A Comparison of Three Stocking Densities for Rearing 150-mm Florida Largemouth Bass, *Micropterus salmoides floridanus*, in Ponds

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ABSTRACT

In 2005, Texas Parks and Wildlife Department fisheries biologists requested advanced largemouth bass (150-mm total length) for research that required rearing 38-mm fish to 150 mm in about 164 d. We evaluated three stocking densities (2,500, 5,000 and 7,500 fish/ha) of 38-mm fish to determine which one promoted the best production performance {size (fish/kg), survival, and harvest length} to produce 150-mm fish in grow-out ponds in 164 d. Fifteen 0.4-ha plastic-lined ponds (five per stocking density treatment) were stocked with 38-mm fingerlings. These fish were fed fathead minnow *Pimephales promelas* and koi (a variant of common carp *Cyprinus carpio*) at 11.3 kg per 1,000 fingerlings at 14-d intervals throughout the study period (May-November). All stocking density treatments produced 150-mm fish in the study time frame. There were no significant differences in harvest length or size among stocking densities. Survival was similar for the 2,500- and 7,500-fish/ha treatments but significantly lower for the 5,000-fish/ha treatment. For efficient use of pond space, the 7,500-fish/ha density may be used for the production of 150-mm fish. Future research should evaluate higher stocking densities since the 7,500 fish/ha did not appear to be the maximum carrying capacity of the study ponds.

INTRODUCTION

Texas Parks and Wildlife Department (TPWD) Inland fish hatcheries produce about 6.9 million 38-mm Florida largemouth bass *Micropterus salmoides floridanus* fingerlings to stock into public waters annually. Of these bass fingerlings, about 80,000 are selectively bred through the TPWD ShareLunker program. Females for the selective breeding program must be at least 5.9 kg and caught from Texas public waters from October through April each year by anglers using hook and line. Anglers donate their fish to the Texas Freshwater Fisheries Center (TFFC) through the TPWD ShareLunker program. After spawning, these females are released back into the waters where they were caught. The males used for the breeding program are from a captive brood stock that consists of progenies of selectively-bred bass. The minimum criterion for males to be eligible for selective breeding is 0.95 kg or two years of age. The selectively-bred fish are called Lunker bass (FLB).

In 2005, TPWD fisheries biologists requested 150-mm FLB for research that required producing these fish from 38-mm fingerlings in about 164 production days. Because fish production variables (e.g., growth rate and survival) are density dependent (Piper et al. 1983), we initiated a study to determine the maximum density that would support production of 150-mm fish in about 164 d using routine fish culture practices. The objective of this study was to compare the effects of three pond stocking densities (2,500, 5,000 and 7,500 fish/ha) on fish size (fish/kg), survival, and harvest length (mm) in grow-out ponds in 164 d.

MATERIALS AND METHODS

Fifteen 0.4-ha plastic-lined ponds at the TFFC located in Athens, Henderson County, Texas were used for this study. Five ponds were randomly assigned to each of three treatments (2,500 fish/ha (low-density), 5,000 fish/ha (mid-density), and 7,500 fish/ha (high-density); and further assigned into five replicate sets, each set consisting of one pond from each treatment. The three ponds in each replicate set were filled at the same time and stocked with fish from the same 38-mm production pond. This approach allowed mean values of stocking variables (e.g., pond stocking period, fish size and condition, and parental contribution to study fish) to be equalized among treatments. Furthermore, this approach was necessary because the brood fish that produced the fingerlings for this study spawned on different dates and therefore their 38-mm progenies were available for the study at different times.

Ponds were prepared for the study by removing as much of the sediments as possible from pond liners and kettles and filling with water from Lake Athens, the source of water for the hatchery. Incoming water was filtered through a 400-μm-mesh sock filter to exclude wild fish. Characteristics of the source water were as follows: total hardness, 12 mg/L as $CaCO_3$; total alkalinity, 12 mg/L as $CaCO_3$; total phosphorus, 0.02 mg P/L; nitrate nitrogen, 0.01 mg N/L; and ammonium nitrogen, 0.03 mg N/L. Ponds were stocked with fish 1-6 d after they were full from 13 May to 2 June 2005.

Fingerlings were acclimated to pond water temperature and pH by slowly exchanging half of the water containing the fish with pond water every 15 min for 45-60 min before stocking.

Fish, forage, and water quality data were collected during the study. Prior to stocking ponds, 30 fish from each of the 38-mm production ponds were individually measured for total lengths and three samples of approximately 100 fish each were weighed to determine the number of fish per kg. Similarly, at pond harvest the 150-mm FLB were sampled for total length and weight. At stocking, average fish length was 49.6 (range = 44.3 - 55.3) mm and mean size (fish/kg) was 808 (range = 483 - 1,055) fish/kg (Table 1). Fingerlings were fed fathead minnows *Pimephales promelas* and koi (a variant of common carp *Cyprinus carpio*) every 14 d at 11.3 kg per 1,000 FLB fingerlings. Water temperature, dissolved oxygen concentration, and pH were measured twice daily at 0700-0800 and 1600-1700 hours using a YSI model 650 MDS handheld meter fitted with a YSI 600 XL multiprobe sensor (Yellow Springs Instruments, Yellow Springs, Ohio).

The data were analyzed by analysis of variance using the General Linear Model procedure (PROC GLM) in the Statistical Analysis System (SAS Institute 2001). The survival data were arcsine-transformed to normalize the data before statistical analysis. When there was a significant difference among treatment means, Turkey's test was used to determine which treatment means were significantly different. Significant difference was set at $P \leq 0.05$.

RESULTS AND DISCUSSION

Water quality was similar among treatments (Table 2) and consequently did not affect the fish production result. Morning and afternoon pond water temperatures averaged 27 and 29°C, respectively. Dissolved oxygen concentration averaged 8.30 mg/L in the morning and 9.43 mg/L in the afternoon. Average pH was 8.9 in the morning and 9.2 in the afternoon. These water quality characteristics were suitable for largemouth bass culture (Piper et al. 1983).

The total weight of forage offered to fish in all study ponds was 2,586 kg. Quantities of forage received by the low-, mid-, and high-density treatments averaged 102.58, 198.84, and 295.38 kg/pond, respectively. At this rate most of the forage was eaten in 5-6 d after the feed was offered to the fish. All ponds in each replicate set were harvested on the same day, and all ponds were harvested over a period of 5 d.

The three density treatments produced fish that were statistically similar in length and size (Table 3), indicating that pond carrying capacity was probably not exceeded and food supply was not limiting for any treatment. Mean harvest lengths and sizes were 166.1-192.3 mm and 14.9-24.6 fish/kg, respectively among treatments. Levene's test of homogeneity of variance did not reject the null hypothesis that variance among treatments was equal for both size (P = 0.944) and harvest length (P = 0.064). At the start of the study, initial stocking densities were equal within each treatment (e.g., all ponds in the low-density treatment were stocked at 2,500 fish/ha). However, survival was not equal among ponds within a treatment, resulting in unequal densities at harvest. Mortality occurred at some unknown point during the culture period. The three ponds with the highest mean harvest length also had the lowest densities at harvest, although two of these ponds were in the mid-density treatment and the other in the low-density treatment. Figure 1 shows the relationship between density at harvest and mean harvest length; fish in ponds with harvest densities less than 1,500 fish/ha had mean harvest lengths of 198.8-216.6 mm while fish in ponds with harvest densities above 1,500 fish/ha had mean harvest lengths of 149.0-184.7 mm. These results appear to suggest there was inadequate forage for the fish (i.e., forage was a limiting factor) in ponds with harvest densities greater than 1,500 fish/ha. However, there was no strong relationship between harvest density and mean harvest length ($P = 0.281$) among ponds with harvest densities greater than 1,500 fish\ha. The effect of density on fish growth in this study appears to be more complex than can be explained by differences in forage availability.

Heidinger (1975) stated that foraging largemouth bass tend to congregate which may lead to a highly competitive foraging environment in aquaculture ponds. Similarly, Randolph (1975) observed that feeding activity can be negatively affected by social interactions among channel catfish *Ictalurus punctatus* in rearing ponds. Jobling (1995) reported that Arctic charr, *Salvelinus alpinus* reared in ponds displayed considerable variability in growth among individuals within a fish group even though there was no restriction on food availability. He suggested that length variation can be an indicator of whether behavioral interactions have caused growth inhibition in the absence of competition for limited forage. As reported in these studies, we suspect that behavioral interactions among the fish may have affected their growth in this study. While there was no strong relationship between harvest density and mean harvest length among ponds with harvest densities greater than 1,500 fish/ha, survival in these ponds was higher. High survival could have been caused by good growth during the early summer months (Gravey et al. 1998) that resulted in uniform fish size and low cannibalism (Miranda and Hubbard 1994). We suspect that larger fish may have cannibalized the smaller fish in the ponds with harvest densities less than 1,500 fish/ha. Previous studies suggested that social hierarchies in fish are diminished at some higher density threshold (Keenleyside and Yamamoto 1962; Buss et al. 1970; Vijayan and Leatherland 1988; Jobling 1995). We suggest that any behavioral interactions that may have caused variability in fish size in this study were less prevalent in ponds with harvest densities greater than 1,500 fish/ha.

Unlike harvest length and size, survival was significantly different among treatments. Survival for the low- or high-density ponds was twice as high as that of the mid-density ponds (Table 3). Tidwell (1998a) demonstrated that pellet-fed largemouth bass can be reared at densities higher than 7,500 fish/ha which is equal to the highest stocking density used in our study. Stocking largemouth bass at high densities creates a competitive feeding environment which produces uniform size fish and reduces cannibalism (Tidwell 1998a), which is consistent with our findings. Kurten (2001) observed that when stocking densities are at a maximum, fish survival can be negatively impacted. During this study, survival values for the low- and high-density ponds were similar; suggesting that our high stocking density was not the maximum for these ponds and that stocking at densities higher than 7,500 fish/ha is worth investigating. Tidwell et al. (1998b) observed that in pellet-fed bass ponds, survival in higher density ponds was equal to or higher than that of lower density ponds, which is consistent with results of this study. In our study, low survival was observed for the mid-density ponds although there were no significant differences in the measured water quality variables among treatments. The lower survival for the mid-density treatment cannot be explained from our data.

Fish yield (fish/ha) from the high-density ponds was significantly higher than those from the other two treatments (Table 3; $P < 0.0003$), being about 186% higher than that from the low- or mid-density ponds (Table 3). Similarly, harvest weight (kg) from the high-density ponds was 43% higher than that from the low-density ponds and 55% higher than that from the mid-density ponds (Table 3). Kubitz and Loshin (1975) reported that if stocking density is at a maximum, harvest weight decreases. We observed total harvest weight to be highest for the high-density treatment, indicating that the fish can be stocked at higher densities than the maximum used in this study.

Unlike the Arctic charr *Salvellnus alpinu L* and rainbow trout *Oncorthychus mykiss* where growth is dependent on density (Baker and Ayles 1990), growth of largemouth bass is more dependent on forage availability than stocking density (Fullerton et al. 1999; Chew 1975). Fullerton et al. (1999) and Chew (1975) also observed that forage availability has a greater affect on largemouth bass growth than on other fish species. In the present study all stocking density treatments produced fish of the target 150-mm length with no correlation between fish size and stocking density ($P = 0.25$). These results suggest adequate forage of the appropriate size was available to the fish (Aggus and Elliott 1975; Goodgame and Miranda 1993; Sutton and Ney 2001).

This study has demonstrated that stocking 38-mm fish at a density of 7,500 fish/ha provided adequate numbers of fish that reached the target 150-mm length in 164 d. The goal of aquaculture is to optimize stocking density without sacrificing fish health and survival. The optimum density is not always the density at which maximum growth is achieved, but the economic objective is to maximum fish production (Baker and Ayles 1990). Kurten (2001) noted that while high stocking densities may negatively affect survival, the effects of low survival can be overcome by increasing stocking rates to increase fish yield, and pond managers should have an understanding of which production variables are of utmost importance. Tidwell et al. (1998b) and Kubitza et al. (1996) reported that pellet-fed largemouth bass can be stocked at densities higher than 12,300 fish/ha to produce 150-mm fish in 167 d. We recommend that future studies investigate the maximum stocking density required to grow 150-mm fish on forage in about 164 d in TFFC hatchery ponds.

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Table 1.—Pond stocking summary for three stocking densities compared in 0.4-ha ponds for the production of 150-mm Florida largemouth bass at the Texas Freshwater Fisheries Center fish hatchery, May-November 2005.

Date stocked	Mean ± SD length (mm)	Size (fish/kg)	Low-density (fish/ha)	Mid-density (fish/ha)	High-density (fish/ha)
19-May	50.47 ± 1.99	777	2,778	5,185	7,750
26-May	44.30 ± 1.74	1,055	2,558	5,143	7,543
3-Jun	49.97 ± 1.73	879	2,748	5,055	7,693
3-Jun	47.90 ± 2.01	845	2,620	5,283	7,943
3-Jun	55.33 ± 4.12	483	2,535	5,192	7,608

Table 2.—Mean values (ranges in parentheses) of water quality variables for Florida largemouth bass rearing ponds stocked at three densities at the Texas Freshwater Fisheries Center fish hatchery, May-November 2005. Differences were considered significant at $P \leq 0.05$.

Variable	2,500 fish/ha	5,000 fish/ha	7,500 fish/ha	*P*-value
Morning temperature (°C)	26.8 (26.6-27.1)	26.8 (26.7-27.1)	26.9 (26.6-27.2)	0.981
Afternoon temperature (°C)	28.5 (28.0-29.0)	28.6 (28.2-28.9)	28.7 (28.3-29.0)	0.604
Morning dissolved oxygen (mg/L)	8.3 (8.2-8.4)	8.2 (8.0-8.5)	8.4 (8.2-8.6)	0.214
Afternoon dissolved oxygen (mg/L)	9.3 (8.9-9.8)	9.3 (9.0-9.5)	9.7 (9.3-10.3)	0.124
Morning pH	8.9 (8.7-9.0)	8.9 (8.8-9.0)	9.0 (8.9-9.2)	0.146
Afternoon pH	9.2 (8.9-9.5)	9.2 (9.0-9.3)	9.3 (9.2-9.6)	0.324

Table 3. Mean ± SD values (ranges in parentheses) of harvest variables for Florida largemouth bass reared in ponds at three stocking densities at the Texas Freshwater Fisheries Center fish hatchery, May-November 2005. Differences were considered significant at $P \leq 0.05$.

Variable	2,500 fish/ha	5,000 fish/ha	7,500 fish/ha	*P*-value
Yield (number/ha)	1,879 ± 656.55[a] (850-2,490)	1,881± 522.57[a] (680-3,660)	5,381± 577.44[b] (3,348-6,663)	<0.0003
Harvest weight (kg/ha)	93.40± 10.30[a] (58.56-116.38)	119.74± 13.30[a] (91.19-172.72)	216.26± 10.71[b] (183.35-248.33)	<0.0001
Survival (%)	71± 14.68[a] (32-90)	36± 13.81[b] (13-71)	70± 10.74[a] (44-88)	0.038
Harvest length (mm)	172.4± 15.56[a] (159.8-198.8)	192.3± 21.57[a] (171.5-216.6)	166.1± 10.14[a] (149.0-175.3)	0.065
Size (fish/kg)	20.1± 6.28[a] (11.2-27.9)	14.9± 6.67[a] (7.0-20.9)	24.6± 6.12[a] (18.0-32.4)	0.093

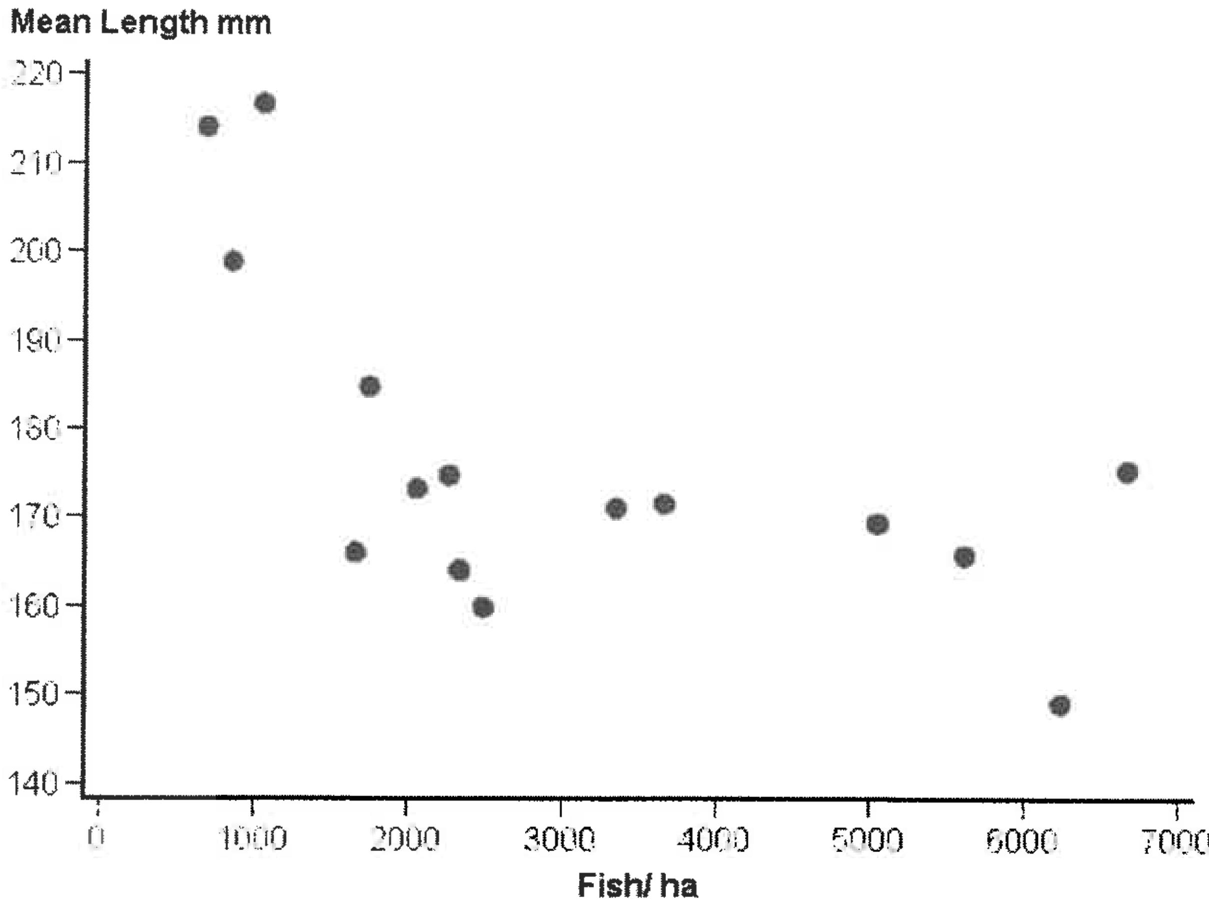

Figure 1.—Relationship between density at harvest and mean harvest length of Florida largemouth bass fingerling reared in ponds at the Texas Freshwater Fisheries Center fish hatchery, May-November 2005.

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