Fisheries Technical Articles

Short-term Post Stocking Survival of Red Drum and Effects of Acclimation Time and Stocking Season on Survival

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Abstract: Texas Parks and Wildlife Department's Inland and Coastal Fisheries Divisions have maintained a cooperative stocking program for marine red drum (*Sciaenops ocellatus*) in six freshwater power plant reservoirs since the early 1980s. We used experimental fish enclosures to analyze the effects of acclimation time (2.5 h vs. 5.0 h) and stocking season (summer vs. fall) on post stocking survival of red drum fingerlings in two of these power plant reservoirs. Calaveras and Tradinghouse Creek reservoirs were similar in size and depth, but Calaveras maintained total dissolved solids (TDS) and salinities twice that of Tradinghouse Creek. Mean summer and fall temperatures recorded during the study were 31.3 C and 16.6 C for Tradinghouse Creek and 32.6 C and 19.7 C for Calaveras, respectively. Overall, 10% of the fingerlings tested survived the 72-h trials, substantially better than observed in an earlier study. Slow-acclimated fingerlings had higher survival than rapid-acclimated fingerlings regardless of reservoir or season. Fall-stocked fingerlings had higher survival than summer-stocked fingerlings regardless of acclimation time or reservoir. Calaveras stocking survival was four times higher than that observed at Tradinghouse Creek. Our results show red drum stockings in freshwater power plant reservoirs should benefit from fall stockings and acclimating fingerlings for at least five hours prior to release.

Key words: red drum, post-stocking survival, acclimation time, stocking season

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Unusual opportunities for establishing put-grow-take red drum (*Sciaenops ocellatus*) fisheries in freshwater have been found in several Texas power plant cooling reservoirs. These reservoirs were selected for red drum introductions in the early 1980s to provide inland anglers with a unique sport fish, and stockings were appropriate because specific physicochemical requirements (i.e., chloride concentrations >130 mg/L and minimum temperature limits >9 C) were met (Miranda and Sonski 1985). Cooperative efforts between Texas Parks and Wildlife Department's (TPWD) Coastal and Inland fishery staffs are responsible for stocking over 25 million red drum inland, since the inception of the program, at a 2008 cost of U.S. .07 cents per fingerling. Management biologists agree red drum are popular among their constituents and rank among top game species sought in their respective reservoirs (J. Dean, Texas Parks and Wildlife Department, personal communication).

Post stocking mortality of fish has been studied extensively in recent decades. Hatchery rearing densities have been linked to post stocking mortality of lake trout (Elrod et al. 1989) and hybrid striped bass (Jenkins et al. 1988). Buckmeier and Betsill (2002) studied the effects of transport mortality and handling techniques for largemouth bass. Other studies have shown a relationship between size of fish stocked and survival (Storck and Newman 1988, Seidensticker and Byrne 1991, Szendrey and Wahl 1996, Johnson and Margenau 1993). Other factors contributing to stress and mortality of stocked fish are stocking season (Elrod and Schneider 1992, Carline et al. 1986), stocking habitat (Hanson and Margenau 1992, Elrod 1997), predation (Matkowski 1989, Buckmeier et al. 2005), prey availability (Fielder 1992), and water chemistry (Mazik et al. 1991).

There has been a fair amount of research on the survival of fingerling red drum. Studies by Miranda and Sonski (1985), Procarione and King (1993), and Lyon and Fisher (1998) helped our understanding of the species' temperature tolerances. Other studies have focused on salinity and freshwater tolerances (Crocker et al. 1981, Weirich and Tomasso 1991, Gatlin et al. 1992, Thomas and Wolters 1992). Thomas and Wolters (1992) studied rate of salinity change, chloride level, and salt and chloride source in earthen ponds and observed an overall survival rate of only 1.2%. Crocker et al. (1981) studied red drum survival in the laboratory and found freshwater tolerance to be size-dependent. Three sizes of red drum were used in the study (6.2 mm, 16.2–19.7 mm, and 56 mm SL), with survival rates of 5%, 70%, and 95%, respectively, after 96 h. Although important, these studies were conducted under controlled conditions and are not representative of actual reservoir conditions which can vary both spatially and temporally.

There are few field studies dealing with the survival of stocked red drum in Texas. Hammerschmidt and Saul (1984) and Hammerschmidt (1986) reported survival rates of 89.4 ± 2.7% and 86.2 ± 2.2%, respectively for fingerling red drum held 24 h in cages in San Antonio, Lower Laguna Madre, and Corpus Christi bays. These high survival rates contrast the survival reported by Pitman and Gutreuter (1993), who studied survival of 10 fish species commonly stocked in Texas freshwater reservoirs, including red drum. Survival rates of red drum fry (7 mm total length TL) and fingerlings (20 and 25 mm TL) ranged from 0% to 12%. Pitman and Gutreuter (1993) recommended further investigation of hauling times and procedures for red drum, and called for a standardization of acclimation procedures. To date, no follow-up research has been conducted and no standard operating procedures exist for freshwater red drum stockings. Therefore, the goals of this study were to 1) examine the current extent of post stocking mortality of red drum in inland reservoirs, and 2) explore practical alternatives for improving these stockings.

Methods

Studies were conducted on Tradinghouse Creek and Calaveras reservoirs during fall 2002 and summer 2003. Tradinghouse Creek is an 814-ha reservoir located east of Waco within McLennan County; Calaveras is a 1397-ha reservoir southeast of San Antonio within Bexar County. Both reservoirs were classified as eutrophic, artificially heated by power plant operations, and had established red drum fisheries at the time of the study.

Trials to determine post stocking mortality consisted of (1) rearing fingerlings to 36.5 mm in full salt water (2) loading fingerlings into hatchery trucks and transporting them to a study reservoir, (3) tempering fingerlings to within one degree Celsius of the receiving reservoir water and 1–2 ppt salinity using one of two acclimation rates, and (4) transferring random samples of fingerlings from each truck compartment to pre-set enclosures in the reservoir for 72 h of monitoring. Thus, a survival trial was defined as a fish delivery to a single reservoir by four hatchery trucks on the same day within a given season and each of the four trials required 24 enclosures.

Study fingerlings were spawned and reared in ambient temperature and salinity at Perry R. Bass Marine Fisheries Station located in Palacios, Texas. Fry were stocked into hatchery ponds at a density of 400,000 per acre. Dissolved oxygen ranged from 4.0 mg/L to saturation, while pH ranged from 8–10. Fingerlings were fed a natural diet of zooplankton maintained by fertilization and supplemented by feed until reaching a TL of 36.5 mm (range = 26-42 mm). Feeding was suspended 3 d prior to harvest.

Fingerlings were loaded onto duel-compartment hatchery trucks in early morning and hauled in partial salt water (mean = 19 ppt) to each reservoir. Travel time from the coastal hatchery to Calaveras and Tradinghouse Creek reservoirs was approximately 3.0 h and 6.0 h respectively. The hauling densities (mean = 73.6 fish/L) used for this study were identical to those employed by TPWD Inland Fisheries staff (T. Engeling, Texas Parks and Wildlife Department, personal communication). Drivers monitored water temperature and dissolved oxygen hourly during the trip.

Tempering was done to reduce stress in study fingerlings by minimizing differences in water temperature and salinity between hauling and receiving waters. Tempering was performed at an access point near each study site by slowly releasing compartment water through a valve and replenishing it with freshwater from the reservoir. Each truck contained two compartments of fingerlings. Fish from one compartment were designated to receive rapid (2.5 h) tempering; fish from the other compartment received slow (5.0 h) tempering. Fingerlings in the rapid-acclimated compartments received 50% water changes every half hour for 2.5 h; those in the slow-acclimated compartments received 50% water changes every hour for 5.0 h.

After tempering, three random samples of fingerlings (n = 100 each) were moved from each compartment to appropriately labeled enclosures in the reservoir (mean = .09 fish/L). Handling was minimized while transferring fingerlings. Fingerlings were first counted and moved from the compartments to minnow buckets using fine-meshed nets, then poured from the minnow buckets to the enclosures in the reservoir. Temperature and dissolved oxygen was measured near enclosures prior to placing fingerlings and every 24 h thereafter for three days. Because survival experiments started at varying times, daily water quality measurement times also varied. Additional continuous water temperature data was collected via submerged probes in both reservoirs near study sites. Mean survival at 72 h post stocking was calculated for each compartment within each truck.

Enclosures were set in four series (n = 6 each; three rapid and three slow) in protected coves near stocking sites. Individual fish enclosures were 1.8 m in height, 0.9 m in diameter, and constructed with 3-mm nylon mesh. Enclosures lacked solid frames but had two 7-mm thick metal hoops sewn into the mesh at top and bottom. Each enclosure opened from the top end and was anchored at the bottom to prevent movement. Additionally, each series of enclosures was anchored at both ends to further prevent movement and collapse.

A mixed-model analysis of variance was used to test the effect of acclimation rate, reservoir, season, and their interactions on mean counts of fish surviving 72 h (mean of three replicates). Because means were input into the analysis, no data transformation was used. Batches (trucks) of fish were treated as a random effect within the analysis. We identified significant fixed effects using Type III sums of squares.

Results

Calaveras and Tradinghouse Creek reservoirs were similar in size, depth, and physicochemical make-up except Calaveras maintained salinities twice that of Tradinghouse Creek and had higher total dissolved solids (Table 1). Mean summer and fall temperatures recorded during the study were 31.3 C and 16.6 C for Tradinghouse Creek and 32.6 C and 19.7 C for Calaveras, respectively. Single-enclosure survival rates ranged from 0% to 69%, with the highest being slow-acclimated fingerlings stocked in Calaveras during fall. Survival rates varied over the three 24-h periods and did not show a consistent temporal pattern.

Reservoir and season had a significant effect on survival as indicated by their main effects and two-way interaction (Table 2). Fall fingerling survival was higher than summer fingerling survival when the reservoir data were combined, even though fall and summer survival within Tradinghouse Creek was not significantly different (Table 3). Eight hundred thirty six of 4,800 fingerlings (17.4%) survived fall trials whereas only 124 (2.5%) survived summer trials. Acclimation time was nearly significant at the α = 0.05 level, with fingerlings acclimated for 5 h typically having better survival than fingerlings acclimated for 2.5 h regardless of reservoir or season (Tables 2, 3). Six hundred fifty of 4,800 fingerlings (13.5%) survived the slow acclimation process while only 310 (6.5%) survived the rapid acclimation process. Calaveras fingerling survival was higher than Tradinghouse fingerling survival when seasons were combined, even though summer survival was not significantly different between Calaveras and Tradinghouse (Table 3).

Discussion

Ninety percent of the fish we stocked into freshwater failed to survive 72 h. We believe this reflects the inherent difficulty of transplanting marine fish into fresh (or slightly brackish) water after extended transport and handling. Good survival rates have been reported by researchers in the past, but those stockings occurred under conditions quite different from conditions routinely faced by Texas freshwater fishery managers. Crocker (1981) and Miranda and Sonski (1985) reported survival of 70%–80% for fingerlings transferred to fresh water under laboratory conditions without hauling and handling stressors. Field studies conducted by Hammerschmidt and Saul (1984) and Hammerschmidt (1986) reported 86%–89% survival at 24-h (24 h survival in our study was 37%) for red drum fingerlings stocked into saline, coastal bay systems. Our study mimicked the typical management stockings of red drum in Texas fresh water – fish are produced in saltwater

Table 1. Measures of dissolved solids (mg/L), dissolved oxygen (mg/L), salinity (ppt), and temperatures (C) found in Tradinghouse Creek and Calaveras reservoirs during summer 2002 and fall 2003 survival trials. The columns titled TDS and DO refer to total dissolved solids and dissolved oxygen.

Location	TDS	Fluoride	Chloride	Nitrite	Bromide	Nitrate	Phosphate	Sulfate	DO	Salinity	Temperature
Tradinghouse Creek Reservoir											
Fall 2002	501	0.8	136	<0.5	1.6	<0.5	<1.0	65	16.3	0.4	16.6
Summer 2003	600	0.6	139	<0.5	1.2	<0.5	<0.5	48	10.0	0.3	31.3
Calaveras Reservoir											
Fall 2002	993	1.0	274	<0.5	3.0	<0.5	<1.0	145	13.7	0.8	19.7
Summer 2003	900	0.9	270	<0.5	3.3	<0.5	0.6	167	12.7	0.8	32.6

Table 2. Results of mixed-model analysis of variance testing for effects of treatment (acclimation rate), season, reservoir, and interactions on mean number of fish surviving 72 h.

Effect	df	*F*	*P*
Treatment	1,24	4.49	0.0446
Reservoir	1,24	14.36	0.0009
Season	1,24	19.69	0.0002
Reservoir x season	1,24	7.94	0.0095
Treatment x reservoir	1,24	3.31	0.0813
Treatment x season	1,24	2.02	0.1682
Treatment x reservoir x season	1,24	2.09	0.1611

Table 3. Number of fish (calculated as a mean of means of three replicates; initially 100 fish alive in each replicate) surviving at 24 h, 48 h, and 72 h for two acclimation rates (rapid or slow) in summer and fall at Calaveras and Tradinghouse Creek reservoirs. Numbers in parentheses are standard deviations.

Location	Time Period	Rapid	Slow	Location	Time Period	Rapid	Slow
Calaveras Reservoir				Tradinghouse Creek Reservoir			
Summer	24 h	8.8 (2.8)	15.9 (10.4)	Summer	24 h	35.9 (22.9)	48.8 (23.2)
	48 h	3.8 (3.5)	8.2 (7.1)		48 h	1.6 (1.3)	7.6 (5.6)
	72 h	2.4 (3.1)	6.0 (6.3)		72 h	0.4 (0.5)	1.5 (1.1)
Fall	24 h	37.2 (15.9)	64.5 (22.3)	Fall	24 h	40.7 (14.9)	44.8 (22.8)
	48 h	20.8 (11.3)	48.4 (24.3)		48 h	21.5 (6.9)	26.7 (16.8)
	72 h	17.1 (9.9)	39.8 (22.9)		72 h	5.9 (3.8)	6.8 (5.2)

hatcheries on the coast, then transported (3 to 6 h) over long distances (> 200 miles) to reservoirs having elevated chloride levels.

Although well below those of Hammerschmidt and Saul (1984) and Hammerschmidt (1986), our survival rates were far better than those reported by Pitman and Gutreuter (1993). Pitman and Gutreuter (1993) observed mean fingerling survival (1%) in Calaveras and Tradinghouse Creek reservoirs which is well below ours even though stocking dates, fingerling sizes, and acclimation times were similar to those in our study. With so many similarities between the Pitman and Gutreuter study and our own, it is difficult not to question the large discrepancy in survival. Pitman and Gutreuter (1993) hypothesized two major causes for poor survival: inadequate development of fry and fingerlings and cage effects. They also noted extenuating circumstances that may have biased the results of their trials. For example, stress and starvation may have influenced survival of fingerlings stocked in Calaveras, while inadequate acclimation times due to high salinity of hauling waters, may have affected fingerlings stocked in Tradinghouse Creek.

Inadequate development of red drum fingerlings in Pitman and Gutreuter's study likely contributed to low survival rates since red drum used in their study were produced at a freshwater hatchery with a low-salinity water supply. It was also noted that most red drum fingerlings stocked in the Pitman and Gutreuter study were immature (i.e., lacked scales). Red drum used in our study (and those currently stocked by TPWD) were produced at a coastal hatchery, so inadequate development of fry to fingerlings was no longer a problem.

Our study had fish enclosure densities similar to those of Pitman and Gutreuter (1993), .09 fish/L vs. 0.15 fish/L, respectively. Although enclosure densities were similar, their size and construction was quite different. Pitman and Gutreuter (1993) suggested cage effects as a possible reason for low survival since their enclosures were subjected to wind and wave agitation. The small size of their enclosure (0.3 x 0.6 m) and frame construction (wood) probably added to fingerling stress and mortality by exaggerating wave and wind effects and limiting fingerling movement. We believe our enclosure was superior because of its larger size (1.8 x 0.9 m) and limited use of hard materials. These qualities, combined with placement of enclosures in protected coves dampened stress from wind and wave action. The mesh size (3 mm) of our enclosure was also larger than that used by Pitman and Gutreuter (1993) which should have increased food available for fingerlings. Overall, our study fingerlings were allowed broader horizontal and vertical mobility to avoid agitation, seek out food items, and find appropriate temperature and DO levels.

Reservoir, season, and acclimation time were investigated as possible main effects on red drum survival. Reservoir was found to have a significant effect (Table 2). According to the research of Miranda and Sonski (1985), red drum should favor the physicochemical makeup and temperature regime of Calaveras over Tradinghouse Creek. Higher TDS and chloride concentrations allow for easier ionic regulation of marine fishes and since these concentrations were nearly twice as high in Calaveras, fingerlings would be expected to survive better in that reservoir (Table 1). Our data corroborated this as mean survival of Calaveras fingerlings (16%) was higher than that of Tradinghouse Creek fingerlings (4%). An alternative explanation for higher survival at Calaveras is that the hauling time to that reservoir was substantially shorter (3 h vs. 6 h) and may have resulted in less stress on stocked fish.

Season was also significant (Table 2) as 17.4% of fingerlings survived fall trials and only 2.5% survived summer trials. Fall trials were conducted during late October and November while summer trials occurred in June and July. Coincidentally, Pitman and Gutreuter conducted their fall trials within weeks of our trial dates, so season probably had little to do with the variation in survival between studies. Although season proved to be a factor in our survival study, inland stockings are reliant on coastal hatchery production, and a large percentage of historical red drum stockings have occurred during summer months. Managers of inland red drum fisheries should weigh the reduced benefits of summer stockings with their fishery needs.

Acclimation times vary among field studies. Hammerschmidt and Saul (1983) acclimated fingerlings an average of 0.8 h (range 0.0 to 2.2 h) and at an exchange rate of 2600 L/h, but recommended increased acclimation times to minimize handling stress during future stockings. Pitman and Gutreuter (1993) acclimated red drum fry for 1 h and red drum fingerlings for 3.5 h, yet did not provide direct exchange rates. They mentioned inadequate acclimation times as an extenuating circumstance which might have decreased survival and biased results. We selected 2.5 h and 5 h for acclimation times, assuming these were practical for field staff and suitable for tempering red drum effectively. We calculated exchange rates at 379 L/h and 190 L/h for rapid-acclimated and slow-acclimated fingerlings respectively. These are much lower than exchange rates provided by Hammerschmidt and Saul (1983); however, we did not analyze exchange rates in this study. Our study found acclimation time to be nearly significant (Table 2); however, its management significance is obvious; higher survival was observed in all study trials when red drum fingerlings were acclimated for 5 h (Table 3).

The management implications of this study are simple yet important. By stocking fingerling red drum during fall and acclimating stocked fingerlings for at least 5 h prior to release into reservoirs, management crews might produce measurable improvements to these fisheries. Pitman and Gutreuter (1993) advocated additional study of hauling and acclimation times of red drum and recommended standardizing acclimation procedures. We feel this study provides the best information to date on red drum post stocking survival in Texas freshwater and propose standardizing acclimation times at 5 h until further research is conducted. Future studies on post stocking survival of red drum should investigate reducing stress associated with handling red drum, optimal hauling salinities, examination of exchange rates, food availability and diet of study fingerlings during post-stocking studies, and effective survival of different sizes of fish stocked.

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