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TEXAS PARKS & WILDLIFE

INLAND FISHERIES DIVISION
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ABSTRACT

Spawning Smallmouth Bass (SMB) in raceways by using procedures successful with Largemouth Bass (LMB) has not produced adequate fry to meet production goals, likely due to the low fecundity of SMB. Because SMB produce about 60% less eggs per kg female than LMB, we compared 20 pairs per raceway (the LMB spawning density; low-density treatment) with 32 pairs per raceway (60% greater to compensate for the low fecundity of SMB; high-density treatment). The objective was to determine if stocking SMB brood fish at 32 pairs per raceway improves spawning performance. The study was conducted in three indoor concrete raceways, each divided into two equal sections and assigned to the treatments. Each raceway section for the high-density treatment received 16 spawning mats placed 1.3 m apart and 16 pairs of brood fish. For the low-density treatment, each raceway section received 10 spawning mats placed 2.4 m apart and 10 pairs of brood fish. None of the spawning performance variables measured significantly differed between treatments ($P > 0.05$). Spawns were collected 53 and 43% of the spawning period for the high- and low-density treatments, respectively. The high-density treatment improved spawn and egg production by 35 and 31%, respectively. These increases were incommensurate with the 60% increase in brood fish density, yet could be of practical importance to culturists. The similarities of the mean number of spawns per female and mean number of eggs per spawn between treatments suggest the high-density treatment had no appreciable adverse effect on spawning. Conversely, percent of mats with spawns and number of times adjacent spawns occurred were 29.6 and 300% less, respectively, with the high-density treatment. This suggests 32 pairs per raceway could be at or near the maximum density for spawning the SMB used in this study. Future studies should examine the high-density stocking rate (64 fish per raceway) with a ratio in favor of females (e.g., 1 male:1.3 females or 1 male:2 females). This could have the potential to improve spawn production from the increased number of females as well as reduce male aggression and thereby improve spawning success.

INTRODUCTION

The Smallmouth Bass *Micropterus dolomieu* (SMB), a popular sport fish, is non-native to Texas. Development of the fishery in Texas was initiated with seed fish (approximately 30,000 fry) obtained from Arkansas in 1934 (Hudson 1989). Over the years, the progeny of these fish and brood fish from other states (e.g., Tishomingo National Fish Hatchery, Oklahoma; Dale Hollow Reservoir, Tennessee; and Wray Fish Hatchery, Colorado) have been the sources of fingerlings for expanding the fishery statewide or supporting natural recruitment of established regional or local fisheries. These fingerlings were produced by Texas Parks and Wildlife Department (TPWD) inland fish hatcheries using extensive and semi-extensive methods in ponds. As the popularity of SMB fishing has increased over the years, so has the annual request for the fingerlings by management biologists, which has been as high as 1 million. Over the past decade, TPWD fish hatcheries have not been able to meet the annual fingerling requests because of limited pond space for spawning brood fish. To improve SMB spawning efficiency and increase fry production, we have been transitioning from pond spawning to raceway spawning of brood fish using procedures that have been successful with Largemouth Bass *Micropterus salmoides* (LMB) spawning and fry production. These procedures have not been as successful with SMB. Nonetheless, the preference has been to improve SMB fry production from raceway spawning because of the many benefits associated with spawning brood fish in raceways. Compared to pond spawning, raceway spawning uses less space to produce large numbers of fry, provides protection to brood fish, gives culturists control over spawning conditions and timing, improves egg hatch rates, and allows stocking of known numbers of fry into ponds which results in better use of pond space for fingerling production (Mayes 1993; Isaac and Staats 1994; Isaac et al. 1998; Arslan and Phelps 2011). Overall, fry production is better in raceways than in ponds. Glenewinkel et al. (2011) reported production of 4,000 and 11,000 fry per kg female for LMB spawned in ponds and raceways, respectively.

Therefore, in 2006 the Possum Kingdom State Fish Hatchery (PKFH) began spawning SMB in raceways by following guidelines developed for LMB spawning (Glenewinkel et al. 2011). This LMB raceway spawning protocol requires providing spawning mats equal to the number of males spaced 2.4 m apart and pairing brood fish into raceways at a density of 20 pairs per raceway. Smallmouth Bass readily spawn in the raceway environment; however, the resulting fry production has been inadequate to meet the annual requests for fingerlings. The low fry production is due, partially, to the low fecundity of SMB compared to LMB. Piper et al. (1982) reported egg production by SMB and LMB to be 17,600 and 28,600 eggs/kg female, respectively. Sparrow and Barkoh (2002) reported a production of 6,142 eggs/kg female for SMB spawned on mats in ponds.

The LMB brood fish stocking rate (20 pairs per raceway) used for spawning SMB could be too small and a plausible reason for the insufficient fry production from raceway spawning. Spawning mat placement in raceways (2.4 m apart), which determines LMB brood fish stocking rate, is within the range observed for LMB nests in the wild (1.8-3.0 m apart; Carr 1942; Clugston 1966; Heidinger 1975). Like LMB, SMB are solitary nest spawners and males are territorial (Breder 1936; Coble 1975; Simon 1999). Thus, the key to spawning success is to place spawning mats apart to avoid aggressive behavior between adjacent males. Piper et al. (1982) recommended locating SMB nests 6.7-7.2 m apart in ponds to prevent male aggressive behavior. Hudson (1983) recommended placing SMB nests 3.1-3.7 m apart in spawning ponds.

In the wild, SMB nests are never closer than 1 m apart unless they are built by the same male or by two males that nest at different times in a season, and the spacing depends on the density of individuals (D. Wiegmann, Bowling Green State University, Bowling Green, Ohio, personal comm.). Thus, it is possible mats for SMB spawning could be placed 1-2 m apart and increase the raceway stocking rate to compensate for the low fecundity.

Using the Piper et al. (1982) estimates of the reproductive potential of the two species, we determined the egg production potential of female SMB to be approximately 60% that of LMB. This suggests females of these black basses in a ratio of 1 LMB:1.6 SMB would produce about the same number of eggs, all other factors being equal. Numerically, this translates into an increase in brood fish density from 20 to 32 pairs per raceway and placement of spawning mats closer than the current 2.4 m for LMB spawning. The objective of this study was to determine if SMB stocked at 32 pairs per raceway improves spawning performance, particularly the number of eggs produced, compared to stocking at 20 pairs per raceway.

METHODS

This study was performed in spring 2011 at the PKFH, near Graford, Texas. We compared the effects of two brood fish stocking rates (20 pairs per raceway, low-density treatment versus 32 pairs per raceway, high-density treatment) on SMB spawning performance in three indoor concrete raceways. Because of the limited number of raceways available for the study, both treatments were tested in the same raceways. Each raceway (24 x 2.4 x 1.3 m) was divided into two equal sections with a screen (Figure 1). Sections of raceway 1 were randomly assigned to treatments by drawing a lot to determine which treatment should be assigned to the front section of the raceway, and then the other treatment was assigned to the back section of the raceway. Treatment locations for raceway 2 were alternated with those of raceway 1, and treatment locations of raceway 3 were alternated with those of raceway 2. Forty-centimeter square pieces of Spawn-Tex® (Blocksom & Co., Michigan City, IN), provided with gravel (30 – 50 mm diameters), served as spawning mats (Isaac and Staats 1994). These mats were placed 2.4 m apart (Glenewinkel et al. 2011) for the low-density treatment and 1.3 m apart for the high-density treatment.

Water for this study was from Possum Kingdom Lake, the source water to the hatchery. Raceways were filled to depths of 0.8-1.1 m (Tester 1930). Water flow rates through raceways were 94.5-189.0 Lpm which maintained dissolved oxygen concentrations of ≥4 mg/L, considered suitable for SMB spawning (Hudson 1989). Water temperatures and dissolved oxygen concentrations in raceways were measured once daily (1500 hours) with a Yellow Springs Instrument (YSI) 650 MDS meter equipped with a 600XL sonde. Collection of water quality data began a week before pairing of brood fish to begin the study and ended with termination of the study on 10 June.

Brood fish were harvested from an outdoor holding pond and held in an indoor raceway for acclimation from 15 March through 7 April. Then, brood fish were paired into raceways for spawning on 8 April when water temperature was 18.6 °C. The high-density section of each raceway received 16 pairs of brood fish and the low-density section received 10 pairs (equivalent to 32 and 20 pairs per raceway, respectively). Brood fish were 2- to 4-years old with females averaging 1.16 kg and males 0.78 kg. Males of similar average weight were used for each high-density or low-density replicate space to avoid, or at least minimize, male aggressive behavior. Likewise, females of similar average weight were used for the high- and low-density replicate spaces because egg production increases with increasing size or age (Hubert 1976; Vogele 1981; Serns 1984). The average fish biomass of the high-density treatment was 1.10 g/L and that of the low-density treatment was 0.74 g/L.

Beginning the day after brood fish pairing, spawning mats were checked for spawns daily between 0900-1200 hours (Lyon et al. 2002). Mats with eggs were removed for egg incubation, and new mats were placed in their locations for additional spawning. Spawning dates and spawn locations were recorded for each raceway along with photographs of each spawn. Then, spawn size (number of eggs per spawn) was ranked separately by two experienced staff members. Spawn size was ranked 1-3: a spawn with an estimated number of eggs >5,000 was ranked 1 (heavy), 3,000 – 5,000 was ranked 2 (moderate), and <3,000 was ranked 3 (light) (Figure 2). This ranking scheme was based on a report that SMB spawned on mats in ponds produced approximately 6,142 eggs/kg female (Sparrow and Barkoh 2002). The study was terminated on 10 June, when pond space was no longer available for fry stocking.

Spawning performance variables including percent of spawning days with spawns, number of spawns per treatment, number of spawns per female, spawn size score, mat utilization rate (percent of mats with spawns), and adjacent spawns frequency (number of times adjacent spawns occurred) were compared between treatments with the two-sample *t*-test procedure of the Statistical Analysis System (SAS Inc. 2001). Data for each variable was tested for normality (Shapiro-Wilks test) and homogeneity of variance (Leven's test) followed by the appropriate transformation, if necessary, before statistical analysis. Differences were considered significant at $\alpha \leq 0.05$.

RESULTS AND DISCUSSION

Dissolved oxygen concentrations averaged 9.7 (range: 5.3 – 14.6) mg/L throughout the 63-d study and likely had no effect on the spawning results. Conversely, water temperature fluctuated considerably and appears to have delayed initiation of spawning as well as disrupted spawning activities on two occasions during the study. Water temperatures in raceways began to decline 2 d after brood fish pairing from 19.0 to 14.2 ^{o}C in 8 d due to a cold spell. Then temperatures increased over a period of 12 d to 18.0 ^{o}C by April 30 when the first group of spawns was collected. Additional cold spells, each lasting about 4 d, occurred in weeks 1 and 5 after spawning started, which seems to have disrupted spawning activities (Figure 3). Both cold spells caused raceway water temperatures to decline approximately 5.8 ^{o}C, followed by temperature uptrends and resumption of spawning activities. The average water temperature was 17.9 ± 2.0 °C during the study.

Our observations of the temperature effects on SMB spawning are not uncommon. Tester (1930) reported that spawning of SMB is dependent on water temperature, and rapid temperature declines cause bass to cease spawning or nest guarding (Chew 1974; Hudson 1983). Cold weather has been reported to cause reduced fingerling production in spawning-and-rearing hatchery ponds (Beeman 1924; Hudson 1983), probably due to reduced spawning or desertion of nests or both (Piper et al. 1982). Beeman (1924) and Chew (1974) observed that cold spells delayed or prolonged bass spawning. In this study, cold spells delayed initiation of spawning for about 3 weeks and then interrupted spawning twice, before the study was terminated for lack of need for additional fry. Nine weeks into the study, the fish were still in spawning mode (Figure 3) when the study was terminated. Based on the spawning trend, the spawning period could have been protracted compared to the 4- to 7-week spawning seasons reported for SMB (Beeman 1924; Hudson 1989).

None of the spawning performance variables significantly differed between treatments (Table 1), partly indicating that the individual females performed identically as would be expected. The brood fish began spawning on day 23 after the study began and continued to spawn for 40 d before the study was terminated. Spawns were collected from the high-density group approximately 53% of the time (21 of 40 days) and from the low-density group 43% of the time (17 of 40 days). Total numbers of spawns were 104 and 77 for the high- and low-density treatments, respectively. This resulted in mean number of spawns per treatment of 34.67 for the high-density and 25.67 for the low-density treatment. Thus, spawn and egg productions were 35 and 31%, respectively, better with the high-density treatment.

However, the increase in mean number of spawns per treatment (35%) for the high-density treatment was incommensurate with the increased brood fish pairing density (60%). Instead, the average numbers of spawns per female were 2.15 and 2.57 in 6 weeks after initiation of spawning for the high- and low-density treatments, respectively (Table 1). These female spawning rates were lower than the maximum 4 spawns per season reported for SMB (Beeman 1924; Coble 1975; Hudson 1989). The two interruptions of spawning activities by low temperatures and premature termination of the study, when females appeared to be still in spawning mode, may explain our low female spawning rates. Nonetheless, the similarities of the mean number of spawns per female and estimated number of eggs per spawn between treatments suggest that the high-density treatment likely had no appreciable adverse effect on spawning activity.

The 35% increase in spawn production with the high-density treatment was not statistically significant but could be practically important to culturists. The next questions are can the 32-pairs per raceway density of the SMB brood fish be increased or the 1 male:1 female ratio modified to further improve egg production? Male-on-male aggression is density depended and a critical factor that influences bass spawning in confinement. Surber (1943) demonstrated in hatchery ponds that nest building and successful spawning of bass were inversely related to brood fish stocking density, with only 6.8% of the fish building nests at the highest tested density of 2,868 fish/ha. Further, many of these nests failed likely due to nest abandonment. Aggressive behavior between adjacent males can disrupt spawning activities and cause nests desertion (Beeman 1924). Results of the mat utilization rate and adjacent spawns frequency did not significantly differ between treatments. However the differences, 29.6% less mat utilization rate and 300% less adjacent spawns frequency with the high-density treatment could be important to culturists. These differences could mean the 32-pairs per raceway density could be at or near the maximum for spawning SMB of the sizes used in this study. Therefore, we do not recommend investigation of a higher density than the 32 pairs per raceway tested herein. Instead, future studies should investigate the high-density (64 fish per raceway) stocking rate with a pairing ratio dominated by females, similar to the 1 male:1.3 females and 1 male:2 females ratios recommended by Hudson (1983) and Snow (1975), respectively. A lower proportion of males to females should minimize any potential male aggressive behaviors that could adversely affect spawning success while increasing spawn production from the increased number of females. This is likely achievable because a male SMB can spawn with different females or several times with the same female in a spawning season (Wiegmann et al. 1992).

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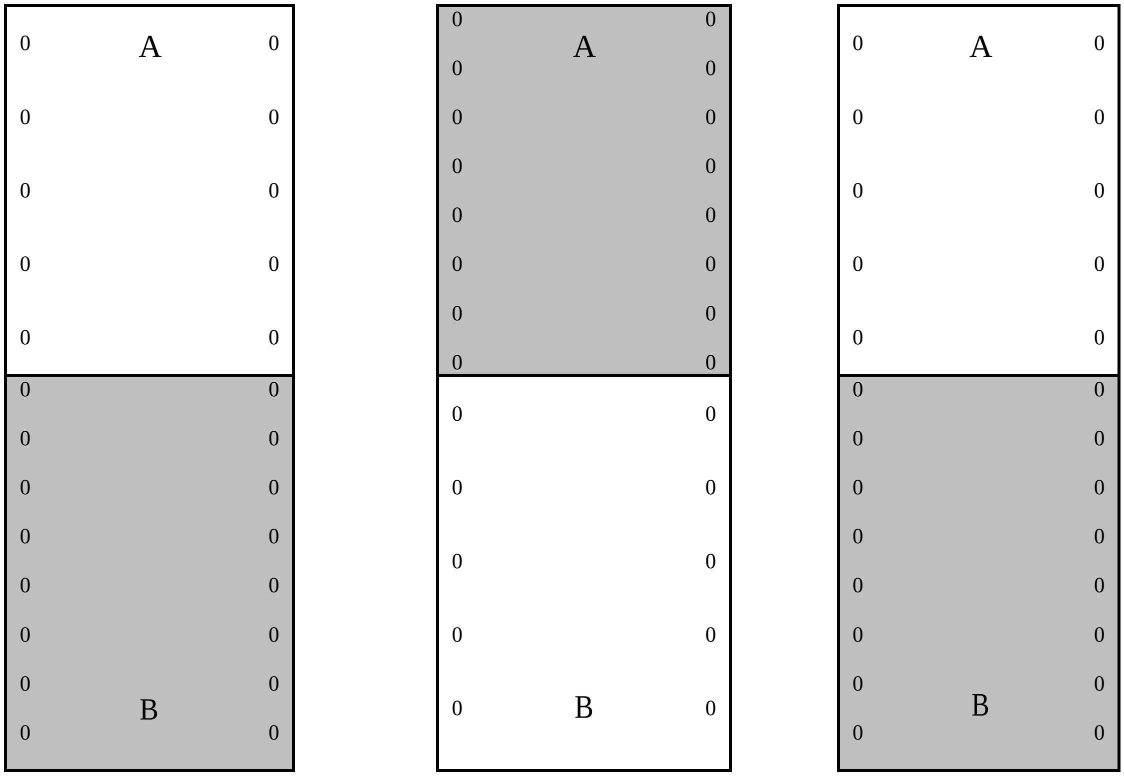

FIGURE 1.—Raceway configuration and spawning mat placement for Smallmouth Bass *Micropterus dolomieu* spawning at the Possum Kingdom State Fish Hatchery, near Graford, Texas in 2011. Shaded areas are high-density (32 pairs per raceway) treatments, unshaded areas low-density (20 pairs per raceway) treatments, and the Os are spawning mat locations.

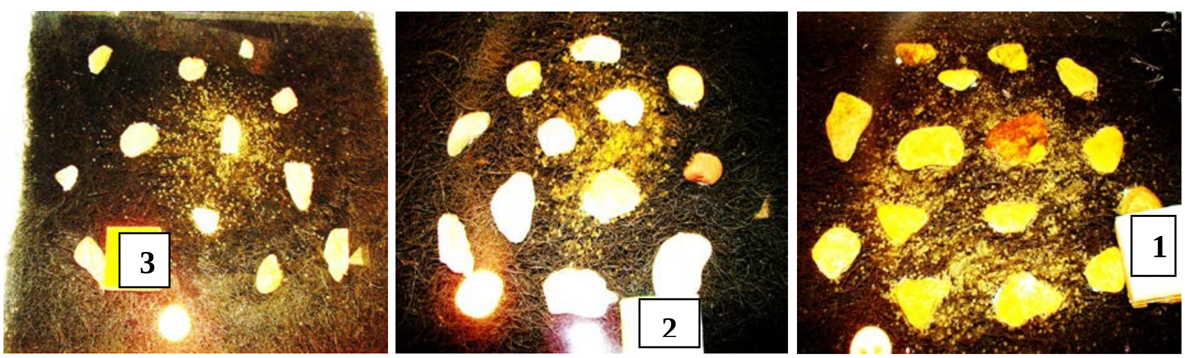

FIGURE 2.—Example of Smallmouth Bass *Micropterus dolomieu* spawn size ranking based on estimated number of eggs per spawn (number of eggs > 5,000 ranked 1; 3,000 – 5,000 ranked 2; and < 3,000 ranked 3) used during a raceway spawning study at the Possum Kingdom State Fish Hatchery, near Graford, Texas in 2011.

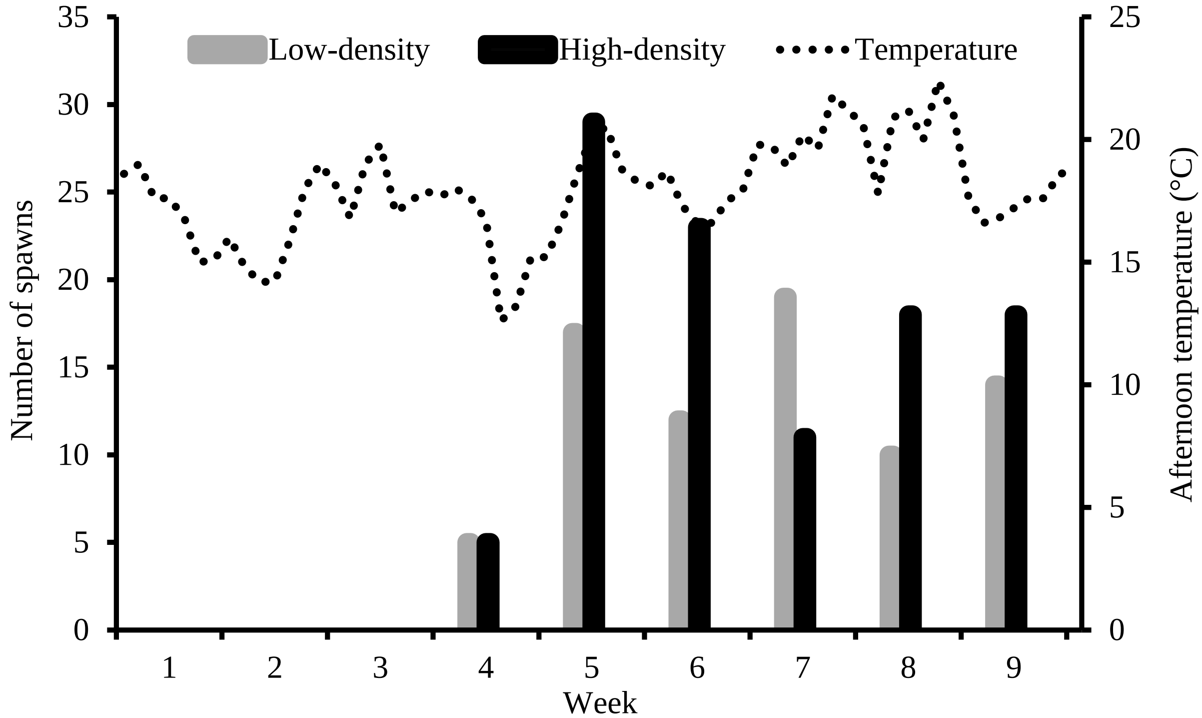

FIGURE 3.—Spawning trends of Smallmouth Bass *Micropterus dolomieu* brood fish subjected to low-density (20 pairs per raceway) or high-density (32 pairs per raceway) treatment in a one-half section of each of three indoor concrete raceways at the Possum Kingdom State Fish Hatchery, near Graford, Texas in 2011. Dotted line is the mean afternoon temperature trend during the 63-d study.

TABLE 1.— Spawning performance summary for Smallmouth Bass *Micropterus dolomieu* brood fish spawned at low-density (20 pairs per raceway) or high-density (32 pairs per raceway) treatment in a one-half section of each of three indoor concrete raceways at the Possum Kingdom State Fish Hatchery, near Graford, Texas in 2011. Values are means ± SDs (ranges in parentheses) of three treatment replicates except for total number of spawns. For all variables, mean values did not significantly differ between treatments ($P > 0.05$).

	Treatment	
Variable	Low-density	High-density
Female weight (kg)	1.21 ± 0.21 (1.01-1.43)	1.11 ± 0.39 (0.45-1.19)
Male weight (kg)	0.81 ± 0.02 (0.79-0.85)	0.75 ± 0.02 (0.71-0.78)
Total number of spawns	77	104
Number of spawns per treatment	25.67 ± 7.57 (17.00-31.00)	34.67 ± 6.11 (28.00-40.00)
Number of spawns per female	2.57 ± 0.76 (1.70-3.10)	2.15 ± 0.41 (1.69-2.50)
Spawn size score (number of eggs per spawn)	2.45 ± 0.18 (2.46-2.61)	2.38 ± 0.06 (2.34-2.44)
Percent of spawning days with spawns	43.00 ± 11.00 (28.00-53.00)	53.00 ± 0.07 (45.00-63.00)
Mat utilization rate (percent of mats with spawns)	70.00 ± 6.93 (60.00-90.00)	54.00 ± 13.11 (31.00-60.00)
Adjacent spawns frequency (number of times adjacent spawns occurred)	4.00 ± 2.65 (1.00-6.00)	1.00 ± 0.52 (0.00-2.00)

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