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The Influence of Disparate Levels of Submersed Aquatic Vegetation on Largemouth Bass Population Characteristics in a Georgia Reservoir

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ABSTRACT

Population characteristics of largemouth bass *(Micropterous salmoides* L.) including growth, body condition (relative weight), size structure, survival, and fecundity were examined in relation to abundance of submersed aquatic vegetation (SAV) coverage (primarily hydrilla *Hydrilla verticillata* L.f. Royle) in three major embayments of Lake Seminole, Georgia. Relative weight, fecundity, and growth of largemouth bass in the Spring Creek embayment (76% areal SAV coverage) was considerably less than measured in the Chattahoochee and Flint river arms that contained lower SAV coverages (26% and 32%). It took fish 1.8 years longer to reach 406 mm in Spring Creek compared to the Chattahoochee-Flint arms. Consequently, fish were smaller in Spring Creek than in the Chattahoochee-Flint arms. In addition, due to slower growth rates and lower fecundity-to-body weight relation, we predicted a 47% reduction in total potential ova production in Spring Creek compared to the other two reservoir embayments. The annual survival rate of 3 to 10 year old largemouth bass was higher in Spring Creek (84%) than in the Chattahoochee-Flint arms (72%) and suggested either lower harvest and/or lower accessibility of particularly larger fish to angling in dense vegetation. Contrary to our expectations, the fit between number-at-age and age in a catch-curve regression was weaker for fish collected in Spring Creek and suggested greater recruitment variability has occurred over time in this highly vegetated embayment. In Lake Seminole, spatial differences in largemouth bass population characteristics were associated with disparate levels of SAV. Our data suggest that a reduction in hydrilla, but maintenance of an intermediate level of SAV in Spring Creek, should improve largemouth bass population in this arm of the reservoir.

Key words: Micropterus salmoides, reproduction, Hydrilla *verticillata*, growth, recruitment, survival.

INTRODUCTION

Submersed aquatic vegetation (SAV) is an integral component of the aquatic environment in lakes and reservoirs. However, excessive aquatic plant growth can be detrimental and may limit navigation, power generation, irrigation and recreational use, and may create an undesirable fishery. The largemouth bass *(Micropterous salmoides* L.) is an important fish species for anglers throughout the United States. Results on interactions between largemouth bass population characteristics and SAV have been mixed with negative, positive and sometimes neutral impacts (Maceina 1996).

Because most researchers typically quantify interactions between aquatic plants and fishes differently (Dibble et al. 1996), most results determining optimal amounts of SAV for fish have been difficult to accurately estimate and compare among water bodies. Maceina (1996) speculated that water body size, type (natural lake or reservoir), and retention (volume/discharge) in reservoirs can influence largemouth bass-plant relations.

Lake Seminole once contained a widely renowned largemouth bass fishery (Shupp 1997) and since impoundment, various aquatic plants have extensively colonized this reservoir. Over time, angler harvest and effort have declined, due primarily to a reduction in anglers seeking largemouth bass (Slipke et al. 1998a). Creel surveys indicated that catch rates for largemouth bass in Lake Seminole were as high as 0.42 fish/h in 1978-79 and declined to 0.28 fish/h in 1985. A creel survey conducted in 1996 confirmed that fishing for largemouth bass was poor and angler catch rates had further declined to only 0.16 fish/h (Slipke et al. 1998a).

Submersed aquatic vegetation communities and abundance have also changed over time. Shortly after impoundment, a diversity of native SAV colonized Lake Seminole (Gholson 1984). Hydrilla (*Hydrilla verticillata* L.f. Royle) was first discovered in 1967 and rapidly increased to cover nearly 70% of the surface of the reservoir by the early 1990s (USACE 1998). Conflicts over aquatic plant management activities have recently occurred (Shupp 1997) as largemouth bass anglers preferred similar or even greater levels of aquatic vegetation, while homeowners that fished desired less vegetation (Slipke et al. 1998a).

Previous research that examined the relation between aquatic plants and largemouth bass populations have focused on whole-lake studies that examined a continuum of aquatic plant conditions (Durocher et al. 1984, Hoyer and Canfield 1996), determined largemouth bass population changes to whole-lake aquatic plant treatments (Shireman et al. 1985, Bettoli et al. 1992), or conducted micro-scale studies (reviewed by Dibble et al. 1996). The objective of this research was to determine the influence of disparate levels of SAV in a single reservoir on adult largemouth bass population characteristics including body condition, growth, surviv-

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al, size structure, and fecundity. We also attempted to identify whole-reservoir environmental factors that may have influenced largemouth bass year-class strength by examining the production of weak and strong year classes in an attempt to determine why angler catch had declined in 1996.

MATERIALS AND METHODS

Study Area

Lake Seminole is a stable water-level reservoir constructed in 1957 at the confluence of the Chattahoochee River and Flint River (Figure 1). Spring Creek is also a major tributary of the reservoir. The reservoir has a surface area of 13,158 ha, a mean depth of 3.0 m, and a maximum depth of 10.7 m. Retention (volume/discharge) is relatively short and has averaged 9 d. The stable water levels (<0.6 m annual fluctuation) and shallow depth of this reservoir have been very conducive to aquatic macrophyte colonization since impoundment (Gholson 1984).

Besides hydrilla, other common submersed aquatic plants found in Lake Seminole include variable-leaf milfoil (*Myriophyllum heterophyllum* Michaux), Illinois pondweed (*Potamogeton illinoensis* Morong), Eurasian water milfoil (*Myriophyllum spicatum* L.), muskgrass *(Chara* sp. L.), stonewort *(Nitella* sp. Agardh), and coontail (*Ceratophyllum demersum* L). From a survey conducted in fall 1997 by the USACE (1998), SAV coverage (primarily hydrilla) was 26% in the Chattahoochee River, 32% in the Flint River, and 76% in the Spring Creek arms (Table 1). Based on observation (D. Morgan, USACE, personal communication), SAV diversity was somewhat higher in the Chattahoochee and Flint arms, but the predominate plant was hydrilla, while Spring Creek contained nearly a monoculture of hydrilla. In addition, floating-leaved and emergent plants were mapped in each reservoir arm in 1997, coverages varied which may have also contributed to habitat differences among the arms (Table 1). To determine species-specific areal cover values was cost prohibitive in this large and extremely dendritic reservoir that contained about 7,400 ha of aquatic vegetation (D. Morgan, USACE, personal communication). We assumed dissimilar levels in SAV among these three reservoir arms was greatest habitat difference that could influence largemouth bass.

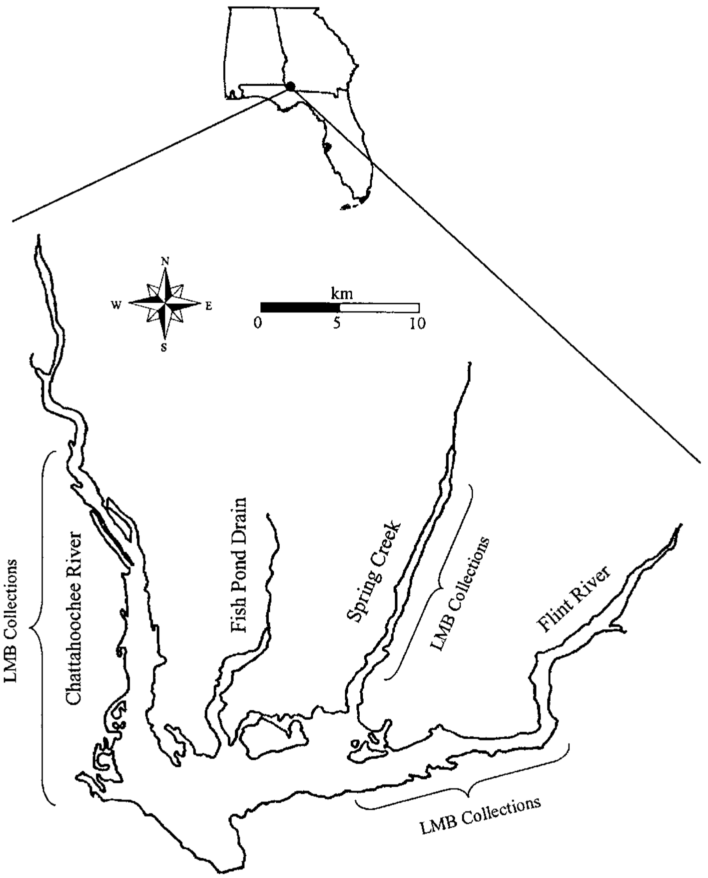

Figure 1. Map and location of Lake Seminole and the three major embayments where largemouth bass were collected. Areas where largemouth bass (LMB) were collected are shown.

Fish Collection and Processing

Largemouth bass ≥203 mm total length (TL) were collected from the Chattahoochee River (N = 214), Flint River (N = 178), and Spring Creek (N = 180) arms, respectively, between March 3 and 19, 1998 using a boom-mounted DC electrofishing air boat. During this time, water temperatures varied from 15 to 17C, represented either pre-spawn or spawning conditions, and was conducive to sampling all sizes of largemouth bass. Electrofishing collecting times were 5.55 h in the Chattahoochee, 7.87 hours in the Flint, and 9.19 hours in the Spring Creek arms. Fish were collected from areas that were conducive to high catch rates. Thus, estimates of abundance for each reservoir arm were not computed from electrofishing catch-per-effort.

Upon collection, fish were placed in a 300 mg/L solution of MS-222 until expired, then placed on ice. Total length (mm) and weight (g) were recorded for all fish. Ovaries were weighed (0.1 g) and placed in Gilson's solution (Kelso and Rutherford 1996) to preserve and separate eggs for fecundity estimates. Otoliths were extracted from each fish and aged (Hoyer et al. 1985, Maceina 1988).

These data were used to describe length structure, body condition (weight:length ratio) or relative weight (W_r), length-at-age (growth), and survival using catch curves in each reservoir arm. Relative weights were computed for four length groups of fish described by Anderson and Neumann

Table 1. Surface area of the three reservoir arms and corresponding percent areal coverage of major plant communities. SAV is submersed aquatic vegetation primarily comprised of hydrilla; FLV is floating-leaved vegetation primarily comprised of American lotus (*Nelumbo lutea* Willd.) and fragrant water lily (*Nymphaea ordorata* Aiton); EAV is emergent aquatic vegetation primarily composed of giant cutgrass (*Zizaniopsis miliacea* Michaux) and cattail (*Typha latifolia* L.).

		Percent cover (%)		
Reservoir arm	Area (ha)	SAV	FLV	EAV
Chattahoochee	4,820	26	7	13
Flint	4,770	32	<1	5
Spring	2,300	76	2	11

(1996) including stock (203-303 mm), quality (304-380 mm), preferred (381-507 mm), and memorable (≥508 mm) lengths. A W_r value of 100 indicates an individual fish is at the upper 25th percentile for weight-at-length that is compared to a national standard (Anderson and Neumann 1996).

Fecundity was determined volumetrically by counting the number of eggs in five 1-ml sub-samples of a known volume of water from each mature female using Image Tool Software (UTHSCSA 1997). Subsampling continued until the coefficient of variation (CV) of the sub-samples was less than 25%. The mean number of eggs per ml was calculated and used to extrapolate the total number of eggs for each fish (Kelso and Rutherford 1996). Eggs greater than 1.0 mm diameter were assumed 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

Brown (1999) found that largemouth bass population characteristics were similar between the Chattahoochee and Flint arms, thus these data were pooled and compared to Spring Creek. T-tests were used to compare differences in GSI values, relative weights, and lengths-at-age of fish between Chattahoochee-Flint and the Spring Creek arms. Because lengths-at-age are typically not independent, a Bonferroni correction (McClave and Dietrich 1988) was applied to adjust probability levels to reduce the risk of making a Type I error. We assumed that physiological processes may affect GSI and relative weights differently on variable fish size, and thus we assumed among length group comparisons were independent for these two variables. Growth differences were also tested by conducting covariate analyses for the linear relation between total length and $\log_{10}$ age. Time to reach 304 mm (minimum length limit) and 406 mm (minimum size in other Chattahoochee River impoundments) were predicted from von Bertalanffy growth equations (Ricker 1975) to describe growth. Differences in length distributions were examined with the Kolmogorov-Smirnov (K-S) test (SAS 1996) and skewness tests (Snedecor and Cochran 1980).

Covariate analyses were also conducted to compare the fecundity-to-weight and number-at-age relations. The weights of female fish were corrected by subtracting gonad weight. Fecundity-to-length equations and coefficients of the von Bertalanffy equations were used in the Fishery Analyses and Simulation Tools software package (Slipke and Maceina 2000) to predict the number of eggs produced by each age class in each study site.

Weighted catch-curve regressions (Maceina 1997) were fit to the number-at-age data to determine annual survival rates from each arm. From age-structure data pooled from all three embayments, the residuals from the catch-curve regression were used to identify strong and weak year classes (Maceina 1997). Environmental variables determined at the time fish were age 0, including macrophyte coverage and reservoir discharge and were included as independent variables in catch-curve regressions to identify potential factors influencing largemouth bass year-class strength (Maceina 1997). Whole-reservoir SAV levels were computed by the USACE (1998) and discharge data was provided by the USACE.

RESULTS

Adult Largemouth Bass Population Characteristics

Largemouth bass growth was faster in the Chattahoochee-Flint arms than in Spring Creek. The slope of the length-to-$\log_{10}$ age regression for data from the Chattahoochee-Flint arms was higher than that of the regression computed for Spring Creek (Figure 2). Also, age 2 to 6 largemouth bass were larger from the Chattahoochee-Flint arms than from Spring Creek (t-test; Bonferroni correction; $P < 0.0071$; Table 1). Von Bertalanffy growth equations predicted largemouth bass from Spring Creek took 0.5 years longer to reach 304 mm and 1.8 years longer to reach 406 mm than fish from the Chattahoochee-Flint arms (Table 2). Consistent with differences in growth, relative weights of quality and preferred size fish were significantly ($P < 0.10$) higher in the Chattahoochee-Flint than in Spring Creek (Figure 3).

Covariate analysis of catch-curve regressions indicated higher survival rates for fish in Spring Creek (Figure 4, ANCOVA, $P = 0.08$). The instantaneous mortality rate (Z) was -0.335 which conferred an annual survival rate of 72% in the Chattahoochee-Flint arms. In Spring Creek, the instantaneous mortality rate was -0.176 with an annual survival rate of 84%. In addition, the lower coefficient of determination for the catch-curve regression in Spring Creek indicated greater variation in year-class strength was evident in Spring Creek than in the Chattahoochee-Flint (Figure 4).

Fish from the Chattahoochee-Flint averaged 371 mm and were significantly ($P < 0.01$) larger than Spring Creek fish (mean TL = 345 mm). Length-frequency distributions of largemouth bass differed between the Chattahoochee-Flint arms and Spring Creek (Figure 5; K-S; $P < 0.01$). Fish lengths from Spring Creek (skewness = 0.50) were significantly skewed ($P < 0.05$) toward smaller fish compared to fish from the Chattahoochee-Flint rivers (skewness = -0.03).

Reproductive Potential

Female largemouth bass from the Chattahoochee and Flint arms produced more eggs than fish from Spring Creek.

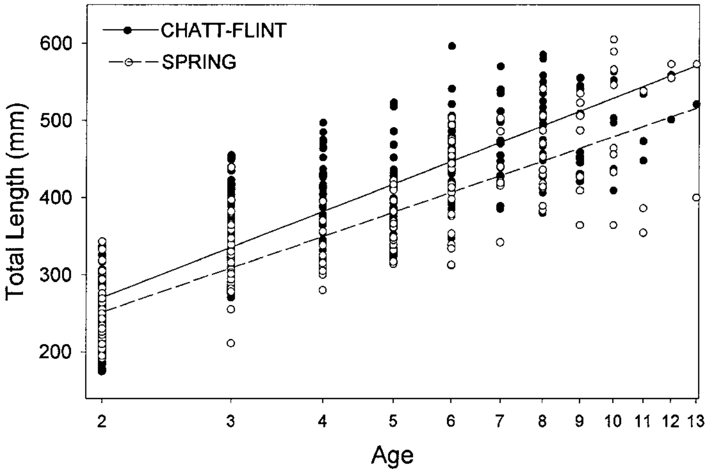

Figure 2. Regressions of total length to $\log_{10}$age for largemouth bass collected from the Chattahoochee-Flint ($r^2 = 0.74 < P < 0.01$) and Spring Creek ($r^2 = 0.75$, $P < 0.01$) arms.

Table 2. Mean total lengths at age (mtl, standard deviations (SD), and number (N) of fish collected at age for the Chattahoochee-Flint River and Spring Creek arms. Differing letters indicate significant ($P \leq 0.0071$; Bonferroni correction) derived from t-tests. age-304 and age-406 are the time in years for largemouth bass to reach 304 and 406 mm tl, respectively. Also included are mean total lengths at age and age-304 and age-406 for fish that represent the state-wide Alabama average (Maceina and Dicenzo 1995).

		Age								
Reservoir arm	Variable	2	3	4	5	6	7	8	AGE-304 (years)	AGE-406 (years)
Chattahoochee-Flint arms	MTL	248^{A}	358^{A}	401^{A}	403^{A}	459^{A}	467^{A}	488^{A}	2.52	4.26
	SD	35	42	46	52	46	52	55		
	N	100	112	43	32	47	20	24		
Spring Creek	MTL	247^{A}	327^{B}	334^{B}	361^{B}	410^{B}	432^{A}	447^{A}	3.02	6.06
	SD	35	43	37	36	56	53	17		
	N	58	35	12	16	22	7	13		
Alabama average	MTL	270	339	392	436	463	495	520	2.47	4.28

The weight-to-fecundity relations were linear in each region and indicated that larger fish were more fecund in the Chattahoochee-Flint embayments than in Spring Creek as slopes differed for these relations (Figure 6; ANCOVA; $P < 0.05$). From these regressions, predicted fecundities for 2 kg fish (corrected weight) were 29,100 eggs in the Chattahoochee-Flint compared to 24,100 eggs in Spring Creek. For 3 kg fish, predicted fecundities were 43,800 eggs in the Chattahoochee-Flint and 35,100 eggs in Spring Creek. Thus, fecundity was about 21 to 25% greater for these larger fish in the Chattahoochee-Flint than in Spring Creek. However, among the four length categories, no significant differences ($P > 0.10$) in GSI values were evident between the two major study regions.

Thus for larger fish, the number of mature ova per gram of ovary weight was greater in the Chattahoochee-Flint arms than in Spring Creek. For example, the number of mature ova per gram of gonad for fish over 1.5 kg (corrected weight) was higher in the Chattahoochee-Flint (351 eggs/g) than in Spring Creek (304 eggs/g; $P < 0.01$), a difference of 15%.

The number of ova produced at each age was much less in Spring Creek because of slower growth and a lower ova-to-body weight relation compared to the Chattahoochee-Flint (Figure 7). For all mature females 3 to 10 years old, we predicted total ova production summed for 8 age classes was 47% less in Spring Creek than in the Chattahoochee-Flint assuming similar age structure and sex ratios.

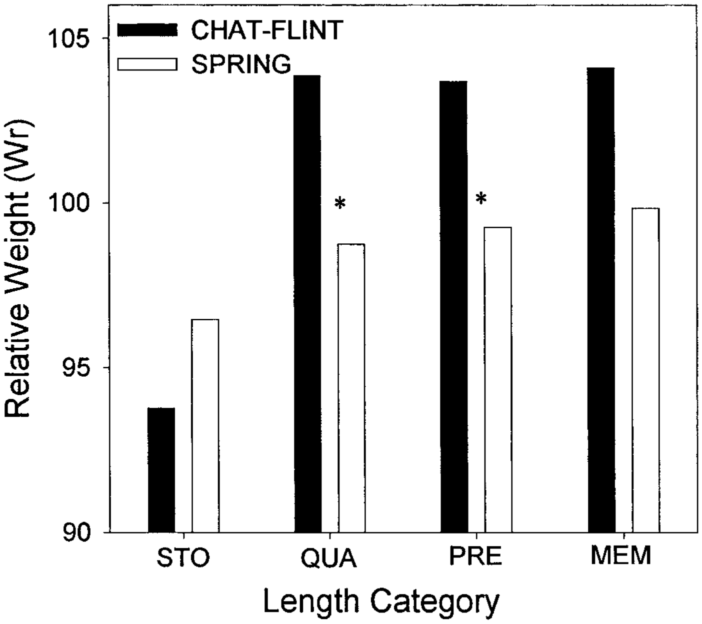

Figure 3. Comparison of mean relative weights between the Chattahoochee-Flint and Spring Creek arms for different length categories. Asterisks indicate significant ($P < 0.10$) differences between embayments. STO, stock; QUA, quality; PRE, preferred; and MEM, memorable length.

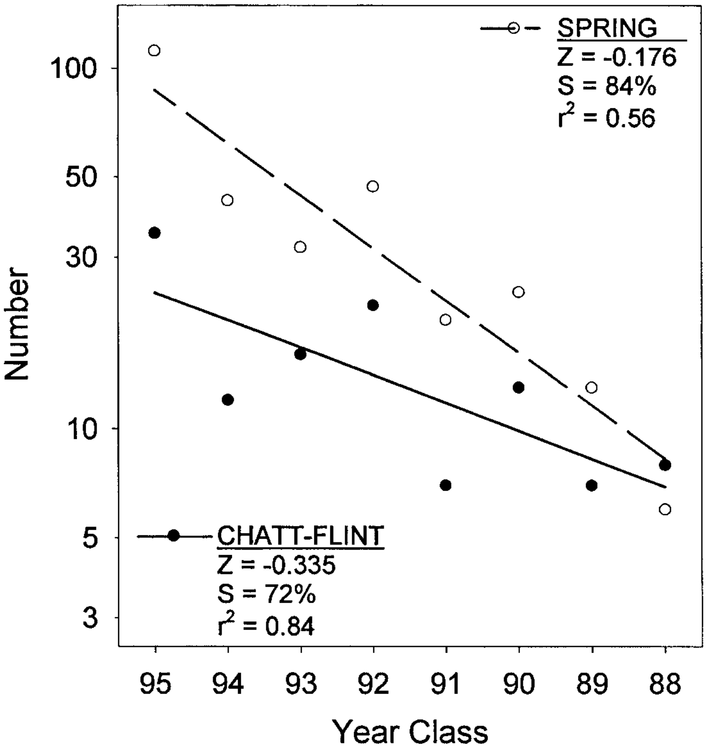

Figure 4. Catch-curves regressions, instantaneous annual mortality rates (Z), and annual survival (S) for age-3 (1995 year class) to age-10 (1988 year class) largemouth bass collected from the Chattahoochee-Flint and Spring Creek arms of Lake Seminole.

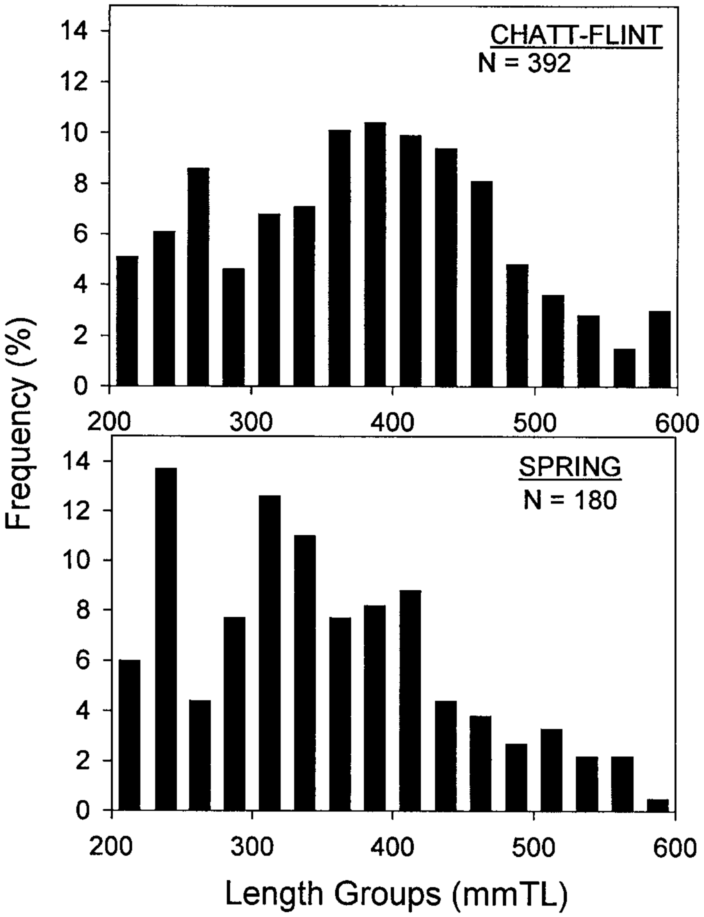

Figure 5. Length-frequency distributions for largemouth bass from the Chattahoochee-Flint and Spring Creek arms.

Hydrologic Factors Related to Formation of Strong and Weak Year-classes

For 3 to 10 year old fish pooled for the entire reservoir, strong year-class production was evident in 1990, 1992 and 1995; whereas, weak year-classes were produced in 1991, 1993 and 1994 (Figure 8). Residuals from the catch-curve regression for Lake Seminole showed no relation to vegetation cover (r = -0.11, P = 0.79), but were negatively correlated (r = -0.69, P = 0.07) with late spring to summer (April-July) discharge (Figure 8). A multiple regression equation was computed to explain variation in year-class strength:

$$\log_{10}(\text{Number}) = 6.176 - 0.286(\text{Age}) - 0.001(\text{Apr-July Discharge } [\text{m}^3/\text{sec}]) \quad \text{(eq. 1)}$$

This multiple regression model explained 92% of the variation in number-at-age and higher discharges predicted lower number of fish for a given age class. Late spring to early summer discharge explained an additional 10% of the variation beyond that explained by age alone (P = 0.06). Generally, stronger year classes were related to discharges less than 550 m^3/sec during dryer spring and early summer conditions. Alternatively, weaker year classes were evident during wetter spring and summer periods with higher reservoir discharge (>550 m^3/sec).

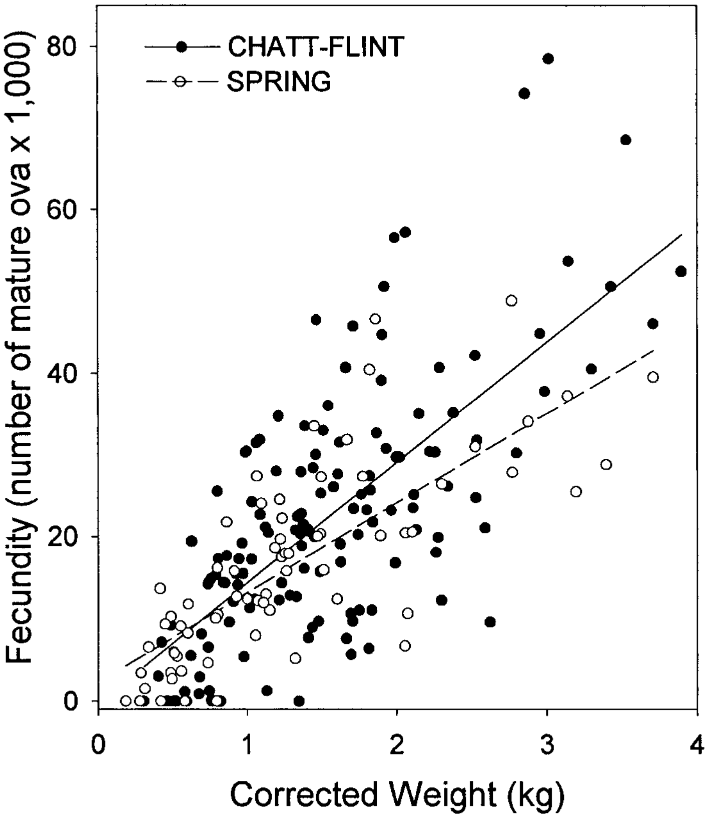

Figure 6. Fecundity-to-weight (corrected weight = body weight - gonad weight) relations for largemouth bass collected from the Chattahoochee-Flint ($r^2 = 0.51$, $P < 0.01$) and Spring Creek ($r^2 = 0.59$, $P < 0.01$) embayments.

DISCUSSION

Variable levels of SAV within Lake Seminole were associated with spatial differences in population characteristics of largemouth bass. Fish grew slower and were in poorer condition in Spring Creek that contained high levels of SAV than the Chattahoochee-Flint arms that contained much lower levels of SAV. Growth of largemouth bass from the Chattahoochee-Flint to age 5 or to 406 mm was similar to the Alabama state-wide average, while growth of fish collected in Spring Creek was consistently slower than the Alabama average (Maceina and DiCenzo 1995).

The length distribution of fish from Spring Creek was skewed more towards smaller fish than in the Chattahoochee-Flint embayments even though survival rates were higher with a larger proportion of older fish in Spring Creek. This disparity between length distributions was undoubtedly due to slower growth in this highly vegetated arm of the reservoir. Wrenn et al. (1996) also found length distributions of largemouth bass were skewed towards smaller, slower growing fish in Lake Guntersville when plant abundance was highest.

Savino and Stein (1989) determined that as plant density increased, largemouth bass switched feeding behavior from searching to ambushing which decreased foraging success. Similarly, Colle and Shireman (1980) reported lower adult largemouth bass condition in Florida lakes when hydrilla coverage was greater than 40%. In Lake Conroe, Texas, largemouth bass fed on smaller fish and invertebrates when

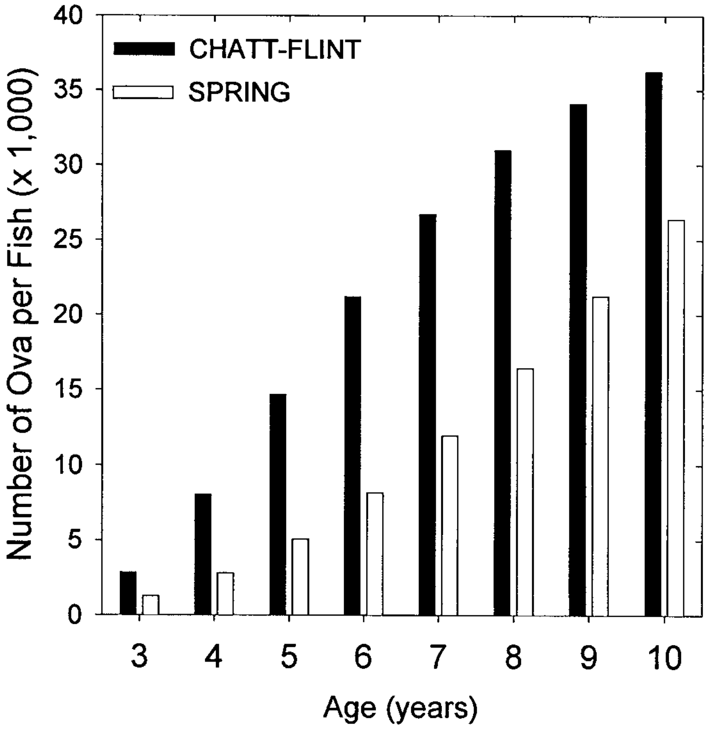

Figure 7. Predicted number of mature ova per individual ages of largemouth bass collected from the Chattahoochee-Flint and Spring Creek arms.

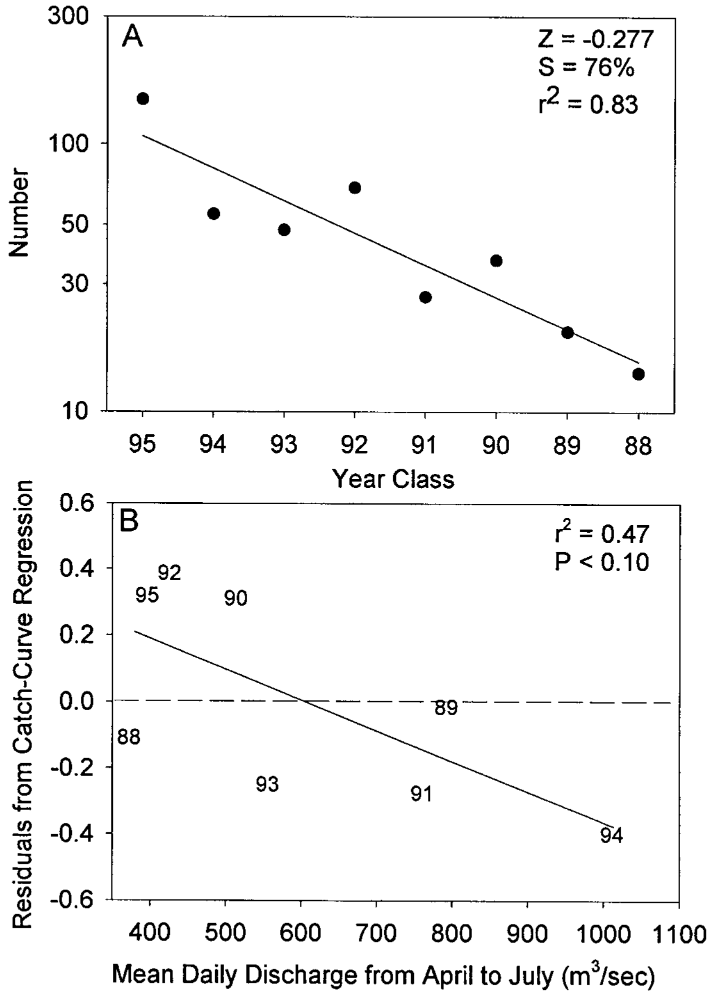

Figure 8. Catch-curves regression, instantaneous annual mortality rate (Z), and annual survival (S) for age-3 (1995 year class) to age-10 (1988 year class) largemouth bass collected from all three embayments of Lake Seminole (A, top). Residuals from the catch-curve regression plotted against mean daily discharge from Lake Seminole from 1 April to 31 July (B, bottom). This time period represented the spawn and post-spawn period when fish were age 0.

vegetation coverage was high (Bettoli et al. 1992), but switched to larger fish when vegetation was eliminated. Decreased foraging success and efficiency due to excess vegetation likely caused decreased growth and condition of fish in Spring Creek.

Catch-curve analysis indicated that survival was higher in Spring Creek than in the Chattahoochee-Flint arms. Lower survival in the Chattahoochee-Flint arms was associated with slightly higher angler harvest rates in these regions (0.31-0.38 kg/ha) compared to Spring Creek (0.26 kg/ha; Maceina and Irwin 1997). Higher survival rates in Spring Creek may also be due to lower angler accessibility of fish caused by extensive plant coverage. Maceina and Reeves (1996) speculated that the inverse relation between catch rates of largemouth bass greater than 2.27 kg and submersed macrophytes in two Tennessee River impoundments was due to reduced fish accessability to angling. Thus, the higher proportion of older fish in Spring Creek which elevated survival rates may have been due to lower exploitation of these larger fish. In addition, catch-curve analysis indicated that largemouth bass survival for the reservoir as a whole was also high and likely due to decreased angling effort for largemouth bass (Slipke et al. 1998a) and possibly greater catch-and-release practices by tournament anglers fishing Lake Seminole.

Catch-curves also showed more variation in year-class strength for Spring Creek than the Chattahoochee-Flint arms. Carline (1986) hypothesized that fish community persistence was a function of environmental stability, which in reservoirs includes minimal water level fluctuation and longer retention. Therefore, SAV which provides cover and abundant food resources for young fish should provide some habitat stability to minimize largemouth bass year-class fluctuation within an hydrologically unstable, short retention main-stem reservoir like Lake Seminole. However, catch-curves showed greater variation of year-class strength in Spring Creek where vegetation was more abundant, contradictory to the theory that high vegetation levels stabilize year-class formation. Possibly, excessive aquatic vegetation in Spring Creek caused low dissolved oxygen during summer (Buscemi 1958, Engel 1990, Frodge et al. 1990), which directly or indirectly via size dependent mortality induced decreased largemouth bass survival.

We found that overall largemouth bass recruitment in Lake Seminole was inversely related to the mean daily discharge from April to July. Mean daily discharge below 550 m^3/sec between April and July typically produced stronger year-classes, whereas, while discharge above 550 m^3/sec tended to produce weaker year-classes. Discharge greater than 550 m^3/sec conferred retention of 7 d or less, lower than the historic average of 9 d. Slipke et al. (1998b) and Maceina and

Bettoli (1998) found a similar pattern for year-class strength of smallmouth bass (*Micropterus dolomieu* L.) and largemouth bass on impoundments of the Tennessee River where low discharges during and after spawning were related to greater recruitment and high discharges during these times were associated with poor year-classes production. Similar to our findings, aquatic vegetation was not the dominant factor associated with largemouth bass recruitment in four main-stem reservoirs of the Tennessee River (Maceina and Bettoli 1998). However, the fit between number-at-age and age in the catch-curve regressions were higher in Lakes Seminole and Guntersville (see Wrenn et al. 1996) which both contained substantial SAV levels and the contribution of discharge to the catch-curve regression was less than in Tennessee River impoundments that were nearly devoid of SAV. Thus, in short retention time main-stem reservoirs such as Lakes Seminole and Guntersville, SAV appear to dampened the deleterious effects of wet climatic conditions during the spawn and post-spawn period and help to stabilize largemouth bass recruitment.

Poor fishing for largemouth bass in 1996 in Lake Seminole was likely due to two factors. 1) Poor year class production occurred in 1991, 1993, and 1994, and these weak year classes of smaller, more readily catchable fish may have resulted in lower angler catch rates. Slipke and Maceina (2000) determined angler catchability of largemouth bass declined for fish larger than 400 mm and smaller fish were caught in disproportionately higher abundances by anglers in Lake Eufaula, an upstream impoundment of the Chattahoochee River. 2) In July 1994, about 60 cm of precipitation fell in the basin in about a 24-h period from Tropical Storm Alberto, discharges were greater than 7,500 m^3/sec and aquatic vegetation was removed from the reservoir. These extreme and abrupt environmental conditions may have caused changes in largemouth bass behavior or distribution.

High SAV in Spring Creek was associated with a decline in the reproductive potential of adult female largemouth bass and the difference were manifested primarily in larger individuals. Although GSI differences were not evident between the Chattahoochee-Flint arms and Spring Creek, fish from the Chattahoochee-Flint were more fecund at larger sizes than fish in Spring Creek. This indicated that the ovaries of fish in both vegetation levels were similar in size per body weight, but fish from Spring Creek did not produce as many mature ova at larger sizes. Reduced growth and condition of larger fish in the Spring Creek arm may have shifted energy use from reproductive processes to respiration and maintenance.

A decrease in fecundity of larger fish may adversely affect recruitment in areas that contain abundant vegetation. Miranda and Muncy (1987) indicated that larger adult largemouth bass spawn earlier in the season than small ones. Other studies indicated that adults that spawned earlier in the season provided an initial length advantage for their progeny over those spawned later which enabled them to switch over to piscivory earlier in the growing season (Miller and Storck 1984, Ludsin and DeVries 1997). Thus, reduced reproductive potential of larger fish in Spring Creek may have adversely affected recruitment and was also possibly related to highly variable year-class production during the past ten years.

Management Implications

Our analyses showed that spatial differences in largemouth bass population characteristics were associated with disparate levels of SAV in a single reservoir. Largemouth bass anglers often view aquatic vegetation as beneficial to quality largemouth bass fishing regardless of the extent of vegetation coverage (Wilde et al. 1992, Slipke et al. 1998a). Although an optimal level of aquatic plant coverage for Lake Seminole could not be estimated from our analyses, hydrilla reduction in the heavily infested (76% SAV) embayment of Spring Creek will likely improve largemouth bass population characteristics. Intermediate levels (26-32%) of SAV that occurred in two reservoir embayments did not appear to be deleterious to our population metrics and would probably satisfy most largemouth bass anglers expectations for quality fishing habitat. Thus, maintaining some intermediate level of plant coverage in all regions of the reservoir is a viable management goal.

Current techniques for controlling and reducing submersed macrophytes in Lake Seminole are 1) EPA approved chemical herbicides including application of a fluridone drip-herbicide system to reduce hydrilla coverage by 1,000 to 2,000 hectares in Spring Creek (USACE 1998), 2) grass carp (*Ctenopharygodon idella* Val.) confinement within smaller embayments with electric barriers (Maceina et al. 1999), and 3) limited mechanical harvesting. Besides hydrilla reduction in Spring Creek, replacement with native SAV and improvement of largemouth bass population characteristics are desired and will be monitored over time. For aquatic plant management, balancing the needs of all types of users including largemouth bass anglers and anglers that target different species, waterfowl hunters, other water recreationalists, and home owners requires careful planning and coordination among government agencies, the public, and constituency groups.

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