EFFECTS OF STOCKING WILD-ADULT LARGEMOUTH BASS ON THE FISHERY AT LAKE GRIFFIN, FLORIDA

By

DARREN JOHN PECORA

A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

UNIVERSITY OF FLORIDA

2009

To my mother, father, and sisters for their unconditional love and support

ACKNOWLEDGMENTS

I thank my graduate advisor, Dr. Dan Canfield Jr., without whom none of this would have been possible. I also thank my committee members, Dr. Charles Cichra and Jim Estes for their guidance and advice. I thank Mark Hoyer for his guidance and assistance and Florida LAKEWATCH staff and graduate students for their field and logistical help, particularly Jesse Stephens, Bubba Thomas, Dana Bigham, Jenney Lazzarino, and Kurt Larson. I thank Sherry Giardina for helping me with forms and meeting deadlines. I thank the following individuals for help on this project Dan Gwinn, Mike Allen, Lauren Marcinkiewicz, Towns Burgess, Jared Flowers, Bill Pine, Matt Catalano, John Benton, and Bill Johnson. I thank my friends and family who have kept encouraging me through this endeavor. Finally, I thank God!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract of Thesis Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Master of Science

EFFECTS OF STOCKING WILD-ADULT LARGEMOUTH BASS ON THE FISHERY AT LAKE GRIFFIN, FLORIDA

By

Darren John Pecora

August 2009

Chair: Daniel E. Canfield, Jr.
Major: Fisheries and Aquatic Science

Lake Griffin was stocked with approximately 14,000 wild-adult largemouth bass from 2005 to 2007 to stimulate economic activity related to the fishery. An electrofishing survey was initiated at Lake Griffin in 2007 to determine the status of the stocked fish population 3 years after stocking. The mean dispersal distance from stocking sites for 122 caught stocked largemouth bass was 2.9 km, with the maximum-recorded distance being 9.2 km. Mean CPUE (fish/hour) of native largemouth bass between canal and main lake areas were not significantly different, indicating stocked and wild fish were mixing evenly. Mortality estimates for stocking years 2006 (Z= 1.087) and 2007 (Z=1.295) are similar to the 2007 native largemouth bass estimates (Z= 1.054). There was no change in native largemouth bass condition post stocking. The stocked largemouth bass in May 2007 contributed 13% to total electrofishing largemouth bass catch, with a CPUE of 0.09 (fish/minute) immediately after the last stocking in 2007. Two years later, in March 2009, the total electrofishing catch of stocked largemouth bass was 3%, with a 0.03 (fish/minute) CPUE. Water level and macrophyte abundances were the primary environmental factors influencing largemouth bass abundance, but management actions focusing on these factors have been rejected by the public, and climatic conditions may prevent enhanced lake fluctuation. To enhance the largemouth bass fishery at Lake Griffin, construction of

artificial habitat is recommended for the main lake along with continued stocking of wild adult largemouth bass. Stocking wild-adult largemouth bass captured from non-fished waters is a cost-effective fisheries management tool, supported by anglers, and the weight of scientific evidence suggests only positive effects.

CHAPTER 1
INTRODUCTION

Largemouth bass (*Micropterus salmoides*) is one of the most sought after sportfish in the United States (U. S. Department of the Interior 2006). Florida largemouth bass (*M.s.floridanus*) is an economically important game fish, contributing 632 million dollars per year to Florida's economy (U. S. Department of the Interior 2006). Lake Griffin, a 6,680-ha hypereutrophic lake in Central Florida, supported a recreational fishery valued at 2.3 million dollars annually in the late 1980s (Milon and Welsh 1989). However, the value of the sport fishery had declined by 90% by the late 1990s, which was directly linked to the decline of the largemouth bass fishery (Benton 2000). According to Larson (2009), the stocking of wild-adult largemouth bass into Lake Griffin by the University of Florida's Florida LAKEWATCH program after 2004 was responsible for an economic improvement of up to 2.7 million dollars per year. The reported economic enhancement by stocking wild-adult largemouth bass, however, has been questioned. Fish sampling revealed that only up to 10% of the Lake Griffin largemouth bass population consisted of the Florida LAKEWATCH-stocked largemouth bass soon after stocking. This lead to the questioning of the effectiveness of the enhancement by Florida Fish and Wildlife Conservation Commission (FFWCC) biologists working on Lake Griffin (HCLRC 2007) and University of Florida faculty (Dr. Mike Allen, personal communication, University of Florida). The low catch rate of stocked fish may have been the result of not stocking enough fish, fish moving out of the lake, or an excessive fish mortality rate from handling stress or a lack of adequate forage.

The sport fish population and fishery of Lake Griffin were at a historical low point in 1999 (Benton 2000). As a result, interest in stocking the lake with largemouth bass became a priority for the Harris Chain of Lakes Restoration Council, a legislatively-appointed citizen's advisory group (Chapter 373.467 F.S. and the Lake County Water Authority, a special taxing district for the management of Lake County's lakes). These groups, after hearing the pros and cons of stocking fingerling, advanced fingerling, and adult largemouth bass, authorized a research/demonstration stocking project by Florida LAKEWATCH in an attempt to enhance the fishery quickly (within 3 years) by increasing the abundance of catchable-size fish. The LAKEWATCH approach was to stock Lake Griffin with large numbers (4,000 plus fish/year) of wild-adult (> 200 mm total length (TL); average size stocked 305 mm TL) largemouth bass taken from private waters (Larson 2009).

Supplemental stocking of hatchery-produced largemouth bass is a common management practice by fish management agencies throughout the United States; Forty-one states have stocked hatchery-raised fry, fingerling, advanced-fingerling, or adult largemouth bass (Smith and Reeves 1986). Limited literature exists on the success of stocking programs for hatchery-raised sub-adult and adult largemouth bass into large systems (Porak 1994, Buynak et al. 1999). Porak et al. (2002), however, suggested stocking advanced fingerling largemouth bass could provide a potential approach to circumvent a largemouth bass recruitment bottleneck caused by the loss of aquatic macrophytes, and increase recruitment of largemouth bass to age one in nutrient-enriched Florida lakes. This suggestion is based in part on research conducted by Wicker and Johnson (1987), who found that high rates of mortality occur when age-0 largemouth bass shift to piscivory in a hypereutrophic Florida lake.

Use of advanced sizes of hatchery produced largemouth bass was also supported by research on a wide range of Florida lakes indicating that poor recruitment in lakes may be related to decreased shoreline habitat to lake surface area ratio (Hoyer and Canfield 1996); hence, the importance of macrophytes is increased for large lakes. Aquatic macrophyte structural complexity is an important habitat feature for young-of-the-year and sub-adult largemouth bass survival (Hoyer and Canfield 1996) by providing reduced predation (Strange et al. 1975) and increased prey (Crowder and Copper 1982). When stocking non-adult largemouth bass into waters with no cover or structure, stocked largemouth bass mortality up to 90% can be expected (Miranda and Hubbard 1994). Although it is now generally accepted that larger-sized stocked largemouth bass exhibit higher survival than smaller fish (Heidinger and Brooks 2002), aquaculture production of advanced fingerlings and adult fish in hatcheries remains difficult and expensive.

Advanced fingerling largemouth bass (65 to 90 mm total length [TL]) are now produced at the Richloam State Fish Hatchery by FFWCC, but successful stocking has only been documented in one Florida lake (Mesing 2008), despite attempts to stock advanced sizes of largemouth bass into Florida lakes (Porak et al. 2002). Lorenzen (1996) found lower mortality for stocked fish that were raised in aquaculture systems where the fish fed on natural foods and were raised in earthen ponds. Lorenzen's (1996) findings led Florida LAKEWATCH to conclude in 2003 that stocking adult-sized fish from non-aquacultured (i.e., wild fish) private natural waters should aid in reducing stocking mortality, and enhance long-term survival of stocked fish in a large lake system where numerous predators such as birds and other fish species exist. In many northern states, stocking hatchery-raised adult trout is a common management practice for a variety of recreational fisheries, especially "put and take" fisheries (Miko et al. 1995). Survival of hatchery reared trout is expected to be low and harvest of these fish is encouraged. The only comparable practice for warm water fish is the collection of fish from drained water bodies and their relocation to other water bodies (e.g., Carlander 1954). In the 1950s, fish rescue programs were conducted frequently in the upper Mississippi River drainage basin where adult fish were relocated from lands flooded by the river to nearby lakes and reservoirs. For a while, the fish rescue programs were an important fisheries management tool. Consequently, collection and stocking of wild-adult largemouth bass from non-fished private Florida waters could also become a useful fisheries management tool in Florida.

As with any tool, its cost-benefit must be considered. There are dollar costs and biological costs, especially if the management tool has a negative impact (e.g., reduced fish condition factor resulting from over stocking) on the fisheries. A review of the literature finds stocking programs often report mixed results because of different agency objectives (Hoffman and Bettoli 2005). More importantly, the positive impacts of largemouth bass stocking programs on fisheries are often underestimated (Copeland and Noble 1994) because there are no established guidelines to measure the success of supplemental stocking (Heidinger and Brooks 2002). Biologists use a number of different criteria to evaluate stocking programs, including: stocked fish harvested, percent of stocked fish in a year class, and cost:benefit ratios (Heidinger and Brooks 2002). Cost-benefit ratios are typically calculated from creel surveys that evaluate the catch of stocked fish by anglers.

Florida LAKEWATCH is the only organization to stock wild-adult largemouth bass on such a massive scale in Florida (Florida LAKEWATCH 2007). Larson (2009) studied the associated economic activity at Lake Griffin for Florida LAKEWATCH following the stocking of wild-adult largemouth bass and concluded the approach was cost-effective based on the estimated revenue generated and the stimulation of angler interest. However, the survival of stocked fish and their contribution to the fishery has been questioned as a result of findings from a FFWCC creel survey of Lake Griffin in 2006, two years after the initial stocking. This creel survey, however, only covered the main stem of Lake Griffin, not its adjoining canals, marshes, the Ocklawaha River, and other backwaters, where the majority (65%) of Florida LAKEWATCH-stocked fish were caught according to angler tag call-in reports (Larson 2009).

Largemouth bass must move at some point in their lives to use available resources throughout a water body/reservoir (Copeland and Noble 1994). Heidinger and Brooks (2002) stated that because stocked largemouth bass are relocated fish, they initially do not have a home range and exhibit more movement than native largemouth bass. Dequine and Hall (1950) found that stocked largemouth bass move variable distances (0 to 9.6 km, with one fish moving 15.3 km) from where they were released. While the movement pattern of stocked Florida LAKEWATCH fish was unknown to Larson (2009), it was clear, from tag returns that stocked fish were moving outside the main area of Lake Griffin. This movement of largemouth bass raised the issue of how long stocked wild-adult largemouth bass would persist in Lake Griffin and how long anglers could expect to catch these fish given the many environmental factors that could also affect largemouth bass survival.

To address some of the biological issues surrounding Florida LAKEWATCH's wild-adult largemouth bass stocking program, this project had four primary objectives:

1) Determine the dispersal distance of stocked wild-adult largemouth bass,
2) Determine the persistence, mortality, and percent contribution over time of the LAKEWATCH stocked largemouth bass,
3) Determine if the stocked largemouth bass were exhibiting greater abundance in canals over the main lake or were being displaced into canal areas,
4) Determine what environmental factors influence largemouth bass abundance and the largemouth bass fishery in Lake Griffin.

The dispersal of stocked largemouth bass was investigated because it provided insight into fish movement that could influence management decisions such as the number of stocking sites needed for a given water body. More importantly, dispersal information provided evidence to help determine if stocked wild-adult fish die from transportation stress or how many adjoining waters could be influenced through a single-lake stocking program. In this project, dispersal information obtained through fishery-independent sampling (electrofishing) also assisted with determining if stocked fish were preferentially using adjoining canals rather than the main lake at Lake Griffin.

The percent contribution of stocked fish to electrofishing catches was determined along with what percent of stocked largemouth bass remained in Lake Griffin after a two-year period of no stocking. The mortality of stocked largemouth bass was determined through information obtained from the electrofishing catches. The estimated mortality rate was compared to native largemouth bass mortality in Lake Griffin to determine if stocked fish mortality is greater.

A change in condition factor for native Lake Griffin largemouth bass after the stocking was investigated to insure there was an adequate forage base. Stocking adult-wild fish could be detrimental to Lake Griffins' largemouth bass population if the existing largemouth bass population is near carrying capacity.

Trends in historical water quality and habitat abundance, especially total phosphorus (µg/L), total nitrogen (µg/L), chlorophyll (µg/L), Secchi depth (cm), mean water level (ft), yearly change in water level (ft), and whole-lake aquatic macrophyte percent aerial coverage were specifically investigated to determine if there are patterns between these environmental variables and Lake Griffin's largemouth bass population size as assessed by historical electrofishing (CPUE) and roving creel surveys. If patterns exist, workable guidelines for the future management of largemouth bass in Lake Griffin could be formulated.

The determination of persistence, mortality, and percent contribution of stocked adult-sized largemouth bass in to the Lake Griffin population of largemouth bass provided information so that managers can make judgments about whether stocking these fish is an effective tool. It also provided information about how often stocking might be needed to meet a particular management goal. Additionally, information about the dispersal of stocked fish, and a determination of whether stocked fish preferentially chose un-surveyed canals was important to explain the patterns of persistence that might be observed. The influence of environmental factors affecting largemouth bass abundance and the fishery was investigated so that the use of the stock enhancement project could be described in a broader management context.

CHAPTER 2
STUDY SITE DESCRIPTION AND LAKE GRIFFIN'S ENVIRONMENTAL HISTORY

Introduction

Lake Griffin is a large (6,680 ha) hypereutrophic (mean chlorophyll 99 µg/L; Table 2-1) freshwater lake in central Florida (Figure 2-1) (Canfield 1981). The lake has been studied by numerous organizations since the 1940s and this study used a great deal of the historical environmental information understand the environmental factors influencing Lake Griffin's largemouth bass population. Water level information from 1946 to 2007 was obtained from St. Johns River Water Management District (SJRWMD). Water quality data including chlorophyll, total nitrogen, and total phosphorus concentrations as well as Secchi depth (1969 to 1978 and 1981 to 1994) were primarily obtained from FFWCC (personal communication Bill Johnson, Eustis Laboratory), but information was also obtained from the files of Florida LAKEWATCH (1979 to 1980; downloaded from wateratlas.org) and SJRWMD (1995 to 2007; personal communication Brian Sparks, Palatka office). Total aquatic macrophyte coverage (percent lake surface area), as estimated by aerial photography since 1947, was obtained from the files of FFWCC (personal communication Bill Johnson, Eustis Laboratory). The Florida Department of Environmental Protection (FLDEP) provided estimates of the percent area coverage of hydrilla (personal communication Rob Kipker, Tallahassee office). Largemouth bass population abundance data, including electrofishing catch-per-unit-effort (CPUE) and roving creel data (harvest, catch, effort), were obtained from FFWCC (personal communication Bill Johnson, Eustis Laboratory).

Geography

Lake Griffin is located primarily in Lake County, Florida, (Shafer et al. 1986) (Figure 2-1) in Florida's Central Valley physiographic region (Canfield 1981). Lakes in the Central Valley are biologically productive lakes (eutrophic to hypereutrophic) and Lake Griffin is one of FFWCC's fish management lakes (Administrative code Rule 68A-20.004). Approximately 3,804 ha constitute the main lake and are used for open water recreational activities (SJRWMD 2003), with the remaining area (2,876 ha) made up of primarily swamp and wetlands which were historically dominated by sawgrass (*Cladium jamaicense*), but were drained and diked off from 1955 to 1990 for muck farming (Marburger et al. 2002). There are approximately 40 canals (24+ kilometers in length) around Lake Griffin which were dredged prior to 1960 to provide landowners access to the lake, and these canals were maintenance-dredged between 2005 and 2007 (Figure 2-2).

Lake Griffin is one of nine water bodies in the Harris Chain of Lakes (also known as Ocklawaha Chain of Lakes). Lake Griffin serves as the headwaters of the Ocklawaha River, a major tributary of the St. Johns River. Lake Griffin receives water, which passes through a dam on Haines Creek primarily from the eight upstream lakes, while a dam downstream on the Ocklawaha River (Moss Bluff) regulates water levels in Lake Griffin according to the U.S. Army Corps of Engineers regulation schedule (Schluter and Godwin 2003).

Water Levels

The mean water level for Lake Griffin since 1946 was 58.65 ft, with a recorded minimum level of 56.63 ft and a maximum level of 60.14 ft (SJRWMD; Table 2-1, Figure 2-3). The mean annual change in water level for the period of record was 1.84 ft, with a recorded annual minimum change of 0.91 ft and an annual maximum change of 7.14 ft (Table 2-1, Figure 2-3). On average, the water levels were much higher in Lake Griffin before 1960 with a peak at 60.14 feet after Hurricane Donna. This overall trend in decreasing water level since 1960 is due to lack of rainfall explained by the Atlantic Multidecadal Oscillation (Kelly and Gore 2008). Major yearly changes in water level occurred in 1974 and 1984. In 1974, the Moss Bluff dam on the outlet of Lake Griffin broke causing a large (4.2 ft) fluctuation in water level (Figure 2-3). The next major event in 1984 (7.1 ft) was an experimental drawdown and subsequent refill by FFWCC to improve the fishery. The least amount of yearly fluctuation occurred between 1995 and 2002 (Table 2-1, Figure 2-3). From 1995 through 2002, Florida was under statewide drought conditions (Veredi et al. 2006).

Water Quality

In many Florida lakes, cultural eutrophication has been a major concern over the past 30 years, with many efforts aimed at reducing nutrient inputs (Terrell et al. 2000). Until recently, Lake Griffin was considered one of the most polluted lakes in Florida (SJRWMD 2003). Over the past 50 years, farming activities, water-level stabilization, and residential development around the lake have caused significant degradation in water quality and clarity (Schluter and Godwin 2003). Large nutrient inputs from adjoining agricultural operations have been targeted as the primary cause of dense algal blooms which have purportedly increased deposition of soft organic sediments to the benthic substrate (Schluter and Godwin 2003). Lake Griffin is the subject of major environmental restoration. Some restoration efforts on Lake Griffin include: farm land acquisition, lake level fluctuation, removal of gizzard shad, and a marsh filtration system (SJRWMD 2003). All of these activities except lake level fluctuation are aimed at reducing nutrient loading to and nutrient concentration in the system, particularly phosphorus, while lake level fluctuations are intended to improve the vegetated habitat of the lake. Consequently, Lake Griffin has been the subject of many environmental studies and a long-term record exists for many physical, chemical and biological attributes.

Total phosphorus concentrations, ranging from 47 µg/L to 181 µg/L, exhibited a downward trend from1973 to 2007 (Figure 2-4), but the long-term phosphorus mean was 100 µg/L (Table 2-1). The highest levels of total phosphorus generally corresponded with low water level years, suggesting wind-induced resuspension when water depth is low (Bachmann et. al. 2000) and the hydraulic flushing rate of the lake may be important factors influencing in-lake water chemistry.

Total nitrogen concentrations, unlike phosphorus concentrations, increased over time (Figure 2-5). Total nitrogen averaged 3140 µg/L, and ranged from 2240 µg/L to 5630 µg/L (Table 2-1). The measured concentrations reflect the nutrient enriched status of Lake Griffin, and like phosphorus, maximum total nitrogen concentrations were typically higher during low water level years (especially the drought period from 1995 to 2002).

Like total nitrogen, chlorophyll concentrations in Lake Griffin increased between 1995 and 2000 (Figure 2-6). For the period of record, chlorophyll concentrations averaged 99 µg/L and ranged from 27 µg/L to 316 µg/L (Table 2-1). Also like total phosphorus and total nitrogen, the maximum chlorophyll values corresponded with low water levels and drought conditions from 1995 to 2002. Water clarity, as measured by use of a Secchi disc declined from 1995 to 2002 (Figure 2-7) as expected since chlorophyll concentrations influence water clarity in Florida lakes (Canfield and Hodgson 1981). Over the historical record, Secchi disc readings averaged 37 cm, ranging from 6 cm to 76 cm (Table 2-1). The lowest water clarity was measured during the 1995 to 2002 drought period when total phosphorus, total nitrogen, and chlorophyll concentrations were the greatest. Water transparency has remained less than 30 cm in Lake Griffin since 1995 (Figure 2-7).

Aquatic Macrophytes

Nearly half of Lake Griffin was covered by aquatic macrophytes (estimated by aerial photograph analysis, Bill Johnson FFWCC), particularly spatterdock (*Nuphar luteum*) (Figure 2-8). Boat trails were cut into the dense aquatic vegetation, primarily on the north end of the lake, to allow boaters access. Aquatic plant surveys conducted between 1983 and 2006 by FLDEP indicate that the non-native hydrilla (*Hydrilla verticillata*) peaked in abundance (11% areal coverage) in 1987 following the 1984 experimental drawdown (Figure 2-9). By 2001, hydrilla coverage was reduced to 0.009% and overall aquatic plant coverage was reduced to <2% by 2006 (Figure 2-9). Lake Griffin has changed from a macrophyte dominated system to an open-water algal system since the 1960s with many of the water quality changes reflecting expectations with the establishment of the new alternative state (Bachmann et al. 1999).

Largemouth Bass Population

Largemouth bass electrofishing CPUE were depressed during the late 1990s and early 2000s (Figure 2-10). Young of the year (<200 mm) largemouth bass electrofishing CPUE was the highest ever recorded following the1984 drawdown (Figure 2-10). This large1984 year class can be seen in the fishery for years following the 1984 drawdown with historic high catches of harvestable sized fish (>360 mm, Figure 2-10).

Largemouth Bass Fishery

Roving creel surveys were first conducted by FFWCC starting in 1966. Estimates of catch and release of largemouth bass were not made during the early years of the creel survey. An estimated 23,722 largemouth bass were harvested during the first year (1968) the survey was conducted, which was the highest harvest on record (Figure 2-11). Catch (catch and release) of largemouth bass, first estimated in 1978, reached a high point of 20,000 fish in 1987 and a low of 121 fish in 2003 (Figure 2-11). Catch and harvest of largemouth bass have declined since 1971 except following the experimental drawdown in 1984.

Table 2-1. Water level and water quality parameters (mean and ranges) for Lake Griffin, Florida.

Parameters	Mean Water Level (ft)	Yearly Change in Water Level (ft)	Total Nitrogen (µg/L)	Total Phosphorous (µg/L)	Secchi (cm)	Chlorophyll (µg/L)
Mean	58.65	1.84	3140	100	37	99
Minimum	56.63	0.91	2243	47	6	27
Maximum	60.14	7.14	5630	181	76	316

Note: Data obtained from FFWCC, Florida LAKEWATCH, and SJRWMD.

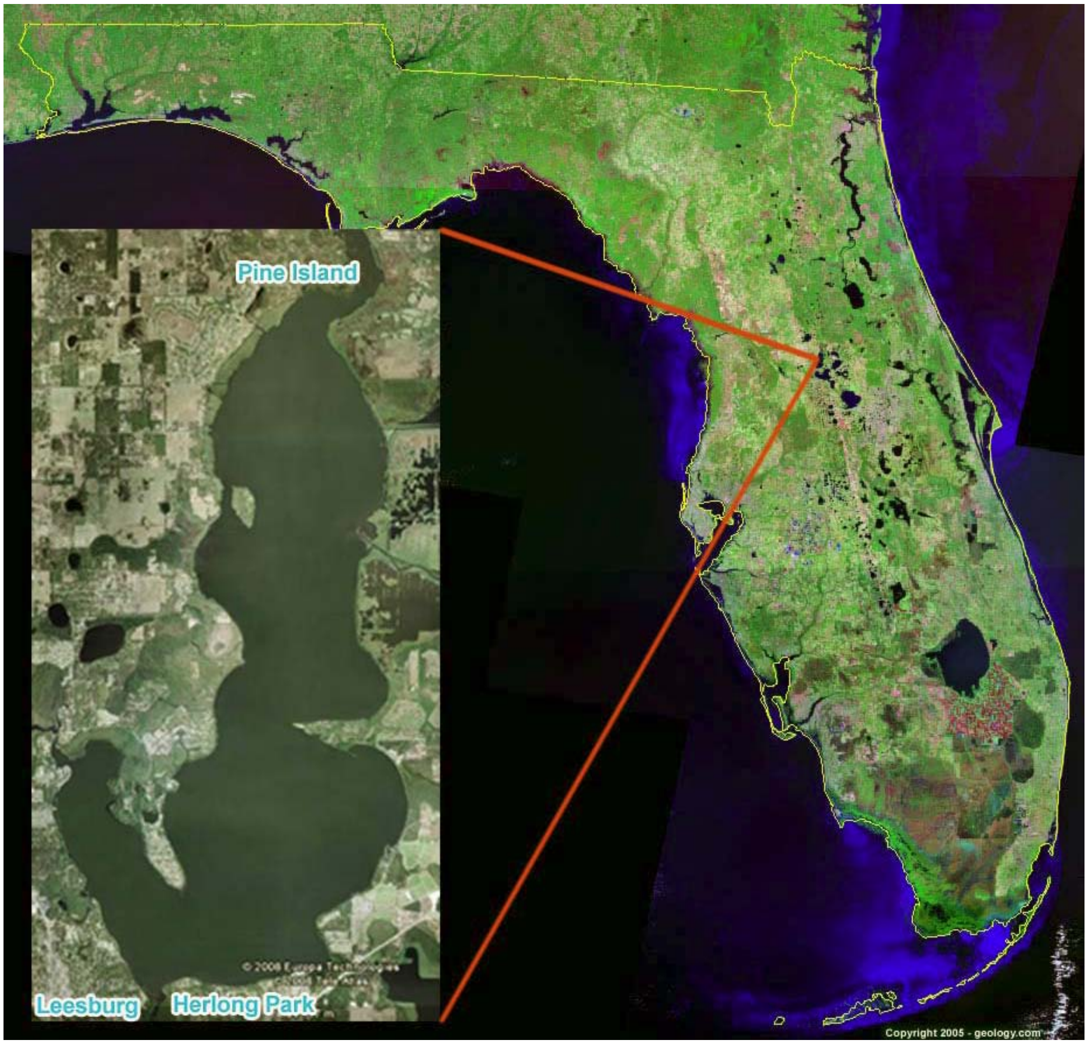


Figure 2-1. Map of Lake Griffin, Lake County, Florida.

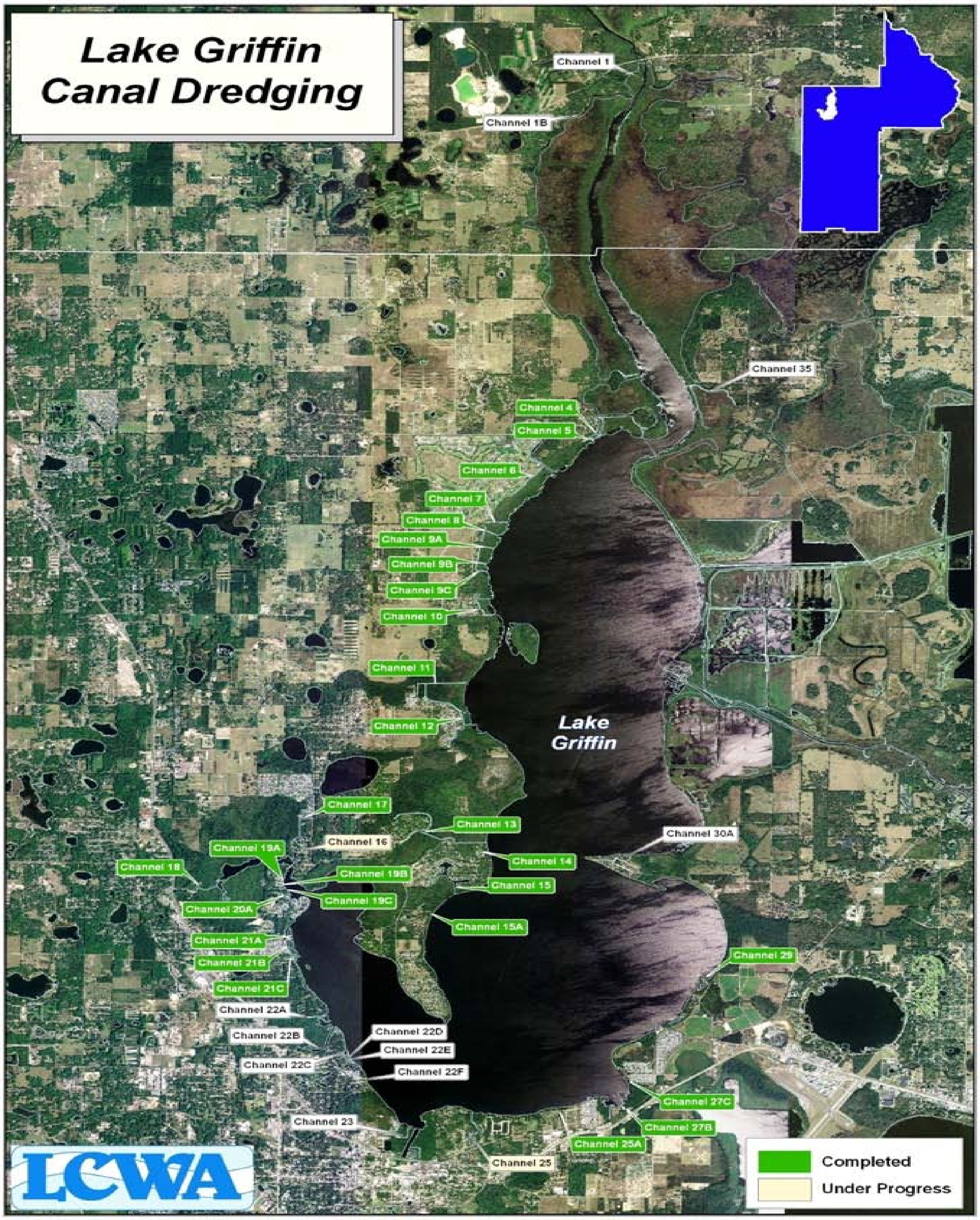


Figure 2-2. Map of Lake Griffin canals which were dredged from 2005 to 2007.

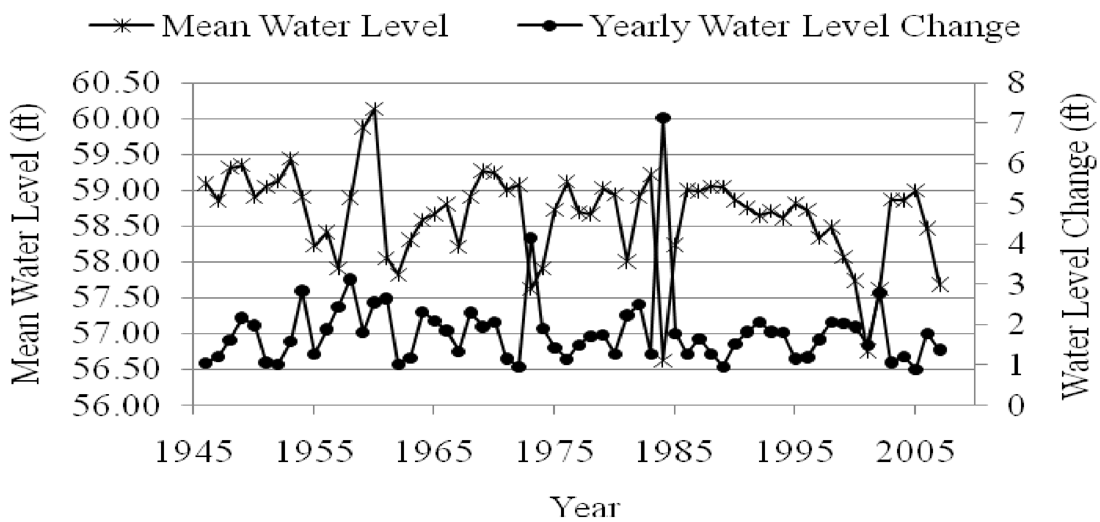


Figure 2-3. Annual mean water level and yearly change in water level from 1946 to 2007, for Lake Griffin, Florida (data obtained from SJRWMD).

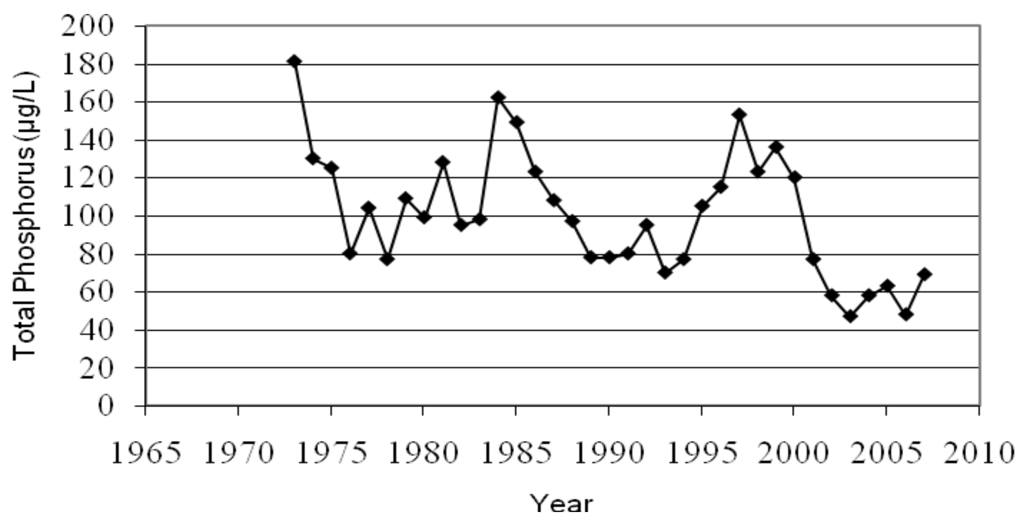


Figure 2-4. Annual mean total phosphorus (µg/L) for Lake Griffin, Florida (data obtained from FFWCC, SJRWMD, and Florida LAKEWATCH).

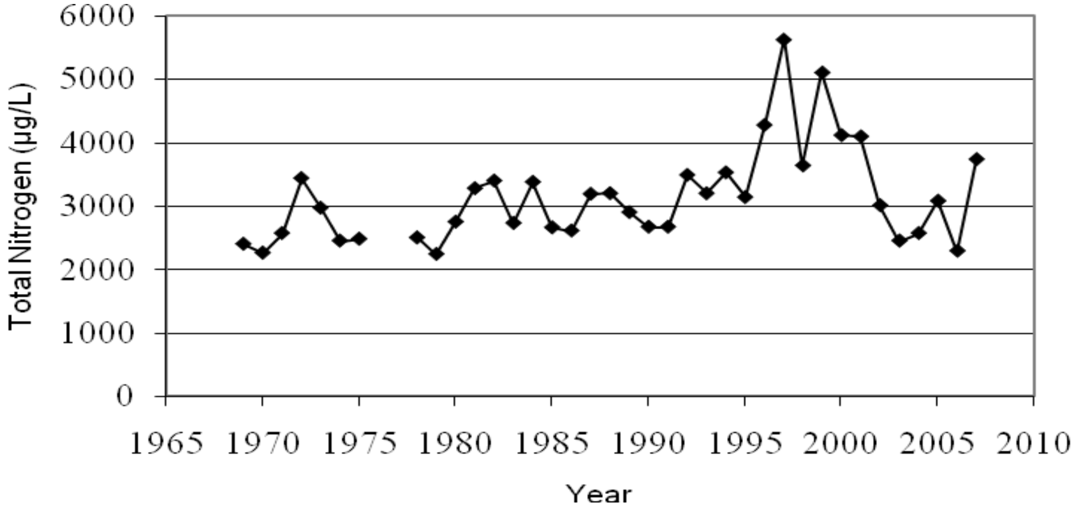


Figure 2-5. Annual mean total nitrogen (µg/L) for Lake Griffin Florida (data obtained from FFWCC, SJRWMD, and Florida LAKEWATCH).

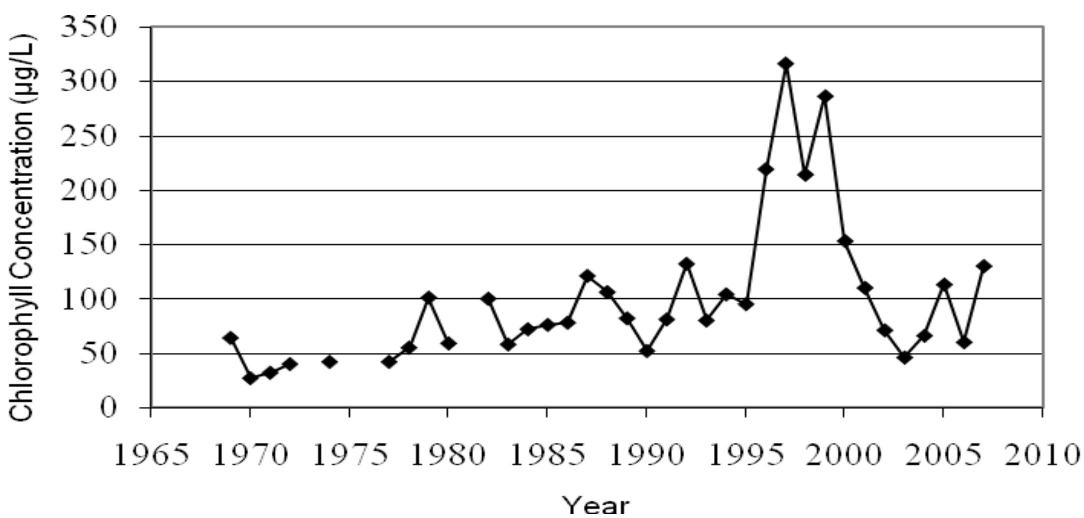


Figure 2-6. Annual mean chlorophyll concentrations (µg/L) for Lake Griffin, Florida (data obtained from FFWCC, SJRWMD, and Florida LAKEWATCH).

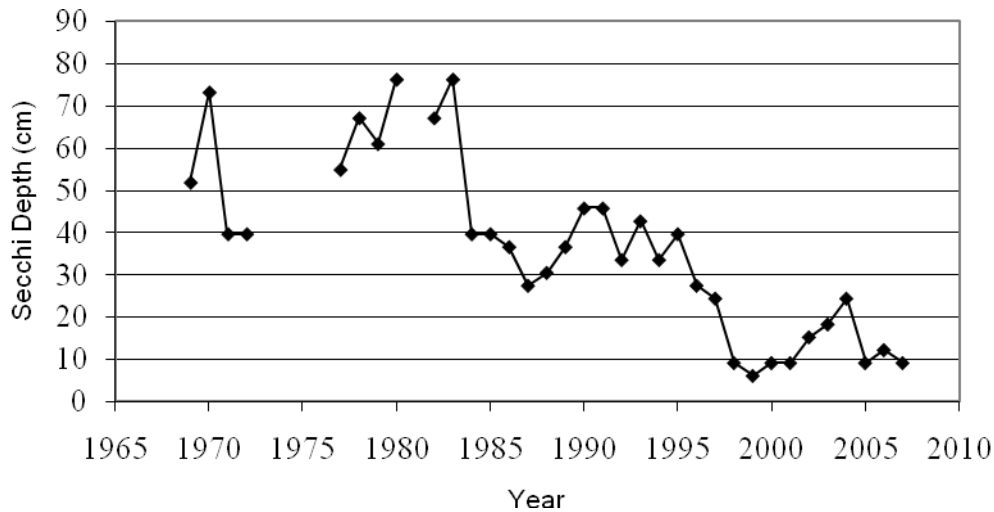


Figure 2-7. Annual mean Secchi depth (cm) for Lake Griffin, Florida (data obtained from FFWCC, SJRWMD, and Florida LAKEWATCH).

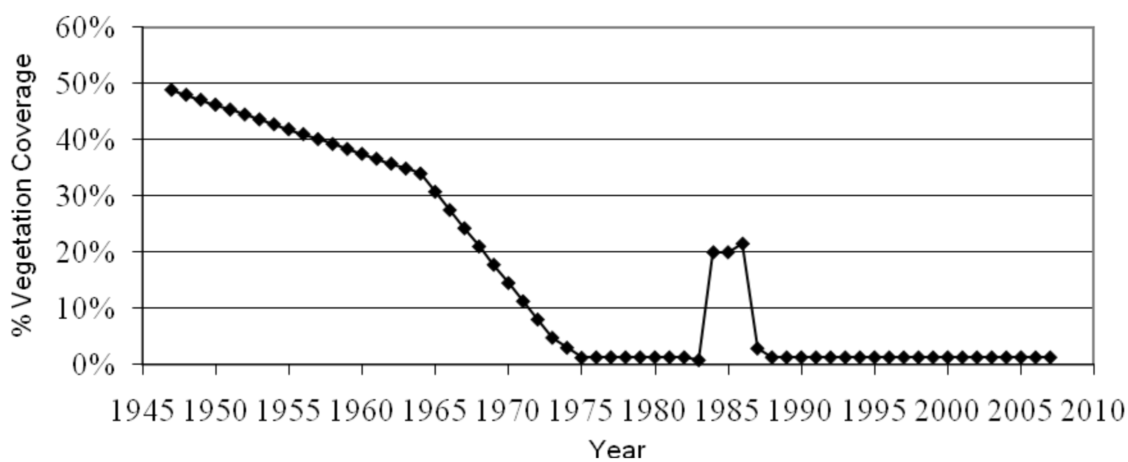


Figure 2-8. Aquatic macrophyte areal coverage estimated by aerial photographs, for Lake Griffin, Florida (data obtained from FFWCC).

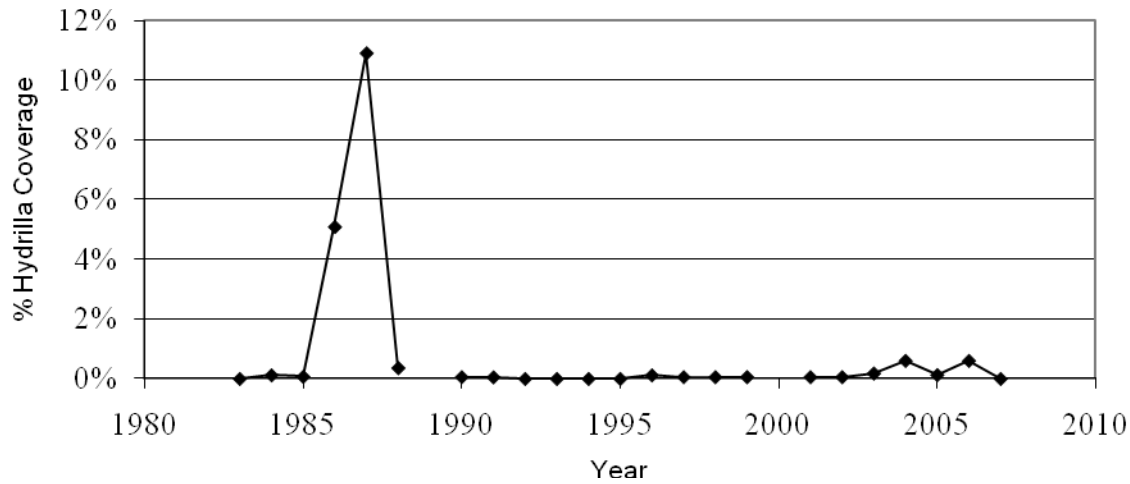


Figure 2-9. Percent area coverage of hydrilla for Lake Griffin, Florida (data obtained from FLDEP).

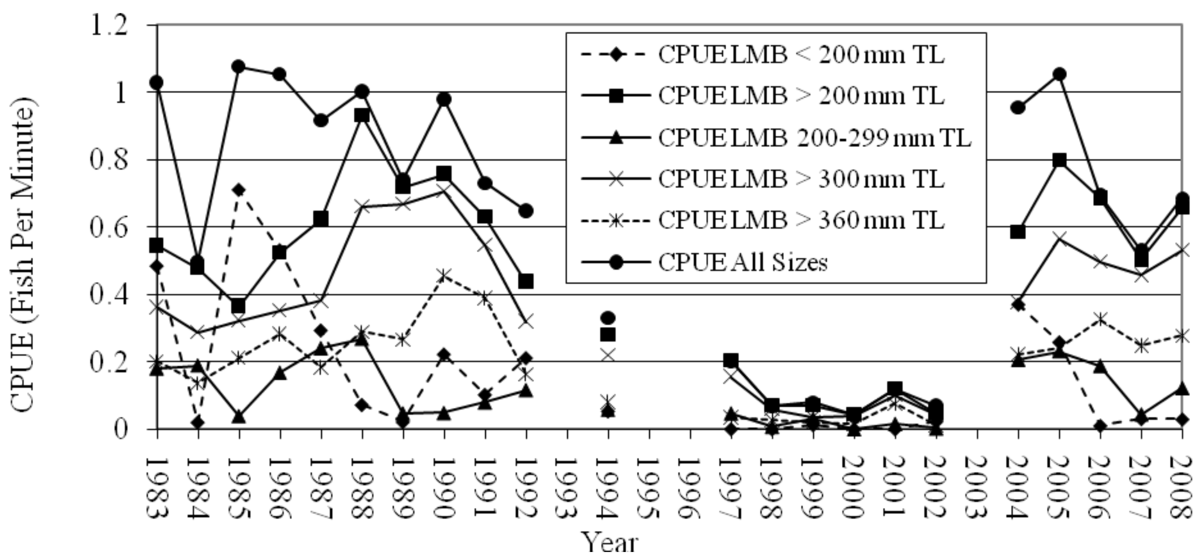


Figure 2-10. Annual mean largemouth bass electrofishing catch per unit effort (CPUE) for a variety of sizes of largemouth bass in Lake Griffin, Florida (data obtained from FFWCC).

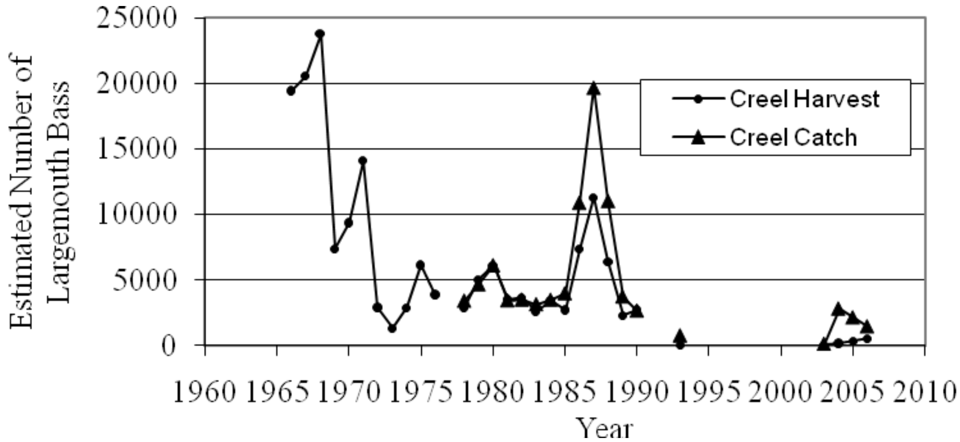


Figure 2-11. Estimated annual angler catch and harvest from Lake Griffin, Florida from 1966 to 2006 (data obtained from FFWCC).

CHAPTER 3
METHODS

A total of 13,933 largemouth bass greater than 200 mm TL were stocked into Lake Griffin during the winter months (December to April) between 2004 and 2007 (4,234 fish stocked in 2005, 5033 fish in 2006, and 4,666 fish in 2007) by Florida LAKEWATCH (Larson 2009). All stocked largemouth bass received a left-pelvic fin clip and fish greater than 275 mm TL (N = 10,538) were dorsally implanted with orange Hallprint PDA plastic-tipped dart tags. Dart tags had individual identification numbers; therefore, each tagged fish could be individually identified upon capture. Florida LAKEWATCH stocked largemouth bass into the main area of Lake Griffin, not into canals or adjoining waters. Larson (2009) provides a full description of the Florida LAKEWATCH largemouth bass stocking program.

Introduced-fish and native largemouth bass were collected by electrofishing in Lake Griffin's near-shore waters and adjoining canals to evaluate dispersal of stocked largemouth bass from their introduction locations (50 plus sites) in the main area of Lake Griffin (FFWCC's creel zone), percent contribution of stocked bass, and the mortality of stocked fish. An electrofishing protocol, similar to that used by FFWCC and Florida LAKEWATCH (Larson 2009), was used during this study. An electrofishing boat equipped with a 5-kw generator (Honda EG5000) and a Smithroot model VI–A pulsator was used to collect largemouth bass. The electrofishing crew consisted of two people; one individual netted fish from the bow and placed fish into a live well, while the other person operated the boat and the pulsator. Between April 2007 and March 2009 (23 sampling days), 364 ten-minute electrofishing transects were sampled (Table 3-1).

Lake Griffin's shoreline vegetation (versus open-water sites) was targeted during electrofishing of the main-lake to enhance the probability of largemouth bass capture. Transects were placed evenly around Lake Griffin's shoreline and a GPS unit recorded start and end-points of each electrofishing transect. All largemouth bass that were caught in each sampling transect were measured for total length in millimeters (mm). Largemouth bass were then examined for pelvic fin clips and/or an orange Hallprint dart tag. Tag numbers and fin clips were recorded and the fish were returned to the lake after processing.

Data Analysis: Dispersal of individual tagged fish was determined using a GPS to determine release coordinates and electrofishing recapture coordinates, which were plotted using ArcView© GIS (HCL Technologies Ltd., New Delhi India). Electrofishing GPS recapture coordinate data were also obtained from FFWCC (personal communication, John Benton, Eustis Laboratory). Once points were loaded for an individual tagged fish, the ArcView© measuring tool was used to estimate dispersal distance. Measurements were made between the stocking point and the closest start or end point in the electofishing transects using straight lines staying in the bounds of Lake Griffin waters and around land features in ArcView©. Minimum, maximum, and mean distance stocked largemouth bass dispersed from release site were calculated.

To determine if wild largemouth bass electrofishing CPUE (largemouth bass per hour of electrofishing) were different between canal and main lake habitats, the mean electrofishing CPUE, fish per hour, was calculated for each transect in canals and the main body. Once the means were calculated for both data sets, the data were transformed [Log10 (catch+1)] to normalize the distribution. The transformed mean CPUE for canals and main lake were then compared using a t-Test: Two-Sample Assuming Unequal Variances. Microsoft Excel was used for this analysis and the alpha level of rejection was set at 0.05.

The percent contribution and persistence of stocked fish was calculated simply by the ratio of marked (tagged and clipped) largemouth bass to all largemouth bass captured during electrofishing for each sampling period. To obtain catch per unit effort for largemouth bass, CPUE was calculated by dividing the total number of fish captured for an individual transect by the total minutes of electrofishing (fish per minute). Sampling transects during each month were grouped together to provide a mean monthly CPUE estimate. Canals and main lake were separated to evaluate the difference in percent contribution between canals and the main lake. The April and May 2007 main-lake transects were combined to provide a single 2007 “May” main-lake CPUE estimate. The “May” estimate was compared to the June 2007 canal CPUE estimate.

To obtain lake-wide percent contribution of stocked fish and their CPUE for each month, the total number of stocked largemouth bass as well as all largemouth bass caught for each main lake and canal transect were combined and then divided by either the total number of largemouth bass caught (% contribution) or the total number of minutes electrofished (CPUE). The April, May, and June 2007 main lake and canal transects were combined to calculate “May” mean percent contribution and CPUE estimate.

To determine if stocked largemouth bass are exhibiting the same mortality rates as native Lake Griffin largemouth bass, two separate CPUE data groupings (2006 tags only and 2007 tags only) were plotted in Microsoft Excel. Mortality estimates for the stocked largemouth bass were calculated from catch curves (Ricker 1975). Tagged (fish with fin clips only were not included) largemouth bass CPUE for 2006 and 2007 stocking years were calculated separately. To calculate individual stocking year mortalities, 2006 and 2007 canal and main lake CPUEs (tagged fish/minute) were again combined for each monthly sampling event. To calculate individual stocking years 2006 and 2007 CPUE (tagged fish/minute), April, May, and June (2007) were combined to obtain the “May” CPUE estimate. Electrofishing data from April 2006 was obtained (Mark Hoyer, personal communication, Florida LAKEWATCH) and used to calculate individual stocking year 2006 mortality estimate. Data were transformed using natural logarithms and then plotted, and CPUE was regressed against time for the sampling period. The slope of this line is represents the instantaneous monthly mortality rate. The monthly rate was multiplied by 12 (12 months in a year) to get an annual estimate of mortality (Z). This total annual mortality rate (Z) was then used to calculate annual survival (S= e –Z) and annual total mortality (A= 1-e –Z), according to Ricker (1975). The mortality calculations were then compared to an estimate provided by FFWCC for Lake Griffin's native largemouth bass for 2007 (John Benton, personal communication, Eustis Laboratory).

To determine if there was a change in native Lake Griffin largemouth bass condition (plumpness) after stocking, weight/length data sets, for native largemouth bass provided by FFWCC (personal communication, John Benton, Eustis Laboratory) for 2004 (pre stocking) and 2008 (post stocking), were compared. Transformed (Log10) weights of fish greater than 150 mm TL were regressed against transformed (Log10) lengths for each year (2004 N= 353, 2008 N= 345) in Microsoft excel. A linear regression line was fit to each year's data and an analysis of covariance (ANOCOVA) was completed using SAS (proc GLM; SAS Institute 2008) to test for differences in intercepts and slopes of the regression, where the alpha level of rejection was set at 0.05. The ANOCOVA model used to test equality of slopes was:

Log 10 WEIGHT = Log 10 TOTAL LENGTH + YEAR + Log 10 TOTAL LENGTH* YEAR

and the ANOCOVA model used to test for differences in intercepts was:

Log 10 WEIGHT = Log 10 TOTAL LENGTH + YEAR

Patterns between available environmental parameters (i.e., total phosphorus, total nitrogen, chlorophyll, Secchi depth, mean water level, yearly change in water level, and whole-lake aquatic macrophyte percent aerial coverage) and largemouth bass abundance estimates (electrofishing CPUE and roving creel catch) were investigated using correlation analysis. JMP version 5.01 software (SAS Institute 1989) was used for all statistical analyses. Data were transformed (Log 10) and the alpha level of rejection was set at 0.05.

Table 3-1. The date and number of electrofishing transects sampled in main lake areas and canal areas of Lake Griffin, Florida from April 23, 2007 to March 13, 2009.

10-Minute Electrofishing Transects on Lake Griffin		
Date	Main Lake Transects	Canal Transects
04/23/2007	17	0
05/15/2007	16	0
05/17/2007	16	0
05/22/2007	16	0
05/23/2007	16	0
05/24/2007	16	0
05/29/2007	16	0
05/30/2007	10	0
05/31/2007	16	0
06/05/2007	0	17
06/06/2007	0	13
06/07/2007	0	9
11/05/2007	15	5
11/06/2007	14	5
02/19/2008	9	8
02/20/2008	12	4
03/12/2008	8	9
03/13/2008	10	7
06/24/2008	14	2
06/25/2008	8	8
06/26/2008	8	8
03/12/2009	8	8
03/13/2009	6	10

CHAPTER 4
RESULTS AND DISCUSSION

Introduction

Florida LAKEWATCH stocked Lake Griffin with 13,933 wild-adult largemouth bass that were placed into the main lake from 2005 to 2007. FFWCC surveyed anglers using Lake Griffin proper in 2006 and showed only a limited catch of stocked fish. Florida LAKEWATCH also found the percent of the largemouth bass population caught by use of electrofishing did not increase above 15% despite stocking 4000 plus fish per year. These findings raised the single most important question related to all stocking programs and that is: What happened to the stocked fish?

Fish Dispersal

Largemouth bass are known to individually exhibit different movement patterns with some individuals being transient while others occupy discrete home ranges (Demers et al. 1996). Larson (2009) reported the majority (65%) of Florida LAKEWATCH-stocked fish were caught by anglers fishing adjoining canals, marshes, and the Ocklawaha River. These angler reports indicated the stocked largemouth bass were moving great distances from their stocking sites. Dispersal movements of the individual stocked adult largemouth bass (N=122 fish), as assessed by this study's electrofishing efforts were highly variable (Figure 4-1). Stocked fish dispersed variable distances in relation to time from stocking release (Figure 4-2). A few (~16%) fish did not leave the immediate stocking area, but the vast majority (84%) of largemouth bass traveled over 0.5 km (Figure 4-1). The mean dispersal distance for the caught stocked fish was 2.9 km, with minimum and maximum recorded distances of 0 and 9.2 km.

The great distance moved by the stocked largemouth bass in Lake Griffin was not a major surprise because of the results of earlier works by Dequine and Hall (1950) and Mesing and

Wicker (1986). Dequine and Hall (1950) conducted a largemouth bass (95 marked fish) migration study at Lake Griffin and found that fish (14 largemouth bass had complete movement data) moved variable distances (0 to 9.6 km, with one fish moving 15.3 km) from where they were released. Mesing and Wicker (1986) conducted a largemouth bass telemetry study on nearby Lake Eustis and Lake Yale and found maximum home range dimensions ranged from 0.05 km to 2.4 km, where the home range dimensions were based on 2,047 radio locations with 22 adult fish. In that study, they also demonstrated that largemouth bass could move large distances or not move at all.

The measured dispersal distances during this study provided evidence that part of the reason why FFWCC reported limited catch of stocked fish in the main area of Lake Griffin was because the fish moved. Lake Griffin is an open system allowing stocked fish to move into adjoining canals, marshes, and the Ocklawaha River. Anglers caught stocked fish below the dam at Moss Bluff, indicating there is an unknown rate of downstream escapement.

Anglers also moved largemouth bass from Lake Griffin. Tournament anglers who traveled from other lakes (via Haines Creek or Ocklawaha River) removed largemouth bass caught in Lake Griffin when they brought them to weigh-ins areas such as Lake Harris (personal communication, numerous anglers). While most largemouth bass anglers practiced catch and release, some anglers reported transporting large (>2.3 kg) stocked largemouth bass in their live wells to stock them into other water bodies. Clearly there is some unknown quantity of stocked and native largemouth bass leaving Lake Griffin due to angler activities.

Following FFWCC's 2006 creel-survey, Florida LAKEWATCH's focus became the disparity in the number of largemouth bass caught in the main area of Lake Griffin and the number of fish caught in adjoining waters, especially in Larson's (2009) study where angler tag call-in survey reported 326 largemouth bass catch locations of which 84 (26%) were from the main part of Lake Griffin (creel zone) and 212 (65%) were reported from non-stocked adjacent waters (e.g., connected canals and marshes). The other 30 caught largemouth bass (9%) were reported from other non-stocked waters (e.g., Lake Eustis). The greater number of largemouth bass caught in the canals (Larson 2009) raised the question of whether the stocked fish were preferentially selecting the adjoining waters or were being displaced into canals due to lack of available habitat in the main lake.

Mesing and Wicker (1986) found several fish migrated up to 3 km from their home ranges during the spawning season to wave-protected sites within canals. Lake Griffin has many wave-protected canals and stocked fish were present in these areas during the spawning season. Differences in the mean CPUE of all largemouth bass captured in the main lake versus the canals were examined to assess if stocked fish were preferentially selecting the canals or being displaced from the main lake. It did not appear that stocked largemouth bass had any greater preference for canals than wild fish. The ratio of the numbers of stocked fish in the canals collected by electrofishing to wild fish was similar to that found in the lake over the study period (Table 4-1, Table 4-2).

When comparing the native largemouth bass electrofishing catch, the mean CPUE for canals was 41fish/hour, with a minimum of 0 fish/hour and a maximum of 114 fish/hour. The mean CPUE for the main lake was 44 fish/hour, with a minimum of 0 fish/hour and a maximum of 138 fish/hour. The results from the t-test comparing the mean CPUE (log10 ([catch +1)] transformed) between canal and main lake areas found that the mean CPUEs were not significantly different ($t = -1.049$, $df = 150$, P two tail = 0.296). This finding strongly suggests that the fish were not preferentially seeking the canals nor were they being displaced from the main lake; rather based on Larson’s (2009) angler survey it might be more reasonable to think the anglers are preferentially targeting canals. Therefore, the disproportionate numbers of the tag returns from the canals must have been the result of angler behavior. The canals offer habitat where the anglers can catch fish and some anglers may be targeting canals for reasons such as, the canals are more accessible to back-yard anglers and safer to fish in boats due to less wind and wave action. The canals are also shaded by trees growing on the banks, making a cooler fishing experience during warm periods.

Mortality

Besides having largemouth bass moving to adjoining waters or completely outside the Lake Griffin system, a great reduction in the number of stocked largemouth bass caught over time could be the result of higher mortality rates. The monthly Lake Griffin electrofishing data and calculated mortality estimates from catch curves were used to compare this study’s estimates of mortality to FFWCC’s mortality estimates for native Lake Griffin largemouth bass. Mortality and survival estimates of stocked fish are similar to native fish (Table 4-3).

Mortality estimates for the individual stocking years, tag year 2006 cohort (Z= 1.087) and 2007 cohort (Z=1.295), were similar to the 2007 native largemouth bass estimate (Z= 1.054). These estimates were made from data collected many months after stocking had occurred. These estimates provide evidence that FFWCC’s reported low catch of stocked fish may have been due to selective die-offs resulting from transportation (approximately 2-3 hours) and stocking stress (Table 4-3). The collection of wild-adult largemouth bass from distant non-fished waters may have been a contributing factor effecting stocked fish mortality. Stocked fish were transported during the cooler months, which was a viable stocking technique employed by Florida LAKEWATCH to reduce mortality.

Persistence

Another important question related to the Florida LAKEWATCH stocking program was the persistence of the stocked fish; this will provide some assessment of how long anglers could expect to catch stocked fish. In this study, the last fish stocking occurred in March 2007. In May and June 2007, the highest percent (13% main lake, 15% canals) of stocked fish was captured and CPUE was the highest measured (0.09 fish/minute in main lake, 0.10 fish/minute in canals; Table 4-1, Table 4-2). Combining the main lake and canal areas for a total contribution percentage and CPUE also yielded the highest catch estimates in May (13% and 0.09 fish/minute CPUE; Table 4-4). Two years after the last stocking event (March 2009), electrofishing demonstrated that stocked largemouth bass were still present in the population (2% and 0.01 fish/minute CPUE in main lake; 4% and 0.03 fish/minute CPUE in canals; Table 4-1, Table 4-2). When the two regions of Lake Griffin are considered a single unit, the estimate was 3% and 0.03 fish/minute CPUE (Table 4-4).

There were no rewards for the largemouth bass that Florida LAKEWATCH stocked and no tag call-in advertisements. Stocked largemouth bass with tags are still being reported in the fishery by anglers (2009, four stocked fish reported) (Larson 2009). Recruitment of largemouth bass into the fishery may also contribute to reduced stocked fish catches.

Lake Griffin Fish Condition

Overstocking a lake with too many top predators can adversely affect the predator prey "balance" and affect the weight of individual fish because of a lack of forage (Noble 1981). The length-weight relationship for native largemouth bass in 2004 (pre-stocking) was compared to the 2008 (post stocking) relationship in Lake Griffin to determine if the condition of resident bass was reduced (Figure 4-3). An ANOCOVA analysis indicated the slopes ($Pr > F = 0.0274$, $> \alpha=0.05$) and intercepts ($Pr > F = 0.018$, $< \alpha=0.05$) of the regression lines were significantly different. However, the 2008 values and most of the measured weights in 2008 were greater than those recorded in 2004 (Figure 4-4). This finding demonstrated no negative change in the weight-length relationship after stocking, suggesting there was plenty of forage in Lake Griffin.

Native Verses Stocked Largemouth Bass Length-Frequency

Stocking adult largemouth bass could potentially alter the length frequency of largemouth bass in Lake Griffin. The length frequency of native verses stocked largemouth bass caught by use of electrofishing on three different sampling events spaced roughly one year apart ((Figure 4-5 (A-F)) are all different, but stocked fish do contribute weakly to the length frequency. The length frequency distribution between fish caught in canals and the main lake also appear to be different ((Figure 4-5 (A-F)). Examining the largemouth bass cohort trends reveal a large size class (301-350 mm TL and 351-400 mm TL) that shows up in the May 2007 catch, and moves through larger size classes over the next two years ((Figure 4-5 (A)). In the main lake sample from March 2009, a large size class (151-200 mm TL), presumably young-of-the-year, enters the catch ((Figure 4-5 (E)). This size class of young-of-the-year was the largest sampled during this project, which indicates that recruitment of largemouth bass was occurring naturally. Recruitment of fish from spawning in Lake Griffin therefore probably diminished persistence and percent contribution estimates and potentially inflated the mortality estimates. Biologists, however, should expect such changes when stocking any lake where a resident population already exists.

Environment Factors and Largemouth Bass

Lake Griffin's largemouth bass fishery and population has gone through many changes. In Florida, lake level fluctuation has often been considered as a dominant factor influencing fish populations (Moyer et al. 1995). Historically, Lake Griffin and the Harris Chain of Lakes fluctuated more than the current regulation schedule permits (Figure 2-3). Water level fluctuation (i.e., drawdown) has therefore been used to enhance fisheries in Florida lakes (Nagid et al. 2003).

FFWCC initiated a major drawdown of water at Lake Griffin in 1984. Following 1984, record angler catches of largemouth bass were measured (Figure 2-11). Electrofishing CPUE (Figure 2-10) also reached record levels. An examination of available data for Lake Griffin found that mean water level and electrofishing CPUE (largemouth bass (LMB) all sizes) were significantly related ($p < 0.05$), but the relationship was weak ($R^2 = 0.31$; N=21).

Based on statistically significant relationships and experience in the field, it is easy to see why a fish and wildlife agency like FFWCC would recommend an experimental drawdown; but in a multi-use lake like Lake Griffin attention must be paid to the concerns of the public (Hoyer and Canfield 1994). Following the 1984 drawdown, the growth of aquatic plants was a beneficial habitat improvement, but these plants became a weed problem for the public because of their interference with navigation. When tested, the percent area coverage of hydrilla and estimated angler catch at Lake Griffin also had a significant relationship ($R^2 = 0.32$; $p < 0.05$, N=12) as was the significant relationship between total percent aerial coverage of vegetation and angler harvest ($R^2 = 0.27$; $p < 0.05$, N=29). These significant relationships, however, are weak suggesting the total amount of plants needed in Lake Griffin may not be as great as produced during the 1984 drawdown to maintain a good fishery, and there may be other factors controlling fish abundance.

How many aquatic plants are needed in an individual water body has been debated for many years. Durocher et al. (1984) determined that any reduction of submerged vegetation below 20% would result in a reduced largemouth bass standing crop in Texas reservoirs. Hoyer and Canfield (1996) reported that there was no correlation between aquatic macrophyte abundance (percent area coverage and percent volume infestation) and largemouth bass standing crop in small (<300 ha) Florida lakes. However, they concluded plants are more important in larger lakes like Lake Griffin. Following the 1984 drawdown, Lake Griffin's aquatic plant community increased from 1% to 20% coverage (Figure 2-8). Hydrilla, a non-native major invasive species in Florida lakes, was the dominant (11%) plant after the 7-foot change in water level (Figure 4-6). Aquatic plants and other associated problems with drawdowns caused public uproar at Lake Griffin among the non-angling public due to issues such as boating access, hydrilla coverage, floating plant islands, and lack of access; all resulted in public opposition to future drawdowns (HCLRC 2007). Therefore, the question that must be asked is what else could be done for a multi-use lake if public support for a massive drawdown cannot be garnered.

It seems based on the historical record and as measured after the 2003 water level rise (Figure 2-3), that an enhanced water level fluctuation of one meter would stimulate enough aquatic plant growth (1-3%) to cause an increase in largemouth bass recruitment (Figure 4-6; Figure 4-7). This enhanced water level fluctuation would become even more important once the adjoining marshes are reconnected to the main lake because high water level caused by the Atlantic Multidecadal Oscillation may be a primary environmental factor driving the fishery at Lake Griffin.

If efforts are to be continued to reestablish aquatic plants in Lake Griffin through planting (HCOLRC 2006), it must be recognized that such efforts will be limited by algal biomass (chlorophyll) in the water column (Figure 4-8). Elevated chlorophyll concentrations affect light attenuation to the bottom sediments (Cole 1994), and because aquatic macrophytes require light to grow, light availability is one of the most important factors regulating the distribution of aquatic macrophytes (Zimmermann et al. 1994). Chlorophyll concentrations are controlled by nutrient concentrations, particularly nitrogen and phosphorus, in Florida's lakes (Canfield 1983); Lake Griffin shows this trend (Figure 4-8).

Chlorophyll concentrations in Lake Griffin were significantly related to total phosphorus, but the relationship was weak (R^2=0.16; $P < 0.05$, N=31) (Figure 4-9). On the other hand, chlorophyll concentrations had a strong relationship (R^2=0.66; $P< 0.001$, N=34) with total nitrogen, which suggests that Lake Griffin is nitrogen limited (Figure 4-10).

Chlorophyll concentrations in Lake Griffin had a significant relationship (R^2=0.31, $P< 0.001$; N=34) with water clarity as measured with a Secchi disc (Figure 4-11). Electrofishing catchability decreases with high chlorophyll concentrations due to reduced water clarity because it is harder to see stunned fish (Reynolds 1996, Mclnerny and Cross 2000). In the sampling events between 1997 through 2002, electrofishing largemouth bass CPUE was at an all time low compared to before and after that time period (Figure 4-12). During these times, high chlorophyll and low water clarity may well have contributed to the lower electrofishing catchability as Secchi depth and CPUE (LMB all sizes) exhibited a significant ($R^2 = 0.43$; $p < 0.05$, N=21) positive relationship (Figure 4-13).

Elevated chlorophyll concentrations at Lake Griffin were associated with low water conditions (Figure 4-14). Areas of Lake Griffin that were targeted for electrofishing were typically emergent vegetation in most years. These plants may not have always been accessible to electrofishing due to low water; therefore, water level in combination with chlorophyll at Lake Griffin may also have had a role in this decrease in CPUE due to electrofishing catchability. The fish may have moved to open water during the drought and were not as vulnerable to the electrofishing gear.

There was no relationship between angler catch and electrofishing CPUE (R^2=0.000013, P > 0.05, N=11) of largemouth bass (Figure 4-15). The primary reason for decreased angler catch of largemouth bass in 2004 to 2006 (3 lowest years ever measured) was a decrease in angler effort (Figure 4-16). Unfortunately, anglers were not surveyed for long periods of time at Lake Griffin by FFWCC's roving creel survey, because of lack of angler effort. Angler effort was highest from 1987-1990 (Figure 4-16) when large year classes were produced in prior years when the lake had 20% coverage of aquatic plants (i.e., 1984 to 1986). These year classes eventually produced trophy fish. In the late 1990s, the lake started getting bad press due to environmental problems (dead floating alligators, toxic algae, low lake levels) and the negative image probably drove anglers and other recreational users away from Lake Griffin (HCLRC 2002).

When creel surveys resumed in 2004, few anglers were using the Lake Griffin resource (Figure 4-16). In 2005, Lake Griffin received its first stocking of adult-sized largemouth bass. Over the next two years, there was a slight increase in angling effort (724 hours 2003, 2649 hours 2004, 4034 hours 2005, and 6443 hours 2006; Figure 4-16). Angler effort in the 2006 creel survey, however, was still low compared to historical levels. Largemouth bass angler catch per effort initially increased greatly in 2004 and has not decreased from historical levels (Figure 4-17).

The electrofishing CPUE of largemouth bass (> 200 mm TL) appears to be back to previously measured levels (Figure 4-12), but creel catch and effort are down (Figure 2-11, 4-16), which suggest that the fishery is partially psychologically driven rather than biologically driven and/or the bad press the lake received in the late 1990s is taking longer than the fish population to recover. Based on electrofishing CPUE, the fish should be there. Larson's (2009) study estimated the economic impact generated by stocking to be ranging into the millions of dollars. During this time period, the lake was getting good press, which most likely had an effect on angler effort. One of the major objectives of Larson's study was to stimulate angler interest in the lake. Stocking large fish in public view should have an effect on effort. A primary goal of fish and wildlife management agencies is to increase angler effort on water bodies because this increases license sales and economic activity associated with the fishery.

Table 4-1. Electrofishing sampling results for canals; total catch of largemouth bass greater than 200 mm TL, stocked largemouth bass catch (marked), stocked fish per minute (CPUE), and percent of stocked fish to total catch (% total catch) for Lake Griffin, Florida.

Electrofishing Sampling For Canals				
Date	Total Catch	Marked	CPUE	% Total Catch
Jun-07	262	39	0.10	15
Nov-07	50	2	0.02	4
Feb-08	94	5	0.04	5
Mar-08	103	7	0.04	7
Jun-08	109	9	0.05	8
Mar-09	134	6	0.03	4

Table 4-2. Electrofishing sampling results for main lake total catch of largemouth bass greater than 200 mm TL, stocked largemouth bass catch (marked), stocked fish per minute (CPUE), and percent of stocked fish to total catch (% total catch) for Lake Griffin, Florida.

Electrofishing Sampling For Main Lake				
Date	Total Catch	Marked	CPUE	% Total Catch
May-07	964	123	0.09	13
Nov-07	191	11	0.04	6
Feb-08	176	8	0.04	5
Mar-08	154	8	0.04	5
Jun-08	174	5	0.02	3
Mar-09	116	2	0.01	2

Table 4-3. A comparison of mortality estimates Z-Annual (instantaneous mortality rate), S-Annual (annual survival), and A-Annual (annual total mortality) of stocked largemouth bass and native largemouth bass from Lake Griffin, Florida.

Lake Griffin Largemouth Bass Mortality Parameter Estimates			
Parameter	2007 Tags Only	2006 Tags Only	Native Fish 2007 Catch Curve
Z-Annual	1.295	1.087	1.054
A-Annual	0.726	0.663	0.652
S-Annual	0.274	0.337	0.348

Table 4-4. Electrofishing sampling combined results for main lake and canal; total catch of largemouth bass greater than 200 mm TL, stocked largemouth bass catch (marked), stocked fish per minute (CPUE), and percent of stocked fish to total catch (% total catch) for Lake Griffin, Florida.

Electrofishing Sampling For Main Lake and Canals					
Date	Total Catch	# Transects	Marked	CPUE	% Total Catch
May-07	1226	178	162	0.09	13
Nov-07	241	39	13	0.03	5
Feb-08	270	33	13	0.04	5
Mar-08	257	34	15	0.04	6
Jun-08	283	48	14	0.03	5
Mar-09	250	32	8	0.03	3

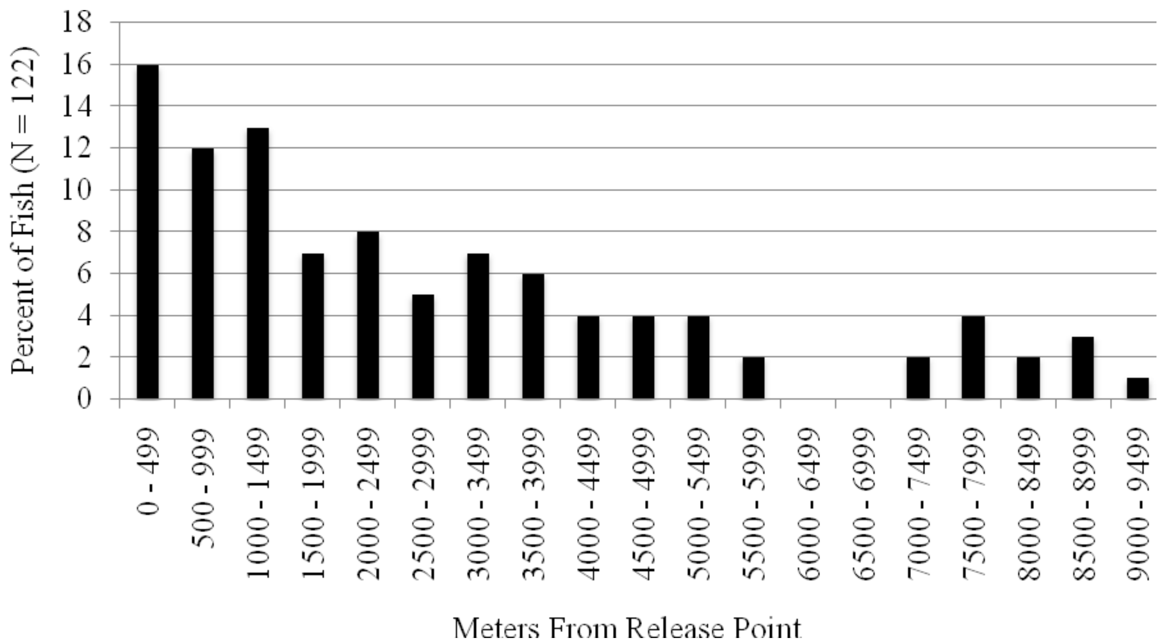


Figure 4-1. The percent of largemouth bass and corresponding distances dispersed from stocking points to electrofishing recapture points in Lake Griffin, Florida.

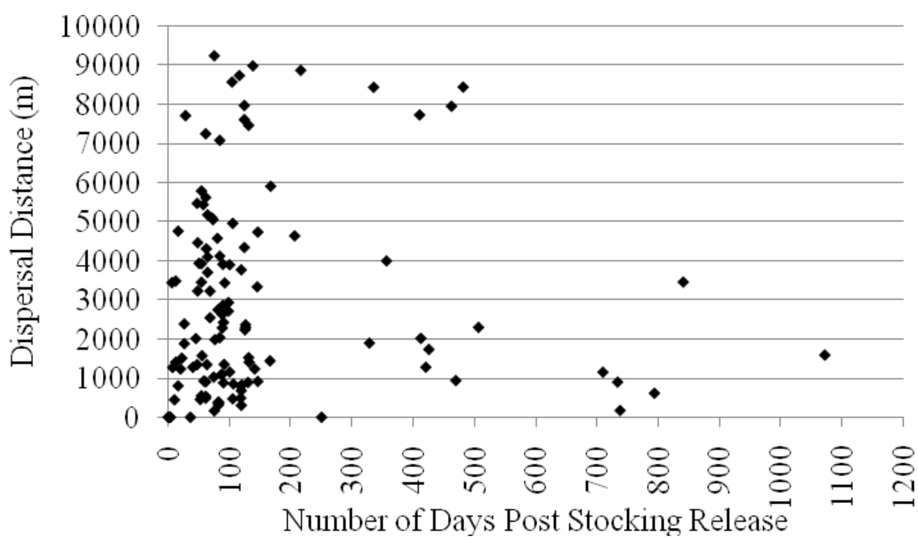


Figure 4-2. The dispersal distance from stocking release point verses the number of days post stocking for electrofished recaptured largemouth bass in Lake Griffin, Florida.

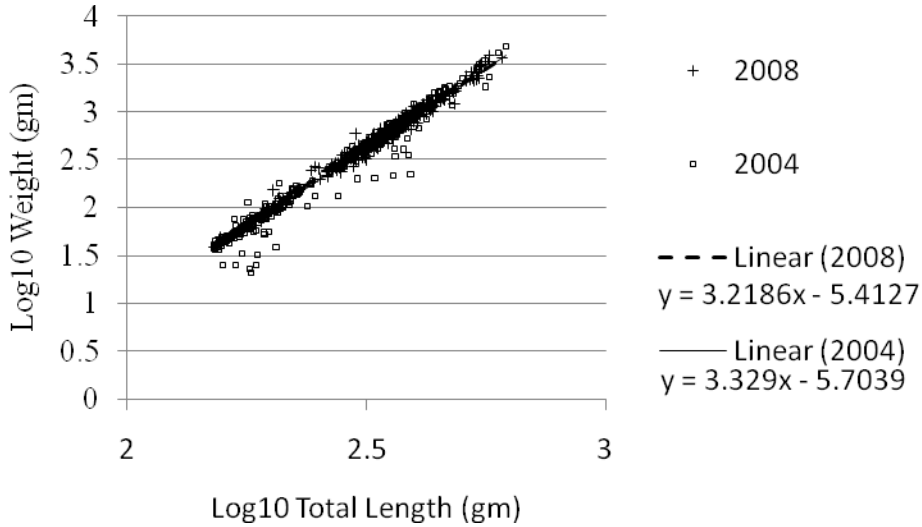


Figure 4-3. The log10 total length verses log10 weight of native largemouth bass pre (2004) and post (2008) stocking in Lake Griffin, Florida (data obtained from FFWCC).

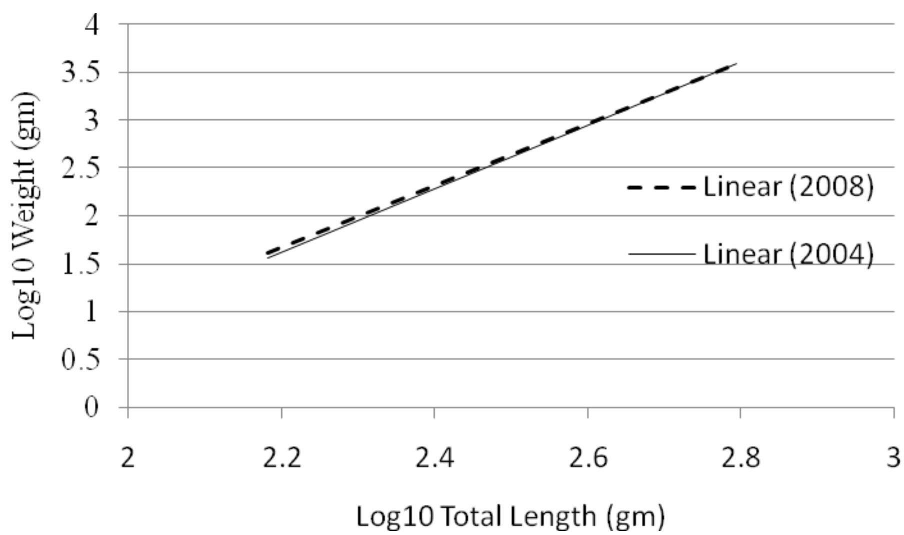
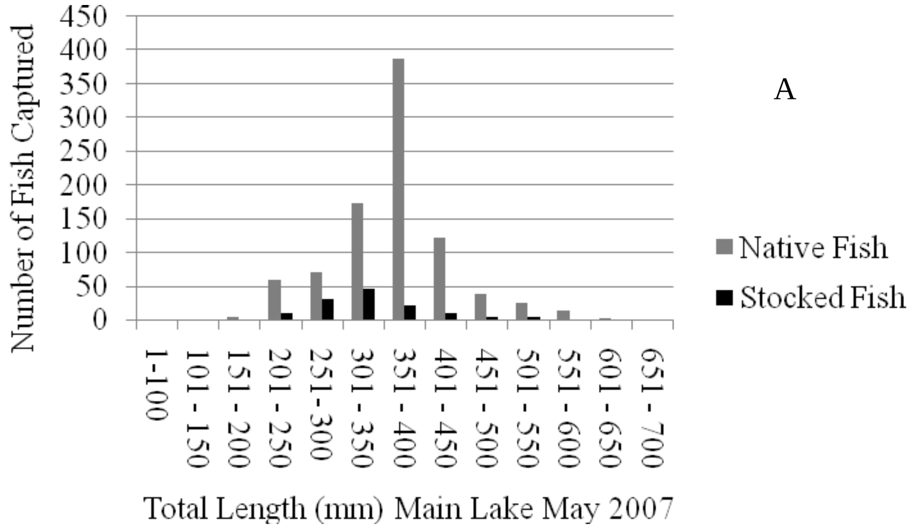


Figure 4-4. The log10 total length verses log10 weight linear regression line comparison of native largemouth bass pre (2004) and post (2008) stocking in Lake Griffin, Florida (data obtained from FFWCC).



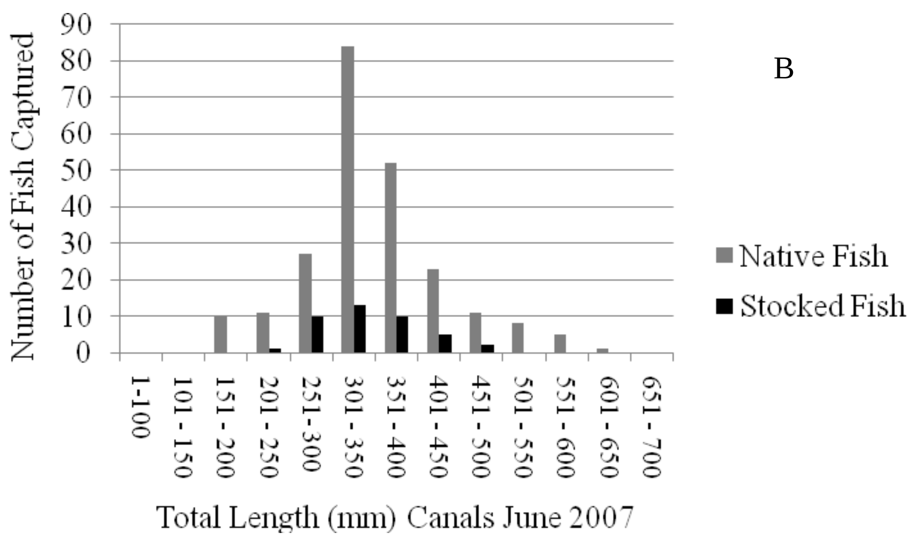
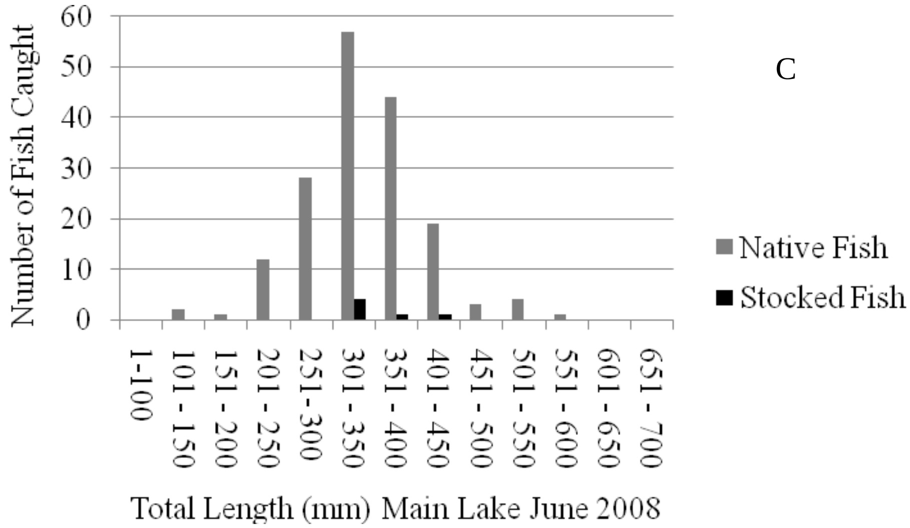


Figure 4-5. The number and size of native and stocked largemouth bass captured via electrofishing in the canals and main lake of Lake Griffin, Florida. A) Main Lake May 2007. B) Canals June 2007. C) Main Lake June 2008. D) Canals June 2008. E) Main Lake March 2009. F) Canals March 2009.



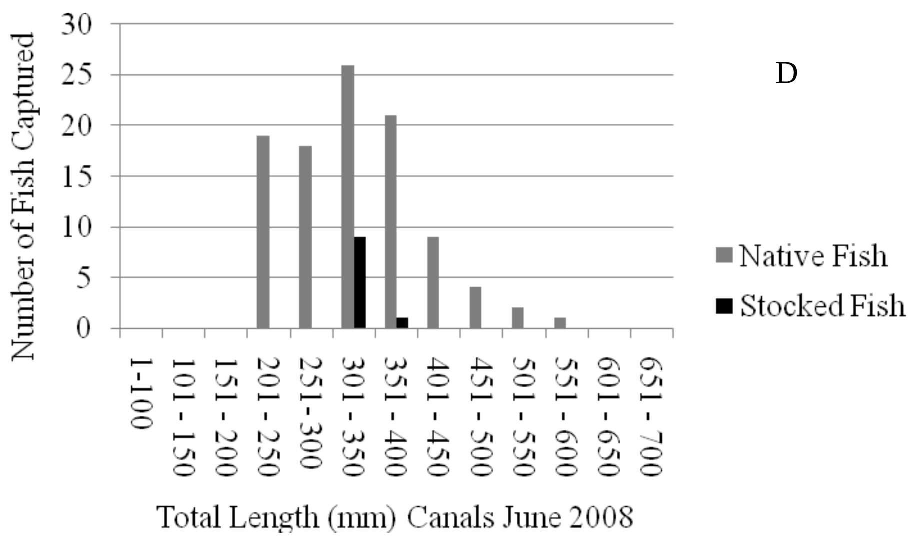
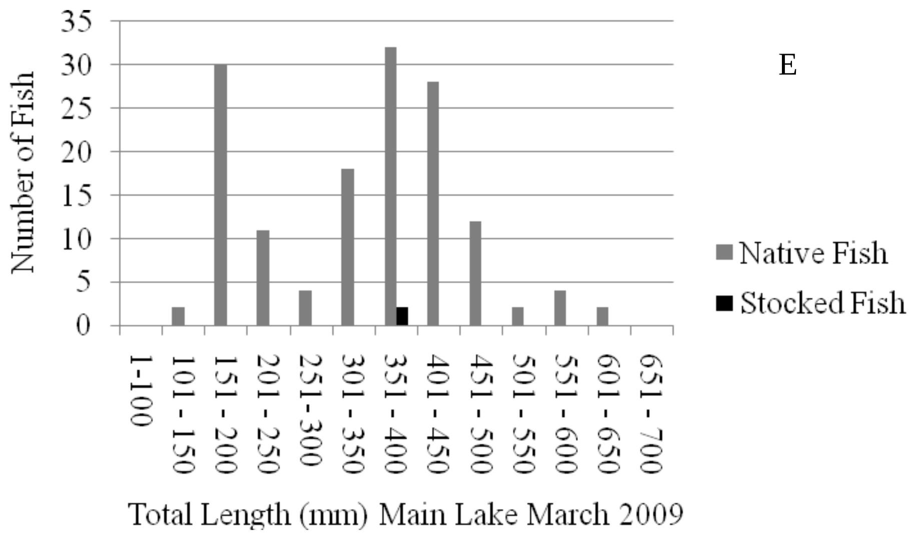


Figure 4-5. Continued.



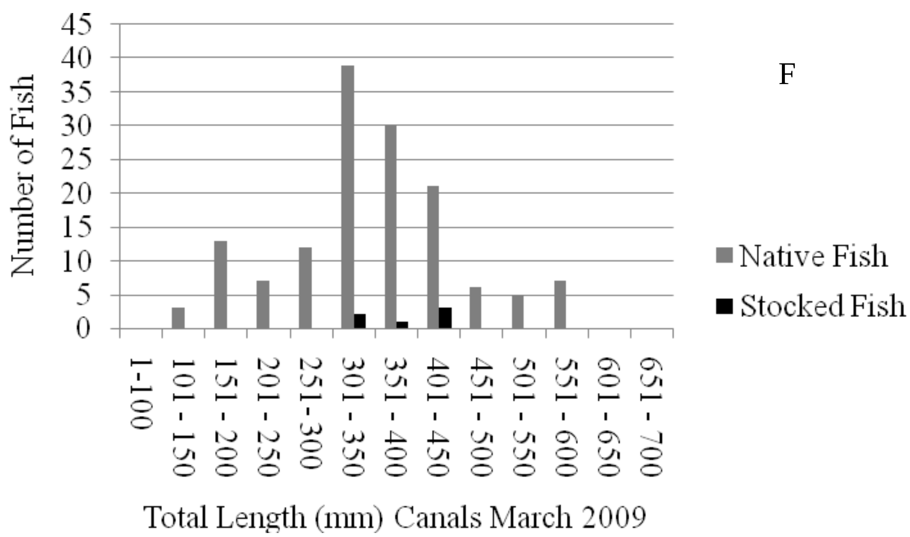


Figure 4-5. Continued.

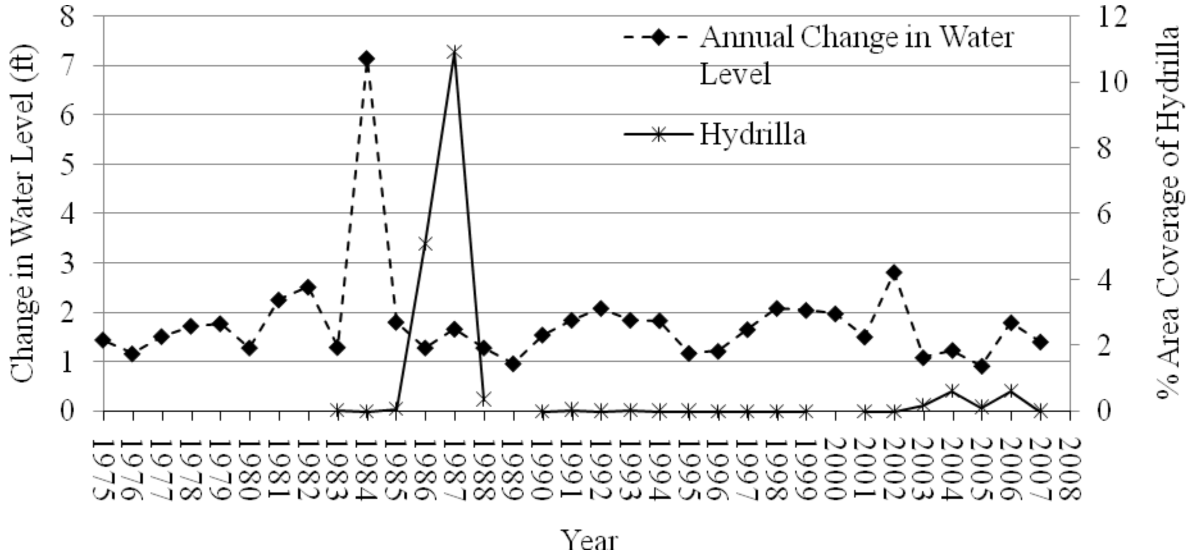


Figure 4-6. The annual change in water level and estimated percent area coverage of hydrilla in Lake Griffin, Florida (data obtained from SJRWMD and FLDEP).

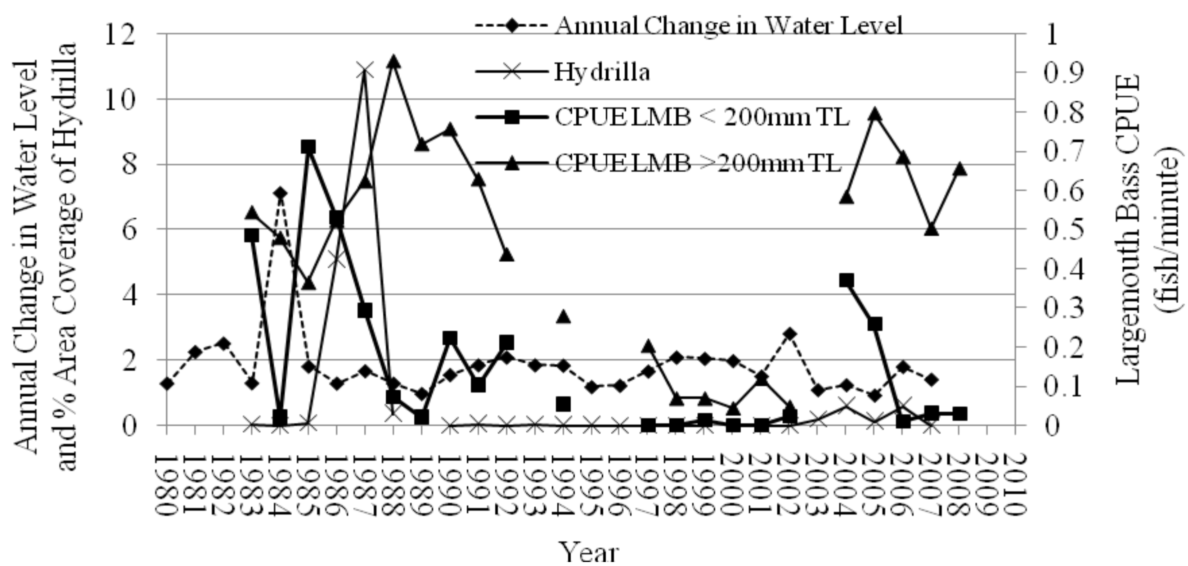


Figure 4-7. Yearly change in water level, percent area coverage of hydrilla, and electrofishing catch-per-unit-effort (CPUE) of largemouth bass (<200 mm TL and > 200 mm TL) for Lake Griffin, Florida (data obtained from SJRWMD, FLDEP and FFWCC).

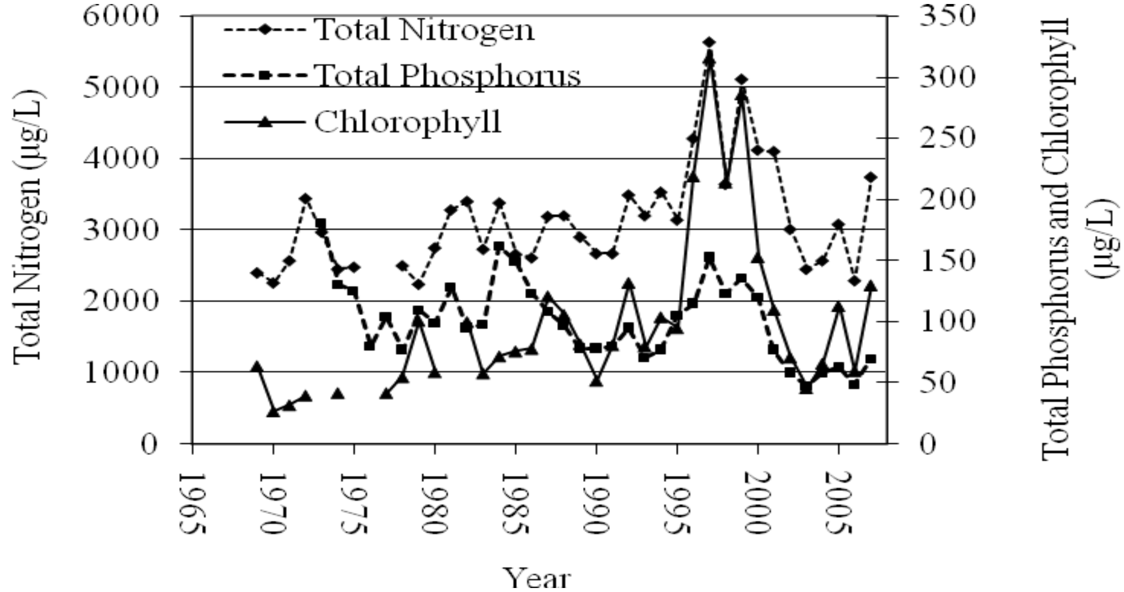


Figure 4-8. Total nitrogen (µg/L), total phosphorus (µg/L), and chlorophyll concentration (µg/L) trends for Lake Griffin, Florida (data obtained from FFWCC, Florida LAKEWATCH, and SJRWMD).

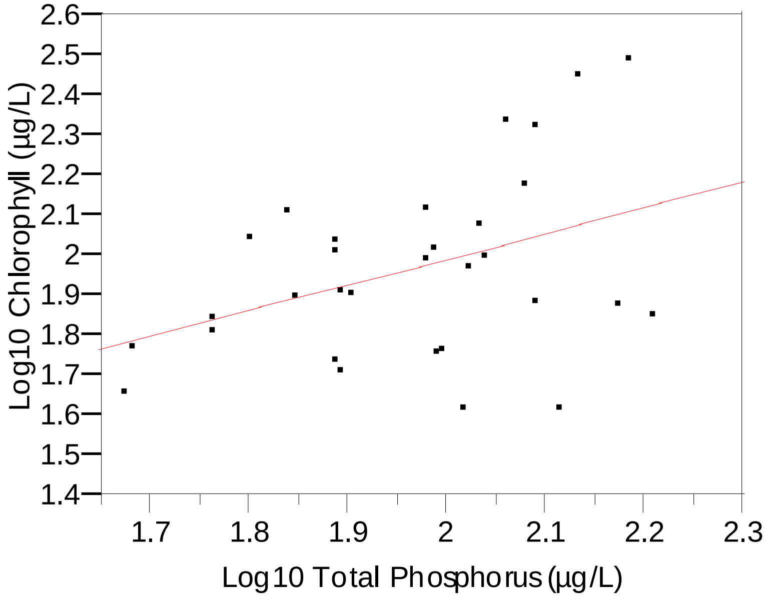


Figure 4-9. Relationship between log10 chlorophyll (µg/L) and log10 total phosphorus (µg/L) with a linear line fit to the data (R^2=0.16), for Lake Griffin, Florida, for data collected from 1974 to 2007 (data obtained from FFWCC, SJRWMD, and Florida LAKEWATCH).

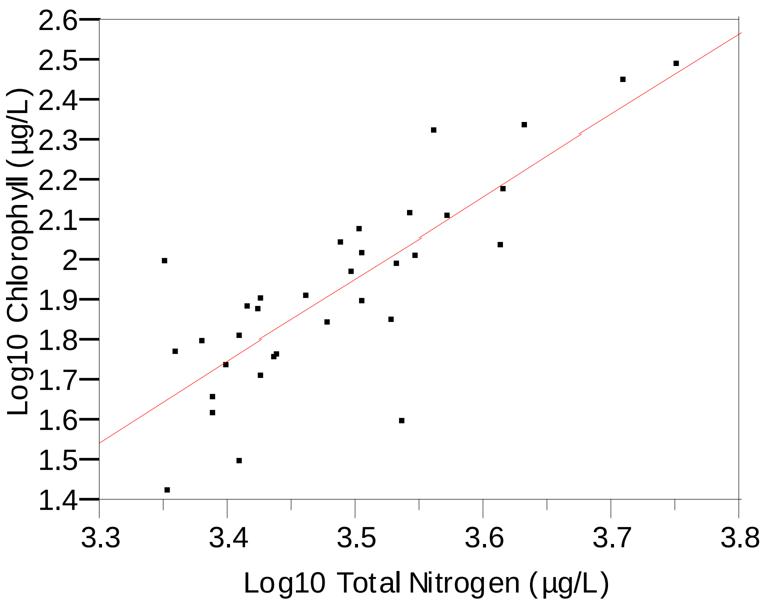


Figure 4-10. Relationship between log10 chlorophyll (µg/L) and log10 total nitrogen (µg/L) with a linear line fit to the data (R^2=0.66), for Lake Griffin, Florida, for data collected from 1969 to 2007 (data obtained from FFWCC, SJRWMD, and Florida LAKEWATCH).

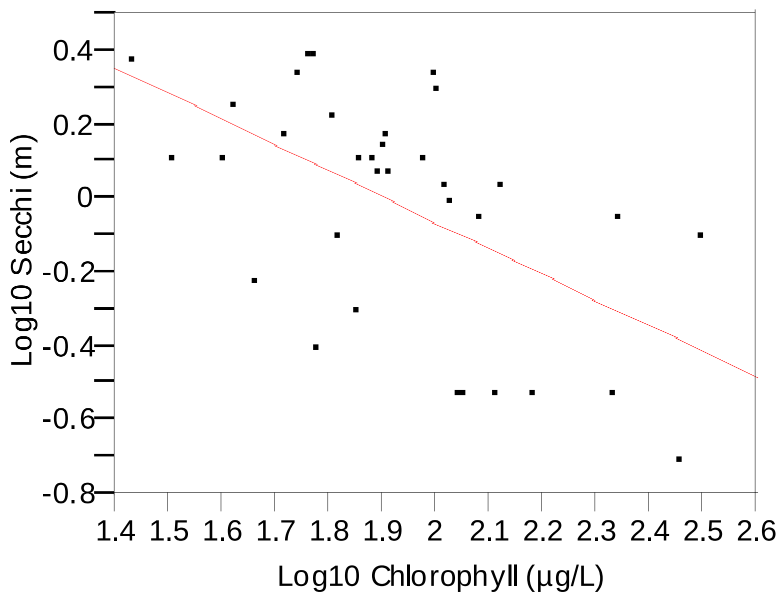


Figure 4-11. Relationship between Log10 Secchi (m) and Log10 Chlorophyll (µg/L) with a linear line fit to the data (R^2=0.31), for Lake Griffin, Florida, for data collected from 1969 to 2007 (data obtained from FFWCC, SJRWMD, and Florida LAKEWATCH).

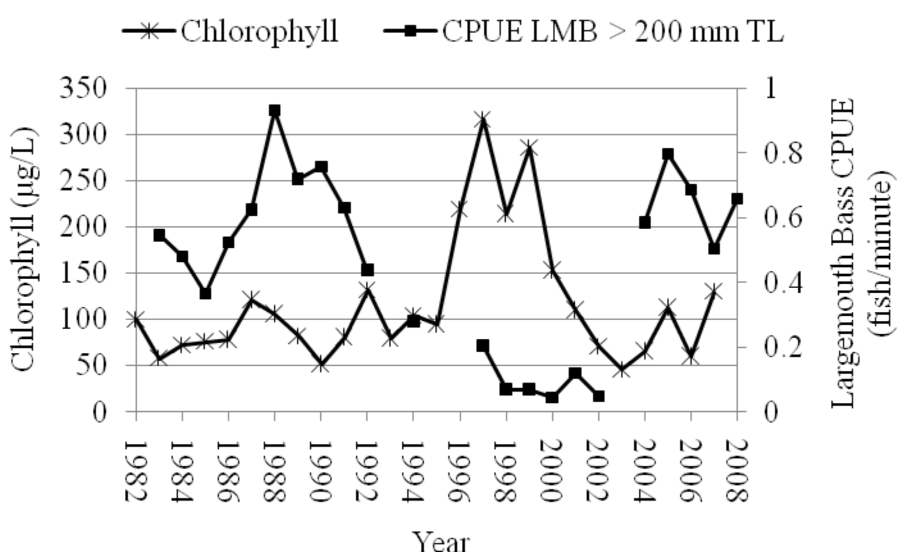


Figure 4-12. Annual mean chlorophyll concentration and electrofishing catch-per-unit-effort (CPUE) of largemouth bass (> 200 mm TL), for Lake Griffin, Florida (data obtained from FFWCC, Florida LAKEWATCH, and SJRWMD).

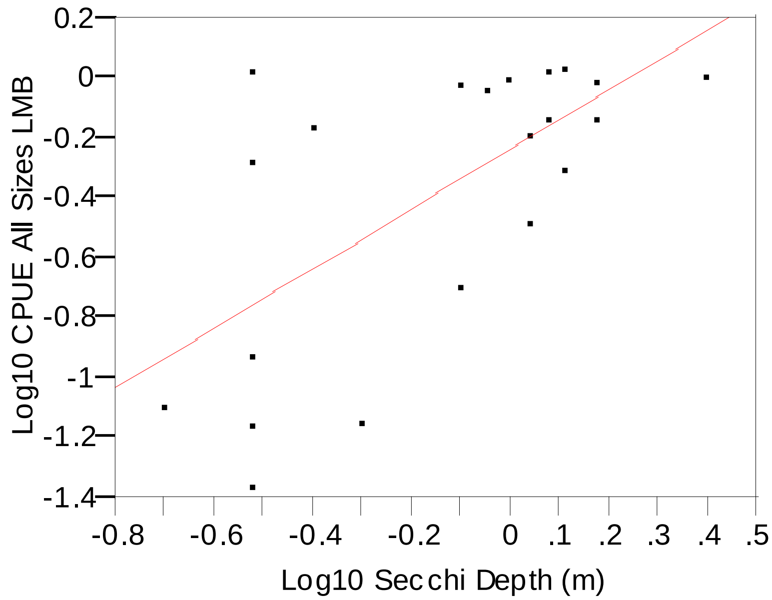


Figure 4-13. Relationship between Log10 CPUE (fish per minute) for all sizes of largemouth bass captured by electrofishing and Secchi depth (m) with a linear line fit to the data (R^2=0.43), for Lake Griffin, Florida, for data collected from 1969 to 2007 (data obtained from FFWCC, SJRWMD, and Florida LAKEWATCH).

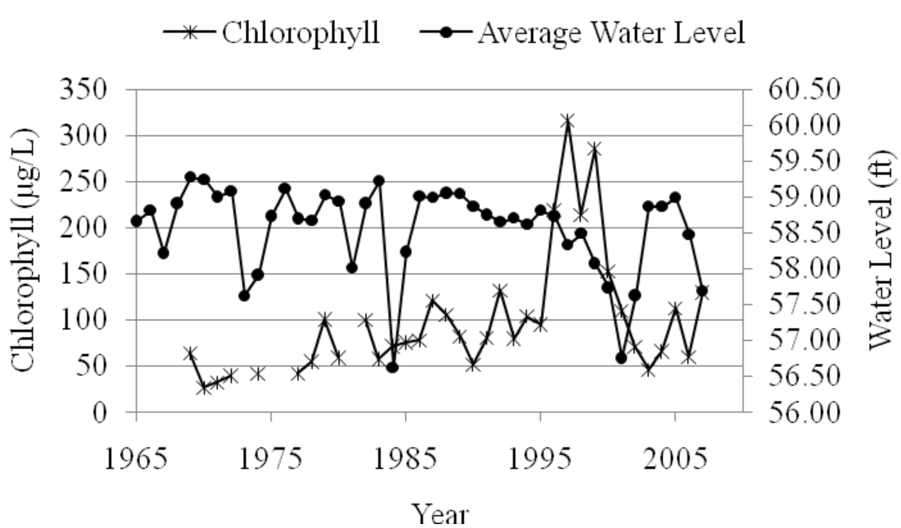


Figure 4-14. Annual mean chlorophyll concentration and annual mean water level for Lake Griffin Florida (data obtained from FFWCC, Florida LAKEWATCH, and SJRWMD).

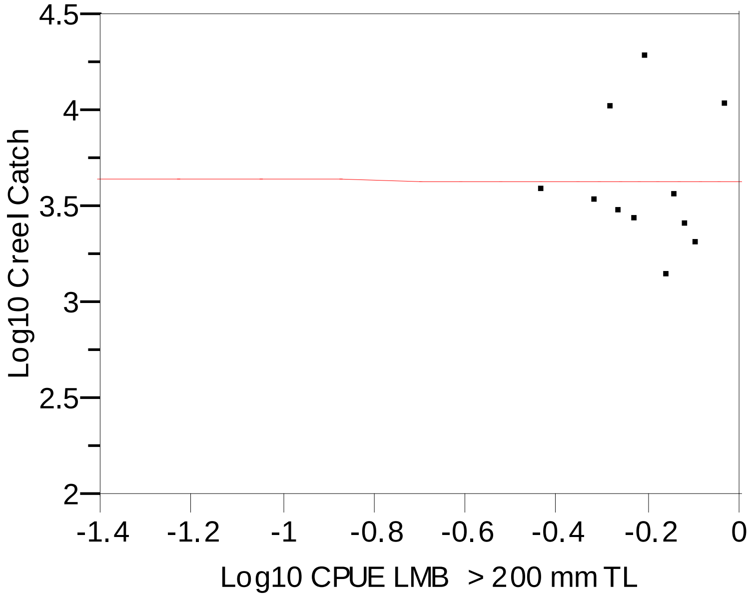


Figure 4-15. Relationship between annual largemouth bass creel catch, estimated by roving creel survey and electrofishing CPUE (fish/minute) of largemouth bass (> 200 mm TL), with a linear line fit to the data (R^2=0.000013), for Lake Griffin, Florida (data obtained from FFWCC).

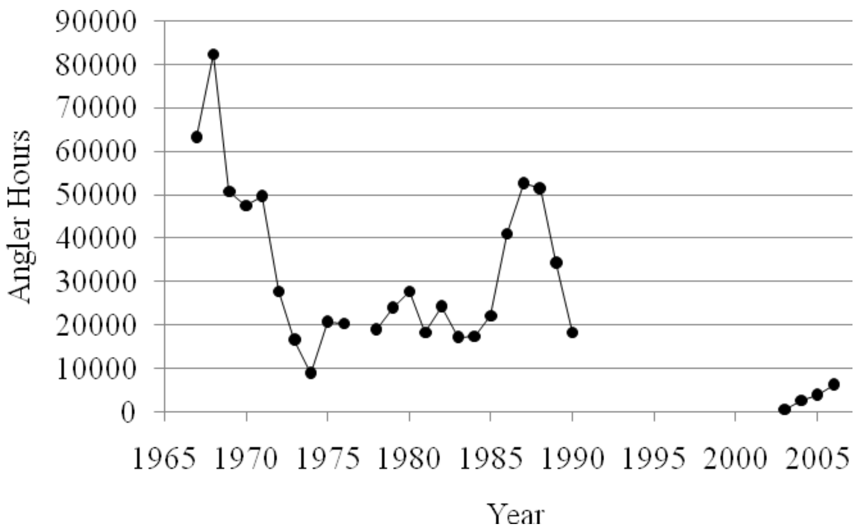


Figure 4-16. Angler effort (hours) for largemouth bass, estimated by roving creel survey for Lake Griffin, Florida (data obtained from FFWCC).

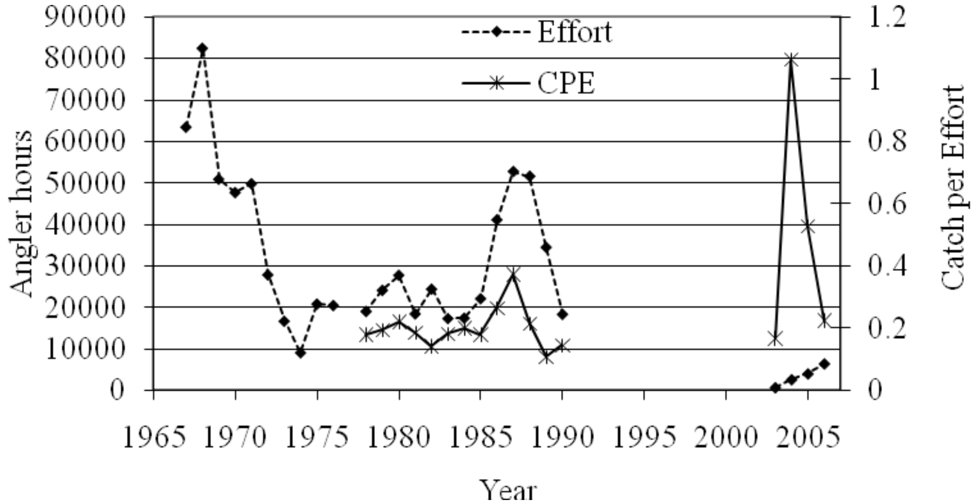


Figure 4-17. Historical angler effort (hours) and catch per effort (fish per hour) for largemouth bass, based on roving creel survey data (data obtained from FFWCC).

CHAPTER 5
FISHERY MANAGEMENT IMPLICATIONS

When Lake Griffin was sampled immediately following the last stocking in 2007, stocked fish represented 10 to 15% of the catch. The percent contribution information demonstrates that the stocking program impacted the largemouth bass population in Lake Griffin. Larson (2009) also estimated that the stocking program enhanced revenues (ranging from $324,000 to 2.7 million dollars) to the local communities. Thus, stocking of wild-adult bass, with its apparent positive cost:benefit ratio, was recommended by Larson (2009) as a viable fish management tool for Lake Griffin.

An angler creel survey is perhaps the most important fisheries management survey to evaluate fisheries, because it provides information on what the anglers are experiencing. Interpretation of results, however, must be placed in context before statements are made regarding the success or failure of a management action. The situation at Lake Griffin is a prime example. The 2006 FFWCC creel survey did not provide evidence for the success of the Florida LAKEWATCH wild-adult largemouth bass stocking program. The creel survey was conducted in the open lake and failed to consider the myriad of canals and adjoining waters where anglers could and did catch fish.

As stated over 20 years ago by Mesing and Wicker (1986), creel surveys on large Florida lakes should include canal areas connected to the lake if realistic harvest figures are to be obtained during the spawning season. When considering the catch information from canals collected by Larson (2009), an argument for the cost-effectiveness of the stocking program can be advanced. However, at Lake Griffin, it is now clear that the presence of canals influenced angler catch and harvest estimates, thus future angler surveys at Lake Griffin should include adjoining waters like canals. The challenge is maintaining the past survey protocol sufficiently so that long-term data sets remain comparable with future creel information. Perhaps, what would be the best approach now would be the implementation of three or four creel surveys that include the adjoining waters like canals as well as the main lake to determine the impact on effort and harvest estimates. This will add costs to the creel survey, but it is clear that the costs will be justified if it helps biologists make better decisions for the resource.

The next phase of restoration at Lake Griffin according to personnel from the St. Johns River Water Management District is reestablishment of spawning and nursery habitat for desirable fish (i.e., largemouth bass) species (Schluter and Godwin 2003). The District's program includes the reconnection of the former adjoining farmlands once wetlands are re-established. The estimated time for complete ecosystem restoration for Lake Griffin, however, is 60 years (HCLRC 2008) because SJRWMD is focusing on nutrient removal. Reconnection of adjoining marshes that were once used for farming, will provide additional spawning habitat, nursery habitat, and fishing areas

If Lake Griffin were solely a "Fish Management" lake and the only consideration for managers was optimization of largemouth bass catch and harvest, a major water level fluctuation would be the first choice to stimulate the largemouth bass population in Lake Griffin. Regularly-scheduled lowering of water levels followed by refill is the least expensive and best approach. This was demonstrated by FFWCC with its 1984 experimental drawdown (Figure 4-7). However, Lake Griffin is a multipurpose recreational lake and there are other considerations such as access issues and growth of the non-native aquatic plants like hydrilla and its effects on non-angling recreation.

While there are a myriad of public concerns, major reductions in Lake Griffin's water level have not been accepted by the public since the 1980s. Recently, the canals around the lake have received maintenance dredging. This dredging was promoted: to increase boaters' access and allow for enhanced lake level fluctuation (i.e., 1-3 feet) (HCLRC 2007). The increased water level, of Lake Griffin after the 2004 hurricane season, coincided with a positive response in the CPUE of largemouth bass, reaching historical high levels (Figure 4-7). Major drawdowns (i.e., 3 feet or more) don't provide boaters access, but enhanced fluctuation is not as disruptive. Therefore, regularly-scheduled enhanced fluctuations (reduce water levels to the outer edge of the emergent macrophytes), such as the one in 2002-2003, would provide fish managers with their best opportunity to maintain a reasonable largemouth bass population, if public support for a major lowering of water levels cannot be garnered.

A potential problem, for even well-managed enhanced water level fluctuations, is that major droughts have struck Florida in recent years. Florida's water managers, therefore, tend to be conservative even with enhanced fluctuation so as not to garner public opposition when drought conditions occur. The water managers rely on weather modeling for precipitation predictions, thus even well-planned enhanced fluctuations could be precluded for extended periods of time, especially if sufficient water cannot be stored in the upstream lakes. Another major drawback of water level fluctuation in the eyes of the public and some environmental agencies is the potential growth of hydrilla. Unless the prevailing attitudes towards hydrilla change (Hoyer et al. 2005), hydrilla at Lake Griffin will have to be managed, which can be expensive.

Like the canals, the presence of reconnected marshes may not substantially increase angler effort within Lake Griffin proper. In examining trends in largemouth bass CPUE for fish >200 mm TL (Figure 4-7), the evidence is pretty strong that harvestable-size largemouth bass should be sufficiently abundant in the main stem of Lake Griffin to support fishing, but angler effort remains low (Figure 4-17). This suggests that there is an angler perception problem and work needs to be directed towards massive habitat work that will induce anglers to fish Lake Griffin proper.

Submerged aquatic macrophytes would be the preferred habitat for many fish biologists, but there are many reasons why submerged plants will not become established in Lake Griffin in a timely manner. One potential approach to attract/produce fish would then be the establishment of large numbers/areas of artificial fish attractors, especially the creation of hard-rock bottom with limestone as done by FFWCC at Lake Eustis off the public fishing pier. Plastic crates filled with lime rock could be anchored in group configurations or reefs into areas of the lake to provide fish refuge. A reef ball structure could also be used at a greater expense as a fish attractor. Another option (even more expensive) is to remediate and or dredge the remaining canals, which exist around the lake to provide additional fish habitat. Largemouth bass use canals for spawning and as nursery habitat. Additional canals could also be dredged on some of the conservation land around the lake and be protected from fishing. These artificial structures will attract anglers as well as fish. The largemouth bass fishery at Lake Griffin is primarily a catch and release fishery (90% of anglers; Larson 2009), so the establishment of artificial attractors will not adversely affect the fish population. The production/attraction issue (a concerned raised by ecologists; Wilson 2001) that is associated with artificial habitat, therefore, is not a major concern at Lake Griffin.

Stocking additional wild-adult largemouth bass is recommended to occur simultaneously with the habitat improvement and expansion projects because the stocked fish will at least provide anglers with a positive outlook on the Lake Griffin fishery. It is also clear from Larson's (2009) work that the cost of stocking (< $150,000 per year) is far less than the potential economic stimulus (ranging from $324,000 up to $2.7 million per year). Also, fisheries managers must understand that the ability of largemouth bass to move distances on the magnitude of kilometers may result in non-stocked adjoining waters being stocked, thus diluting the impact of stocking on the receiving water. Depending on lake size, stocking at multiple sites quickly disperse fish throughout the system.

CHAPTER 6
CONCLUSION

The stocking of wild-adult largemouth bass resulted in an estimated 10 to 15% contribution to the abundance in CPUE of largemouth bass in electrofishing catches in May and June 2007. If it were possible to double or triple this stocking rate, there might be an even greater effect on abundance of largemouth bass in the system. My results confirm that stocked largemouth bass are indeed moving outside of the creel area where they were stocked and into canals. FFWCC did not sample canals in their creel survey, primarily because they were following their long-term creel protocol. Canals are clearly utilized by fishermen according to Larson's (2009) report and my electrofishing efforts, but largemouth bass abundance was similar in the canals and the main lake.

Florida LAKEWATCH stocked Lake Griffin at ~1 fish per hectare. I also believe that an adult largemouth bass stocking project like this one will have a more profound effect on a smaller system if stocked at a higher rate. In 2008, nearby Lake Dora was stocked by Florida LAKEWATCH with ~4000 largemouth bass greater than 200 mm TL. Post-stocking electrofishing revealed ~20% contribution to the greater than 200 mm TL population of largemouth bass. Lake Dora is nearly half the size (1810 ha) of Lake Griffin and does not have nearly the same amount of canals for stocked fish to disperse into. Stocking adult fish at higher rates or into smaller lakes should be done with caution as the fisheries biologist must make certain there is an adequate forage base. However, in hypereutrophic lakes like Lake Griffin this should not be an issue.

Based on my evaluations and those of Larson (2009), the weight of evidence supports the stocking of wild-adult largemouth bass using the Florida LAKEWATCH protocol. Large numbers (4000 plus fish per year) of wild-adult bass were procured for three years from private non-fished waters and there are many others sources of wild adult largemouth bass in Florida. Stocking these fish into a large hypereutrophic lake resulted in a significant increase of fish, although, we don't know if it is an addition or replacement. Stocked largemouth bass dispersed over distances ranging up to 9 km and fish did not seem to suffer abnormal mortality rates compared to the native fish due to stocking stress. Stocked fish are still present in the Lake Griffin fishery two years after the last stocking event and the mortality rate was similar to the native fish in the lake. The stocking event did not cause a change in fish condition indicating that there is plenty of forage available. Stocked largemouth bass were not being displaced into canals and seem to be mixing evenly throughout the population in the main lake, strongly suggesting better habitat is needed in the main lake to attract fish and anglers.

Overall, there have been no measurable negative effects of stocking and given the "weight of evidence argument", fish management agencies should consider the stocking of wild-adult largemouth bass as a viable fishery management tool. When assessing complex environmental issues such as those at Lake Griffin, it is difficult to prove anything with 100% certainty or establish strong environmental/biological relationships. Consequently, fisheries management is art and science; for many issues such as supplemental fish stocking, the scientific community shall remain divided, with some individuals being strong advocates for stocking and some being just as strong detractors (Mesing et al. 2008). Such controversy will probably continue to exist after decades of debate because the criteria for success are ever changing.

LIST OF REFERENCES

Bachmann, R. W., M. V. Hoyer, and D. E. Canfield, Jr. 1999. The restoration of Lake Apopka in relation to alternative stable states. Hydrobiologia 394:219-232.

Bachmann, R. W., M. V. Hoyer, and D. E. Canfield, Jr. 2000. The potential for wave disturbance in shallow Florida lakes. Lake and Reservoir Management 16:281-291.

Benton, J. W. 2000. Central Florida Fisheries Development: Lake Griffin Fisheries Improvement. Annual Report for 1999-2000. Florida Game and Freshwater Fish Commission. Tallahassee, FL. P.10-31.

Buynak, G. L., B. Mitchell, D. Michaelson, and K. Frey. 1999. Stocking subadult largemouth bass to meet angler expectations at Carr Creek Lake, Kentucky. North American Journal of Fisheries Management 19:1017-1027.

Canfield, Jr., D.E. 1981. Chemical and trophic state characteristics of Florida lakes in relation to regional geology. Florida Agricultural Experimental Station Journal Series 3513.

Canfield, Jr., D.E. 1983. Prediction of chlorophyll a concentrations in Florida lakes: the importance of phosphorus and nitrogen. Water Recourses Bulletin 19:255-62.

Canfield, Jr, D.E., and L. M. Hodgson. 1981. Prediction of Secchi disc depths in Florida lakes; Impact of algal biomass and organic color. Florida Agricultural Experimental Station Journal Series 3255.

Carlander, H.B. 1954. A history of fish and fishing in the Upper Mississippi River. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Cole, G.A. 1983. Textbook of Limnology, 3rd Edition. C.V. Mosby Company. St. Louis, Missouri.

Copeland, J. R., and R. L. Noble. 1994. Movements by young-of-year and yearling largemouth bass and their implications for supplemental stocking. North American Journal of Fisheries Management 14:199-124.

Crowder, L. B., and W. E. Cooper. 1979. Structural complexity and fish-prey interactions in ponds: A point of view. Pages 2-10 *in*, Johnson, D. L., and R. A Stein, editors. Response of fish to habitat structure in standing water. North Central Division, American Fisheries Society, Spec. Publication No. 6.

Demers, E., R. S. McKinley, A. H. Weatherley, and D. J. McQueen. 1996. Activity patterns of largemouth and smallmouth bass determined with electromyogram biotelemetry. Transactions of the American Fisheries Society 125:434-439.

Dequine, J. F., and C. E. Hall, Jr. 1950. Results of some tagging studies of the Florida largemouth bass, *Micropterous salmoides floridanus*. Transactions of the American Fisheries Society 79:155-166.

Durocher, P. P., W.C. Provine, and J.E. Kraai. 1984. Relationship between abundance of largemouth bass and submersed vegetation in Texas reservoirs. North American Journal of Fisheries Management 4:84-88.

Florida LAKEWATCH. 2007. Restoration of the Economic Vitality of Lake Griffin's Largemouth Bass Fishery: A Research/Demonstration Project / Phase III. Final Report. Department of Fisheries and Aquatic Sciences. Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida.

(HCLRC) Harris Chain of Lakes Restoration Council. 2002, 2006, 2007, 2008. Reports to the Legislature. Tallahassee, Florida.

Heidinger, R. C., and R. C. Brooks. 2002. Relative contribution of stocked minnow-fed and pellet-fed advanced fingerling largemouth bass to year-classes in Crab Orchard Lake, Illinois. Pages 703-714 *in* D.P. Philippi and M.S. Ridgeway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda Maryland.

Hoffman, K.J., and P. W. Bettoli. 2005. Growth, dispersal, mortality, and contribution of largemouth bass stocked into Chickamauga Lake, Tennessee. North American Journal of Fisheries Management 25:1518-1527.

Hoyer, M. V. and D. E. Canfield, Jr. 1994. Bird abundance and species richness on Florida lakes: influence of trophic status, lake morphology, and aquatic macrophytes. Hydrobiologia 297/280:107-119.

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.

Hoyer, M. V., M.D. Netherland, M.S. Allen, and D.E. Canfield, Jr. 2005. Hydrilla management in Florida: A summary and discussion of issues identified by professionals with future management recommendations. Proceeding of a Special Symposium. Florida LAKEWATCH, Department of Fisheries and Aquatic Sciences, University of Florida, Institute of Food and Agricultural Sciences. Gainesville, Florida.

Kelly, M.H., and J.A. Gore. 2008. Florida river flow patterns and the Atlantic multidecadal oscillation. River Research and Applications. 24: 598-616.

Larson, K.W. 2009. Stocking wild-adult largemouth bass *Micropterus salmoides floridanus* to improve fishing and associated economic activity at Lake Griffin, Florida. Masters thesis. University of Florida. Gainesville, Florida.

Lorenzen, K. 1996. The relationship between body weight and natural mortality in fish: a comparison of natural ecosystems and aquaculture. Journal of Fish Biology 49:627-647.

Marburger, J. E., W. E. Johnson, T. S. Gross, D. R., and Di. J. Douglas. 2002. Residual organochlorine pesticides in soils and fish from wetland restoration areas in central Florida, USA. Wetlands 22:705–711.

McInerny M. C, and T. K. Cross. 2000. Effects of sampling time, intraspecific density, and environmental variables on electrofishing catch per effort of largemouth bass in Minnesota lakes. North American Journal of Fisheries Management 20:328–336.

Mesing, C. L., and A. M. Wicker. 1986. Home range, spawning migrations, and homing of radio-tagged Florida largemouth bass in two central Florida lakes. Transactions of the American Fisheries Society 115:286-295.

Mesing, C. L., R. L. Cailteux, A. P. Strickland, E. A. Long, and M. W. Rogers. 2008. Stocking of advanced-fingerling largemouth bass to supplement year-classes in Lake Talquin, Florida. North American Journal of Fisheries Management 28:1762-1774.

Miko, D.A., H. L. Schramm, Jr., S. D. Arey, J. A. Dennis, and N. E. Mathews. 1995. Determination of stocking densities for satisfactory put-and-take rainbow trout fisheries. North American Journal of Fisheries Management 15:823-829.

Milon, J. W., and R. Welsh. 1989. An economic analysis of sport fishing and the effects of hydrilla management in Lake County, Florida. Economic Report 118, Food and Resource Economics Department. University of Florida. Gainesville, Florida.

Miranda, L. E., and W. D. Hubbard. 1994. Winter survival of age-0 largemouth bass relative to size, predators, and shelter. North American Journal of Fisheries Management 14:790-796.

Moyer, E. J, M. W. Hulon, J. J Sweatman, R. S. Butler, and V. P. Williams. 1995. Fishery responses to habitat restoration in Lake Tohopekaliga, Florida. North American Journal of Fisheries Management 15:591–595.

Nagid, E. J., M. S. Duncan, and T. M. Tuten. 2003. Largemouth bass age distribution on Rodman Reservoir following an extreme drawdown. Florida Fish and Wildlife Conservation Commission. Completion Report, Lower Ocklawaha Basin Fisheries Investigations. Gainesville, Florida.

Noble, R. L. 1981. Management of forage fishes in impoundments of the southern United States. Transactions of the American Fisheries Society 110:738-750.

Porak, W. F. 1994. Largemouth bass investigations: research and management of trophy largemouth bass. Florida Fish and Wildlife Conservation Commission. Project F-24. Study XVI.

Porak, W.F., W.E. Johnson, S. Crawford, D.J. Renfro, T.R. Schoeb, R.B. Stout, R. A. Krause, and R.A. DeMauro. 2002 Factors affecting survival of largemouth bass raised on artificial diets and stocked into Florida lakes. Pages 649-666 *in* D.P. Philippi and M.S. Ridgeway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland.

Reynolds, J.B. 1996. Electrofishing. Pages 221-253 in B. R. Murphy, and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Department of the Environment, Fisheries and Marine Science, Bulletin 191, Ottawa, Canada.

Schluter, C. A., and W. F. Godwin. 2003. Lake Griffin Fish Habitat Suitability Study. Available: http://proceedings.esri.com/library/userconf/proc03/p0792.pdf. (March 2008).

Shafer, M. D., R. E. Dickinson, J. P. Heaney, and W. C. Huber. 1986. Gazetteer of Florida Lakes. Publication No. 96. Florida Water Resources Research Center. University of Florida. Gainesville, Florida.

Smith, B. W., and W. C. Reeves. 1986. Stocking warmwater species to restore or enhance fisheries. Pages 17-29 *in* R. H. Stroud, editor. Fish culture in fisheries management. American Fisheries Society, Fish Culture Section. Bethesda, Maryland.

(SJRWMD) St. Johns River Water Management District. 2003. Lake Griffin : Fast Facts. Available: www.sjrwmd.com/publications/pdfs/fs_lgriffin.pdf. (February 2008).

Strange, R. J., C. D. Berry, and C. B. Schreak. 1975. Aquatic plant control and reservoir fisheries. Pages 513-525 *in* H. Clepper, editor. Black bass biology and Management. Sport Fishing Institute, Washington, D. C.

Terrell, J. B., D. L. Watson, M. V. Hoyer, M. S. Allen, and D. E. Canfield, Jr. 2000. Temporal water chemistry trends (1967-1997) for a population of Florida water bodies. Lake and Reservoir Management 16:177-194.

U.S. Department of Interior, Fish and Wildlife Service and U.S. Department of Commerce, Census Bureau. 2006. National survey of fishing, hunting, and wildlife-associated recreation.

Verdi, R. J., Tomlinson, S. A., and R. L. Marella. 2006. The drought of 1998-2002: impacts on Florida's hydrology and landscape. U.S. Geological Survey Circular 1295.Tallahasse, Florida

Wicker, A. M., and W. E. Johnson. 1987. Relationships among fat content, condition factor, and first-year survival of Florida largemouth bass. Transactions of the American Fisheries Society 116:264-271.

Wilson, J., C. W. Osenberg, C. M. St. Mary, C. A. Watson, and W. J. Lindberg. 2001. Artificial reefs, the attraction-production issue, and density dependence in marine ornamental fishes. Aquarium Science and Conservation 3:95-105.

Zimmerman, R. C., A. Cabello-Pasini, and R. S. Alberte. 1994. Modeling daily production of aquatic macrophytes from irradiance measurements: a comparative analysis. Marine Ecological Progressive Series 114:185-196.

BIOGRAPHICAL SKETCH

Darren John Pecora was born in 1979, to John S. and Jolanta A. Pecora. He grew up in Unionville, Connecticut, on a small lake, where he spent his childhood swimming, fishing, and exploring. As he matured, his curiosity of the outdoors led him to become an avid outdoorsman, hunting, fishing and camping around New England. He graduated from Avon Old Farms Prep School in 1997 with an interest in ecology. Darren earned his B. S. in environmental science in 2001, majoring in both wildlife biology and fisheries science at Unity College in Maine. After graduation, Darren worked around the country for a variety of fish and wildlife agencies. First, he worked for the Maine Atlantic Salmon Commission, where he worked on the restoration of endangered Atlantic salmon. Next, he worked for U. S. Geological Survey's Pacific Islands Ecosystem Research Center, Hawaii Volcanoes National Park, Hawaii on an endangered bird restoration project. Then, he worked for the Connecticut Department of Environmental Protection Fisheries Division on fisheries management projects and later, was employed by the U. S. Geological Survey's Columbia River Research Laboratory Cook, Washington, where he conducted research on the efficacy of alternative technology fish screens. Next, he worked for U.S. Fish and Wildlife Service in the Fairbanks, Alaska office on a project that was focused on estimating the abundance of migrating Yukon River fall chum salmon for in-season management of the subsistence fishery. Finally, he made his way down to the University of Florida in 2006, where he started off as a technician for Dr. Bill Pine working on the Apalachicola River and in Sarasota Bay. In the fall of 2006, Darren joined Dr. Daniel E. Canfield, Jr.'s lab, where he worked on the Lake Griffin largemouth bass stocking project. In August 2007, Darren began his master's research at the University of Florida, Department of Fisheries and Aquatic Sciences. Darren completed his master's research in 2009.