AN EVALUATION OF METHODOLOGY, DISPERSAL AND HABITAT USAGE OF LARGEMOUTH BASS (*MICROPTERUS SALMOIDES FLORIDANUS)* FROM A SUPPLEMENTAL STOCKING ON LAKE OKEECHOBEE, FLORIDA

by

Alyssa Jordan

A Thesis Submitted to the Faculty of

The Charles E. Schmidt College of Science

in Partial Fulfillment of the Requirement for the Degree of

Master of Science

Florida Atlantic University

Boca Raton, Florida

May 2012

AN EVALUATION OF METHODOLOGY, DISPERSAL AND HABITAT USAGE OF LARGEMOUTH BASS (*MICROPTERUS SALMOIDES FLORIDANUS)* FROM A SUPPLEMENTAL STOCKING ON LAKE OKEECHOBEE, FLORIDA

by

Alyssa Jordan

This thesis was prepared under the direction of the candidate's thesis advisor, Dr. Jon Moore, Department of Biology, and has been approved by the members of her supervisory committee. It was submitted to the faculty of the Charles E. Schmidt College of Science and was accepted in partial fulfillment of the requirements for the degree of Master of Science

SUPERVISORY COMMITTEE:

Jon Moore, Ph.D.
Thesis Advisor

Erik Noonburg, Ph.D.

Timothy Theisen, Ph.D.

Rodney K. Murphey, Ph.D.
Chair, Department of Biology

Gary W. Perry, Ph.D.
Dean, The Charles E. Schmidt College of Science

Barry T. Rosson, Ph.D.
Dean, Graduate College

April 4, 2012
Date

ACKNOWLEDGMENTS

This project took a lot of effort by many people to make all the wheels turn. I would like to thank all of the people who helped me complete this project at Florida Fish and Wildlife Conservation Commission, which provided and helped stock the largemouth bass. They also provided all of the needed equipment for this study. I would particularly like to thank those who aided in their knowledge and collection of bass: Donald Fox, Corey Lee and Brent Bachelder. I also would like to thank those over at FWRI in St. Petersburg who did the genetics, particularly Dr. Brandon Barthel and Dr. Michael Tringali who put up with a lot of questions and expended a lot of effort to get the results. Thanks also to those in the FWC Eustis office who also provided me a lot of knowledge and papers on the subject: Wes Porak and Nick Trippel in particular. The Florida Bass Conservation Center (FBCC) collected the broodstock and provided the fingerling bass for this study. I'd also like to thank all of my committee members: Dr. Jon Moore, Dr. Erik Noonburg and Dr. Timothy Theisen for sitting down with me, providing information and going over my paper multiple times with me. I'd also like to thank my family who all provided the motivational support for me to get this done.

ABSTRACT

Author: Alyssa Jordan

Title: An Evaluation of Methodology, Dispersal and Habitat Usage of Largemouth Bass (*Micropterus salmoides floridanus)* from a Supplemental Stocking on Lake Okeechobee, Florida

Institution: Florida Atlantic University

Thesis Advisor: Dr. Jon Moore

Degree: Master of Science

Year: 2012

The largemouth bass (*Micropterus salmoides*) fishery was at an all time low on Lake Okeechobee when experimental supplemental stockings were done to try and enhance local bass populations. Largemouth bass had never been stocked on a large lake like Lake Okeechobee. The objectives were to develop a methodology, study dispersal, and compare stocked versus wild bass habitat choices. The methodology underwent considerable changes between studies. Bass dispersed to the edges by the second sampling period, so a larger sampling area may be needed. Water depth and pH were found to be significantly different between wild and stocked bass. Hatchery bass are naïve about predators, which may have resulted in stocked bass not moving to shallower areas like wild bass. The pH was weakly correlated with depth, so differences may be partially due to the fact that as depth increases, pH may also increase.

AN EVALUATION OF METHODOLOGY, DISPERSAL AND HABITAT USAGE OF LARGEMOUTH BASS (*MICROPTERUS SALMOIDES FLORIDANUS)* FROM A SUPPLEMENTAL STOCKING ON LAKE OKEECHOBEE, FLORIDA

TABLES

FIGURES

INTRODUCTION

Recreational fishing in Florida is attributed to have provided 23,500 jobs in recreational freshwater fishing, involved 1.4 million freshwater anglers, and yielded 24.5 million fishing days with an overall economic impact of $1.4 billion (U.S. Department of the Interior 2006). In 2000, retail freshwater fishing sales from the five counties surrounding Lake Okeechobee were estimated at $117 million (Florida Fish and Wildlife Conservation Commission 2012). Largemouth bass (*Micropterus salmoides*) are one of the most popular sport fish in North America. It is estimated that approximately 10 million anglers fish for largemouth bass in the U.S., 8.2 million of those in Florida (U.S. Department of the Interior 2006).

Young largemouth bass survival and recruitment in Florida is related to availability of spawning and nursery habitats (Porak et al. 2002). Water drawdowns on lakes with degraded aquatic vegetation communities often cause aquatic vegetation to increase or come back, and may often be followed by strong year classes of largemouth bass (Wegener and Williams 1985; Nordhaus 1989). In systems where drawdowns are not possible, or in systems where there are no bass at all, this option is not viable for repopulating bass. Due to the popularity of largemouth bass, stocking has become an accepted practice for replacing or enhancing wild populations (Mesing et al. 2008). The public often feels that stocking largemouth bass will increase angler catch rates, and in some cases, they are correct.

Potential benefits of supplemental stocking include: increasing harvest rates (Boxrucker 1986; Buynak and Mitchell 1999), supplementing weak year-classes (Boxrucker 1986; Mesing et al. 2008), altering the genetics of an existing population (Rieger and Summerfelt 1978; Buckmeier et al. 2003; Hoffman and Bettoli 2005), and increasing the number of predators if the forage populations are too high (Mundahl et al. 1998; Boxrucker 2002). Stocking success is variable, and often the contribution of stocked fish to year classes can be low (Boxrucker 1986; Crawford and Wicker 1987; Porak et al. 2002 and Hoffman and Bettoli 2005). In some cases there is documented success, such as in the study of Mesing et al. (2008) which found 40% and 37% contributions of stocked fish in samples at age 0 and age 3. Four years after stocking it was estimated that at least 20% of the tournament catches were from hatchery fish. Other studies have also reported success with their stockings (Buynak and Mitchell 1999).

Timing of stocking is important in order to reduce competition with wild spawned bass, and to ensure adequate prey. If hatchery bass are the same size as wild bass when stocked, competition for the same foods can lead to higher mortality in both wild and stocked bass. If hatchery bass are stocked at sizes slightly larger than wild bass, mortality may decrease since the wild and hatchery fish are eating two different sized prey (and sometimes different types of prey if wild bass are still eating insects while hatchery bass have moved on to eating small fish). It is recommended that largemouth bass be stocked at times that are ideal for that geographic location (Neal et al. 2002). Ensuring there are adequate and correctly sized prey for stocked bass can lead to a more successful stocking. Ponds with greater amounts of small prey, such as

bluegill (*Lepomis macrochirus*), result in higher relative weights in largemouth bass (Hoxmeier and Wahl 2002; Sammons and Maceina 2005).

The size of bass at the time of stocking can also affect the success of the stocking (Wahl et al. 1995; Hoffman and Bettoli 2005; Diana and Wahl 2009). Wild bass have high mortality at small sizes, and it could be assumed that stocked bass of the same size would also have the same high mortality (Buckmeier and Betsill 2002). To reduce mortality in stocked bass, larger fish are sometimes stocked instead. Survival of stocked bass has been found to be higher in lakes where the stocked bass were larger and had a size advantage over the natural bass (Parkos et al. 2001, Diana and Wahl 2009). However, in Florida, hatchery bass change from an insect/zooplankton diet (natural in the ponds) to an artificial pellet diet once they reach approximately 35 mm TL. Studies have been conducted on the effects of pellets on hatchery fish, and many hatchery bass have been unable to adequately switch from pellets back to a wild diet of live fish after being released into a lake. Abnormalities in the liver have also created health issues in pellet fed bass. Until these issues are resolved, it may be best to stock bass before the need to switch to a pellet diet in the hatchery (Porak et al. 2002; Pouder et al. 2010).

Predation is also a large factor that affects the success of a stocking (Wahl and Stein 1989; Buckmeier and Betsill 2002; Hoxmeier and Wahl 2002). An environment with few predators of small bass may help reduce mortality and stress. It is suspected that many failed stockings may be due to predation, possibly due to naïve fingerlings (Suboski and Templeton 1989; Buckmeier et al. 2005). Unfortunately, stocking in systems with few or no predators is not always an option. Studies have found that

allowing bass to become habituated, or accustomed to the environment (and thus to predators), before release has led to significant increases survival rates in stocked bass (Schlechte et al. 2005).

The amount of bass stocked may also influence the success of a stocking (Bennett 1962; Boxrucker 1986; Buynak and Mitchell, 1999; Mesing et al. 2008). If there are too few bass, it can become difficult or impossible to see the effects on catch rates, making it difficult to evaluate. High stocking amounts may also exceed carrying capacity and may decrease survival of both wild and stocked bass (Buynak and Mitchell 1999). Mesing et al. (2008) recommended stocking 70 fish/ha, though other quantities have been used due to a variety of factors including the availability of funds, hatchery ability to produce fish and size of year class already present in the lake. The amount of wild bass already present in the water body may also make a difference (Terre et al. 1993). Negative correlations were found between growth of stocked bass and abundance of wild juvenile bass (Neal et al. 2002). Similar to stocking densities and high amounts of predators, too many juvenile wild bass can increase competition for food, and again, result in high mortality (Terre et al. 1993).

While many if not all of these conditions need to be met to have a successful stocking, some studies may have underestimated the success of their stockings due to the methods used in evaluating (Jackson and Noble 1995). Stocking variability may occur because many of these water bodies are in different geographic regions, may have different levels of productivity, different predator densities, and different habitats. The "cookbook" strategies for stocking should not be used, and instead each water body (or types of water bodies) evaluated separately (Mesing et al. 2008). In

addition, many studies do not look at habitat as a possible reason for failed stockings. If the habitat is limited, the many organisms that depend on vegetation for food or spawning have nothing to live on. Often bass are stocked to increase the population, but if the habitat is not there to support it, the stockings either completely fail or need to be redone every year (since no recruitment can occur). Some water bodies are unable to regain suitable habitat, and stocking every year is considered acceptable in those cases. But in a water body where a sustainable fishery is desired, improving the habitat needs to be a primary focus, and possibly part of the reason for past failures.

Background and Rationale:

Many years of high water levels in the late 1990's on Lake Okeechobee resulted in the loss of much of the aquatic vegetation, particularly submersed vegetation and important emergent species such as bulrush (*Schoenoplectus californicus*) and spikerush *Eleocharis* sp. Adequate aquatic vegetation is important for both largemouth bass spawning and prey production. With the 2004 hurricanes (Hurricane Frances and Hurricane Jeanne), high wave action further destroyed vegetation and made the water highly turbid for about three or four years allowing little or no re-growth of vegetation. Aquatic vegetation and largemouth bass populations were at all time lows in the following years (Florida Fish and Wildlife Conservation Commission 2009a) resulting in poor fishing. A subsequent drought in 2007 and 2008 dropped water levels, allowing the turbid waters to clear and vegetation to grow. In August 2008, Tropical Storm Fay caused lake levels to dramatically increase (five foot increase in one month), and the aquatic vegetation

expanded. This renewed marsh habitat allowed important prey populations for largemouth bass, such as invertebrates and small fish, to increase.

Due to the size of Lake Okeechobee (1,730 km^2), a drawdown of lake level was not possible through human means. The drought created a natural drawdown that in normal situations would possibly allow bass to repopulate the lake on their own with enough time. Because the population had been low for so long, and fishermen wanted to see a more immediate increase in bass populations, it was decided that supplemental stocking would help speed the recovery of the largemouth bass population. With the return of viable habitat and prey for largemouth bass, 2009 was deemed a good year to begin an experimental stocking of largemouth bass on Lake Okeechobee. Typically, stocking any species of fish in a system as large as Lake Okeechobee for the purpose of *repopulation* is generally considered infeasible and not economically worthwhile. Stocking a density of bass that would significantly alter the population in Lake Okeechobee is unlikely. If the estimate of stocking 70 Phase II bass/ha was used (Mesing et al. 2008) on Okeechobee, over 13 million Phase II bass would be needed to stock >189,000 ha Lake Okeechobee. More bass would be needed to make a significant contribution to the lake as a whole than there are hatcheries in the country (it would also be extremely expensive). Instead of trying to repopulate the entire lake, small protected coves were stocked instead. The rationale was that the local populations in these coves could be increased and the smaller geographic scale would allow easier sampling. However, these "smaller" coves are still large relative to many previously stocked bodies, and fish are still able to disperse out of these areas.

Effective methods for sampling this type of large system are still being developed and multiple methods have been used. A system this large is almost comparable to an open marine system where fish can move anywhere, and often outside of the sampling areas. Looking at the red drum (*Sciaenops ocellatus*) stocking program in Florida gives some insight on the difficulty and importance of sampling stocked fish in large systems (Tringali et al. 2008). It took many years of research, trial and errors to optimize that program. Initially, the program stocked small 20-40 mm red drum and, for the most part, did not monitor the progress. After multiple years of this approach, the program was evaluated and it was suggested that the stocked size be increased and that stockings be monitored. Currently the red drum stocking program is sampled using a variety of methods to gain all of the data needed for analysis. Scientists sample red drum on a yearly basis and are aided by the public. Because the red drum had been stocked at larger sizes, it was possible to tag them. The fish could then be reported by outside samplers such as anglers and other sampling programs, which increases the "sampling area" and number of recaptures for these fish. The red drum program continues to be monitored and research is ongoing to improve the success of future stockings (Tringali et al. 2008).

One of the more controversial topics is what constitutes the optimal size for largemouth bass stocked into a Florida system. Porak et al. (2002) found that Phase II largemouth bass (bass large enough to be switched to a fish or artificial pellet diet, typically 67-335 mm TL) raised in Florida, have some issues in the hatchery staying healthy on an artificial pellet diet in the hatchery. At the time of this study, Porak et al. (2002) found liver anomalies in 22% of stocked fish, which included lipid

accumulation, degeneration and necrosis of hepatocytes, a mild inflammatory response, and nodular regeneration. Vitamin C deficiency was also suspected in these pellet-reared fish. The Phase II bass also had the further problem of having a reduced feeding efficiency when switched from artificial pellets to live food. The highest survival rates of stocked bass of this size were found in bass on Lake Hollingsworth that had been raised on a live diet at the hatchery. These fish were conditioned to eat live prey before stocking, and post-stocking feeding efficiency did not appear to be a problem in these fish (Porak et al. 2002). On Lake Okeechobee, it was determined Phase I bass (typically 28-35 mm TL and still foraging on invertebrates and zooplankton) were more suitable for stocking due to the many problems with Phase II bass. In addition, the number of bass requested to be stocked in Lake Okeechobee would require more Phase II individuals than the hatchery could handle at one time.

Typically, the timing of stocking tends to work around threadfin shad (*Dorosoma petenense*) or bluegill spawn times to increase prey for stocked fish. However, bass in Lake Okeechobee show rapid growth (compared to other waters in Florida) and historically appear to not be dependent on any one organism for food. Fox (1987) found in a food habit analysis of largemouth bass that there were 15.9% grass shrimp (primarily *Palaemontes paludosus*), 10.1% killifish (primarily *Fundulus seminolis*, *Heterandria formosa* and *Lucania goodie*), 15.5% bream (other *Lepomis* species), 11.6% bluegill, and 10.1% redear sunfish (*Lepomis microlophus*). Surprisingly, unlike diet studies on other lakes, shad comprised only 2.2% of largemouth bass prey (Fox 1987). Because these bass have a variety of foods available at multiple times of the year, it's likely the timing is not quite as critical on Lake Okeechobee other than to

make an effort to have hatchery-reared bass that are larger than wild bass at the time of stocking to decrease cannibalism and competition.

Study Site:

Lake Okeechobee (26°58'N, 80°50'W) is located in south-central Florida and is the second largest freshwater lake contained entirely within the lower 48 states. It is a large (approximately 700 mi^2 or 1,730 km^2 in size), eutrophic, shallow lake with average depths of approximately 9 feet (2.7 m) and maximum depths less than 16 feet (4.9 m). Water input to the lake comes from rainfall and the Kissimmee River to the north. Lake Okeechobee is known for its largemouth bass and black crappie (*Pomoxis nigromaculatus*) fisheries, which generated $28.4 million in annual revenue in 1986 (Bell 1987). With 2011 inflation estimates, this value is at approximately $58 million today (Sah 2011). Bell (1987) found a total fishery value of $100 million which is approximately $206 million with 2011 inflation (Sah 2011). Lake Okeechobee is also a main source of drinking water for lakeside towns, and a backup source of drinking water for the 6 million residents of Florida's lower east coast (South Florida Water Management District 2000). The lake also provides irrigation water for the $1.5 billion per year agricultural sector. Ecologically, Lake Okeechobee is a vital habitat for wading birds, migratory waterfowl, and endangered species such as the Everglade snail kite (*Rostrhamus sociabilis*), wood stork (*Mycteria americana*), and Okeechobee gourd (*Cucurbita okeechobeensis*). Lake Okeechobee is also a critical water source for the Everglades ecosystem (Steinman and Rosen 2000).

Cody's Cove and Tin House Cove are two coves located in the northwestern marsh of Lake Okeechobee and were used in these stocking projects (Figure 1). In 2001, 2007 and 2008 Florida Fish and Wildlife Conservation Commission (FWC) and South Florida Water Management District (SFWMD) projects removed roughly 1.1 million cubic yards of invasive aquatic plants and associated organic sediment (muck) from a seven-mile long berm in the northwest marsh, and 436 acres of Cody's Cove/Tin House Cove littoral zone marsh. This was accomplished by using mechanical equipment when the lake level was low enough that the lake bottom was exposed. The objectives were to increase diversity of plant species, improve water quality, and improve water flow within littoral areas by allowing the flushing of accumulated detritus (Florida Fish and Wildlife Conservation Commission 2009a). When water levels came up following these projects (mostly due to Tropical Storm Fay), native and desirable aquatic vegetation were able to re-establish within a few years. The Cody's Cove and Tin House Cove 2008 restoration sites were the areas that were focused on in this project (Figure 2).

The Cody Cove stocking and sample areas were not actually located on the Cody Cove restoration site, but were actually adjacent to sites s6 and s7. At the time, the actual Cody's Cove restoration site did not have sufficient plant cover or prey to stock small largemouth bass within it, but it was anticipated that when the vegetation recovered in this area, the largemouth bass could utilize this area at a later time. The Tin House Cove stocking was done a year after Cody's Cove, and by that time there was sufficient plant cover to stock within the Tin House Cove scrape site (since it had also been restored in 2008). The sampling area was created around the restoration

site. Stocked bass had the newly improved sandy bottom and vegetation within the scrape site to use, or they could choose to move to the edges and use the denser, muckier areas surrounding the scrape site.

Objectives:

There were three main objectives of this study. The first was to develop an appropriate sampling methodology for stocking largemouth bass in a large freshwater system, such as Lake Okeechobee. Lake Okeechobee had never been stocked with largemouth bass, and a stocking of largemouth bass had not previously been documented on a freshwater system as large as Lake Okeechobee. Comparing the two stocking events on Lake Okeechobee was expected to provide valuable data on the strengths and weaknesses of different methodologies. This will provide a starting point for developing a working methodology for evaluating largemouth bass stocking on large lakes.

The second was to investigate stocked largemouth bass dispersal in a large system. Using protected coves, which are somewhat similar to smaller lakes, dispersal can be monitored. In a large system, mortality cannot be accurately determined, but if bass were seen to get further from the initial stock point over time, it might be possible to differentiate between dispersal out of the sample areas and mortality. In a study by Hoffman and Bettoli (2005), 31% of recaptured bass occurred more than 600 m from the nearest stocking site, indicating rapid dispersal by some fish. After 7 days, almost 30% of the recaptures were more than 700 m from the stocking site. At about 19 days post-stocking, dispersion appeared to stabilize, which corroborates a study done by

Buckmeier and Betsill (2002). A recent telemetry study on Lake Carlton, FL showed that stocked bass have the capacity to travel long distances before finally settling in a location, as demonstrated by one bass in the study that travelled $\geq$ 2,010 m in 14 days. The stocked bass also travelled further and more often than wild fish that were also tracked (Porak et al. 2011). While it may be relatively simple to determine success in smaller lakes, studies need to be done on larger systems determine the best methods for sampling and assessing the success of the stocking. Due to the large size of Lake Okeechobee, methods similar to those used in marine stockings would likely be the most beneficial.

The third objective was to look at habitat usage. Not all stockings occur in lakes with adequate habitat for sustaining bass populations and factors such as habitat preference and other ancillary data can also be evaluated to determine if there are any differences between occurrence of wild and stocked bass. Looking at how stocked bass fare in a large, vegetated system may provide new data.

MATERIALS AND METHODS

A previous study completed by Florida Fish and Wildlife Conservation Commission in 2009 in Cody's Cove was the first largemouth bass stocking ever attempted on Lake Okeechobee (Florida Fish and Wildlife Conservation Commission 2009a). In 2010, a second stocking at Tin House Cove was completed as part of this thesis project. The two stocking methodologies are being compared, so both methodologies are presented. For both studies, water temperature (^{o}C), acidity (pH), dissolved oxygen (mg/L), turbidity (NTU), and conductivity (µS/cm) were collected at the surface using a Eureka Amphibian® display and Manta® probe. At the end of each 15-minute sampling run water depth (meters, m), Secchi depth (m), sediment type and habitat type were recorded. The dominant submersed, emergent and floating plant species were recorded as a proportion of the vegetation community (%). At each site, GPS coordinates were recorded using a Garmin GPS. A 2008 GEOXT Trimble® was used to find sampling locations and to stay within sampling areas. ArcGIS 9.2 was used to produce all maps. A Polar Kraft electrofishing boat (with a GPP 9.0 Smith-Root electrofishing unit) was used in the Cody's Cove study along with a back-pack electrofishing unit (Smith-Root LR-24) for areas with denser vegetation. A Diamondback electrofishing airboat (with a GPP 7.5 Smith-Root electrofishing unit) was used in the Tin House Cove study. Stunned fish were collected using 3/8-inch

mesh nets and were placed in a live well on the boat until the end of the sampling run. Fin clips were taken as tissue samples from all young largemouth bass collected, and genetic analysis of DNA extracted from fin clips were conducted according to the protocol by Tringali et al. (2010). Statistical analysis was completed using SYSTAT 8.0 with some graphs being made in Microsoft Excel 2007.

Genetic Analysis:

For these studies, a fin clip from each individual fish was sent to a Fish and Wildlife Research Institute (FWC) genetic laboratory in St. Petersburg, FL. Ten microsatellite markers were used in a co-parentage analysis to determine the parentage of the sampled fish. Co-parentage analysis tests whether each captured individual's genotype is consistent with a mating between a male and a female brood fish, i.e. whether each potential pair of parental genotypes could have produced each collected offspring's genotype. For a pair of broodfish to be the true parents, the offspring must share an allele with each of the two parents for each of the ten molecular markers that have been pre-determined (Tringali et al. 2010).

Study 1: Cody's Cove (2009):

The Cody's Cove stocking effort was begun by Florida Fish and Wildlife Conservation Commission (Florida Fish and Wildlife Conservation Commission 2009a) on February 12, 2009 when approximately 80 adult male and female largemouth bass (*Micropterus salmoides*) were collected from the rim canal of Lake Okeechobee by electrofishing. Each collected bass was tagged and sexed at the time

of collection. The bass were then transferred by truck to the Florida Bass Conservation Center (FBCC) in Webster, FL. Only bass found to be pure *floridanus* subspecies were kept as broodstock (identified by genetic analysis) to keep stocks pure. These bass were bred, and produced approximately 99,000 Phase I fingerlings (under 2 inches or 51 mm TL) for transfer to Lake Okeechobee.

The fingerlings were released into Cody's Cove, an isolated cove (cut off by thick vegetation from the open water) in northwestern Lake Okeechobee. On March 26, 2009 approximately 22,000 fingerlings were released into four areas. On April 8, 2009 approximately 52,000 additional fingerlings were released into another ten areas of Cody's Cove. The final release on April 22, 2009 released approximately 25,000 fingerlings into six more areas (Figure 3).

The sampling site at Cody's Cove (475 ha.) in Lake Okeechobee was divided into two zones, each with seven subdivisions (sites). The western subdivisions closest to shore were the areas that were originally stocked with fingerlings from the hatchery. This area was referred to as the "stocked" zone which included sites s1 – s7. The seven adjacent eastern sites are the areas closer to the open water where it was assumed the fish would head if they dispersed. This area was referred to as the "dispersal zone" and included sites d1 - d7 (Figure 3). Starting May 6, 2009 (2-6 weeks after stocking), at a lake level of 10.93 ft. NGVD, sampling began and was conducted approximately every other week. For each sampling trip, four sites were randomly chosen (random number generator used in selecting sampling sites was from the website graphpad.com) for the stocked area and the dispersal area. Within the individual sampling sites, four crayfish funnel traps were set in the shallower and

denser vegetation areas and were allowed to soak for one day. The following day the traps were collected and a 15-minute electrofishing sample using a Polar Kraft boat was done in the same sites encompassing all available habitat types. A boat speed of approximately 1 mph was maintained while shocking. The amps, pulse frequency and voltage were recorded for each sample. Some adjustments were needed due to rising and falling lake levels during this time. In sites where the water was too shallow or had too much vegetation, two extra traps were added to the area to make up for not being able to electrofish. Back-pack electrofishing (Smith-Root LR-24) was attempted in a few shallow areas with dense vegetation, but had minimal results. Only small areas were covered, and the back-pack shocker seemed to have an small range (no further than we could reach). In sites where water was too deep for deployment of traps, traps were not placed and instead another 15-minute electrofishing sample was added using the electrofishing boat. By the end of the sampling electrofishing with the boat was being used for the majority of the sampling since the water was too deep for the traps and the traps had been largely unsuccessful anyway.

Fin clips (usually from the anal fin) were taken from each largemouth bass sampled at 5 inches (127 mm) in total length or less, and it was assumed the stocked bass could not have grown larger than that size during that time. Total length (mm) was recorded for each bass and each fin clip sample was placed in a vial with alcohol with a labeled tag. A total of 443 clips were collected from 660 minutes of shocking and 72 crayfish traps. The genetic samples were then sent to the Fish and Wildlife Research Institute lab in St. Petersburg for DNA analysis to determine if the bass were wild or brood stock progeny. In addition, approximately 30 of these largemouth bass

were kept each sampling period and brought back to the lab to determine stomach content (fish, shrimp, invertebrate, empty). A total of 173 bass were kept for stomach analysis. All of these bass were measured for total length (mm) and weighed to the nearest gram. Stomach contents were identified, counted and weighed (g).

A total of five sampling periods occurred throughout the summer and ended the week of July 6, 2009, the last day being July 7, 2009. This was 7 to 11 weeks from the time the bass were originally stocked. At that point the water had risen so much (lake level on July 7 was 12.91 ft. NGVD) that there was difficulty collecting fish and it was assumed that the bass had dispersed too far outside of the sampling area to get adequate samples.

Study 2: Tin House Cove (2010)

Preliminary sampling was done in the Tin House Cove scrape site by Florida Fish and Wildlife Conservation Commission to determine species composition and sizes in the area closest to where the fish would be stocked (mainly in the scrape area). Four 15-minute electrofishing runs were conducted using the Polar Kraft boat, (in four separate geographic locations within the 2008 Tin House Cove scrape site) and species were identified, measured (mm TL), weighed (g) and recorded.

Completed as part of this thesis project (IACUC #A10-09) the 53 brood fish for Tin House Cove came from Lake Tohopekaliga, Lake Istokpoga and from the previous year's brood stock that had been collected from the Lake Okeechobee rim canal. The bass for this project were spawned in late February and early March 2010. On April 21, 2010 there were 134,713 fingerling largemouth bass stocked in an

isolated area of the lake called Tin House Cove. All fingerling bass were stocked at a single point in the center (Figure 4). Another 100,410 were stocked on April 28, 2010 and a final 105,558 stocked on April 29, 2010 all at the same center point. A total of 340,681 Phase I fingerling bass were stocked with a mean weight at stocking of 1.41 g per fish. The stocking time was reduced from that of the Cody Cove study (from a period of almost a month to 8 days) to make travel distance of each bass possible to determine.

The sampling site at Tin House Cove was made into a large grid (296 ha.) around the center stocking point (a change from the Cody Cove study to be able to calculate travel distances and see possible dispersal patterns). Each box within the grid was approximately 216 m x 216 m in size. During each sample period 16 randomly chosen sites were sampled over a period of two to three days (using 2007 Microsoft Excel random number generator). The sampling site grid was set up to make sure each "ring" of the grid was sampled each sampling period and to ensure sampling at multiple distances from the stocking point each week. This was set up with having one sample per four boxes chosen per ring: the inner ring, Ring 1 contained 4 boxes. This resulted in 1 site being chosen in this ring. Ring 2 contained 12 boxes and resulted in 3 samples. Ring 3 contained 20 boxes and resulted in 5 samples and finally, Ring 4 contained 28 boxes and resulted in 7 samples (Figure 5). Sampling for Tin House Cove began on May 17, 2010, and like the sampling at Cody's Cove, was every other week. The lake level at this time was 14.64 ft NGVD.

Every sampling period, 15-minute electrofishing runs were used to collect bass (traps that were used in Cody's Cove were deemed as unsuccessful and not used).

Similar to Cody's Cove, fin clips were taken from the anal fin of each fish collected. This time, only fish 4 inches (102 mm) and less in total length were collected since the previous length of 5 inches in the Cody Cove study was deemed too large. For a majority of the sampling, a Diamondback airboat was used since the area was too shallow and vegetated for a regular boat, and trouble with access to parts of the sites in the Cody Cove study made the use of an airboat ideal for this study. Like the Cody Cove study, the amps, frequency and voltage were recorded each run. A boat speed of approximately 1 mph was maintained for each run. Every fish had total length recorded (mm) and each fin clip sample was placed in a vial with alcohol with a labeled tag. A total of 322 clips were collected in 1200 minutes of electrofishing. The genetic samples were then sent to the FWRI lab in St. Petersburg for DNA analysis to determine if the fish were wild or brood stock progeny. Unlike Cody's Cove, no fish were kept for stomach analysis. Like Cody's Cove, five sampling periods were completed and the last week of sampling began on July 12, 2010 (with the last sample day being July 13, 2010). The lake level on July 13 was 14.41 ft. NGVD.

Supplemental Studies: October 2009 and 2010

As a supplement to the 2009 and 2010 sampling, in October 2009 and 2010 fin clips were collected from largemouth bass during normal FWC fall electrofishing survey. This was to potentially see if the stocked bass had moved further away from stocking sites. FWC collected 11 bass fin clips, lengths (mm TL) and weights (g) in October 2009 in the areas immediately around Cody's Cove. Clips were taken from

bass no larger than 8 inches (203 mm) in length. The clips were placed in vials with alcohol and labels and sent to the FWRI lab in St. Petersburg for DNA analysis.

In October 2010, 104 fin clips were collected, but from fish between 8 and 15 inches (203 mm to 381 mm) to ensure fish from both Cody's Cove and Tin House Cove stockings could be collected. Areas between Cody's Cove and Tin House Cove bass were sampled, and areas on either side of these coves as well (Figure 6). Previous studies have shown stocked fish often travelling many miles before finally settling in a location (Buckmeier and Betsill, 2002; Hoffman and Bettoli 2005; Porak et al. 2011). Using a Polar Kraft boat with a Smith-Root GPP 9.0 electrofishing unit, fin clips were collected (from the anal fin), total lengths (mm) and weights (g) recorded. Fin clips were placed in vials with alcohol and labels and sent to the FWRI lab in St. Petersburg for DNA analysis.

RESULTS

Study 1: Cody's Cove

In Cody's Cove 443 fin clips were collected from largemouth bass that were between 32 to 131 mm TL (up to about 5 inches) with an average length of 84.95 mm. Out of these samples, there were 6 recaptures of stocked bass (1.4% recapture probability compared to wild bass). These bass were between 52 to 81 mm TL, with an average length of 66 mm (Table 1). Four of the six recaptured bass collected had been used in the diet study, and all four of these bass had food in their stomachs. Food items in stocked bass were similar to that of wild fish (3 bass contained shrimp and 2 contained small fish). All stocked fish showed they were finding prey since none had empty stomachs (Table 2). The recapture locations and dates for the six recaptured stocked bass can be seen in Figure 7. Stocked bass were found scattered throughout the sampling area and except for the last sampling period, there was at least one stocked bass sampled per sampling period.

Dispersal and Distribution

The mean travel distance of a captured bass from the nearest stocking location was 117 m. The greatest distance travelled was 192 m, at approximately 28 days post stocking. The catch per unit effort (CPUE) of wild largemouth bass in Cody's Cove

was 0.66 (no effort sites excluded) and ranged from 0.0 fish/minute in site d5 to 1.7 fish/min in site s6. Stocked bass CPUE was 0.01fish/min (no effort sites excluded) and ranged from 0.0 fish/min (sites s2, s4, s5, s7, d1, d2, d5 and d7) to 0.07 fish/min in s6. Site s1 was never sampled so cannot be analyzed for CPUE (Figure 8). The site with the most largemouth bass (wild and stocked combined) was s6 with a CPUE of 1.77 fish/min. Overall, the CPUE for entire Cody's Cove site (no effort sites were excluded) was 0.67 fish/min.

Water Quality and Habitat

Water quality data were collected, but no statistical tests were done due to the low numbers of recaptures, which made statistical analysis unreliable. The water temperature ranged from 25.84°C to 32.65°C, the dissolved oxygen ranged from 2.34 mg/L to 8.08 mg/L, the pH ranged from 7.54 to 9.49 and the water depth ranged from 0.4 m to 0.81 m. Table 3 and Figure 9 depicts the dominant types of cover (mostly vegetation types) that occurred in Cody's Cove. Percent coverage was broken into four categories: 0-25% cover, 26-50% cover, 51-75% cover and 76-100% cover. A majority of the sites (61.9%) in Cody's Cove had 76-100% coverage. There were no sites that had 0-25% cover. The rest of the sites were in the other two categories. Over half of the sites had a dominant cover type of hydrilla (*Hydrilla verticillata*) at 57.1%. American eelgrass (*Vallisneria americana*) dominated 40.4% of the sites. Cattail (*Typha* sp.) and spikerush (*Eleocharis* sp.) dominated 9.5% and 2.4% of the sites, respectively.

Stocked bass were found in 33.3% of the 76-100% coverage areas and 50.0% of the bass were in the 51-75% cover areas. The final 16.7% of stocked bass were found in the 26-50% covers. Occurrence rate was calculated by dividing the percent of fish caught (capture rate) by the percent of cover type. Occurrence rates of over 1 showed a higher incidence of capture in a certain cover type compared to the amount of cover type actually available (over 1 is a positive occurrence). Occurrence of stocked bass in areas with 76-100% cover was 0.54 (negative). The 51-75% cover had an occurrence rate of 2.99 (positive) and for 26-50% the occurrence rate was 0.78 (negative). Stocked bass had the highest abundance in eelgrass and hydrilla but had occurrence rates of 1.24 (positive) and 0.88 (negative) respectively. The highest occurrence rates (highest proportion of bass compared to the amount of habitat present) occurred in the spikerush (6.96 - positive) with a 16.7% capture rate. Cattail also had a 16.7% capture rate and a fairly high occurrence rate (1.76) of bass.

A majority of the wild bass were found in areas of 76-100% or more cover (58.1% abundance) but with an occurrence rate of 0.94 (negative). Samples with 51-75% coverage captured 13.3% of wild bass, and also had a negative occurrence rate of 0.80. The 26-50% cover sites contained 28.6% of the wild bass and had a positive occurrence rate of 1.34. The highest abundance of wild bass was in eelgrass (53.8%), which also had the highest occurrence rate of 1.33 (positive). Hydrilla had the second highest abundance of wild bass at 45% and had an occurrence rate of 0.79 (negative). Spikerush had the second highest occurrence rate (1.29), but had the lowest abundance of bass (3.1%). Cattail had a 0.62 occurrence rate with 5.9% of wild bass caught there.

Study 2: Tin House Cove

In Tin House Cove, 322 fin clips were collected in fish between 32 and 103 mm TL (up to about 4 inches). Genetic results showed 28 of the collected fin clips were from hatchery bass (8.7% recapture probability), with at least one stocked bass being caught every period of sampling (Figure 10). Six of the fin clips were unable to be determined, possibly due to degraded DNA. An error at the hatchery where the stocked bass were spawned resulted in five of the brood stock fish (out of a total of 53) not being fin clipped at the start and therefore were not genotyped. Attempts were made to retrieve the fish to collect DNA, but were not successful (the fish had most likely died in the interim). Because the genetic analysis in this study looked at co-parentage, any recaptured bass that had either parent as a missing fish would not be able to be identified as a stocked bass and would likely show up as a wild bass. Because of this, there was a chance that more than 28 of the sampled bass were stocked bass. Over the five sampling periods, an average length of 72 mm was found for all collected stocked fish. An average of 75 mm was found for all collected wild fish. Every sampling period showed an increase in average length of fish captured for both stocked and wild fish. The only outlier was during sampling period 4 (which only had four stocked fish), where the average length decreased, possibly due to the small sample size (Figure 11).

Dispersal and Distribution

Travel distance from the central stocking point was measured for each individual stocked bass. Over the five sampling periods, an overall mean distance of

343 m was travelled. Sampling period one (approximately 4 weeks poststocking) showed an average distance of 199 m travelled with a maximum distance of 296 m and a minimum distance of 175 m. Sampling period two (approximately 6 weeks poststocking) showed an average of 195 m travelled with a maximum distance of 692 m travelled and a minimum distance of 71 m. Period three (approximately 8 weeks poststocking) showed an average travel distance of 427 m with a maximum travel distance of 727 m and a minimum of 207 m. Period four (approximately 10 weeks poststocking) showed an average distance of 497 m with a maximum of 694 m and a minimum of 167 m travelled. And period five (approximately 12 weeks poststocking) showed an average travel distance of 371 m and a maximum of 819 m and a minimum of 41 m travelled (Figure 12).

The CPUE of wild largemouth bass was 0.24 fish/min (no effort sites excluded) ranged from 0.0 fish/min (in sites 18, 34, 43, 60, 63, 64) to a maximum of 0.87 fish/min in site 29. The CPUE's of stocked largemouth bass ranged from 0.0 fish/min (in 33 sites out of 47 sampled sites) to a maximum CPUE of 0.27 fish/min in site 2. Both wild and stocked bass CPUE's can be seen in Figure 13. The site that had the highest CPUE of bass (both stocked and wild bass) was at 0.87 fish/min in site 29 (which contained only wild bass). The overall CPUE for all of Tin House Cove (no effort sites were excluded) was 0.27 fish/min. A t-test was done comparing the CPUE's of stocked and wild bass in Tin House Cove and confirmed a significant difference in CPUE's ($P<0.001$). The wild bass had a mean CPUE of 0.24 fish/min (standard deviation of 0.048) while the stocked bass showed a mean CPUE of 0.02 fish/min (standard deviation of 0.211). To see if there were further differences, t-tests

were done comparing stocked and wild bass CPUE's in the restored (sandy sediment) and non-restored (muck sediment) locations of the site. A non-significant difference was found in the stocked fish between the restored and non-restored (P=0.072) areas. The wild bass showed a similar non-significant trend between the restored and non-restored areas (P=0.073) (Figure 14).

Using the percent frequency of largemouth bass where the number of bass found in a sediment type was divided by the total number of bass caught (either stocked or wild). A total of 61% of stocked bass were found in the restored "sand" areas as opposed to the wild bass which were found in "sand" areas 22% of the time. Conversely, 39% of stocked bass were found in non-restored "muck" areas, while 78% of wild bass were found in these areas (Figure 15).

Water Quality and Habitat

The t-test was used to test for significant differences between 28 stocked and 288 wild fish in water temperature (C), dissolved oxygen (mg/L), water pH and water depth (m). Temperature (Figures 16 and 17) and dissolved oxygen (Figures 18 and 19) showed no significant differences. Significant differences were found in pH (Figures 20 and 21) and water depth (Figures 22 and 23).

Mean temperature for stocked fish was 31.23 C (standard deviation of 1.499) with a maximum of 33.5 C and a minimum of 28.2 C. Variance was 2.248. Mean temperature for wild fish was 31.07 C (standard deviation of 1.595) with a maximum temperature of 35.1 C and a minimum of 26.70 C. Variance was 2.542. When

compared, the t-test showed P=0.592 which showed no significant temperature difference between stocked and wild bass.

Mean dissolved oxygen for stocked fish was 4.82 mg/L (standard deviation of 1.997) with a maximum of 7.8 mg/L and a minimum of 1.1 mg/L). Variance was 3.987. Mean dissolved oxygen for wild fish was 4.10 mg/L (standard deviation of 1.555) with a maximum of 7.83 mg/L and a minimum of 0.79 mg/L. Variance was 2.418. When compared, the t-test showed P=0.075, which showed no significant difference in dissolved oxygen between stocked and wild fish.

The mean pH for stocked fish was 8.12 (standard deviation of 0.432) with a maximum of 8.8 and a minimum of 7.2. Variance was 0.186. Mean pH for wild fish was 7.86 (standard deviation of 0.379) with a maximum of 8.8 and a minimum of 7.0. Variance was 0.143. When compared, the t-test showed P=0.005, which was a significant difference in pH between stocked and wild fish.

The mean depth for stocked fish was 0.82 m (standard deviation of 0.631) with a maximum of 1.10 m and a minimum of 0.46 m. Variance was 0.398. The mean depth for wild fish was 0.69 m (standard deviation of 0.679) with a maximum depth of 1.13 m and a minimum of 0.40. Variance was 0.461. When compared, the t-test showed P=0.001, which was a significant difference in water depth between stocked and wild fish. A Pearson Correlation test showed a weak positive correlation between depth and pH (r=0.239, n=317).

Similar to that in Cody's Cove, the dominant types of cover (i.e. vegetation types) that occurred at Tin House Cove (Figure 24 and Table 4) were split into four categories: 0-25% cover, 26-50% cover, 51-75 cover and 76-100% cover. Like

Cody's Cove, the 76-100% cover was found in the most sites (48.7%) and the 0-25% cover was found in the least amount of sites (2.6%). 26.9% of sites had 51-75% cover and 21.8% of sites had 26-50% cover. Lilies (*Nymphaea* sp.) were the most common dominant cover at 39.3%. Yellow water lily (*Nymphaea mexicana*) had 26.6% coverage and fragrant water lily (*Nymphaea odorota*) had 12.7% coverage. Hydrilla was the second most dominant type of coverage at 17.7% and spikerush was at 8.9% coverage. Other dominant species included filamentous algae at 7.6% coverage, pickerelweed (*Pontedaria cordata*) and dead/organic material both at 6.3% coverage, and alligator weed (*Alternanthera philoxeroides*) and torpedo grass (*Panicum repens*) at 5.1% coverage. Bladderwort (*Utricularia* sp.), duck-potato (*Sagittaria lancifolia*), frog's-bit (*Limnobium spongia*), slender spikerush (*Eleocharis baldwinii*) and smartweed (*Polygonum* sp.) all had 2.5% coverage. American cupscale grass (*Sacciolepis striata*), buttonbush (*Cephalanthus occidentalis*), cattail and willow (*Salix* sp.) were at 1.3% coverage.

Occurrence rate was calculated by dividing the percent of fish caught (capture rate) by the percent of cover type. Occurrence rates of over 1 showed a higher incidence of capture in a certain cover type compared to the amount of cover type actually available (occurrence rates over 1 are positive). While lilies were the most dominant species found in the sites, stocked bass were found in only 10.7% of the samples (0.27 occurrence rate - negative). Stocked bass were more commonly found in hydrilla (50% with a 2.82 occurrence rate), spikerush (21.4% with a 2.4 occurrence rate) and duck-potato (10.7% with a 4.28 occurrence rate). All three of those species

had positive occurrence with duck-potato having the highest occurrence rate for stocked bass.

Wild bass also were found more often than stocked bass in lilies at 24% (0.61 occurrence rate) of the samples. Wild bass were more commonly found in hydrilla (29.4% with a 1.66 occurrence rate). They were also commonly found in spikerush (9.7% with a 1.09 occurrence rate) and duck-potato (9.7% with a 3.88 occurrence rate). Wild bass in hydrilla, spikerush and duck-potato, like stocked bass, all had positive occurrence rates.

Supplemental Studies: October 2009 and 2010

No recaptures of stocked bass were found in either the October 2009 or October 2010 sampling periods.

DISCUSSION

Methodology comparison:

The Cody's Cove study evaluated the first largemouth bass stocking of Lake Okeechobee, and the first known stocking of largemouth bass on a lake this large. Because this was a pilot project there were a few initial flaws in the methodology. From the Cody's Cove study to the Tin House Cove study, many changes were made. If a third study were ever done, additional changes would also be made to improve recapture rates and analysis.

Fry and juvenile bass mortality is generally much higher than adult bass mortality. Stocked bass often have an even higher mortality rate than their wild counterparts (Dieperink et al. 2001). Because only six stocked bass were recaptured in the Cody's Cove study (most likely due in part to high mortality, the size of the system and the inability to get to areas where stocked bass likely went), the Tin House Cove study increased the number of bass stocked from approximately 99,000 in Cody's Cove to 340,681 in Tin House Cove the following year which likely aided in the higher number of recaptures. The increase in bass hopefully offset some of the mortality issues that may have occurred in the first study and made the bass easier to detect within the existing population. By increasing the number of bass stocked, it was hoped that enough bass could be recaptured in the Tin House Cove study to evaluate. Due to hatchery space and costs, it was not possible to stock more than the

340,681 (without adequate reason) or to stock that many in multiple, distant locations to replicate the study.

The number of stocking locations was reduced from twenty-one spread-out locations in Cody's Cove to just one location in Tin House Cove. Stocking small amounts of bass in multiple locations caused any evaluation of the dispersal of stocked bass to be impossible. Because the origin of each recaptured stocked bass was unknown, the best that could be determined was the distance a bass was from the nearest stocking point. Some of the bass probably came from a more distant stock point (and just ended up near another stocking point) so dispersal was likely underestimated. By stocking in one location, there was a possibility of increasing mortality. Copeland and Noble (1994) and Hoffman and Bettoli (2005), found that stocked largemouth bass had limited dispersal, so they felt stocking in one location may increase competition for food and decrease survivability. This was possibly due to the fact that this study occurred in a lake much smaller than Lake Okeechobee (Okeechobee is unlikely to have a shortage of food for the relatively small amount of bass stocked per acre of lake). Not all studies have found a negative effect of higher stocking densities, and in fact some found positive benefits for a few years (Boxrucker 1986; Buynak and Mitchell 1999; Hoxmeier and Wahl 2002). A recent telemetry study by Porak et al. (2011), showed hatchery bass are capable of and often travel large distances in a short period of time. In fact, they often travel more than wild bass that have been similarly tracked. The travel ability of hatchery bass should allow them find more suitable habitat if they need to reduce competition, and may possibly be part of the reason they move so often during the first few weeks. As Mesing et al. (2008)

stated, not all lakes are alike and "cookbook" methods or strategies may not work. Each lake needs to be evaluated individually for levels of productivity, food availability, predators, and carrying capacities. Because bass have the ability, and often will, travel far distances, the potential risk in stocking so many bass together was deemed acceptable in order to make the study of dispersal possible. The bass in Tin House Cove were stocked over an eight-day period instead of over a multiple-week period as in Cody's Cove. By narrowing the stocking time range it was possible to more accurately track how long dispersal took. A possible change in methodology (for future stockings) would have been to increase replications and to split the 340,681 bass into three distant locations (approximately 115,000 in each), but it was feared that the same problem of low recapture that was found in the Cody Cove study would re-occur and no statistical evaluation could be completed.

Due to fluctuating water levels in the Cody Cove study, sampling in many of the heavily vegetated areas was impossible with a motorized boat. This limited the number of bass and the number of habitats that could be sampled, thus reducing the chance of catching a stocked bass (or seeing any type of trend in vegetation types). Many of the stocked bass had been placed near these inaccessible vegetated areas and had possibly ventured inside. In the Tin House Cove study, this problem was taken care of in two ways. One, an airboat was used for electrofishing instead of an outboard motor. This allowed sampling to be done in thicker vegetation and increased access by enabling us to cross shallow spots or extremely densely vegetated areas to get to sample sites. Two, the sampling area was changed from a "stocked" versus "dispersal" setup to a grid of 64 smaller 216 m x 216 m squares. Every ring in this

grid system was sampled during each sampling period to evaluate the dispersal of the bass. It was hoped that if bass were able to make their way to the edge of the grid, it could be concluded that some of the decrease in recaptures was due to the bass dispersing out of the sample area, and not all because of mortality. By the second sampling period (around 6 weeks after stocking), there were already bass at the outer ring of the grid. Bass moved at faster speeds than anticipated. Starting sampling the first week or two after stocking may produce higher initial recaptures and a more complete look at dispersal. If a future stocking study is done on Lake Okeechobee, a larger sampling area would be better to help counteract that. Unfortunately, due to the size of the lake (and number of personnel), it is impossible to sample the whole littoral zone on the lake, which is typically what is done on smaller lakes.

In the Cody Cove study, bass of up to 127 mm (5 inches) were collected, but recaptured bass were found only up to 81 mm (a little over 3 inches). For the Tin House Cove study (which would cover the same amount of sampling time), the sampling size for bass to be fin clipped was lowered to 102 mm (4 inches) to reduce the number of bass that had no possibility of being stocked bass. If the Cody's Cove bass were re-evaluated by taking out all the bass over 102 mm, there would have been a total of 347 bass collected instead of the 443 (Table 1). This overestimation of the potential stocked fish growth resulted in over 100 extra wild bass to be collected and genetically tested. Comparing the 347 bass under 102 mm (341 wild and 6 stocked) in Cody's Cove to the 322 bass collected in Tin House Cove shows a roughly equal amount of fish of suitable size were collected in both studies. By only looking at the bass under 102 mm in Cody's Cove, the mean length of wild bass is reduced from 85

mm (n = 437) to 77 mm (n = 341). The average length of wild bass in Tin House Cove was 75 mm, and eliminating bass over 102 mm showed that wild bass between the studies were fairly similar in size. The stocked bass between the two studies would have likely been closer in size if more had been recaptured in Cody's Cove. After changing the Tin House Cove study to collect bass only 102 mm or smaller, the size range seems adequate for this range of sampling time. Only one stocked bass, caught in the last sampling period in the Tin House Cove study, was over 100 mm.

Dispersal and Distribution:

A telemetry study done by Porak et al. (2011) showed stocked bass moved anywhere from 12 to 1,340 m after 7 days and 11 to 2,010 m after 14 days (and were likely limited by the lake's small size). They had one bass travel a total of 6,005 m within 18 days (334 m per day), with some bass exhibiting movement of up to 500 m per day. Nearly 60% of their fish dispersed over 400 m by day 7. So by the end of the Tin House Cove collection (a maximum of 83 days after stocking), a bass could have theoretically travelled over 27,000 m (assuming the average 334 m per day were travelled). Even though that is an extreme example, it shows that bass are capable of travelling large distances when needed. Porak et al (2011) found bass crossing or staying in open water for periods of time. In addition, newly stocked bass were found to have significantly higher movement per day than wild bass, perhaps in attempt to find a good location to settle. However, these were larger hatchery bass (about 100 mm in length) and had been raised in raceways instead of ponds like the Cody's Cove

and Tin House Cove bass. These factors may have influenced the amount the bass moved.

In both the Tin House Cove and Cody's Cove studies, the sample areas were small in comparison to the amount of distance a bass can travel. In Cody's Cove, the distance from the stocking point to the edge of the sampling area ranged from at least 6 m (closest stock point to an edge) to approximately 600 m (furthest stocking point to the nearest edge). From the central stocking point in Tin House Cove, the shortest route to an edge was 848 m. By the second sampling period (34-48 days post stocking) of the Tin House Cove study, one bass was found 692 m from the stocking location. By the third sampling period, that bass and others, could have left the sampling area. In Cody Cove the furthest distance a bass was found from a stocking point was 192 m in the second sampling week (42 days). Since bass have been proven to travel further than that in that time frame, it's possible that the fish did not originate from the nearest stocking point. So making just one stocking point in the Tin House Cove study proved to be the more accurate in determining travel distances (though still not as accurate as a telemetry study which would have tracked total movement). In future studies, a larger sampling area might also be desired to get a better idea of maximum ranges for dispersal if telemetry is not available. Increasing the sample area and the sample size could help rule out mortality as being the fate for some of the stocked bass. While recreational fishermen were able to fish in the projects sites throughout these studies, it was extremely unlikely that any of the stocked fish were caught. Most of these fish would have been too small (under 100 mm or 4 inches in length) to be caught by fishermen within the time limits of this study. If any stocked

bass had been caught, the anglers would have been unable to harvest the bass since the minimum size limit on Lake Okeechobee for keeping a bass is 18 inches. The sampling in October 2009 and 2010 collected no stocked largemouth bass, which may have either been due to mortality, or the bass dispersing so much (and possibly not to the sampled locations) that their numbers were diluted within the larger population of wild bass and thus undetectable.

The overall CPUE (of sampled bass) was 0.67 fish/min in Cody's Cove and was higher than that found the following year in Tin House Cove, which was 0.27 fish/min. Again, by eliminating bass that were sampled in Cody's Cove that were over 102 mm, the CPUE can then be lowered to 0.52 fish/min. There was still a difference in CPUE between the two sites which may have been due to a variety of reasons (water levels, spawns, forage, etc.). Looking at the stocked and wild CPUE's separately though, the Tin House Cove had the higher CPUE for stocked bass (0.02 fish/min in Tin House compared to 0.01 fish/min in Cody's Cove). The difference was in the number of wild bass that were sampled between the two sites. It is possible that the increased number of wild bass caught in the Cody's Cove site could have influenced the amount of stocked bass caught. Mortality from larger bass and prey competition could have led to less stocked bass in the Cody's Cove area.

The Tin House Cove study also further evaluated the CPUE's of bass in muck versus sand sediments (non-restored site versus habitat restoration site). Cody's Cove did not have a restoration site within the study site to evaluate. While the benefit of restoration efforts that remove muck sediment from the lake floor to expose the natural sandy bottom has been shown in vegetation restoration (Welch 2009), less conclusive

studies have been done looking at the effect on largemouth bass, particularly stocked bass. Evaluation of adult largemouth bass after a restoration project on Lake Kissimmee, Florida was inconclusive, and detecting fish population-level responses to habitat enhancements were deemed problematic (Allen et al. 2003). In the Tin House Cove study, no statistical difference was found in wild or stocked bass between the sand and muck sediments. However, there were only 6 restored sandy locations (all directly around the stocking location) and there were 41 non-restored muck locations. This disparity may have made any statistical difference difficult to detect. Percent frequency of stocked bass found in sand areas versus muck areas did show 61% of stocked bass were found in sand areas compared to only 22% of the wild bass. So perhaps there was a difference, but because the bass were stocked in the center of the restoration area (all sandy), any true evaluation would have had to be done with tagged wild and stocked bass being dropped in the same location to determine differences. Lab studies on sediment choices may also help determine if there are any benefits to juveniles.

Water Quality and Habitat:

The Cody's Cove study did not have enough recaptured bass (n = 6) to do any reliable statistical measurements of water quality. The water temperature, dissolved oxygen, pH and water depth that stocked bass were found in were fairly variable, which would have led to high variance in a statistical test. In the Tin House Cove study, the only significant differences between stocked and wild bass were found in water depth (meters) and pH.

Shallow water depth has long been associated as a safe haven for smaller fish by providing protection from larger aquatic predators (Ruiz et al. 1993). A telemetry study done by Porak et al. (2011) found stocked bass spend significantly more time offshore than wild fish and the mean depth used by hatchery bass was significantly deeper than that used by wild fish. The Tin House Cove study found similar differences in depth. Wild bass were found in significantly shallower depths (mean depth of 0.69 m) than the stocked bass (mean depth of 0.82 m). While these depths did show a statistically significant difference, in reality, these 13 centimeters may not have been biologically significant and may have been a factor of the relatively low range of depths sampled. However, prior studies on predation show that stocked bass are naïve about predators (Suboski and Templeton 1989), and as a result, most likely have no knowledge to go to areas that reduce predation. Porak et al. (2011) found that all mortality in stocked fish during the telemetry portion of the stocking study was due to predation. In comparison, wild counterparts in this study suffered no mortality, every single one was tracked and found alive. This naïveté may lead stocked bass to remain in areas that are slightly deeper than wild bass are found in. Ongoing studies to reduce the naïveté of stocked bass have found that habituating bass to predators (in predator free enclosures) before stocking may reduce mortality from predation (Schlechte et al. 2005). Habituation to predators may possibly lead to stocked bass being found in shallower depths and decrease mortality from predation.

Significant differences were found in pH from water where stocked and wild bass were collected. Largemouth bass are known do best in a pH of 6.5 - 8.5 (Stroud 1967). The pH of the water can affect photosynthesis in plants. An increase in pH will

decrease photorespiration, which will decrease photosynthesis (Servaites and Ogren 1977), thus having an effect on the type of plants that may grow in an area. Plants may also influence the pH of the surrounding water (the degree depends on how alkaline the water is). Respiration of plants and decomposition processes may lower pH. In addition, depth of the water may also influence the pH due to changes in photosynthesis with depth. Less photosynthesis (or deeper water) leads to an increase in pH (Michaud 1991). With these variables in mind, the bass may have been choosing areas based on the vegetation in the area (thus seeming to choose for pH), they may have actually been choosing for pH (and appearing to choose certain vegetation types), or they may have been entirely influenced by the water depth (of which pH is a byproduct of). It seemed most likely that the bass were choosing areas based on habitat type or water depth since these would provide the best protection from predators, and possibly the best prey (Bettoli et al. 1992). Stocked bass were found at a higher mean pH (8.12) than wild bass (7.86). These slightly deeper waters may have been the main reason for the higher mean pH that stocked bass were found at. A weak positive correlation had been found ($r = 0.239$) between depth and pH indicating that this may have been a contributing factor. Further study would need to be done to determine if habitat or some other variable were contributing factors.

Vegetation provides both foraging opportunities for predators and refuge from predation for prey (Anderson 1984). An interesting overall trend that was found in Tin House Cove was that the highest cover sites were the most common (meaning Tin House Cove was thickly vegetated), and when the percent of cover decreased, so did the occurrence of these sites (there were few sites with low vegetation cover). The

opposite trend was found where bass were captured. Instead, as cover increased, occurrence rate of bass found decreased (meaning the proportion of bass decreased compared to the amount of sites that had high vegetation). It would appear that the higher the cover got, the less likely you were to find bass, and at coverage between 76 and 100% (which was the most common type of habitat found) the lowest occurrence rate for bass was found. Both stocked and wild bass had the highest occurrence rates in the 0-25% cover (2.73 and 2.81, respectively) and the lowest occurrence rates in the 76-100% cover (0.22 and 0.57, respectively). While it could possibly be argued that the stocked bass were found so often in lower cover areas due to being stocked in a restoration area, which by definition has less cover than non-restored sites, the same trend was found in the wild bass. The wild bass had not been placed in the restoration site, and so could choose where to go on their own, and they still had the same choices as the stocked bass. It was unlikely that the reduced catchability of bass in heavy vegetation or the decrease in catchability of smaller bass with electrofishing would affect the differences seen between wild and stocked bass since both would have been equally affected. However, the decreased catchability of bass in heavier vegetation may have possibly affected the overall amount of bass caught in these areas.

There was a similar trend found in the Cody's Cove study, except that there were no sites with 0-25% cover, so that could not be compared. Keeping in mind the low sample size of the stocked bass (n=6), both stocked and wild bass showed negative occurrence rates in the 76-100% cover even though that was the dominant type of cover found in sites (61.9%). Stocked and wild bass were found in different amounts in the other categories though. The stocked bass were most abundant in the

51-75% cover, and also had the highest occurrence rates in this cover type (2.99). The wild bass, while most abundant in the highest cover sites, had their highest occurrence rate in the areas with the least amount of cover (like that of Tin House Cove). Since there were no 0-25% cover areas available, the wild bass had their highest occurrence rate in the 26-50% cover areas. So while the wild bass in Cody's Cove showed a very similar occurrence rate to those found in Tin House Cove, it's possible that the low sample size of stocked bass made it difficult to discern what type of cover they would have occurred the most often in.

A study by Bettoli et al. (1992) found an absence of cover in some areas might be beneficial because it allows young bass to become piscivores earlier in life. Some nearby cover is needed though to reduce the effects of predation on the bass themselves. Bettoli and others also found that having submerged cover (SAV) could enhance foraging opportunities and growth. Excessive aquatic vegetation however, may cause stunted fish populations and reduced fish growth and condition (Brown and Maceina 2002). Optimal cover should correspond to 40-60% of the littoral area and too much cover may reduce prey availability (Saiki and Tash 1979). Habitat suitability indexes often vary in what is considered to be the best amount of cover, however most agree that too much cover is negative and at least some cover (even if it's nearby) is beneficial. The Tin House Cove study seemed to show that bass occurred more often in areas that had less than 25% cover, but since there was such a low number of these sites, denser cover was likely nearby allowing bass to escape from predation and forage more effectively. There were no immediately obvious differences between stocked and wild bass occurrence in different coverage in Tin

House Cove. However, looking at plant stem densities where bass were captured may provide additional information.

Not many studies have looked at differences in wild and stocked bass abundance in specific aquatic macrophytes. Typically, submersed vegetation (SAV) is analyzed as present or absent, or at as coverage amounts. However, I wanted to see if there were any noticeable differences between the wild and the stocked bass in areas of various aquatic macrophyte coverage. Porak et al. (2011) had evaluated habitat in wild versus stocked bass, and had not found any significant differences in habitats, but their habitat was less complex than that of Lake Okeechobee. Even with the increased habitat complexity, the Tin House Cove study showed both stocked and wild bass occurred in similar habitat types. While some of the rates of occurrence within a species often differed slightly, wild and stocked bass mostly remained either all positive or all negative occurrences. The three top occurrence species were duck-potato, hydrilla and spikerush. While the Cody's Cove Study had more variation between the wild and stocked bass, there was a reduced sample size of stocked bass, which limited the conclusions that could be made. The top occurrence species were eelgrass and spikerush. There was no duck-potato in Cody's Cove or eelgrass in Tin House Cove to see if there would have been similar occurrence rates between the two sites. While Tin House Cove had hydrilla as a species with a high occurrence rate for wild and stocked bass, Cody's Cove actually saw a negative occurrence rate in bass. This is interesting, because one of the main species found in Cody's Cove was hydrilla. Dense amounts of hydrilla have been found to inhibit growth and foraging of largemouth bass when compared to littoral zones with a mix of native plant species

(Perret 2007). While stems were not counted, and densities not determined, from personal observation, it did seem as though the Cody Cove hydrilla seemed much denser than that found in Tin House Cove. That may be a possible explanation for why the occurrence rates were so different between the sites, but an additional study would need to be done to determine if that was true. Unfortunately, determining occurrence rates by only looking at the dominant plant species where bass occur may not provide complete information on what type of habitat a bass was really choosing. This method did not look at surrounding habitat, habitat complexity or density of cover.

CONCLUSIONS

There is room for improving both the stocking success and evaluation of stocking bass on Lake Okeechobee after the completion of this project. Using an airboat and reducing the sampling size to bass of 102 mm and smaller were steps in the right direction. The amount of bass stocked approximately tripled between Cody's Cove (@99,000) and Tin House Cove (over 300,000), but the amount of recaptured bass more than quadrupled between the studies (from 6 recaptures to 28 recaptures), indicating that the increased recaptures may have benefitted from the methodology changes. Using the more grid-like sample area in the Tin House Cove study was also a good change since it allowed for a better understanding of dispersal. Increasing the size of the sampling area would prevent fish from leaving the sampling area too early. Earlier sampling will also yield more information. Multiple locations (far enough away from each other to not have overlap of stocked fish) with larger numbers of stocked bass in each location may prove to be stronger statistically.

Using larger stocked bass may be an alternative solution to stocking more bass because of the reduced mortality in larger size bass (Wahl and Stein 1989). Predation (mainly due to larger bass) has been found to account for up to 27.5% of mortality in fingerling bass within the first 12 hours (Buckmeier et al. 2005). Most predation occurs within the first 7 days after stocking, and stocked bass are shown to have higher mortality from predation (Porak et al. 2011). Increasing the size of the bass

stocked would minimize mortality from predation. Since the completion of this study, the health problems related to pellet feeding larger largemouth bass has been resolved (Cardeilhac 2010).

Stocking a lake the size of Lake Okeechobee is probably comparable to stocking fish in the Great Lakes and in marine environments. Using methodologies similar to those done in larger water bodies may prove to be more useful than that of typical freshwater stockings, even though very different species are being stocked. Those in marine environments typically stock larger species fish such as red drum (*Sciaenops ocellatus*) and common snook (*Centropomus undecimalis*). Red drum stocking programs in Florida initially began releasing drum 20-40 mm in length (the same as this study) in Biscayne Bay. This was largely unevaluated until 1994 when they concluded that stocking small red drum was ineffective, and they recommended stocking larger red drum to reduce mortality (Serafy et al. 1999). Later red drum releases tested stocking at various sizes with many fish being large enough to have external tags applied. This allowed for anglers to call a number when they catch a tagged fish and increased the recapture sample size. They also introduced an angler clip program where anglers could pick up kits and clip fins of red drum (similar to the clipping done in these largemouth bass studies). Approximately 6% of the stocked drum had been recaptured by hook and line sampling near the release areas. There was also about a 1% recapture return for drum using the angler fin clip program, which covered a much larger area (Tringali et al. 2008). The Cody's Cove study had a stocked contribution of approximately 1.4% (1.8% if you discount fish over 102 mm), and the Tin House Cove study had an increased contribution of 8.7%. While this may

be low compared to stockings done on small lakes, keep in mind the amount of bass stocked into Lake Okeechobee was likely much lower in proportion to that stocked in smaller systems. These small systems at times stocked as many or more bass than this study, yet their current bass populations were much smaller than Lake Okeechobee (Mesing et al. 2008). Because of that, the contribution of stocked bass to the overall population would be much smaller. Compared to a marine stocking, the Tin House Cove study had a higher return than the red drum study, which most likely had suffered less mortality due to larger stocking sizes. If larger largemouth bass were tagged and stocked on Lake Okeechobee an even higher recapture rate may be possible. If this were to ever become a long-term sampling program, it would also be beneficial to implement an angler clip program, which would increase the sampling area and increase the number of samples. Lake Okeechobee is so large that sampling the whole lake, like they do on smaller systems, is simply not viable. It is possible however that the stocked bass could spread out to such an extent (and occur in such a small proportion to the wild bass) that sampling the whole lake might be needed to get a more accurate dataset. Finding the contribution of the bass to the overall population of the coves (or even the lake) would be beneficial in determining the effectiveness of the stocking. Currently there are no sampling methods on the lake that are sufficient to determine the actual population size of wild bass in the lake. A sampling method such as block-netting would probably be the best to determine the amount of bass per hectare of littoral zone.

To further analyze habitat difference between stocked and wild bass, vegetation would need to be sampled in a more quantitative manner to allow for better

statistical analysis. Stem count densities may be most beneficial in determining how dense the vegetation may be, and determining the complexity of the habitat may also prove beneficial. The way the vegetation data was collected in the Tin House Cove and Cody Cove studies made it difficult to fully evaluate the differences in habitat that the bass preferred. However, looking at occurrence rates of bass in different types of vegetation did indicate a possible preference for areas that have less vegetation (but not bare). Future studies could keep this in mind while stocking. This may decrease the amount of movement bass do after a stocking and make them easier to study (and possibly reduce mortality related to movement between areas). Lab studies could also be conducted to determine if wild and stocked bass show a true preference for differences in habitat or if occurrence has more to do with closeness to stocking location, naïveté about predators or another type of difference. Looking for differences in stocked bass habitat preferences over time may also be interesting. Do stocked bass learn to be in habitats similar to that of wild bass? There are few studies looking at the differences between wild and stocked bass, but these differences may be important to look at in the future to help increase the survivability of stocked bass. Many lakes and ponds that have largemouth bass stocked have varying amounts and types of habitats. Studies determining the success of stockings vary wildly as well. Further investigations comparing habitat differences between wild and stocked bass may prove the most insightful in determining why some stockings fail, why some succeed and why results are so variable.

Table 1. Cody's Cove 2009. Number of stocked and wild largemouth bass caught during sampling. Average lengths (mm), weights (g) and number of sampled fish that were used for stomach content analysis.

	Stocked	**Wild**	**Wild ≥102 mm**
# largemouth bass	6	437	341
Average length (mm)	66	85	77
Average weight (g)	4	8	6
# sampled for stomach content	4	169	141

Table 2. Cody's Cove 2009. Frequency of type of food found in 169 wild largemouth bass stomachs and 4 stocked largemouth bass stomachs.

	invertebrate	**shrimp**	**fish**	**empty**
Stocked	0	3	2	0
Wild	7	62	89	21

Table 3. Cody's Cove 2009. Dominant cover occurrence per site. Percent frequency of largemouth bass found in each cover type. Occurrence rate is fish caught / sample site. Occurrence rate over 1 indicates that fish occurrence is higher than cover occurrence (positive).

	Samples Sites (%)	**Stocked Caught (%)**	**Stocked Occurrence Rate**	**Wild Caught (%)**	**Wild Occurrence Rate**
0-25 cover	0	0	**NA**	0	**NA**
26-50 cover	21.4	16.7	**0.78**	28.6	**1.34**
51-75 cover	16.7	50.0	**2.99**	13.3	**0.80**
76-100 cover	61.9	33.3	**0.54**	58.1	**0.94**
Dominant Cover					
Cattail	9.5	16.7	**1.76**	5.9	**0.62**
Eelgrass	40.4	50	**1.24**	53.8	**1.33**
Hydrilla	57.1	50	**0.88**	45	**0.79**
Spikerush	2.4	16.7	**6.96**	3.1	**1.29**

Table 4. Tin House Cove 2010. Dominant cover occurrence per site. Percent frequency of largemouth bass found in each cover type. Occurrence rate is fish caught per sample site. Occurrence rate over 1 indicates that fish occurrence is higher than cover occurrence (positive).

	Samples Sites (%)	**Stocked Caught (%)**	**Stocked Occurrence Rate**	**Wild Caught (%)**	**Wild Occurrence Rate**
0-25 % cover	2.6	7.1	**2.73**	7.3	**2.81**
26-50 % cover	21.8	46.4	**2.13**	33.2	**1.52**
51-75 % cover	26.9	35.7	**1.33**	31.8	**1.18**
76-100 % cover	48.7	10.7	**0.22**	27.6	**0.57**
Dominant Cover					
Filamentous algae	7.6	7.1	**0.93**	8	**1.05**
dead/organic	6.3	7.1	**1.13**	8.7	**1.38**
American cupscale grass	1.3	0	**0.00**	0	**0.00**
Alligator weed	5.1	3.6	**0.71**	4.9	**0.96**
Bladderwort	2.5	0	**0.00**	3.1	**1.24**
Buttonbush	1.3	0	**0.00**	0	**0.00**
Cattail	1.3	0	**0.00**	2.1	**1.62**
Duck-potato	2.5	10.7	**4.28**	9.7	**3.88**
Frog's-bit	2.5	3.6	**1.44**	3.1	**1.24**
Fragrant water lily	12.7	7.1	**0.56**	9.7	**0.76**
Yellow water lily	26.6	3.6	**0.14**	14.3	**0.54**
Hydrilla	17.7	50	**2.82**	29.4	**1.66**
Pickerelweed	6.3	3.6	**0.57**	3.8	**0.60**
Slender spikerush	2.5	0	**0.00**	1.7	**0.68**
Smartweed	2.5	0	**0.00**	3.1	**1.24**
Spikerush	8.9	21.4	**2.40**	9.7	**1.09**
Torpedograss	5.1	0	**0.00**	5.6	**1.10**
Willow	1.3	0	**0.00**	0.3	**0.23**
All lily species	39.3	10.7	**0.27**	24	**0.61**

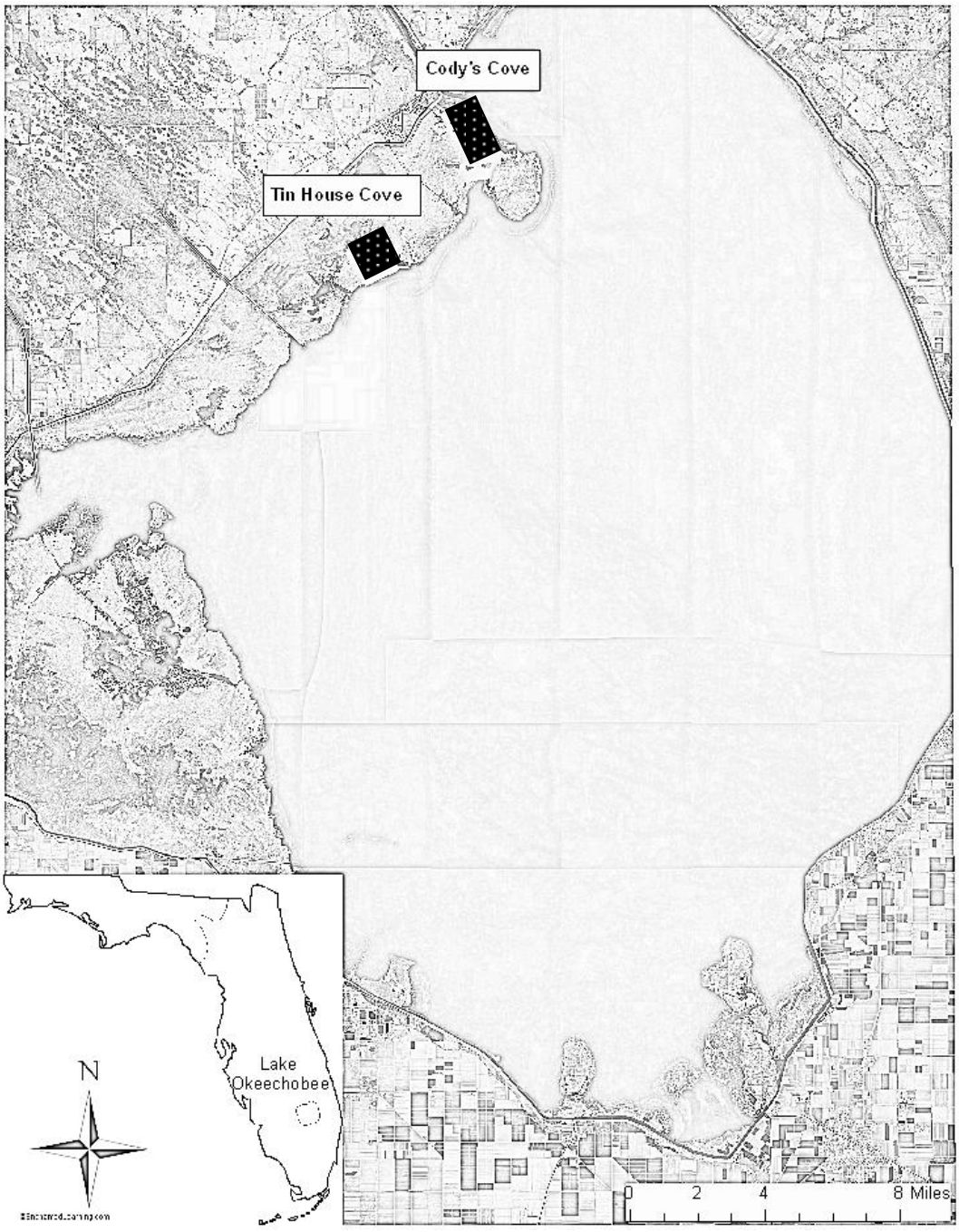

Figure 1. Cody's Cove and Tin House Cove, both located in the northwest marsh of Lake Okeechobee. Location of Lake Okeechobee within Florida is pictured in the bottom left.

Figure 2. Habitat restoration sediment removal (scrape) sites in the northwest marsh of Lake Okeechobee. The 436 acres (176.4 ha) are the Tin House Cove area and Cody's Cove sediment removal areas. The area to the southwest is Tin House Cove, the area to the northeast is Cody's Cove. (Florida Fish and Wildlife Conservation Commission, 2009b).

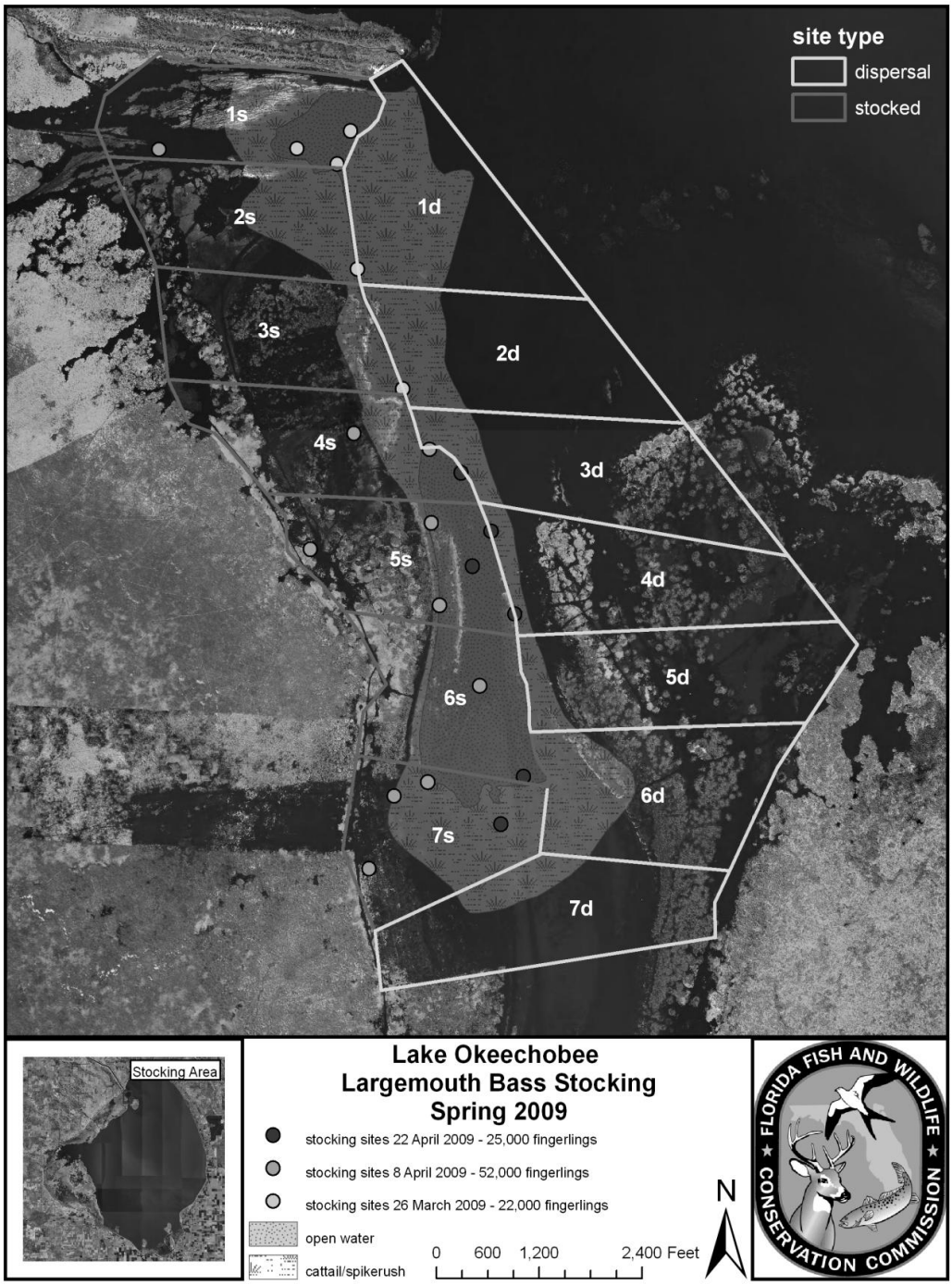

Figure 3. 2009 Cody's Cove sampling area (475 ha) located in the northwestern marsh of Lake Okeechobee as indicated by the mini map. Areas labeled with an "s" were "stocking" locations where largemouth bass were stocked. The three dates and locations of stocking are indicated on the map. Areas with a "d" were designated the dispersal sample areas (Florida Fish and Wildlife Conservation Commission, 2009a).

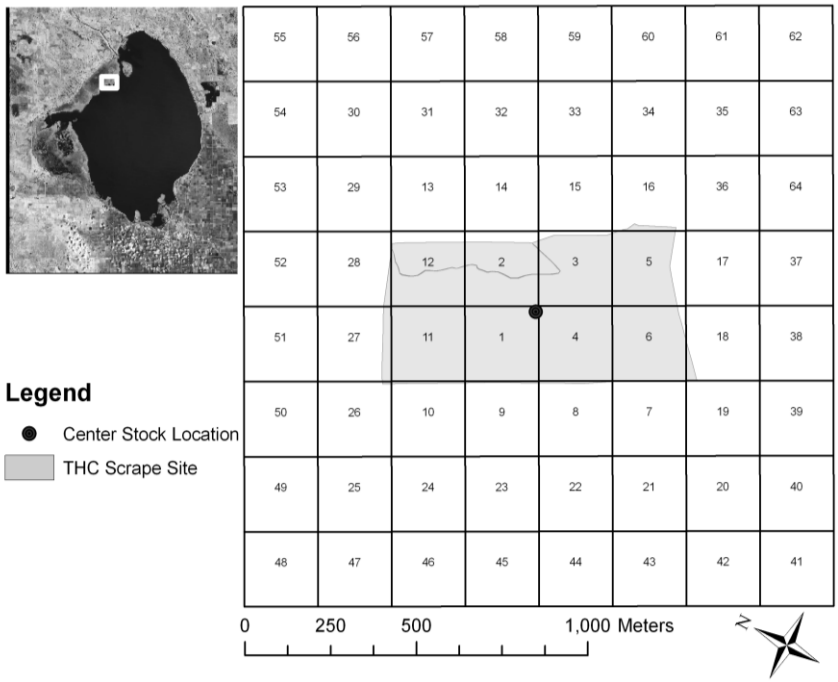

Figure 4. 2010 Tin House Cove sampling area with boxes labeled from 1 to 64. The site is located in the northwest marsh of Lake Okeechobee as indicated by the mini map. The center point location is where all largemouth bass were stocked.

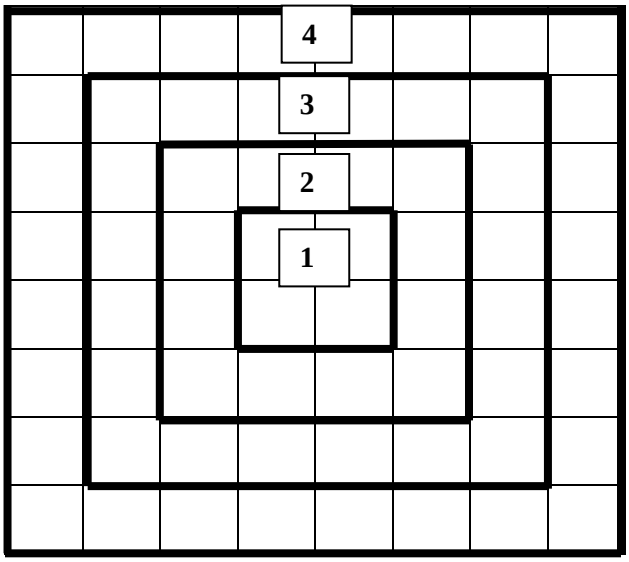

Figure 5. Drawing explaining the selection of grids during each sampling period in Tin House Cove. There is one sample per 4 boxes in each ring: Ring 1 (4 boxes) =1 sample; Ring 2 (12 boxes) = 3 samples; Ring 3 (20 boxes) = 5 samples; Ring 4 (28 boxes) = 7 samples.

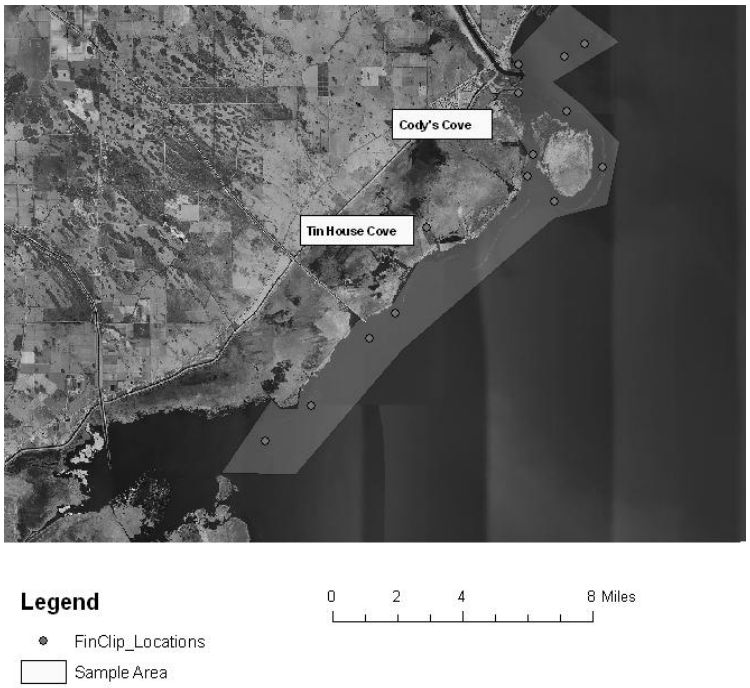

Figure 6. October 2010 sampling area (designated by the lighter colored background) and sampling/fin clip locations. Encompasses both Tin House Cove and Cody's Cove. Area covers most of the northwestern part of Lake Okeechobee.

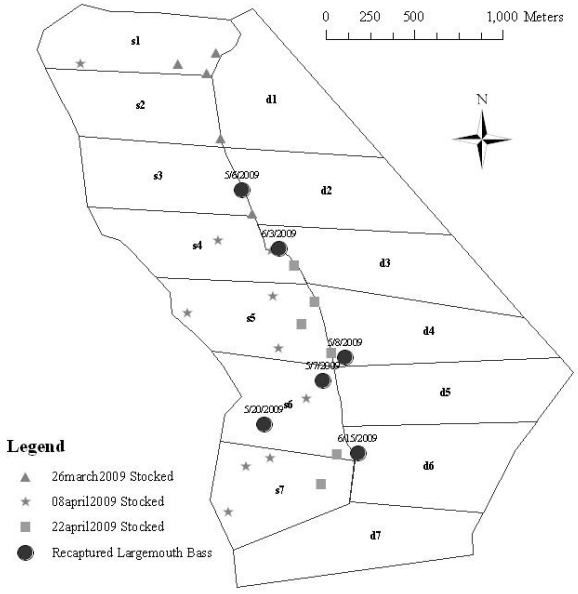

Figure 7. Dates and locations of the six stocked bass recaptures in Cody's Cove. The map also shows the initial stocking locations.

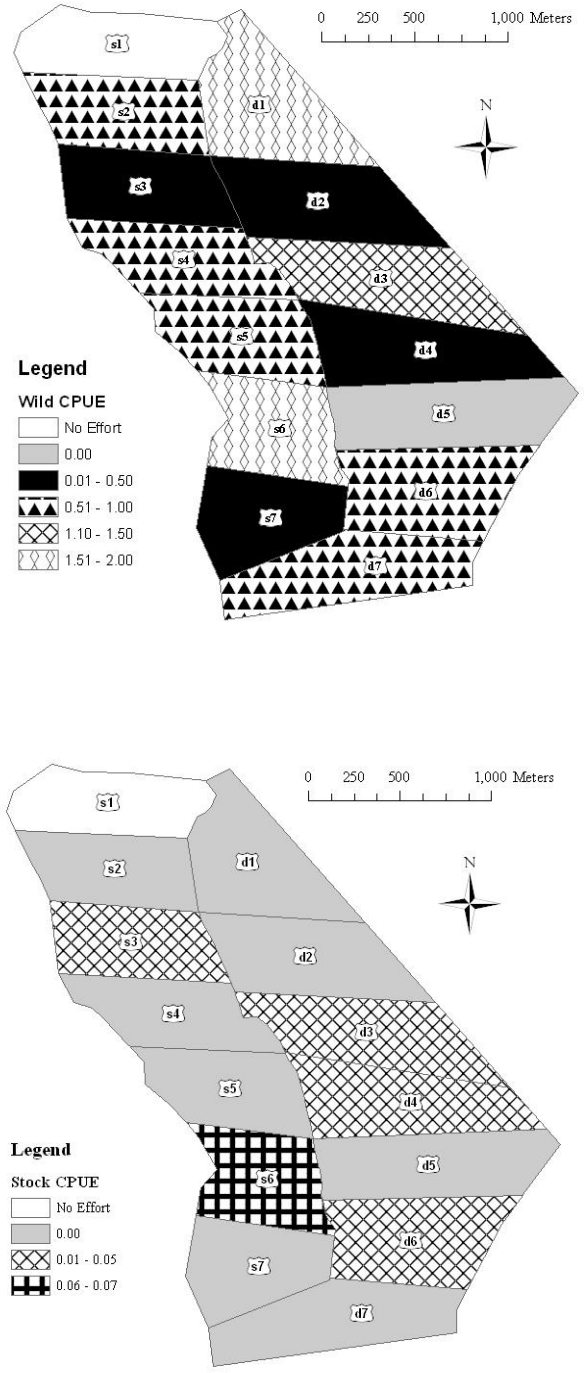

Figure 8. Cody's Cove 2009. CPUE's (fish per minute) of 437 wild (top), and 6 stocked (bottom) bass collected from each site.

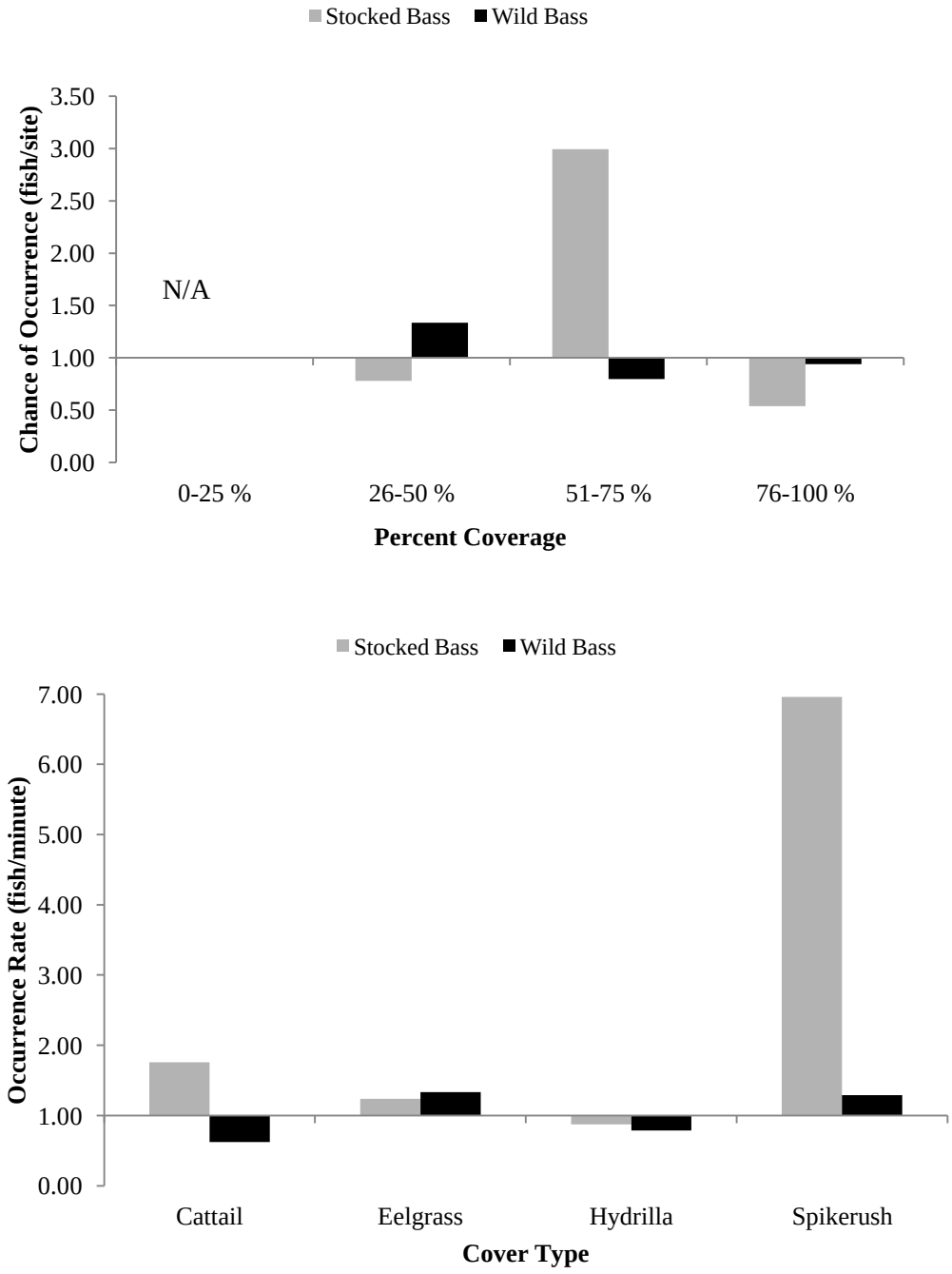

Figure 9. Cody's Cove 2009. Dominant cover type occurrence. Chance of occurrence of bass found in cover type. Occurrence over 1 indicates that fish occurrence is higher than cover occurrence. Top graph shows percent coverage of vegetation, bottom graph shows specific types of coverage.

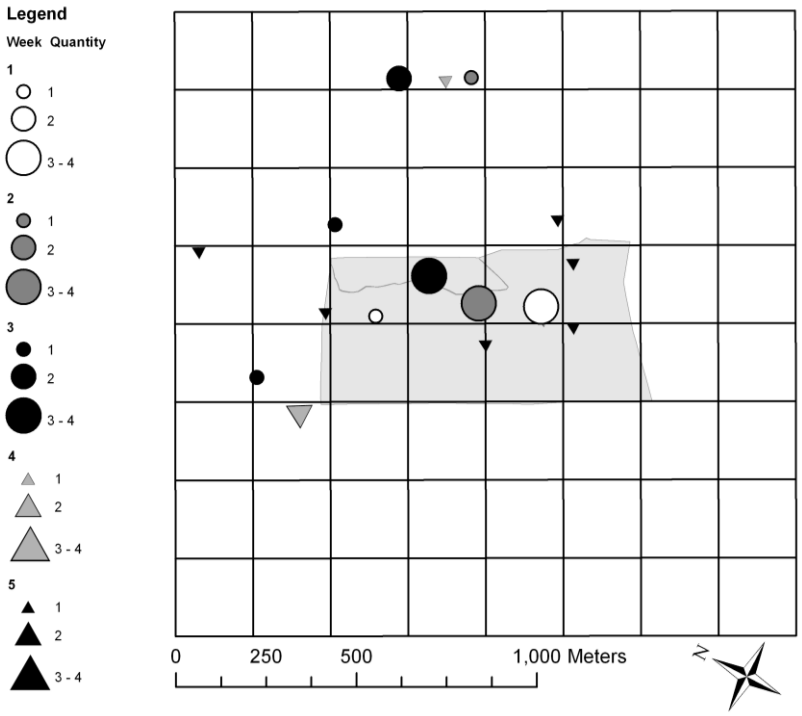

Figure 10. Tin House Cove 2010. Locations of recaptured stocked fish by period/week (periods 1-5). Symbol size indicates number of fish caught at each point.

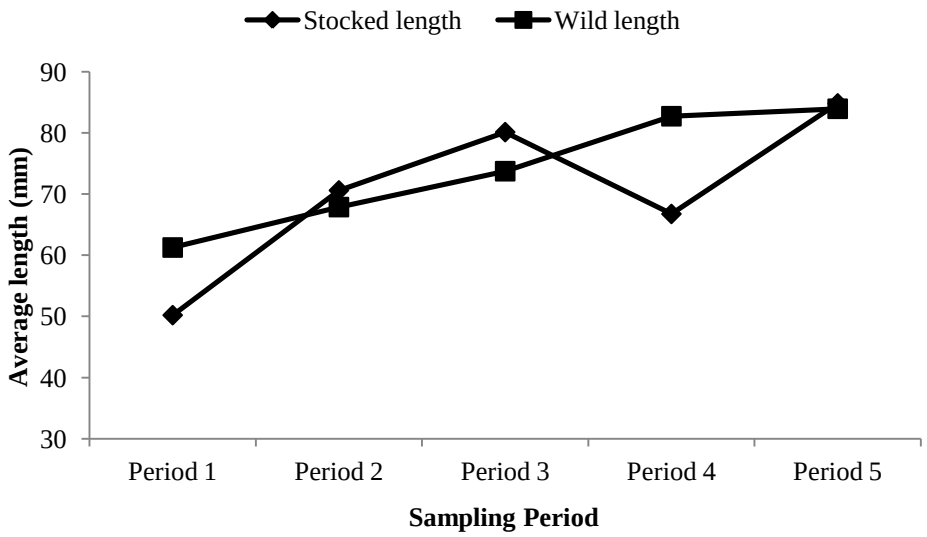

Figure 11. Tin House Cove 2010. The average length for each sampling period of stocked and wild bass from May 17, 2010 to July 13, 2010. The overall average length of stocked bass was 72 mm and the average length of wild bass was 75 mm.

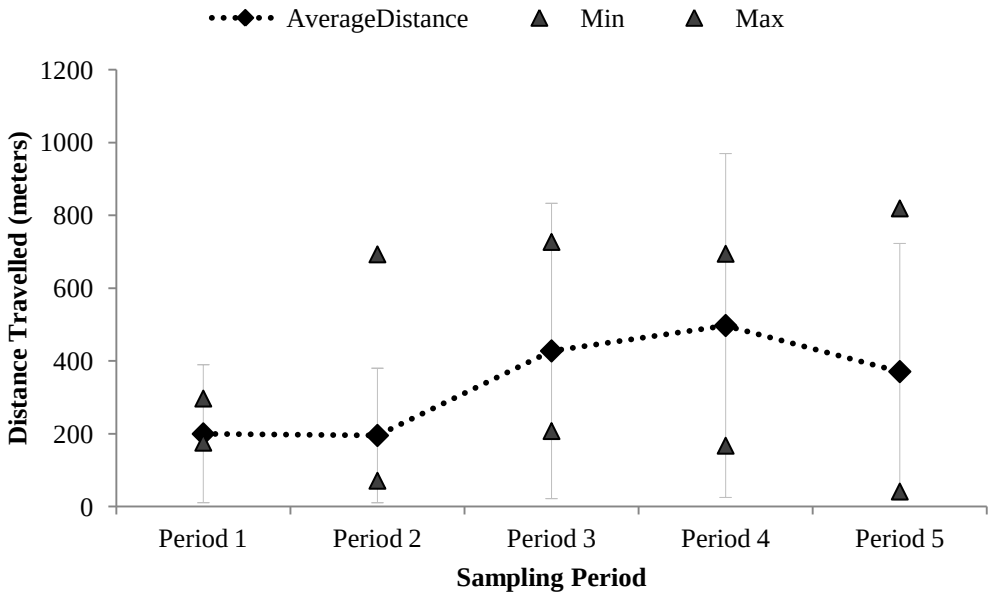

Figure 12. Tin House Cove 2010. Average distance travelled by sample period (343 m average for all periods). Minimum and maximum travel distances are also shown. A confidence interval of 95% are shown as error bars.

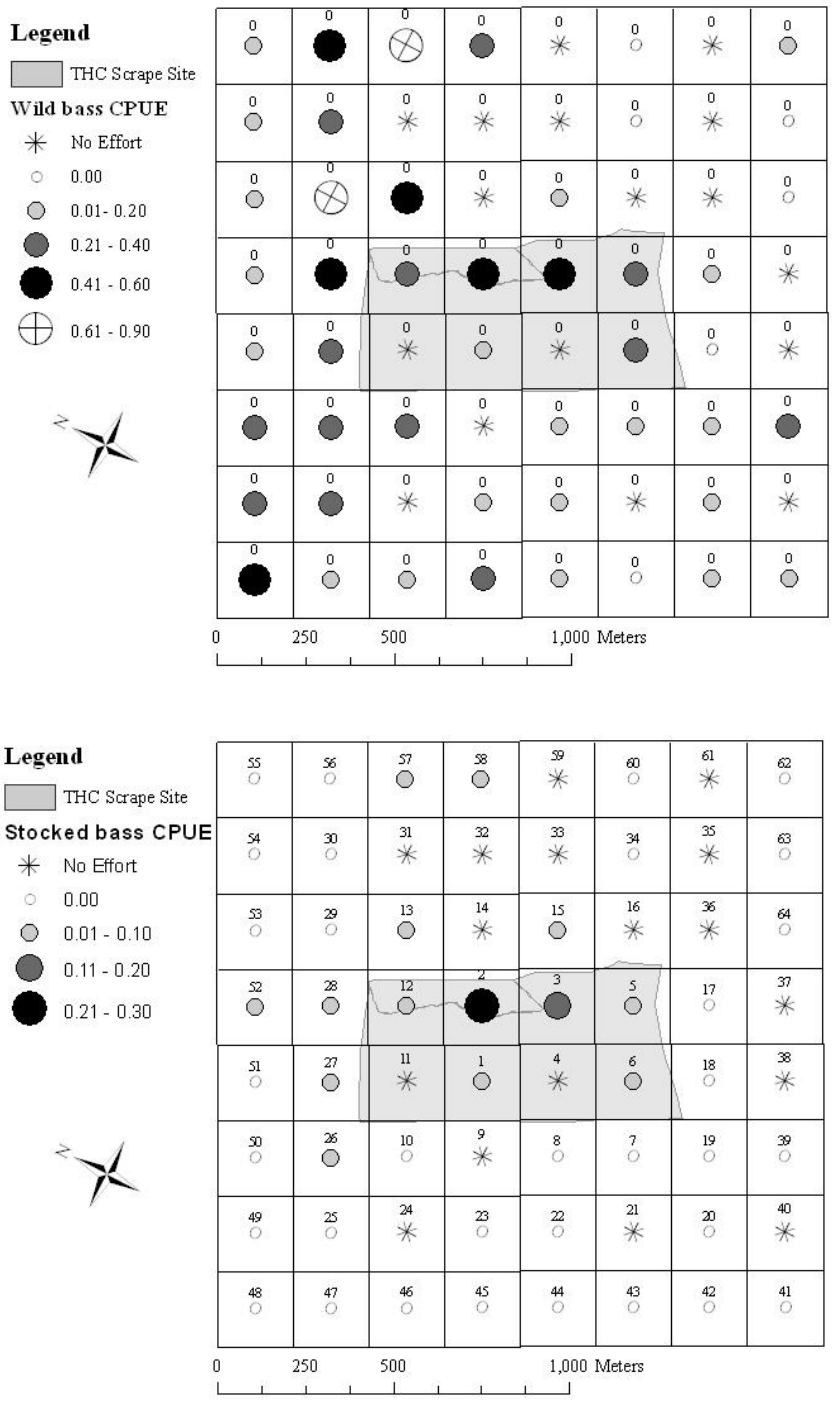

Figure 13. Tin House Cove 2010. Catch per unit effort (fish per minute) of 288 wild bass (top) and 28 stocked bass (bottom) in each site. Sites that were not sampled are labeled as "no effort" (*).

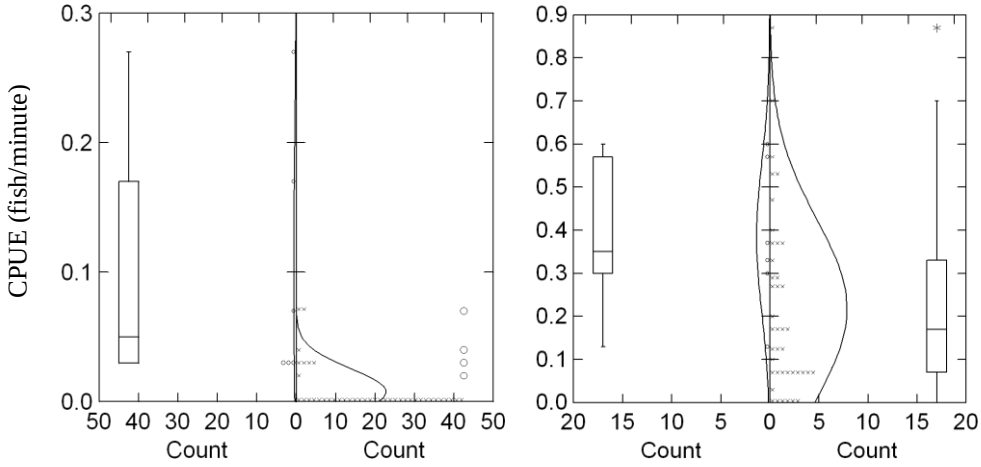

Figure 14. Tin House Cove 2010. Left graph: 28 stocked largemouth bass comparing 6 restored (sand) sites on the left versus 41 non-restored (muck) sites on the right. T-test showed P=0.072 and is not significant. Right graph: 28 wild largemouth bass comparing 6 restored (sand) sites on the left versus 41 non-restored (muck) sites on the right. T-test showed P=0.073 and is not significant.

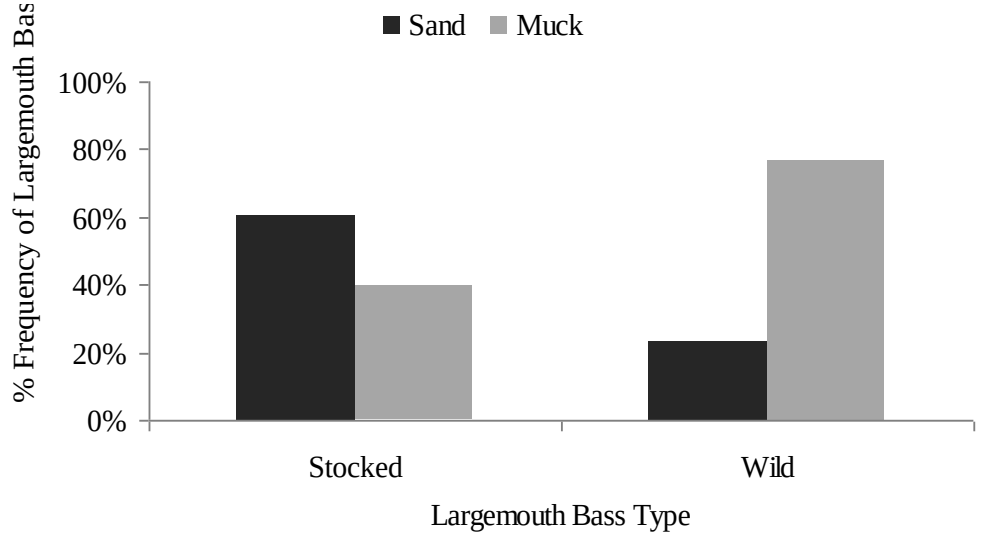

Figure 15. Tin House Cove 2010. Percent frequency of 288 wild and 28 stocked largemouth bass found in restored "sand" and non-restored "muck" locations.

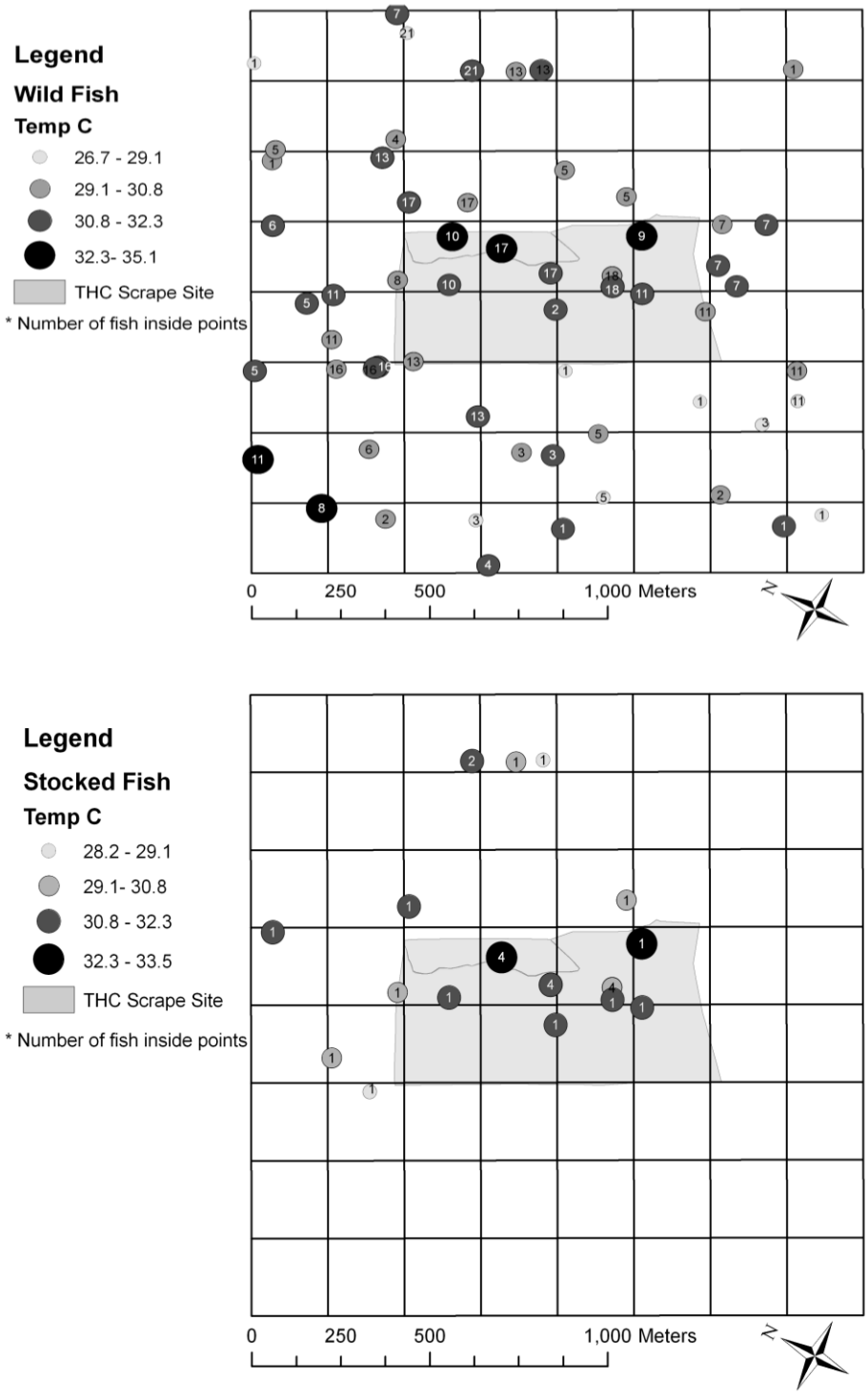

Figure 16. Tin House Cove 2010. Water temperatures (°C) of captured 288 wild (top) and 28 stocked (bottom) largemouth bass.

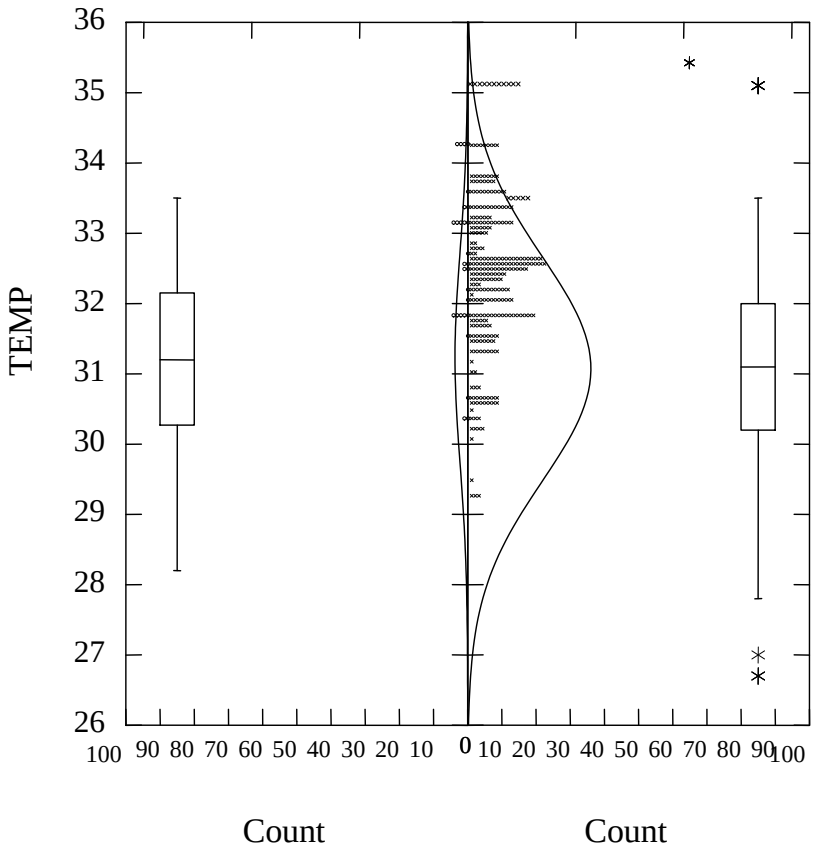

Figure 17. Tin House Cove 2010. Temperatures (°C) for 28 stocked bass are shown on the left and 288 wild bass are shown on the right. The mean temperature for stocked bass is 31.23 C and the mean temperature for wild bass is 31.07 C. T-test showed P=0.592 and is not significant.

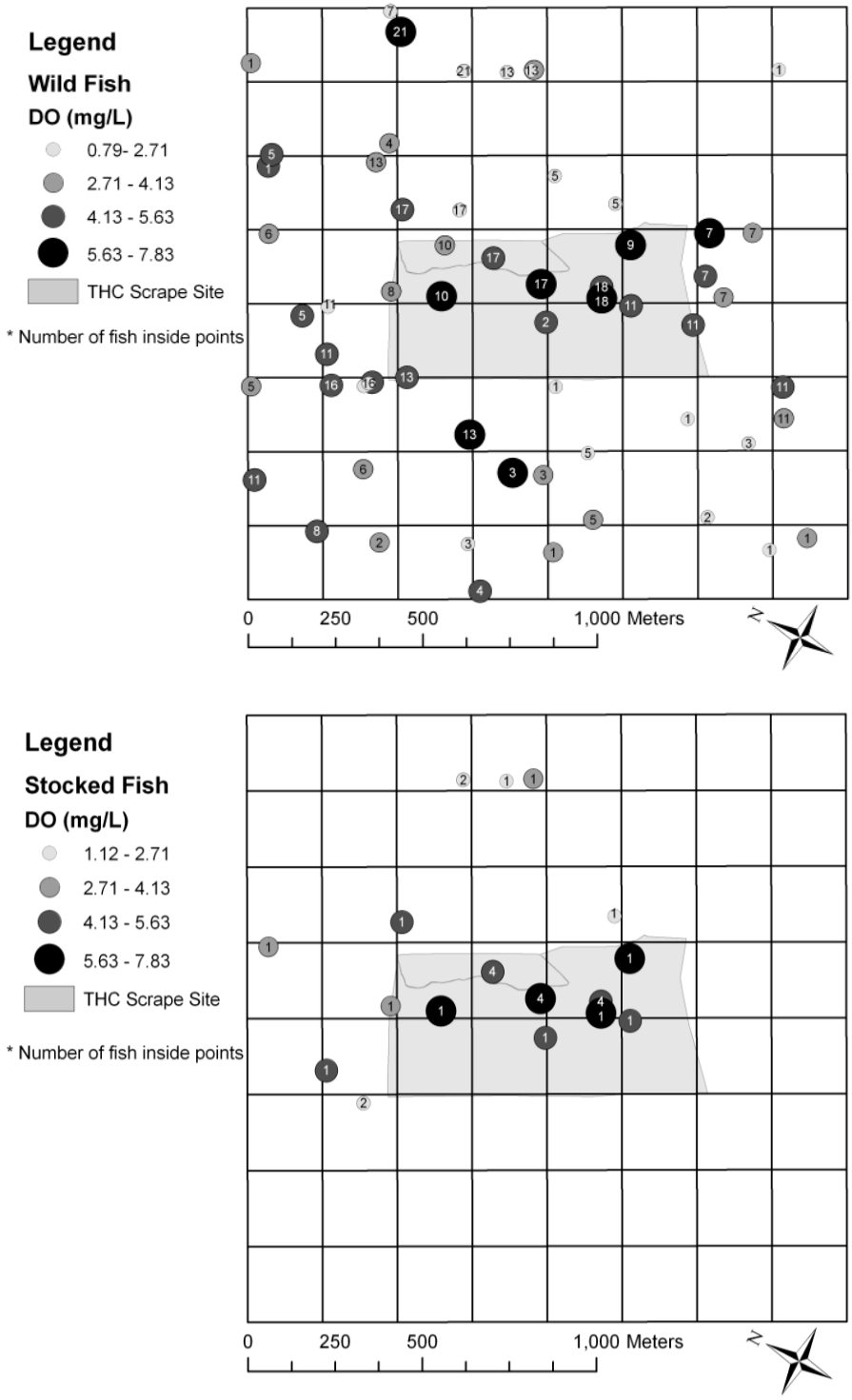

Figure 18. Tin House Cove 2010. Dissolved oxygen (mg/L) of captured 288 wild (top) and 28 stocked (bottom) largemouth bass.

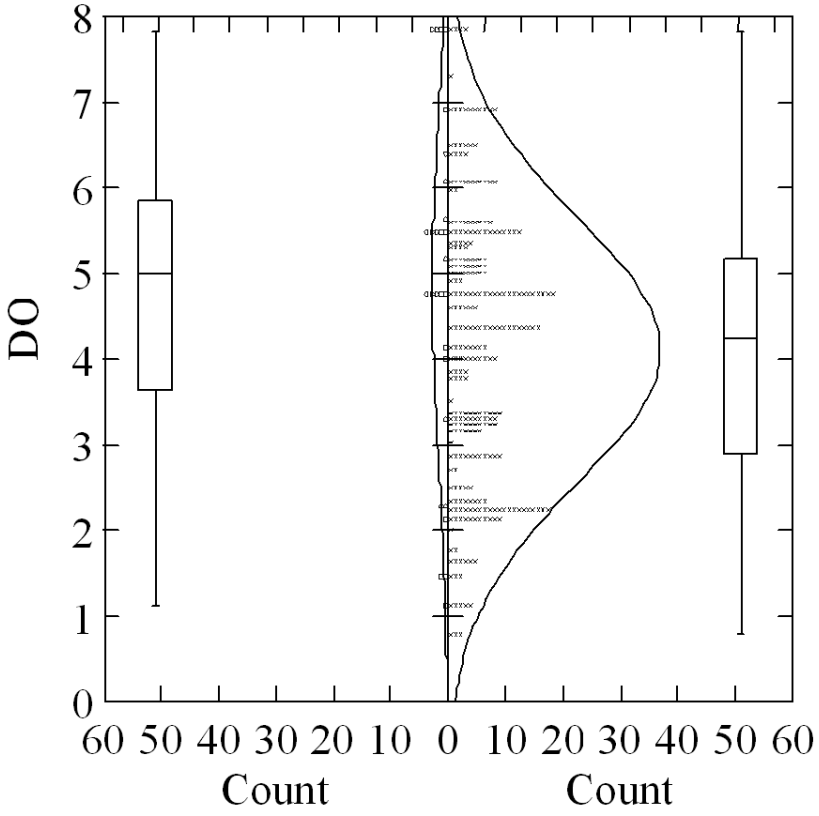

Figure 19. Tin House Cove 2010. Dissolved oxygen (mg/L) for 28 stocked bass are shown on the left and 288 wild bass are shown on the right. The mean DO for stocked bass is 4.82 mg/L and the mean DO for wild bass is 4.10 mg/L. T-test showed P=0.075 and is not significant.

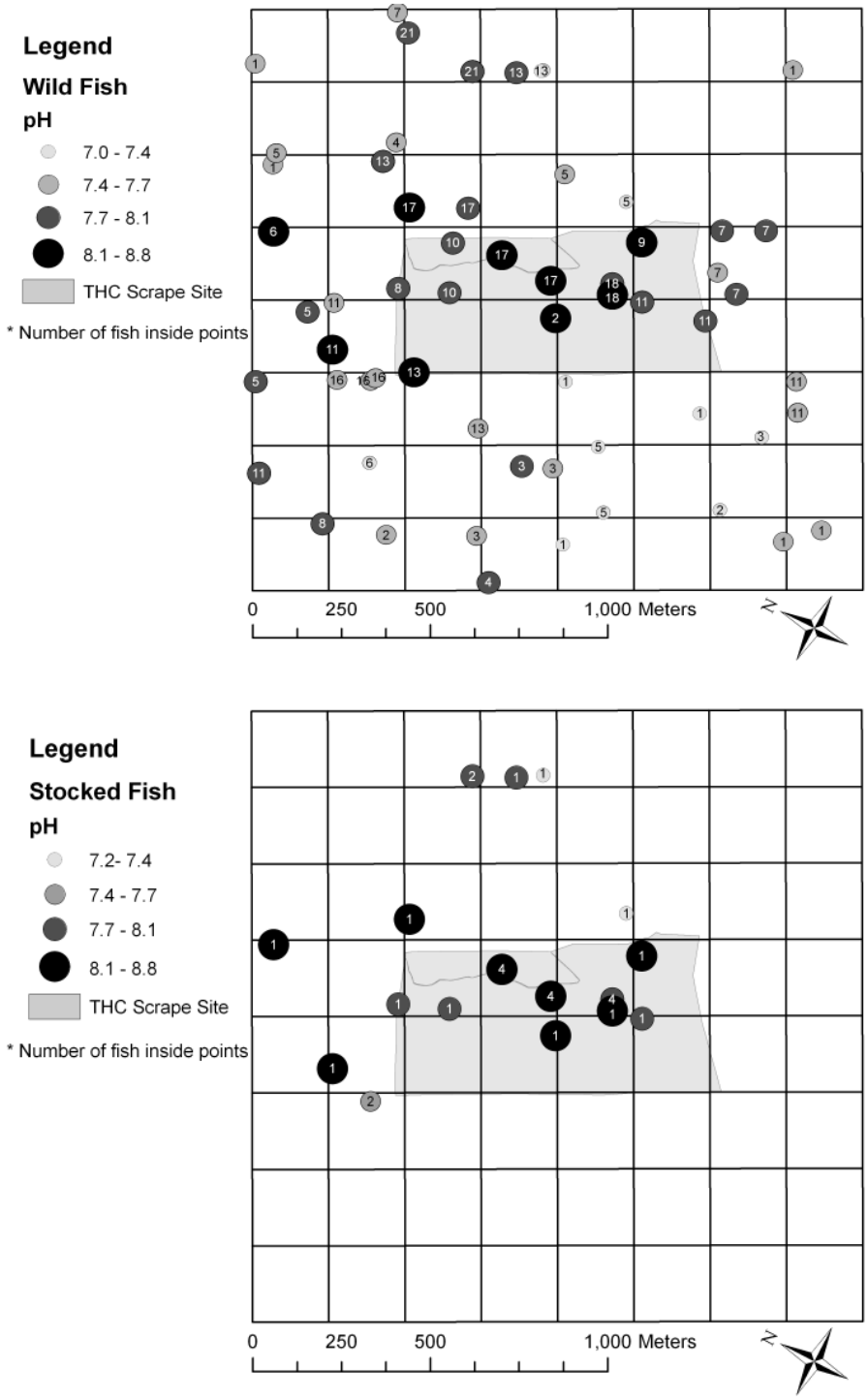

Figure 20. Tin House Cove 2010. pH of captured 288 wild (top) and 28 stocked (bottom) largemouth bass.

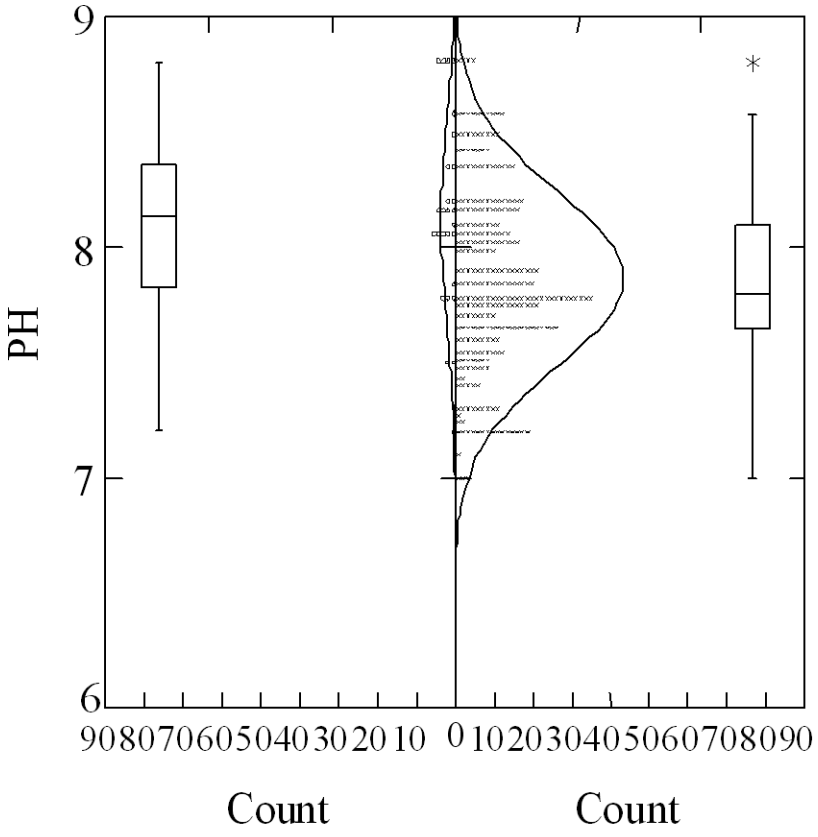

Figure 21. Tin House Cove 2010. pH for 28 stocked bass are shown on the left and 288 wild bass are shown on the right. The mean pH for stocked bass is 8.11 and the mean pH for wild bass is 7.86. T-test showed P=0.005 and is significant.

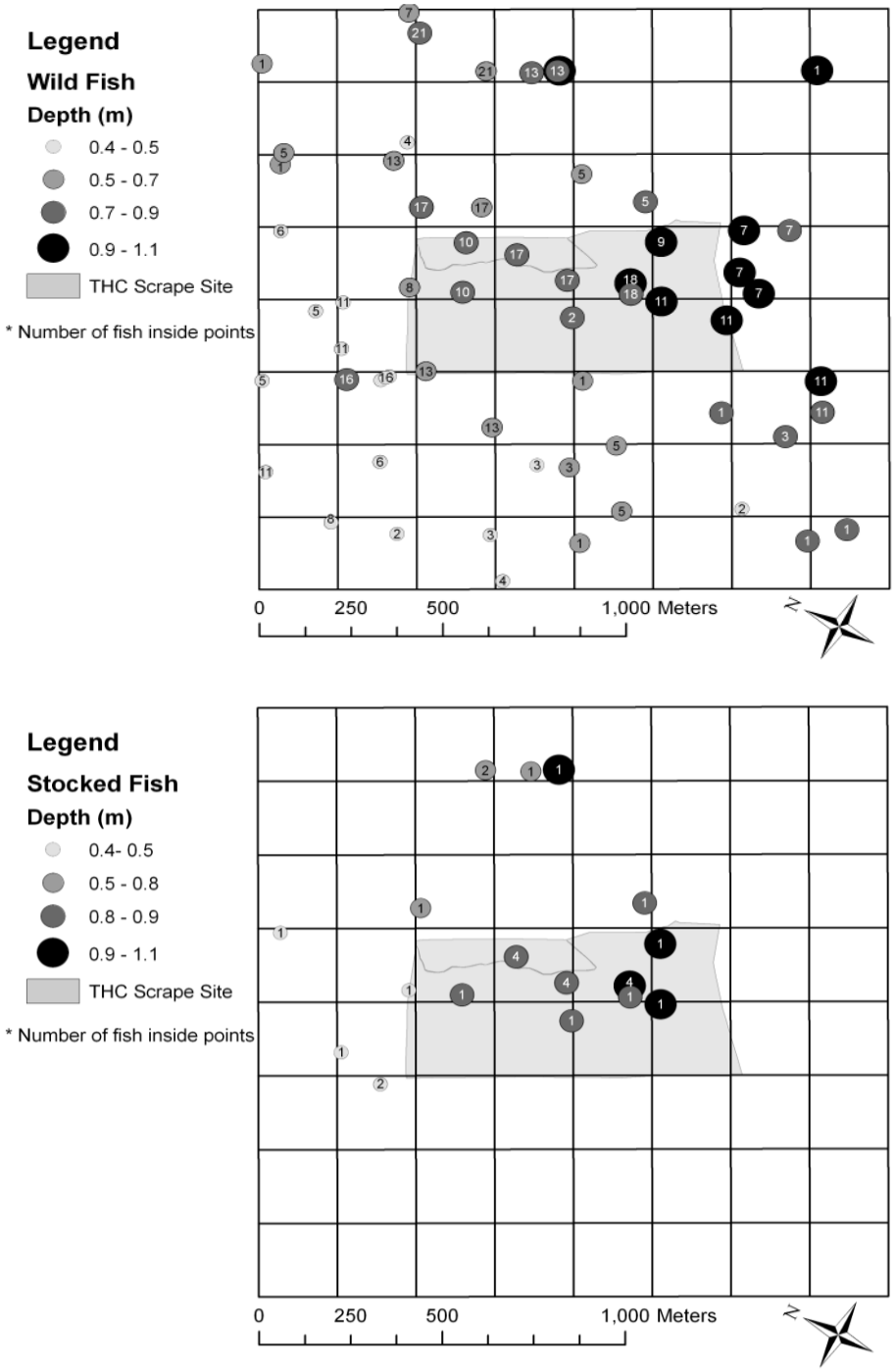

Figure 22. Tin House Cove 2010. Average water depth (feet) of captured 288 wild (top) and 28 stocked (bottom) largemouth bass.

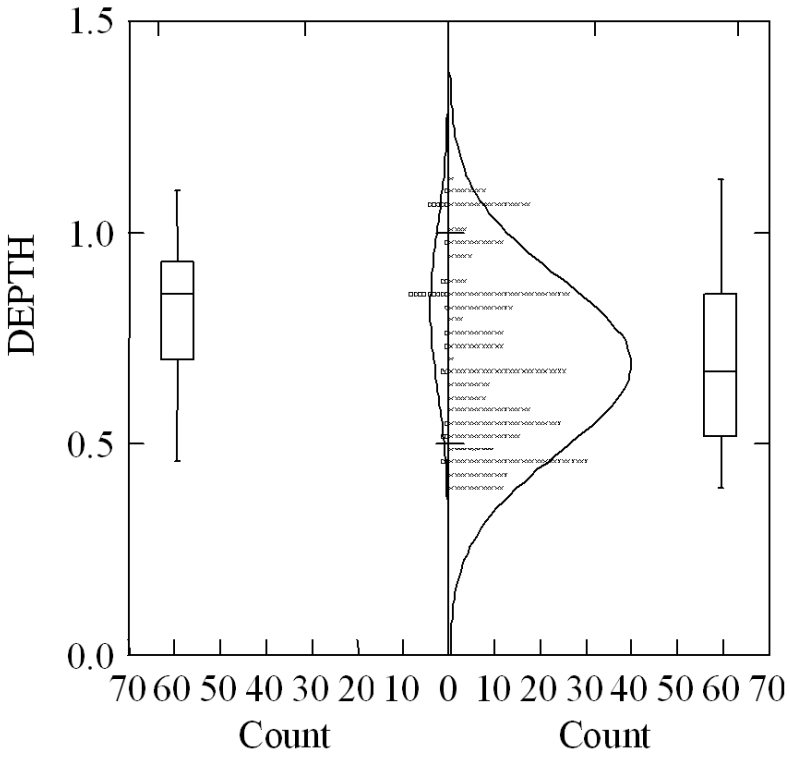

Figure 23. Tin House Cove 2010. Depths (meters) for 28 stocked bass are shown on the left and 288 wild bass are shown on the right. The mean depth for stocked bass is 0.82 m and the mean depth for wild bass is 0.69 m. T-test showed P=0.001 and is significant.

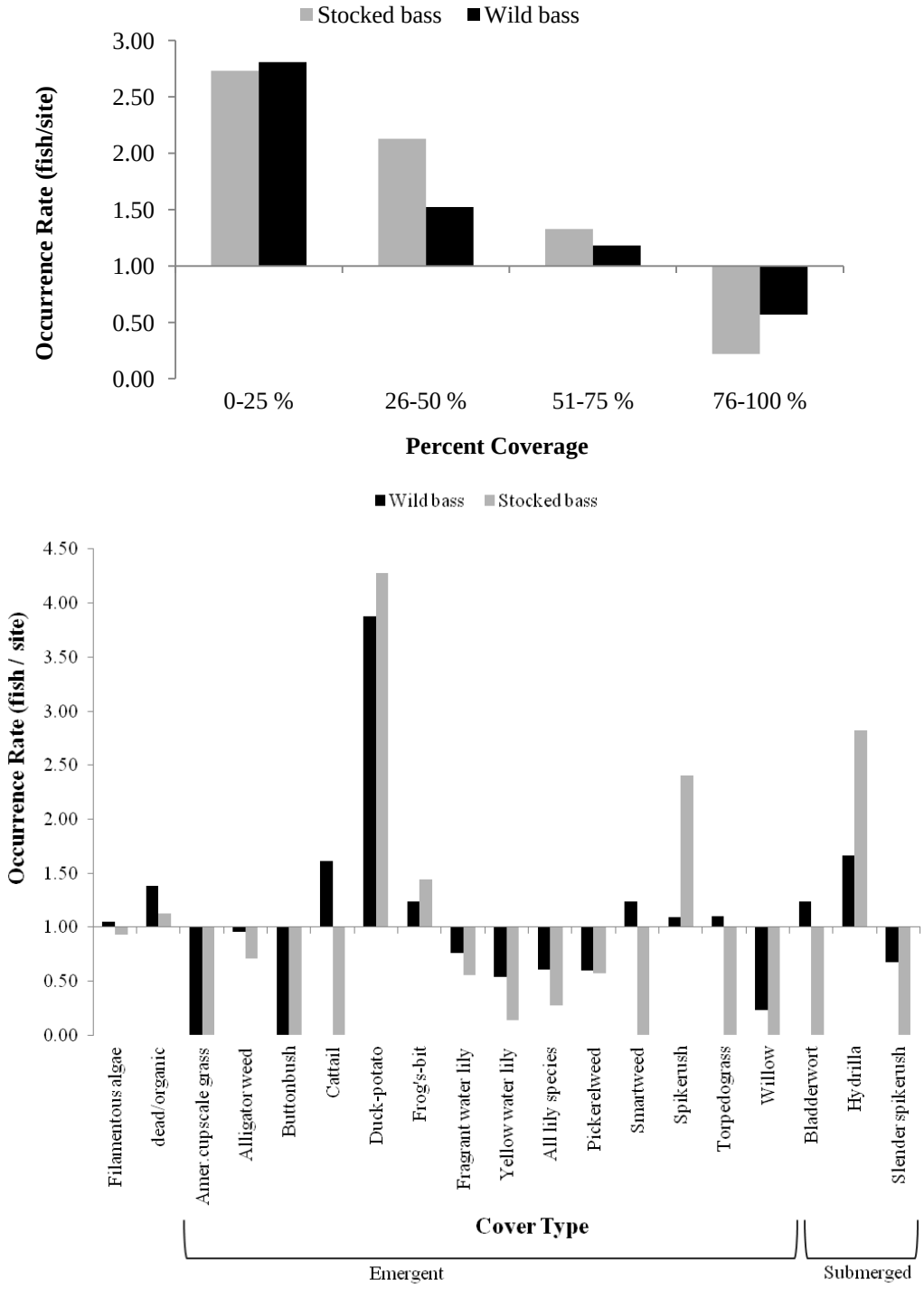

Figure 24. Tin House Cove 2010. Dominant cover type occurrence. Chance of occurrence of bass found in cover type. Occurrence over 1 indicates that fish occurrence is higher than cover occurrence. Top graph shows percent coverage of vegetation, bottom graph shows specific types of coverage.

REFERENCES

Allen MS, Tugend KI, and Mann MJ. 2003. Largemouth bass abundance and angler catch rates following a habitat enhancement project at Lake Kissimmee, Florida. North American Journal of Fisheries Management. 23:845−855.

Anderson RO. 1984. Optimal foraging by largemouth bass in structured environments. Ecology. 65:851–861.

Bell FW. 1987. The economic impact and valuation of the recreational and commercial fishing industries of Lake Okeechobee, Florida. Florida Game and Fresh Water Fish Commission, Tallahassee, FL.

Bennett GW. 1962. Management of artificial lakes and ponds. NY: Reinhold Publishing Corporation.

Bettoli PW, Maceina MJ, Noble RL and Betsill RK. 1992. Piscivory in largemouth bass as a function of aquatic vegetation abundance. North American Journal of Fisheries Management. 12:509–516.

Boxrucker JC. 1986. Evaluation of supplemental stocking of largemouth bass as a management tool in small impoundments. North American Journal of Fisheries Management. 6:391-396.

Boxrucker JC. 2002. Improved growth of a white crappie population following stocking of saugeyes (sauger x walleye): a top down, density-dependent growth response. North American Journal of Fisheries Management. 22:1425-1437.

Brown SJ and Maceina MJ. 2002. The influence of disparate levels of submersed aquatic vegetation on largemouth bass population characteristics in a Georgia reservoir. Journal of Aquatic Plant Management 40:28–35.

Buckmeier DL and Betsill RK. 2002. Mortality and dispersal of stocked fingerling largemouth bass and effects on cohort abundance. In: Phillip DP and Ridgway MS, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland. p. 667-676.

Buckmeier DL, Schlechte JW, and Betsill RK. 2003. Stocking fingerling largemouth bass to alter genetic composition: efficacy and efficiency of three stocking rates. North American Journal of Fisheries Management. 23:523-529.

Buckmeier DL, Betsill RK and Schlechte JW. 2005. Initial predation of stocked fingerling largemouth bass in a Texas reservoir and implications for improving stocking efficiency. North American Journal of Fisheries Management. 25:652-659.

Buynak GL and Mitchell B. 1999. Contribution of stocked advanced-fingerling largemouth bass to the population and fishery and Taylorsville Lake, Kentucky. North American Journal of Fisheries Management. 19:494-503.

Cardeilhac PT. 2010. Development of a pelleted feed for the intensive culture of Florida largemouth bass (*Micropterus salmoides floridanus*). Webster, Florida. Florida Fish and Wildlife Conservation Commission. Federal Aid Wallop Breaux Final Report F-129-R.

Copeland JR and Noble RL. 1994. Movements by young-of-year and yearling largemouth bass and their implications for supplemental stocking. North American Journal of Fisheries Management. 14:119-124.

Crawford S and Wicker A. 1987. Recruitment of stocked largemouth bass fingerlings into a general Florida fishery. Florida Scientist. 50(1):211-215.

Diana MJ and Wahl DH. 2009. Growth and survival of four sizes of stocked largemouth bass. North American Journal of Fisheries Management. 29:1653-1663.

Dieperink C, Pedersen S and Pedersen MI. 2001. Estuarine predation on radio tagged wild and domesticated sea trout smolts. Ecology Freshwater Fish. 10:177-183.

Florida Fish and Wildlife Conservation Commission. 2009a. 2008-2009 South Florida Aquatic Resources - Okeechobee Project. Study 1: Lake Okeechobee aquatic resource management. Annual progress report.

Florida Fish and Wildlife Conservation Commission. 2009b. Aquatic habitat restoration and enhancement projects: Northwest marsh, Lake Okeechobee FL. Unpublished map made by Brent Bachelder.

Florida Fish and Wildlife Conservation Commission. 2012. Freshwater Fishing – Lake Okeechobee. < http://myfwc.com/fishing/freshwater/sites-forecast/s/lake-okeechobee>. Accessed 2012 Feb 22.

Fox DD. 1987. Lake Okeechobee Fisheries. Aquatics. June 1987:12-20.

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

Hoxmeier J and Wahl DH. 2002. Evaluation of supplemental stocking of largemouth bass across reservoirs: effects of predation, prey availability, and natural recruitment. In: Phillip DP and Ridgway MS, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland. p. 639-647.

Jackson JR and Noble RL. 1995. Selectivity of sampling methods for juvenile largemouth bass in assessments of recruitment processes. North American Journal of Fisheries Management. 15:408-418.

Mesing CL, Cailteux RL, Strickland PA, Long EA and Rogers MW. 2008. Stocking of advanced-fingerling largemouth bass to supplement year-classes in Lake Talquin, Florida. North American Journal of Fisheries Management. 28:1762-1774.

Michaud JP. 1991. A Citizen's Guide to Understanding and Monitoring Lakes and Streams, 1st ed. M.B. McAuliffe. Washington State Department of Ecology. p. 12-13.

Mundahl ND, Melnytschuk C, Spielman DK, Harkins JP, Funk K and Bilicki M. 1998. Effectiveness of bowfin as a predator on bluegill in a vegetated lake. North American Journal of Fisheries Management. 18:286-294.

Neal JW, Noble RL and Churchill TN. 2002. Timing of largemouth bass supplemental stocking in a tropical reservoir: impacts on growth and survival. In: Black bass: ecology, conservation, and management. In: Phillip DP and Ridgway MS, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland. p. 691-701.

Nordhaus JJ. 1989. Estimating the effects of a north Florida reservoir drawdown utilizing creel data. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies. 43:29-35.

Parkos J, Hoxmeier J, Ostrand K, Siepker M, Kassler T, Philipp D and Wahl D. 2001. Factors influencing largemouth bass recruitment: implications for the Illinois management and stocking program. Annual Progress Report. Aquatic Ecology Technical Report. Illinois Department of Natural Resources.

Perret AJ. 2007. A multi-scale approach to evaluate the effect of the invasive aquatic plant hydrilla (*Hydrilla verticillata*) on littoral zone habitat of juvenile largemouth bass (*Micropterus salmoides*) [thesis]. Mississippi State University. p. 74.

Porak WF, Johnson WE, Crawford S, Renfro DJ, Schoeb TR, Stout RB, Krause RA, and DeMauro RA. 2002. Factors affecting survival of largemouth bass raised on artificial diets and stocked into Florida lakes. In: Phillip DP and Ridgway MS, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland. p. 649-666.

Porak WF, Trippel N, Thompson B and Bisping S. 2011. Stock enhancement of largemouth bass. Completion report for the Federal Aid in Sport Fish Restoration Act Grant F-132-R to the U.S. Department of Interior, Fish and Wildlife Service from the Florida Fish and Wildlife Conservation Commission.

Pouder WF, Trippel NA and Dotson JR. 2010. Comparison of mortality and diet composition of pellet-reared advanced- fingerling and early-cohort age-0 wild largemouth bass through 90 days postocking at Lake Seminole, Florida. North American Journal of Fisheries Management. 30:1270-1279.

Rieger PW and Summerfelt RC. 1978. An evaluation of the introduction of Florida largemouth bass into an Oklahoma reservoir receiving a heated effluent. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies. 30(1976):48-57.

Ruiz GM, Hines AH and Posey MH. 1993. Shallow water as a refuge habitat for fish and crustaceans in nonvegetated estuaries: an example from Chesapeake Bay. Marine Ecology Progress Series. 99(1):1-6.

Sah RC. June 2011. Consumer price index (CPI) conversion factors 1774 to estimated 2021 to convert to dollars of 2010. Political Science Department. Oregon State University. < http://oregonstate.edu/cla/polisci/faculty-research/sahr/sahr.htm>. Accessed 2012 Jan 19.

Saiki MK and Tash JC. 1979. Use of cover and dispersal by crayfish to reduce predation by largemouth bass. In: Johnson DL and Stein RA, editors. Response of fish to habitat structure in standing water. North Central Division. American Fisheries Society Special Publication 6. p.44-48.

Sammons SM and Maceina MJ. 2005. Population size, survival, growth of largemouth bass one year after stocking in four ponds. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies. 59:241-250.

Schlechte JW, Betsill RK and Buckmeier DL. 2005. A laboratory evaluation of poststocking predatory losses for cultured largemouth bass. Transactions of the American Fisheries Society. 134:141-148.

Serafy JE, Ault JS, Capo TR and Schultz DR. 1999. Red drum, *Sciaenops ocellatus*, stock enhancement in Biscayne Bay, FL, USA: Assessment of releasing unmarked early juveniles. Aquaculture Research. 30:737–750.

Servaites JC and Ogren W. 1977. pH Dependence of photosynthesis and photorespiration in soybean leaf cells. Plant Physiology. 60:693-696.

South Florida Water Management District. 2000. Lake Okeechobee managed recession after action report and priority action plan. Water Supply Division and Watershed Research and Planning Division, p. AA-9.

Steinman AD and Rosen BH. 2000. Lotic-lentic linkages associated with Lake Okeechobee, Florida. Journal of the North American Benthological Society. 19(4):733-741.

Stroud RH. 1967. Water quality criteria to protect aquatic life: a summary. American Fisheries Society Special Publication. 4:33-37.

Subosky MD and Templeton JJ. 1989. Life skills training for hatchery fish: social learning and survival. Fisheries Research. 7:343-352.

Terre DR, Magnelia SJ and Ryan MJ. 1993. Year class contribution of genetically-marked Florida x northern largemouth bass stocked in three Texas reservoirs. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies. 47:622-632.

Tringali MD, Leber KM, Halstead WG, McMichael R, O'Hop J, Winner B, Cody R, Young C, Neidig C, Wolfe CH, Forstchen A and Barbieri L. 2008. Marine stock enhancement in Florida: A multi-disciplinary, stakeholder-supported, accountability-based approach. Reviews in Fisheries Science. 16(1–3):51–57.

Tringali M, Porak W, Bellotti P, Seyoum S, Trippel N, Strickland A, Knight J, Paxton C, Puchulutegui C and Davis M. 2010. Population genetics of freshwater fishes for fish management and stock enhancement. Completion report for the Federal Aid in Sport Fish Restoration Act Grant F-128 to the U.S Department of the Interior and Fish and Wildlife Service from the Florida Fish and Wildlife Conservation Commission.

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

Wahl DH and Stein RA. 1989. Comparative vulnerability of three esocids to largemouth bass (*Micropterus salmoides*) predation. Canadian Journal of Fisheries and Aquatic Sciences. 46:2095-2103.

Wahl DH, Stein RA and DeVries DR. 1995. An ecological framework for evaluating the success and effects of stocked fishes. In: Schramm HL, Jr and Piper RG, editors. Uses and effects of cultured fishes in aquatic ecosystems. American Fisheries Society, Symposium 15, Bethesda, Maryland. p. 176-189.

Wegener W and Williams V. 1975. Fish population responses to improved lake habitat utilizing extreme drawdown. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies. 28:144-161.

Welch ZC. 2009. Restoring pattern without process in lake restoration: a largescale littoral habitat enhancement project on Lake Tohopekaliga, Florida [dissertation]. University of Florida.