell below 2 PCU. This is why *both* chlorophyll concentrations and color should be monitored if water clarity is a major lake management issue.

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[5] *Brown, C.D., D.E. Canfield, Jr., R.W. Bachmann, and M.V. Hoyer. 1998. Seasonal patterns of chlorophyll, nutrient concentrations and Secchi disc transparency in Florida lakes. Lake and Reservoir Management 14: 60-76.*

Part 3

Water Clarity and Biological Productivity

Joe Richard

Floridians, like people throughout the world, are concerned about water quality. Determining the water quality of our aquatic resources is a major responsibility of water managers and scientists. One way they approach this task is to evaluate a waterbody's biological productivity.

Biological productivity is defined as the ability of a waterbody to support life such as plants, fish, and wildlife. However, measuring the ability of a waterbody to support all aquatic life is difficult and prohibitively expensive by most standards. For this reason, many scientists try to estimate a lake's ability to support life by measuring a few basic parameters, namely chlorophyll concentrations in water, water clarity, nutrient concentrations in water, and aquatic plant abundance. Read on to discover how these four parameters serve as important clues to a lake's biological productivity.

Chlorophyll Concentrations

Out of these four parameters, chlorophyll concentrations (i.e., phytoplankton) are used most often to estimate biological productivity because algae represent the actual base product of a lake's food web. For example, if we know that chlorophyll concentrations are low in a lake, then we can generally estimate that the number of other aquatic organisms will be low — especially those that rely on algae for food (i.e., zooplankton, insects, fish, etc.). Conversely, if algae are abundant in a lake, then we can generally estimate that there is the potential for more wildlife. In fact, research in Florida lakes has shown that there is a direct correlation between chlorophyll concentrations in a lake and the number of zooplankton, fish, birds, and even alligators.

Water Clarity

As one might imagine, it's not always possible to sample lake water for chlorophyll concentrations. (Not all research programs are fortunate enough to have dedicated LAKEWATCH volunteers collecting samples.) So how can we estimate the biological productivity of a lake without collecting and analyzing water samples?

Thanks to historical water chemistry data, scientists noticed certain patterns when comparing chlorophyll and water clarity data. After looking at hundreds of lakes, it became clear that, in most lakes, as chlorophyll concentrations (phytoplankton) increase, water clarity decreases.

This led them to believe that, for the most part, they could begin to predict how biologically productive a lake is based on its water clarity. They hypothesized that if lake water is not very clear, it's more than likely due to an abundance of algae. The presence of large amounts of algae suggests that the lake is a productive system — providing an abundance of food for aquatic life.

However, if a lake has clear water, it's more likely to *not* be productive due to the small amounts of algae available to the food web.

This strong relationship between chlorophyll measurements and water clarity is why scientists have adopted use of the Secchi disc as an easy and inexpensive way to determine a lake's biological productivity. However, it should be noted that there are always exceptions; dissolved substances (color) in the water can greatly affect water clarity, as can suspended particles such as clay.

Nutrient Concentrations

Just like the flowers in your garden or the grass in your lawn, algae and aquatic macrophytes are also dependent upon nutrients for growth. Two of the more important nutrients are phosphorus and nitrogen. Both of these compounds are found naturally in rocks, soils, and even lake water.

While phosphorus and nitrogen concentrations can certainly affect a lake's biological productivity, the relationship between algae and these nutrients can be somewhat complicated. For this reason, scientists often refer to other parameters such as chlorophyll concentrations or Secchi depth measurements to estimate a lake's biological productivity.

☛ *For more on nutrients and their relationship to algal abundance, see Florida LAKEWATCH Information Circular 102* ***A Beginner's Guide to Water Management — Nutrients.***

Aquatic Plant Abundance

Aquatic plants are another indicator of a lake's biological productivity. If there are small amounts of aquatic macrophytes and algae, one can generally state that the lake is unproductive. Whereas, if a lake has clear water, due to low chlorophyll concentrations, but has large amounts of aquatic macrophytes, it can be stated that the lake is a biologically productive system.

But there's an additional twist to these relationships when considering the more biologically productive lakes. While the presence of large amounts of aquatic macrophytes can affect water clarity,[6] the reverse is also true; water clarity can affect aquatic macrophyte growth. Picture this: When lake water is turbid, sunlight can't penetrate as far into the water, limiting the maximum depth at which aquatic macrophytes can grow.

This inverse relationship between water clarity and aquatic macrophytes suggests that the biological productivity of a lake can shift between being a lake dominated with phytoplankton to a lake dominated by rooted aquatic macrophytes.

Similar to the time and expense associated with collecting chlorophyll measurements, the collection of aquatic macrophyte data is not always feasible. Fortunately, now that we know how closely linked water clarity is to aquatic macrophyte growth, the Secchi disc can be a useful tool in predicting the potential for aquatic plant growth. Water clarity or Secchi depth measurements can help scientists estimate the depth at which underwater aquatic macrophytes will be expected to survive. A general rule of thumb is that aquatic macrophytes can grow to a depth of about 1.5 times the Secchi depth measurement. For example, if a Secchi depth measurement is three feet, the depth at which aquatic macrophytes can grow is limited to about 4.5 feet.

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[6] *For more on this, see Aquatic Plants in Part 2 on page 4.*

This inverse relationship between water clarity and aquatic macrophytes suggests that the biological productivity of a lake can shift between being a lake dominated with phytoplankton to a lake dominated by rooted aquatic plants.

Biological Productivity and Trophic State

When faced with the challenge of trying to describe the various levels of biological productivity in a lake, scientists developed a system called the **Trophic State Classification System**. Using this approach, lakes are traditionally classified into four groups according to their level of biological productivity or "trophic state."

The names of these four trophic states from the lowest productivity level to the highest are **oligotrophic**, **mesotrophic**, **eutrophic**, and **hypereutrophic**.

Oligotrophic (oh-lig-oh-TROH-fic) waterbodies have the lowest level of biological productivity.

Mesotrophic (mes-oh-TROH-fic) waterbodies have a moderate level of biological productivity.

Eutrophic (you-TROH-fic) waterbodies have a high level of biological productivity.

Hypereutrophic (HI-per-you-TROH-fic) waterbodies have the highest level of biological productivity.

Using Secchi Depth to Determine Trophic State

As discussed earlier in this section, overall biological productivity is difficult to measure in a lake. However, based on what we know about the strong relationship between water clarity (Secchi depth measurements) and chlorophyll concentrations, aquatic scientists often choose to use Secchi depth measurements as an *indirect* way of assessing biological productivity and its associated trophic state.

To do this, professionals may use the criteria developed for lakes by two Swedish scientists, Forsberg and Ryding. There are other classification systems available, but Florida LAKEWATCH uses the Forsberg and Ryding classification system because it seems to work well for Florida lakes. Forsberg and Ryding's trophic state classification system, using Secchi depth, is as follows:[7]

Criteria for Determining Trophic State Based on Secchi Depth

- lakes with Secchi depths greater than 13 feet are classified as ***oligotrophic***;
- lakes with Secchi depths ranging from 8 feet to 13 feet are classified as ***mesotrophic***;
- lakes with Secchi depths ranging from 3 feet to 8 feet are classified as ***eutrophic***; and
- lakes having Secchi depths less than 3 feet are generally classified as ***hypereutrophic***.

Using average Secchi depth readings from more than 500 Florida lakes in the LAKEWATCH database (analyzed prior to January 2000), Florida lakes were found to be distributed into the four trophic states as follows:[7]

- approximately 7% of the lakes would be classified as ***oligotrophic*** (those with Secchi depths greater than 13 feet);
- about 22% of the lakes would be classified as ***mesotrophic***(those with Secchi depths between 8 and 13 feet);
- 45% of the lakes would be classified as ***eutrophic*** (those with Secchi depths between 3 and 8 feet); and
- 26% of the lakes would be classified as ***hypereutrophic*** (those with Secchi depths less than 3 feet).

Using Algae to Determine Trophic State

While Secchi depth readings can help us estimate a lake's biological productivity, at some point, we may want to base a lake's trophic state classification on *algal* levels (often measured as chlorophyll concentrations.)

Why?

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[7] *This distribution of trophic state is based solely on Secchi depth values. It should be noted that trophic state determinations are more useful when scientists consider not only Secchi depth but the concentrations of total nitrogen and total phosphorus, chlorophyll concentrations, and aquatic macrophyte abundance.*

Algae are the base product of a lake's food web and give us a direct indication of a lake's biological productivity. In other words, if algae are abundant, then other forms of aquatic life will be abundant. Forsberg and Ryding's criteria for chlorophyll concentrations (algae) are as follows[7]:

Criteria for Determining Trophic State Based on Chlorophyll Concentrations

♦ lakes with chlorophyll concentrations less than or equal to 3µg/L are classified as ***oligotrophic***;

♦ lakes with chlorophyll concentrations ranging from 4 to 7 µg/L are classified as ***mesotrophic***;

♦ lakes with chlorophyll concentrations ranging from 8 to 40 µg/L are classified as ***eutrophic***;

♦ lakes having chlorophyll concentrations greater than 40 µg/L are generally classified as ***hypereutrophic***.

Using average chlorophyll concentrations from more than 500 Florida lakes in the LAKEWATCH database (analyzed prior to January 2000), Florida lakes were found to be distributed into the four trophic states as follows:[8]

♦ approximately 12% of the lakes would be classified as ***oligotrophic*** (those with chlorophyll concentrations less than 3µg/L) ;

♦ about 31% of the lakes would be classified as ***mesotrophic*** (those with chlorophyll concentrations ranging from 4 to 7 µg/L);

♦ 41% of the lakes would be classified as ***eutrophic*** (those with chlorophyll concentrations from 8 to 40 µg/L); and

♦ 16% of the lakes would be classified as ***hypereutrophic*** (those with chlorophyll concentrations greater than 40 µg/L).

It's important to know that a lake may be classified in more than one trophic state depending on the criteria used. For example, a lake with a chlorophyll concentration of 2 µg/L could be classified as oligotrophic based on the amount of phytoplankton found in the lake. However, the same lake, with a Secchi depth of 4 feet could be classified as eutrophic, based on its water clarity .

This inconsistency may seem troublesome but it is, in fact, useful information. It tells us that the reduced Secchi depth could be related to dissolved substances in the water (i.e., color) or high sediment concentrations — instead of phytoplankton abundance.

While Florida LAKEWATCH uses criteria from the Forsberg and Ryding trophic state classification system, it's important to know that other professionals in the water management arena may use a slightly different set of criteria to determine trophic state. Generally, the differences are not that great, but non-professionals should be aware that they do occur.

It's also important to understand that it is a misuse of the trophic state classification system to use trophic categories as indicators of water quality. Each trophic state classification has attributes that may be judged as having "good" qualities or "poor" qualities.

Judgements of quality depend largely on how people want to use the waterbody. For example, an oligotrophic waterbody may be good for swimming because it will typically have clear water, but may not be a rewarding fishing site, because it does not support large fish populations.

Joe Richard

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8 *This distribution of trophic state is based solely on chlorophyll concentrations. Trophic state determinations are more useful when scientists consider not only chlorophyll concentrations but also the concentrations of total nitrogen and total phosphorus, Secchi depth, and aquatic plant abundance. For more on trophic states, see LAKEWATCH information pamphlet entitled* ***Trophic State: A Waterbody's Ability to Support Plants, Fish, and Wildlife****. For a free copy call 1-800-LAKEWATCH (1-800-525-3928).*

Part 4

Managing Lakes for Water Clarity


Joe Richard

Lake management, or the management of any waterbody, should always begin with the establishment of goals. And like anything else, lake management goals are often as varied as the people who live on or use lakes. Some people are most interested in improving fishing, while others are concerned with an over-abundance of aquatic macrophytes, reducing boat traffic, or preventing shoreline erosion. However, because water clarity is such a noticeable attribute in lakes, it could be listed as one of the top management concerns for most lake users or residents.

But how does one manage water clarity? Is it necessarily good to have extremely clear water in a lake? When is there too much phytoplankton? These are questions that can only be answered based on our needs, activities, or expectations for a particular lake. There are times when no matter what our preferences are for water clarity, nature calls the shots and determines nutrient levels or phytoplankton concentrations, and thus water clarity.

Hypothetically Speaking

Let's say that our goal is to increase water clarity on a hypothetical lake called My Lake. Based on the large amount of data collected for Florida lakes, it appears that potential strategies for improving water clarity on My Lake would involve changing the abundance of phytoplankton.[9] But is this always the case?

The practice of managing water clarity by controlling algal growth has sparked an intense interest in being able to predict how much change is likely to occur in water clarity, based on changes in phytoplankton abundance. Water managers have a particular interest in being able to make this type of prediction, because management strategies may only be considered successful when water clarity is improved noticeably. For example, it's been shown that even if a lake's chlorophyll concentration was reduced from 250 µg/L to 50 µg/L (a five-fold reduction), Secchi depth measurements would most likely not change noticeably. This is due to the hyperbolic relationship between water clarity and chlorophyll concentrations.

☛ *See **hyperbolic relationships** on pages 13-15.*

In this instance, the cost-effectiveness and success of such a strategy may be questioned by the citizenry. For this reason, managers and users need a way to predict before-hand whether their proposed management strategy will produce significant results or be worth the cost. The following segment provides a mathematical approach for making such predictions.

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[9] *This is generally true, except in waterbodies where water clarity is influenced by other factors such as color or other non-algae particulates.*

Using Water Chemistry Data to Predict Water Clarity

In their efforts to predict how specific management techniques will affect water clarity in a lake, scientists and/or lake managers often use mathematical techniques or *models*. Two of the more widely used mathematical techniques include the use of **hyperbolic relationships** and/or **empirical models**. Read on to learn more about how these techniques can be used to predict water clarity.

Hyperbolic Relationships

Science is often a matter of studying relationships among two or more variables. By observing the way these variables relate to one another, scientists are able to spot relationships.

For example, when Secchi depth measurements are plotted on a graph along with other lake variables — such as phytoplankton abundance or the color of the water — patterns often emerge.

Figure 1 on page 14 is an example of a hyperbolic relationship that emerges when Secchi depth measurements were plotted with chlorophyll concentrations on a graph. Figure 2 shows a comparison between Secchi depth and color. Notice the plotted points form distinctive "L" shapes or curves, also known as mathematical **hyperbolas**, hence the phrase "hyperboolic relationships."

Joe Richard

Secchi Depth and Chlorophyll

Figure 1 provides us with an excellent example of how the relationship between Secchi depth and total chlorophyll concentrations for Florida lakes is a hyperbolic relationship. To better understand the Secchi depth/chlorophyll relationship in Florida lakes, study Figure 1 to see if you can recognize the following patterns:

♦ Lakes with extremely low chlorophyll levels are shown to potentially have high Secchi disc readings (greater than 24 feet).

♦ For lakes in the lower chlorophyll range, water clarity decreases rapidly as chlorophyll concentrations increase — so rapidly that even small increases in chlorophyll levels produce substantial decreases in water clarity.

♦ Once chlorophyll concentrations exceed 25 µg/L (the chlorophyll value at the rounded corner of the graph), Secchi disc readings level off and change little — even when chlorophyll concentrations increase significantly.

Secchi Depth and Color

There is a similar hyperbolic relationship between Secchi depth and true color (from dissolved substances) in water. See Figure 2 for an illustration of this relationship. In this case, the hyperbolic relationship has the following attributes:

♦ Lakes with low color levels have a high probability of having clear water.

♦ For lakes in the lower color range (0 - 50 PCU), water clarity decreases rapidly as color increases — so rapidly that even small increases in color produce substantial decreases in water clarity (Secchi depth).

♦ Once color levels exceed 50 PCU (the color value at the rounded portion of the graph), water clarity is likely to be substantially reduced and remain relatively constant for higher levels of color.

Figure 1 Secchi Depth and Total Chlorophyll

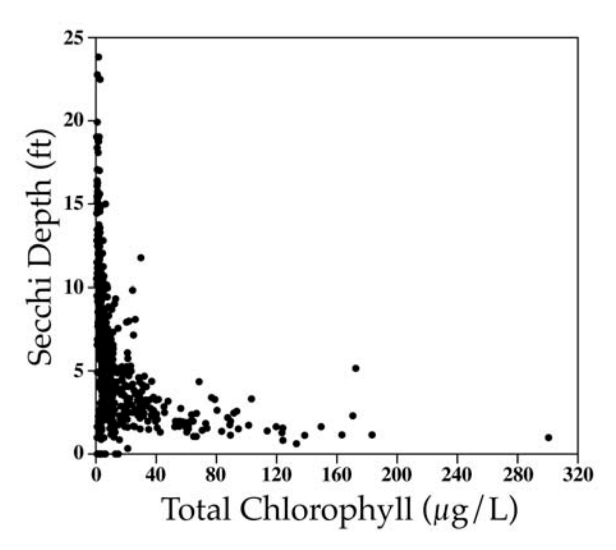
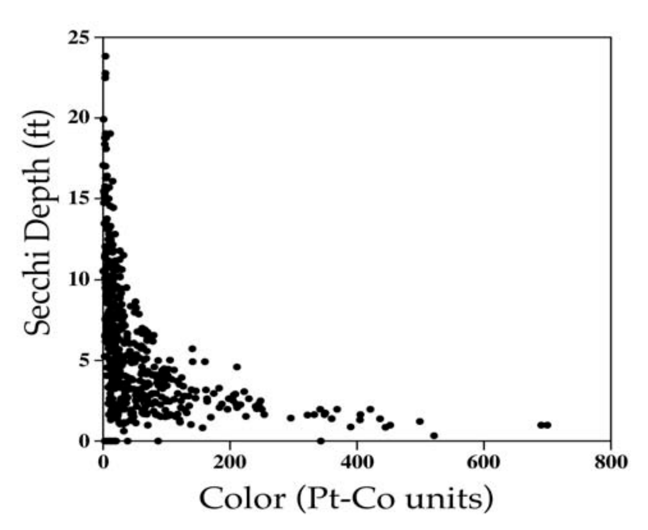


Figure 2 Secchi Depth and Color



The relationship between <u>Secchi depth and total chlorophyll</u> (Figure 1) and <u>Secchi depth and color</u> (Figure 2) for Florida lakes are illustrated here as hyperbolic relationships.

These relationships are considered to be "hyperbolic" because the plotted points form a curved "L" shape — a mathematical hyperbola. While it may be difficult to isolate individual data points on the graph, the overall image is what's important.

The Relationship Between Water Clarity, Phytoplankton Abundance, and Water Color

The knowledge that water clarity[*] is *hyperbolically* related to phytoplankton abundance[**] and dissolved substances[***] in lake water has significant implications for anyone interested in managing a lake's water clarity.

Graphing these relationships, as seen in Figures 1 and 2 (page 14) and below, provides a quick way of interpreting or predicting how a lake's water clarity will "react" to increases or decreases in phytoplankton abundance and/or true color. It all depends on where the water clarity value for the lake is plotted on the graph: whether it's above or below the rounded corner of the hyperbolic "L" shaped curve.

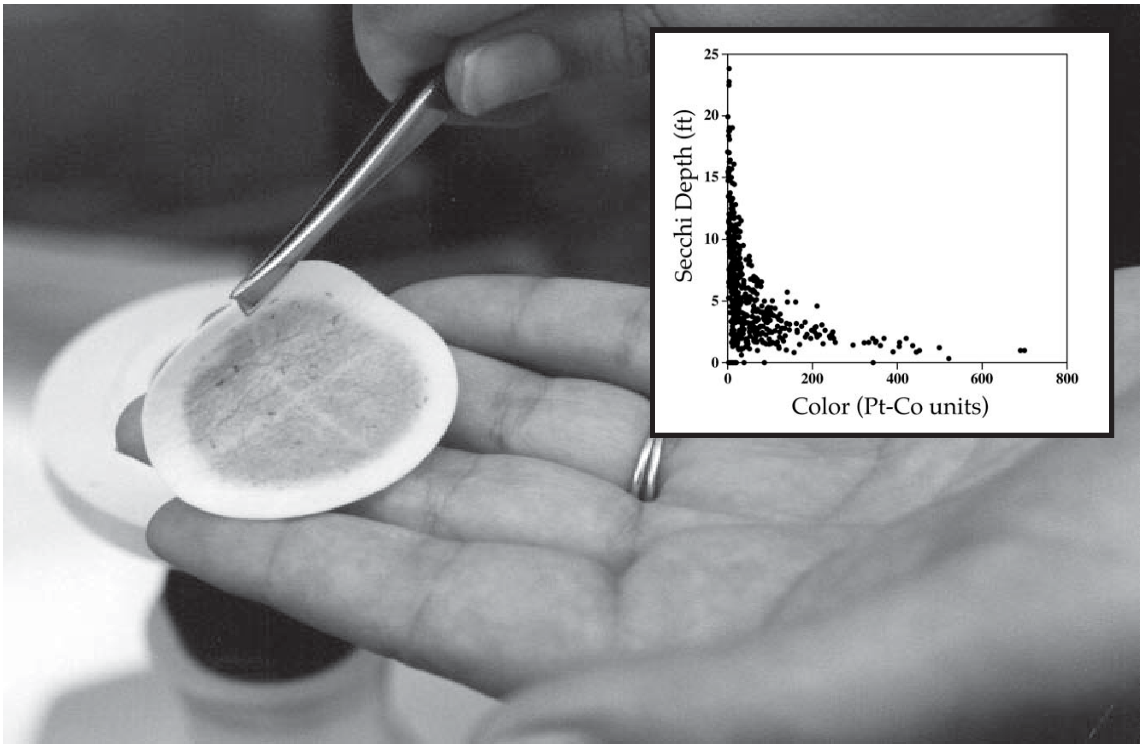
If the water clarity value for a lake, measured as Secchi depth, is plotted above (to the left of) the rounded corner of the hyperbola, it means the lake is probably more susceptible to dramatic changes in water clarity if phytoplankton abundance or the color of the water should happen to change. Conversely, if a water clarity value for a lake is plotted below (to the right of) the rounded corner of the graph, then the lake is less susceptible to change. In other words, lakes that already have low water clarity will show negligible changes in water clarity when phytoplankton growth or color concentrations increase.

There are exceptions to every rule, but these basic generalizations provide a good starting point for managing lakes for water clarity.

[*] *LAKEWATCH measures this as Secchi depth, in feet.*

[**] *LAKEWATCH measures this as chlorophyll concentrations in* ***micrograms per liter (µg/L)****.*

[***] *LAKEWATCH measures this as* ***Platinum Cobalt Units*** *or* ***PCU****s.*



Amy Richard

LAKEWATCH volunteers filter lake water through special filters to "trap" phytoplankton on the surface of the filter. The samples are then frozen and later analyzed for chlorophyll concentrations.

Empirical Models

A more precise way of using the same water chemistry data is to transform it into a mathematical format called an **empirical model**. An empirical model is an equation or a set of equations derived from statistical analysis of a specific set of data — a chosen group of lakes.

Using Empirical Models for Predicting Water Clarity

The following segment introduces four empirical models developed by Florida LAKEWATCH staff, using the LAKEWATCH database.

The first model, the **Secchi depth – chlorophyll** empirical model on page 17 is used to identify relationships between Secchi depth (water clarity) and chlorophyll concentrations (algae) in a lake. It can be used to predict water clarity, based on chlorophyll concentrations.

The other three models, on pages 18 and 19, are **chlorophyll – nutrient** models. These models relate chlorophyll concentrations to nutrients (phosphorus, nitrogen, or both). Similar to the **Secchi depth** – **chlorophyll** empirical model on page 17, **chlorophyll – nutrient** models can be used to predict how an increase or reduction of nutrients might affect chlorophyll levels and thus water clarity. In fact, **chlorophyll – nutrient** empirical models are now routinely used in conjunction with the **Secchi depth – chlorophyll** model to develop lake management strategies for water clarity. Here's how they work:

Surveys of lakes throughout the world and whole-lake experiments have shown that chlorophyll concentrations in lakes are also related to their nutrient concentrations, especially phosphorus. Consequently, there has been a major effort to develop empirical models for chlorophyll – phosphorus relationships, chlorophyll – nitrogen relationships, or chlorophyll – nutrient relationships (using both phosphorus and nitrogen).

If you happen to know what the average chlorophyll concentration and/or nutrient concentrations are for a lake over a given period of time, it's possible to plug those concentrations into the equations and after doing a few calculations, estimate what the average water clarity should be.

This can be taken one step further by plugging in *hypothetical* chlorophyll and/or nutrient concentrations — as a way of *predicting* what water clarity should be. This type of exercise can be invaluable in determining whether or not a particular algae management strategy is worth the cost of implementing. For example, is it worth a large expenditure of dollars to decrease phytoplankton levels through nutrient control if water clarity will only be increased from 0.5 foot of visibility to an estimated 1.0 foot?

For step-by-step instructions on how to use empirical models see page 17. Once you've mastered the **Secchi depth – chlorophyll** empirical model on page 17, try your hand at calculating each of the three **chlorophyll – nutrient** empirical models on pages 18-19.

You may want to have your Florida LAKEWATCH data packet handy so you can use your lake's average Secchi depth, chlorophyll, total phosphorus and/or total nitrogen concentrations for the calculations. Or as mentioned earlier, you can plug in hypothetical numbers to see how your lake's phytoplankton levels might be expected to change.

Clues to understanding empirical models

In the empirical equations on pages 17-19, you'll see the words "log" and "antilog." The term **log** is an abbreviation for the mathematical term **logarithm**. A logarithm is the "exponent that indicates the power to which a number is raised to produce a given number." [For the equation $\mathbf{10^2 = 100}$, the log of **100** is **2**. Using the equation $\mathbf{10^3 = 1000}$, the log of **1000** is **3**.]

The term **antilog** is an abbreviation for the mathematical term **antilogarithm**. An antilogarithm is "the number corresponding to a given logarithm." [For the equation $\mathbf{10^2 = 100}$, the antilog of **2** is **100**. Using the equation $\mathbf{10^3 = 1000}$, the antilog of **3** is **1000**.]

How To Use An Empirical Model

Consider that a hypothetical lake called **My Lake** has an average chlorophyll concentration of **30 µg/L** and water clarity of **3.1 feet**. Let's suppose that our lake homeowner's association is interested in improving the water clarity by reducing the amount of algae in the lake. They decide to decrease chlorophyll to **10 µg/L**. With the following empirical **Secchi depth – chlorophyll** model, developed from Florida LAKEWATCH data, we can plug in this hypothetical chlorophyll concentration of 10 µg/L and "predict" what the water clarity is expected to be after reducing the chlorophyll.

$$\text{Log (Secchi)} = 1.171 - 0.463\ \text{Log (Chlorophyll)}$$

Where: Log is the common logarithm (base 10),
Secchi is the annual mean Secchi depth in feet, and
Chlorophyll is the annual mean chlorophyll concentration in µg/L.

To make this calculation...

use a calculator with a LOG button and follow these step-by-step instructions.

Step 1 **Start by plugging in the hypothetical chlorophyll concentration of 10 *µ*g/L into the equation** (replace the word "chlorophyll" with the number 10). Now find the Log of 10 on your calculator.
To find the log of a number on your calculator, type in the number on the key pad (in this instance, type in the number 10), push the button marked "log," then push the "=" button. For this exercise, you should get an answer of 1.

Example: **Log (Secchi) = 1.171 – 0.463 x Log (chlorophyll)**

Log (Secchi) = 1.171 – 0.463 x **Log (10)**

Step 2 **Multiply that number (1) by <u>0.463</u> (from the equation).**

Example: Log (Secchi) = 1.171 – **0.463 x 1.0**

Log (Secchi) = 1.171 – **0.463**

Step 3 **Now subtract 0.463 from 1.171.**

Example: Log (Secchi) = **1.171 – 0.463**

Log (Secchi) = **0.708**

Step 4 **Find the antilog of your result.** *To find the antilog, leave the log (the number from the right side of the equation) on the calculator. You should see the Number **0.708**. While that number is on your screen, push the antilog key, which is usually represented by the symbol* $\mathbf{10^x}$*, then push the "=" button. (If your calculator doesn't have the* $\mathbf{10^x}$ *button, check the instruction booklet.)*

You should get an answer of <u>5.1</u>, which is your predicted Secchi depth in feet.

An Empirical Model That Predicts Chlorophyll Concentrations (i.e., phytoplankton abundance) from Phosphorus

For Florida lakes, the following empirical **chlorophyll – phosphorus** model has been developed from the Florida LAKEWATCH database of 534 waterbodies. Using this model, you can predict phytoplankton abundance (chlorophyll concentrations) by plugging in a hypothetical total phosphorus concentration for a lake. [See the example ***How To Use An Empirical Model*** for step-by-step instructions on how to do the calculations.]

$$\text{Log (Chlorophyll)} = -0.369 + 1.053 \text{ Log (TP)}$$

Where:
Log is the common logarithm (base 10),
Chlorophyll is the annual mean chlorophyll concentration in µg/L, and
TP is the annual mean total phosphorus concentration in µg/L.

Confidence Limit Statement:

Data analysis shows this model has a 95% confidence interval that ranges from 30% to 325%. For more on confidence limits, see ***How Much Confidence Can You Have In An Empirical Model?*** *on page* ***20***.

An Empirical Model That Predicts Chlorophyll Concentrations (i.e., phytoplankton abundance) from Nitrogen

Empirical **chlorophyll – nitrogen** models can be derived in a manner similar to that described for the **chlorophyll – phosphorus** model above. For Florida lakes, the following empirical **chlorophyll – nitrogen** model has been developed from the Florida LAKEWATCH database of 534 waterbodies. Using this model, you can predict chlorophyll concentrations (phytoplankton levels) by plugging in a hypothetical total nitrogen concentration for a lake. [See the example ***How to Use An Empirical Model*** for step-by-step instructions. Apply the same steps to the equation below.]

$$\text{Log (Chlorophyll)} = -2.42 + 1.206 \text{ Log (TN)}$$

Where:
Log is the common logarithm,
Chlorophyll is the annual mean chlorophyll concentration in µg/L, and
TN is the annual mean total nitrogen concentration in µg/L.

Confidence Limit Statement:

Data analysis shows this model has a 95% confidence interval ranging from 23% to 491% for predicted chlorophyll concentrations (compared to 30% to 325% for the previous phosphorus-chlorophyll model). For more on confidence limits, see ***How Much Confidence Can You Have In An Empirical Model?*** *on page* ***20***.

An Empirical Model That Predicts Chlorophyll Concentrations (i.e., phytoplankton abundance) From Phosphorus and Nitrogen

The most reliable model is an empirical **chlorophyll – nutrient** model that factors in *both* phosphorus and nitrogen concentrations to predict chlorophyll levels. Using this model, you can predict phytoplankton levels (chlorophyll concentrations) by plugging in hypothetical total phosphorus and total nitrogen concentrations for a lake. For Florida lakes, the following empirical nutrient-chlorophyll model has been developed from the Florida LAKEWATCH database of 534 waterbodies. **[See the example *How to Use an Empirical Model* for step-by-step instructions. Apply the same steps to the equation below.]**

$$\mathbf{Log\ (Chlorophyll) = -1.10 + 0.91\ Log\ (TP) + 0.321\ Log\ (TN)}$$

Where: **Log** is the common logarithm (base 10),
Chlorophyll is the annual mean chlorophyll concentration in µg/L,
TP is the annual mean total phosphorus concentration in µg/L, and
TN is the annual mean total nitrogen concentration in µg/L.

Confidence Limit Statement:

Data analysis shows that this model is the best available model for Florida lakes. It has a 95% confidence interval ranging from 33% to 312% for predicted chlorophyll concentrations. This is the smallest confidence range for any published empirical chlorophyll – nutrient model that has been tested for Florida lakes. The confidence interval is also smaller than those established for the simple empirical phosphorus-chlorophyll (30% to 325%) or nitrogen-chlorophyll (23% to 491%) models. For more on confidence limits, see ***How Much Confidence Can You Have In An Empirical Model?*** *on page* ***20****.*

Wakulla River

Jess VanDyke

How much confidence can you have in an empirical model?

Scientists often choose to answer this question by calculating confidence limits for their predictions. By doing a mathematical analysis from the same database used to create the empirical models, scientists can calculate these confidence limits.

A 95% confidence interval gives the range of chlorophyll values that a measured chlorophyll should fall into 95% of the time. Confidence intervals can be smaller when the degree of certainty does not need to be as stringent (e.g., 90% confidence, 85% confidence, etc.). However, water managers usually prefer to be more confident. Use of a 95% confidence interval reflects the desire of professionals to have their predictions correct 95% of the time.

To further explain this concept, let's use an example of a lake with total phosphorus concentrations of 20 µg/L. If we plug this lake's total phosphorus concentration of 20 µg/L into the **chlorophyll – phosphoru**s empirical model (see page 18), we find that the lake is predicted to have a total chlorophyll concentration of approximately 10 µg/L.

How much confidence can we have in this prediction?

According to our calculations, the 95% confidence limits for that particular **chlorophyll – phosphorus** empirical model ranges from 30% to 325%. In other words, there is a 95% confidence that the actual chlorophyll concentration will fall somewhere between 3 µg/L and 33 µg/L. See **Calculate this yourself** (top right) for an explanation of how these percentages (30% - 325%) were translated into whole numbers (3 µg/L - 33 µg/L).

Joe Richard

Calculate this yoursel f

Using the **chlorophyll – phosphorus** empirical model example on page 18, we know that a chlorophyll concentration of 10 µg/L was predicted. We can use this predicted chlorophyll concentration of 10 µg/L along with the 95% confidence limits of 30% (0.30) to 325% (3.25), to do the following calculations:

30% of 10 µg/L is 3 µg/L

0.30 X 10 µg/L = 3 µg/L

and

325% of 10 µg/L approx. = 33 µg/L

3.25 X 10 µg/L approx. = 33 µg/L

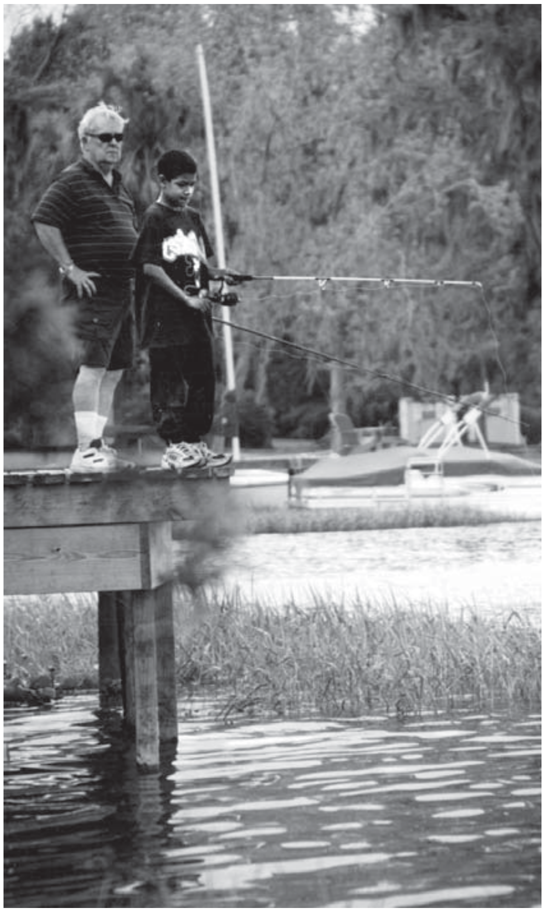
In other words, the actual chlorophyll value for this sample lake should be somewhere between 3 µg/L and 33 µg/L, 95% of the time.

Empirical Models and Their Limitations

While the confidence interval for this empirical model may seem large (30% to 325% is a rather expansive range), it's not unusual. The confidence limits of even the most reliable empirical model can yield a broad range of chlorophyll values.

The confidence limits provided with the three nutrient empirical models in this circular are based on Florida LAKEWATCH lakes and truly reflect the variability of chlorophyll concentrations found in waterbodies in this state. (Look for confidence interval statements at the bottom of each of the nutrient empirical models on pages 18 and 19.) Such variability makes predictions from all empirical **chlorophyll – nutrient** models somewhat uncertain, particularly when only small changes occur in nutrient concentrations.

Also, keep in mind that when dealing with real waterbodies, as opposed to hypothetical ones, there is a broad range of possible chlorophyll concentrations that can occur based on any specific amount of nutrients in the system.
It's difficult to predict precise quantities when dealing with real-world waterbodies and the


Joe Richard

Probably the most important lesson to be learned from empirical models is that, in Florida lakes, it's been found that small changes in nutrient concentrations will not produce noticeable changes in water clarity, except perhaps in lakes with generally low productivity.

In other words, if you want to decrease chlorophyll concentrations (meaning algal levels) to the point where people actually see a change in water clarity, you will have to dramatically decrease nutrient concentrations.

multitude of factors that can come into play.

Because other environmental factors such as local climate, geology, and aquatic macrophytes can also influence phytoplankton levels, managers may make their predictions more accurate by developing empirical models using data from waterbodies within the same local geographic region. When developing these empirical models, a basic understanding of how waterbodies function in that area should be combined with the best available data.

Of course, there are instances when an individual lake may fall outside the predictions found while using any empirical model. When this happens, it's important for that lake to be studied independently of others in its region to find out what is "driving" the phytoplankton productivity of the lake.

While there are several empirical models currently being used throughout Florida, we strongly suggest that lake managers and citizens consider using the **Secchi depth – chlorophyll** model (page 17) as well the three **chlorophyll – nutrient** empirical models provided in this circular (pages 18 – 19). These models are based on a large number of Florida lakes and offer a good starting point for determining the most appropriate management options for your lake or waterbody.

Lastly, remember that empirical models merely provide a framework for evaluating how changing nutrient concentrations could affect phytoplankton levels in a lake, and thus water clarity. These models provide a guide, not absolute answers.

Appendix A

Descriptions of Terms

Excerpts from Florida LAKEWATCH Information Circular 101

Algae

are a wide variety of tiny, often microscopic, plants (or plant-like organisms) that live both in water and on land. The word "algae" is plural (pronounced AL-jee), and "alga" is the singular form (pronounced AL-gah).

One common way to classify water-dwelling algae is based on where they live. Using this system, three types of algae are commonly defined as follows:

♦ **phytoplankton** float freely in the water;

♦ **periphyton** are attached to aquatic vegetation or other structures;

♦ **benthic algae** grow on the bottom.

Algae may further be described as being **single-celled, colonial** (grouped together in colonies), or **filamentous** (hair-like strands). The most common forms of algae are also described by their colors: green, blue-green, red, and yellow. All these classifications may be used together. For example, to describe blue-green, hair-like algae that are attached to an underwater plant, you could refer to them as "blue-green filamentous periphyton."

In addition to describing types of algae, it is useful to measure their quantity. The amount of algae in a waterbody is often called **algal biomass**. Scientists commonly make estimates of algal biomass based on two types of measurements:

♦ Because most algae contain chlorophyll (the green pigment found in plants), the concentration of chlorophyll in a water sample can be used to indicate the amount of algae present. This method however, does not include all types of algae, only the phytoplankton. Chlorophyll concentrations are measured in units of micrograms per Liter (abbreviated **µg/L**) or in milligrams per cubic meter (abbreviated **mg/m³**).

♦ In certain cases, scientists prefer to count and measure individual algal cells in a sample and use their count to calculate the volume of the algae.

Most people consider algae to be unsightly, particularly when it is abundant. For instance, a phytoplankton bloom can make water appear so green that it's described as "pea soup."

In Florida, when chlorophyll concentrations reach a level over 40 µg/L some scientists will call it an "algae bloom" or "algal bloom." The public, however, usually has a less scientific approach. They often define an algal bloom as whenever more algae can be seen in the water than they are accustomed to seeing (even though this may be a low concentration in some cases).

Algal blooms may be caused by human activities, or they may be naturally occurring. Sometimes, what seems to be an algal bloom is merely the result of wind blowing the algae into a cove or onto a downwind shore, concentrating it in a relatively small area. This is called "windrowing."

The Role of Algae in Waterbodies:

Algae are essential to aquatic systems. As a vital part of the food web, algae provide the food necessary to support all aquatic animal life.

♦ Filamentous algal blooms and benthic algal blooms have the potential to interfere with recreational uses like boating and fishing.

♦ An algal bloom can trigger a fish kill. In Florida, this is most likely to occur after several days of hot weather with overcast skies.

Aquatic Macrophytes

are aquatic plants that are large enough to be apparent to the naked eye. In other words, they are larger than microscopic algae. The general phrase "aquatic plants" usually refers to aquatic macrophytes, but most scientists use it to mean aquatic macrophytes and algae.

Aquatic macrophytes characteristically grow in water or in wet areas and are quite a diverse group. For example, some are rooted in the bottom sediments, while others float on the water's surface and are not rooted to the bottom. Aquatic plants may be native to an area, or they may have been imported (referred to as "exotic").

Most aquatic macrophytes are vascular plants, meaning they contain a system of fluid-conducting tubes, much like human blood vessels. Cattails, waterlilies, and hydrilla are examples. Large algae such as *Nitella*, *Lyngbya*, and *Chara* are often included in the category of aquatic macrophytes.

Even though they are quite diverse, aquatic macrophytes have been grouped into four general categories:

♦ **emergent** aquatic plants are rooted in the bottom sediments and protrude up above the water's surface;

♦ **submersed** aquatic plants primarily grow completely below the water's surface; and

♦ **floating** aquatic plants float on the water with roots suspended down into the water;

♦ **floating-leaved** aquatic plants can be rooted to bottom sediments and have leaves that float on the water's surface.

Aquatic macrophytes are a natural part of waterbodies, although in some circumstances they can be troublesome. The same plant may be a "desirable aquatic plant" in one location and a "nuisance weed" in another. When exotic aquatic plants have no natural enemies in their adopted area, they can grow unchecked and may become overly abundant.

In Florida for example, millions of dollars are spent each year to control two particularly aggressive and fast-growing aquatic macrophytes — water hyacinth, an exotic floating aquatic plant that is thought to be from Central and South America, and hydrilla, an exotic submersed aquatic plant that is thought to be from Asia. However, the term "weed" is not reserved for exotic aquatic plants only. In some circumstances, native aquatic plants such as cattails or *Potamogeton* (i.e., pondweed) can cause serious problems.

When assessing the abundance of aquatic plants in a waterbody, scientists may choose to measure or calculate one or more of the following:

♦ **PVI** (Percent Volume *Infested* or Percent Volume *Inhabited*) is a measure of the percentage of a waterbody's volume that contains aquatic plants;

♦ **PAC** (Percent Area Covered) is a measure of the percentage of a waterbody's bottom area that has aquatic plants growing on or over it;

♦ **frequency of occurrence** is an estimate of the abundance of a specific aquatic plant; and

♦ **average plant biomass** is the average weight of several samples of fresh, live aquatic plants growing in a given amount of a lake's area.

The Role of Aquatic Macrophytes in Waterbodies:

Aquatic macrophytes perform several functions in waterbodies, often quite complex ones. A few are briefly described below.

♦ Aquatic macrophytes provide habitat for fish, wildlife, and other aquatic animals.

♦ Aquatic macrophytes provide habitat and food for organisms that fish and wildlife feed on.

♦ Aquatic macrophytes along a shoreline can protect the land from erosion caused by waves and wind.

♦ Aquatic macrophytes can stabilize bottom sediments by dampening wave action.

♦ The mixing of air into the water that takes place at the water's surface can be obstructed by the presence of floating plants and floating-leaved plants. In this way, they can cause lower oxygen levels in the water.

♦ Floating plants and floating-leaved plants create shaded areas that can cause submersed plants beneath them to grow slower and even die.

♦ When submersed aquatic plants become abundant, these plants can cause water to become clear. Conversely, the removal or decline of large amounts of submersed aquatic plants can cause water to become less clear.

♦ When aquatic macrophytes die, the underwater decay process uses oxygen from the water. If massive amounts of plants die simultaneously, a fish kill can result due to low oxygen.

♦ Decayed plant debris (dead leaves, etc.) contributes to the buildup of sediments on the bottom.

Biological Productivity

is defined conceptually as the ability of a waterbody to support life (such as plants, fish, and wildlife). Biological productivity is defined scientifically as the rate at which organic matter is produced. Measuring this rate directly for an entire waterbody is difficult and prohibitively expensive.

For this reason, many scientists base estimates of biological productivity on one or more quantities that are more readily measured. These include measurements of concentrations of nutrients in water, concentrations of chlorophyll in the water, aquatic plant abundance, and/or water clarity. The level of biological productivity in a waterbody is used to determine its trophic state classification.

Chlorophyll

is the green pigment found in plants and in nearly all algae. Chlorophyll allows plants and algae to use sunlight in the process of photosynthesis for growth. Thanks to chlorophyll, plants are able to provide food and oxygen for the majority of animal life on earth.

Scientists may refer to **chlorophyll *a***, which is one type of chlorophyll, as are **chlorophyll *b*** and **chlorophyll *c***. Measurements of **total chlorophyll** include all types. Chlorophyll can be abbreviated **CHL**, and total chlorophyll can be abbreviated **TCHL**.

The Role of Chlorophyll in Waterbodies:

Measurements of the chlorophyll concentrations in water samples are useful to scientists. For example, they are often used to estimate algal biomass in a waterbody and to assess a waterbody's biological productivity.

In Florida:

Waterbodies in the Florida LAKEWATCH database analyzed prior to January 2000, had average chlorophyll concentrations which ranged from less than 1 to over 400 µg/L. Using these average chlorophyll concentrations from this same database, Florida lakes were found to be distributed into the four trophic states as follows:

♦12% of the lakes would be classified as oligotrophic (those with chlorophyll values less than or equal to 3 µg/L);

♦ about 31% of the lakes would be classified as mesotrophic (those with chlorophyll values greater than 3 and less than 7 µg/L);

♦ 41% of these lakes would be classified as eutrophic (those with chlorophyll values greater than 7 and less than or equal to 40 µg/L); and

♦ nearly 16% of the lakes would be classified as hypereutrophic(those with chlorophyll values greater than 40 µg/L).

In Florida, characteristics of a lake's geographic region can provide insight into how much chlorophyll may be expected for lakes in that area. For example, water entering the waterbodies by stream flow or underground flowage through fertile soils can pick up nutrients that can then fertilize the growth of algae and aquatic plants. In this way, the geology and physiography of a watershed can significantly influence a waterbody's biological productivity.

Health Concerns:

Chlorophyll poses no known direct threat to human health. There are some rare cases where algae can produce toxins in high enough abundance to cause concern. However, toxic algae are generally not a problem.

Eutrophic

is an adjective used to describe the level of biological productivity of a waterbody. Florida LAKEWATCH and many professionals classify levels of biological productivity using four trophic state categories (**oligotrophic**, **mesotrophic**, **eutrophic**, and **hypereutrophic**). Of the four trophic state categories, the eutrophic state is defined as having a high level of biological productivity, second only to the hypereutrophic category. The prefix "eu" means good, well, or sufficient.

A eutrophic waterbody is capable of producing and supporting an abundance of living organisms (plants, fish, and wildlife). Eutrophic waterbodies generally have the characteristics described below:

♦ Eutrophic lakes are more biologically productive than oligotrophic and mesotrophic lakes and are often some of Florida's best fishing lakes. They usually support large populations of fish, including sportfish such as largemouth bass, speckled perch (black crappie), and bream (bluegill).

♦ Typically, eutrophic waters are characterized as having sufficient nutrient concentrations to support the abundant growth of algae and/or aquatic plants.

♦ When algae dominate a eutrophic waterbody, its water will have high chlorophyll concentrations (i.e., greater than 7 µg/L). The water will be less clear, causing Secchi depth readings to be low. In contrast, when instead of algae, aquatic plants dominate a eutrophic waterbody, its water will have lower chlorophyll concentrations and often lower nutrient concentrations and clearer water. The resulting water clarity will be reflected in Secchi depth readings that are greater than in eutrophic waterbodies that have few aquatic plants.

Despite being classified as eutrophic, these plant-dominated waterbodies display the clear water, low chlorophyll concentrations, and low nutrient concentrations that are more characteristic of mesotrophic or oligotrophic waterbodies.

♦ Regardless of whether eutrophic waterbodies are plant-dominated or algae-dominated, they generally have a layer of sediment on the bottom resulting from the long-term accumulation of plant debris. In some eutrophic lakes, however, the action of wind and waves can create beaches or sand-bottom areas in localized places.

♦ Eutrophic waterbodies can have occasional algal blooms and fish kills. However, fish kills generally occur in hypereutrophic lakes when chlorophyll concentrations exceed 100 µg/L.

Geologic Region

is an area that has similar soils and underlying bedrock features. The characteristics of the geologic region in which a waterbody is located may be responsible for the water's chemical characteristics and trophic state. Geology can also have a significant influence on the shape of a waterbody's basin, a factor that affects many of features of a waterbody.

Hypereutrophic

is an adjective used to describe the level of biological productivity of a waterbody. Florida LAKEWATCH and many professionals classify levels of biological productivity using four trophic state categories — **oligotrophic**, **mesotrophic**, **eutrophic**, and **hypereutrophic**.

Of the four trophic state categories, the hypereutrophic state is defined as having the highest level of biological productivity. The prefix "hyper" means over abundant. Hypereutrophic waterbodies are among the most biologically productive in the world. Hypereutrophic waterbodies generally have the characteristics described below.

♦ Hypereutrophic waterbodies have extremely high nutrient concentrations.

♦While hypereutrophic waterbodies can be dominated by non-sportfish species (gizzard shad or threadfin shad), they can also support large numbers and large sizes of sportfish including largemouth bass, speckled perch (black crappie) and bream (bluegill).

♦ A hypereutrophic waterbody has either an abundant population of algae or an abundant population of aquatic macrophytes — and sometimes it will support both.

♦ Hypereutrophic waterbodies that are dominated by algae are characterized by having high chlorophyll concentrations (greater than 40 µg/L). These waterbodies will have reduced water clarity, causing Secchi depth readings to be less than 1 meter (about 3.3 feet). In contrast, when aquatic macrophytes instead of algae dominate a hypereutrophic waterbody, its water can have lower chlorophyll concentrations. The resulting water clarity will be reflected in higher Secchi depth readings (clearer water), mimicking those of less biologically productive waterbodies.

♦ Regardless of whether a waterbody is plant-dominated or algae-dominated, typically it will have organic bottom sediments as the decaying plant and/or algal debris accumulates.

♦ Hypereutrophic waterbodies may experience frequent algal blooms.

♦ Oxygen depletion may also be a common cause of fish kills in these waterbodies.

Lake region

is a geographic area in which lakes have similar geology, soils, chemistry, hydrology, and biological features. In 1997, using Florida LAKEWATCH data and other information, the United States Environmental Protection Agency divided Florida into 47 lake regions using these similarities as their criteria.

Lakes in an individual lake region exhibit remarkable similarities. However, lakes in one lake region may differ significantly from those in a different lake region. For example, most lakes in the New Hope Ridge/Greenhead Slope lake region in northwestern Florida (in Washington, Bay, Calhoun, and Jackson counties) tend to have lower total nitrogen, lower total phosphorus, lower chlorophyll concentrations, and greater Secchi depths when compared to other Florida lakes.

While lakes in the Lakeland/Bone Valley Upland lake region in central Florida (in Polk and Hillsborough counties) tend to have higher total nitrogen, higher total phosphorus, higher chlorophyll concentrations, and reduced Secchi depths when similarly compared.

Using descriptions of lake regions, waterbody managers can establish reasonable, attainable water management goals for individual lakes. Lake region characteristics can also be used to help choose management strategies that are likely to be effective in achieving management goals. In addition, lakes with water chemistry that differs markedly from that of other lakes in the same lake region can be identified and investigated to determine the cause of their being atypical.

The lake regions are mapped and described in ***Lake Regions of Florida*** (EPA/R–97/127). The Florida LAKEWATCH Program can provide you with a free handout describing (1) how and why the lake regions project was developed; (2) how to compare your lake with others in its Lake Region; and (3) how the Lake Region Classification System can be useful to you.

Limnology

is the scientific study of the physical, chemical, and biological characteristics of inland (non-marine) aquatic systems. A limnologist is a scientist who studies inland aquatic systems.

Macrophytes

See *Aquatic Macrophytes.*

Mean Depth

is another way of saying “average water depth.” The mean water depth is measured in either feet or meters and is designated in scientific publications by the letter “**z**.”

Mean depth can be estimated by measuring the water depth in many locations and averaging those values. Individual depth measurements may be taken by using a depth finder (fathometer) or by lowering a weight, at the end of a string or rope, into the water and measuring how far it sinks below the surface until it rests on the bottom.

If more accuracy is needed, mean depth should be calculated by dividing a waterbody’s volume by its surface area. This method will often result in a different value than if measured depths are averaged.

Mesotrophic

is an adjective used to describe the level of biological productivity of a waterbody. Florida LAKEWATCH and many professionals classify levels of biological productivity using four trophic state categories — **oligotrophic**, **mesotrophic**, **eutrophic**, and **hypereutrophic**.

Of the four trophic state categories, the mesotrophic state is defined as having a moderate level of biological productivity. The prefix “meso” means mid-range. A mesotrophic water-body is capable of producing and supporting moderate populations of living organisms (plants, fish, and wildlife). Mesotrophic waterbodies generally have:

♦ moderate nutrient concentrations;

♦ moderate growth of algae, aquatic plants or both;

♦ water that is clear enough (visibility between 8 and 13 feet) that most swimmers are not repelled by its appearance and can generally see any potential underwater hazards.

Nitrogen

is an element that, in its different forms, stimulates the growth of aquatic plants and algae.

Nutrients

are chemicals that algae and aquatic plants need for their growth. Nitrogen and phosphorus are the two most influential nutrients in Florida waterbodies. Nutrients can come from a variety of sources.

In most cases, nutrients are carried into a waterbody primarily when water drains through the surrounding rocks and soils, picking up nitrogen and phosphorus compounds along the way. For this reason, knowledge of the geology and physiography of the area can provide insight into how much nutrient enrichment can be reasonably expected in an individual waterbody from this natural source.

For example, lakes in the New Hope Ridge/ Greenhead Slope lake region in northwestern Florida (in Washington, Bay, Calhoun, and Jackson counties) can be expected to have low nutrient levels, because they are in a nutrient-poor geographic region. While lakes in the Lakeland/Bone Valley Upland lake region in central Florida (in Polk and Hillsborough counties) can be expected to have high nutrient levels, because the land surrounding the lakes is naturally nutrient-rich.

There are many other sources of nutrients that are generally not as substantial as nutrient contributions from surrounding rocks and soils. Some occur naturally, and some are the results of human activity. For example nutrients are conveyed in rainfall, stormwater runoff, seepage from septic systems, bird and animal feces, and the air itself. Most nutrients can move easily through the environment. They may come from nearby woods, farms, yards, and streets — anywhere in the watershed.

Oligotrophic

is an adjective used to describe the level of biological productivity of a waterbody. Florida LAKEWATCH and many professionals classify levels of biological productivity using four trophic state categories — **oligotrophic**, **mesotrophic**, **eutrophic**, and **hypereutrophic**.

Of the four trophic state categories, the oligotrophic state is defined as having the lowest level of biological productivity. The prefix "oligo" means scant or lacking.

An oligotrophic waterbody is capable of producing and supporting relatively small populations of living organisms (plants, fish, and wildlife). The low level of productivity in oligotrophic waterbodies may be caused by there being a low level of a limiting nutrient in the water, particularly nitrogen or phosphorus, or by limiting environmental factors other than nutrients.

Oligotrophic waterbodies generally have the following characteristics:

♦ Because nutrients are typically in short supply, aquatic plants and algae in oligotrophic waterbodies are in low abundance.

♦ An oligotrophic waterbody typically will have little plant debris accumulated on the bottom since aquatic plants and algae are in low abundance.

♦ Oligotrophic waterbodies will often tend to have clear water, because the clarity is not diminished by the presence of free-floating algae in the water. The clarity may be decreased, however, by the presence of color, stirred-up bottom sediments, or washed-in particulate matter.

♦ Fish and wildlife populations will generally be small, because food and habitat are often scarce. Oligotrophic waterbodies usually do not support abundant populations of sportfish such as largemouth bass and bream, and it usually takes longer for individual fish to grow in size. Fishing may be good initially if the number of anglers is small, but can deteriorate rapidly when fishing pressure increases and fish are removed from the waterbody.

♦ A waterbody may have oligotrophic characteristics even though it has high nutrient levels. This can occur when a factor other than nutrients is limiting the growth of aquatic plants and algae. For example, where a significant amount of suspended sediments (stirred-up sediments or particles washed in from the watershed) or darkly colored water is retarding plant growth by blocking sunlight.

PAC

is an abbreviation for **percent area covered** and is a measure of the percentage of a waterbody's bottom area that has aquatic plants growing on or over it. Scientists use PAC to assess the abundance and importance of aquatic plants in a waterbody.

Waterbodies in the Florida LAKEWATCH database analyzed prior to January 2000, had PAC values that ranged from 0 to 100%. PAC values are linked with the biological productivity (trophic state) of waterbodies:

♦ In the least productive (oligotrophic) waterbodies, PAC values are usually low. In rare cases where PAC values are high (occasionally reaching 100%), it is usually due to a thin layer of small plants growing along the bottom.

♦ In moderately productive (mesotrophic) and highly productive (eutrophic) waterbodies, PAC values are generally greater than those measured in oligotrophic waterbodies, and the average plant biomass is also greater.

♦ In extremely productive (hypereutrophic) waterbodies that are dominated by algae, PAC values are often less than 25%. In Florida however, many hypereutrophic waterbodies contain mostly aquatic plants, not algae. In these cases, PAC values often tend to be greater than 75%.

Particulates

are any substances in the form of small particles that are found in waterbodies, often suspended in the water column. Substances in water are either in particulate form or in dissolved form. Passing water through a filter will separate these two forms. The filter will trap most of the particulates, allowing the dissolved substances to pass through.

Phosphorus

is an element that, in its different forms, stimulates the growth of aquatic plants and algae in waterbodies.

Physiographic region

is a geographic area whose boundaries enclose territory that has similar physical geology (i.e., soil types, land formations, etc.).

Phytoplankton

are small, free-floating aquatic plants that are suspended in the water column. They are sometimes called "planktonic algae" or just "algae." Though small, phytoplankton perform important functions in waterbodies. For example, phytoplankton abundance often determines how biologically productive waterbodies can be — how much fish and wildlife waterbodies can support. Also, the public is concerned about the abundance of phytoplankton, because it significantly affects water clarity.

Aquatic scientists assess phytoplankton relative abundance by estimating its biomass. Two common methods are used: (1) viewing phytoplankton through a microscope and counting them, and (2) measuring the chlorophyll concentrations in water samples. Florida LAKEWATCH uses the chlorophyll method because it's faster and less costly.

Planktonic Algae

See ***Phytoplankton.***

PVI

is a measure of the percentage of a waterbody's volume that contains aquatic plants. Historically, PVI represented the **percent volume *infested*** with aquatic plants. Recently, it has become an abbreviation for the more neutral phrase **percent volume *inhabited***. Regardless of the terminology, PVI is used to assess the abundance of aquatic plants in a waterbody.

In Florida:

Numerous plant surveys performed on Florida LAKEWATCH lakes have shown that prior to January 2000, PVI values ranged from 0 to 100%. In Florida, PVI values are strongly linked with the biological productivity (trophic state) of waterbodies as described below:

♦ In the least biologically productive waterbodies, (oligotrophic) PVI values are generally low.

♦ In moderately biologically productive waterbodies (mesotrophic) and highly productive waterbodies (eutrophic) dominated by aquatic plants, PVI values are higher than those measured in oligotrophic waterbodies.

♦ The most highly biologically productive (hypereutrophic) waterbodies that are dominated by algae usually have low PVI values. However, hypereutrophic waterbodies dominated by aquatic plants usually have high PVI values.

Secchi depth

is a measurement that indicates water clarity. Traditionally, the transparency or water clarity of a waterbody has been measured using an 8-inch diameter disc called a **Secchi disc**, that was named in honor of its inventor. A Secchi disc is usually painted in alternating quadrants of black and white, although it can be solid white. There is a line (a rope or chain) attached through the Secchi disc's center that is marked off in intervals, usually in feet or meters.

To use the Secchi disc to measure water clarity, it's lowered into the water to find the depth at which it first vanishes from the observer's sight.

Note that if the disc can still be seen as it rests on the lake bottom or if it disappears into plant growth, the depth at which this happens is not a measurement of the waterbody's Secchi depth.

Surface Water

is water found on the earth's surface. It is distinguished from "groundwater" which is found underground. Surface waters include many types of waterbodies such as estuaries, lakes, marshes, ponds, reservoirs, rivers, streams and swamps.

Total Chlorophyll

is a measure of all types of chlorophyll. The Florida LAKEWATCH abbreviation for total chlorophyll is CHL.

Total Nitrogen

is a measure of all the various forms of nitrogen that are found in a water sample. Nitrogen is a necessary nutrient for the growth of aquatic macrophytes and algae. Not all forms of nitrogen can be readily used by aquatic macrophytes and algae, especially nitrogen that is bound with dissolved or particulate organic matter. The chemical symbol for the element nitrogen is **N**, and the symbol for total nitrogen is **TN**.

Total nitrogen consists of inorganic and organic forms. Inorganic forms include nitrate ($\mathbf{NO_3^-}$), nitrite ($\mathbf{NO_2^-}$), unionized ammonia ($\mathbf{NH_3}$), ionized ammonia ($\mathbf{NH_4^+}$), and nitrogen gas ($\mathbf{N_2}$). Amino acids and proteins are naturally-occurring organic forms of nitrogen. All forms of nitrogen are harmless to aquatic organisms except unionized ammonia and nitrite, which can be toxic to fish. Nitrite is usually not a problem in waterbodies because nitrite is readily converted to nitrate.

The Role of Nitrogen in Waterbodies:

Like phosphorus, nitrogen is an essential nutrient for all plants, including aquatic macrophytes and algae. In some cases, the inadequate supply of TN in waterbodies has been found to limit the growth of free-floating algae (i.e., phytoplankton). This is called "nitrogen limitation," and occurs most commonly when the ratio of total nitrogen to total phosphorus is less than 10 (in other words, the TN concentration divided by the TP concentration is less than 10: $TN/TP < 10$). TN in waterbodies comes from both natural and man-made sources, including:

♦ the air (some algae can "fix" nitrogen; that is, the algae can pull it out of the air in its gaseous form and convert it to a form they can use);

♦ stormwater run-off (even "natural" run-off from areas where there is no human impact, because nitrogen is a naturally-occurring nutrient found in soils and organic matter);

♦ fertilizers; and

♦ animal and human wastes (sewage, dairies, feedlots, etc.).

In Florida:

Waterbodies in the Florida LAKEWATCH database analyzed prior to January 2000, had total nitrogen concentrations which ranged from less than 50 to over 6000 µg/L. Using these average concentrations of total nitrogen from this same database, Florida lakes were found to be distributed into four trophic states as follows.

♦ approximately 14% of the lakes would be classified as oligotrophic (those with TN values less than 400 µg/L);

♦ about 25% of the lakes would be classified as mesotrophic (those with TN values between 401 and 600 µg/L);

♦ 50% of the lakes would be classified as eutrophic (those with TN values between 601 and 1500 µg/L); and

♦ nearly 11% of the lakes would be classified as hypereutrophic (those with TN values greater than 1500 µg/L).

The location of a waterbody has a strong influence on its total nitrogen concentration. For example, lakes in the New Hope Ridge/Greenhead Slope lake region in northwestern Florida (in Washington, Bay, Calhoun, and Jackson counties) tend to have total nitrogen values below 220 µg/L. While lakes in the Lakeland/Bone Valley Upland lake region in central Florida (in Polk and Hillsborough counties) tend to have values above 1700 µg/L.

Health Concerns:

The concentration of total nitrogen in water is not a known direct threat to human health. It is the individual forms of nitrogen that contribute to the total nitrogen measurement and the use of the water that need to be considered.

For example, nitrate in drinking water is a concern. Drinking water with nitrate concentrations above 45 mg/L has been implicated in causing blue-baby syndrome in infants. The maximum allowable level of nitrate, a component of the total nitrogen measurement, is 10 mg/L in drinking water. Concentrations of nitrate greater than 10 mg/L generally do not occur in waterbodies, because nitrate is readily taken up by plants and used as a nutrient.

Total Phosphorus

is a measure of all the various forms of phosphorus that are found in a water sample. Phosphorus is an element that, in its different forms, stimulates the growth of aquatic macrophytes and algae in waterbodies. The chemical symbol for the element phosphorus is “P,” and the symbol for total phosphorus is “TP.” Some phosphorus compounds are necessary nutrients for the growth of aquatic macrophytes and algae. Phosphorus compounds are found naturally in many types of rocks. Mines in Florida and throughout the world provide phosphorus for many agricultural and industrial uses.

The Role of Phosphorus in Waterbodies:

Like nitrogen, phosphorus is an essential nutrient for the growth of all plants, including aquatic macrophytes and algae. Phosphorus in waterbodies takes several forms, and the way it changes from one form to another, also called cycling, is complex. Because phosphorus changes form so rapidly, many aquatic scientists generally assess its availability by measuring the concentration of total phosphorus rather than the concentration of any single form. In some waterbodies, phosphorus may be at low levels that limit further growth of aquatic macrphytes and/or algae. In this case, scientists say phosphorus is the “limiting nutrient.”

For example, waterbodies having TP concentrations less than 10 µg/L will be nutrient poor and will not support large quantities of algae and aquatic macrophytes. There are many ways in which phosphorus compounds enter water. The more common ones are described below:

♦ Some areas of Florida and other parts of the world have extensive phosphate deposits. In these areas, rivers and water seeping or flowing underground can become phosphorus enriched and may carry significant amounts of phosphorus into waterbodies.

♦ Sometimes phosphorus is added intentionally to waterbodies to increase fish production by fertilizing aquatic macrophytes and algal growth.

♦ Phosphorus can enter waterbodies inadvertently as a result of human activities like landscape fertilization, crop fertilization, wastewater disposal, and stormwater run-off from residential developments, roads, and commercial areas.

In Florida:

Waterbodies in the Florida LAKEWATCH database analyzed prior to January 2000, had total phosphorus concentrations which ranged from less than 1 to over 1000 µg/L. Using these average concentrations of total phosphorus from this same database, Florida lakes were distributed into the four trophic states as follows:

♦ approximately 42% of the lakes would be classified as oligotrophic (those with TP values less than 15 µg/L);

♦ about 20% of the lakes would be classified as mesotrophic (those with TP values between 15 and 25 µg/L);

♦ 30% of the lakes would be classified as eutrophic (those with TP values between 25 and 100 µg/L); and

♦ nearly 8% of the lakes would be classified as hypereutrophic (those with TP values greater than 100 µg/L) .

The location of a waterbody has a strong influence on its total phosphorus concentration. For example, lakes in the New Hope Ridge/ Greenhead Slope lake region in northwestern Florida (in Washington, Bay, Calhoun, and Jackson Counties) tend to have total phosphorus values below 5 µg/L. While lakes in the Lakeland/Bone Valley Upland lake region in central Florida (in Polk and Hillsborough Counties) tend to have values above 120 µg/L.

Health Concerns:

There is no known level of total phosphorus in water that poses a direct threat to human health.

Transparency

See ***Water Clarity.***

Trophic State

is defined as "the degree of biological productivity of a waterbody." Scientists debate exactly what is meant by *biological productivity*, but it generally relates to the amount of algae, aquatic macrophytes, fish and wildlife a waterbody can produce and sustain.

Waterbodies are traditionally classified into four groups according to their level of biological productivity. The adjectives denoting each of these trophic states, from the lowest productivity level to the highest, are **oligotrophic**, **mesotrophic**, **eutrophic**, and **hypereutrophic**. Aquatic scientists assess trophic state by using measurements of one or more of the following:

♦ total phosphorus concentrations in the water;
♦ total nitrogen concentrations in the water;
♦ total chlorophyll concentrations — a measure of free-floating algae (phytoplankton), in the water column;
♦ water clarity, measured using a Secchi disc;
♦ aquatic macrophyte abundance.

The Florida LAKEWATCH professionals base trophic state classifications primarily on the amount of chlorophyll in water samples. Chlorophyll concentrations have been selected by LAKEWATCH as the most direct indicators of biological productivity, since the amount of algae actually being produced in a waterbody is reflected in the amount of chlorophyll present. In addition, Florida LAKEWATCH professionals may modify their chlorophyll-based classifications by taking the aquatic plant abundance into account.

Water Clarity

is the transparency or clearness of water. While many people tend to equate water clarity with water quality, it's a misconception to do so. Contrary to popular perceptions, crystal clear water may contain pathogens or bacteria that would make it harmful to drink or to swim in, while pea-soup green water may be harmless.

Water clarity in a waterbody is commonly measured by using an 8-inch diameter Secchi disc, attached to a string/rope. The disc is lowered into the water, and the depth at which it vanishes from sight is measured. Measured in this way, water clarity is primarily affected by three components in the water:

♦ free-floating algae called **phytoplankton**,

♦ dissolved organic compounds that color the water reddish, brown, or black, and

♦ sediments suspended in the water, either stirred up from the bottom or washed in from the shore.

Water clarity is important to individuals who want the water in their swimming areas to be clear enough so that they can see where they are going. In Canada, the government recommends that water should be sufficiently clear so that a Secchi disc is visible at a minimum depth of 1.2 meters (about 4 feet). This recommendation is one reason that many eutrophic and hypereutrophic lakes that have abundant growths of free-floating algae do not meet Canadian standards for swimming and are deemed "undesirable." It should be noted that these lakes are not necessarily "undesirable" for fishing nor are they necessarily polluted in the sense of being contaminated by toxic substances.

The Role of Water Clarity in Waterbodies:

Water clarity will have a direct influence on the amount of biological production in a waterbody. When water is not clear, sunlight cannot penetrate far and the growth of aquatic plants will be limited. Consequently aquatic scientists often use Secchi depth measurements (along with total phosphorus, total nitrogen, and total chlorophyll concentrations) to determine a waterbody's trophic state.

Because plants must have sunlight in order to grow, water clarity is also directly related to how deep underwater aquatic macrophytes will be able to live. This can be estimated using Secchi depth readings. A rule of thumb is that aquatic macrophytes can grow to a depth of about 1.5 times the Secchi depth measurement. For example, for a Secchi depth measurement of 3 feet, the depth at which aquatic macrophytes can grow is limited to about 4.5 feet.

Water clarity affects plant growth but conversely, the abundance of aquatic plants can affect water clarity.

Generally, increasing the abundance of submersed aquatic macrophytes to cover 50% or more of a waterbody's bottom may have the effect of increasing the water clarity.

One explanation is that either the submersed macrophytes, or perhaps the algae attached to the aquatic macrophytes, use the available nutrients in the water, depriving the free-floating algae of them. Submersed macrophytes also anchor the nutrient-rich bottom sediments in place — buffering the action of wind, waves, and human effects — depriving the free-floating algae of nutrients contained in the bottom sediments that would otherwise be stirred up.

In Florida:

Waterbodies in the Florida LAKEWATCH database analyzed prior to January 2000, had Secchi depths ranging from less than 0.2 to over 11.6 meters (from about 0.7 and 38 feet).

The trophic state of a waterbody can be strongly related to the water clarity. Using these average Secchi depth readings, Florida lakes were found to be distributed into four trophic states as follows:

♦ approximately 7% of the lakes would be classified as oligotrophic (those with Secchi depths greater than 3.9 meters— about 13 feet) ;

♦ about 22% of the lakes would be classified as mesotrophic (those with Secchi depths between 2.4 and 3.9 meters — between about 8 and 13 feet);

♦ 45% of the lakes would be classified as eutrophic (those with Secchi depths between 0.9 and 2.4 meters — between about 3 and 8 feet); and

♦ 26% of the lakes (those with Secchi depths less than 0.9 meters —about 3 feet) would be classified as hypereutrophic.

The location of a waterbody has a strong influence on its water clarity. For example, lakes in the New Hope Ridge/Greenhead Slope lake region (in Washington, Bay, Calhoun, and Jackson counties) tend to have Secchi depths greater than 9 feet (3 meters). While lakes in the Lakeland/Bone Valley Upland lake region (in Polk and Hillsborough counties) tend to have Secchi depths less than 3 feet (0.9 meters).

Health Concerns:

Water clarity is not known to be directly related to human health.

Water Depth

is the measurement of the depth of a waterbody from the surface to the bottom sediments. Water depth can vary substantially within a waterbody based on its morphology (shape).

Florida LAKEWATCH volunteers measure water depth using a weighted Secchi disk attached to a string or cord that is marked in one-foot increments. The weighted Secchi disk is dropped down until it hits bottom and then the distance is determined by measuring the length of rope between the bottom and the surface of the water. These measurements are then recorded for future reference.

Water depth can also be measured using a device called a fathometer by bouncing sonic pulses off the bottom and electronically calculating the depth. Several fathometer readings taken continuously along a number of transects (shore-to-shore trips across the waterbody) are used to calculate an average lake depth. This technique can be used instead of the traditional method of dividing the lake's volume by its surface area to obtain a "mean depth."

Water Quality

is a subjective, judgmental term used to describe the condition of a waterbody in relation to human needs or values. The terms "good water quality" or "poor water quality" are often related to whether the waterbody is meeting expectations about how it can be used and what the attitudes of the waterbody users are.

Water quality is not an absolute. One person may judge a waterbody as having good water quality, while someone with a different set of values may judge the same waterbody as having poor water quality. For example, a lake with an abundance of aquatic macrophytes and algae in the water may not be inviting for swimmers but may look like a good fishing spot to anglers.

Water quality guidelines for freshwaters have been developed by various regulatory and governmental agencies. For example, the Canadian Council of Resource and Environmental Ministers (CCREM) provides basic scientific information about the effects of water quality parameters in several categories, including raw water for drinking water supply, recreational water quality and aesthetics, support of freshwater aquatic life, agricultural uses, and industrial water supply.

Water quality guidelines developed by the Florida Department of Environmental Protection (FDEP) provide standards for the amounts of certain substances that can be discharged into Florida waterbodies (Florida Administrative Code 62.302.530). The FDEP guidelines provide different standards for waterbodies in each of five classes that are defined by their assigned designated use as follows:

- **Class I waters are for POTABLE WATER SUPPLIES;**
- **Class II waters are for SHELLFISH PROPAGATION OR HARVESTING;**
- **Class III waters are for RECREATION, PROPAGATION AND MAINTENANCE OF A HEALTHY, WELL-BALANCED POPULATION OF FISH AND WILDLIFE;**
- **Class IV waters are for AGRICULTURAL WATER SUPPLIES; and**
- **Class V waters are for NAVIGATION, UTILITY AND INDUSTRIAL USE.**

All Florida waterbodies are designated as Class III unless they have been specifically classified otherwise; refer to Chapter 62.302.400, Florida Administrative Code for a list of waterbodies that are not Class III.

Watershed

is the area from which water flows into a waterbody. Drawing a line that connects the highest points around a waterbody is one way to delineate a watershed's boundary. A more accurate delineation would also include areas that are drained into a waterbody through underground pathways.

In Florida, these might include drainage pipes or other man-made systems, seepage from high water tables, and flow from springs. Activities in a watershed, regardless of whether they are natural or man-made, can affect the characteristics of a waterbody.