Introgression, health, and condition of Florida, northern, and Fx hybrid largemouth bass in Louisiana water bodies

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INTRODUCTION, HEALTH, AND CONDITION OF FLORIDA, NORTHERN, AND F_x HYBRID LARGEMOUTH BASS IN LOUISIANA WATER BODIES

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DEDICATION

I dedicate this thesis to my parents, Douglas and Susan Fries, who first introduced me to the outdoors by taking me on picnics to metro parks, letting me stomp mushrooms to my heart's content, and teaching me that beech trees were the ones with names carved in them. Some of my favorite memories are from those summer picnics and nature walks. My love for wildlife and nature started with them, and for that I will be forever grateful.

I couldn't ask for more caring parents, and I count myself lucky every day to have them in my life. Their support and love gave me the confidence to choose my own path and follow my heart, no matter where it led me.

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ABSTRACT

Since 1982, the Louisiana Department of Wildlife and Fisheries (LDWF) has stocked Florida-strain largemouth bass (FLMB; *Micropterus salmoides floridanus*) to incorporate Florida alleles into native populations (NLMB; *M. s. salmoides*) and enhance recreational fishing opportunities. I collected habitat data and largemouth bass samples from 12 LDWF stocked reservoirs and disconnected oxbow lakes to examine the relationships between reservoir characteristics, genetic identity, relative weight (W_r), liver somatic index (LSI), parasite loads, and back-calculated length-at-age. I examined the relationships between water body and genetic identity with W_r, LSI, and back-calculated length-at-age by ANOVA. Parasite loads were analyzed with ordinal regression. Principle component analysis was used to reduce the dataset into a smaller number of principal components and group the study lakes as habitat types. I then used ANOVA to assess whether W_r, LSI, or length-at-age were influenced by genetic strain or habitat type as represented by the principal components and logistic regression to determine whether principal component influenced the abundance of NLMB or non-native largemouth bass. Although similar across bass strains, W_r, LSI, and length-at-age varied by lake (all P<0.0001). Parasite loads were not significantly different between years or among water bodies or genetic strain. Based on the ANOVA results, shallow, nutrient rich lakes with high chlorophyll *a* concentrations and large littoral zones appeared to promote high W_r and non-native largemouth bass. Conversely, northern largemouth bass were more prevalent, and W_r was lower, in lakes with dense vegetation. Aquatic macrophytes may reduce foraging efficiency of larger, piscivorous fish while increasing survival of young-of-the-year largemouth bass. Reservoirs with

little vegetative cover may reduce natural recruitment of resident largemouth bass allowing rapid genetic introgression. These findings may improve our understanding of the effects of FLMB stocking activities and provide the opportunity to modify stocking protocols to better achieve the management goals of the largemouth bass program.

INTRODUCTION

The largemouth bass (*Micropterus salmoides*) is one of the most widely sought after sportfish in North America, and has become a management priority for many state fisheries agencies (Buynak et al. 1999; Noble 2002; Carlson and Isermann 2010). Maintaining angler satisfaction is a particularly important concern for fisheries managers and is often the driving force behind many bass management decisions. Attempts at creating trophy largemouth bass fisheries by stocking, managing habitat, and adjusting creel limits have been reported in most states where largemouth bass are stocked (Hughes and Wood 1995; Crawford et al. 2002; Wilson and Dicenzo 2002; Myers and Allen 2005). Although trophy bass fisheries are consistently sought after by managers and anglers alike and are known to generate positive economic benefits for local communities (Chen et al. 2003), many anglers are also interested in catching large numbers of fish (Wilde et al. 1998). Promoting strong year classes to provide anglers with the opportunity to consistently catch high quantities of largemouth bass requires a very different strategy than one maximizing large size (Summerfelt 1999), but regardless of the ultimate goal, managers often focus on maintaining high growth rates to produce rotund, healthy fish.

Maximizing growth of largemouth bass in large reservoirs can be difficult because of inherent variability in environmental conditions such as temperature (McCauley and Kilgour 1990), available forage (Timmons and Shelton 1980), aquatic macrophyte coverage (Savino and Stein 1982; Durocher et al. 1984; Hoyer and Canfield 1996; Unmuth et al. 1999; Valley and Bremigan 2002; Strakosh et al. 2009), and water quality parameters such as turbidity or chlorophyll *a* concentrations (Jones

and Hoyer 1982; Sweka and Hartman 2003). As a consequence, maximizing growth and recruitment of sportfish to harvestable size often requires managers to focus on maintaining abundant forage, providing optimal amounts of aquatic vegetation and woody debris, and stocking juvenile sportfishes to supplement natural populations.

Unfortunately, maintaining optimal coverage of aquatic vegetation has become a leading management problem in many states throughout the U.S., largely because of invasions of non-native macrophytes, often compounded by watershed sediment and nutrient inputs (Lacoul and Freedman 2006; Moore et al. 2010). The ability to maintain levels of vegetation that support and protect juvenile sportfish and prey species while providing piscivorous predators with ample forage continues to be problematic in many systems. Reservoirs with little to no macrophyte coverage often exhibit poor recruitment of age-0 fish and low standing crops of harvestable largemouth bass because of a lack of habitat complexity and protective cover (Durocher et al. 1984; Bettoli et al. 1993; Havens et al. 2005; Strakosh et al. 2009). Conversely, dense aquatic vegetation may reduce forage availability and impact growth and condition of piscivorous largemouth bass as a result of an inaccessible prey base (Heman et al. 1969; Colle and Shireman 1980; Savino and Stein 1982; Hoyer and Canfield 1996; Mason 2002; Valley and Bremigan 2002; Maceina and Splike 2004). Additionally, as lentic vegetative cover increases, survival of juvenile fishes also increases (Tate et al. 2003), resulting in elevated trophic competition and reduced growth (Wrenn et al. 1996; Unmuth et al. 1999). Intermediate densities of aquatic vegetation (e.g., 20%; Miranda and Pugh 1997) have been reported to maximize the abundance and growth of young-of-year and adult largemouth bass in large reservoirs (Trebitz et al. 1995; Maceina

1996; Valley and Bremigan 2002; Sammons et al. 2005). As a consequence, providing optimal macrophyte densities can be an important part of lentic habitat management programs directed at maximizing sport fish growth and abundance.

In addition to macrophyte control, stocking has also been incorporated into largemouth bass management programs in many parts of the U.S. and can significantly affect juvenile fish abundance, population genetics, and year class strength (Heidinger 1999). Stocking Florida-strain largemouth bass (*Micropterus salmoides floridanus*; FLMB) has become a common management tool in the southeastern U.S., based on the premise that incorporating Florida strain alleles into northern (*Micropterus salmoides salmoides*; NLMB) populations will increase growth rates and promote development of trophy fisheries (Chew 1975; Maceina et al. 1988; Myers and Allen 2005). Largemouth bass found in southern Florida are often noted for their large size and rapid growth, which have been attributed in part to longer growing seasons and different habitat conditions found in peninsular Florida (Chew 1975). Interestingly, studies outside Florida that compared growth rates of FLMB, NLMB, and F_x hybrid bass (F_xLMB) have yielded highly variable results regarding the growth superiority of FLMB (Bailey and Hubbs 1949; Clugston 1964; Addison and Spencer 1972; Zolczynski and Davies 1976; Inman et al. 1978; Smith and Wilson 1982). However, these studies relied on meristic counts to differentiate the genetic strains, and electrophoretic evaluation of several bass populations has suggested that meristic counts are unreliable for identifying FLMB, NLMB and their hybrids Phillip et al. (1981, 1983). Subsequent electrophoretically-based research has reported a genetic basis for growth differences between the subspecies, with FLMB growth rates exceeding those of NLMB at older ages (Johnson

and Graham 1978; Maceina and Murphy 1988). In addition to superior growth, FLMB are believed to exhibit greater longevity and lower catchability than NLMB (Zolczynski et al. 1976), ultimately providing larger individuals than resident NLMB stocks (Pelzman 1980; Kleinsasser et al. 1990).

Although stocking FLMB has sometimes failed to result in significant contribution of stocked fish to the harvestable portion of the population (Terre et al. 1995, Ryan et al. 1998; Buckmeier et al. 2003; Hoffman and Bettoli 2005), stocking programs in other southeastern lakes and reservoirs have often been successful in increasing the catch and harvest of larger fish (Buckmeier et al. 2005). For example, largemouth bass taken from stocked water bodies in Alabama were larger on average than fish from lakes without Florida bass influence (Hendricks et al. 1995). Further, Myers and Allen (2005) reported that catch of trophy size bass in Texas was 29% greater in reservoirs stocked with FLMB. These growth patterns, along with the possibility that FLMB remain in the fishery longer than NLMB (Zolczynski and Davies 1976; Neal and Noble 2002), have continued to make stocking FLMB an attractive reservoir management option in the southern U.S. (Chen et al. 2003).

In addition to increasing growth rates or altering size distributions, benefits of stocking sport fish may include supplementing weak year classes (Boxrucker 1986), enhancing angler opportunities (Buynak and Mitchell 1999), or altering the genetic make-up of natural populations (Maceina et al. 1988; Gilliland 1994; Terre et al. 1995; Buckmeier et al. 2003). However, these benefits are only seen in systems where survival and contribution of stocked fish is relatively high. The success of largemouth bass supplemental stockings has been highly variable, and even repeated, large scale

stockings may yield modest results (Boxrucker 1986; Ryan et al. 1998; Buckmeier and Betsill 2002; Hoxmeier and Wahl 2002; Porak et al. 2002; Hoffman and Bettoli 2005; Diana and Wahl 2009). Successful stockings, however, have been reported in Florida where Mesing et al. (2008) identified 37% of the age-3 catch as stocked fish, and in a Texas reservoir where stocked FLMB and F_xLMB comprised 72% of the sample 3 years post-stocking (Maceina et al. 1988). Several studies that reported low initial survival of stocked fish still continued to see moderate contributions to resident populations at least one year post-stocking (11.6%, Buynak and Mitchell 1999; 14.9%, Buckmeier et al. 2003; 17.6%, Colvin et al. 2008). Despite these success stories, significant or moderate contribution of hatchery fish to natural populations is not common. Hoffman and Bettoli (2005) reported only 2% contribution one year after stocking, and stocked reservoirs in Texas experienced between 0% and 6.7% contribution of hatchery fish one year post-stocking (Ryan et al. 1998). Buckmeier and Betsill (2002) reported high mortality rates (2.33-2.48% per day) of stocked fish up to 150 days post-stocking, and Porak et al. (2002) found only 32% of stocked bass survived for one year.

Survival and recruitment of stocked fish to the adult population is dependent on many factors including habituation time (Buckmeier et al. 2005; Schlechte and Buckmeier 2006), predation (Hoxmeier and Wahl 2002; Buckmeier et al. 2005; Schlechte, et al. 2005), size of fish at stocking (Hoffman and Bettoli 2005; Colvin et al. 2008; Diana and Wahl 2009), available forage (Hoxmeier and Wahl 2002), number of fish stocked (Boxrucker 1986; Buckmeier et al. 2003), and interactions among wild and stocked fish (Terre et al. 1995). High initial mortality of stocked fish is often attributed to increased predation after stocking (Buckmeier and Betsill 2002; Jackson et al. 2002),

which may be reduced by habituation in small enclosures prior to release (Schlechte et al. 2005). Stocking larger fish has also been reported as a means to increase post-stocking survival and has been employed by many states including Louisiana. Although this technique has been successful for many other fish species (Wahl and Stein 1993; Szendrey and Wahl 1996; McKeown et al. 1999), few studies have reported significant differences in the long-term contribution of large fingerlings or subadult largemouth bass (Buynak et al. 1999; Colvin et al. 2008). Diana and Wahl (2009) did find reduced initial mortality for fingerlings greater than 150 mm in length, but the contribution of the larger individuals after one year was similar to that of smaller fingerlings. Stocking rates, in addition to fish size, have been studied as a way to maximize stocking success. Buckmeier et al. (2003) determined that an intermediate stocking rate (10,000 fish/2 km of shoreline) was the most effective in Texas reservoirs. Stocking excessive numbers of largemouth bass can be wasteful, inefficient, and may not increase the contribution of hatchery fish to resident populations (Buynak and Mitchell 1999; Buckmeier et al. 2003).

Despite mixed results and reported low returns after extensive stockings, many state agencies continue to fund largemouth bass stocking programs to enhance recreational fishing. For the past 25 years, Louisiana Department of Wildlife and Fisheries (LDWF) has been stocking fingerling FLMB in reservoirs across the state. The long term goal of the LDWF stocking program is to incorporate Florida-strain alleles into NLMB populations, thereby changing largemouth bass size distributions and enhancing recreational fishing opportunities. In 1988, the School of Renewable Natural Resources at the Louisiana State University (LSU) Agricultural Center began to monitor the relative success of genetic introgression of stocked FLMB by sampling and

genetically identifying largemouth bass from various lakes and reservoirs across the state. Recently, Kaller et al. (2006) analyzed the influence of stocking rates, time since initial stocking, stocking size, and number of years stocked on the proportions of FLMB and F_xLMB in native NLMB populations using the stocking and genetic dataset collected by LDWF and LSU from 1988-2005. Statewide, a 1.56% increase in the proportion of FLMB and a 15.65% increase in F_xLMB over time was reported in Louisiana reservoirs, but the magnitude of this change varied considerably by water body. Similarly, after more than 20 years of FLMB stocking in Texas, Forshage and Fries (1995) reported an average of 36.3% bass with FLMB alleles in stocked reservoirs, although levels of introgression ranged from 0-80% among lakes. Unlike previous studies in Alabama (Dunham et al. 1992) and Texas (Kulzer et al. 1985) that reported stocking frequency and time since initial stocking as significant factors in determining the relative success of genetic introgression, Kaller et al. (2006) could not explain the apparent lack of introgression of FLMB in approximately 50% of the sampled reservoirs.

The findings of Kaller et al. (2006) suggest that factors other than stocking frequency and duration must be influencing the introgression of FLMB in Louisiana lakes, and my study was designed to investigate whether habitat and water quality characteristics could account for some of the observed variability in FLMB and F_xLMB abundance in Louisiana bass populations. My approach was to first determine whether a relationship existed between levels of FLMB introgression and the macrophyte abundance, shoreline development (McMahon et al. 1996), reservoir morphology, and physicochemistry of twelve lakes located throughout the state. I then used this analysis

of lake characteristics to examine habitat and strain-related differences in length-at-age, condition, and parasite loads of NLMB, FLMB, and F_xLMB.

METHODS

Study Sites

I examined the physicochemistry and largemouth bass stock characteristics in Black Bayou Lake, Bundick Lake, Caney Creek Reservoir, Chicot Lake, False River (a disconnected Mississippi River oxbow lake), Kincaid Reservoir, Lac des Allemands, Lake Bruin (also a disconnected oxbow lake), Lake Claiborne, Lake Rodemacher, Poverty Point Reservoir, and Spanish Lake (Figure 1). These lakes were chosen based on the status of the largemouth bass fishery as assessed by the local Louisiana Department of Wildlife and Fisheries (LDWF) fisheries biologists, current and future plans for aquatic plant management, and the relative success of genetic introgression. Water bodies with significant management plans such as drawdowns during the period of this study were not considered as study sties. The long-term genetics dataset collected by LDWF and the School of Renewable Natural Resources at Louisiana State University (LSU) Agricultural Center from 1988-present was used to estimate relative success of genetic introgression. Lac des Allemands, Lake Claiborne, Bundick Lake, and Kincaid Reservoir are all characterized by relatively “poor” introgression, with few FLMB identified each year despite repeated stocking efforts (Table 1). Black Bayou Lake, Lake Bruin, and Lake Rodemacher were rated as intermediate or average lakes, yielding an average of 20-30% Florida and hybrid bass in each annual sample. Finally, False River, Caney Creek Reservoir, Chicot Lake, Poverty Point Reservoir, and Spanish Lake were all considered successful lakes with hybrid and Florida bass comprising 30- 55% of the annual sample (Table 1).

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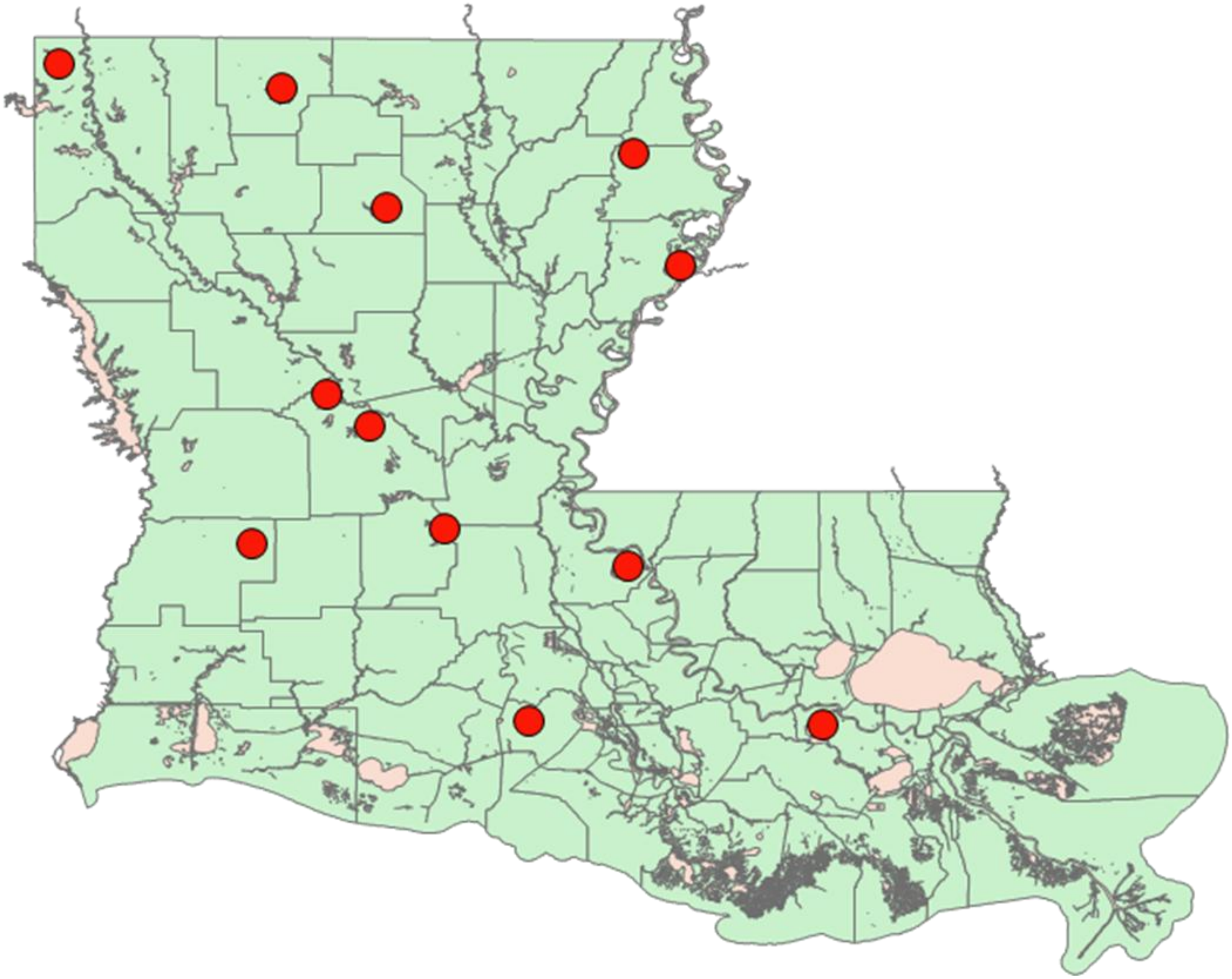

Figure 1. Locations of the 12 study lakes in Louisiana.

Table 1. The number of years stocked, number of fish stocked, and average percent of northern, Florida, and F_x hybrid largemouth bass sampled from each of the 12 study lakes from 1988-2009.

Study Site	Years Stocked	Fish Stocked	Northern (%) ± SE	Florida (%) ± SE	F_x Hybrid (%) ± SE
Black Bayou Lake	16	692,666	74 ± 4.8	5 ± 1.1	21 ± 4.3
Bundick Lake	4	122,375	88 ± 2.6	0 ± 0.3	12 ± 2.6
Caney Creek Reservoir	19	4,931,953	42 ± 6.4	22 ± 3.4	37 ± 3.4
Chicot Lake	22	2,319,538	59 ± 3.2	11 ± 1.9	30 ± 3.2
False River	18	2,330,966	64 ± 3.6	9 ± 1.6	26 ± 3.0
Kincaid Reservoir	9	179,450	92 ± 5.1	0 ± 0.0	8 ± 5.1
Lac Des Allemands	11	1,692,030	89 ± 3.0	3 ± 1.0	8 ± 2.6
Lake Bruin	8	248,898	88 ± 12.8	2 ± 1.6	10 ± 11.3
Lake Claiborne	10	704,516	92 ± 2.3	2 ± 0.9	6 ± 2.1
Lake Rodemacher	17	2,101,440	57 ± 7.9	14 ± 5.4	29 ± 6.6
Poverty Point Reservoir	11	1,979,700	62 ± 5.0	16 ± 3.6	22 ± 5.1
Spanish Lake	11	1,045,460	57 ± 10.3	22 ± 4.9	20 ± 5.9

Data Collection

Lake Characteristics

In early (May-June) and late (August-September) summer of 2008 and 2009, I collected lake morphology, water quality, and aquatic vegetation data in each lake. Lake morphology was evaluated with four depth transects: one along the longest axis of the lake and three transects perpendicular to the first. Continuous depth readings were recorded by a portable sonar and GPS unit (Eagle Electronics®, Catoosa, OK). Maximum depth of each lake was obtained from these depth transects.

Water quality data, including water temperature (°C), dissolved oxygen concentration (DO; mg/L), pH, turbidity (NTU), and specific conductance (uhms/cm), were collected with a hand held probe (YSI, Inc., Yellow Springs, OH) at two haphazardly-placed points in each lake during the four habitat sampling periods. Temperature and DO profiles were recorded by taking readings at one meter increments from 0.5 m below surface to the bottom at each of the water quality points. Thermocline depth and percent water column hypoxia were calculated for each lake based on the temperature and DO profiles. Water samples were collected from each lake one meter below the surface at two haphazardly-determined points during each of the four habitat sampling periods. Samples were analyzed in the laboratory at the School of Renewable Natural Resources, LSU Agricultural Center, for chlorophyll *a*, dissolved organic and inorganic carbon, total nitrogen, nitrate, nitrite, ammonia, phosphate, and suspended and volatile solids. Chlorophyll *a* (ug/L) was analyzed via method 10200 H (American Public Health Association 2005). Carbon samples (mg/L) were analyzed with a Shimadzu TOC-V Combustion Analyzer (Shimadzu North

America, Columbia, MD, USA) via Method 5310 B (American Public Health Association 2005). Total Nitrogen (mg/L), nitrate (mg/L), nitrite (mg/L), ammonia (mg/L), and phosphate (mg/L) samples were analyzed with a DR/2500 Hach Spectrophotometer (Hach Company, Inc., Loveland, CO) via Hach methods 10072, 8192, 8507, 8155, and 8048, respectively. Finally, solids were analyzed via method 2540 D (American Public Health Association 2005).

Habitat characteristics of the littoral zone of each lake were evaluated with a series of 10 transects perpendicular to shore in each of the four cardinal directions from the center point of each lake. The shoreline transects were spaced 300 m apart and began 100 m away from the shoreline. Distance from shore was estimated with a laser rangefinder (Bushnell Corporation, Overland Park, KS), and depth was recorded 100, 75, 50, and 25 m from the shoreline along the transect. If present, the lake-ward edge of aquatic vegetation was located and the distance to shore recorded to define the extent of the vegetated littoral zone. Any aquatic vegetation or bare substrate observed within one meter on either side of the 100 m transect was identified and visually estimated as percent cover. Vegetation was classified as submerged, emergent, or floating and identified to species. All woody debris within the 2-m band along the transect was counted, and the presence or absence of shoreline characteristics such as docks, lawns, trees, and roads were recorded at the shoreward edge of each transect.

Depth measurements were converted into GIS layers for definition and estimation of available habitat with computer software (ARC MAP, ESRI, Inc., Redlands, CA). I defined the littoral zone as the area of the lake with depths < 3.5 m

and estimated the percent area of the lake that would be considered littoral zone using GIS software.

Largemouth bass

LDWF fisheries biologists sample a subset of lakes in Louisiana each fall (September-November) and collect largemouth bass for analysis of growth and genetic identity. In the falls of 2008 and 2009, I accompanied LDWF biologists to collect samples of largemouth bass from the 12 study lakes using LDWF standardized boat electrofishing techniques using a boat mounted DC electrofishing unit (Table 1). We electrofished four sites in lakes under 2,023 ha, with one site added for each additional 405 ha. Shocking occurred along the shoreline of the lake, and total shock time at each site was 900 seconds. All largemouth bass were netted, kept on ice, and transported to the School of Renewable Natural Resources, LSU Agricultural Center. Fish sampling and handling followed LSU Agcenter IACUC protocol AE2008-07.

Total length (TL) and weight (W) of each fish was recorded to the nearest millimeter and gram, respectively. Sagittal otoliths were removed from each bass, washed, and stored in dry vials. Otoliths were later ground down to the nucleus from the posterior and anterior side with a Dremel® tool (Robert Bosch Tool Corporation, Racine, WI) and sanded with 600 grain wet-dry sandpaper similar to methods described by Maceina (1996). Resulting cross-sections were mounted with super glue (Loctite Super Glue, Westlake, Ohio) on microscope slides and were viewed with a Labrolux K binocular, transmitted light microscope at 40x magnification (Leica Microsystems, Wetzlar, Germany). A Nikon Digital Sight DS-Fi1 camera (Nikon Instruments, Inc. Tokyo, Japan) mounted on the microscope was used to display the image on a

computer monitor, and the distance from the nucleus to each annulus and the total otolith diameter were measured on the monitor to the nearest millimeter for growth calculations (Hoyer et al. 1985).

Fish health was evaluated by estimating parasite loads and calculating a liver somatic index (LSI) for each fish (Heidinger and Crawford 1977). The gills, liver, epidermis, muscle tissue, and peritoneal cavity of each fish were inspected for the presence of parasites. Parasite load was visually estimated for each area on the fish on a scale from 0 to 5, with 0 indicating the absence of parasites and 5 indicating a severe infestation or infection. The liver was removed from each bass and weighed to calculate LSI values.

$$LSI = (\text{Liver weight} / W) * 100$$

Growth and condition are often highly correlated in largemouth bass, with slow and fast growth reflected in low condition and high values, respectively (Cooper et al. 1963; Clugston 1964). In this study, I used relative weight (W_r; Anderson and Neumann 1996) and length at age as indicators of largemouth bass growth history. Relative weight of each fish was calculated as (Wege and Anderson 1978):

$$W_r = (W / W_s) *100, \text{ where } W_s = -5.316(TL)^{3.191}$$

Sections of livers weighing approximately 1 g were placed on ice and stored at -4 C, for allozyme analyses. Liver tissue was homogenized in distilled water and stored at -80 C. Horizontal starch gel electrophoresis was performed at 5 C with constant voltage for 12 hours in a single tris-cirate (TC) buffer system at a pH of 7.0 (Shaw and Prasad 1970). Histochemical stains described by Shaw and Prasad (1970) were used to identify banding patterns of two enzymes, Isocitrate dehydrogenase (IDH, EC

1.1.1.42) and Aspartate aminotransferase (AAT, EC 2.6.1.1). These enzymes are known to have a different fixed allele in NLMB and FLMB and a polymorphic banding pattern in hybrids, allowing genetic identification of each bass strain and F_xLMB.

Data Analysis

Analysis of variance (ANOVA, PROC MIXED SAS vers. 9.2) was used to detect differences in LSI, and W_r among lakes, between sampling years, among bass strains, and between sexes. Lake, strain, and year were treated as fixed effects. Residuals were examined to assess the assumptions of ANOVA, and log_{10}-transformations were applied when necessary to better approximate normality. Mulit-category logistic regression (PROC GENMOD, SAS vers. 9.2) was used to examine differences in parasite loads between sampling years and among strains and study lakes. Scores of 0 and 1 were grouped as low, 2 and 3 as medium, and 4 and 5 as high parasite loads. Low parasite load was described by scores of both 0 and 1 because few bass were given a 0 designation at each location. I also used simple linear regression (PROC REG, SAS vers. 9.2) to examine the effects of year and bass strain on the relationship between log_{10}-transformed lengths and weights (data pooled across lakes).

Because the number of measured vegetation and water quality parameters exceeded the number of observations, I used principal component analysis (PCA; PROC FACTOR, SAS vers 9.2) to reduce the dimensionality of these data into a smaller number of principal components (PCs) for subsequent analyses, similar to King and Jackson (1999), Aguilera et al. (2006), and Troutman et al. (2007). Data collected in June and August of each sampling year were pooled to create mean values for 2008 and 2009, and the PCA (based on the correlation matrix of mean values for all non-

commensurable variables (Khattree and Naik 2000) and coefficients of variation of selected variables) allowed me to avoid psuedoreplication and draw inferences regarding the distribution of parameters (Palmer et al. 1997). I used varimax rotation of the PCs to enhance interpretation (Khattree and Naik 2000), a scree plot to determine the number of PCs retained for interpretation (Cattell 1966), and adjusted the magnitude of interpretable correlation for sample size (Stephens 2002). I used the scores of the lakes on each PC to group the lakes as habitat types, and then compared LSI values and W_r with ANOVA to assess whether habitat type was related to fish health or condition. Lake scores were also used in a logistic regression (PROC GENMOD, SAS vers 9.2) to determine the relative abundance of each largemouth bass strain among habitat groups. For this analysis, I grouped F_xLMB and FLMB in the logit model as non-native largemouth bass because of inadequate numbers of FLMB. I included total number of FLMB stocked per hectare in each water body as a covariate in the logistic regression to account for the influence of stocking on the abundance of non-native bass.

The Fraser-Lee method of back-calculation was used to estimate length-at-age based on otolith annuli measurements (DeVries and Frie 1996). Back-calculations of length were only calculated for the most recent annulus. Regression analysis (PROC REG, SAS vers 9.2) determined the relationship between otolith radius at age and back-calculated length-at-age. The intercept obtained from this regression (13.67) was used as the Fraser-Lee correction factor. Residuals were examined to assess the assumptions of simple linear regression. Log-transformations were applied when necessary to better approximate the assumptions of simple linear regression.

I only used otoliths from bass collected in 2009 for the length-at-age analysis, because 2008 fish were aged by LDWF biologists, and I could not assess variability in the data due to differing otolith preparation techniques, viewing equipment, and readers, which would have made length comparisons among lakes inappropriate. I restricted my analysis of bass length differences among lakes to fish from ages 1-3, as older age classes were represented by few individuals. Spanish Lake and Black Bayou Lake were also excluded from this analysis because of small sample sizes and missing year classes.

Because length at successive ages was not linear across age classes, but was reasonably linear within an age class, I could not use multivariate analysis of variance to simultaneously assess differences in length at ages 1-3 for NLMB, FLMB, and F_xLMB among lakes. Therefore I used separate ANOVAs for each age class, with a Bonferroni-corrected alpha-level of 0.029, to assess differences in length at age, with lake and strain as fixed effects (ANOVA, PROC MIXED, SAS vers 9.2).

Similar to the LSI and W_r analyses, I used PCA to investigate the effects of habitat type on length-at-age. However, this PCA excluded habitat data from Black Bayou Lake and Spanish Lake because these two water bodies did not yield enough bass to be included in the length-at-age analysis. Scores of the remaining 10 lakes on the PCs from this analysis were used in an ANOVA with to detect significant relationships between length-at-age and habitat type.

RESULTS

Samples collected in 2008 yielded a total of 726 largemouth bass, and electrophoretic analysis indicated 473 fish were NLMB (65%), 80 were FLMB (11%), and 173 were F_xLMB (24%). In 2009, 768 largemouth bass were collected, which included 552 NLMB (72%), 40 FLMB (5%), and 176 F_xLMB (23%). The greatest percentage of FLMB was found in Spanish Lake in 2008 (33.33%) and Caney Creek Reservoir in 2009 (14.41%). No FLMB were collected from Kincaid Reservoir in 2008 or from Black Bayou Lake, Bundick Lake, Kincaid Reservoir, Lac Des Allemands, Lake Claiborne, and Spanish Lake in 2009. The highest incidence of F_xLMB was found in Lake Rodemacher (39.39%) in 2008 and Spanish Lake (83.33%) in 2009, whereas Kincaid Reservoir produced the lowest percentage of hybrid bass in both 2008 and 2009 (4.94% and 8.00%, respectively). In 2008, Lake Bruin yielded the highest percentage of NLMB (95.24%), whereas 92% of the Kincaid Reservoir sample was identified as NLMB in 2009 (Table 2).

Condition and Health

Mean LSI values were not different between years (P=0.6067) or bass strains (P=0.1807), but did vary significantly among the study lakes (P<0.0001; Figure 2). Internal, external, gill, and liver parasite loads also exhibited a near-significant trend between lakes (P=0.0783) and years (P=0.0552), but not among bass strains (P=0.1034). Mean largemouth bass W_r differed among lakes (P<0.0001), years (P=0.0004), and their interaction (P<0.0001), but not among bass strains (P=0.9247). Mean W_r during the study period ranged from 93.31 in Lake Rodemacher to 124.72 in

Table 2. Percent composition of northern, Florida, and F_x hybrid largemouth bass from 12 study lakes sampled in the fall of 2008 and 2009.

	2008			
Study Site	**Northern**	**Florida**	**F_xHybrid**	**N**
Black Bayou Lake	76.47	2.94	20.59	34
Bundick Lake	88.00	2.00	10.00	50
Caney Creek Reservoir	48.13	19.38	32.50	160
Chicot Lake	55.56	11.11	33.33	27
False River	59.15	4.23	36.62	71
Kincaid Reservoir	95.06	0.00	4.94	81
Lac Des Allemands	85.71	2.86	11.43	35
Lake Bruin	95.24	2.38	2.38	42
Lake Claiborne	89.80	2.04	8.16	49
Lake Rodemacher	45.45	15.15	39.39	66
Poverty Point Reservoir	44.12	24.51	31.37	102
Spanish Lake	33.33	33.33	33.33	9
	2009			
Study Site	**Northern**	**Florida**	**F_xHybrid**	**N**
Black Bayou Lake	66.67	0.00	33.33	9
Bundick Lake	81.13	0.00	18.87	53
Caney Creek Reservoir	53.39	14.41	32.20	118
Chicot Lake	56.00	6.00	38.00	50
False River	67.31	3.85	28.85	52
Kincaid Reservoir	92.00	0.00	8.00	200
Lac Des Allemands	85.19	0.00	14.81	27
Lake Bruin	86.21	1.15	12.64	87
Lake Claiborne	88.37	0.00	11.63	43
Lake Rodemacher	42.86	14.29	42.86	35
Poverty Point Reservoir	46.59	13.64	39.77	88
Spanish Lake	16.67	0.00	83.33	6

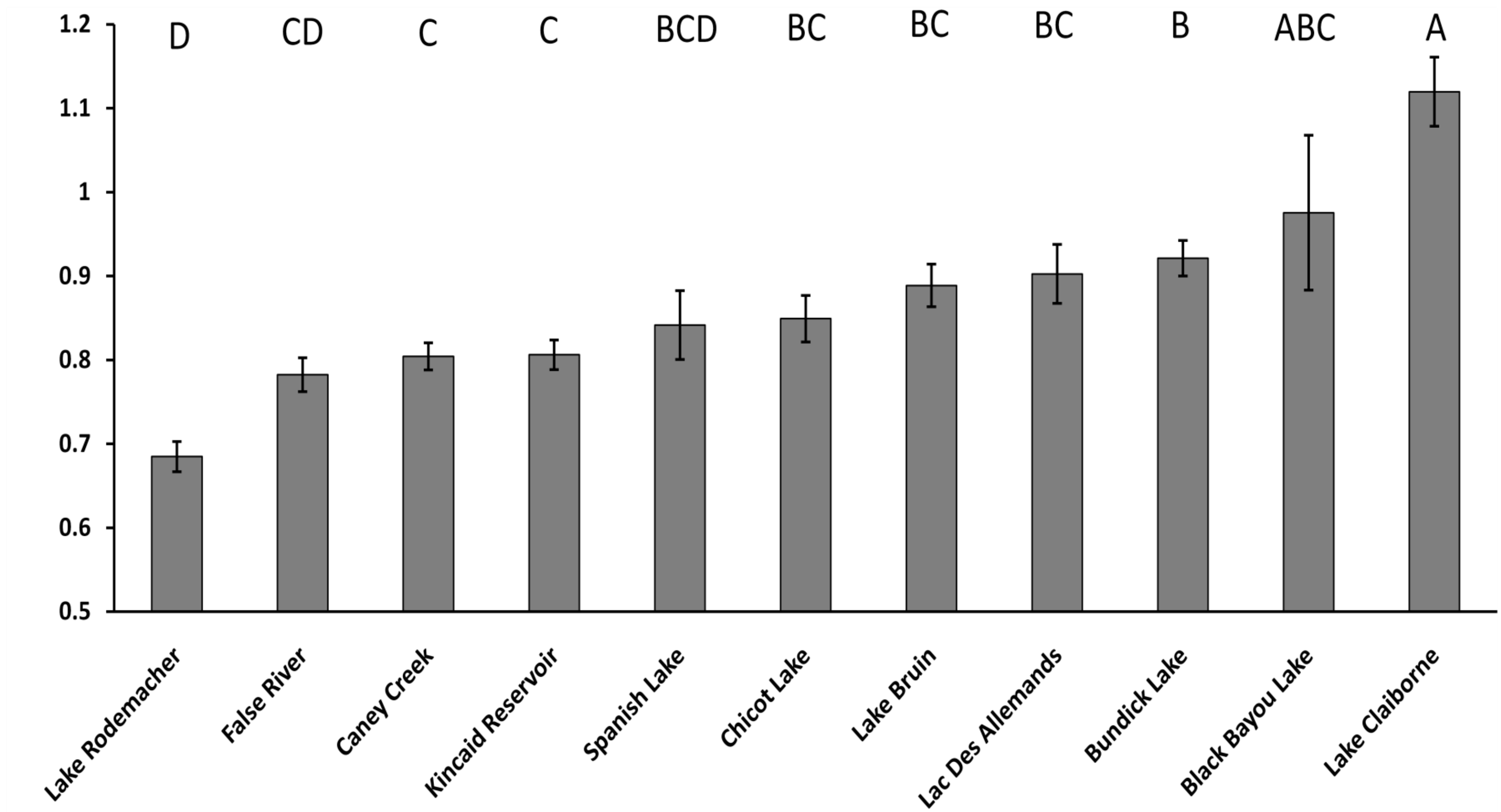

Figure 2. Mean liver somatic indices for each study lake over both sampling years (2008-2009) with standard error. Letters indicate statistically significant differences among study lakes.

Spanish Lake, and there was considerable variation in mean W_r among the study lakes in both years. Within lakes, there were differences in W_r between years for Kincaid Reservoir (104.24 $\pm$ 1.00 SE in 2008, 119.84 $\pm$ 1.04 SE in 2009; P<0.0001), and Lake Bruin (100.40 $\pm$ 1.21 SE in 2008, 107.36 $\pm$ 0.96 SE in 2009; P=0.0433; Figure 3).

Regression analysis of $\log_{10}$-transformed weight-length data revealed that In 2008, FLMB and F_xLMB exhibited significantly lower slopes than NLMB (P=0.0003). Bass sampled in 2009 yielded a higher regression slope than in 2008 (P=0.0063), with no differences among the three bass strains. During both years and for all bass strains, slope of the regression line ranged between 3.049 and 3.214, indicating positive allometric growth as length increased (Figure 4).

The first PCA including all 12 study lakes reduced the lake habitat dataset to five principal components (PCs) explaining approximately 86% of the variability in the data. Lakes with higher scores on PC1 tended to be shallow with high ammonia, dissolved organic carbon, total nitrogen, and a large littoral zone. High PC2 scores described cooler, less turbid lakes with dense floating and submerged aquatic vegetation, larger hypoxic zones, and lower mean DO concentrations. Lakes scoring highly on PC3 tended to be shallow, have increased emergent and floating vegetation and a large littoral zone, whereas high scores on PC4 described larger lakes with high phosphate and DO concentrations. Finally, lakes scoring highly on PC5 had high nitrate, total nitrogen, and chlorophyll *a* concentrations (Tables 3, 4).

Because LSI and W_r varied among study sites, I compared these two indices among lake types described by the first PCA based on habitat and water quality characteristics. LSI was not statistically significantly related to lake type, but largemouth

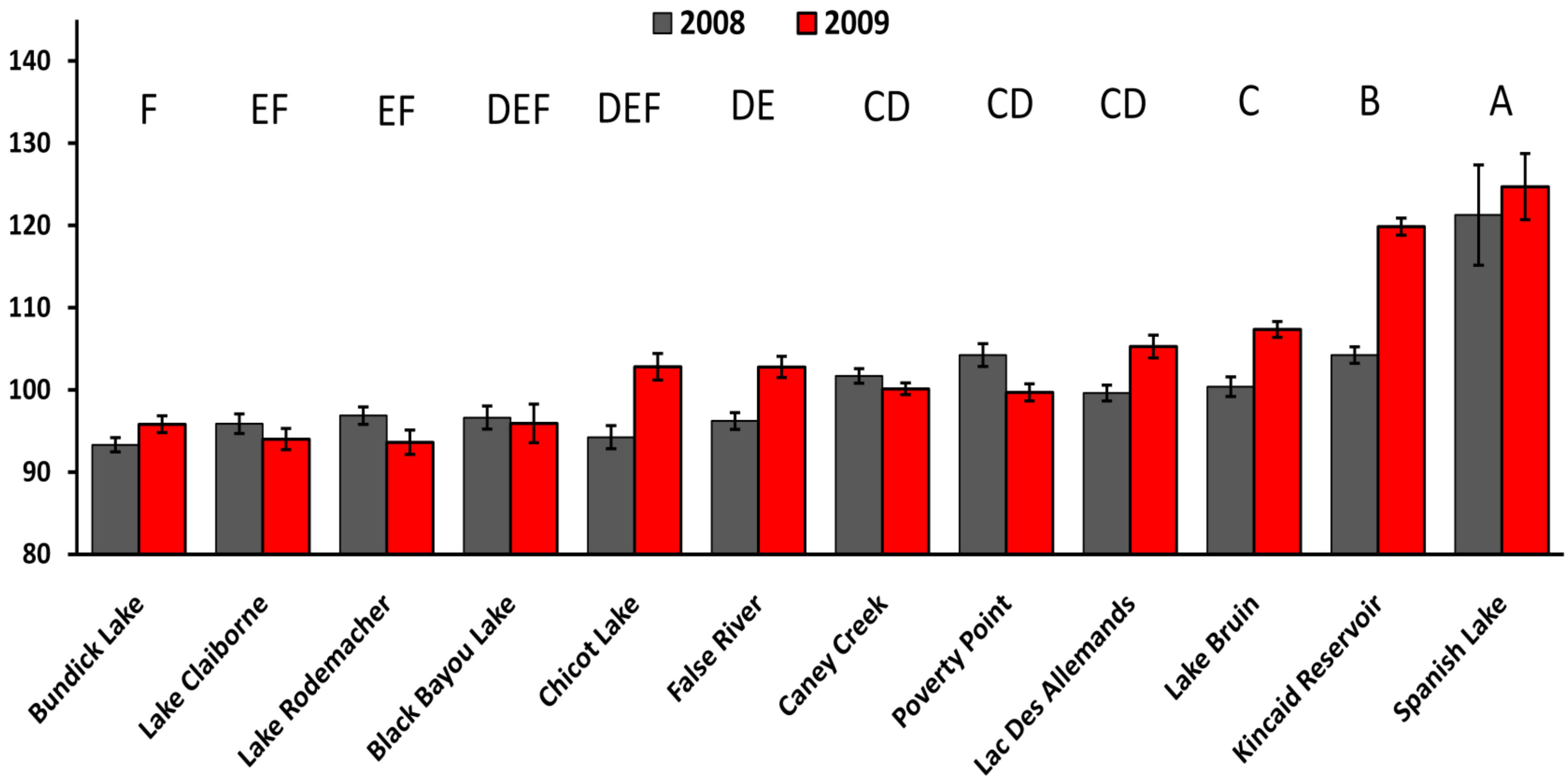

Figure 3. Mean relative weights for 2008 and 2009 samples from 12 study lakes with standard error. Letters indicate statistically significant differences among study lakes over both sampling years.

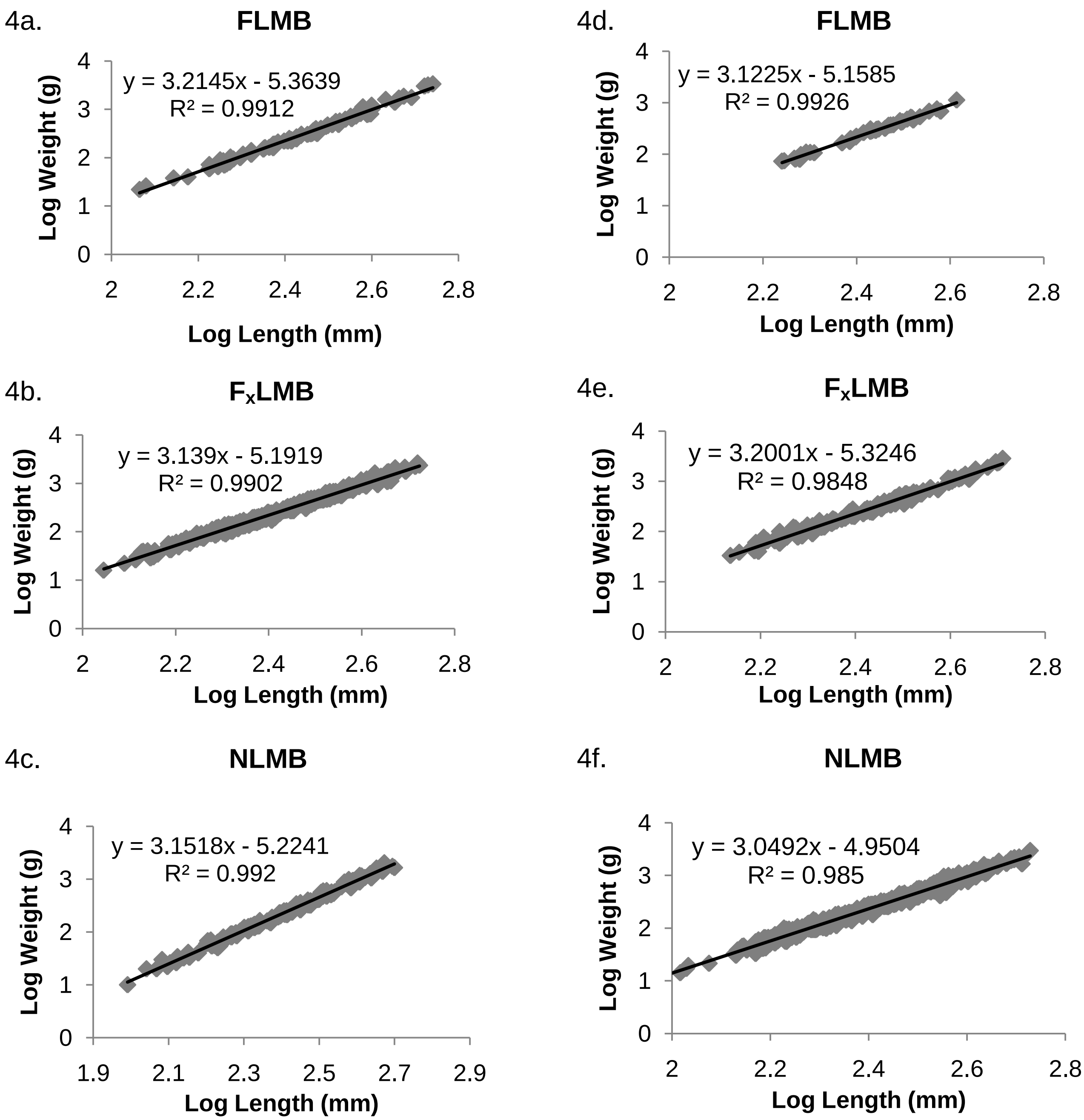

Figure 4. Linear regression analysis of logarithmically transformed weight-length data for 2008 the Florida subspecies (3a), the northern subspecies (3b), and F_x hybrid (3c) largemouth bass and 2009 the Florida subspecies (3d), the northern subspecies (3e), and F_x hybrid (3f) largemouth bass from 12 stocked Louisiana water bodies.

Table 3. Principal component scores for all 12 study lakes based on water quality and habitat data from 2008 and 2009. The highest and lowest scores for each lake over both sampling years are marked in bold.

Study Site	Year	PC 1	PC 2	PC 3	PC 4	PC 5
Black Bayou Lake	2008	0.54	**2.52381**	**1.30715**	-0.21101	-0.17731
Black Bayou Lake	2009	0.49291	**1.95769**	**2.0941**	-0.29145	**-0.53675**
Bundick Lake	2008	-0.19486	-0.99403	0.88389	0.02508	-0.82415
Bundick Lake	2009	-0.61415	-0.95472	1.45032	-0.20551	-0.20023
Caney Creek Reservoir	2008	-0.46093	-0.11236	-0.7068	-0.45869	-0.69157
Caney Creek Reservoir	2009	-0.69222	0.08956	-0.63043	-0.56753	-0.04595
Chicot Lake	2008	0.06559	0.14252	0.56907	-0.54673	-0.34795
Chicot Lake	2009	0.08178	0.72437	1.12049	-0.6467	0.33697
False River	2008	**-0.91762**	0.25076	-0.49803	-0.15359	**0.36329**
False River	2009	-0.86737	0.94834	-1.654	-0.35947	1.55936
Kincaid Reservoir	2008	-0.43523	-0.54234	-0.59671	-0.27261	-0.66022
Kincaid Reservoir	2009	-0.49737	-0.14001	-0.79443	**-0.56931**	-0.10015
Lac des Allemands	2008	0.75923	0.30651	-0.24152	**3.04442**	-0.47322
Lac des Allemands	2009	**0.75906**	-0.19393	0.08555	**2.92786**	0.93561
Lake Bruin	2008	-0.31892	0.66474	-0.6229	-0.20009	-0.64159
Lake Bruin	2009	**-0.89318**	0.62897	-0.72369	0.2342	0.33986
Lake Claiborne	2008	-0.58159	-0.16506	-0.73932	0.02766	**-1.10188**
Lake Claiborne	2009	-0.48862	0.64813	**-0.99956**	-0.19687	-0.50656
Lake Rodemacher	2008	-0.43687	**-1.55945**	0.77773	0.23777	-0.68003
Lake Rodemacher	2009	-0.8904	**-1.93333**	1.76772	-0.35317	1.00429
Poverty Point Reservoir	2008	0.81291	-0.56931	-0.57648	0.42952	-0.47146
Poverty Point Reservoir	2009	0.2631	-0.64496	-0.47897	0.12613	-0.29224
Spanish Lake	2008	**3.80371**	-0.81338	**-0.86829**	**-1.57116**	-0.41923
Spanish Lake	2009	0.71102	-0.26253	0.07511	-0.44873	**3.63111**

Table 4. Variable correlations (x100) for the six principal components (PC) retained by principal component analysis on habitat and water quality data. Interpretable variables for each PC are bold and marked with an asterisk (*).

Variable	PC 1	PC 2	PC 3	PC 4	PC 5
Temperature	5	**-87***	-4	14	15
Turbidity	33	**-57***	48	9	27
DO	38	**-53***	-37	**53***	14
NO3	3	-34	24	-11	**81***
NH4	**83***	-20	-14	-33	-5
PO4	-4	-23	30	**71***	34
TS	24	-29	7	47	45
DOC	**91***	1	14	13	20
TN	**75***	-12	-14	19	**58***
Chlorophyll *a*	22	4	-24	28	**78***
Emergent	-2	2	**80***	-16	-4
Floating	19	**69***	**65***	3	-2
Submergent	14	**76***	44	9	-17
Total Area	0	-2	-19	**89***	-5
Max Depth	**-66***	4	**-51***	-21	-2
Hypoxic zone	-30	**82***	-1	-27	-2
Littoral zone	**69***	0	**60***	12	15

bass had higher W_r in lakes loading highly on PC 1 (P<0.0003) and PC 5 (P=0.0025), which tended to be shallow, nutrient rich lakes with high chlorophyll *a* concentrations and relatively large littoral zones. Alternatively, average W_r were lower in lakes scoring highly on PC 3 (P=0.0037), which were characterized by dense vegetation and large littoral zones (Table 5).

Genetic Introgression

Logistic regression revealed a significant relationship between the relative proportions of the three bass strains and the habitat types described by the first PCA. Genetic strain was related to PC1 (P=0.0003), PC2 (P=0.0034), PC4 (P=0.0059), and PC5 (P<0.0001). Non-native largemouth bass were more abundant in lakes scoring highly on both PC1 (P=0.0045) and PC5 (P=0.0012) and less prevalent in habitats described by PC2 (P=0.0080) and PC4 (P=0.0117). Conversely, NLMB were more abundant in lakes scoring highly on PC 2 (P=0.0209) and PC 4 (P=0.0425) and were less abundant in lakes scoring highly on PC 1 (P=0.0015) and PC 5 (P=0.0004; Table 6). The number of FLMB stocked per hectare was not significantly related to the relative abundance of NLMB or non-native largemouth bass (P=0.3116).

Length-at-age

For the 2009 length-at-age data that I generated, ANOVA revealed significant differences among lakes for age 1 (P<0.0001), age 2 (P<0.0001), and age 3 (P<0.0001) largemouth bass (Figure 5). Comparison of length-at-age among strains was not possible for age-2 bass because of extremely unequal sample sizes among lakes, but there were no significant differences in length-at-age among FLMB, NLMB, and F_xLMB at age 1 (P=0.7067) or age 3 (P=0.0671) .

Table 5. Parameter estimates, standard errors, and *P*-values from the ANOVA of relative weight and lake habitat types (PCs).

Effect	Estimate	Standard Error	P-value
PC 1	5.00	1.39	0.0003
PC 2	0.97	1.32	0.4616
PC 3	-3.20	1.10	0.0037
PC 4	0.52	1.48	0.7251
PC 5	3.05	1.01	0.0025

Table 6. Parameter estimates, standard errors, and *P*-values from the logistic regression of genetic strain and lake habitat types (PCs).

Effect	Strain	Estimate	Standard Error	P-value
PC1	Northern	-1.14	0.36	0.0015
	Non-northern	1.01	0.36	0.0045
PC2	Northern	0.85	0.37	0.0209
	Non-northern	-1.03	0.39	0.0080
PC3	Northern	-0.50	0.35	0.1503
	Non-northern	0.60	0.36	0.0972
PC4	Northern	0.75	0.37	0.0425
	Non-northern	-0.92	0.37	0.0117
PC5	Northern	-1.27	0.36	0.0004
	Non-northern	1.16	0.36	0.0012

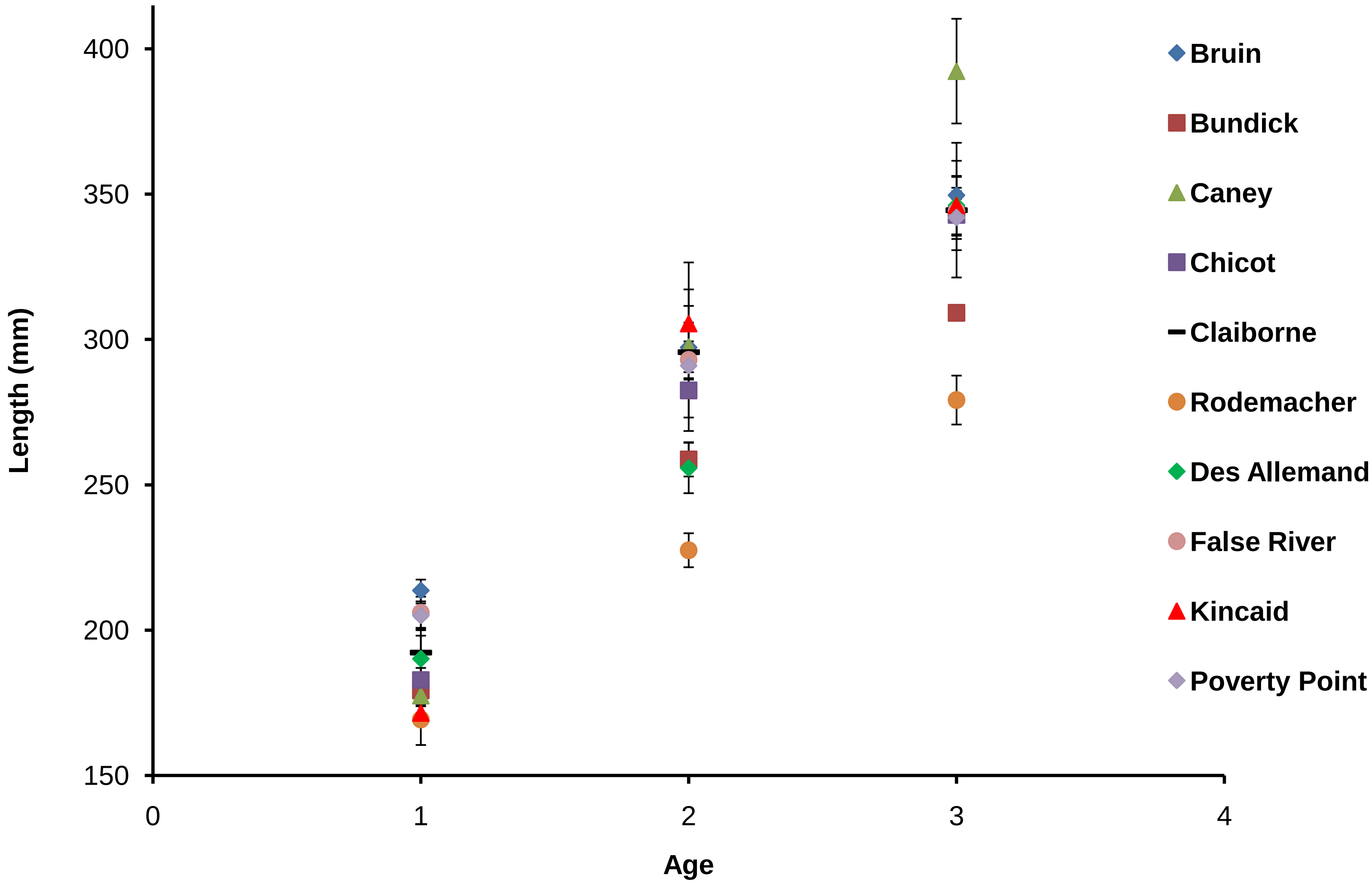

Figure 5. Mean length-at-age with standard error for all largemouth bass collected at each of the 12 study lakes.

The second PCA excluding Black Bayou Lake and Spanish Lake (too few bass collected for accurate length-at-age data) also produced 5 PCs, explaining approximately 84% of the variability in the habitat dataset. Sites scoring highly on PC 1 tended to be large lakes with high total solids, dissolved organic carbon, total nitrogen, chlorophyll *a* and DO concentrations, whereas high scores on PC 2 described deeper lakes with lower DO concentrations, less littoral zone area, and larger hypoxic zones. Lakes scoring highly on PC 3 were warmer and more turbid, with higher nitrate, ammonia, and phosphate levels. Sites scoring highly on PC 4 had lower DO and dense emergent and floating aquatic vegetation, whereas high scores on PC 5 described cooler lakes with increased submerged vegetation (Tables 7, 8).

Length-at-age varied among the habitat types described by the 5 PCs from the second PCA (Table 9). Back-calculated lengths for age-1 bass tended to be higher in lakes described by PC 1 (P=0.0300), PC 2 (P<0.0001), and PC 5 (P<0.0001), whereas age-2 and age-3 bass showed a decrease in length in lakes described by PC 3 (P<0.0001; P=0.0155, respectively). Length-at-age 1 was greater in either nutrient rich lakes with high DO and cholorphyll a concentrations, deep lakes with lower mean DO and less littoral zone area, or lakes with cooler mean temperatures and dense submerged vegetation. Age-2 and Age-3 bass tend to be smaller in length in warm lakes with elevated turbidity, nitrate, phosphate, and ammonia levels.

Table 7. Principal component scores for 10 study lakes (excluding Black Bayou Lake and Spanish Lake) based on water quality and habitat data from 2008 and 2009. The highest and lowest scores for each lake over both sampling years are marked in bold.

Study Site	Year	PC 1	PC 2	PC 3	PC 4	PC 5
Bundick Lake	2008	-0.90846	-1.02527	0.30448	-0.02397	0.06882
Bundick Lake	2009	**-0.77439**	-0.38687	0.86484	0.93831	-0.12736
Caney Creek Reservoir	2008	-0.74697	0.16478	-0.57828	-0.24472	-0.00179
Caney Creek Reservoir	2009	-0.13284	0.76542	-0.55809	0.15828	-0.93142
Chicot Lake	2008	-0.299	-0.58746	-0.6342	**1.63475**	-0.30467
Chicot Lake	2009	-0.04551	-0.32933	-0.63025	**3.33842**	0.21487
False River	2008	0.22475	**1.6437**	0.4403	-0.03753	0.3805
False River	2009	1.47418	**2.19413**	-0.35293	-0.15554	**-1.38962**
Kincaid Reservoir	2008	-0.48258	-0.25671	-0.57193	-0.87153	**-1.00307**
Kincaid Reservoir	2009	-0.22584	0.12108	-0.70568	-0.29253	-1.14913
Lac des Allemands	2008	**1.54556**	-1.14032	-0.07243	-0.49896	2.14244
Lac des Allemands	2009	**3.0666**	-0.72555	0.63721	0.19865	-0.07923
Lake Bruin	2008	-0.69605	0.75222	-0.27676	-0.40819	**2.53872**
Lake Bruin	2009	0.16281	1.36956	-0.0771	-0.34643	**0.70629**
Lake Claiborne	2008	**-0.98012**	-0.09876	**-0.68904**	-0.82037	0.3827
Lake Claiborne	2009	-0.46207	0.57807	**-0.91073**	-0.29049	0.65691
Lake Rodemacher	2008	-0.68552	-0.73945	**1.3752**	-0.65805	-0.53117
Lake Rodemacher	2009	-0.517	0.43266	**3.38126**	0.14252	-0.19066
Poverty Point Reservoir	2008	0.42676	**-1.53655**	-0.45	**-0.93894**	-0.39431
Poverty Point Reservoir	2009	0.05567	**-1.19536**	-0.4959	**-0.8237**	-0.98885

Table 8. Variable correlations (x100) for the four principal components (PC) retained by principal component analysis on habitat and water quality data for 10 study lakes (excluding Black Bayou Lake and Spanish Lake). Interpretable variables for each PC are bold and marked with an asterisk (*).

Variable	PC 1	PC 2	PC 3	PC 4	PC 5
Temperature	17	-40	**61***	-1	**-51***
Turbidity	9	-26	**92***	-2	-4
DO	**53***	**-55***	7	**-50***	15
NO3	-5	4	**79***	29	-14
NH4	10	-46	**79***	2	-11
PO4	49	-18	**60***	3	37
TS	**58***	-25	43	-27	-12
DOC	**64***	-46	15	39	33
TN	**91***	-26	9	6	19
Chlorophyll *a*	**86***	15	-4	19	-27
Emergent	-15	-3	35	**86***	7
Floating	25	-26	-9	**90***	12
Submergent	15	4	-17	14	**81***
Total Area	**71***	-20	4	-16	37
Max Depth	-17	**89***	-10	-17	1
Hypoxic zone	-4	**89***	-35	12	4
Littoral zone	22	**-83***	27	28	-2

Table 9. Parameter estimates, standard errors, and *P*-values from the ANOVA of length-at-age and lake habitat types (PCs).

	Effect	Estimate	Standard Error	***P*-value**
Age-1	PC 1	5.12	2.35	0.0300
	PC 2	12.14	2.97	<0.0001
	PC 3	-1.17	2.39	0.6266
	PC 4	-0.28	2.07	0.8934
	PC 5	13.71	2.77	<0.0001
Age-2	PC 1	-2.70	3.00	0.3698
	PC 2	7.13	4.78	0.1403
	PC 3	-17.44	3.12	<0.0001
	PC 4	-3.03	4.18	0.4710
	PC 5	1.29	5.27	0.8073
Age-3	PC 1	3.35	8.51	0.6952
	PC 2	-0.96	12.70	0.9401
	PC 3	-18.62	7.46	0.0155
	PC 4	-3.13	10.18	0.7600
	PC 5	-3.11	13.60	0.8200

DISCUSSION

In this study, I attempted to determine whether a relationship existed between levels of FLMB introgression and the macrophyte abundance, basin morphology, and physicochemistry of 12 lakes located throughout the state. Further, I used this analysis of lake characteristics to examine habitat and strain-related differences in condition, health, and length-at-age of NLMB, FLMB, and F_xLMB.

Condition, Health, and Length-at-age

No significant differences in parasite loads, LSI, W_r, or length-at-age among FLMB, NLMB or F_xLMB or between sexes were detected in this study. I had no reason to expect significant differences in health (LSI or parasite load) among NLMB, FLMB, and F_xLMB, as I found no indication in the literature that parasite loads or LSI values should differ by genetic strain. Additionally, I did not expect to see differences in health or W_r by sex because sampling occurred in the fall rather than during spring spawning when male and female largemouth bass typically exhibit variable condition (Rice et al. 1983).

Condition and growth, however, have varied by genetic strain in previous studies. Results of these studies have been highly variable, with research conducted in a variety of locations and under very different conditions. Isely et al. (1987) and Phillip and Whitt (1991) both reported superior growth and survival of NLMB compared to FLMB, but each of these studies were conducted in Illinois farm ponds. It is reasonable that FLMB, which are adapted to warmer climates and different habitat conditions, would exhibit slower growth and poorer condition compared to native NLMB in a much more temperate climate. Bottroff (1967), Childers (1975), Johnson and Graham (1978),

Maceina and Murphy (1988), Hendricks et al. (1995), and Myers and Allen (2005) provided evidence of greater growth of FLMB in more southern states. Although FLMB may have a disadvantage or lowered fitness when raised in northern climates (Isely et al. 1987; Phillip 1991; Phillip and Whitt 1991), NLMB are native to the southeast and are able to survive in warmer conditions. Many studies have reported extremely high growth rates for the northern subspecies at southern latitudes with similar habitat conditions to those found in the native range of FLMB (Clugston 1964; Zolczynski and Davies 1976; Maceina and Murphy 1988; Kleinsasser et al. 1990; Neal and Noble 2002). Given the variable results of largemouth bass growth studies, the similarity in length-at-age and condition among subspecies and intergrade bass in this study is not surprising. Rather than suggesting no genetic difference exists in length-at-age or condition, the similar values by strain reported here may simply indicate the presence of suitable habitat and forage for both subspecies of largemouth bass and their hybrid in Louisiana water bodies.

Phillip et al. (1983) described the natural intergrade zone of FLMB and NLMB as extending as far north as North Carolina on the Atlantic Coast and as far east as Mississippi. The climate and environmental conditions present in Louisiana are similar to those found in other southern states in the Florida-northern subspecies intergrade zone. Comparable environments suggest that Louisiana water bodies may provide adequate habitat conditions for the rapid growth of FLMB, as well as NLMB and F_xLMB, resulting in negligible differences in length-at-age and condition among the strains. Similar to my results, Leitner et al. (2002) also found a difference in growth by stocking location instead of genetic strain. This finding agrees with previous research suggesting

environmental conditions may be more important than possible genetic differences in growth capabilities of largemouth bass (Sasaki 1961; Clugston 1964). Based on these results, I believe that although caution should be taken when stocking any non-native species, incorporating FLMB in aquatic systems of southern states poses little threat to the fitness of native NLMB stocks.

Many agencies stock FLMB based on the premise that Florida bass not only exhibit higher growth rates but also greater longevity and higher growth potential, making FLMB more likely to contribute to a trophy fishery (Maceina et al. 1988; Buckmeier and Betsill 2002; Neal and Noble 2002; Buckmeier et al. 2003). Maceina and Murphy (1988) reported that under similar environmental conditions and across several seasons, small (<300mm) FLMB had lower body weights and condition values than NLMB of the same size. In the same study, samples of age-3 FLMB and NLMB showed the opposite relationship with FLMB exhibiting higher relative weights. Similarly, Johnson and Graham (1978) found comparable growth rates between the two subspecies from ages 0 to 3, but at age 4 and 5, FLMB exhibited faster growth. Kaller et al. (2006) reported that F_xLMB greater than 542.5 mm had significantly greater W_r than NLMB in Louisiana. In the current study, however, the sample size of older fish (over age-3) was extremely small and inconsistent among water bodies, precluding any analysis of changes in length-at-age or condition with increased age. Future research targeting larger, older individuals may be necessary to determine if FLMB exhibit these growth patterns or remain longer in Louisiana fisheries than NLMB.

Although no differences in growth, health, or condition were detected between largemouth bass strains, LSI values, W_r, and length-at-age did differ by water body. LSI

has been postulated to be a quick index of growth, a gauge of daily food intake, and an indicator of pollutants or chemical inputs (Bulow et al. 1978). Here, I used LSI values as an indicator of overall fish health. Generally, higher LSI values indicate possible exposure to pollutants whereas lower values may suggest starvation, an acidic environment, or the presence of some chemical compounds. Although in-depth analysis of LSI values for Louisiana bass populations was outside the scope of this study, examining LSI indices and mean W_r simultaneously may provide some insight into overall fish health. For example, Lake Claiborne and Lake Rodemacher had two of the lowest mean W_r values over both sampling years (Figure 2), yet Lake Claiborne had the highest LSI index among the study lakes, and Lake Rodemacher had the lowest mean LSI (Figure 1). Lake Rodemacher is a relatively turbid reservoir with a poor forage base (R. Moses, Louisiana Department of Fish and Wildlife, personal communication). Relatively low LSI values coupled with low W_r may indicate available forage limitation or turbidity-related reductions in foraging efficiency of bass in this system. This finding is similar to that of Sweka and Hartman (2003), who reported a reduction in foraging success of smallmouth bass (*Micropterus dolomieu*) in more turbid conditions. Alternatively, Lake Claiborne is a large, clear, nutrient poor reservoir in northern Louisiana. Relatively high LSI values along with low W_r in this system may suggest the presence of some stressor, potentially a pollutant, which is causing bass livers to enlarge, allowing for greater detoxification. To fully understand and interpret an LSI index, knowledge of pristine and polluted environments, as well as, natural variability within the study area is necessary. A more comprehensive examination of

water quality and fish health in Louisiana would be necessary to determine the exact cause for the variation in LSI by water body.

A nearly significant trend was observed in parasite load by lake in this study, and although seemingly unrelated to mean relative weight, lakes with lower average parasite loads did exhibit relatively high LSI values. Further investigation of parasite loads and LSI values from reservoirs across the state may be helpful in determining the relationship between parasites, LSI, and condition of largemouth bass in Louisiana.

Fish condition, as interpreted by W_r, varied by individual lake as well as overall habitat type. Shallow, productive (high chlorophyll *a*), nutrient rich (high total nitrogen and dissolved organic carbon) lakes with large littoral zones but little aquatic vegetation, including Spanish Lake, Poverty Point Reservoir, and Lac Des Allemands, seemed to promote higher bass condition (Tables 3, 4). Alternatively, average W_r values in bass from lakes with large littoral zones and dense aquatic macrophytes such as Black Bayou Lake, Chicot Lake, Lake Rodemacher, and Bundick Lake, were significantly lower (Tables 3, 4).

The relationship of fish condition to lake productivity, represented by chlorophyll *a* concentrations, is not surprising given that chlorophyll concentrations have been used as an index of lake trophic state (Carlson 1977), photosynthetic activity (Smith 1979), and zooplankton biomass (McCauley and Kalff 1981). This suggests that chlorophyll *a* could be a useful indicator of fisheries yield and productivity (Jones and Hoyer 1982) in Louisiana reservoir systems. Crawford et al. (2002) reported a significant positive relationship between lake productivity and growth of largemouth bass in Florida, and it

is likely that high lake productivity leads to abundant forage and high largemouth bass body condition.

Additionally, bass in productive but sparsely vegetated lakes may experience optimal foraging opportunities, resulting in higher condition values, because of lower levels of vegetative cover for prey. Foraging opportunities and efficiency in systems infested with dense vegetation have been reported to decline precipitously, resulting in slow growth and poor condition (Wrenn et al. 1996; Mason 2002; Valley and Bremigan 2002; Maceina and Splike 2004; Sammons et al. 2005). Maceina and Splike (2004) and Sammons et al. (2005) both reported a negative relationship between largemouth bass size and percent cover of aquatic vegetation. Similarly, the average weight of fish caught during largemouth bass tournaments in Tennessee declined with peak macrophyte coverage (Maceina and Reeves 1996). In a multi-system study over two years, Colle and Shireman (1980) found that depressed condition factors for bluegill (*Lepomis machrochirus*), redear (*L. microlophus*), and largemouth bass occurred when hydrilla (*Hydrilla verticillata*) coverage reached 30% or more of the total area of the lake. In subsequent years, condition factors for all three species increased as hydrilla coverage declined. Importantly, the abundance and composition of the forage community in these systems did not change with a reduction in submerged vegetation (Colle and Shireman 1980), indicating that a shift in the availability of prey after hydrilla reduction caused the marked increase in condition. Similar studies in Oklahoma and Arkansas have also reported increased condition factors for bluegill, redear, and largemouth bass when aquatic macrophytes were removed or controlled with herbicides (Cope et al. 1969; Cope et al. 1970; Bailey 1978). Dense vegetation creates visual

barriers and allows prey to hide and escape more effectively (Savino and Stein 1982; Hoyer and Canfield 1996). When aquatic vegetation is reduced, prey populations may become more available, allowing for increased foraging opportunities by piscivorous fishes (Bennett 1948; Barnett and Schneider 1974).

My results indicate that the sparse vegetation present in lakes corresponding to higher mean W_r may help maximize largemouth bass condition by providing adequate cover for abundant prey populations while simultaneously allowing efficient foraging behavior. Miranda and Pugh (1997) reported higher growth rates of largemouth bass in coves with little or intermediate (20%) aquatic macrophyte coverage. Valley and Bremigan (2002) reported that largemouth bass experienced shorter search times and greater foraging success when aquatic vegetation was moderate in density, and Trebitz (1995) showed the relationship between growth of young sunfishes and vegetation is parabolic, with maximum growth occurring at intermediate plant densities.

Decreases in condition or growth of largemouth bass in heavily vegetated systems are predominately found in larger fish >150mm (Colle and Shireman 1980; Hickman and Congdon 1972). Smaller bass that have not made the ontogenetic shift to piscivory are able to adequately forage on the abundant aquatic invertebrates found in dense stands of macrophytes, whereas the prey base for larger individuals becomes inaccessible (Colle and Shireman 1980; Hoyer and Canfield 1996; Valley and Bremigan 2002). Largemouth bass in the Atchafalaya Basin, Louisiana made the switch to piscivory sooner in habitats with reduced hydrilla densities, and fish rapidly became less dominant in diet composition as vegetation began to increase (Mason 2002). Survival of juvenile bass may also increase as aquatic vegetation increases as a result of

predator avoidance (Wrenn et al. 1996; Unmuth et al. 1999; Tate et al. 2003; Strakosh et al. 2009). Density-dependent mechanisms such as increased competition and activity costs associated with high densities of fishes may strongly influence bass growth and condition (Boisclair and Leggett 1989; Bowen et al. 1991; Shoup et al. 2007). Although my study did not include smaller largemouth bass (< 200 mm), the increased condition found here in productive, sparsely vegetated water bodies may be a result of increased foraging opportunity as well as minimal trophic competition associated with low to moderate bass densities.

Although mean W_r was lower in more heavily vegetated systems, I did find a positive relationship between length of age-1 largemouth bass and lakes with increased amounts of submerged vegetation. Age-1 largemouth bass have likely already made the switch to piscivory (Olson 1996; Post 2003), but they may be able to forage more efficiently than older individuals in densely vegetated systems because of their smaller size. Lengths of age-2 and age-3 largemouth bass were not significantly related to the same habitat types that showed higher mean W_r. Instead, 2 and 3 year old bass appeared to be shorter in length in warm, turbid lakes with high nitrate, ammonia, and phosphate levels. This relationship may be a result of reduced feeding efficiency in turbid water (Sweka and Hartman 2003).

Genetic Introgression

The number of FLMB stocked per hectare in each reservoir was not significantly related to the relative abundance of NLMB or non-native largemouth bass, suggesting that stocking factors may not account for the varying levels of genetic introgression seen in reservoirs in this study. This finding is similar to that of Kaller et al. (2006)

where length of stocked bass, number of years stocked, time since initial stocking, and number of bass stocked did not explain the success or failure of FLMB in over 50% of sampled Louisiana water bodies. Based on these results, variables not related to stocking rate may be influencing genetic introgression.

Interestingly, the habitat types that appeared to promote fish condition were also the habitats where non-native largemouth bass were most prevalent. The abundance of non-native largemouth bass in nutrient rich, productive lakes with reduced vegetation may be a result of reduced natural recruitment of resident largemouth bass, allowing stocked FLMB to incorporate rapidly into the population. Delayed mortality of stocked fish that is unrelated to initial predation or stocking stress has been reported for largemouth bass (Boxrucker 1986; Neal et al. 2002; Diana and Wahl 2008), perhaps due to starvation or competition with existing natural populations (Diana and Wahl 2009). Although I did not assess age-0 mortality rates, I have no reason to believe that post-stocking mortality differences among lakes would have resulted in the observed abundance patterns of NLMB, FLMB, and F_xLMB. High recruitment of juvenile largemouth bass is often found in heavily vegetated systems because of increased cover and abundant invertebrate forage (Wrenn et al. 1996; Unmuth et al. 1999; Allen and Tugend 2002; Tate et al. 2003); perhaps increased competition with resident juvenile bass in densely vegetated systems reduces growth and survival of stocked FLMB. Alternatively, little to no aquatic macrophyte coverage often yields poor natural recruitment of age-0 bass (Durocher et al. 1984; Bettoli et al. 1993; Havens et al. 2005; Strakosh et al. 2009), possibly resulting in a survival advantage for stocked FLMB.

I found higher proportions of non-native largemouth bass in the sparsely vegetated water bodies, despite the presumed higher predation rates related to the lack of macrophyte cover (Schlechte et al. 2005; Schlechte and Buckmeier 2006). This result suggests that only moderate survival rates of stocked fish may be needed to incorporate FLMB into resident bass populations if native fish consistently produce weak year classes. Low natural recruitment of resident bass may be an important factor in the relative success of FLMB introgression in Louisiana, and may explain the significant shift in genetic composition of the largemouth bass stock in Caney Creek Reservoir, a 2023-ha impoundment in north central Louisiana constructed in 1986. Hydrilla and water hyacinth (*Eichornia crassipes*) were introduced to the reservoir soon after impoundment, and by 1993, total aquatic vegetation coverage was estimated at 605 ha. In an attempt to control aquatic macrophytes, the reservoir was stocked with 12,000 triploid grass carp (*Ctenopharyngodon idella*) in February 1994, resulting in near eradication of macrophytes and by the summer of 1996. Prior to inundation, NLMB were found throughout the surrounding watershed. FLMB stocking began one month after water control structures were closed and continued annually from 1986-1989 and 1992-present (Hughes and Wood 1995). NLMB were dominant to non-native largemouth bass in LDWF fall samples from 1988 (87%), 1992 (62%), and 1994 (63%). The 1995 sample, however, showed a sharp decline in NLMB relative abundance to only 18% of the sample. Subsequent samples continued to report low relative abundances of NLMB (Figure 6). This dramatic increase in non-native largemouth bass following widespread removal of aquatic vegetation may be attributed to reduced natural

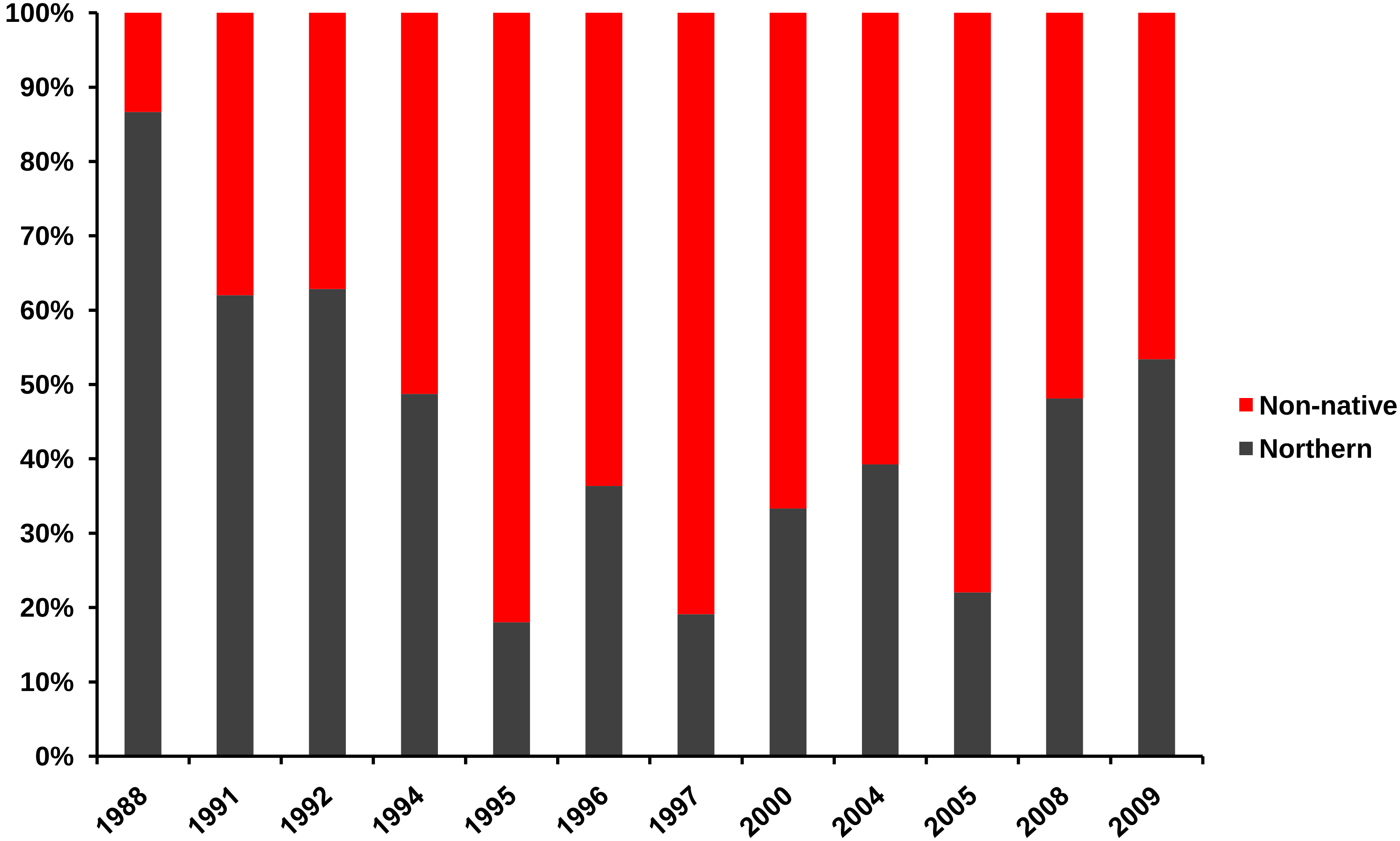

Figure 6. Percent composition of northern and non-native largemouth bass sampled from Caney Creek Reservoir annually from 1988-present.

recruitment of resident bass, allowing increased influence of stocked FLMB (M. Wood, Louisiana Department of Fish and Wildlife, personal communication).

The success of genetic introgression of FLMB into Louisiana bass stocks is likely determined by the survival and growth of age-0 and age-1 largemouth bass, particularly the relative rates of post-spawning mortality of bass in early life-stages and post-stocking mortality of introduced juveniles (Diana and Wahl 2009). My study did not specifically target age-0 individuals, and further research focusing on the survival of resident age-0 bass and stocked FLMB are needed to examine the influence of size-dependent and stocking-related survival on the success of FLMB introgression in the various reservoir habitat types throughout the state.

Management Recommendations

Although evaluation of LDWF's stocking program was not a goal of my project, the results may offer some insight into enhancing the current FLMB program. Stocking techniques, such as fingerling transport and care, stocking locations and timing of stocking, may vary by district and by water body because LDWF does not use a statewide stocking protocol. Accounting for these factors across nine LDWF districts and among water bodies was not possible in my study, but research in this area could yield important information on the importance of stocking-related variables in determining fingerling survival.

An evaluation of stocking rates and habitat types where stocking may be most effective, however, is possible based on the results of this study. Calculating the percent contribution of hatchery raised fish to wild populations is very common and considered to be an effective way to evaluate the relative success of a stocking

program. This method, however, does not determine how stocked fish contribute to the population. Stocking can be additive, increasing fish density, or it can maintain the density of the natural population. Overstocking a water body is inefficient and wasteful because stocked fish may exceed the carrying capacity of the lake, resulting in reduced growth or survival of both wild and hatchery fish. Therefore, the stocking rate or number of fish stocked has a strong influence on the success or failure of a stocking program (Buckmeier et al. 2003). Fielder et al. (1992) proposed stocking walleye (*Sander vitreus*) based on area of suitable habitat rather than total area of a water body. This management technique can be applied to largemouth bass by stocking according to littoral zone area. Littoral habitat is critical to hatchery raised fish because most stocked fingerling bass remain in shoreline areas within 1 km of their stocking site (Buckmeier and Betsill 2002; Hoffman and Bettoli 2005). The littoral zone continues to be important habitat in later life stages as deep water habitats (>4 m) are rarely utilized by largemouth bass (Colle et al. 1989; Lyons 1993), particularly in southern states such as Louisiana where much of the water column becomes hypoxic for a portion of the year. Stocking largemouth bass based on the area of the littoral zone may reduce waste and the negative effects that can arise from overstocking.

I used depth profiles collected by a simple sonar recording device to rapidly estimate the percent of each water body that could be considered littoral zone or largemouth bass habitat. I defined the extent of bass habitat as the area of the lake < 3.5 m deep, which is where largemouth bass spend the majority of their time (Colle et al. 1989; Lyons 1993; Sammons and Maceina 2005). Although larger bass may establish home ranges in deeper water or offshore areas (Colle et al. 1989; Hanson et

al. 2007), stocking rates should primarily consider the habitat most useful to fingerling and young largemouth bass. I did find increased abundance of non-native largemouth bass in productive lakes with high chlorophyll *a* and nutrient concentrations and large littoral zones relative to the size of the water body, suggesting that stocking may be more effective in these systems. Further research and more detailed estimates of largemouth bass habitat in stocked water bodies may be helpful in determining if stocking by littoral zone area would be effective in Louisiana.

Based on the results from this study and public interest in largemouth bass stocking programs across the country, FLMB stocking appears to be a successful management program for LDWF. Stocking FLMB does not appear to negatively affect or reduce the fitness of native populations in Louisiana. Although I did not find significant differences in condition or length-at-age by strain, Kaller et al. (2006) did report differences in W_r by strain for Louisiana waterbodies, which may have been a result of a larger sample size in older age groups. Further investigation of growth variation among age-3 and above FLMB, NLMB, and F_xLMB may provide more data on the benefits of the Louisiana FLMB stocking program, particularly the ability to produce trophy individuals.

Stocking FLMB based on the type of available habitat may also increase survival and contribution of stocked fish. Additional research on forage availability may be needed to further understand the mechanisms regulating largemouth bass survival, growth, and condition in these systems. However, my study suggests that focusing assessments of largemouth bass fisheries potential on reservoir productivity, turbidity, and macrophyte composition and abundance may be particularly important in Louisiana.

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APPENDIX A: Percent Cover of Vegetation ± Standard Error

Study Site	Year	Emergent	Floating	Submergent
Black Bayou Lake	2008	4.7 ± 1.08	52.5 ± 4.17	46.3 ± 2.77
Black Bayou Lake	2009	12.2 ± 1.20	47.8 ± 3.01	56.8 ± 2.86
Bundick Lake	2008	6.2 ± 1.37	4.1 ± 0.95	0.0 ± 0.00
Bundick Lake	2009	8.8 ± 1.48	7.3 ± 0.94	1.6 ± 0.66
Caney Creek	2008	2.0 ± 0.58	0.9 ± 0.24	0.0 ± 0.00
Caney Creek	2009	4.3 ± 0.74	1.1 ± 0.28	0.2 ± 0.13
False River	2008	5.6 ± 2.39	1.7 ± 0.50	0.0 ± 0.00
False River	2009	0.8 ± 0.23	0.3 ± 0.07	0.3 ± 0.18
Kincaid Reservoir	2008	0.5 ± 0.20	0.0 ± 0.00	0.4 ± 0.18
Kincaid Reservoir	2009	0.8 ± 0.23	0.0 ± 0.00	1.7 ± 0.77
Lac des Allemands	2008	1.4 ± 0.45	9.3 ± 1.20	16.0 ± 3.23
Lac des Allemands	2009	4.0 ± 0.68	15.5 ± 1.92	10.0 ± 2.09
Lake Bruin	2008	2.8 ± 1.39	0.4 ± 0.20	31.3 ± 2.67
Lake Bruin	2009	2.9 ± 0.42	0.4 ± 0.14	5.0 ± 1.08
Lake Chicot	2008	6.8 ± 1.00	17.8 ± 2.19	5.2 ± 1.72
Lake Chicot	2009	11.0 ± 1.03	36.4 ± 3.01	11.3 ± 2.07
Lake Claiborne	2008	0.3 ± 0.15	0.0 ± 0.01	1.2 ± 0.89
Lake Claiborne	2009	0.9 ± 0.26	1.5 ± 0.65	13.9 ± 2.52
Lake Rodemacher	2008	4.0 ± 1.44	0.1 ± 0.10	0.0 ± 0.00
Lake Rodemacher	2009	5.6 ± 1.46	0.9 ± 0.21	0.92 ± 0.54
Poverty Point	2008	0.1 ± 0.06	0.0 ± 0.00	0.5 ± 0.15
Poverty Point	2009	0.5 ± 0.16	0.2 ± 0.07	0.30 ± 0.14
Spanish Lake	2008	2.8 ± 0.65	0.0 ± 0.00	0.0 ± 0.00
Spanish Lake	2009	1.5 ± 0.22	4.6 ± 2.58	0.0 ± 0.04

APPENDIX B: Annual Water Quality Measurements ± Standard Error

Study Site	Year	Temp	Turbidity	DO	PO4	NH4	TS	DOC	TN	Chl *a*
Black Bayou Lake	2008	25.81 ± 0.90	34.07 ± 16.07	1.21 ± 0.90	0.16 ± 0.05	0.71 ± 0.20	0.14 ± 0.02	13.41 ± 1.15	0.71 ± 0.08	18.02 ± 3.69
Black Bayou Lake	2009	25.99 ± 0.60	39.35 ± 19.46	2.32 ± 0.76	0.13 ± 0.03	0.38 ± 0.06	0.07 ± 0.00	12.50 ± 0.93	0.69 ± 0.05	35.44 ± 8.30
Bundick Lake	2008	28.75 ± 0.30	58.20 ± 5.89	6.14 ± 0.50	0.23 ± 0.08	0.45 ± 0.22	0.17 ± 0.03	9.36 ± 0.21	0.64 ± 0.04	12.85 ± 2.17
Bundick Lake	2009	29.73 ± 0.50	57.35 ± 8.84	4.06 ± 0.91	0.32 ± 0.11	0.47 ± 0.05	0.12 ± 0.00	8.88 ± 0.86	0.70 ± 0.03	29.91 ±3.49
Caney Creek	2008	28.26 ± 0.80	11.62 ± 5.58	5.29 ± 0.62	0.09 ± 0.02	0.09 ± 0.01	0.03 ± 0.01	9.06 ± 1.47	0.53 ± 0.03	22.70 ± 6.28
Caney Creek	2009	28.88 ± 1.01	27.97 ± 27.40	4.83 ± 0.73	0.05 ± 0.01	0.13 ± 0.03	0.05 ± 0.00	6.13 ± 0.37	0.53 ± 0.09	64.17 ± 5.45
False River	2008	28.00 ± 0.70	23.83 ± 10.87	5.33 ± 1.07	0.26 ± 0.09	0.26 ± 0.01	0.15 ± 0.01	10.30 ± 1.58	1.00 ± 0.09	30.04 ± 2.02
False River	2009	28.51 ± 0.70	5.25 ± 0.80	4.04 ± 0.67	0.16 ± 0.05	0.21 ± 0.03	0.17 ± 0.00	7.88 ± 0.21	1.10 ± 0.17	107.04 ± 14.90
Kincaid Reservoir	2008	29.77 ± 0.34	5.75 ± 3.83	5.51 ± 0.37	0.08 ± 0.03	0.20 ± 0.02	0.19 ± 0.12	5.74 ± 0.96	0.64 ± 0.03	17.02 ± 1.60
Kincaid Reservoir	2009	29.46 ± 0.12	8.32 ± 1.96	5.00 ± 0.89	0.11 ± 0.05	0.23 ± 0.04	0.06 ± 0.01	5.43 ± 0.06	0.69 ± 0.03	62.89 ± 22.99
Des Allemands	2008	28.26 ± 1.18	40.07 ± 12.97	9.26 ± 1.88	0.46 ± 0.11	0.44 ± 0.19	0.16 ± 0.02	17.00 ± 1.10	1.78 ± 0.36	62.58 ± 7.29
Des Allemands	2009	30.83 ± 0.57	81.83 ± 28.52	9.68 ± 0.49	0.39 ± 0.12	0.55 ± 0.05	0.27 ± 0.01	18.30 ± 1.63	2.26 ± 0.54	117.77 ± 21.35
Lake Bruin	2008	27.67 ± 0.44	18.34 ± 18.34	5.67 ± 0.87	0.12 ± 0.02	0.19 ± 0.01	0.10 ± 0.00	9.24 ± 0.91	0.82 ± 0.01	14.02 ± 3.28
Lake Bruin	2009	27.40 ± 0.94	3.69 ± 0.99	5.79 ± 1.04	0.34 ± 0.18	0.18 ± 0.03	0.11 ± 0.00	6.87 ± 0.39	0.86 ± 0.08	47.00 ± 15.52
Lake Chicot	2008	29.00 ± 0.81	19.39 ± 12.53	3.26 ± 0.59	0.16 ± 0.05	0.45 ± 0.06	0.07 ± 0.01	12.02 ± 0.61	1.01 ± 0.14	42.89 ± 17.23
Lake Chicot	2009	28.37 ± 1.24	8.13 ± 2.42	3.72 ± 0.33	0.16 ± 0.07	0.29 ± 0.03	0.06 ± 0.01	15.44 ± 3.41	0.94 ± 0.06	60.20 ± 15.04
Lake Claiborne	2008	27.88 ± 0.65	7.48 ± 1.18	5.21 ± 0.57	0.16 ± 0.07	0.14 ± 0.02	0.05 ± 0.01	6.13 ± 0.37	0.41 ± 0.02	14.02 ± 2.92
Lake Claiborne	2009	27.83 ± 1.06	7.17 ± 3.67	4.76 ± 0.62	0.09 ± 0.04	0.14 ± 0.01	0.03 ± 0.01	5.95 ± 0.43	0.51 ± 0.05	47.87 ± 8.74
Lake Rodemacher	2008	30.96 ± 0.48	73.51 ± 7.37	6.12 ± 0.60	0.26 ± 0.11	0.93 ± 0.03	0.20 ± 0.02	9.14 ± 0.62	0.54 ± 0.04	14.85 ± 3.06
Lake Rodemacher	2009	30.70 ± 0.43	169.59 ± 2.05	5.44 ± 0.76	0.34 ± 0.18	0.92 ± 0.09	0.13 ± 0.06	9.35 ± 0.26	0.81 ± 0.11	46.55 ± 15.58
Poverty Point	2008	28.80 ± 0.65	52.34 ± 7.87	9.68 ± 0.92	0.18 ± 0.02	0.61 ± 0.06	0.15 ± 0.02	13.86 ± 0.44	1.37 ± 0.03	52.57 ± 10.02
Poverty Point	2009	29.49 ± 0.97	27.10 ± 6.54	9.38 ± 1.69	0.14 ± 0.03	0.37 ± 0.10	0.14 ± 0.00	8.12 ± 0.45	0.98 ± 0.11	50.42 ± 13.73
Spanish Lake	2008	29.65 ± 0.53	96.22 ± 13.72	7.76 ± 0.18	0.10 ± 0.02	18.90 ± 17.70	0.13 ± 0.00	28.66 ± 3.05	2.98 ± 0.23	53.90 ± 4.05
Spanish Lake	2009	28.82 ± 0.90	68.17 ± 7.36	7.96 ± 0.17	0.29 ± 0.13	1.24 ± 0.22	0.22 ± 0.04	16.32 ± 3.13	3.12 ± 0.12	116.47 ± 35.15

VITA

Melissa Ann Fries was born in November 1984 in Columbus, Ohio. After graduating from Bishop Watterson High School in 2003, she attended Ohio University and The Ohio State University from 2003-2007. Melissa graduated from The Ohio State University in 2007 with a Bachelor of Science in fisheries and wildlife management. In January 2008, she began her work toward a Master of Science in fisheries at Louisiana State University. Melissa is currently a graduate student in the School of Renewable Natural Resources and plans to graduate in the summer of 2010.