



## **Introduction**

- \* **Did you know that in the Leon County/Tallahassee area there are over 200 lakes?**
- \* **And, did you know that within the city limits there are over 50 lakes?**

These lakes are a valuable natural resource in addition to being an asset to a quality of life, the tourism trade and over all aesthetics of the Tallahassee area. The City of Tallahassee (COT) has created the Surface Water Monitoring Program (SWP) to evaluate the health of these sensitive resources.

Below you'll find information on the SWP, results from past monitoring of area lakes, and how to contact the COT folks who can answer your questions regarding concerns about local lakes.

The lakes within and adjoining the COT are among the area's most significant natural resources. Due to the lakes' physical position in their basin, lake health is inherently one of the best indicators of environmental health in a community. Unregulated growth leads to increased nutrient pollution and sedimentation, the two major threats to area lakes. Monitoring the health of area lakes provides information to determine if current growth management regulations are effectively protecting the water quality and ecological health of area lakes.

The objective of the SWP is to build a database of information and monitor the health of lakes on a continuing basis to provide trend information on area lakes. This information will be used to develop lake management plans for all significant receiving waterbodies.

This page will be updated often. Additional lakes are being added to the study list as often as the financial resources make it possible. A report covering additional lakes including Hall, Overstreet, Piney Z, Foxcroft, and Elizabeth will be completed as information is gathered and interpreted; monitoring is ongoing at these and additional waterbodies.



While the planet we inhabit is called Earth, it might have been more appropriately named "Aqua." People might then realize this planet is unique in the solar system (and perhaps the universe) because of the presence of free water upon which life depends and which covers over 75% of this planet.

With 320 named springs, 1,700 miles of rivers, thousands of miles of streams, and 7,800 identified lakes, Florida is a region synonymous with water. Leon County and the City of Tallahassee are fortunate to be able to claim 109 of the natural lakes plus a similar number of reservoirs. Most, if not all, of the natural lakes in this coastal plain area of Florida are solution lakes. Solution lakes are characteristic of lands recently elevated above sea level and consist chiefly of carbonate rocks (Russell, 1895; Dellards, 1914; Cooke, 1939). Most of Leon County's large natural lakes have sinks, and limited discharge still occurs through these sinks within many of these lakes including Jackson, Iamonia, Miccosukee, Lafayette, and Bradford.

The Tallahassee area is recognized by many as ecologically unique. Numerous descriptions of this area recorded by early settlers have been compiled by local historians. The following perspectives of historians and early settlers have primarily been excerpted from Clifton Paisley's writings, and they further illustrate the uniqueness and rarity of the natural resources in Tallahassee and the adjoining physiographic features.

Ivory spear points (made from mastodon tusks) produced in the same way as Clovis points (the earliest evidence of human habitation in the United States), indicate big game hunters were here 12,000 years ago. This discovery is significant because it identifies this area as one of very few in North America having clear evidence of a society dependent on the richness of the wildlife present 12,000 years ago. We could speculate that the first humans in this part of the continent chose to live where the game was most plentiful and where the climate and other natural resources (such as the numerous and productive natural lakes) made survival most practicable.

Quotes from historian Clifton Paisley's writings are used (with Mr. Paisley's consent) to illustrate that those who depended most on the quality of natural resources and who were the first to choose where to live, seemed to prefer the Tallahassee area.

"Travelers from the earliest times have commented on the beauty of this area, on its hill and valley character with an abundance of lakes and springs and a vegetation indicating naturally rich soils. Cooled by the breezes and rains from the Gulf in the sub-tropical summers and warmed by the Gulf in frosty winters, with its rich soils, broad lakes, interesting terrain, woods full of game, rivers full of fish, and many crystal springs, this area of Florida seemed likely to attract a large population, especially of farmers. This it did long before it was discovered by the white man on the journeys of Panfilo de Narvaez and Hernando de Soto in 1528 and 1539."

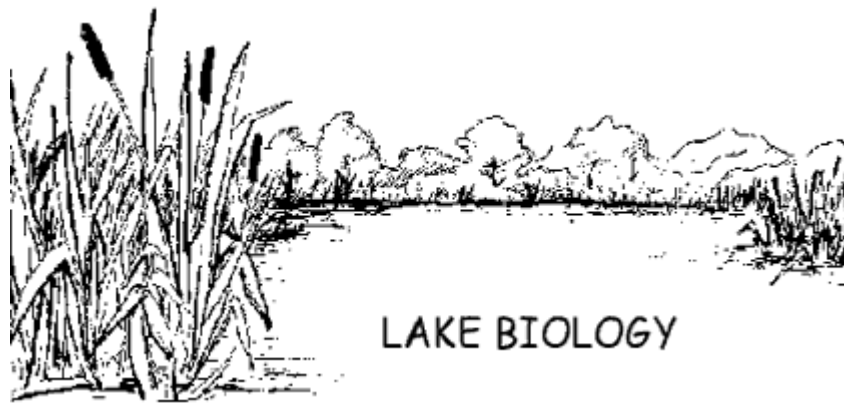
The following quotes are recorded observations from early travelers and inhabitants of the Tallahassee area, they are significant in that they were made during a time when natural

resources were abundant and only truly outstanding and rare natural resources were notable. In the interest of brevity, literary license has reduced the quotes into specifically applicable forms.

1827 - "With its reddish soils, cool lakes and fine hardwood forests finding this land after passing through interminable tracts of stunted pine trees was like escaping suddenly from the infernal Hades into paradise." Michael Portier, Catholic Bishop for Alabama and Florida.

1880 - "...an area at once the most fertile, the most picturesque and most salubrious to be found south of the North Georgia mountains." Maurice Thompson.

Even in an era when resources and unspoiled lakes were commonplace, the Tallahassee area was regarded as a special place because of its outstanding natural resources including its lakes, forests and soils. This may help illustrate the magnitude of the responsibility with which the citizens and their elected representatives have been entrusted: that is, to protect the unique and irreplaceable lakes and natural resources in our area.



## **EUTROPHICATION AND TROPHIC STATES**

Trophic state can be loosely defined as the nutritional status of a lake and can provide insight into the productivity and health of a lake. When a lake is formed, the natural process of aging begins. As a lake continues to age, a process known as eutrophication may occur. Although it is widely believed that the higher the nutrient concentration the more eutrophic the system, this is a gross generalization and is not true in many instances. A polluted eutrophic waterbody in an area of naturally nutrient-poor water may have a smaller nutrient load than an undegraded waterbody in a naturally nutrient-rich catchment. Eutrophication should be gauged in relation to the natural nutrient concentration prevalent for a given basin's area and size. In addition, eutrophic waters do not necessarily have high levels of nutrients present at all times. The nutrients may be gleaned and utilized by the plants (especially algae) so quickly that notable concentrations at any one instant are undetectable. Measurements of the physicochemical characteristics of habitat are often instantaneous. These data tell us what the environment is like at a specific instant on one day of one year of the whole life of a lake or river. This illustrates the need for a combination of biological and chemical monitoring to determine overall lake health as biological monitoring results can reflect limiting conditions that may have occurred some time previous.

As time passes, a lake may become progressively enriched with mineral salts and organic matter. Some of the first symptoms of lake "aging" can include increased primary productivity, reduced clarity, and reduced "water quality." This "aging process" may also lead to an increase in bacterial activity; the bacteria perform many functions including the breakdown of complex organic materials into simpler forms which are then utilized by macrophytes and the microscopic algae. Beyond a certain level, which varies from one waterbody to another, the breakdown process cannot balance primary production (plant and algal growth). As a consequence, there is a continuous accumulation of organic material in the water and sediment. These processes can

result in a series of changes in the lake as it passes through successive trophic states. The stages are termed oligotrophic, mesotrophic, and eutrophic. Eutrophication is the effect of natural aging of a lake. The time required to reach a trophic level is dependent upon a number of factors including morphometric characteristics of the lake, hydrologic retention time, size, lithology of its catchment area, vegetation in the basin, and climate. The aforementioned factors' effect on the flora and fauna of an aquatic system should be evaluated before actions are implemented which may alter eutrophication processes.

The degree of eutrophication and a lake's intended use will determine whether or not the eutrophication process is considered a degradation process. Lakes with a high degree of eutrophication (hypereutrophic) may experience fish kills, excessive aquatic plant and algal growth, loss of fish, loss of recreational usage, and other water quality related problems. Hypereutrophic systems have very unstable oxygen levels, frequent or regular fish kills, noxious algae, and bacterial blooms. These systems have extreme fluctuations in water quality and productivity on a seasonal and daily basis. Oxygen saturation levels sometimes reach 200% of the "normal" oxygen saturation and even lower levels of supersaturation can be fatal to fish. For example, a dissolved oxygen (DO) concentration of 12 mg/l at 30 degrees centigrade and one atmosphere of pressure and can be fatal to fish (gas bubble disease). Nutrients are not entirely assimilated even at maximum plant growth. Unfortunately, most lakes that reach this level of ecological dysfunction have been adversely altered by anthropogenic (man-induced) effects.

Activities associated with increased population density can drastically accelerate eutrophication. This process, called "cultural eutrophication," has generated much concern about the effects of urbanization on lakes. Cultural eutrophication has the potential to drastically reduce the life span of a lake through accelerated aging.

The length of time between formation and extinction of a lake depends on climate, watershed characteristics, shape, and many other factors. This natural process usually requires thousands of years to complete. Florida lakes are particularly susceptible to eutrophication since most are generally shallow warm water lakes with a large littoral zone. In Leon County most of the natural lakes go dry often enough to reduce the effects of this natural aging process. Naturally high phosphorous concentrations (often due to phosphate deposits and the long growing season) also contribute to lake eutrophication. The combination of these factors can lead to excessive growth of plants, making navigation of the lakes difficult and decreasing recreational opportunities, and depleting oxygen levels while increasing sedimentation rates as plants die and decay. The classic final stage in lake aging may be the disappearance of the lake as it becomes a marsh or bog (Hutchinson, 1950).

Human activities contributed dramatically to the deterioration of Florida's waters. Municipalities discharged millions of gallons of treated sewage into our waters -- sewage rich in nitrogen, phosphorus, and other nutrients. This practice has been discontinued in Tallahassee but continues in some Florida municipalities. Waters became convenient dumping sites for industries and wastewater treatment plants, the best example being the Fenholloway River near Perry, Florida. Agriculture contributes to water quality degradation by allowing water containing fertilizers, herbicides, fungicides and insecticides to run-off from pastures and crop lands into waterbodies. Development fills in wetlands, paving, building-out, and altering surrounding watersheds, eliminating the valuable filtration role these systems play in a complete ecosystem. The ability of biological communities to store nutrients is often exceeded when the system is anthropogenically altered.

Stormwater runoff is the major water quality problem facing municipalities today, and is generally included within the category of non-point source pollution because its pollutants are not generated from one specific point. However, stormwater discharges are now in the process of being reclassified as point source discharges by FDEP (Florida Department of Environmental Protection) and USEPA (United States Environmental Protection Agency) under the NPDES (National Pollution Discharge Elimination Schedule) program. Non-point source pollution

increases as areas become more developed and rainfall washes nutrients and toxic chemicals from lawns, roads, and parking lots into waterbodies.

When it rains, stormwater flows over streets, yards, farmlands and parking lots. As water flows over these areas, it picks up soil, debris, fertilizers, pesticides, oils, gasoline, and other chemicals plus animal wastes which are then carried into the nearby surface water, such as a lakes, streams, rivers or swamps. Stormwater contaminants contribute to the degradation and poor water quality of many lakes. The City's Surface Water Program and other local studies will provide information concerning the effects of the implementation of the Leon County/City of Tallahassee Comprehensive Plan and Environmental Management Ordinance on the water quality of this area's waterbodies. The extent to which stormwater impacts area lakes has been mitigated by these new regulations is not known at this time, but through continued study a method to determine this will be developed or utilized in conjunction with the database the SWP program is currently building.

## **EFFECTS OF EUTROPHICATION**

Hypereutrophic waters can exhibit a thick pea-soup look. Dense algal blooms are often the first noticeable indication of over-enrichment. Algal blooms can decrease oxygen concentrations and suffocate natural fish foods, such as crawfish, and immature insects including dragonflies and mayflies. Algal blooms limit sunlight, which can result in the death of certain species of desirable submerged aquatic plants. As these plants decay, organic sediments accumulate on the lake bottom, resulting in the loss of both spawning and nursery areas for fish.

Toxins and noxious odors develop from cyanophytes and bacterial decomposition of organic matter which can affect the surrounding environments. A bacterium, *Clostridium botulinum*, flourishes in anoxic sediments. This is a widespread organism but when populations bloom, toxins which affect birds and mammals build up, producing the muscle paralysis that results in what is known as botulism.

Human health problems can also be associated with eutrophication of water. Some algal toxins affect humans who swallow water while swimming. Pathogens which may be present in eutrophic waters include viruses, bacteria, protozoa, fungi, and metazoan animal parasites such as flukes and tapeworms. Their presence is often associated with other polluting effluent, notably sewage, the prime concern being direct health risk to humans. These risks can be harmful or merely irritating such as "swimmers itch" resulting from the (usually) unsuccessful attempts of the infective stages of worm parasites to penetrate human skin. It should be apparent at this point that grossly polluted waters can be significantly altered in a visual and olfactory sense. These obvious changes can greatly reduce or completely do away with the amenity value of lakes, including reductions in the value of "lakeside property." Hyper-eutrophication, as has occurred at Banana Lake and other Florida lakes, can reduce or eliminate the recreational value of lakes. Lake Jackson's annual value to the City and County was recently estimated at 10 million dollars according to NFWFMD (Northwest Florida Water Management District) personnel.

The ultimate test of lake protection and restoration programs is whether or not lake degradation continues at a rate faster than would occur through natural processes alone. Although eutrophication is often a natural stage in the maturation of a lake, rapid acceleration brought about by human activity (cultural eutrophication) does not have to occur. It is possible to alleviate the effects of cultural eutrophication, and better still, to prevent it entirely. Municipalities such as Seattle and Tampa have been successful in restoring the health of their major waterbodies.

By reducing or eliminating the delivery of cultural pollutants into lakes, each individual can help reduce or prevent cultural eutrophication. One preventive action is to leave shoreline vegetation in place. As pleasing as broad beaches are, alternate access methods such as piers, swimming platforms, or narrow access zones are healthier for the lake. Terracing or swales and berms can be used to reduce erosion and stormwater runoff near lakes. The use of fertilizers, herbicides,

and pesticides should be reduced or eliminated, especially near the water's edge. Storm drains should not be used for the disposal of yard clippings, litter, or trash since these materials will eventually reach the waterway. Detergents containing phosphates or those which are non-biodegradable should not be used.

Some water quality problems can be alleviated by individual actions. However, others are best handled by collective or community action. Local governments can adopt regulations which have proven useful in protecting lakes and their watersheds: zoning laws that limit development in certain areas, buffer zones around lakes to protect natural habitats and prevent erosion, and commissions with the authority to modify or deny development plans which do not protect water quality standards, are just some of the useful means of protecting Florida's waters. Communities around the country have worked together to reverse the effects of cultural eutrophication and to protect and restore many notable waterbodies. The City of Tallahassee and Leon County have taken steps to protect the water quality of area lakes; baseline and long-term water quality monitoring will help to determine the effect of these steps.



## **WATER QUALITY PARAMETERS**

Each of the 12 lakes has been sampled for more than 35 parameters. These parameters, individually and in combination, measure different aspects of a waterbody's characteristics. The parameters, analyses, and interpretation of the results collectively represent the scientific investigation applied to each of the sampling stations in order to develop a baseline of information. This information is used to illustrate the ambient condition and some of the limiting factors for each of the lakes. In addition, analysis of these parameters can help provide remedies that can be applied in order to reverse trends indicating degradation or provide insight as to the efforts needed to help maintain a lake's current overall condition. Some of the parameters and analyses (e.g. Lake Rating Methods) provide general or broad overviews of a lake's status. In contrast, the biological, chemical, and physical parameters provide specific information about individual characteristics or health of a waterbody.

The parameters and analytical methods discussed below are the set of measures that were applied to the 12 lakes in this study. The objective of choosing this investigative procedure was to develop baseline information in as short a time frame as possible. The Lake Rating Methods and biological analyses allows this objective to be accomplished in an efficient, cost effective manner.

## **LAKE CONDITION INDEX**

The Lake Condition Index (LCI) is used to evaluate the ecological health of Florida lakes. The product of the calculations used to derive the index value is a single number that can be assigned to one of the following four lake health categories: healthy, unaltered (greater than 20); moderately altered (6-19); grossly altered (0-5); or dystrophic. The LCI combines scores assigned for species of macroinvertebrates present, diversity of macroinvertebrate communities taxa, total phosphorus, total nitrogen, and chlorophyll a levels. This rating system is weighted toward biological factors such as the presence of macroinvertebrate species that indicate good water quality, and the diversity of the macroinvertebrate fauna present.

The Lake Condition Index is based on a more detailed analysis of lake conditions than some other lake rating methods such as the Trophic State Index (TSI). In addition, the LCI is sensitive to changes in the biotic community which occur due to anthropogenic and natural stresses, while the TSI rating method is not.

## **TROPHIC STATE INDEX**

TSI is also used to provide a cursory classification of the lakes. The TSI is based on concentrations of total nitrogen, total phosphorus, chlorophyll, and secchi disk depth values. The TSI is based on a trophic classification scheme derived by R.E. Carlson in 1977. Criteria were developed for Florida lakes from a regression analysis of 313 Florida lakes. Numerical scores received under this rating scheme are assigned to the following categories: good (0-59), fair (60-69), or poor (70-100).

## **BIOLOGICAL PARAMETERS:**

### **ALGAL GROWTH POTENTIAL**

This parameter is important in determining a waterbody's maximum yield of algal biomass that can be supported based on the bio-available nutrients present. The data can be used to determine mean annual standing crops of algae and compared to values from other area lakes to determine the existing trophic state of the lake.

Trend data regarding lake health can also be derived from Algal Growth Potential (AGP) data. Any standing crop of algal biomass above five milligrams dry weight per liter in a southeastern lake indicates that the lake may be subject to nuisance algal blooms and fish kills (Raschke and Schultz, 1987). Excessive populations of algae in a waterbody can cause supersaturation of dissolved oxygen levels during the day (photosynthetic activity) as well as severe reductions in oxygen levels during the night or on cloudy days (algal respiration). In lieu of detailed taxonomic/statistical studies of algal populations (which can be extremely costly and labor intensive), AGP may be the most important parameter related to algae and the interactions of nutrient-related growth in lakes not dominated by macrophyte growth.

### **CHLOROPHYLL A**

Chlorophyll a levels are an indirect measure of the quantity of planktonic algae present in a body of water. Chlorophyll a is the most common algal pigment; it is the dominant pigment in blue-green and eukaryote photosynthesis. Chlorophyll a is found in all photosynthesizing plants and is the final energy recipient from a series of accessory pigment molecules. Accessory pigments and chlorophyll a use wavelengths of light from 400 to 900 nm as an energy source for phototropic organisms. Chlorophyll a provides a relatively efficient transfer of light energy to chemical energy through the process of photosynthesis. Chlorophyll a, then, is the most important pigment in the link between the non-living (abiotic) and living (biotic) worlds. Chlorophyll a in the presence of sunlight and water (through photosynthesis) form the base of almost all the food chains on Earth.

Chlorophyll a is thought to make up approximately one to two percent of the dry weight of organic material in all planktonic algae and is the preferred indicator for algal biomass estimates. The chlorophyll content of cells varies, however, by species and is affected by age, growth rate, light, and nutrient conditions. If an assumption is made that chlorophyll a constitutes on average 1.55% of the dry weight of organic matter (ash free weight) of algae, the algal biomass can be estimated by multiplying the chlorophyll a content by a factor of 67. Chlorophyll a values can also be used in conjunction with values determined for the rate of C (carbon) being fixed per unit area to determine primary plant productivity and a nutrient assimilation capacity number for a waterbody.

## **BENTHIC MACROINVERTEBRATES**

### **"BENTHOS"**

For purposes of this study, benthic macroinvertebrates (benthos) are invertebrate organisms found within or on the bottom substrate of a waterbody visible to the unaided eye and retained by a number 30 sieve (0.595 mm openings). Any substrate located on or near the bottom may provide habitat for benthic macroinvertebrates. Common suitable habitats include organic debris, bottom sediments and macrophytes (though technically macroinvertebrates on plants are considered epiphytic macroinvertebrates).

The major taxonomic groups of benthos commonly collected include immature freshwater insects, annelids, mollusks, flatworms, roundworms and crustaceans. Benthos occupy many levels in the trophic structure; they may be detritus feeders, parasites, scavengers, grazers, or predators. Benthic macroinvertebrates are a major link in the food chain between plants and animals. A loss of the macroinvertebrate fauna in a waterbody can cause severe disruptions in the food webs of aquatic ecosystems.

Many studies have shown that some aquatic macroinvertebrates are very sensitive to environmental stress and are, therefore, useful in detecting contaminants caused by anthropogenic impacts as well as natural stresses. In addition, benthos can accumulate substances such as pesticides and toxic metals in their tissues and are thus used to detect periodic sub-lethal discharges that might otherwise go unnoticed outside the aquatic ecosystem. The fact that many benthic macroinvertebrates are sedentary and must tolerate introduced contaminants or die, makes them a more reliable biological indicator of the health of a lake than those species that can simply move to more favorable areas in a waterbody.

## **BACTERIOLOGICAL MONITORING**

Fecal coliform are a subset of the total coliform group and indicate the presence of fecal material from warm blooded animals. This group is used as an indicator of the impact of fecal pollution and is the quick test of choice for pollution identification. The most likely sources for fecal coliform bacteria in lake water are municipal sewage collection systems, septic tank leachate, and runoff from livestock operations. However, there are a number of limitations in the use of coliform bacteria for water quality monitoring. One of the most limiting is their relatively short life span of approximately 48 hours in natural waters. This makes the rapid discovery, proper sampling, and analysis of sewage spill sites imperative if valid results are to be obtained. Additionally, the survivability of fecal coliform bacteria decreases markedly with water temperatures at or above 30 degrees Celsius (LaRock, 1990). Water temperatures of lakes in and adjoining the Tallahassee area commonly exceed 30 degrees Celsius during the summer months (see water temperature graph in the appendix of this document). Data indicates water temperatures reached or exceeded 30 degrees Celsius during collection of approximately 20% of the bacteria samples to date. The significance being the possibility that a decidedly downward skewing of the reported bacterial data may have occurred.

Fecal streptococci bacteria are not part of the fecal coliform group. These organisms do inhabit the intestinal tract of warm-blooded animals and thus are another type of fecal pollution indicator. These organisms are found in greater densities in animals other than man. Bacterial ratios

greater than 4.0 (fecal coliform/fecal streptococci) strongly indicate the presence of a human associated source for pollution in freshwaters. Ratios of less than 0.1 strongly indicate the presence of agricultural or non-human animal pollution. Ratios between 4.0 and 0.1 indicate both human and non-human bacterial sources (Geldreich and Kenner, 1969; Ross, 1990).

The USEPA and FDEP have established criteria for the presence of fecal coliform as an indicator group for potential risks to human health and the maintenance of water quality for fish and wildlife (Florida's Class III Waters). EPA's evaluation of bacteriological data indicates that using the fecal coliform indicator group at the maximum geometric mean of 200 colonies per 100 ml of lake water would cause an estimated eight illnesses per 1000 incidences of body contact in freshwater systems, and 19 illness per 1,000 at marine beaches. The bacterial levels chosen as acceptable risk are arbitrary and based on levels of illness historically thought of as acceptable risk. Due to incidence of disease outbreak (i.e. cholera) in brackish and marine waters where shellfish are harvested for consumption, a much more restrictive standard of 15 fecal colonies per 100 ml (median value MPN) has been established.

Total coliform bacteria generally indicate the presence of soil-associated bacteria and result from natural influences on a water body such as rainfall runoff as well as sewage inflows. Total coliform levels have been found in numerous studies to increase by a factor of 100 after heavy rainfall events.

## **MACROPHYTES**

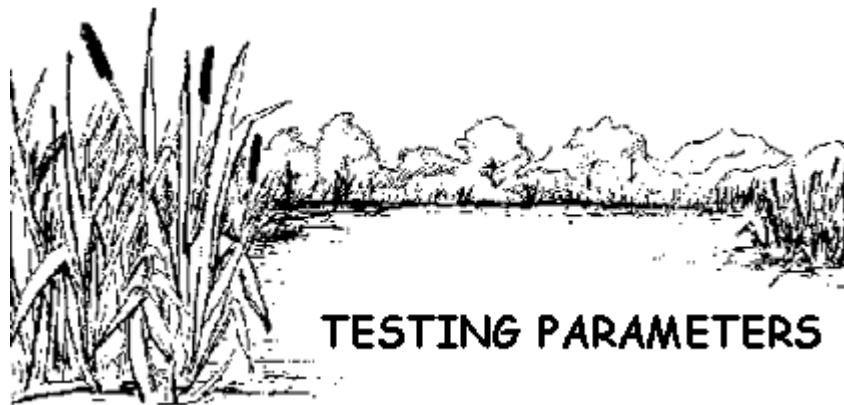
Macrophytes are those species of aquatic plants and algae readily visible to the unaided eye. In Florida, most of the information the public receives regarding aquatic plants relates to the control of exotic and nuisance species. One unfortunate consequence of this limited knowledge is the impression that all aquatic plants are a nuisance and best removed from the system; nothing could be further from the truth. Particular species may be considered noxious in high densities, however macrophytes are an invaluable part of aquatic ecosystems.

Macrophytes and algae form the base of the food web in lakes. Photosynthesis, carried out by plants which contain chlorophyll, is the most basic process in the food chain. Using sunlight, plants convert water and carbon dioxide into oxygen and sugars. Photosynthesis is the process that links the non-living and the living worlds. Inorganic compounds are combined to form organic compounds that are then available to plants and organisms that feed on the plants, as energy sources. Algae and plants are fed upon by invertebrates and small fish which in turn serve as food for larger consumers. Additionally, plants use the nutrients that wash into the water, including phosphorus and nitrogen, to help them grow. Finally, when the macrophytes die, their remains are used for food by various decomposers such as fungi, bacteria, detritivorous micro and macroinvertebrates and fish.

By providing cover, nursery, and rearing habitat, the existence of macrophytes in abundance is often critical to the survival of fish and wildlife. It is generally recommended that for maximum benefit to wildlife and fisheries most waterbodies have a macrophyte coverage of 30-50% for at least some portion of the year. Aquatic plants compete with algae for available nutrients and can form a dense mass that shades out algae. Thus the presence of aquatic plants reduces the likelihood of algal blooms, as their respective densities are inversely proportioned. This should not be construed to suggest that macrophyte coverage up to 30 to 50% of a lake's surface area is detrimental to lake health. Numerous studies indicate that the opposite is true. Recent long term studies have indicated that in lakes where macrophyte coverage is allowed to increase to approximately one half of the surface acreage, fish populations can be greatly increased, up to seven fold, with an even greater increase in the survivability of young. Percent coverage is only one aspect of macrophytes in waterbodies, equally important considerations are patchiness and form (emergent and submergent) and the range of habitats occupied.

Unfortunately, macrophyte coverage greater than approximately 40% can make feeding difficult for carnivorous fish, resulting in reduced growth rates for gamefish populations. In addition, some macrophytes which float on the surface such as duckweed, water hyacinths, and water lettuce may become so abundant that they shade out other species of plants and algae. Overabundance of these floating macrophytes may also block the air/water surface interface. These effects can cause the dissolved oxygen levels to drop to near zero just a few inches below the surface. Excessive macrophyte coverage can also reduce some forms of recreational usage if high density macrophyte infestations occur.

There is no all-encompassing magic formula for the management of macrophytes. Each and every waterbody is unique with individual circumstances, problems, and solutions. Unfortunately, many people object to the presence of macrophytes on aesthetic grounds, believing that any water not "weed free" and as clear as tap water is inherently unsightly. The removal of macrophytes should be carefully approached to avoid the annihilation of fish and invertebrate populations that often occurs when their habitat is removed. When all macrophytes are removed, the more motile populations of wildlife, such as waterfowl, can hypothetically move to another lake; overcrowding of ducks and geese can lead to infrequent but lethal cholera outbreaks. Since there are a limited number of lakes which provide suitable habitats, education and careful management are sorely needed to prevent the destruction of these valuable habitats. In addition, if too many macrophytes are removed, the nutrients that have supported the macrophyte populations can be released and result in the formation of algal blooms.



## **NUTRIENTS**

Nitrogen - Nitrogen is an element that is common in the earth and the atmosphere. Although it is essential for life, nitrogen's importance is often overlooked due to its abundance and wide range of sources. Although nitrogen does have many sources and may lead to lake degradation when present in excessive concentrations, steps can be taken to control levels of nitrogen entering receiving waterbodies.

Major sources for nitrogen in Florida waterbodies include wastewaters, fertilizers, septic tanks, feed lots and agricultural runoff. Significant non-point sources include lawn fertilizers, atmospheric inputs, agricultural runoff, and organic runoff from soil.

Although nitrogen is generally abundant and not usually a "limiting factor" anthropogenic additions of phosphorus to waterbodies have been shown to cause nitrogen to become the limiting factor. Blue-green algae have the ability to "fix" and store nitrogen and they can begin to dominate (algal populations) when nitrogen is "limiting". Thus lowering the nitrogen to phosphorus ratio can decrease total algal biomass but conversely cause dominance of algal species harmful to aquatic systems.

Phosphate - Phosphate is a compound made up of phosphorus and oxygen, and is one of the major nutrients required for plant growth. Anthropogenic activities often increase phosphate loads to the point where growths of macrophytes and algae become excessive, this in turn accelerates lake eutrophication. Phosphorus is usually the limiting nutrient in a lake; that is, it is present in the least amount relative to plant requirements. Therefore, an increase in phosphorus allows use of the other nutrients already present for plant growth. In addition, it has been shown that in most instances phosphorus is the element most easily controlled artificially (EPA, 1986).

There are many sources of phosphorus in the environment. The larger sources include sewage, stormwater runoff, runoff from agricultural lands and natural phosphate deposits. Additional contributing sources include cattle feedlots, chicken houses, domestic and wild waterfowl populations, atmospheric inputs and lawn fertilizers.

High phosphorus concentrations are often associated with the accelerated eutrophication of waters if other contributing factors are present. Phosphorus levels are generally more critical in lakes when compared with those values found in flowing streams. Lake sediments commonly serve as sediment sinks, or places of storage, for phosphorus. Phosphorus that has been stored in the sediment can be released back into the water.

Levels of phosphorus (concentration or total loading) which can be retained, or "assimilated," vary from lake to lake. The amount or percentage of inflowing nutrients that may be retained by a lake depends on factors such as total nutrient loading, the volume of the euphotic zone, the extent of biological activity, the detention time within a lake, and the level of discharge from a lake. Left undisturbed, much of the phosphorus which becomes permanently bound within sediments will not be recycled into the system.

The majority of Florida's eutrophication problems are associated with phosphorus levels of lakes. The levels of phosphorus that will lead to cultural eutrophication vary widely and limits must be established for each waterbody, although there is too much variability between systems for any specific standard to apply to all waterbodies.

There are two basic reasons for establishing a phosphorous criterion for a waterbody: one is to control nuisance levels of plant growth and the other is to protect the downstream receiving waterbodies, regardless of their proximity in linear distance. It is evident that a portion of the phosphorus that enters a stream or waterway will eventually reach a downstream receiving lake or estuary either as a component of the fluid mass (moving water), as streambed load sediments carried downstream, or in organic materials drifting just above the streambed or floating on the water's surface. Phosphorus loading also occurs from atmospheric fallout (atmospheric loading) and direct runoff from surrounding shoreline areas.

It should be noted that limiting macrophyte growth and protecting downstream receiving waters can be opposing objectives. Equations used to calculate critical concentration and loading levels of lake phosphorus indicate that depth and hydraulic detention times are important in determining the amount of phosphorus retained by a lake. This in turn indicates the need for construction of retrofit or stormwater facilities that increase the retention time of the inflow and are shallow enough to allow maximum biological activity. The macrophyte growths can act as a mechanical means of filtering sediment and nutrient loads. While this may reduce the expected life of the waterbody, it would help protect receiving waters downstream. A number of factors influence the effect of phosphorus on a waterbody and related management strategies:

- \* nutrients other than phosphorus may be limiting;
- \* cost effective retrofit activities may or may not be feasible;
- \* naturally occurring silts and coloration may reduce light penetration so that excessive macrophyte and algal growth are not possible;
- \* morphometry (steep sides, great depth and flow etc.) may be such that plant problems cannot develop;

\* waters may be managed to enhance habitat for waterfowl, wildlife or fisheries.

Aquatic bacteria compete with algae for available phosphorus in a system, with cycling rates for bacteria averaging approximately five minutes (Rigler, 1964). The rate at which phosphorous can be transformed from biotic to the abiotic forms and back indicates that total phosphorous may be the most reliable parameter for quantifying phosphorous levels in a waterbody.

Cultural eutrophication impacts from pollutants have stimulated the research for ways to keep excess phosphorus out of lakes. From this research the concept of nutrient loading was developed. The term nutrient loading quantifies the nutrients entering a lake and provides a basis on which a relationship between a lake's trophic state and nutrients entering the lake can be described. Shoreline, volume, area, water retention time and flushing rate are critical factors. A number of equations for phosphorus loading rates are currently in use, however, exact figures are not available for non-point source loading, and the equations themselves are updated periodically. Models are developed in an attempt to deal with the complexities of the living ecosystems. The models do make the problems seem less complex but models are based on a number of simplistic assumptions with limited ranges of applicability.

Phosphorus levels and their interactions with other nutrients and micronutrients have effects on most of the organisms in aquatic ecosystems. As an example, phytoplankton populations are structured, in part, by the relations among nutrients needed for growth. Green and blue-green algae exhibit shifts in their population numbers and dominance as the nutrient inputs are altered.

## **METALS IN LAKE SEDIMENTS**

Metals have become a matter of concern and increasing significance. All metals can be toxic in certain forms at some level. The term toxic is used in this section to describe metal species which can readily bioaccumulate in the human body through the food chain and produce chronic or acute effects at relatively low concentrations such as mercury, lead, and cadmium. "Toxic" forms or species of metals should not be confused with generally benign forms of metals such as iron for which minimum daily dietary requirements have been established and which are vital to biological processes. The potential ecotoxic effects of metals such as cadmium, lead, and mercury originates from their ability to accumulate and concentrate in the vital organs of man and animals. If they accumulate in the body, they may produce progressively increasing toxic effects over the life span of the individual. Therefore, an important task of environmental protection is to control the anthropogenic input of toxic metals to the environment.

Metals tend to accumulate in lake sediments and assessments of the degree of toxic metal accumulation generally involves sediment analyses. Recent studies which have been completed at several universities may assist us in accurately gauging the potential health and ecological hazards of metals in lake sediments. Predicting the bioavailability and toxicity of metals in aquatic sediments should be a critical component in developing sediment quality criteria. Due to the complex nature of lake ecosystems the use of total sediment metal concentrations have not proven effective in predicting effects of metals on ecosystems. There is an extremely wide variation in lake sediment toxicity although total concentrations in sediments may be identical. This is important to Tallahassee because several lakes within and adjoining the City appear to be similar to lakes that have been shown to bioconcentrate metals (i.e., mercury) in living organisms.

Analysis of metal concentrations is difficult due to the sensitive analytical procedures necessary for accurate determinations and the high cost of analyses. A prerequisite for efficient and reliable environmental protection is the monitoring of metals by reliable and sensitive analytical procedures. For each monitoring station the metal content should be determined for the water and the sediments. In an aquatic system sediments constitute a place of storage for the metals introduced into the system and can be an important indicator for metals (Duinker and Kramer, 1977). The current monitoring plan measures levels of only certain metals in the lake sediments. It is designed as a screening process to determine whether further monitoring is necessary.

Metals in waterbodies can take on special significance because they are essentially non-biodegradable. They cycle through the environment with varying accumulations and residence times in different systems and may be transformed to more or less toxic species. Many lakes, rivers, and streams in the United States have been permanently and culturally degraded due to the often impractical, if not impossible, task of removing metals from a waterbody.

Heavy metal deposits in lake sediments can become a long term hazard because they may in some instances be continuously released into the water. This effect can be enhanced if the organics, which may attach to the metals, form compounds more soluble in water, thereby increasing their bioavailability. Care must be taken to avoid making decisions intent on reducing eutrophication that actually result in the release of metals from the sediments into more soluble and toxic forms that can bioaccumulate in the tissues of aquatic and terrestrial organisms.

As a general rule, heavy metals are toxic but are often complexed with insoluble compounds and not toxic. However, acid waters may dissolve out more metals than non-acid waters. Concentrations of several metals, including mercury and zinc, increase in acidic waters. Numerous studies have shown that aluminum toxicity can be a significant problem. Aluminum is an abundant element at the Earth's surface but much more soluble in acid conditions than circum-neutral. Worse still, its toxicity increases as pH values decrease. Changes in the pollutant toxicity in response to other physiochemical factors is common and these interactions are called synergisms.

Aluminum complexes with hydrogen ions (H<sup>+</sup>) and can interfere with ion regulation important to fish respiration. Gas exchange is disrupted by interference of gill function by aluminum. The irritation produced causes mucus secretion, clogging, and eventual suffocation in fish. Aluminum has also been associated with skeletal and developmental deformity, and immunological and endocrinological disruption.

This information points out the necessity of protecting aquatic ecosystems from the future effects of metals. It is important that practices thought to assist the aquatic systems (such as the use of alum-injection systems) are not misused, resulting in irrevocable harm to the community's aquatic systems. Anthropogenic inputs of metals into our aquatic systems can and definitely should be controlled by sound lake management practices.

The existence of heavy metals in the sediment does not necessarily indicate that bioconcentration or biomagnification of toxic metal(s) in the tissue of fish or other aquatic organisms in the lake is occurring. In some lakes metals and other potential toxins are deposited in the sediment with little possibility of leaching into the water column. In contrast, in some lakes inorganic mercury may be converted into soluble and extremely toxic methyl mercury (even though no non-atmospheric source is apparent [Ridley, 1977]). Ironically, some studies indicate that eutrophic lakes are less likely to have problems with bioaccumulation of mercury than oligotrophic systems. FGFWFC studies have indicated that there is an inverse relationship between chlorophyll a in the water column and mercury concentration in the tissue of fish. There is a direct correlation between regeneration of metals in sediments and lower dissolved oxygen levels including hypoxic and anaerobic conditions.

## **DISSOLVED OXYGEN**

Lakes which do not maintain acceptable dissolved oxygen (DO) levels cannot support the fish, wildlife, and all the biota that make lakes complex living systems. Even short periods of low DO can cause shifts in invertebrate populations favoring facultative anaerobes or pioneer species thereby lowering species diversity.

Dissolved oxygen levels vary considerably diurnally. During the day algae and macrophytes produce oxygen as a by-product of photosynthesis (the plant's means of producing food).

Contrary to popular belief, plants do not "breathe in carbon dioxide and breathe out oxygen." Plants utilize oxygen in their metabolic processes as do animals. However, plants have the ability to convert inorganic materials into organic material (sugar) in the photosynthetic process. A by-product of this reaction is oxygen which is released into the air or water through the stomata of the plant. During algal blooms, or if the density of macrophytes is great, under certain environmental conditions much more oxygen is produced than can be utilized by organisms present in the aquatic environment. When this occurs oxygen is essentially "bubbled" into the water until super-saturation occurs. Super saturation of water with oxygen can kill aquatic organisms, and in addition, when algae and or macrophytes are present in sufficient quantity to cause supersaturation, hypoxia can also result. The overabundance of plants can utilize more oxygen than is present during low light conditions (in the aquatic environment) causing a DO sag that can kill fish and other aquatic organisms. During the night plant respiration continues though photosynthesis has ended, and more oxygen is generally taken from the water by plants than enters the water column through gas exchange and wave action. Thus, dissolved oxygen levels drop throughout the night and are usually lowest just at daybreak.

Monitoring for dissolved oxygen levels in lakes should include diurnal monitoring to ascertain effects of plant respiration on oxygen levels and to provide a measure of the effects of primary productivity. Dissolved oxygen levels taken from diel sampling events can be used to estimate the net primary productivity of a water body. Biologically derived decreases in dissolved oxygen levels can often be attributed to the respiration of plants and animals and the aerobic bacteria of decay. Purely chemical oxidation occurs, but oxidative processes in aquatic habitats are most often mediated by bacterial action in the sediments. There is considerable loss of dissolved oxygen at the interface of organic lake sediment and the overlaying water where bacterial decay occurs. In this microzone, the oxygen content may be much less than it is just a few centimeters above. For this reason the morphology of a lake can influence the vertical oxygen curve. Essentially, the greater the area of sediment in contact with the water, the more dissolved oxygen that can be used up, although the extent and rate of biological activity in the sediments is tremendously variable. Thus the greater the sediment contact with the water column per volume of water, the greater the potential effect on DO levels.

Numerous past studies have shown that in warm water environments (such as Florida), very slight impairment of the most sensitive aquatic life may occur at a DO concentration of 7.5 mg/l. Slight production impairment of aquatic life tends to occur when DO levels fall to 5.5 mg/l. Moderate impairment of aquatic life is considered to occur when DO levels taper off to 5.0 mg/l. Acute mortality of early life stage fishes, macro and micro invertebrates can occur as the dissolved oxygen levels drop below 4.0 mg/l. Acute mortality of many adult fishes may occur as dissolved oxygen levels drop below 3.0 mg/l. However, some fish can survive with as little as 1.0 part-per-million (ppm) DO by gulping air at the surface. In situations where continuous monitoring is not possible or practical, serious DO lags causing periods of extra stress or mortality may go undetected for an extended period of time.

The death and decomposition of massive algal blooms have been shown to deplete dissolved oxygen levels causing massive fish kills. The extent of the fish kill is dependent upon other related factors such as water temperature, weather, species of fish present, season, and timing. In addition, the inappropriately timed treatment of macrophytes through chemical or mechanical means often results in massive fish kills.

The Environmental Protection Agency's standards state that the minimum dissolved oxygen levels which are recommended do not represent the concentration believed to protect the more sensitive populations of organisms against potentially damaging production impairment. All minima should be considered as instantaneous concentrations to be achieved at all times. Where natural conditions alone create dissolved oxygen concentrations less than 110 percent of the applicable criteria means or minima or both, the minimum acceptable concentration is 90 percent of the natural concentrations (Shumway, 1970). Absolutely no anthropogenic dissolved oxygen

depression into the potentially lethal range (below the one day minima) should be permitted (EPA, 1986).

## **CONDUCTIVITY**

Conductivity is an indirect measure of the electrolyte (ion) concentration in water, measured by determining the level of electron flow between electrodes set one centimeter apart. Pure distilled water is very resistant to the flow of electrons between electrodes, so in a general sense the greater the level of impurities, the greater the conductance. Consequently, conductivity is used as a rough measure of the impurities in a given water sample. "Unfortunately, conductivity values lump together all chemical species capable of conducting electricity without providing any information on what is present and in what proportion" (LaRock, 1990).

LaRock's 1990 Lake Jackson Report also indicated that there was a strong correlation between percent increase in conductivity at a station and the percent increase in impervious area in a watershed. Future monitoring efforts will allow staff to determine if a correlation can be shown between increases in impervious areas in our lakes' watersheds and rises in conductivity at our sampling stations. We will also be able to determine whether changes in lake protection (such as lake protection zoning and stormwater facilities) will alter, reduce, or eliminate the trend of increasing conductivity.

## **PH**

pH is a measure of the hydrogen ion (H<sup>+</sup>) activity, based on the negative base 10 logarithm of hydrogen ion concentrations. For our purposes, pH levels are an indication of the acidity or alkalinity of a waterbody. pH levels often directly affect the reproductive success of aquatic organisms. Lowering pH levels in a water body can produce fatal results by releasing toxic substances (such as metals) from sediments.

When evaluating the effects of various pH levels on a waterbody's fish and wildlife population it must be noted that a pH range not considered directly lethal is not the same as the range for unimpaired fish and wildlife growth and reproduction. As pH values shift from the narrow "optimum range" (7-9) a gradual deterioration of the habitat value occurs until the point of acute toxicity is reached.

Unpolluted rain is naturally a weak carbonic acid and has been attributed with pH values as low as 5.8. The overall pH of a waterbody depends on its basin, especially the geology and basic ion and vegetation composition throughout the watershed. Plant species that may increase acidity such as pine, cypress trees, and sphagnum mosses are especially significant.

There are a number of naturally acidic blackwater systems in the Tallahassee area. One of the more notable is the Bradford Brook Chain of Lakes. These low pH blackwater lakes and streams are generally surrounded by forests and have deeply tannic stained "black" water with an average pH range of 4.0-5.5. These lakes are often dystrophic i.e., organic matter is plentiful (in contrast to oligotrophic lakes) but naturally acid conditions often result in slower (when compared to many non-acid systems) decay and cycling processes due partially to the relative scarcity of detritivores in the sediments which assist in breaking down the organic material. Studies have shown that in some instances coarse organic detritus collects as the decomposition of cellulose is halved in systems with an average pH of 5.2 when compared to otherwise similar systems with a pH of 7.0.

Low pH levels in lakes may have a number of other effects. Evidence has been presented that blue-green algae populations do not exist in habitats where the pH is below 4.0 and rarely occur where the pH is below 5.0, although many genera of the more advanced eukaryotic species thrive.

In addition, studies have shown some invertebrate-feeding birds rarely nest on lakes with a pH less than 5.6. Though in our blackwater systems this is natural due to the narrower range of species adapted to the blackwater environment, lowering of the pH due to cultural effects would have a similar result.

Aquatic insects and many macroinvertebrates are affected differently by pH changes and fall into three broad groups: generally intolerant, generally tolerant, and those groups with considerable intraspecific variation. Mayflies (Ephemeroptera) are vulnerable, with species losses at pH<6.5 and only a few species survive pH values of 4.5. Alternatively, beetles (coleopterans), true bugs (hemipterans and homopterans), dragonflies and damselflies (odonates) are very tolerant, and many survive pH's of 4.5. Species living in sediment seem to tolerate low pH better than those living on detrital matter. This seems to be evident in this study to date: few macroinvertebrates were found in the organic detritus of Lake Cascade. Field observations made during sediment sampling indicate that macroinvertebrate populations in the sediment fluctuate seasonally.

Populations of wading birds, raccoon, and otter, though present on the Bradford Chain of Lakes may be limited in density by the comparatively low population of fish and macroinvertebrates. They may be vulnerable to population crashes of fish, crayfish, and macroinvertebrates.

The pH of our lakes is measured in the field. Measurements are made at top, middle, and bottom depths. In addition, pH measurements are taken at one foot intervals if substantial variation in pH is noted in the water column at a particular site. pH levels have been shown to be elevated by photosynthetic activity, and are usually higher in summer and generally higher at midday when compared with night readings.

## **ALKALINITY**

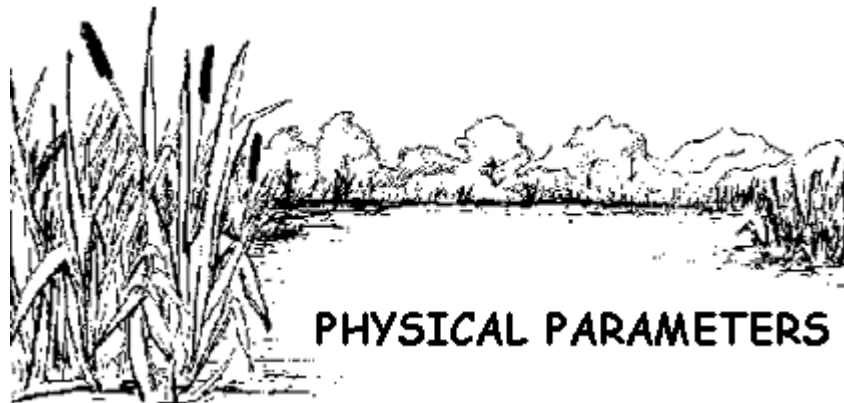
Alkalinity represents the sum total of components which elevate the pH of water above a value of (about) 4.5. Alkalinity, therefore, is a measure of the buffering capacity of the water, and since pH has a direct effect on the toxicity of certain pollutants in the water, buffering capacity is important to water quality. Examples of commonly occurring materials in natural waters that increase the alkalinity are carbonates, bicarbonates, phosphates, and hydroxides.

The alkalinity of water is important in neutralization of acid produced when materials such as aluminum sulfate are used to coagulate water and wastewater. Hydrogen ions subsequently produced lower the pH which is in turn buffered by high alkalinity. Alkalinity is important for fish and other aquatic life in freshwater systems because it buffers pH changes that occur naturally as a result of photosynthetic activity. Furthermore, a high correlation has been established between excellent waterfowl habitats and waterbodies with alkalinities greater than 25 mg/l (NTAC, 1968).

Alkaline substances such as carbonate and bicarbonate will complex with metals and reduce their toxicity by precipitating them out of solution and making them less likely to bioconcentrate. For these reasons, the National Technical Advisory Committee (NTAC, 1968) recommended a minimum alkalinity of 20 mg/l and that natural alkalinity levels not be reduced by more than 25%, although no absolute minimum value for it was determined. A 25% reduction allows one to avoid the problem of establishing standards on waters where natural alkalinity is at or below 20 mg/l. For such waters, alkalinity should not be further reduced. The Environmental Protection Agency's (EPA) standard presently sets a minimum of 20 mg/l in surface waters. The Florida Department of Environmental Protection (FDEP) also has a minimum concentration standard of 20 mg/l, except where the concentration is naturally lower. In those instances the alkalinity may not be further reduced by more than 25% of the natural background level.

Alkalinity may reflect long term changes in water quality. Alkalinity increases in response to photosynthetic activity because plants remove carbon dioxide from the system, resulting in higher pH values. An organic carbon source is needed to drive the process, such as CO<sub>2</sub> from increased plant production or nutrients from accelerated nutrient runoff (LaRock, 1990).

Therefore, high alkalinities may indicate greater plant productivity and nutrient inputs. It should be noted that all of the lakes in this study consistently exhibited alkalinity levels of less than 20 mg/l, which is typical for lakes in this area.



## PHYSICAL PARAMETERS

### WATER LEVEL FLUCTUATIONS

Natural water level fluctuations and controlled drawdowns may be the single most important phenomena that affects the lakes in Leon County. All of the lakes are subject to drying out during drought including our largest natural lakes. Lake Cascade has gone dry repeatedly during the six years that this program has been in place and the following narrative lists just some of the many effects of droughts and drawdowns on lakes. The stress of natural water level fluctuations on the lake includes influxes of nutrients from reflooded terrestrial areas (Ness, 1964; Cooper, 1966; McLachlan et al., 1972), increased turbidity due to shoreline erosion and resuspension of bottom sediments (Grimas, 1962; Swanson, 1967; Geen, 1974; Osborne et al., 1987), the rapid reflooding of shallow lakes (Hestand and Carter, 1974), or the increased concentrations of dissolved materials due to water loss by evaporation (McLachlan et al., 1972).

Water level fluctuations in lakes generally cause a reduction in species diversity and abundance of invertebrates (Fisher and LaVoy, 1972). Some species have only a limited ability to retreat with the lowering water levels and become trapped in plant materials or stranded in small depressions (Bennett, 1954; Aassi, 1960; Cooper, 1966). In contrast, species with the ability to migrate during changing water levels (e.g., chironomids) and other motile benthos may actually increase in numbers in the remaining water (Dahl, 1932; Grimas, 1962; Martin et al., 1972). However, in some situations the benthic fauna can be completely wiped out by the loss of weed beds and direct exposure to wave action (Geen, 1974).

Increased predation of forage fishes may also occur during a drawdown, this can be helpful if populations of forage fish are too high but detrimental if populations are too low (Paetz, 1959; Aassi, 1960; Tyurin, 1961). As the water levels of a lake drop the often abundant shoreline cover becomes unavailable, causing forage fish to become more readily available for consumption by predator fish, which increases the proportion of predators to prey. Large numbers of forage fish are commonly stranded in isolated pools that gradually dry up resulting in mortality for all of the stranded fish. This phenomena was evident in the most recent Lake Talquin drawdown. In most instances drawdowns are very beneficial to lake systems. Most (if not all) of the natural lakes in the Tallahassee area are solution lakes with a history of going dry through sinks and evapotranspiration during periods of drought. De-watering exposes the sediments and greatly accelerates the oxidation and breakdown of the muck that accumulates on the lake bottom. Natural drawdowns slow the eutrophication process and extend the life span of the lakes. This process also helps to keep the macrophyte cover in balance, preventing the greater than 80% macrophyte coverage that presently exists on some area lakes where the sinks have been plugged in an effort to prevent drawdowns. In some instances (such as some lakes that exist in closed basins) man-induced impacts can greatly accelerate the natural aging process (cultural

eutrophication). Natural drawdowns reverse some of the cultural impacts and often result in an increase in biomass of gamefish species (dependent upon the timing, duration and species of fish present in the lake system).

## **TEMPERATURE**

Temperature in the aquatic environment is critical to the species composition of a waterbody. Without appropriate temperature levels, and fluctuations within those levels, few aerobic organisms can thrive or survive. Since most organisms which continuously occupy the aquatic environment are poikilotherms (cold-blooded), it becomes apparent that the temperature regime in a waterbody is critical to all aquatic life. The Federal Water Pollution Control Administration in 1967 referred to water temperature as "a catalyst, a depressant, an activator, a restrictor, a stimulator, a controller, a killer, one of the most important and influential water quality characteristics to life in water."

Temperature also affects the "self-purification" of a waterbody and therefore the aesthetic and sanitary qualities. Increased temperatures accelerate the biodegradation of organic material both in the overlying water and in bottom sediments which in turn increases demands on the dissolved oxygen resources of the system. The higher the temperature the lower the potential for water to hold oxygen. Consequently, as the demand for oxygen increases due to biological activity, the water's ability to physically hold dissolved oxygen is decreased. This phenomena can result in total oxygen depletion and result in anaerobic conditions. The relationship between temperature, oxygen, and biological activity has been described by Velz (1970). Increased water temperature can intensify water odor due to the increased volatility of odor-causing compounds (Bumson, 1938).

Extensive laboratory and field research has been conducted to attempt to determine temperature ranges in which various aquatic biota can survive and/or thrive. Temperature ranges should be maintained which provide for maximum fish and wildlife diversity and which prevent the creation of nuisance growths of organisms such as blue-green algae.

It has frequently been demonstrated that water temperature affects metabolism, respiration, behavior, distribution, migration, feeding rate, growth and reproduction of aquatic organisms. In addition, the temperature levels which become lethal for fish and other aquatic biota are dependent upon exposure time, activity, stress, and even weather (Parker and Krenkel, 1969). When attempting to predict mortality, chronic, or acute effects of inappropriate temperature regimes on the aquatic environment many factors must be examined and their synergistic effects understood.

In summary, the temperature regime within a waterbody influences all aspects of aquatic life including both short and long term survivability, reproduction, and the ecological health of the entire system.

## **TURBIDITY**

Turbidity is a measure of light dispersion caused by particulate matter suspended in the water column. Turbidity levels provide an indication of the amount of inorganic and organic muck that may be accumulating in the bottom of a waterbody, directly affecting the primary productivity of a waterbody. Turbidity levels are also an indication of erosional forces in the watershed such as construction activities. Muck accumulation caused by excess turbidity can greatly alter the wildlife and fisheries components of a waterbody regardless of other water quality and biological values. The introduction of sediment loads above those naturally found in a lake system is one of the two greatest potential threats to our aquatic systems. In addition, sediments washed from roadways and commercial/industrial sites are reservoirs for compounds with currently unknown effects on aquatic environments. Until the potential for bioaccumulation or toxic effects from the man-

induced introduction of organics is known, it would be prudent to limit their introduction in aquatic environments.

EPA 1986 Water Quality Standards state that settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than ten percent from the seasonally established norm for aquatic life.

The effects of excessive turbidity levels are numerous and most are detrimental to a waterbody. Excess turbidity levels can result in the following:

- \* Kill fish and other aquatic organisms.
- \* Reduce fish growth rates.
- \* Modify the movements of fish.
- \* Prevent the successful development of fish eggs and larvae.
- \* Reduce the ability of fish to locate food and cause decreases in the food sources available to fish
- \* Decrease or eliminate reproduction of many aquatic organisms
- \* Decrease organisms resistance and increase disease rates.
- \* Provide a source of sediments that cover the bottom of lakes and destroy habitat for many aquatic organisms

FDEP standards state that conditions may not exist that cause an increase in turbidity levels in excess of 29 Nephelometric Turbidity Units (NTUs) over baseline levels. Many experienced aquatic biologists believe that impacts to aquatic biota occur at levels much lower than this arbitrary standard.



### **Moore Lake**

Moore Lake is a control lake located in a small closed basin in the Apalachicola National Forest. This 60 acre lake has no development in its basin and rated good to excellent on all of the lake rating indices.

### **Tom Brown Park Lake (TBPL)**

TBPL is the second most degraded lake of the twelve covered in this report. The combination of water quality and benthic macroinvertebrates rated grossly altered. The lake essentially functions as a stormwater treatment facility and receives runoff from areas that include ball fields, roads and the federal prison. The lake is very eutrophic; its flow-through nature and the fountain help it maintain a productive fishery. The installation of a drawdown structure and the development of a ten-year drawdown and maintenance schedule, with accompanying removal of accumulated sediment, could improve the water quality of this lake.

## **Campbell Pond**

Campbell Pond is located largely within the City's Campbell Pond Park. This lake is located in the Woodville Karst Plain and has survived urbanization somewhat intact. Water quality is rated as good, and species diversity of macroinvertebrates was the third best of the 12 lakes covered in this report. The lake is eutrophic and supports a productive fishery. The Florida Game and Fresh Water Fish Commission has expressed an interest in managing this lake as a part of their urban fishery program. These lake management partnerships with FGFWFC should be encouraged due to the mutual cost savings and increased recreational opportunities they would create.

## **Lake A.J. Henry**

Lake A.J. Henry is a 13.5 acre reservoir located partially within the city park of the same name. This lake has been severely degraded by sediment inflows from past erosion and sediment control failures from construction in its basin. This is the only lake among the 12 covered in this report that rated poor in water quality and "grossly altered" on the Lake Condition Index Scale. In addition, 20% of the samples exceeded Florida Department of Environmental Protection (FDEP) Class III water quality standards for turbidity. This lake has experienced several green and blue-green algal blooms and fish kills within the last three years. Erosion and sediment control enforcement must be strengthened in this lake's basin and a drawdown with accompanying sediment removal would benefit this lake.

## **Grassy Lake**

Grassy Lake is a marshy wetland that serves to filter stormwater from Munson Slough that would otherwise flow directly into Lake Bradford. Grassy Lake and its surrounding woodlands serve as a refuge for a variety of wildlife species.

## **Lake Hilaman**

Lake Hilaman is a combination of two in-line reservoirs located within the city's Hilaman Park. The lake is very nutrient-enriched and supports a fishery and wildlife including beaver. This lake scored "fair" on the Trophic State Index (TSI) a water quality scale and occasionally exceeds FDEP Class III water quality standards for bacterial counts in water. Results of the study show a slight improvement in water quality from the inflow to the outflow, indicating that stormwater runoff causes more impact than maintenance activities associated with the golf course. Installation of the aeration system purchased in 1994, and continuing the reuse of water at the golf course may improve the water quality in this lake.

## **Lake Killarney**

The water quality in Lake Killarney rated good on the TSI for most of the monitoring events covered in this report. This lake's Lake Condition Index (LCI) score falls into the grossly altered category. The flow-through nature of this reservoir helps it to maintain a productive fishery, however, reductions in the overall frequency of flow in this reservoir may lead to algal blooms and fish kills. Native wetland vegetation should be reestablished in the littoral zone of this lake and dewatering and sediment removal could also improve the water quality in this lake.

## **Lake Kanturk**

Lake Kanturk is located immediately east and downstream of Lake Killarney. This lake scored good on the TSI scale and moderately altered on the LCI scale. Data indicate that this lake is healthier than most comparable urban lakes in this study. The filtering and settling of sediments and nutrients that occur in upstream Lake Killarney serve to slightly improve the water quality of this lake. It appears that temporal and flow variations account for much of the variation in the

water quality of this lake. Installing a drawdown structure that would allow for the periodic dewatering of this lake could prove beneficial in expanding the useful life span of this lake.

### **Gilbert Pond**

This reservoir scored better on all lake health indicators than any other comparable water body. Lower residential and commercial densities, better macrophyte coverage and frequent scheduled drawdowns probably account for most of the difference in water quality between this and similar lakes in this study. With continued management this reservoir should maintain a productive fishery and good water quality.

### **Lake Cascade**

This natural lake is one of the least impacted large blackwater lakes in Leon County. Lake Cascade's surface is dominated by second growth cypress trees and myrtle-leaved holly that provide wildlife habitat for a diverse assemblage of species. The frequent natural drawdowns serve to keep muck from accumulating on the bottom of this lake and contribute to this lake's excellent water quality.

### **Lake Hiawatha**

The water quality in this dystrophic blackwater system is very good to excellent as indicated by this lake's mean TSI score of 45. Due to the blackwater nature of this lake, macrophyte and macroinvertebrate populations are suppressed. However, the lake still supports a diverse assemblage of wildlife. Given the generally low assimilative capacities of blackwater lakes, this lake could be susceptible to anthropogenic degradation and merits a high degree of protection. Continued monitoring is recommended to detect changes in water quality.

### **Lake Bradford**

Lake Bradford, with a surface area of 149 acres, is the largest and most accessible member of the Bradford Brook Chain of Lakes. Lake Bradford's watershed of over 3,000 acres is the largest of any lake in this study. Water quality is still good and comparable to that found in lakes Hiawatha and Cascade. Lake Bradford is probably the most important lake covered in this report with respect to both recreation potential and the uniqueness of the natural resources found in the lake and its basin. By nature, the assimilative capacity of this blackwater system renders it vulnerable to anthropogenic impacts. Monitoring of the stormwater that enters the lake through Munson Slough is recommended to determine the long-term impacts of the runoff.

### **Conclusion**

The lakes covered in this study are generally in good condition. In order to maintain their water quality, any long-term objective of lake conservation or restoration should include a combination of insightful planning, effective erosion and sediment control and treatment of stormwater prior to its entering lakes. The Environmental Services Division will begin to develop more comprehensive guidelines for sediment and erosion control and any necessary code changes for City Commission consideration. Included in these proposed code changes will be a proposal to allow environmental inspectors to cite contractors for failures of sediment and erosion control systems on active construction sites. Staff will also investigate methods of rewarding contractors who actively promote and use effective erosion control techniques. The sediment and erosion control guidelines and the proposed plan to allow inspectors to cite violators for sediment and erosion control failures will be submitted for Commission consideration within 12 months of the publication of this document. Lake management strategies should be developed to prevent unnecessary restrictions on development while preserving or improving the existing health of area lakes. Environmentally sensitive development should be rewarded, while development that leads to taxpayer funded restoration of lakes should be avoided through cost efficient regulation.