Mortality and Growth of Young-of-year Wild Largemouth Bass following Stocking of Hatchery-reared Fingerlings

Jeffrey R. Horne,[1] *Aquaculture/Fisheries Center, University of Arkansas at Pine Bluff, Mail Slot 4912, 1200 N. University Dr., Pine Bluff, AR 71601*

Steve E. Lochmann, *Aquaculture/Fisheries Center, University of Arkansas at Pine Bluff, Mail Slot 4912, 1200 N. University Dr., Pine Bluff, AR 71601*

Abstract: Stocking hatchery-reared largemouth bass (*Micropterus salmoides*) fingerlings to supplement wild populations is a common practice, but assessment of the influence of such stocking practices on the wild population is less common. In September 2007 and 2008, we estimated abundance of wild young (age 0 and age 1, respectively) largemouth bass in backwaters of the Arkansas River before and after stocking with hatchery-reared largemouth bass (100–150 mm TL). Two backwaters were sampled as reference populations, four backwaters were unstocked for comparison with stocked locations. Five backwaters were stocked with 60 fish/ha. We found no differences in mortality, length, weight, or condition of wild age-1 largemouth bass from stocked and unstocked backwaters. Stocking hatchery-reared largemouth bass did not appear to affect mortality, growth, or condition of the wild year class.

Key words: largemouth bass, fingerling, stock, wild, mortality

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The Arkansas Game and Fish Commission stocks largemouth bass (*Micropterus salmoides*) fingerlings (20- to 250-mm TL young-of-year fish) into the Arkansas River as a means of supplementing the existing population (Heitman et al. 2006). Stocking hatchery-reared largemouth bass to supplement wild populations is a common management activity (Hoffman and Bettoli 2005). Supplemental stocking is used by fisheries managers in systems that exhibit poor recruitment (Smith and Reeves 1986, Hoffman and Bettoli 2005).

Stocking studies commonly compare the length, weight, growth rate, and mortality rate of wild and hatchery-reared fish. For example, a study examining survival from spring (when fish were stocked) to the subsequent fall in an Illinois impoundment found no significant difference in survival of wild and hatchery-reared largemouth bass (Hoxmeier and Wahl 2002). Heitman et al. (2006) stocked 50-mm TL largemouth bass in two pools of the Arkansas River in June. The following May, wild and hatchery-reared largemouth bass had similar growth rates. Studies examining the effect of hatchery-reared largemouth bass on growth or mortality rates of wild largemouth bass, with a control of wild largemouth bass uninfluenced by hatchery-reared fish, are less common. We found only one such study. On a Tennessee reservoir system, stocking hatchery-reared fingerling largemouth bass did not affect the mortality of wild age-0 largemouth bass (Hoffman and Bettoli 2005). It is important for management agencies to not adversely impact the wild population, and no studies to date have definitively shown stocking to be benign to the existing population.

Management agencies that stock fingerling largemouth bass into bodies of water with existing largemouth bass populations should take into consideration the potential effects on age-0 fish from the wild population. Copeland and Noble (1994) suggested that the carrying capacity of a system be determined before hatchery-reared largemouth bass are stocked, to limit the potential effect of stocking on survival and growth of wild fish. The objective of this study was to determine whether the mortality, growth, or condition (defined as relative weight, Wege and Anderson 1978) of young wild largemouth bass varied between fish from stocked and unstocked backwaters (i.e., still waters of inlets off the main channel) of the Arkansas River.

Study Site

The study area for this project was Pool 4 of the McClellan-Kerr Arkansas River Navigation System (Figure 1). Pool 4 is approximately 32 km long, stretching from Lock and Dam 5 near Jefferson, Arkansas, to Lock and Dam 4 near Pine Bluff, Arkansas. Pool 4 has 12 distinct backwaters, which we numbered 1–12 for

1. Present address: Maryland Department Natural Resources, 580 Taylor Avenue, Tawes State Office Building, Annapolis, MD 21401.

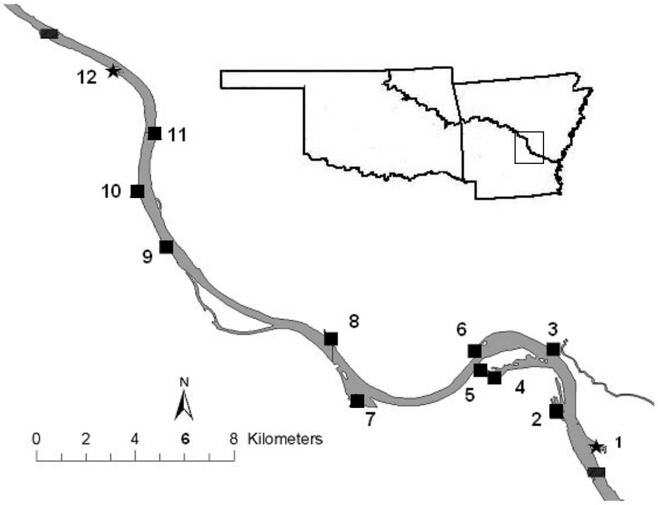

Figure 1. Map of the study site showing the locations of 12 backwaters on Pool 4 of the Arkansas River. Black squares are study backwaters, stars are the reference backwaters, and rectangles are the upstream and downstream dams.

Table 1. Abundance and density of age-0 wild largemouth bass for 2007 and age-1 wild largemouth bass for 2008 in backwaters of the Arkansas River. The table also includes backwater area and number of hatchery-reared largemouth bass stocked. Backwaters 2, 3, 4, 9, and 11 were stocked. Backwaters 5, 7, 8, and 10 were unstocked.

Backwater	Area (ha)	2007 abundance (fish)	2007 density (fish/ha)	Number stocked (fish)	2008 abundance (fish)	2008 density (fish/ha)
2	2.6	na[a]	na	156	na	na
3	1.2	18	15	72	14	12
4	1.9	na	na	114	17	9
9	3.2	85	27	192	7	2
11	2.6	57	22	156	6	2
5	4.5	na	na	0	43	10
7	16.6	454	27	0	400	24
8	2.4	68	28	0	13	5
10	3.8	90	24	0	3	1

a. na means no estimate was possible due to no or limited recaptures.

this study (Figure 1). The first and twelfth backwaters were sampled as reference areas to determine up-stream or down-stream movement of hatchery-reared fish. We excluded from the study Lake Langhofer, an oxbow that was created when the Corps of Engineers leveed part of the Arkansas River. Lake Langhofer has a surface area of more than 900 ha and therefore differs considerably from the other backwaters in this study. Backwater 6 was excluded from the analysis, because access was blocked by a sandbar during the study. The nine backwaters included in the analysis ranged in size from 1.2 to 16.6 ha (Table 1), and were generally similar in depth and water quality.

Methods

Wild age-0 largemouth bass abundance in each backwater was estimated using the Jolly-Seber mark-recapture method (Hightower and Gilbert 1984) and electrofishing. Largemouth bass were collected by barge and boat electrofishing. Barge electrofishing was used in wadeable areas, and handheld electrofishing from a boat was used in deeper areas. Both gears utilize the same electrofishing probe and generator. Electrofishing settings were standardized based on water temperature and conductivity (Burkhardt and Gutreuter 1995). Sampling was conducted along shoreline habitat from a random starting point. In large backwaters (≥2 ha), sampling was conducted until one pass around the backwater was completed or 120 min had elapsed. In small backwaters (<2 ha), cessation of sampling occurred after two passes around the backwater were completed or 120 min had elapsed. This scheme standardized effort among backwaters.

The Jolly-Seber method was used to estimate abundance and density of wild age-0 largemouth bass in 2007 and wild age-1 largemouth bass in 2008. The Jolly-Seber mark-recapture studies on wild age-0 largemouth bass were conducted in four sampling periods one week apart throughout September 2007. During the first sample period, age-0 largemouth bass were marked with an orange visible implant elastomer (VIE) mark on the right cheek in the subcutaneous tissue, measured for total length and weight, and released. Any largemouth bass <150 mm TL was considered an age-0 largemouth bass. This age group was based on existing age and length data from the Arkansas River (Batten 2008). During the second sample period, age-0 largemouth bass were examined for the orange VIE mark and a blue VIE mark was applied (next to the orange mark, if present). During the third sample period, age-0 largemouth bass were examined for orange or blue VIE marks, and marked with a red VIE mark next to the previous marks (if present). During the fourth sample period, largemouth bass were examined for the three previous VIE marks.

Captive spawned largemouth bass fingerlings (75–100 mm TL) were transported to the University of Arkansas at Pine Bluff Aquaculture Research Station in August 2007. Each largemouth bass was marked by clipping off the left pelvic fin (Boxrucker 1982). These largemouth bass were stocked into three 0.1-ha earthen ponds at 16,000 fish/ha and reared to 100–150 mm TL. The ponds were aerated from 2000–0800 hours each day. Largemouth bass were fed fathead minnows (*Pimephales promelas)* at approximately 4% of their body wt/d.

In October 2007, the ponds were harvested. Left pelvic fins of all harvested fish were examined to ensure that hatchery-reared fish could be discerned from wild fish. Left pelvic fins were reclipped as needed. A sample of 100 hatchery-reared largemouth bass were individually weighed and measured. At the end of a 72-h holding period, the hatchery-reared largemouth bass were stocked into five randomly-selected backwaters at a rate of 60 fish/ha (the median stocking density from existing literature, see Heitman et al. 2006). The other four backwaters were not stocked. To determine handling mortality, 60 hatchery-reared largemouth bass were placed on the boat during stocking and subsequently placed into three 80-L tanks.

In September 2008, Jolly-Seber mark-recapture studies were conducted to determine abundance of wild age-1 largemouth bass in each backwater. Boat-mounted electrofishing in shoreline habitat was used, because largemouth bass were large enough to be fully susceptible to this gear. Largemouth bass from 150–300 mm TL were considered age-1 fish (Batten 2008). As before, all backwaters were electrofished until one (in large backwaters) or two (in small backwaters) passes around the backwater were completed or 120 min had elapsed. Wild age-1 largemouth bass received VIE marks on the left cheek during the first three of the four sample periods, as previously described. Total length and weight were recorded for all age-1 largemouth bass.

Population densities were expressed as fish/ha and used to calculate instantaneous mortality rates during the study period. Daily instantaneous mortality rates were calculated by regressing the natural log of density on sample day, with the instantaneous mortality rate being the slope of this regression. A two-sample *t*-test ($\alpha = 0.05$ in all statistical tests) was performed to compare the instantaneous mortality rates in stocked and unstocked backwaters.

Average weights and lengths of wild age-0 largemouth bass from each backwater were compared to the average weight and length of hatchery-reared age-0 largemouth bass using a one-sample *t*-test. Age-1 largemouth bass condition was estimated using relative weight. Average conditions of age-1 wild largemouth bass from stocked and unstocked backwaters were compared with a two-sample *t*-test. Average lengths and weights of age-0 and age-1 wild largemouth bass were used to estimate growth in length and growth in weight of wild largemouth bass for each backwater. Growth in weight was determined using regression to calculate instantaneous growth rates for each backwater. Growth in length for each backwater was the difference between average length of age-0 and age-1 wild largemouth bass divided by the average number of days between the two samples. Two-sample *t*-tests were used to compare growth in weight and growth in length of wild largemouth bass from stocked and unstocked backwaters.

Results

There was no significant difference between the average weight or length of wild and hatchery-reared largemouth bass at the time of stocking (weight: $t = -0.32$, df = 8, $P = 0.76$; length: $t = 0.46$, df = 8, $P = 0.66$). The average weights of wild largemouth bass ranged from 12–21 g, whereas the average (SD) weight of hatchery-reared largemouth bass at the time of stocking was 17 (12) g (Table 2). Average total lengths of wild largemouth bass ranged from 102–120 mm, whereas the average total length of hatchery-reared largemouth bass was 106 (22) mm (Table 2). Handling mortality from the stocking process was 6.7% after one week.

Abundance of wild age-0 largemouth bass ranged from 18–454 in 2007 (Table 1). Abundance of wild age-1 largemouth bass ranged from 3–400 in 2008. Abundances could not be calculated for backwater 2 in either 2007 or 2008, nor for backwaters 4 and 5 in 2007 because of low recapture rates. Density of wild age-0 largemouth bass ranged from 15.0–28.3 fish/ha in 2007, while density of wild age-1 largemouth bass ranged from 0.7 to 24.1 fish/ha in 2008 (Table 1). No hatchery-reared fish were captured in the reference backwaters 1 or 12.

Daily instantaneous mortality for wild largemouth bass in unstocked backwaters ranged from 0.0004–0.0100, and averaged 0.0051 (0.0048), whereas in stocked backwaters largemouth bass daily instantaneous mortality ranged from 0.0006–0.0066, and averaged 0.0048 (0.0036). Daily instantaneous mortality was not significantly different between stocked and unstocked backwaters ($t = 2.78$, df = 4, $P = 0.94$).

No significant difference was found between the average relative weights of wild largemouth bass in stocked and unstocked backwaters ($t = 0.62$, df = 7, $P = 0.55$). Similarly, no difference was found in instantaneous growth in weight or length of wild largemouth bass in stocked and unstocked backwaters (weight: $t = 0.30$,

Table 2. Average (SD) weight and length of wild age-0 largemouth bass in backwaters of the Arkansas River before stocking. Hatchery-reared largemouth bass are included in this table for comparison. Backwaters 2, 3, 4, 9, and 11 were stocked. Backwaters 5, 7, 8, and 10 were unstocked.

Backwater	Weight (g)	Length (mm)
2	18 (11)	113 (20)
3	15 (16)	103 (31)
4	12 (6)	102 (16)
9	17 (10)	115 (18)
11	15 (8)	109 (16)
5	14 (11)	104 (21)
7	13 (8)	102 (17)
8	19 (11)	116 (19)
10	21 (14)	120 (23)
Hatchery-reared largemouth bass	17 (12)	106 (22)

Table 3. Average (SD) weight, average length, average condition, growth in weight, and growth in length of wild age-1 largemouth bass after stocking. Condition is relative weight (W_r). Backwaters 2, 3, 4, 9, and 11 were stocked. Backwaters 5, 7, 8, and 10 were unstocked.

Backwater	Average weight (g)	Average length (mm)	Condition (W_r)	Growth (instant wt)	Growth (mm/d)
2	231 (81)	256 (28)	98 (1)	0.007	0.40
3	184 (62)	242 (31)	95 (8)	0.007	0.39
4	230 (90)	253 (41)	96 (8)	0.008	0.43
9	193 (73)	245 (31)	94 (7)	0.007	0.37
11	229 (72)	261 (32)	92 (7)	0.008	0.43
5	234 (93)	257 (38)	95 (8)	0.008	0.43
7	235 (75)	261 (30)	95 (7)	0.008	0.45
8	207 (86)	250 (36)	93 (8)	0.007	0.38
10	193 (73)	245 (29)	94 (4)	0.006	0.35

df = 7, $P = 0.77$: length: $t = 0.06$, df = 7, $P = 0.95$). Average relative weights of wild largemouth bass ranged from 92–98 and 93–95, in stocked and unstocked backwaters, respectively (Table 3). The instantaneous weight gain for wild largemouth bass in stocked and unstocked backwaters ranged from 0.007–0.008 and 0.006–0.008, respectively (Table 3). Growth in length for wild largemouth bass in stocked and unstocked backwaters ranged from 0.37–0.43 mm/d and 0.35–0.45 mm/d, respectively.

Discussion

The observation of similar mortality rates for wild largemouth bass in stocked and unstocked backwaters is consistent with the one other comparable study. Hoffman and Bettoli (2005) detected no effect of stocking hatchery-reared largemouth bass fingerlings on the mortality of wild age-0 largemouth bass. However, daily instantaneous mortality rates for wild largemouth bass were greater in their study than in our study. Hartman and Janney (2006) reported that hatchery-reared largemouth bass also did not affect the mortality of wild largemouth bass, though hatchery-reared fish were stocked at much larger sizes in their study than in our study.

Another similarity between this and previous studies is high variability of juvenile largemouth bass mortality rates. Hightower et al. (1982) reported wild age-0 largemouth bass annual mortality rates ranging from 0–89% for different year classes from Lake Oconee, Georgia. Although it seems unlikely that mortality rates are ever zero, the Hightower et al. (1982) study illustrates the variability inherent in age-0 largemouth bass mortality. Mortality rates for young largemouth bass can vary for a number of reasons, including water conditions, winter severity, growing season length, and size of largemouth bass by the end of the first growing season (Hightower et al. 1982, Fullerton et al. 2000, Jackson and Noble 2000, Pine et al. 2000). We are unsure of the specific reasons for variable juvenile mortality rates among Arkansas River backwaters that appear similar. Determining the causes of this variability was beyond the scope of this study.

Ensuring high statistical power is difficult in this type of study. Hoffman and Bettoli (2005) failed to reject the null hypothesis of hatchery-reared largemouth bass having no effect on mortality of the wild year class. However, the power of their experiment was low due to small sample size. They had four stocked and two control backwaters. We attempted to increase the number of stocked and control backwaters, but poor recaptures during the Jolley-Seber procedures led to our study also having low sample size. The high variability of juvenile largemouth bass mortality rates, and the similarities in mean mortality rates between stocked and unstocked backwaters, also reduced statistical power in our study ($1 - \beta = 0.05$). Therefore, our failure to reject the hypothesis of no difference in mortality rates of wild largemouth bass between stocked and unstocked backwaters must also be presented with caution.

The length and weight of wild largemouth bass and hatchery-reared largemouth bass were similar at the time of stocking in our study. Other studies have found that hatchery-reared largemouth bass, stocked at the same size as wild largemouth bass, have no apparent feeding or competitive advantage over their wild counterparts (Colvin et al. 2008). Hatchery-reared largemouth bass stocked at the same size as wild largemouth bass are generally the same size after being in the system more than six months (Buckmeier and Betsill 2002, Neal et al. 2002, Colvin et al. 2008, the present study). In the Arkansas River, size-dependent mortality, if present, should not be different for hatchery-reared and wild largemouth bass.

Growth in length of Arkansas River largemouth bass was similar to growth reported from other studies involving supplemental stocking of largemouth bass. Hoffman and Bettoli (2005) reported growth rates for wild (0.40 mm/d) and hatchery-reared (0.50 mm/d) largemouth bass. Growth rates of wild and hatchery-reared fish were equivalent in both studies, and the actual growth rates were similar between these two studies. Although relative weight targets depend on specific management goals (Murphy et al. 1991), Anderson and Gutreuter (1983) suggest that mean relative weight values near 100 generally represent, "ecological and physiological optimality within the fish population in question." Average relative weights of age-1 largemouth bass at the end of our study were near 100 in both stocked and unstocked backwaters. Together, these results appear to indicate that stocking hatchery-reared largemouth bass had little or no effect on the growth or condition of wild largemouth bass from the same year class.

For a supplemental stocking program to be successful, hatchery-reared fish should not negatively affect mortality or growth of wild fish, and hatchery-reared fish should be present when the year class enters the fishery. Our results indicate that in Pool 4 of the Arkansas River, supplemental stocking of hatchery-reared largemouth bass advanced-fingerlings did not negatively influence growth or condition. We failed to reject the hypothesis that there was no difference in mortality of wild largemouth bass in the 2007 year class in stocked and unstocked backwaters. However, these results are clearly influenced by stocking density and the size of the wild year class. If the wild year class was stronger, or the stocking density was higher, competition for resources would be more likely. Therefore, future research might focus on quantifying the relationship between year-class strength, stocking density, and influence of stocking on growth and survival of wild age-0 largemouth bass. This would allow managers to determine the point of diminishing return, where stocking more hatchery-reared largemouth bass would negatively influence growth and survival of wild fish from the same year class. Furthermore, future studies might run for longer periods to confirm the presence of hatchery-reared fish in a year class, as the year class enters the fishery.

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