Population Size, Survival, and Growth of Largemouth Bass One Year After Stocking in Four Ponds

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Abstract: Juvenile largemouth bass (*Micropterus salmoides;* approximately 50 mm total length) were stocked into four ponds (0.9 to 5.3 ha) at a rate of 248 fish ha^{-1} in late May 2003. Ponds were sampled the following spring to determine population characteristics. Largemouth bass survival ranged from 39% to 57% and appeared to be inversely related to pond size. Growth was rapid, with mean weight increasing from 1.8 g to 200–273 g in 300 days. Faster growing largemouth bass expressed greater relative weights. Catch rates of small (75 to 130 mm) bluegill (*Lepomis macrochirus*) were highly correlated to pond size and bluegill may have reduced largemouth bass survival. Catch rates of large (130 to 150 mm total length) bluegills varied much less among ponds, but ponds with bluegill catch rates ≧100 fish/hour electrofishing were characterized by greater largemouth bass relative weights. Bioenergetic models predicted that largemouth bass in these ponds were consuming food (primarily bluegill) at extremely high rates (*P*-values [proportion of maximum consumption] 0.98 to 1.04) in order to maintain the observed fast growth. Estimated bluegill consumption by largemouth bass varied between 132 and 171 kg ha^{-1} among the four ponds. This study demonstrated the potential of initial year classes of largemouth bass to maintain high growth rates during their first growing season, which likely will produce trophy-sized fish in a relatively short time.

Key words: largemouth bass, ponds, population density, survival, bioenergetics

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The concept of balance in pond management has been examined from the beginning of fisheries management in the United States (Swingle 1950*a*). Largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis macrochirus*) are typically stocked at rates to achieve a sustainable harvest of both species over time (Swingle 1950*a,* Geihsler and Holder 1983). Typically angler catch for both species is initially high (Fisher 1971) but often declines quickly, particularly when pond balance is lost due to poor pond management practices by pond owners (Geihsler and Holder 1983).

Ponds and small impoundments constitute an important fisheries resource across the United States (Mudre et al. 2000). Hess (1978) found that 40% of all fishing trips in Georgia occurred in lakes and ponds ≤19.8 ha. Management of these resources in the southeastern United States consumed an average of 10% of state fisheries and wildlife agency budgets and 11% of the personnel hours in the late 1990s (Mudre et al. 2000). Despite the obvious importance and benefit of these small systems, little research has been conducted on pond sportfish management in the last 20 years.

Although pond management has traditionally focused on maximizing fish production (Swingle 1950*a*), in recent years a paradigm shift has occurred where many pond owners desire to maximize trophy largemouth bass production (Latona 2005). Observational evidence suggested that the initial year classes of fish produce excellent fishing (Fisher 1971) and likely have the greatest potential to maximize trophy fish production (B. Deener, Georgia Department of Natural Resources, personal communication). However, little research has been conducted on population dynamics of the initial year class of largemouth bass stocked into ponds. Thus, the objectives of this study were to: 1) determine the first-year survival, density, and growth of largemouth bass stocked into new ponds and, 2) use bioenergetic simulations to estimate food consumption required to maximize growth of bass in these systems.

Methods

Study Sites and Pond Maintenance

This study was conducted at four private research ponds located at the North Auburn Fisheries Unit of Auburn University, Alabama. Ponds ranged from 0.9 to 5.3 ha but had similar mean depths (1.6 to 1.8 m) and shoreline developments (1.1 to 1.5). All ponds were completely drained in January 2003 and rotenone was applied to any remaining puddles to completely eliminate any existing fishes. Ponds were refilled in February 2003 and lime was applied in early March at the recommended rate of 7.3 mt ha^{-1}. Shortly after liming, the ponds were fertilized using a water-soluble fertilizer (10-52-4, Southeastern Pond Management, Calera, Alabama; Rushton and Boyd 2000). Fertilizer was applied at 1- to 2-week intervals at a rate of 0.7 to 1.5 kg ha^{-1} to achieve a Secchi depth of 406 to 610 mm (Rushton and Boyd 2000). Once Secchi depths reached the desired range, fertilizer was applied at the lowest rate whenever water clarity exceeded the desired range until October 2003. Ponds were stocked with bluegills (mean weight 1.4 g) in mid March 2003 at a rate of 3,705 fish ha^{-1}. The bluegill stocking rate was 50% higher than normally recommended as we attempted to maximize food resources for largemouth bass (Masser 1992). Largemouth bass (mean weight 1.8 g) were stocked into the ponds at the standard rate of 248 fish ha^{-1} (Swingle 1950*b*) in late May 2003, after bluegills had spawned.

Fish Sampling

Largemouth bass and bluegill were collected at night using a boom-mounted electrofishing boat in mid–March 2004. Each pond was divided into 2 or 3 transects of 5- or 10-minute duration, depending on the size of the pond. All fish were collected during the first five minutes of each transect, thereafter only largemouth bass were collected until the end of the transect. Additional largemouth bass were collected in each pond to compute a population estimate; sampling effort was not recorded for these additional sampling transects.

All largemouth bass collected were measured (total length, TL), weighed (g), marked with a fin clip and released. All bluegill over stock size (75 mm TL) were measured. All ponds were sampled again in 7 to 10 days to estimate the largemouth bass population in each pond; all largemouth bass collected were measured, weighed, and examined for the presence of a mark. In the largest pond (S-30), unmarked largemouth bass were marked with a fin clip and a third collection was made 7 days later to increase the number of recaptured fish, which decreased the variation of the population estimate.

Data Analysis

Population Estimates. In the three smaller ponds (S-15, S-22, S-28) the largemouth bass population was estimated using the Chapman's modified Petersen/Lincoln single census mark-recapture estimator of the form:

$$N = \frac{(M + 1)(C + 1)}{(R + 1)} \quad (1)$$

Where N = estimated population size, M = number of fish marked during the first run, C = the number of fish (marked and unmarked) collected during the second run, and R = the number of marked fish recaptured in the second run. The variance of the estimate was calculated using the normal approximation method:

$$Var_N = \frac{(M + 1)(C + 1)(M - R)(C - R)}{(R + 1)^\wedge 2 * (R + 2)} \quad (2)$$

In S-30 the largemouth bass population was estimated using the Schnabel multiple census mark-recapture estimator of the form:

$$\frac{1}{N} = \frac{\sum Rt}{\sum (Ct * Mt)} \quad (3)$$

Where N = population estimate, t = sample number, M = number of marked fish at large in the pond during each sample, and R and C are as defined above. The reciprocal of N was used to estimate population size because the reciprocal was more normally distributed (Ricker 1975). The variance of the estimate was calculated using:

$$Var_{(1/n)} = \frac{\sum Rt}{(\sum Ct * Mt)^\wedge 2} \quad (4)$$

Confidence intervals (95%) were computed for each population estimate by multiplying the standard error by a t-value of 1.96 as C was greater than 30 fish for each estimate.

Population Characteristics. First-year survival of stocked largemouth bass was calculated for each pond by dividing the population estimate by the initial number stocked. Catch-per-effort (CPE; number per hour) was calculated for two size class-

Table 1. Initial number stocked, population estimate after one year (95% confidence intervals), one-year survival estimate, density, biomass and electrofishing catch rates (standard deviation) of largemouth bass in four ponds at Auburn University, Alabama.

	Ponds			
	S-15	S-22	S-28	S-30
Pond area (ha)	2.3	0.9	1.9	5.3
Initial *N* stocked	570	215	474	1320
Population estimate	285	123	209	509
	(242, 327)	(111, 134)	(187, 231)	(429, 625)
Survival (%)	50	57	44	39
	(42, 58)	(52, 63)	(39, 49)	(33, 47)
Density (*N*/ha)	124	137	110	96
Biomass (kg/ha)	26.0	34.4	22.0	26.5

es of bluegills (small fish, 75 to 129 mm TL; and large fish, 130 to 150 mm TL) and compared among ponds using an ANOVA (SAS 2002). All CPE data were $\log_{10}$-transformed prior to analysis. Total lengths and relative weight (Anderson and Neumann 1996) of largemouth bass and bluegills were compared among ponds using an ANOVA. Relations among population characteristics of both species and pond size were examined with a Pearson correlation (SAS 2002). All statistical comparisons and correlations were considered significant at $P \leqq 0.10$.

Bioenergetics Modeling. Food consumption by largemouth bass was simulated using a generalized bioenergetics model (Hanson et al. 1997) for all four study ponds. Largemouth bass diet composition was assumed to be similar to that found in a previous study in these same ponds (Irwin et al. 2003) and these data were used in the bioenergetics model. Water temperatures were taken in each pond periodically during the study. Caloric density of diet items were taken from a previous study on these ponds (Irwin et al. 2003). All metabolic variables for the mass balance equation were the default values in the Wisconsin model (Rice et al. 1983), which have been validated for largemouth bass (Rice and Cochran 1984).

Daily food consumption of largemouth bass was estimated for the period between the day when the fish were stocked and the time of sampling in March 2004 (300 total days). The percent of maximum consumption (*P*-value) was estimated for each pond, based on mean initial (stocking) and ending (sample) weight of largemouth bass. Total predator demand of bluegill for prey was estimated for each pond by combining estimated consumption of bluegill with population and survival estimates.

Results

Largemouth bass population size ranged from 123 to 509 individuals, which conferred densities between 96 and 137 fish ha^{-1} (Table 1). First-year survival of

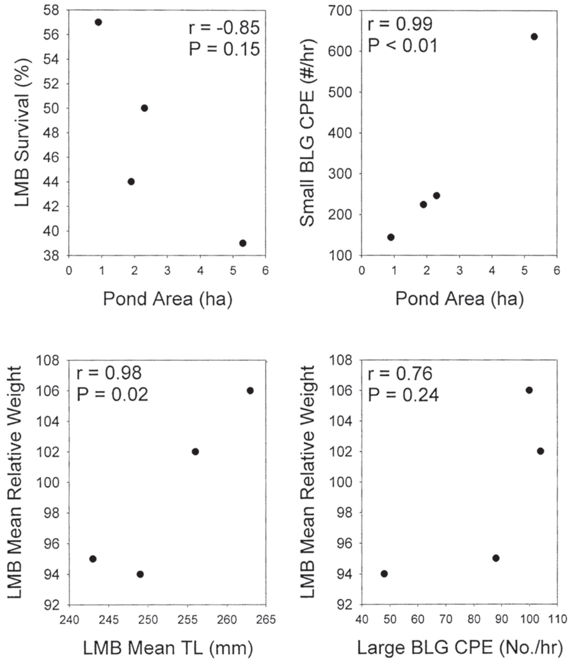

Figure 1. Correlations between pond area and population characteristics of largemouth bass (LMB) and bluegill (BLG) in four ponds at Auburn University, Alabama.

largemouth bass ranged from 39% to 57% (Table 1) and appeared to be inversely related to pond size (Fig. 1). Three of the ponds supported similar biomass of largemouth bass after one year (22 to 27 kg ha^{-1}); however, biomass was noticeably higher (34 kg ha^{-1}) in the smallest pond, S-22 (Table 1).

Size of largemouth bass differed among all four ponds, but was not related to pond size (Table 2; $P > 0.10$). Largemouth bass growth was rapid; on average, fish grew from 1.8 g to 200–276 g in about 300 days. Weights of largemouth bass in two of the ponds was considerably less than in the other two ponds, and these fish expressed lower relative weights (Table 2). Fish in ponds with the largest size also expressed the highest relative weights (Table 2; Fig. 1). Catch rates of small stock–size bluegills varied more than four-fold and were highly correlated to pond size (Table 3; Fig. 1). Catch rates of large stock-size bluegills varied much less among ponds and was not correlated to pond size ($P > 0.10$), but ponds with catch rates ≥ 100 fish/hour tended to have higher largemouth bass relative weights (Table 3; Fig. 1).

Daily growth rates simulated by bioenergetics models were similar between S-15 and S-28, and similar between S-22 and S-30 (Table 4). Estimated *P*–values were quite high, ranging from 0.98 to 1.04 among simulations, which was expected based on the observed rapid growth (Table 2). Bioenergetic models estimated that the largemouth bass population in these ponds consumed between 132 and 171 kg ha^{-1} of bluegills to maintain the observed growth (Table 4).

Table 2. Mean total lengths, mean weights, and mean relative weights of largemouth bass in four ponds at Auburn University, Alabama. Numbers in parentheses are standard deviations. Means followed by the same letter were similar (Student-Newman-Keuls test, $P > 0.10$).

	Ponds			
	S-15	S-22	S-28	S-30
Mean total length (mm)	249c	256b	243d	263a
	(20)	(18)	(21)	(24)
Mean weight (g)	211c	252b	200c	276a
	(72)	(66)	(79)	(89)
Mean relative weight	94c	102b	95c	106a
	(8)	(7)	(11)	(9)

Table 3. Mean CPE of two size classes and mean total length of bluegill in four ponds at Auburn University, Alabama. Numbers in parentheses are standard deviations. Means followed by the same letter were similar (Student-Newman-Keuls test, $P > 0.10$).

	Ponds			
	S-15	S-22	S-28	S-30
Mean CPE, 75–129 mm TL	246b	144b	224b	636a
	(110)	(21)	(62)	(176)
Mean CPE, ≥ 130 TL	48a	104a	88a	100a
	(17)	(62)	(28)	(62)
Mean total length (mm)	104c	126a	119b	108c
	(22)	(16)	(16)	(18)

Table 4. *P*-value, daily specific growth rate, and bluegill consumption of largemouth bass estimated using a bioenergetics model in four ponds at Auburn University, Alabama.

Pond	Daily specific growth rate (g/g/d)	*P*-value	Annual consumption of bluegills (kg/ha)
S-15	0.0161	0.99	144.77
S-22	0.0167	1.02	171.08
S-28	0.0159	0.98	131.48
S-30	0.0170	1.04	159.92

Discussion

Not surprisingly, the densities of largemouth bass found in this study were lower than those reported for more established systems consisting of multiple year classes of fish (Irwin et al. 2003). Irwin et al. (2003) found densities of largemouth bass as high as 351 fish ha^{-1} in similar systems that were established for 8–10 years. Growth of largemouth bass was extremely fast in these newly stocked ponds, gaining an average of 0.66 to 0.91 g d^{-1}. Fast growth should be expected for largemouth bass in renovated ponds, assuming that a food supply was established before the largemouth bass are stocked. Due to the high bluegill stocking rate, largemouth bass presumably had an abundant food supply. The relatively low density of largemouth bass, coupled with an assumed unlimited food supply, allowed these fish to forage at close to maximum rates, leading to rapid growth and high condition or relative weight (Guy and Willis 1990). Other authors have found high growth rates for initial year classes of largemouth bass in newly impounded reservoirs (Shelton et al. 1979, Maceina and Isely 1986).

Survival of stocked largemouth bass were similar to results found in other pond studies (Swingle 1950*b,* Johnson and MacCrimmon 1967, Stone and Modde 1982), which was surprisingly low, considering they were stocked at relatively low densities into predator-free ponds. Late summer survival of age-0 largemouth bass found in this study was similar to the rates in a Tennessee reservoir in years characterized by stable water levels (Sammons et al. 1999). In contrast, Boxrucker (1983) found that largemouth bass stocked at 448 ha^{-1} contributed more than 68% of year-class strength up to one year after stocking into an 82-ha Oklahoma lake. However, the survival rates observed in this study were much greater than those observed for stocked largemouth bass in large reservoirs (Neal and Noble 2002, Buckmeier et al. 2003). The largemouth bass in this study were stocked into ponds containing a high density of bluegills, which may have affected survival of largemouth bass through competition (Brenden and Murphy 2004). Further supporting this hypothesis was the fact that largemouth bass survival was lowest in the pond with the highest bluegill CPE.

Given the fast growth of the initial year class of largemouth bass in these ponds, estimated predator demand was high. Each population of largemouth bass was predicted to have consumed 4.2 to 6.7 times their own biomass in bluegills to maintain these growth rates and biomass. These estimates are quite high; however, annual production of prey fishes in fertilized North Carolina ponds was estimated at 166 kg ha^{-1} (Neal et al. 1999), which was within the range of consumption estimated from this study. Bioenergetic models estimated that largemouth bass consumption was at or slightly above maximum rations to maintain the high growth rates observed during this study. These high *P*-values were unusual, but appeared to be close approximations based on the *P*-values found by Irwin et al. (2003) for largemouth bass populations with much lower growth rates. Largemouth bass growth rates were lower in these ponds during that study due to the high biomass of fish that had accumulated over 8–10 years (Irwin et al. 2003), thus consumption would be lessened. Other studies have observed fishes consuming maximum rations in experimental systems (Breck 1993). However, recent research has revealed consumption-dependent error in many bioenergetic models, including the one used in this study, which was particularly large when growth rates were fast (Bajer et al. 2004). Thus, the *P*-value and consumption by largemouth bass estimated in this study were likely underestimates, which may indicate that the bluegill densities in the ponds we used in this study may not be great enough to meet predator demand in the future, leading to slower growth, poorer condition, and a possibly lower production of trophy-sized fish.

In summary, the initial year class of largemouth bass stocked into these ponds were characterized by relatively low first-year survival, further reducing already low largemouth bass densities. These low densities combined with a high density of bluegills for prey allowed largemouth bass to forage at almost maximum rates for close to a year, leading to fast growth and high relative weight. Growth and survival rates of largemouth bass during their first year of life have been found to be critical factors determining the future contribution of that year class to the fishery (Sammons et al. 1999). Obviously, largemouth bass growth and relative weight in ponds are highly dependent on the population density of largemouth bass and their prey (Guy and Willis 1990, Irwin et al. 2003). Subsequent year classes of largemouth bass in these systems are not likely to exhibit the fast growth observed in this study, as largemouth bass densities increase (Irwin et al. 2003). This study has demonstrated the potential of initial year classes of fish to produce trophy-sized fish in small ponds, and illustrated the importance of low largemouth bass densities in maintaining rapid growth, coupled with high initial bluegill stocking rates. However, the fact that the high consumption rates of largemouth bass found in this study may have been underestimates serves as warning of how delicate predator-prey balances are in small ponds, and how easily predator demand can exceed prey supply if predator densities are not strictly controlled (Geihsler and Holder 1983).

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