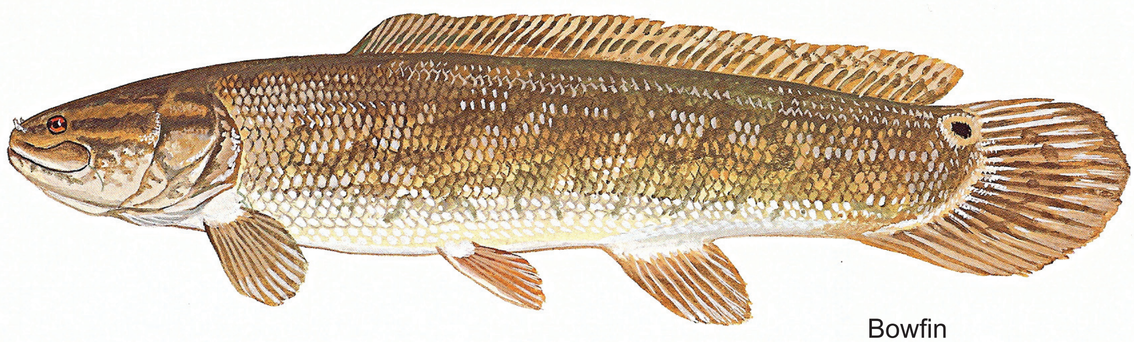
A Beginner's Guide to Water Management

Fish Communities and Trophic State in Florida Lakes

Information Circular 110



Bowfin
(Amia calva)

Florida LAKEWATCH

Department of Fisheries and Aquatic Sciences

Institute of Food and Agricultural Sciences

University of Florida

Gainesville, Florida

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As always, we welcome your questions and comments.

Introduction

When the issue of nutrient enrichment (eutrophication) arises at a lake, the public often fears that increases in nutrient concentrations will ultimately lead to the demise of the lake's fish community. This fear is based in part on past experiences in northern lakes where nutrient enrichment has been associated with the loss of fish for two different reasons. First, many of the lakes where eutrophication has been cited as the cause for changes in fish communities are deep, stratified (warmer water layered on top of colder water) lakes in the northern regions of the United States, where cold-water fish such as salmon or trout have been reduced or eliminated. Increases in nutrients cause increases in algae cells that often sink into the hypolimnion (the deep cold water portion of the lake below the thermocline), where bacteria use oxygen to digest the cells. Trout and salmon and other coldwater species require highly oxygenated colder water to survive. Thus, when the hypolimnion loses oxygen due to eutrophication, trout and salmon are forced into upper waters where it is too warm for them to survive. Therefore, loss of dissolved oxygen in the hypolimnion of stratified lakes, which is important habitat, causes a reduction of these species of fish.

Secondly, northern nutrient-rich lakes with thick ice cover often undergo winterkill. During winter, after oxygen in the water is consumed by fish, aquatic plants, bacteria and other aquatic organisms, fish often die. The ice that covers the lake's surface prevents oxygen from entering the lake and snow on the surface of the ice prevents light from entering the lake for plants to use for photosynthesis, which produces oxygen. Eutrophication has also been cited as a cause for the decline in fish species richness.

Florida lakes, however, are shallow, do not have cold hypolimnia, and do not support cold-water species such as salmon and trout. As you might expect, fish species in Florida are well adapted to shallow, warm water. Ice cover on lakes in Florida is a rare occurrence, eliminating the possibility of fish-kills under the ice, which occasionally happens in some northern lakes during the winter. Even though these two situations do not occur in Florida, eutrophication is still a concern because of the state's rapid population growth as people flee the cold north to live in sunny Florida. This growing human population brings changes in land use that may increase nutrient inputs to many lakes. The impact of nutrient concentrations on algal populations (Florida LAKEWATCH Circular 102) and that of algal communities on water transparency (Florida LAKEWATCH Circular 103) in Florida lakes are well documented. However, there is less information available to the public on the effects of eutrophication on fish populations in Florida's lakes.

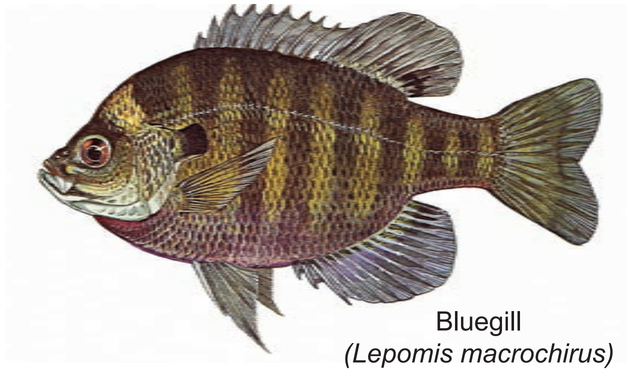
Prior to 1947, Lake Apopka was covered with aquatic plants maintaining clear water and an extensive largemouth bass fishery. After 1947, the lake switched to an algal-dominant system with turbid water and the largemouth bass fishery collapsed. The blame for this was placed on nutrient additions to Lake Apopka from agricultural activities. Now, Lake Apopka has become Florida's "poster child" for the potential adverse effects of nutrient enrichment because it has lost its major largemouth bass fishery. Because of this, Apopka is also the target of a massive and expensive restoration program by the St. Johns River Water Management District. In fact, the Florida media once described Lake Apopka as a dead lake, which contributed to the effort to restore Lake Apopka. Because of what has occurred at Lake Apopka, there is special interest concerning eutrophication that is occurring at Lake Okeechobee, a large, shallow, eutrophic lake in south Florida that supports a major recreational fishery. Annual total phosphorus concentrations in the lake have increased from 49 µg/L to about 200 µg/L from 1974 to 2006, and many people fear Lake

Okeechobee is headed the way of Lake Apopka. A 1980 study conducted by the Florida Game and Freshwater Fish Commission (now the Fish and Wildlife Conservation Commission) support this fear because it suggests that sportfish populations reach maximum biomass and optimal densities in mesotrophic to eutrophic lakes, but suffer adverse effects at higher levels of biological productivity. It is natural that many Floridians are concerned that the loss of recreational fishing at Lake Apopka will be the same fate for Lake Okeechobee and for the local lakes they live on and/or fish!

General ecological principles suggest that, all other things being equal, an increase in productivity at the base of the food chain in a lake should lead to an increase in the abundance of fish at higher trophic levels (see the trophic status sidebar on page iv). There are many quantitative fisheries studies that support this. Fish yields in northern lakes have been positively related to summer phytoplankton standing crops (the weight of algae that can be sampled from a given volume of water) as measured by chlorophyll or annual primary productivity. Studies of tropical lakes in Africa and India also found that fish yields increased with primary production. The overwhelming evidence from the studies of lakes outside of Florida is that as lakes become more eutrophic the standing crops (the weight of fish that can be sampled from a given area), productivity, and yields of fish increase. Furthermore, people who raise fish for a living – aquaculturalists – fertilize their waters and feed to increase fish production; even recreational pond owners will fertilize and feed their ponds to have more fish (see University of Florida/IFAS Fact Fheet FA-13 for more information).

The increase in fish biomass with nutrient enrichment has been cited by some professional fisheries biologists as one of the positive consequences of eutrophication. Yields of sportfish to angler harvest in the United States have also been related to phytoplankton standing crop as measured by chlorophyll. This relationship is the basis for many fish management agencies, such as the Florida Fish and Wildlife Conservation Commission (FFWCC), to intentionally fertilize some lakes. In Florida, the FFWCC fertilizes Bear Lake in Santa Rosa County and Karick Lake in Okaloosa County. In south Florida, nutrient-rich runoff from agricultural lands is now diverted into impoundments for the purpose of protecting Florida's natural waters from eutrophication, yet these impoundments such as the Stick Marsh in Indian River County have developed nationally recognized largemouth bass fisheries. Even with all of this evidence, people consistently make the statement that eutrophication will hurt fish populations. So why does the myth of eutrophication causing dead lakes persist?

In light of such popular misconceptions surrounding fish populations and nutrient enrichment, one thing is clear – all Florida residents and visitors stand to benefit from a greater understanding of the fish populations in lakes of different trophic state (productivity) in Florida. The relationships between fish populations and trophic state discussed in this circular are based on a study of many Florida lakes of varying trophic state rather than on an individual lake undergoing eutrophication over time. This approach is taken because there are virtually no long-term studies of fish populations in Florida lakes undergoing eutrophication. Before you begin, however, we encourage you to read **A Beginner's Guide to Water Management – Nutrients** (Circular #102) and **A Beginner's Guide to Water Management –Water Clarity** (Circular #103). It might also be useful to peruse **A Beginner's Guide to Water Management – The ABCs** (Circular #101) to become acquainted with the meaning of some commonly used words. These publications can be downloaded for free from the Florida LAKEWATCH web site at http://lakewatch.ifas.ufl.edu.



Bluegill
(Lepomis macrochirus)

Lake Stratification and Temperature Profiles

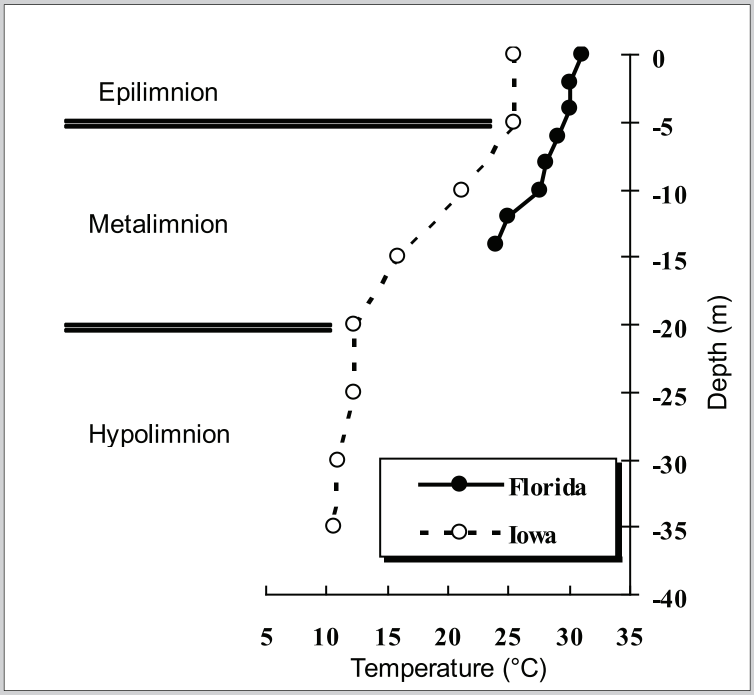


Figure 1 above compares the relationship between lake depth and temperature for a lake in Iowa with a lake in Florida. Both temperature profiles shown in the graph were taken in August.

As illustrated in the graph, the upper-most layer of warmer water is called the epilimnion. The deeper, relatively undisturbed layer of cooler water is called the hypolimnion and the water between these two layers is called the metalimnion. This is the zone where water temperature changes the most rapidly in a vertical direction; it is also known as the thermocline. The Florida lake does not appear to stratify as strongly because it is shallower.

Notice, in the Florida lake, that there is a much smaller temperature difference between the surface and the bottom; temperatures range from about 32°C (90°F) down to 23°C (73°F), a difference of only 9°C. In the Iowa lake, the temperature span is considerably larger, ranging from 25°C (77°F) to about 10°C (50°F), a difference of 15°C. This tells us that the stratification in the Florida lake is not as strong or as stable as the stratification in the Iowa lake. While strong stratification happens much less frequently in Florida's shallow lakes, it does occur in the deeper sink hole lakes found throughout the state.

Trophic State

Trophic status is defined as "the degree of biological productivity of a waterbody." Scientists debate exactly what is meant by biological productivity but, generally, it 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 in the water;
- water clarity, measured using a Secchi disc; and
- aquatic plant abundance.

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 indicator of biological productivity, since the amount of algae actually being produced in a body of water is reflected in the amount of chlorophyll present. In addition, Florida LAKEWATCH professionals may modify their chlorophyll-based classifications by taking the aquatic macrophyte abundance into account.

This circular provides a first step towards understanding a complex subject that professionals still intensely debate. Basic information on how fish are sampled by professionals as well as how fish abundance and species composition are related to trophic state is provided in the following parts:

1. Techniques for Estimating Fish Populations in Florida Lakes
2. Trophic State and Total Fish Biomass
3. Trophic State and Sport Fish Biomass
4. Trophic State and Species Richness
5. Trophic State and Some Common Florida Fish Species

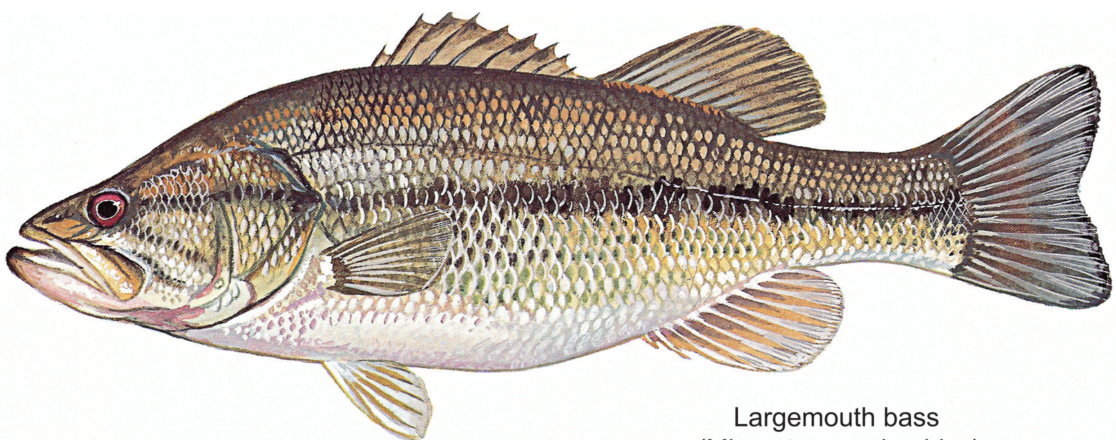
Warmouth
Lepomis gulosus

Part 1
Techniques for Estimating Fish Populations in Florida Lakes

There is a limit as to how useful the published literature can be in determining what effect nutrient enrichment (eutrophication) might have on fish populations on Florida lakes. In particular, many of the studies cited by professionals, even those working in Florida, have been carried out on deep, northern lakes that support fish communities very different than Florida's. For example, many northern lakes with their cold, oxygenated water support trout and salmon, whereas warm shallow Florida lakes do not support these cold-water fish. Florida lakes support a variety of warm-water fish including largemouth bass, black crappie, redear sunfish and bluegill – all major sportfish in Florida. Consequently, the results from more northern studies may not directly apply to shallower lakes in a warmer climate.

Fisheries biologists face a difficult problem when asked to assess the fish community in a lake. Like anglers, they must first catch the fish! Unfortunately, there is no one sure-fire technique for catching all and sizes of fish or determining the absolute amount of fish in a lake. Biologists in Florida use multiple techniques such as electrofishing, gillnetting, and rotenone sampling with blocknets to determine fish abundance and to catch as many fish species as possible. Faced with the reality of limited resources, the fisheries biologist often must rely on only one technique to meet a project objective.

Florida LAKEWATCH works cooperatively with the Florida Fish and Wildlife Conservation Commission to provide long-term assessments of fish populations in selected Florida lakes. We will start this circular with a description of electrofishing because Florida LAKEWATCH and most state and federal agency biologists use electrofishing as the primary technique to sample fish communities. ♦



Largemouth bass
(Micropterus salmoides)

Electrofishing

Florida LAKEWATCH

Electrofishing uses electric current to capture fish. This sampling technique is called an "active gear" as the fisheries personnel motor around a lake to capture fish from different areas. Electrofishing can be used on virtually all Florida lakes, although it is less effective in lakes with low specific conductivity (see box on p. 4).

Electrofishing is usually conducted using aluminum boats carrying portable generators. The boats are equipped with one or two booms (poles) extending forward from the front of the boat for the support of the electrodes. Boats equipped with one boom typically use the boat as the cathode (-) and the electrodes on the boom as the anode (+). Boats with two booms use both booms as the anode in an attempt to increase the area fished.

Electrofishing is often used by fisheries biologists because it is a capture technique that minimizes fish mortality. Four types of electrical current are typically used: direct current (DC), pulsed DC, alternating current (AC) and pulsed AC. Each boat is equipped with a "control box" for managing the different current types. Electrofishing effectiveness depends upon the type of lake being sampled (specifically, the lake's conductivity) as well as water depth, water clarity and the wattage of the generator creating the current.

Fish react to electric current in two basic ways. Fish in the "escape" field of the electrical current, far away from the boat and electrodes, show a "fright" response and swim away unaffected. Fish in the "stun" field, typically between the boat and electrodes, show effects such as forced swimming, but ultimately become immobilized or stunned when electrical current and water conditions are correct. Their reaction is similar to a human being hit with an electrical stun gun. Fisheries personnel can capture these fish with long-handled dip nets. In most cases, the captured fish become mobile in a few minutes. Once the fish are mobile, they are typically released back into the lake unless they are needed in the laboratory for additional research, such as for age and growth, mercury analysis, and/or reproductive studies.

Direct current (DC) is often used in turbid waters because fish tend to move toward the anode where they roll over and are more easily captured. This current type is useful in turbid waters because the fish tend to move from the deeper water to the surface, near the anode, where they can be seen and captured with dip nets. Pulsed DC is generally better than the continuous, unmodified DC because it requires less voltage and thus causes less harm to the fish.

Alternating current (AC) is typically used in Florida's mineral-poor lakes (specific conductance less than 100 µS/cm at 25°C). In these lakes, high voltage is needed to stun the fish. Continuous, unmodified AC is potentially the most damaging type of current to use as it can cause hemorrhaging, ruptured swim bladders, and fractured vertebrae. Pulsed AC may cause similar responses, but it is not potentially as harmful as continuous, unmodified AC. The adverse effects typically occur when the alternating current is suddenly activated and the fish is near the electrode. Having the current active before the boat enters the sampling area can minimize many of the adverse effects. Regardless of which current is used, as the generator wattage increases the strength and size of the stun field increases, increasing the effectiveness of the unit.

Electrofishing efficiency is influenced by many factors. Electrofishing is basically a shallow water (less than 8 feet) fish sampling technique. Fish that live along the shore of a lake, such as largemouth bass and bluegill, can be sampled relatively efficiently but consideration must always be given to the potential existence of offshore populations. Electrofishing is not effective for fish such as gizzard shad and catfish that live offshore or near the bottom. Fish size also affects electrofishing efficiency, with larger fish being stunned more effectively than smaller fish because the larger fish have more surface area for the current to come in contact with. Even when small fish are stunned, there is a tendency for the dip-netters to select the large fish and it is often difficult to collect all of the small fish when large numbers of these fish are simultaneously stunned, especially when a large school of fish is encountered.

Factors such as water temperature, water transparency, dissolved oxygen concentration, number and experience or skill of dip-netters, and weather can all affect fish capture rates. The bottom line is that the results from any single day of electrofishing need to be examined cautiously because electrofishing could be either very effective or less effective on that particular day resulting in very high or very low capture rates. The results become useful for assessing relationships among lakes and for determining long-term trends within the fish community of a single lake if factors such as those listed above are taken into account.

Fish population abundance can be estimated with electrofishing by calculating Catch-Per-Unit-Effort (CPUE). CPUE is a useful and easily obtained index for the abundance of many fish species. Fisheries personnel electrofish a given lake for a defined time period (about 10 minutes in Florida) and collect all stunned fish. The total number or weight of all fish collected can then be calculated as number or weight of fish per hour of electrofishing. The timed fishing transects are conducted at multiple sites and often on multiple days for a lake to provide a mean estimate of fish abundance for that specific lake. These estimates can then be compared with estimates from other lakes of varying trophic state or compared to estimates from other years for the same lake, if data are available. Florida LAKEWATCH and FFWCC are currently using electrofishing CPUE to monitor long-term fish abundance trends for 52 Florida lakes.

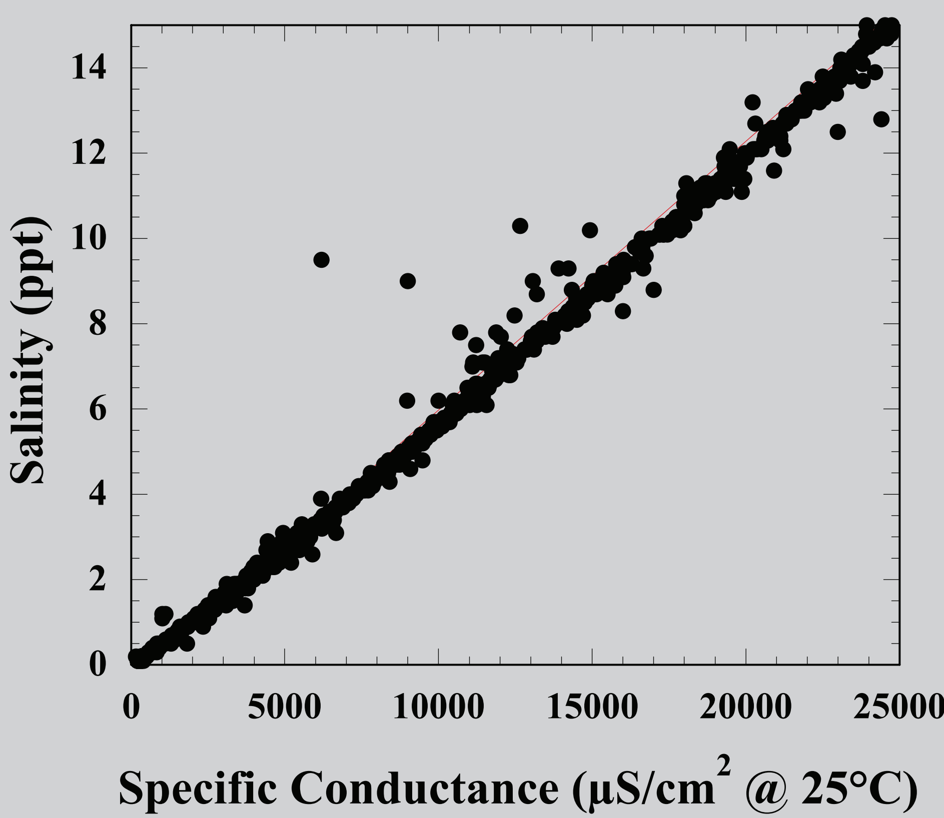
Specific Conductance

Specific conductance is a measure of the capacity of water to conduct electricity. A higher value of conductance means that the water is a better electrical conductor. The unit of measure for conductance is the microSieman per centimeter of water measured at a temperature of 25 degrees Celsius (abbreviated "µS/cm @ 25°C"). "Micromhos/cm" (abbreviated "µmhos/cm) is also used. These two units are equal to each other.

Specific conductance increases when more salts, including the most common sodium chloride, are dissolved in water. For this reason, conductance is often used as an indirect measure of the salt concentration in a waterbody. In general, lakes with more salts are more productive except of course where there are limiting nutrients or other limiting factors involved.

The location of a waterbody has a strong influence on its specific conductance. For example, lakes in the New Hope Ridge/Greenhead Slope lake region in northwestern Florida (Washington, Bay, Calhoun, and Jackson counties) tend to have conductance values below 20 µS/cm @ 25°C while lakes in the Winter Haven/Lake Henry Ridge lake region in central Florida (Polk County) tend to have values above 190 µS/cm @ 25°C. However, environmental factors also can cause higher conductance values. For example, drought conditions can increase the salt concentrations in a waterbody in two ways: 1) drought can cause inflowing waters to have higher salt concentrations and 2) heat and low humidity can increase the evaporation of water, leaving the waterbody with higher concentrations of salt. Waterbodies in the Florida LAKEWATCH database, analyzed through 2006, ranged from 11 to more than 5500 µS/cm @ 25°C. More than 75% of these waterbodies had conductance values less than 190 µS/cm @ 25°C.

Salinity (ppt) = -0.332 + 0.00063 * Conductance (µS/cm² @ 25°C)



Relation between salinity and specific conductance for data collected from five Florida coastal rivers. The regression equation for calculating salinity (parts per thousand) from specific conductance (microSieman per centimeter of water measured at a temperature of 25 degrees Celsius) is above the graph.

Between 1999 and 2006, Florida LAKEWATCH and the Florida Fish and Wildlife Conservation Commission (FFWCC) electrofished four to six transects from 32 lakes each year, when access was available. This yielded a total of 1277 ten-minute transects, capturing a total 56 fish species. The total number of species in a lake ranged from eight in E Lake, Miami-Dade County to 34 in Lake Panasoffkee in Sumter County. Table 1 shows summary statistics for those fish species that were caught in ten or more lakes. The data show that the three most recreationally sought-after freshwater fish in Florida are also the most commonly sampled fish in Florida lakes (bluegill in 32 lakes, largemouth bass in 32 lakes, and redear sunfish in 31 lakes). Table 1 also shows the large range in CPUE by individual species (e.g., bluegill averaged 150 fish/hr, but ranged from 22 fish/hr to 682 fish/hr, depending on the lake).

Electrofishing can also be used in mark-recapture studies to try to provide a more definitive estimate of the abundance of one or more fish species in a lake. There are many types of mark-recapture methodologies and some are extremely complicated. All of the methods, however, involve capturing the fish, giving the fish a mark that will be recognized at a later date (for example, colored tags or fin clips), releasing the fish alive, and later sampling the fish population to look for the marks.

A simple estimate of abundance can be obtained using the Petersen mark-recapture method. In this approach, electrofishing is used to capture fish for a period of time. During this "marking" phase, a substantial proportion of the fish population is marked in an attempt to gain better confidence in the final estimate. After a sufficient number of fish have been marked (usually 10% or more of the fish species being estimated), sampling is stopped to allow the marked fish to mix with the unmarked fish. After this mixing period (usually at least a week), the census period begins. During this census period, electrofishing is again used to capture fish. Fisheries personnel record the number of marked fish and the total number of fish collected. All fish are given a distinctive second mark prior to their release to prevent the fish from being counted twice during the census period. The abundance estimate is calculated using the following formula:

$$N = \frac{M*C}{R}$$

Where:

N = the number of estimated fish in the population;

M = the number of fish marked during the marking period;

C = the number of fish caught during the census period; and

R = the number of fish, marked during the marking period that were recaptured during the census period.

Electrofishing can also provide useful information on the *size composition* of harvestable sportfish such as the largemouth bass. In other words, what proportion of a fish species is comprised of a given length fish in the lake? This information is crucial for evaluating if regulations such as size limits are working. Electrofishing is also useful for *species detection*. In Florida, electrofishing will capture the most common species. However, a complete listing of all species in a water body can only be obtained if other sampling techniques are employed. This is necessary because electrofishing has sampling limitations, such as the water depth at which it will effectively sample fish.

Spotted sunfish
Lepomis punctatus

Common Name	Lakes	Mean (fish/hour)	Minimum (fish/hour)	Maximum (fish/hour)
Bluegill	32	150.3	22.0	682.3
Largemouth bass	32	52.7	1.8	214.3
Lake chubsucker	31	12.6	0.1	65.0
Redear sunfish	31	23.7	0.3	71.5
Warmouth	31	7.7	0.5	34.9
Brown bullhead	28	3.7	0.1	27.2
Florida gar	28	11.8	2.4	34.8
Golden shiner	28	26.1	0.1	273.6
Black crappie	27	5.1	0.1	30.6
Bowfin	27	3.3	0.2	14.6
Brook silverside	27	30.1	0.2	156.5
Eastern mosquitofish	26	16.5	0.1	196.1
Seminole killifish	25	16.6	0.1	117.4
Chain pickerel	24	3.2	0.2	9.4
Taillight shiner	24	18.5	0.1	178.9
Dollar sunfish	22	4.7	0.1	58.5
Bluespotted sunfish	19	1.5	0.1	6.8
Gizzard shad	19	12.4	0.1	120.0
Threadfin shad	18	23.0	0.1	151.0
Spotted sunfish	17	1.8	0.1	11.5
Yellow bullhead	17	0.8	0.1	5.1
Bluefin killifish	14	3.7	0.2	34.4
Golden topminnow	12	0.3	0.1	0.8
Blue tilapia	11	1.8	0.1	5.4
Swamp darter	11	0.3	0.1	0.6
Inland silverside	10	7.4	0.4	16.1
Redfin pickerel	10	0.8	0.1	2.5

Table 1. Overall species mean, minimum, and maximum electrofishing CPUE (number of fish/hr) for all species captured in at least 10 lakes. Individual fish species statistics were calculated first for each lake by year including any zero CPUE values if the species was not caught in an individual transect but was captured at least once in all transects over all years. Then all years were averaged among all lakes by individual species.

Gillnets

Matt Catalano

Gillnets are vertical walls of netting set out in the open-water in a straight line. Gillnets provide a “passive” capture method that works by entanglement in the net. Fish are caught as they attempt to swim through the opening in the mesh and get stuck. The gear is called “passive” because fisheries personnel do not actively move the nets once they are placed into the water.

Gillnets, like most passive gear, have an advantage because they are simple in their design and construction. They can be repaired relatively easily and at a low cost; this is all important when used in lakes where large numbers of alligators live. Alligators can make large holes in the nets, destroying the net’s effectiveness; nothing is worse than trying to remove a live, mad alligator from a net!

The catch of fish in a gillnet (assuming other variables are equal) is often proportional to the abundance of fish in a lake. Gillnet CPUE (number of fish caught per gillnet per day) is especially helpful in determining the relative abundance of fish in waters where electrofishing is not that effective. Gillnets can effectively sample open-water oriented species such as black crappie, gizzard shad, lake chubsucker, and sunshine bass. Fish such as catfish are often caught by the spines, making it difficult to remove them from the net. In Florida lakes, “experimental gillnets” are often used because these types of nets have five or six sections, each with a different size mesh. This allows a single net to capture different size fish. It is important to remember that mesh size generally determines the size of fish captured and catch requires an encounter between the fish and the gillnet.

Because most Florida lakes are shallow, nets are typically positioned along the bottom of the lakes. The typical experimental gillnet used by the Department of Fisheries and Aquatic Sciences of the University of Florida is approximately 165 feet long and 8 feet tall (50 m x 2.4 m). The nets generally have five 33-ft (10-m) panels of different mesh size. The measurement of one side of an opening in the mesh is call "bar mesh" and the bar sizes are generally as follows: 3/4, 1, 1.5, 2.0, 2.5 inch (19, 25, 38, 51, 63 mm). The nets are typically fished for 24 hours during the summer. Although the captured fish are destroyed, only a small number of fish relative to the size of the lake's fish community are captured, so scientific gillnetting has little effect on the fish community. During the summer, entangled fish may die due to stress in the warm water; the Florida Fish and Wildlife Conservation Commission requires any fish captured by a gillnet to be disposed of properly. 💧

Florida's Fish

Common name	Scientific name	Common name	Scientific name
American eel	*Anguilla rostrata*	Largemouth bass	*Micropterus salmoides*
Atlantic needlefish	*Strongylura marina*	Least killifish	*Heterandria formosa*
Banded sunfish	*Enneacanthus obesus*	Lined topminnow	*Fundulus lineolatus*
Black crappie	*Pomoxis nigromaculatus*	Longnose gar	*Lepisosteus osseus*
Blackbanded sunfish	*Enneacanthus chaetodon*	Pugnose minnow	*Opsopoeodus emiliae*
Blue tilapia	*Oreochromis aureus*	Pygmy killifish	*Leptolucania ommata*
Bluefin killifish	*Lucania goodei*	Pygmy sunfish	*Elassoma sp.*
Bluegill	*Lepomis macrochirus*	Redbreast sunfish	*Lepomis auritus*
Bluespotted sunfish	*Enneacanthus gloriosus*	Redear sunfish	*Lepomis microlophus*
Bowfin	*Amia calva*	Redfin pickerel	*Esox americanus americanus*
Brook silverside	*Labidesthes sicculus*	Sailfin molly	*Poecilia latipinna*
Brown bullhead	*Ameiurus nebulosus*	Seminole killifish	*Fundulus seminolis*
Chain pickerel	*Esox niger*	Spotted sunfish	*Lepomis punctatus*
Channel catfish	*Ictalurus punctatus*	Swamp darter	*Etheostoma fusiforme*
Coastal shiner	*Notropis petersoni*	Tadpole madtom	*Noturus gyrinus*
Dollar sunfish	*Lepomis marginatus*	Taillight shiner	*Notropis maculatus*
Eastern mosquitofish	*Gambusia holbrooki*	Threadfin shad	*Dorosoma petenense*
Florida gar	*Lepisosteus platyrhincus*	Tidewater silverside	*Menidia peninsulae*
Gizzard shad	*Dorosoma cepedianum*	Walking catfish	*Clarias batrachus*
Golden shiner	*Notemigonus crysoleucas*	Warmouth	*Lepomis gulosus*
Golden topminnow	*Fundulus chrysotus*	White catfish	*Ameiurus catus*
Grass carp	*Ctenopharyngodon idella*	Yellow bullhead	*Ameiurus natalis*
Inland silverside	*Menidia beryllina*		
Lake chubsucker	*Erimyzon sucetta*		

Table 2. Common and scientific names (genus and species) for the most prevalent fish in Florida lakes.

Rotenone Sampling with Blocknets

Aaron Bunch

Hook and line fishing is one of the oldest and most enjoyable methods for capturing fish. Sampling fish with toxicants, however, is also one of the oldest and most reliable methods for capturing fish. In some communities in Asia, sodium cyanide is used to kill fish for commercial harvest. The most commonly used EPA-approved fish toxicant in the United States is rotenone. In Florida, fisheries personnel typically use rotenone in conjunction with nets (called blocknets) to limit the size of the sampling area. This type of sampling, despite the number of fish killed during the sampling operation, does not seriously harm the lake's fish community and provides good estimates of fish abundance.

Rotenone is a naturally occurring toxicant extracted from plants of the Fabaceae (bean) family. In Florida, rotenone is generally applied in a liquid form containing from two to five percent of the active ingredient. Rotenone kills fish by interfering with a mechanism required for respiration; the fish essentially suffocates. Rotenone applied at two to five mg/L generally insures a complete kill of all sizes and species of fish. Rotenone is sometimes used at concentrations less than 1 mg/L to selectively remove fish like grass carp and shad without harming desirable fish like largemouth bass.

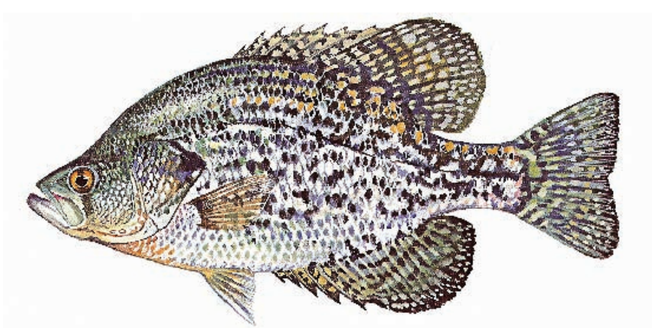
The duration of rotenone toxicity is highly dependent on water temperature and the concentration of suspended solids. Rotenone toxicity lasts longer in cold water that has few suspended solids. Rotenone sampling in Florida is generally conducted during the summer when water is warm. Many Florida lakes have high concentrations of suspended solids. Consequently, rotenone toxicity generally lasts for less than two days in Florida lakes. Rotenone is not considered toxic to most mammals and birds, although swine have been affected at the concentrations used to kill fish. Rotenone will kill zooplankton and other aquatic invertebrates such as crawfish and grass shrimp. The effects are short term and affect only a very small percentage of the lake-wide populations of these animals.

Blocknets are fine mesh nets that are used by fisheries personnel to cordon off specific areas of a lake for fish sampling. The nets are often about 3 to 4 m (9.8 – 13.1 ft) deep and made of netting with 3–mm (1/8 in) wide openings. The length of the nets varies depending on the study's objectives, but typically 0.08 ha (1/5–acre) to 0.4 ha (one-acre) areas are sampled in Florida. The primary purpose of the net is to block fish movement out of the sampling area. One advantage of using several small blocknets rather than one large blocknet to sample an area such as a cove is that more habitats can be sampled in a lake and far less rotenone is used.

Sampling with rotenone typically takes place over three days. Shortly after the net is set and rotenone is applied, the field crew begins to collect the fish. As the rotenone begins to effect the fish, the fish swim to the surface. It is at this time that a frantic effort is made to capture as many fish as possible. Working with fresh fish is easier than working with fish that have been dead for one or two days. Depending on the fish species and their size, some fish may dive to the bottom and bury themselves in the mud. With Florida's warm water, the dead fish will quickly bloat as a result of bacterial decay and float to the surface. Biologists remove the dead fish from the water surface for the next two days.

Generally, fish outside the blocknets can detect the rotenone and swim to safety. During most sampling programs, few fish outside the net are killed. However, sometimes fish kills do occur. Quite often these kills are limited to rotenone-sensitive fish like gizzard shad, threadfin shad and grass carp – thus these types of kills do little to adversely affect the recreationally-important sportfish, but they are noticeable to the public and can cause great concern if not addressed immediately. Regardless of what appears to be a large number of fish, these "outside the net" kills affect only a very small percentage of the total fish community.

Sampling fish with rotenone and multiple blocknets is one of the best methods for obtaining an estimate of total standing crop or fish biomass (per area) at a specific time. The key phrase here is "at a specific time." Fish communities are highly dynamic. Fish abundance can change significantly from year to year. Any sampling, however, will produce results for a specific lake and time that may be highly variable. Recovery of fish from the sampling area may be incomplete. Fish can and do move past the nets. Birds and alligators may eat some of the fish that are killed before biologists can collect them. Some fisheries personnel question the value of rotenone sampling. However, rotenone sampling remains a reliable method for assessing patterns of fish response to differences in lake trophic state within a lake over time or among lakes of varying trophic state. ♦



Black crappie
(Pomoxis nigromaculatus)

PART 2

Trophic State and Total Fish Biomass

Florida LAKEWATCH

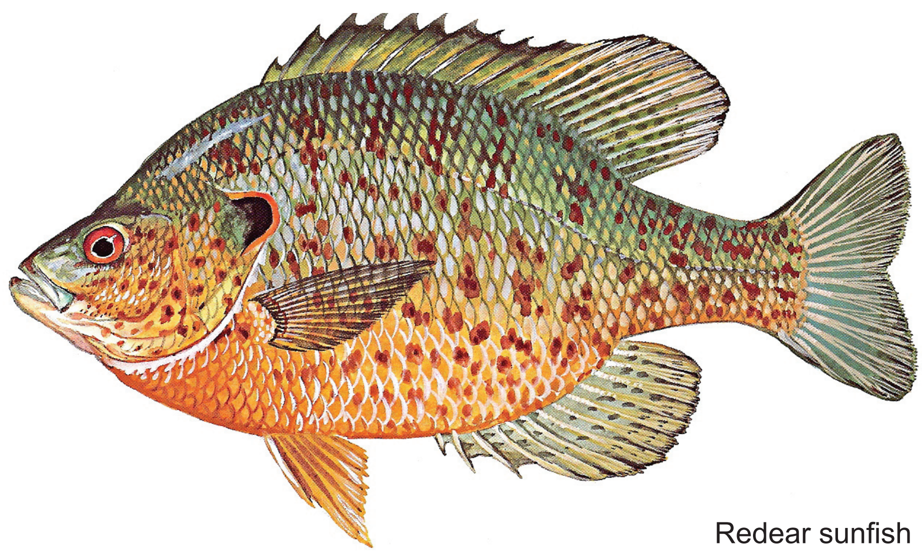
Florida has over 7,700 lakes greater than ten acres in size. Some lakes are biologically unproductive, whereas others support a tremendous amount of fish and wildlife. Professionals often classify lakes according to their biological productivity using one of several trophic state classifications systems. In these systems, the least productive lakes are called oligotrophic lakes. Moderately productive lakes are classified as mesotrophic lakes. Productive lakes are termed eutrophic and the most productive lakes are called hypereutrophic. Lake trophic state is further discussed in greater detail in **A Beginner's Guide to Water Management – Nutrients** (Circular #102).

Professionals generally use four measurements to assess lake trophic state: total phosphorus, total nitrogen, chlorophyll, and Secchi depth. When available, chlorophyll measurements are the best for assigning trophic state because chlorophyll is the most direct measure of biological productivity. Florida LAKEWATCH has shown that average lake chlorophyll concentrations in Florida lakes, participating in the LAKEWATCH program, range from less than one µg/L to over 400 µg/L. Using only Florida LAKEWATCH chlorophyll data, about ten percent of the 1,600 sampled lakes would be classified as oligotrophic (those with chlorophyll values less than or equal to 3 µg/L) and approximately 32% of the lakes (those with chlorophyll values greater than 3µg/L and less than or equal to 7 µg/L) would be classified as mesotrophic. Eutrophic lakes (those with chlorophyll values greater than 7 µg/L and less than or equal to 40 µg/L) would represent about 410% of the lakes; nearly 17% of the lakes (those with chlorophyll values greater than 40 µg/L) would be classified as hypereutrophic.

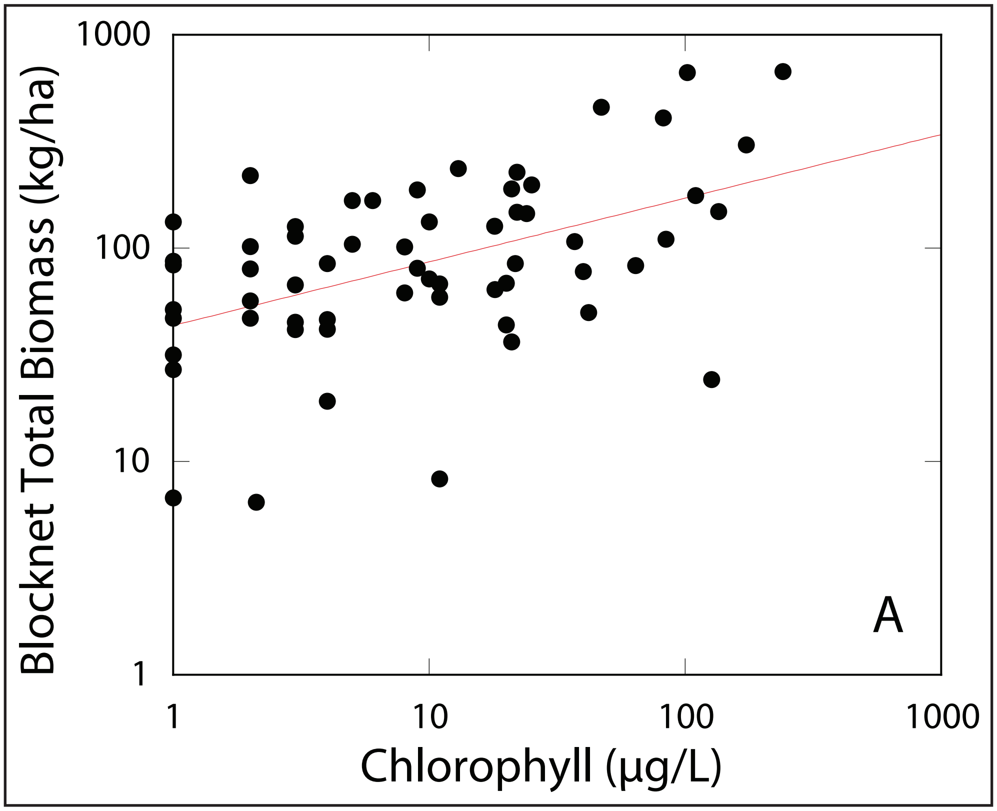
Studies of fish populations in Florida lakes have shown that total fish abundance (expressed by weight) increases with lake trophic state (as indicated by chlorophyll concentrations). This trend is found regardless of whether fish abundance is estimated by use of either rotenone, electrofishing, or gillnet sampling (Figure 2, A-C). On average, fish abundance increases from oligotrophic to hypereutrophic in Florida lakes with no sign of a decrease in the most hypereutrophic lakes. These relationships are consistent with conventional wisdom and with numerous published scientific relations between fish standing crop or yield and several different measures of lake trophic state.

When examining changes in the standing crop of individual fish species, increases in biomass for gizzard shad and threadfin shad are particularly noteworthy. Both fish species are practically absent in oligotrophic-mesotrophic lakes, but increase in both frequency of occurrence and standing crop based on blocknet rotenone sampling in eutrophic and especially hypereutrophic lakes. The average standing crop for gizzard shad, for lakes in which this species is found, is about 66 kg/ha (59 lbs/acre). This is the highest mean biomass for all fish species encountered in studies of Florida lakes. The standing crop for threadfin shad is 21 kg/ha (18.7 lbs/acre) and ranks third behind bluegill (38 kg/ha or 33.8 lbs/acre).

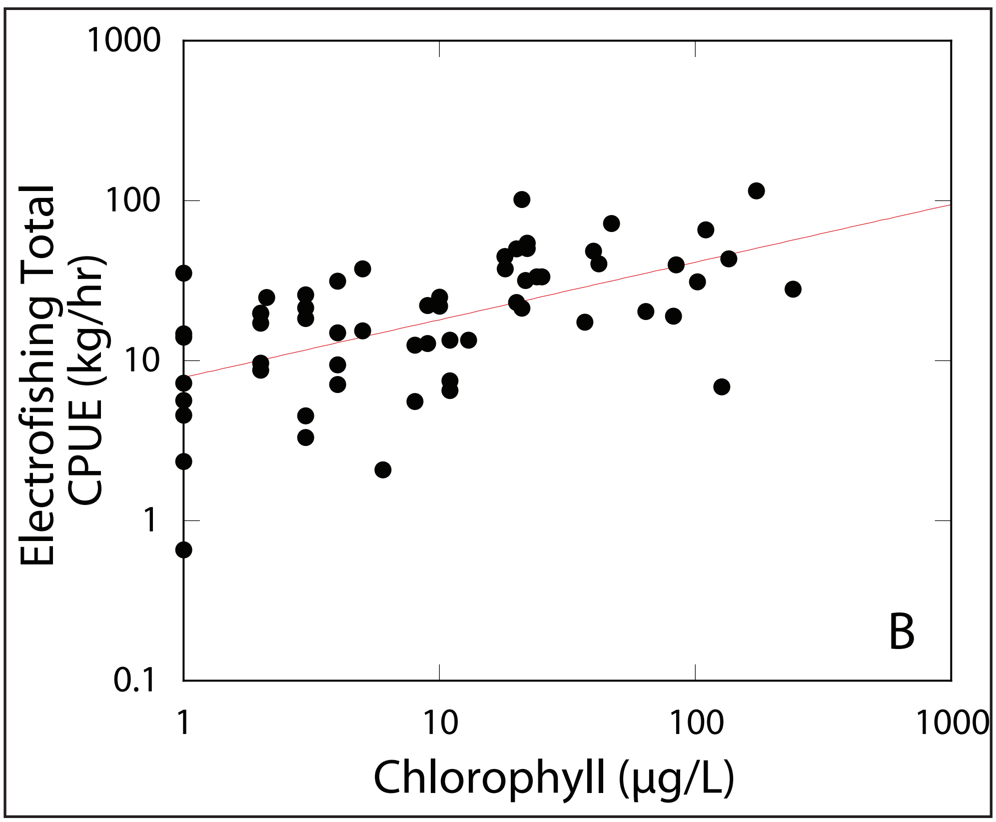
Although there are significant differences in the mean values among the four trophic levels, there is tremendous variability in total fish abundance within any given trophic level (Figure 3). This variability is not unique to Florida lakes, but reflects the importance of other environmental factors such as a lake morphometry, presence of aquatic plants, clay turbidity and population dynamics. There are also practical sampling problems associated with estimating the biomass of wild fish populations. For these reasons, predictions based on the relationships are imprecise; however, holding all other things constant, the total standing crop of fish in a Florida lake should change in the direction that the lake's trophic state changes.



Redear sunfish
(Lepomis microlophus)



Blocknet Total Biomass (kg/ha)
1000
100
10
1
1
10
100
1000
Chlorophyll (µg/L)
A



Electrofishing Total CPUE (kg/hr)
1000
100
10
1
0.1
1
10
100
1000
Chlorophyll (µg/L)
B

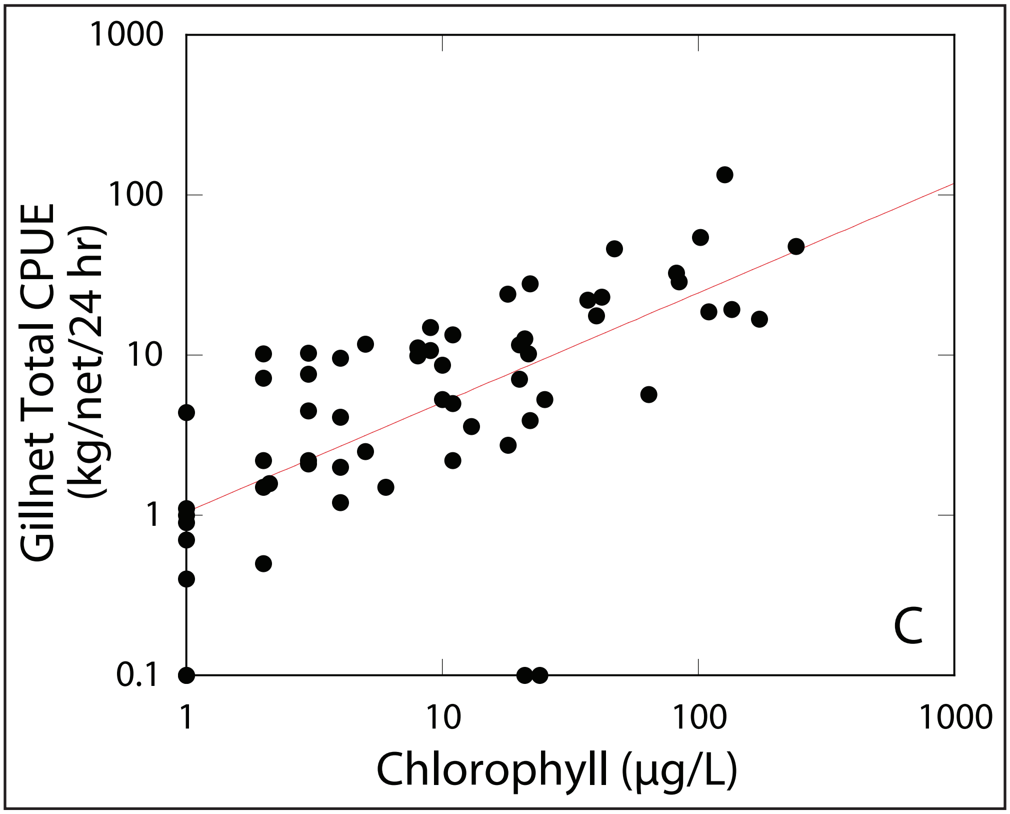


Figure 2 (left and above). Relationships between lake trophic state (chlorophyll concentration) and total fish abundance as estimated with blocknet and rotenone sampling (A), electrofishing (B), and gillnets (C) for 60 Florida lakes. Data for both axes were changed with a logarithmic (base 10) transformation to normalize extreme measurements for comparisons.

Florida gar
(Lepisosteus platyrhincus)

PART 3

Trophic State and Sportfish Biomass

Florida LAKEWATCH

An enduring belief from northern lakes associated with lake eutrophication is that a change to a higher trophic state, resulting from nutrient enrichment of the water body, causes the loss of sportfish populations. This association is untrue for Florida lakes. Blocknet with rotenone, electrofishing, and gillnet sampling all demonstrate that more harvestable sportfish are generally captured in eutrophic and hypereutrophic lakes than oligotrophic lakes (Figure 4, A-C). The belief that sportfish are lost with increases in trophic state is based in part on the fact that piscivorus fish (fish-eating fish), such as largemouth bass, comprise a smaller percentage of the total fish biomass as lakes become more eutrophic. In Florida, studies have shown that piscivorus species as a group averaged about 22% of the total fish biomass, but can range from 0% to 73%. The absolute weights of piscivores do not decrease with increasing trophic state. However, when expressed as a percent of the total biomass, the relative importance (percent abundance) of this group declines as lakes became more productive. On average, the percentage of piscivores for oligotrophic, mesotrophic, eutrophic, and hypereutrophic lakes are 25%, 28%, 21%, and 11% of the total fish biomass, respectively.

One of the most important piscivores, the largemouth bass, on average makes up 15% of the total fish biomass in Florida lakes, but can range as low as 0% to over 69%. As with the biomass of piscivores, the absolute biomass of largemouth bass population does not decrease with an increase in trophic state though their percentage of the total fish biomass becomes smaller at higher trophic state. On average, the percentages of largemouth bass by weight of the total fish biomass in oligotrophic, mesotrophic, eutrophic, and hypereutrophic lakes are approximately 20%, 17%, 16%, and 4%, respectively. Mark-recapture studies show that oligotrophic lakes support just under ten harvestable (>10 inches or 250 mm total length) largemouth bass/ha and eutrophic Florida lakes support between 25 and 30 harvestable largemouth bass/ha. This is why Florida's eutrophic lakes are some of the State's best fishing lakes. Although hypereutrophic lakes have largemouth bass populations that make up only about four percent of the total fish biomass, these lakes support nearly 20 largemouth bass/ha (8 bass/acre), which is a greater abundance than that supported by Florida's oligotrophic and mesotrophic lakes.

Most sportfish in Florida belong to the family of fish called Centrarchidae. This family of fishes includes the largemouth bass (*Micropterus salmoides floridanus*), bluegill (*Lepomis machrochirus*), redear sunfish (*Lepomis microlophus*), and black crappie (*Pomoxis nigromaculatus*), which are the primary freshwater sportfish in Florida. On average, studies of 60 Florida lakes indicate that Centrarchids make up 66% of the total fish biomass. Centrarchid biomass, however, ranges from 15% to 99% across the 60 lakes. This group of fish also shows a pattern of increasing absolute biomass with increase in trophic state and a decrease in percent biomass in lakes of higher trophic state.

Bluegill show no changes in mean standing crops or in proportions of larger fish with increases in trophic status. The redear sunfish, also known as the shell-cracker, generally increases in biomass with increases in lake trophic state. Another important Centrarchid, the black crappie or speckled perch also becomes more common and has higher standing crops in more eutrophic lakes. While black crappie biomass increases, there is a tendency for a smaller proportion of quality-sized (larger) fish in more eutrophic lakes.

Redear sunfish (shell-cracker) are not commonly found in Florida's oligotrophic lakes. This is probably the result of the low pH, total alkalinity, and hardness associated with many of the State's oligotrophic lakes, which limits the preferred food (snails) of the shell-cracker. Black crappie are also not found in abundance in Florida's oligotrophic lakes because low lake productivity limits the food supply for this species. One type of Centrarchid commonly found in the oligotrophic lakes is the warmouth. Warmouth, unlike other Centrarchids, shows increases in standing crop with decreases in trophic state.

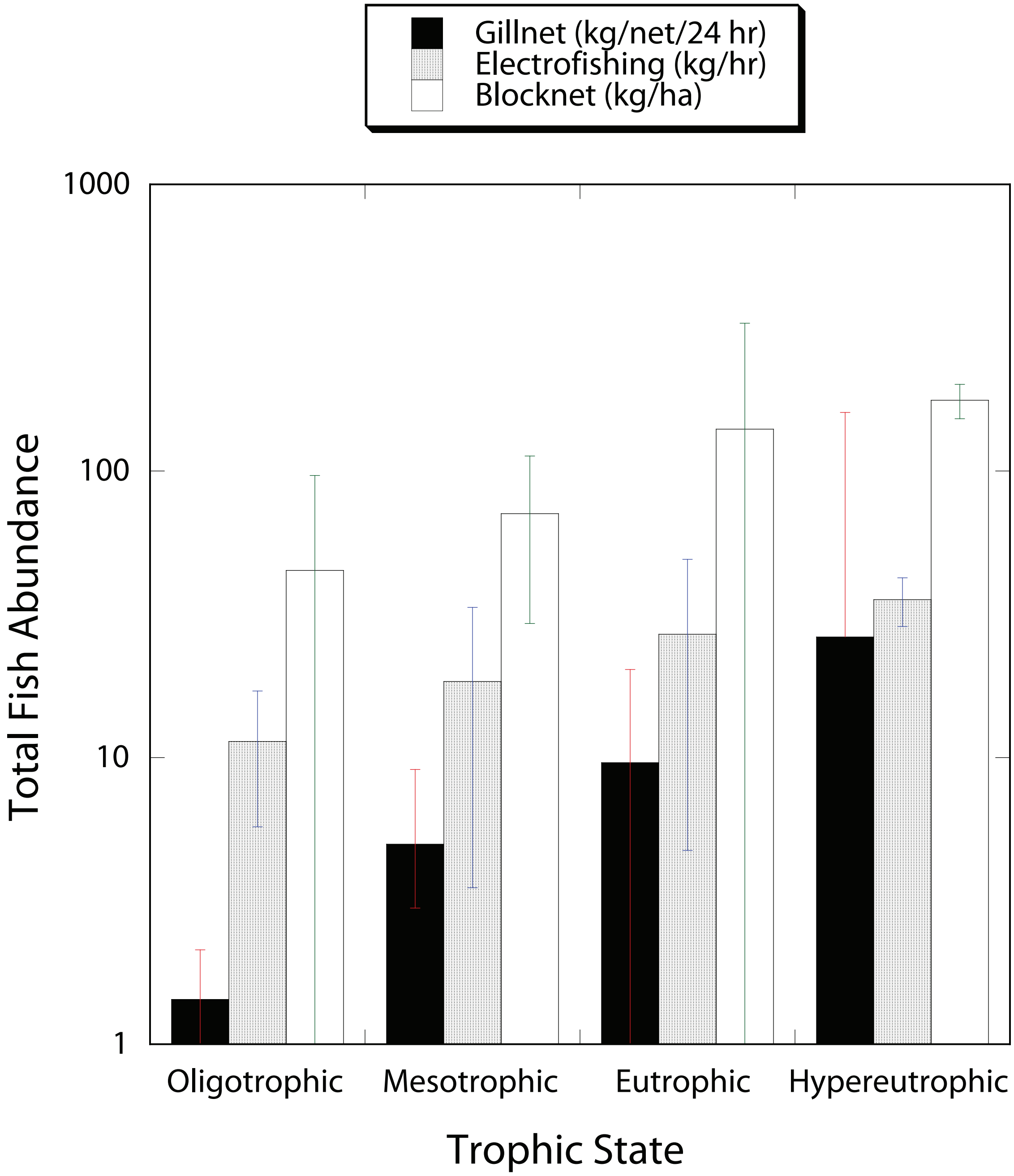
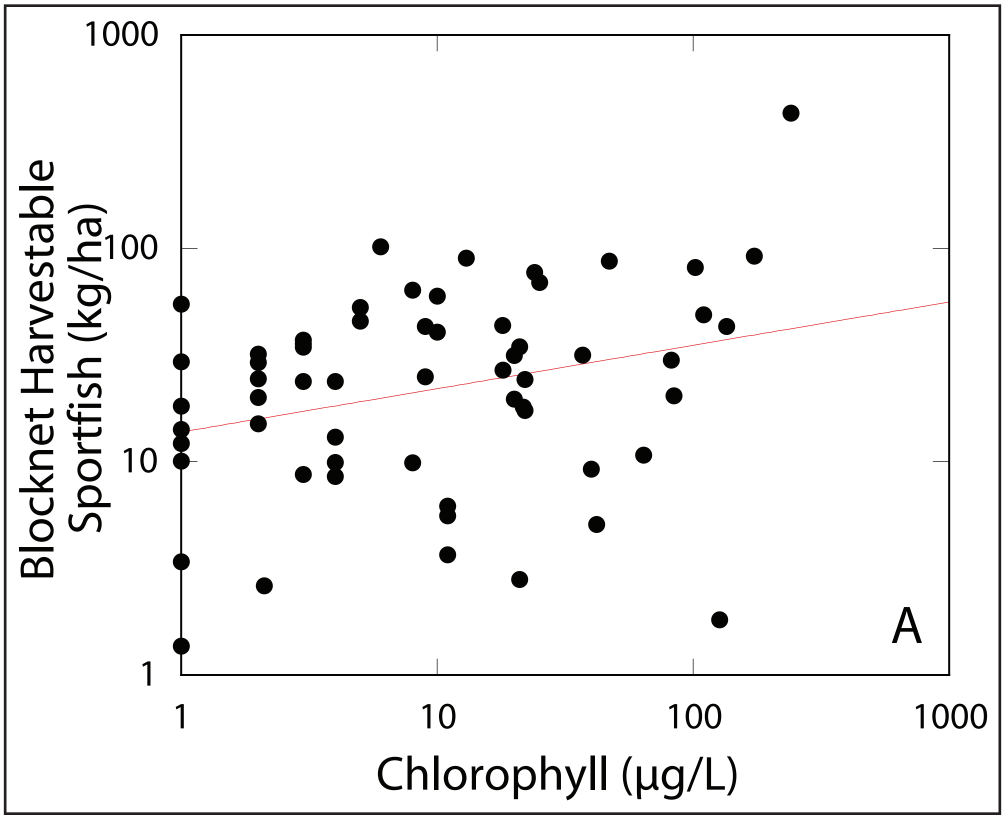
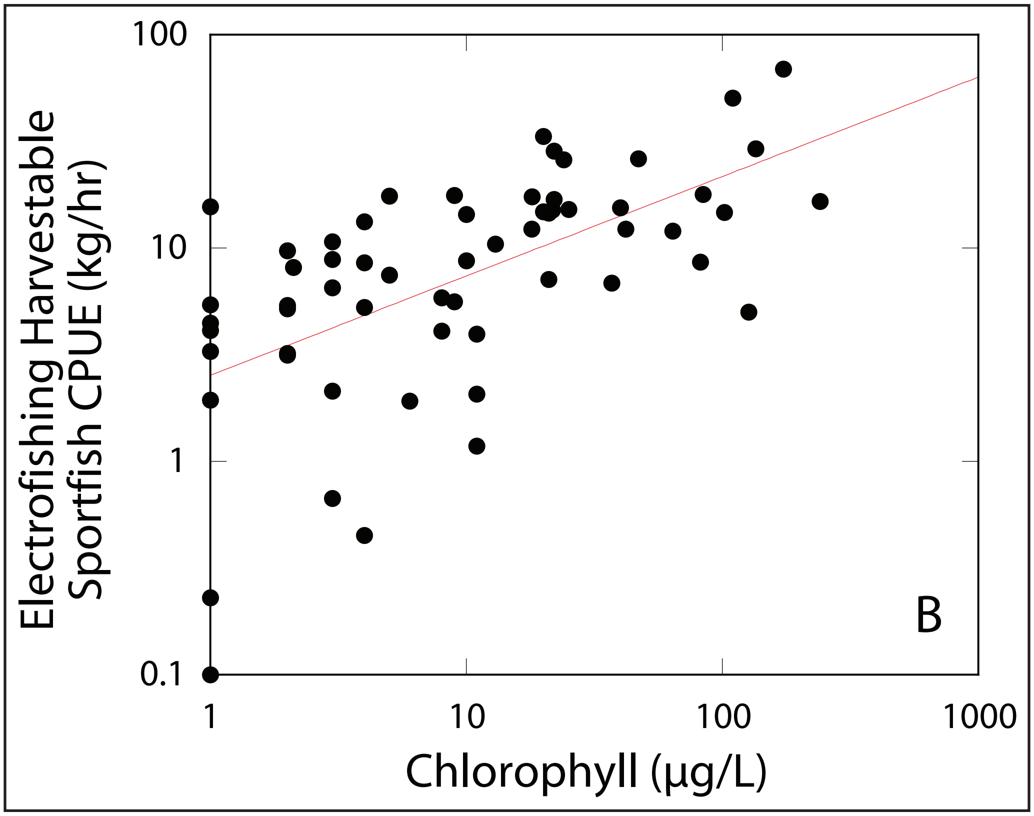


Figure 3. Mean total fish abundance estimated with gillnets, electrofishing, and blocknets (with rotenone) by lake trophic state for 60 Florida lakes. The bars indicate means and lines represent the 95% confidence intervals. There were 8, 7, 25, and 20 lakes for oligotrophic, mesotrophic, eutrophic and hyperuetrophic groups, respectively.


1000
100
10
1
1
10
100
1000
Blocknet Harvestable Sportfish (kg/ha)
Chlorophyll (µg/L)
A


100
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1000
Electrofishing Harvestable Sportfish CPUE (kg/hr)
Chlorophyll (µg/L)
B

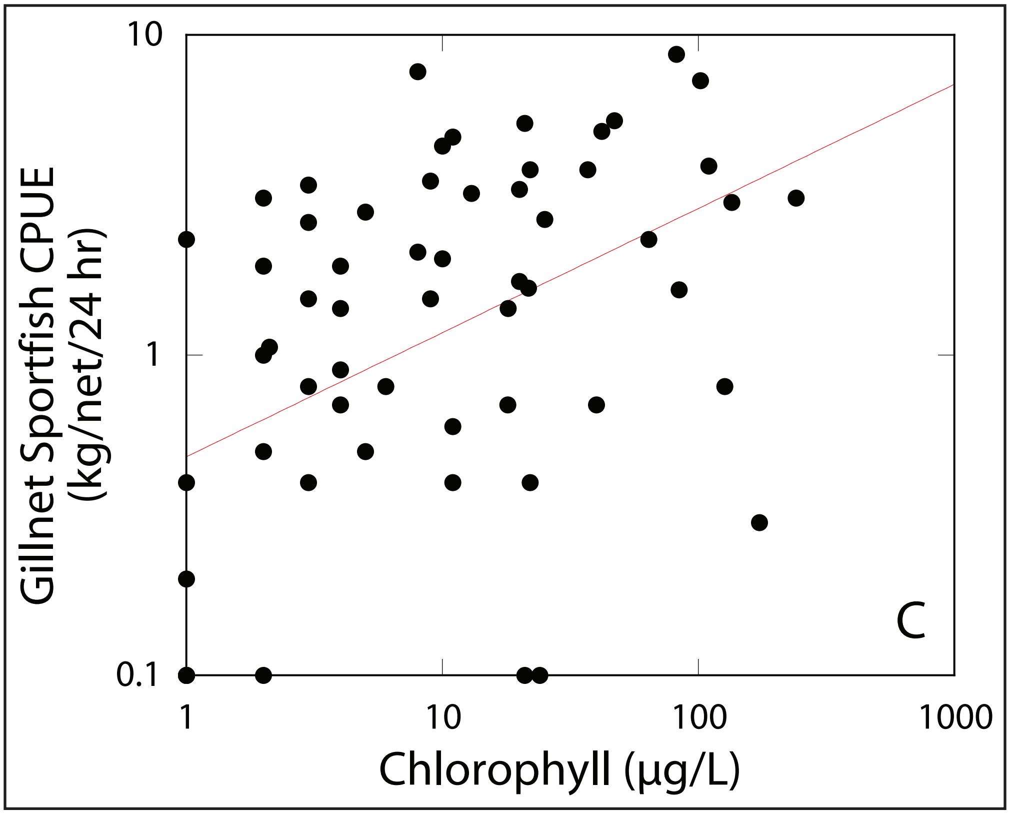


Figure 4 (above and at left). Relationships between lake trophic state (chlorophyll concentration) and harvestable sportfish abundance as estimated with blocknet and rotenone sampling (A), electrofishing (B), and gillnets (C) for 60 Florida lakes. Data for both axes were changed with a logarithmic (base 10) transformation to normalize the extreme measurements for comparisons.

PART 4

Trophic State and Species Richness

The number of different species of fish (species richness) inhabiting a lake is often used as an indicator of fish community quality and lake quality. Florida lakes support more than 100 species of fish, but all of these species are rarely, if ever, collected in a single lake. The large number of species encountered reflects the fact that Florida is at the center of some major biogeographical (animal dispersal) movements. Non-native fish are colonizing lakes in south Florida. Waters in the panhandle of Florida support species that have evolved in the central continental

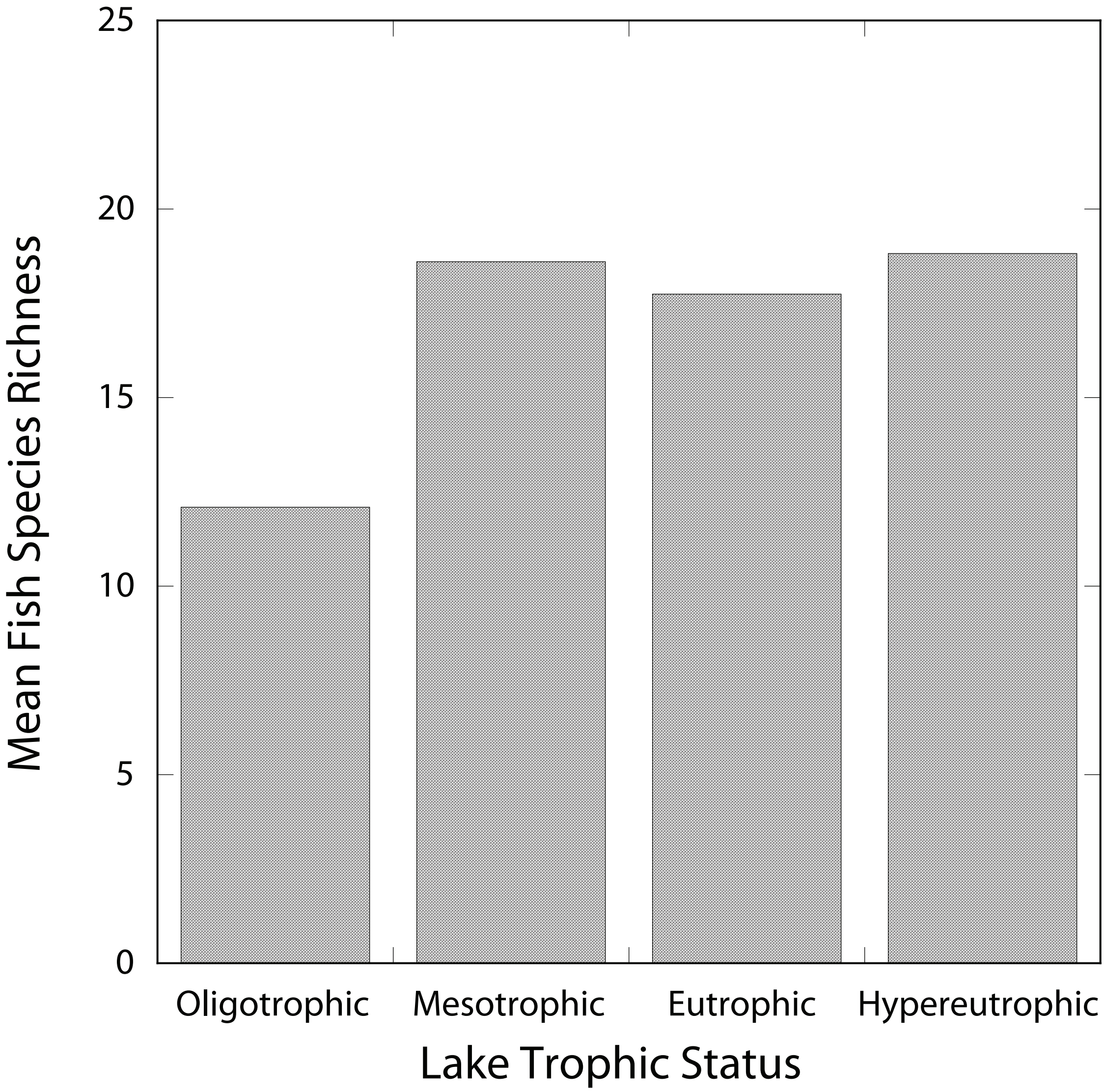


Figure 5. Relationship between lake trophic state (estimated with chlorophyll concentration) and mean fish species richness for 60 Florida lakes.

United States. Waters in northeast Florida support fish species that have evolved along the Atlantic coast. Some lakes, like Lake Okeechobee, even support marine fishes because there are often no physical barriers preventing the inland movement of these fishes.

The number of fish species per lake does not decrease in eutrophic and hypereutrophic Florida lakes (Figure 5). The most important determinant of fish species richness is lake surface area; larger lakes tend to have higher species richness than smaller lakes (Figure 6). For example, Lake Okeechobee, a large lake in south Florida, has 41 species of fish, while Lake Lawbreaker, a small lake (5 ha or 12 acres) in central Florida, maintains only four species of fish. Surface area explains about 70% of the variation in species richness. Species richness is only weakly related to the commonly measured trophic state variables of total phosphorus, total nitrogen, chlorophyll, and Secchi depth. However, there is no correlation between the number of fish species per lake and the various trophic state indices, after first accounting for lake surface area. ♦

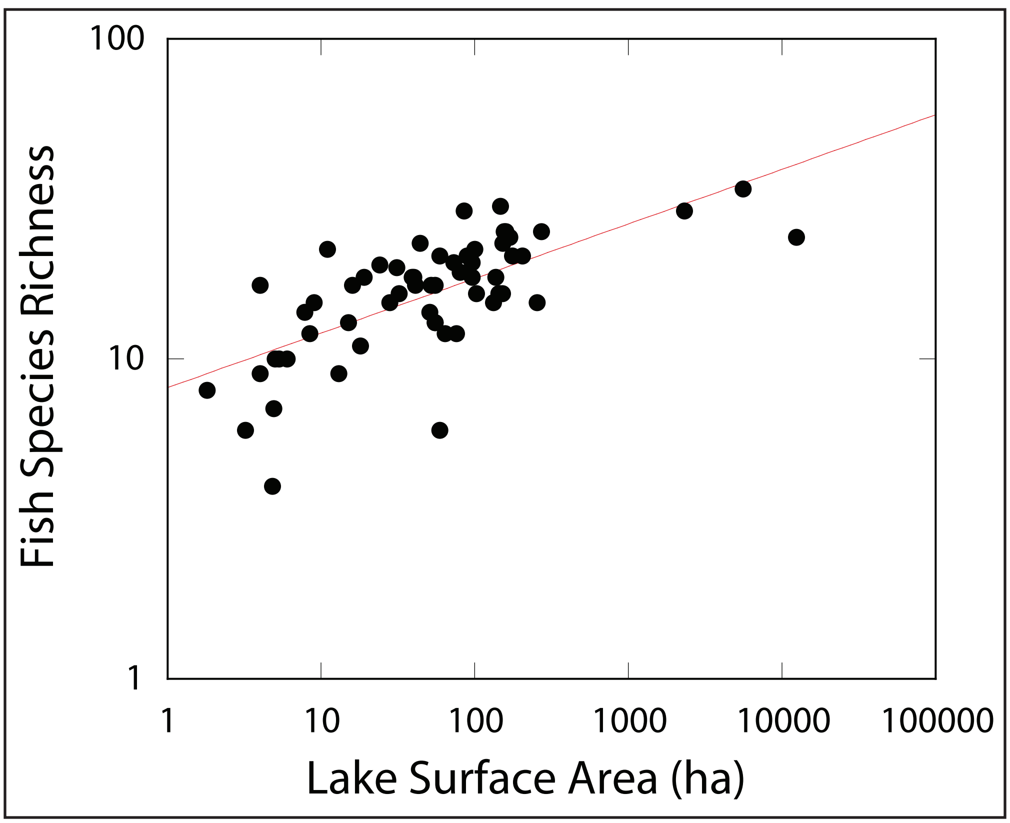


Figure 6. Relationship between lake surface area and fish species richness for 60 Florida lakes.

PART 5

Trophic State and Some Common Florida Fish Species

The public is often concerned about specific fish species rather than all species of fish. As of 2007, it is difficult to make statements regarding the pattern of response of many fish species to lake eutrophication. This situation exists because many fish species are extremely low in abundance and occur in only a small percentage of Florida lakes; there is therefore, little information on many of the fish species.

The Department of Fisheries and Aquatic Sciences at the University of Florida collected more than sixty different fish species during a five-year study of 60 Florida lakes. Table 2 on page 7 shows the most prevalent fish in Florida lakes. Some species, such as bluegill, largemouth bass, warmouth, mosquitofish, and redear sunfish, were commonly encountered and found in greater than 75% of the study lakes. Fifteen of the fish species collected during this study were found in only a single lake.

Redfin pickerel were found to be most common in less productive lakes, while channel catfish were more likely to be in lakes of higher productivity. However, of the 29 species with sufficient information for statistical tests, only 3 species, the lake chubsucker, the golden topminnow, and the lined topminnow showed decreases in frequency of occurrence (number of lakes within a given trophic status) with increasing trophic state. All other species either stayed the same or increased in frequency of occurrence in the eutrophic and hypereutrophic lakes.

A similar pattern was found for average standing crops of individual species in lakes of differing trophic status. Most species showed no significant difference in biomass (kg/ha) among lakes of different trophic state. However, warmouth decreased while five additional species, the gizzard shad, threadfin shad, black crappie, redear sunfish, and blue tilapia showed increases in standing crops with increasing trophic state. Again, for the recreationally important Centrarchids, the only negative changes noted with increasing trophic status were a decrease in the standing crops of warmouth and a decrease in the proportion of larger-sized black crappie. On the positive side, the Centrarchids as a group showed an increased biomass in the more eutrophic lakes. The redear sunfish and black crappie increased in average standing crop and the largemouth bass had a higher proportion of larger fish in the more eutrophic lakes.

Brown bullhead
(Ameiurus nebulosus)

Implications for the Management of Florida Lakes

Many Floridians have come to Florida from northern states. The same is true for many of the professionals involved in Florida lake management. The beliefs of many citizens and professionals are based on experiences and information derived from northern lakes. Thus, it is important to consider the similarities and differences between Florida and northern lakes when evaluating the effects of changing trophic state on fish communities and the ecology of the lakes in general.

The fish population trends discussed in this circular for Florida lakes fit the patterns found for other lakes discussed in the published fisheries literature. There is an increase in the total standing crops of fish as the concentrations of total phosphorus, total nitrogen, and chlorophyll increase and as the Secchi depth decreases. On average, fish standing crops increase about ten-fold from the oligotrophic to the hypereutrophic Florida lakes, with no sign of a decrease in the most hypereutrophic lakes.

There is considerable unexplained variation (approximately 75%) in these relationships due in part to other factors influencing fish standing crops and the practical sampling problems associated with estimating the biomass of wild fish populations. This is true for both Florida lakes and northern lakes. For this reason, predictions based on these relationships are imprecise; however, holding all other things constant, the standing crop of fish in a Florida lake or northern lake should increase as the nutrient concentrations increase.

This is not surprising considering that the abundance of many aquatic organisms in Florida lakes as well as other lakes around the world have been shown to be positively related to lake trophic state, which is generally defined by the limiting nutrient concentrations, primarily phosphorus. Chlorophyll concentrations (Canfield 1983), zooplankton abundance (Canfield and Watkins 1984), fish biomass (Jones and Hoyer 1982), bird abundance (Nilsson and Nilsson 1978), and even the abundance of top predators, such as the alligator (Evert 1999), have all been shown to be positively related to the trophic status of lakes. The bottom line is that when the base productivity of a system is increased, the biomass of aquatic organisms will likely increase.

The relationships discussed in this circular between fish populations and trophic status are based on the study of many Florida lakes of varying trophic status rather than individual lakes that have undergone eutrophication over time. This places a limit on predictions that can be made for any single lake. Because of the scatter in the original data, due in part to the many unexplained factors influencing fish populations and the problems associated with obtaining accurate standing crop information for fish, there would be problems in making precise predictions of fish standing crops for a specific lake that only has data on basic water chemistry.

On the other hand, there are some general patterns in the relationships between lake trophic state and the total biomass, species richness, species composition, and species standing crops of fish in Florida lakes that should be useful in a predictive manner. First, the number of fish species in a lake seems to be determined primarily by the area of the lake and not its trophic status, so one should not expect dramatic changes in total species numbers as a lake becomes more or less eutrophic. Second, there might be shifts in species composition with changes in trophic state, though only a few species show significant changes in their standing crops. In particular, the recreational sportfish do not show large changes over the trophic spectrum. Finally, no critical points on the trophic spectrum can be identified that cause dramatic changes in fish abundance and standing crops; there is nothing comparable in Florida lakes to the loss of dissolved oxygen in the hypolimnion of eutrophic northern lakes.

Florida lakes, with up to 240 µg/L of algal chlorophyll (hypereutrophic), show no decrease in biomass of important sport fish, except the warmouth. Although some people believe that Lake Okeechobee is undergoing eutrophication and the lake's fisheries are threatened, there is no evidence of a declining fishery. Many fisheries biologists believe that the loss of submersed macrophytes due to high water levels is an issue of greater concern. Even Lake Apopka, Florida's most talked about hypereutrophic lake, is not a "dead" lake. The lake supports many fish including the recreationally important black crappie and commercially valuable catfish. What the lake does not support is a large population of largemouth bass, which is the fish that once made Lake Apopka a world-class fishing lake. Why the largemouth bass is virtually absent from the lake is debated, but what is known is that largemouth bass live in Lake Apopka and the ones that survive are some of the fastest growing largemouth bass in Florida. It seems the biggest problem is the lack of habitat for young fish, particularly submersed macrophytes. Submersed plants were lost in this lake during the late 1940s.

These studies illustrate a paradox in lake management. For many purposes, the public would prefer to have less productive lakes where low nutrient concentrations result in low plankton productivity and high water clarity. These lakes are most suitable for water supply and contact (swimming, water skiing, etc.) recreation and also have pleasing aesthetic properties. On the other hand, the more eutrophic lakes have larger fish populations and a potential for higher yields for sport fisheries. This basic fact has caused some professionals to worry not about eutrophication, but cultural oligotrophication - the reduction of nutrient inputs due to human management activities. Thus, if a nutrient reduction program is successful and reduces algal populations, it will benefit one group of lake users, but at the same time, there is the potential to reduce fish abundance to the detriment of other users.

Other Relevant Research and Information

Bachmann R. W., B. L Jones, D. D. Fox, M. Hoyer, L. A., and D. E. Canfield, Jr. 1996. Relations between trophic state indicators and fish in Florida (U.S.A.) lakes. Canadian Journal of Fisheries Aquatic Sciences 53: 842-855.

Bays, J.S., and T.L. Crisman. 1983. Zooplankton and trophic state relationships in Florida lakes. Canadian Journal of Fisheries and Aquatic Sciences 40: 1813-1819.

Canfield, D.E., Jr. 1983. Prediction of chlorophyll a concentrations in Florida lakes: the importance of phosphorus and nitrogen. Water Resources Bulletin 19: 255-262.

Canfield, D.E., Jr., and C.E. Watkins, II. 1984. Relationships between zooplankton abundance and chlorophyll a concentrations in Florida lakes. Journal of Freshwater Ecology 2: 335-344.

Canfield D.E., Jr., and M.V. Hoyer. 1992. Aquatic macrophytes and their relation to limnology to Florida lakes. Final Report submitted to the Bureau of Aquatic Plant Management, Florida Department of Natural Resources. Tallahassee, Florida. University of Florida, Gainesville, Florida. 598 pp.,

Colby, P.J., G.R. Spangler, D.A. Hurley, and A.M. McCombie. 1972. Effects of eutrophication on salmonid communities in oligotrophic lakes. Journal of the Fisheries Research Board of Canada 29: 975-983.

Evert, J.D. 1999. Relationships of alligator (*Alligator mississippiensis*) population density to environmental factors in Florida Lakes. M. S. Thesis. University of Florida. Gainesville, Florida. 88 pp.

Hanson, J.M., and W.C. Leggett. 1982. Empirical prediction of fish biomass and yield. Canadian Journal of Fisheries and Aquatic Sciences 39: 257-263.

Hoyer, M.V., and D.E. Canfield, Jr. 1996. Largemouth bass abundance and aquatic vegetation in Florida lakes: an empirical analysis. Journal of Aquatic Plant Management 34: 23-32.

Jones, J.R., and M.V. Hoyer. 1982. Sportfish harvest predicted by summer chlorophyll a concentration in midwestern lakes and reservoirs. Transactions of the American Fisheries Society 111: 176-79.

Kautz, R.S. 1980. Effects of eutrophication on the fish communities of Florida lakes. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 34: 67-80.

Keller, A.E. and T.L. Crisman. 1990. Factors influencing fish assemblages and species richness in subtropical Florida lakes and a comparison with temperate lakes. Canadian Journal of Fisheries and Aquatic Sciences 47: 2137-2146.

Lee, G.F., P.E. Jones, and R.A. Jones. 1991. Effects of eutrophication on fisheries. Reviews in Aquatic Sciences 5: 287-305.

Nilsson, S.G., and I.N. Nilsson. 1978. Breeding bird community densities and species richness in lakes. Oikos 31: 214-221.

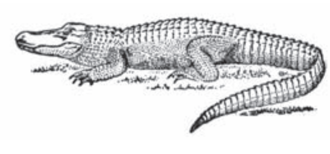
Oglesby, R.T. 1977. Relationships of fish yield to lake phytoplankton standing crop, production, and morphoedaphic factors. Journal of the Fisheries Research Board of Canada 34: 2271-79.

Schultz E.J., M.V. Hoyer, and D.E. Canfield, Jr. 1999. An index of biotic integrity: a test with limnological and fish data from sixty Florida lakes. Transactions of the American Fisheries Society 128: 564-577.

Stocker J.G., E. Rydin, and P. Hyenstrand. 2000. Cultural oligotrophication causes and consequences for fisheries resources. Fisheries 25: 7-14.

Yurk, J.J., and J.J. Ney. 1989. Phosphorus-fish community biomass relationships in southern Appalachian reservoirs: Can lakes be too clean for fish? Lake and Reservoir Management 5: 83-90.

Notes:



Florida LAKEWATCH

Florida LAKEWATCH (FLW) is one of the largest citizen-based volunteer monitoring endeavors in the country with more than 1,500 individuals monitoring more than 700 lakes and other bodies of water in more than 50 Florida counties. Staff from the University of Florida's Department of Fisheries and Aquatic Sciences train volunteers throughout the state to conduct monthly long-term monitoring of both fresh and saline waterbodies. LAKEWATCH uses the long-term data to provide citizens, agencies and researchers with scientifically-sound water management information and educational outreach.

To become part of the Florida LAKEWATCH team, volunteers are required to have access to a boat and complete a two-hour training session. During the session, volunteers learn to collect water samples, take water clarity measurements, and prepare algae samples for laboratory analysis. Once a volunteer is certified by a regional coordinator and sampling sites are established, he or she will sample the designated stations once a month. Samples are frozen immediately upon being collected and are later delivered to a collection center, where they are stored until they can be picked up by Florida LAKEWATCH staff and delivered to the Univerity of Florida IFAS water chemistry laboratory at the Department of Fisheries and Aquatic Sciences.

In return for participation, volunteers receive:

- Personalized training in water monitoring techniques;
- Use of lake sampling materials and water chemistry analysis;
- Periodic data reports, including an annual data packet regarding their waterbody;
- Invitations to meetings where FLW staff provides an interpretation of the findings as well as general information about aquatic habitats and water management;
- Access to freshwater and coastal marine experts;
- Free newsletter subscription and educational materials regarding lake ecology and water management.

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