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Population Characteristics of Largemouth Bass Associated with Changes in Abundance of Submersed Aquatic Vegetation in Lake Seminole, Georgia

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ABSTRACT

Population characteristics of largemouth bass (*Micropterus salmoides* L.) including growth, body condition (relative weight), survival, and egg production were examined in relation to abundance of submersed aquatic vegetation (SAV) coverage (primarily hydrilla [*Hydrilla verticillata* L.f. Royle]) in three embayments of Lake Seminole, GA, and compared to a previous study conducted in 1998. Hydrilla in the Spring Creek arm was reduced by a drip-delivery fluridone (1-methyl-3-phenyl-5-[3-(trifluoromethyl) phenyl]-4(1H)-pyridinone) system beginning in May 2000; total SAV coverage declined from 76% to 22% between 2000 and 2001. In contrast, SAV in the Flint River arm increased slightly from 1997 to 2000 (32% to 40%) then declined again in 2001 (28%). Plant coverage in the Chattahoochee River arm remained similar between 1997 and 2000 (26%) and declined in 2001 (15%). Following hydrilla reduction in Spring Creek, relative weight increased 3% to 7% between 1998 and 2003 for two of four length groups of largemouth bass. In the other two reservoir arms relative weight either declined or remained the same between the time periods. Growth of age 1-3 largemouth bass was higher in Spring Creek than in the other embayments and time to reach 305 mm and 406 mm decreased by 17% and 33%, respectively, between 1998 and 2003. Time to reach 305 mm and 406 mm remained similar between 1998 and 2003 in

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the Chattahoochee River arm but declined by 19% and 11%, respectively, in the Flint River arm. Mean annual survival of largemouth bass declined 21% to 23% in all three reservoir arms of Lake Seminole between 1998 and 2003. With faster growth, egg production of largemouth bass doubled in Spring Creek after the SAV reduction; whereas, egg production increased 65% between 1998 and 2003 in the Chattahoochee River and increased only 33% in the Flint River, which was lowest among embayments in 2003. The large reduction of hydrilla in Spring Creek was associated with faster growth, higher relative weights, greater egg production, and lower survival for largemouth bass. However, survival declined throughout Lake Seminole; thus, reduced survival in Spring Creek was likely not related to the fluridone treatment. Abundance of SAV continues to be a strong structuring factor influencing largemouth bass population characteristics in Lake Seminole. Our study demonstrated initial benefits in growth and condition of largemouth bass can result from large-scale removal of SAV in heavily vegetated reservoir systems.

Key words: hydrilla, fluridone, egg production, growth, condition, survival.

INTRODUCTION

Submersed aquatic vegetation (SAV) is one of the strongest factors structuring freshwater aquatic ecosystems (Benson and Magnuson 1992, reviewed by Dibble et al. 1996). Presence of SAV provides suitable substrate for the proliferation of high macroinvertebrate production, causing trophic cascading effects, resulting in stimulation of the entire food chain and an abundant and diverse fish community (Engel 1986, Dibble et al. 1996). Similar to other fish species, recruitment of largemouth bass is often highest at intermediate SAV densities (Moxley and Langford 1983, Wiley et al. 1984, Maceina 1996, Miranda and Pugh 1997). However, high plant densities often decrease predation efficiency of younger fish, causing a delay to piscivory that results in poor 1st-year growth (Bettoli et al. 1992, Miranda and Pugh 1997) as well as lower growth and condition of all sizes of largemouth bass (Colle and Shireman 1980, Cailteux et al. 1998, Pothoven et al. 1999, Brown and Maceina 2002). However, largemouth bass anglers often prefer fishing vegetated habitats and typically do not support large-scale vegetation reduction (Wilde et al. 1992, Slipke et al. 1998).

Thus, fisheries and lake managers are often confronted with balancing aquatic plant management activities to maximize benefits for fish populations and fisheries, as well as other users of water bodies (Henderson 1996, Pothoven et al. 1999). Most studies of fish-plant interactions have found that intermediate plant densities are optimal for fish populations (Dibble et al. 1996). However, intermediate plant densities are difficult to achieve and maintain, particularly with the establishment of the exotic submersed macrophyte hydrilla in many water bodies.

Attempts to eradicate hydrilla while maintaining native SAV have generally been unsuccessful, and as a result managers attempt to control hydrilla using either chemical, biological, or mechanical means (Haller 1977). Mechanical removal is rarely successful at controlling hydrilla (Haller et al. 1980), and management using grass carp (*Ctenopharyngodon idella* Valenciennes) often results in little control of hydrilla or complete eradication of the entire SAV community (Bailey 1978, Bettoli et al. 1993). Thus many control programs use various herbicides, including fluridone (1-methyl-3-phenyl-5-[3-(trifluoromethyl) phenyl]-4(1H)-pyridinone). Applied at typical levels of 10 to 20 mg/L, fluridone reduces turion and tuber production and growth and reduces biomass of hydrilla (Netherland et al. 1993).

Lake Seminole is a widely renowned largemouth bass fishery, located in southwest Georgia on the Florida border (Figure 1). Angler harvest and total angler effort declined from the late 1970s through 2001 (Slipke et al. 1998, D. Partridge, GDNR, unpubl. data), coincident with an increase in hydrilla. Spring Creek is a 2,343-ha embayment of Lake Seminole that has a history of excessive aquatic vegetation (U.S. Army Corps of Engineers [USACE] 1998). An areal survey in 1997 indicated that coverage of submersed aquatic plants, primarily hydrilla, was 76% in Spring Creek, compared to 26% in the Chattahoochee River and 32% in the Flint River arms (Table 1; USACE 1998). The high water clarity and low flows of Spring Creek supported high density of hydrilla compared to the Chattahoochee and Flint River arms, which are subject to high turbidity and flows that naturally control hydrilla. To partially reduce hydrilla in Lake Seminole, the USACE (Mobile District) initiated a drip delivery fluridone system (Haller et al. 1990, Fox et al. 1994) in Spring Creek in May 2000 (Figure 1), with the intent of reducing hydrilla coverage in Spring Creek to levels similar to those found in the other two embayments.

Previous work on Lake Seminole in 1998 found that growth, relative weight, and egg production of largemouth

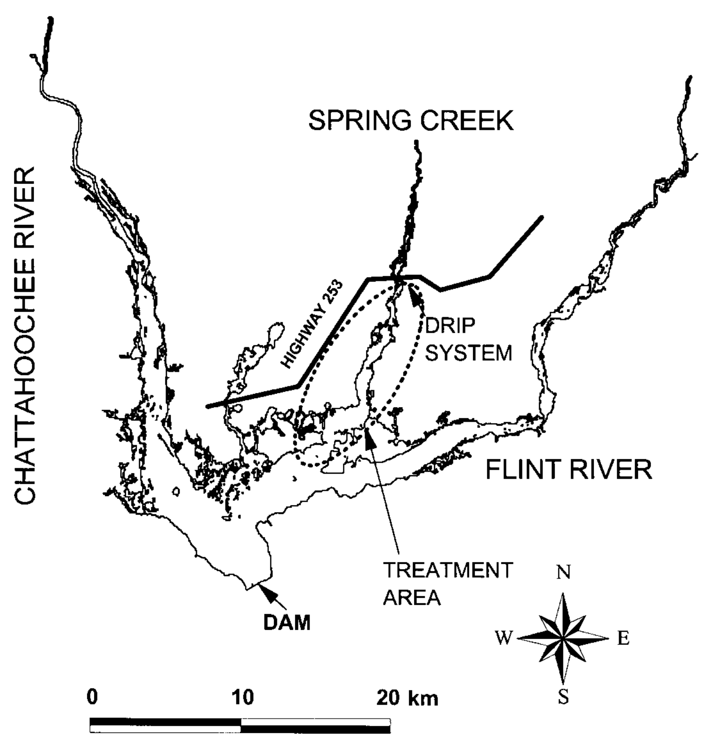

Figure 1. Map of Lake Seminole showing the three reservoir arms sampled during this study and the location of drip system on the Spring Creek arm.

TABLE 1. TOTAL AREA AND PERCENT COVERAGE OF SUBMERSED AQUATIC VEGETATION OF THREE AREAS OF LAKE SEMINOLE, GA. DATA IS FROM SURVEYS CONDUCTED IN THE FALL OF EACH YEAR BY THE U.S. ARMY CORPS OF ENGINEERS.

		SAV coverage (%)		
Reservoir arm	Area (ha)	1997	2000	2001
Chattahoochee River	5,144	26	26	15
Flint River	4,769	32	40	28
Spring Creek	2,343	76	72	22

bass were considerably lower in Spring Creek than in the other two embayments of the reservoir; whereas annual survival rates were higher (Brown and Maceina 2002). Brown and Maceina (2002) predicted that a reduction of SAV in Spring Creek would improve the population metrics of largemouth bass inhabiting this area. Thus, the objectives of this study were to examine these same metrics for the largemouth bass populations in the three areas of Lake Seminole 5 years after the Brown and Maceina (2002) study, and 2 years after a large reduction in hydrilla occurred in Spring Creek.

MATERIALS AND METHODS

Hydrilla Control Activities and Aquatic Plant Surveying

The USACE initiated and maintained the fluridone drip system from late May until mid to late August 2000, when most of the hydrilla canopy collapsed in about a week (D. Morgan, USACE, pers. comm.). Hydrilla regrowth caused the USACE to restart the system in October 2000 and maintain it until early December 2000. The fluridone drip system was initiated again in May 2001 and remained on until September 2001, thereafter it was operated on biweekly intervals through the end of the year. The system was operated in a similar manner in 2002. Submersed aquatic plant mapping throughout Lake Seminole was conducted by the USACE in 2000 and 2001.

Aquatic plants were surveyed reservoir-wide in late August-early September in 2000 and 2001 by the USACE. In 2000, the reservoir was flown with standard aerial photography. Quantitative assessments of SAV were conducted using a point intercept method to document species presence and absence and hydroacoustic transects to determine SAV abundance. These data were combined with the aerial photography results using ArcMap/ArcInfo software (ESRI 2000) to create a coverage map for the entire reservoir. In 2001, SAV was mapped reservoir-wide using remote-sensing imagery that recorded differences in reflectance of light for each vegetation type. Reflectance values for each type (floating, emergent, submersed, topped) were determined in the field and assigned in the model for the entire area. Coverage of each type was then determined using ArcMap/ArcInfo software.

Fish Collection and Processing

A total of 914 largemouth bass of all sizes were collected from the Chattahoochee River, Flint River, and Spring Creek arms between February 20 and March 13, 2003, using boom-mounted electrofishing boats. Water temperatures were generally at or below 15 C, representing pre-spawning conditions (Heidinger 1975). We also collected approximately 100 age-1 fish from the Spring Creek and Chattahoochee River embayments in March 2002 to examine first-year growth of the 2001 year class. Maceina and Slipke (2004) also collected age-1 fish from Spring Creek in March-April 1998 and these length distributions were compared to data collected in 2002 and 2003. All fish were collected in the same manner and from generally the same areas as in the Brown and Maceina (2002) study. Total length (mm) and weight (g) were recorded for all fish. Otoliths were extracted and examined according the methods described in Maceina (1988).

These data were used to describe length-frequency distribution, condition, growth, and survival of largemouth bass in each reservoir arm. Relative weight (W_r) was used to describe condition; fish were divided into four length categories: stock (203 to 303 mm), quality (304 to 380 mm), preferred (381 to 507 mm), and memorable (508 to 630 mm) as described by Anderson and Neumann (1996). A W_r value of 100 indicates an individual fish is at the upper 25^{th} percentile for weight-at-length that is compared to a national average (Anderson and Neumann 1996).

Ovaries were weighed (0.1 g) and placed in Gilson's solution to preserve and separate eggs for fecundity estimates (Kelso and Rutherford 1996). Fecundity or egg production was determined volumetrically as described in Brown and Maceina (2002). Eggs greater than 1.0 mm diameter were considered to be mature ova (Timmons et al. 1980). The female gonadosomatic index (GSI) was computed by dividing gonad weight by body weight minus gonad weight.

Data Analysis

Unlike the results from Brown and Maceina (2002), largemouth bass population characteristics were not similar between the Chattahoochee and Flint arms in 2003, and thus were analyzed separately. One-way ANOVAs were used to compare differences in GSI values, the number of mature ova per gram of gonad of fish greater than 1.5 kg, and relative weights among reservoir arms. Because lengths-at-age are not independent over a range of ages, alpha levels were adjusted using the Bonferroni correction. T-tests were used to compared these metrics between the present study and the Brown and Maceina (2002) data. Time to reach 304 mm (minimum length limit on Lake Seminole), and 406 mm were predicted from the von Bertalanffy (1938) growth models used to describe and compare growth rates in each reservoir arm between studies.

Weighted catch-curve regressions were fit to number-at-age data to determine annual survival rates from each arm (Maceina 1997). These regressions were compared among reservoir arms and between studies using covariance analysis to test for differences in overall annual survival. Length frequencies and age frequencies were compared between studies using Kolmogorov-Smirnov tests. Covariate analyses were conducted to compare the fecundity-to-weight relations between 1998 and 2003 for each embayment. The weights of female fish were corrected by subtracting gonad weight. Fecundity-to-length equations, length-to-weight equations, and coefficients of the von Bertalanffy equations were used in the MOCPOP software package (Beamesderfer 1991) to predict the number of mature ova produced by each age class in each embayment for both the Brown and Maceina (2002) and the present studies. All statistical tests were performed using SAS version 8.2 (SAS Institute 2001); significance for all comparisons in this study was set at $P \leq 0.10$ (except for those with a Bonferroni correction).

RESULTS AND DISCUSSION

Hydrilla coverage in Spring Creek declined from over 70% to nearly 0% when the hydrilla canopy collapsed in late August 2000 (just after the USACE conducted the plant survey). Thereafter, SAV coverage never rose above 30% in Spring Creek, and a survey conducted in late summer 2001 by the USACE indicated that SAV coverage in Spring Creek had decreased to 22% (Table 1); about 1,800 ha of hydrilla in Spring Creek was eliminated. Some native plant species began recolonizing areas that were formerly monotypic hydrilla stands, including tape-grass (*Vallisneria americana* Michaux), spatterdock (*Nuphar luteum* L.), muskgrass (*Chara* sp. L.), Illinois pondweed (*Potamogeton illinoensis* Morong), and small pondweed (*P. pusillus* L.). These plants covered less than 100 ha in 2001, but abundance increased rapidly in 2002, reaching a coverage of almost 30% for brief periods (D. Morgan, USACE, pers. comm.). Hydrilla remained largely confined to the lower part of Spring Creek (below the study site) throughout 2002; however, some regrowth was observed in the study area, amounting to <10% of total SAV coverage (D. Morgan, USACE, pers. comm.). The 2000 survey found that SAV coverage remained similar to 1997 levels in the Chattahoochee River arm (26%) but had increased to 40% in the Flint River arm (Table 1). Because of high river flows in the winter of 2000-2001, SAV coverage fell to 15% in the Chattahoochee River arm and 28% in the Flint River arm by September 2001 (Table 1).

Following hydrilla reduction in Spring Creek, relative weight increased ($t = 2.13$ to 3.00; $P < 0.05$) between 1998 and 2003 for two of four length groups of largemouth bass (Figure 2). In the other two arms, relative weights either declined ($t = 3.41$; $P < 0.01$) or remained the same between time periods (Figure 2). In 2003, relative weights were higher in Spring Creek and the Flint River arms than in the Chattahoochee River arm for stock-sized fish ($F = 3.37$; $P < 0.05$). Relative weight of largemouth bass were similar among arms for all other sizes ($P > 0.10$).

Growth of largemouth bass increased after hydrilla reduction in Spring Creek as lengths of fish in Spring Creek were longer in 2003 than in 1998 for ages 2 to 5 (Table 2). However, lengths-at-age were generally longer in 1998 than in 2003 for ages 2 to 4 in the Chattahoochee River and ages 3 to 4 in the Flint River, whereas, the opposite was observed for age 5 fish in both embayments (Table 2). Von Bertalanffy growth equations showed similar patterns in growth between 1998 and 2003 in both the Chattahoochee and Flint River arms: growth was faster in 2003 for younger fish, then eventually became slower than 1998 for older fish (Figure 3). However, great divergence in growth models occurred between 1998 and 2003 for fish in Spring Creek (Figure 3). Growth declined in the Chattahoochee River and Flint River arms as time to reach 305 mm increased between 1998 and 2003 (Table 2). In contrast, the time for fish to reach 305 mm was

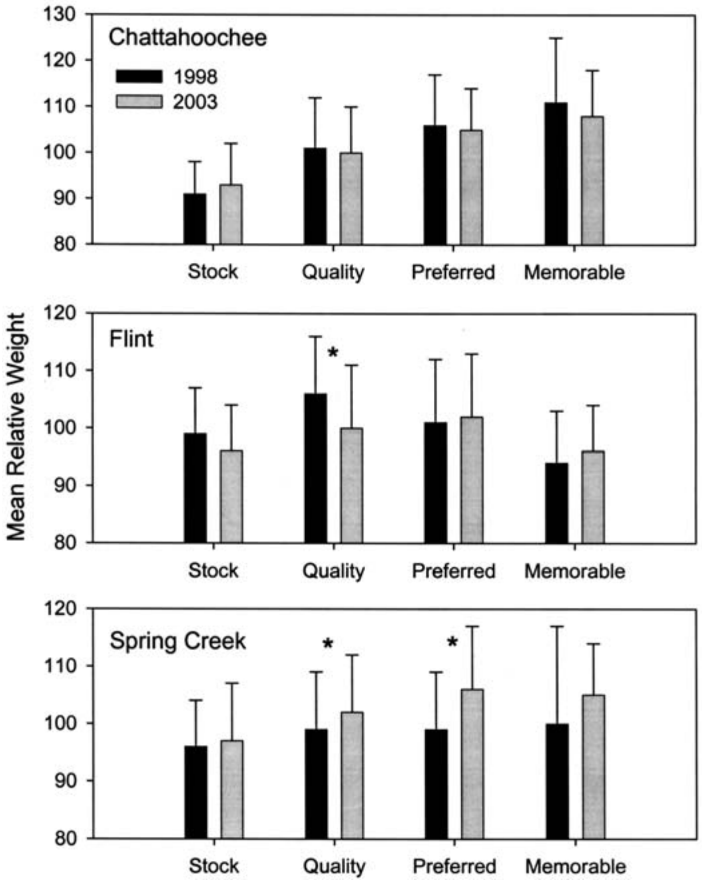

Figure 2. Mean relative weight (+1 standard deviation) of largemouth bass of four size groups (see text for descriptions) collected in 1998 and 2003 from three areas of Lake Seminole. Asterisks denote significant differences between samples (t-test, $P < 0.10$).

faster in 2003 than 1998 in Spring Creek (Table 2). Similarly, it took fish longer to reach 406 mm in the Flint River but less time in Spring Creek in 2003 compared to 1998 (Table 2). Age-1 growth rates (mean length at age 1) after SAV reduction (2002 year class) in Spring Creek increased 35% compared to 1998, was 38% greater than age-1 growth in the Chattahoochee River arm in 2003, and 48% greater than in the Flint River arm in 2003 (Figure 4). Mean length at age 1 of the 2003 year class in Spring Creek was only 4% larger than 1998 growth; however, larger individuals were still produced in 2003 compared to pre-hydrilla reduction (Figure 4).

Based on age-structure data, average annual survival rates of largemouth bass declined in all three arms of Lake Seminole between 1998 and 2003. Survival of age 3 to 11 fish declined from 73% in 1998 to 56% in 2003 in the Chattahoochee River arm (Covariance; $F = 9.35$; $P < 0.01$), declined from 72% in 1998 to 57% in 2003 in the Flint River arm ($F = 7.25$; $P < 0.05$), and declined from 82% in 1998 to 63% in 2003 in the Spring Creek arm ($F = 8.96$; $P < 0.01$). For data collected in 2003, covariance analysis found no difference in annual survival among arms when slopes of the catch-curve regressions were compared ($F = 0.89$; $P > 0.10$).

Throughout Lake Seminole, significantly more older fish were collected in 1998 than in 2003 ($KSa = 3.94$; $P < 0.01$). In

Table 2. Mean lengths at age ± standard error (sample size) and time in years to reach 305 mm and 406 mm for largemouth bass collected from three reservoir arms of Lake Seminole, GA, in 1998 and 2003. Time to reach certain lengths were predicted using von Bertalanffy growth models. Means with the same superscript were not different between years within each arm (t-test, P = 0.02). Comparisons were made only for ages where at least 10 individuals were collected each year.

		Ages				Time (y) to Reach	
Area	Year	2	3	4	5	305 mm	406 mm
Chatt	1998	252^{z} ± 4 (64)	363^{z} ± 6 (57)	403^{z} ± 9 (18)	421^{z} ± 10 (27)	2.5	4.3
	2003	246^{z} ± 4 (57)	349^{z} ± 4 (74)	387^{z} ± 8 (46)	445^{z} ± 13 (22)	2.7	4.3
Flint	1998	241^{z} ± 6 (36)	353^{y} ± 6 (55)	400^{y} ± 10 (25)	382^{z} ± 10 (15)	2.6	4.5
	2003	242^{z} ± 4 (69)	317^{z} ± 5 (70)	369^{z} ± 8 (42)	421^{y} ± 8 (24)	3.1	5.0
S. Creek	1998	247^{z} ± 5 (58)	327^{z} ± 7 (35)	334^{z} ± 11 (12)	361^{z} ± 9 (16)	3.0	6.1
	2003	277^{y} ± 4 (133)	356^{y} ± 7 (55)	366^{y} ± 9 (26)	418^{y} ± 15 (16)	2.5	4.1

1998, age 8 to 11 fish composed 18% of all age 3 to 11 fish in the population compared to 5% in 2003. Although growth rates increased in Spring Creek after hydrilla reduction, average annual survival rates declined, and length distributions of fish > 203 mm declined (t = 2.12; KSa = 1.43; P < 0.05) between 1998 and 2003. Similarly, fish were smaller (t = 1.77 to 5.80; P < 0.10; KSa = 1.57 to 2.90; P < 0.05) in 2003 in both the Chattahoochee River and Flint River arms than in 1998. In 2003, fish from the Chattahoochee River arm were longer (F = 5.83; P < 0.01) than fish collected from Spring Creek or the Flint River arm.

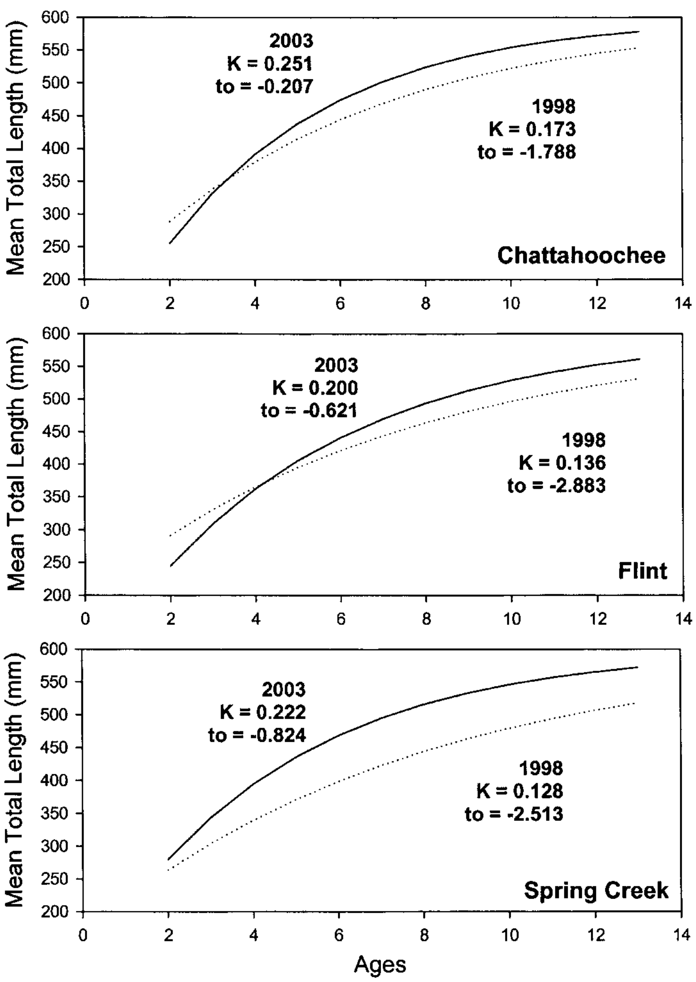

Figure 3. Von Bertalanffy growth models for largemouth bass collected from three areas of Lake Seminole, in 1998 and 2003. Length infinity was constrained to 600 mm for all models. K is the predicted growth coefficient and t_0 is the predicted length at age 0 for each growth model.

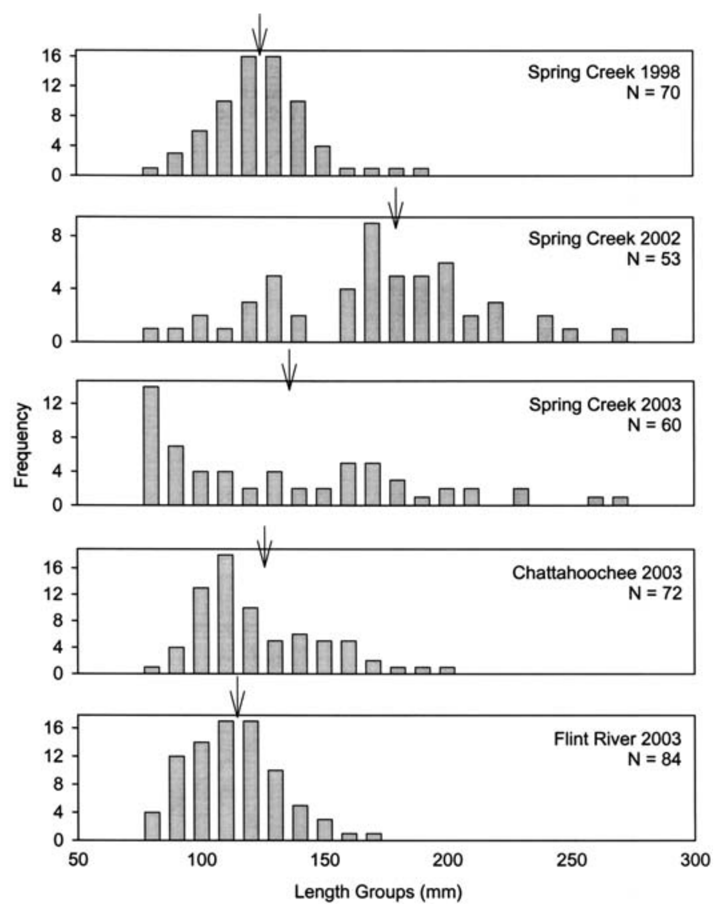

Figure 4. Length frequencies (10-mm length groups) of age-1 largemouth bass collected in three areas of Lake Seminole. Data from 1998 was collected by Brown and Maceina (2002). Arrows denote mean length of age-1 largemouth bass in each sample.

In 2003, gonadosomatic indices were similar across embayments (F = 1.07; P > 0.10) and no differences were observed for GSI values between 1998 and 2003 in any embayment (t = 1.00 to 1.20; P > 0.10). In 2003, slopes of the weight-to-fecundity relations were similar among reservoir arms (Covariance, F = 0.43; P > 0.10). Adjusted mean fecundities were highest in the Chattahoochee River arm (5,259 eggs/fish) and lowest in the Spring Creek arm (4,502 eggs/fish), while mean fecundities were intermediate in the Flint River arm (4,834 eggs/fish) and similar to the other two embayments (Covariance; P < 0.10). Although Brown and Maceina (2002) reported finding fecundity of larger females (>2 kg) were less fecund in Spring Creek in 1998, weight-to-fecundity relations did not differ between studies in any embayment (Covariance; P > 0.10). The number of mature ova per gram of gonad for fish over 1.5 kg (corrected weight) was similar among embayments in 2003 (ANOVA; F = 0.25; P = 0.78), but declined from 1998 values in the Flint River arm (t = 1.83; P < 0.10) and remained similar in the Chattahoochee River and Spring Creek arms (t = 0.01 to 1.53; P > 0.10). The number of mature ova produced at each age in 1998 was similar among embayments at ages 3-5; however, at ages ≥6 fecundity was always highest in the Chattahoochee River arm, intermediate in the Flint River arm, and lowest in the Spring Creek arm (Figure 5). Overall egg production increased 65% in the Chattahoochee River arm in 2003 and was still higher than the other embayments. However, egg production more than doubled in the Spring Creek arm by 2003, and was essentially similar to egg production in the Chattahoochee River arm for most age classes (Figure 5). Egg production only increased 33% in the Flint River during this time, and was lowest among the embayments in 2003 (Figure 5).

Submersed aquatic vegetation in the Spring Creek arm declined dramatically between 1997 and 2001, whereas SAV in the Flint River arm increased slightly from 1997 to 2000 then declined again in 2001. Plant coverage in the Chattahoochee River arm remained similar between 1997 and 2000 and declined in 2001. In general, largemouth bass growth and condition increased between 1998 and 2003 in the Spring Creek arm, decreased in the Flint River arm, and remained relatively similar in the Chattahoochee River arm. Brown and Maceina (2002) found in 1998 that relative weight of fish quality size and larger was higher in the Chattahoochee and Flint River arms than in Spring Creek. In contrast, fish of all sizes in Spring Creek expressed higher condition than those in the Flint River and were comparable to condition in the Chattahoochee River arm in March 2003. Similarly, Brown and Maceina (2002) reported that fish in Spring Creek in 1998 had much slower growth than those in the Chattahoochee and Flint River arms, taking 1.8 years more to reach 406 mm. Growth rates in Spring Creek had increased dramatically by March 2003, reaching 406 mm 0.2 and 0.9 years earlier than fish in the Chattahoochee River and Flint River, respectively. Times to reach 305 and 406 mm changed little (<8%) between 1998 and 2003 in the Chattahoochee River arm, increased 11-19%, in the Flint River arm and decreased 17-33% in the Spring Creek arm. Thus, the greatest increase in growth over time occurred in Spring Creek among the three arms.

Dense SAV creates a refuge for prey fish (Engel 1986, Savino and Stein 1989, Hayse and Wissing 1996), and the rapid loss of plants from Spring Creek likely created a large food source released to predation, leading to higher condition and growth for largemouth bass. Pothoven et al. (1999) found that largemouth bass growth increased and bluegill abundance decreased following a large-scale macrophyte reduction. They also documented an increase in numbers of prey fish found per largemouth bass stomach and attributed the lower bluegill abundance to predation. Similarly, Bettoli et al. (1992) documented an increase in piscivory for age-0 largemouth bass following eradication of hydrilla in Lake Conroe, Texas, leading to greater first-year growth. Cailteux et al. (1998) found fewer empty stomachs and greater piscivory in small largemouth bass in vegetated lakes than in unvegetated lakes in Florida. Miranda and Pugh (1997) reported that lengths of juvenile largemouth bass was highest in coves with the least SAV in a Mississippi reservoir. Our results also showed the impact of hydrilla reduction on the growth and condition of smaller largemouth bass. Maximum size of age-1 largemouth bass in Spring Creek was 194 mm in 1998, but after SAV was reduced, increased to 276 mm in 2002 and 262 mm in 2003. Mean total lengths of age-1 largemouth bass in

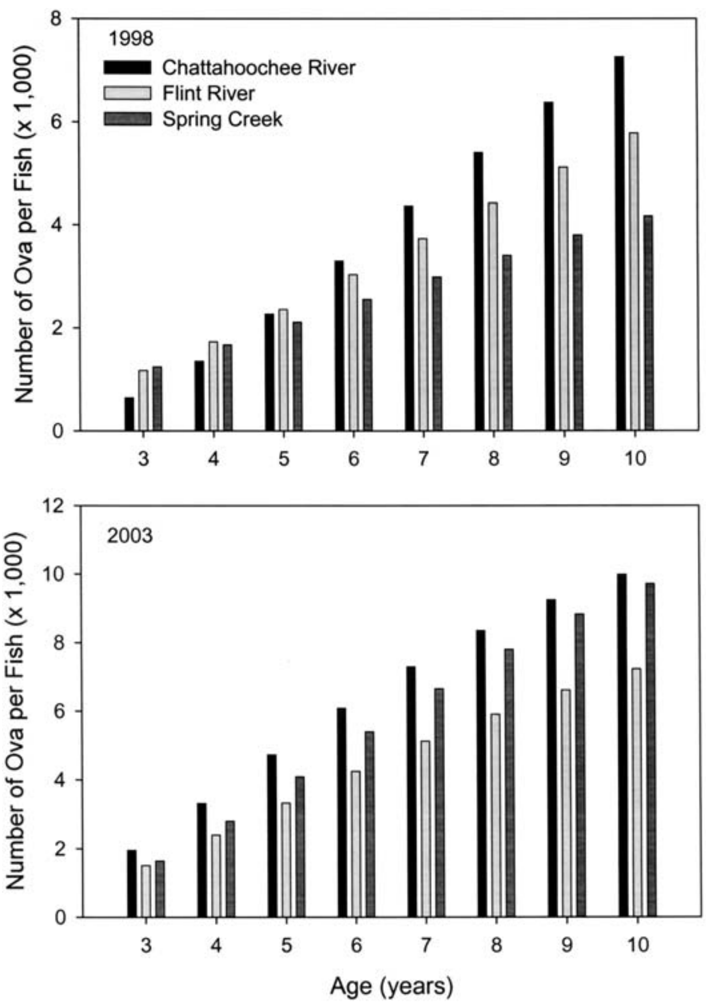

Figure 5. Predicted number of mature ova per individual (determined volumetrically) for largemouth bass ages 3-10 in three areas of Lake Seminole in 1998 and 2003.

Spring Creek was only 4% higher in 2003 than in 1998, because small bass were collected in isolated pockets of heavier vegetation. However, similar to the 2002 sample, some age-1 fish were still attaining much larger lengths by the end of their first year than they had before hydrilla reduction. Growth of fish during their first year is one of the most important factors determining subsequent size structure of the population (Gutreuter and Anderson 1985). Sammons and Bettoli (1998) documented that year classes of largemouth bass in Normandy Reservoir, TN, that obtained a growth advantage as age-0 fish maintained this growth advantage at age 3, leading to more catchable fish in the population.

Abundance of age-0 largemouth bass has been found to be positively correlated to SAV coverage (Tate et al. 2003) and often decreases after macrophyte removal (Shireman et al. 1985, Bettoli et al. 1992). However, age-0 largemouth bass usually attain larger sizes after SAV removal (Bettoli et al. 1992, Maceina and Slipke 2004), but this may or may not result in greater recruitment to harvestable sizes. In Lakes Conroe, Texas, and Baldwin, Florida, complete elimination of SAV by grass carp resulted in fewer, but faster growing young largemouth bass (Shireman et al. 1985, Bettoli et al. 1992). Largemouth bass density declined, but biomass remained similar over time in these two water bodies (Shireman et al. 1985, Bettoli et al. 1993).

Lower average annual survival of largemouth bass age 3 and older in 2003 across all three embayments was enigmatic. Brown and Maceina (2002) theorized that dense SAV, particularly in Spring Creek, acted as a refuge from angling for larger fish, effectively increasing overall survival. Submersed aquatic vegetation declined in both the Chattahoochee River and Spring Creek arms, and fluctuated in the Flint River arm. However, reduced largemouth bass survival was observed throughout the reservoir and did not appear to be related to SAV. In all three embayments we sampled in Lake Seminole, fish were smaller in 2003 than in 1998, due to the collection of fewer old and large fish. Thus, lower survival rates in 2003 were due to a paucity of older fish in the population. Maceina and Reeves (1996) found an inverse relation between angler catch of large memorable-size largemouth bass (>2.27 kg) and SAV coverage in two Tennessee River impoundments. However, exploitation of black bass has decreased over the last 10 years as more anglers practice catch and release (Quinn 1996). Estimated largemouth bass exploitation in Lake Walter F. George, GA-AL, decreased from 23% in 1987-1991 to 6% in 2000 (D. Partridge, GDNR, unpubl. data). Lake Seminole is the next major impoundment downstream of Lake Walter F. George, thus exploitation is likely similar to Lake Walter F. George.

Brown and Maceina (2002) found that egg production was lower in the Spring Creek arm than other areas of the reservoir in 1998, which they attributed lower relative weights and growth related to the dense SAV community present in that embayment. Snow (1970) and Tyler and Dunn (1976) showed that fecundity varied directly with food consumption. Although fecundity-to-body weight relations did not change between 1998 and 2003 in Spring Creek, largemouth bass egg production doubled, and growth and condition increased, which was associated with greater food consumption after hydrilla reduction (Sammons 2004). In contrast, fecundities in the Flint River showed only a small increase from 1998 to 2003, and by 2003 were lowest among the embayments. Unlike the other embayments, SAV cover in the Flint River generally increased between 1998 and 2003, which may have negatively impacted largemouth bass feeding rates, growth, condition, and ultimately egg production.

Many authors have found that moderate coverages of SAV (20-40%) maximizes largemouth bass production by providing adequate habitat for prey fish recruitment while still allowing for successful predation (Wiley et al. 1984, Moxley and Langford 1985, Maceina 1996). Gotceitas and Colgan (1989) found that foraging success of largemouth bass was lower when stem density increased above 350 stems/m^2 and predicted that a stem density of at least 276 stems/m^2 would be required to decrease foraging success. The fluridone treatment of Spring Creek removed problematic levels of the exotic hydrilla while maintaining an intermediate level of a mixed community of native species, resulting in increased predation efficiency, higher growth and condition, and increased egg production.

In summary, our results demonstrated that large-scale reduction of SAV increased growth, condition, and egg production of largemouth bass in Spring Creek. However, older and larger fish were rarer in Spring Creek after SAV reduction, but was confounded by lower survival throughout the reservoir that was not treated with fluridone. Previous work in Spring Creek determined that largemouth bass remained in the fluridone treatment area in Spring Creek, but exhibited more movement and inhabited deeper water (Sammons et al. 2003). The results of that study coupled with the current study suggested that largemouth bass changed behavior to capitalize on greater prey resources available after SAV reduction, leading to better condition and faster growth.

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