Red Drum Life History and Sport Fishing Trends in a Freshwater Reservoir

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Abstract: Growth, survival, angler utilization, and fishery characteristics of red drum (*Sciaenops ocellatus*) were monitored after introduction into Braunig Reservoir, a freshwater urban power-plant cooling reservoir in South Texas. Growth was rapid with individuals reaching 412, 592, 683, and 728 mm TL by 12, 24, 36, and 48 months, respectively. Red drum reached harvestable size (51 cm TL) within 2 years after stocking. Average annual survival was 35.7%, higher than reported for Texas coastal populations. Red drum harvest rate was also generally higher in Braunig Reservoir than in Texas coastal fisheries. Cost:benefit ratios of the Braunig Reservoir red drum fishery were 1:65, 1:147 and 1:382 for 1982, 1983 and 1984, respectively.

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Red drum is a large marine predator that often inhabits brackish waters (Simmons and Breuer 1962) and supports major fisheries on the Texas coast (Green et al. 1991). Individuals transplanted into several Texas reservoirs survived, grew, and were harvested by anglers (Henderson 1972, Lasswell et al. 1977), indicating red drum may serve a role in freshwater fishery management.

Spawning and culture techniques have been developed (Arnold et al. 1977, Lasswell et al. 1977, Roberts et al. 1978, McCarty et al. 1986) allowing production of large numbers of red drum for stocking. Although red drum eggs, larvae, and fry have been found to poorly tolerate fresh water (Crocker et al. 1981, Holt et al. 1981), fingerlings (>40 mm TL) have routinely been acclimated from salinities ≥28 ppt to <1 ppt over 3 hours with high survival rates (Lasswell et al. 1977). Miranda and Sonski (1985) determined fingerlings required ≥130 ppm chloride concentration and temperature above 9° C for survival in fresh water, thereby establishing criteria for

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stocking red drum in reservoirs as large predators to better utilize prey fish populations.

Considerable life history information is available for red drum in marine environments (Matlock 1984), but little is known in fresh water. Red drum introductions into Braunig Reservoir (a reservoir with large prey populations and other established sport/predator fishes) allowed this study to determine red drum life history and evaluate sport fishery development in fresh water, considering growth rate, annual survival, and angler effort for and harvest of red drum.

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Methods

Braunig Reservoir, located 16 km south of San Antonio, Bexar County, Texas, was impounded in 1967 for power-plant cooling. The reservoir has a surface area of 546 ha, mean depth of 5.5 m and maximum depth of 17 m. Relatively constant water level is maintained by pumping from the San Antonio River, which receives City of San Antonio sewage-treatment plant effluent approximately 3 km upstream from the pumping site. Nutrient-rich water and thermal effluent from the power plant create a highly productive system with abundant prey and prolonged growing season. Basic water quality is described by the following parameter means ($\pm$ SD, $N = 36$; 1983–1985): total alkalinity $= 200.8 \pm 15.40$ ppm as $CaCO_3$; chloride $= 236.2 \pm 29.93$ ppm; and specific conductance $= 1{,}247.2 \pm 115.72$ μmhos/cm^2. Recreational facilities, reservoir angler access March to November each year, and total annual attendance were provided by SARA.

Juvenile red drum were first stocked into Braunig Reservoir in 1976 with annual stockings beginning in 1980 (Table 1). A 10 fish/day bag and minimum 41 cm total-length (TL) limit for harvest of red drum was established from 1982 to 1985. Red drum regulations were changed to 5 fish/day and minimum 46 cm TL for harvest, 1986–1988, and again to 3 fish/day and minimum 51 cm TL for harvest, 1989–1990. Other major sport fishes in the reservoir were largemouth bass (*Micropterus salmoides*), channel catfish (*Ictalurus punctatus*), and striped bass X white bass (*Morone saxatilis* X *M. chrysops*). Reproduction of red drum in Braunig Reservoir was not possible as discussed for similar Calaveras Reservoir, Texas, by Prentice and Dean (1991).

Red drum were collected quarterly, 1981–1985, by variable mesh-size gill nets as described by Prentice and Dean (1991). Weight (g), TL (mm), scale sample (3 or more scales taken below the lateral line near the tip of the left pectoral fin), and, when possible, sex determination were taken/recorded from each red drum collected.

Red drum ages were determined by 2 independent readers by examination of plastic scale impressions as described by Prentice and Dean (1991) and by length

Table 1. Stocking history for red drum, Braunig Reservoir, Texas, 1976–1990.

Year	Season[a]	*N* stocked	Stocking rate (*N*/ha)	Size[b]
1976	Spring	2,100	3.8	S
1980	Spring	3,100	5.7	F,S
1981	Spring	135,000	247.3	F
1982	Fall	135,000	247.3	F
1983	Spring	126,000	230.8	F
1984	Fall	162,000	296.7	F
1985	Spring	447,000	818.7	F
1986	Spring	293,200	537.0	F
1987	Fall	180,000	329.7	F
1988	Fall	19,700	36.1	F
1989	Spring	2,800	5.1	F
1990	Fall	215,000	393.8	F

[a]Spring = Apr–Jun; Fall = Sep–Nov.
[b]F = fingerling (<125 mm TL); S = subadult (125–350 mm TL).

frequencies from gill net collections. Red drum in Braunig Reservoir constitute a closed, non-reproducing population with a known once per year stocking history which allowed length-frequency separation of age groups. Individuals with questionable age assignment based on length-frequency were not used in growth rate determinations. Red drum growth rate was determined by fitting mean length-at-age and known age (months from stocking to capture plus hatchery rearing time) from length-frequency data (1981–1985) to the von Bertalanffy growth model: $L_t = L_{inf}\{1-\exp[-K(t-t_0)]\}$; L_t is total length (mm) at age t (years), L_{inf} is asymptotic total length, K is the growth coefficient, and t_0 is the age at zero length. The model was fitted to data by unweighted nonlinear least-squares with Marquardt's (1963) algorithm.

Linear regression and analysis of covariance were used to calculate red drum weight-length relationships and compare regression lines between sexes. Condition (K) was calculated by the equation: $K_{SL} = (W/SL^3)\,10^5$, where W is weight and SL is standard length (estimated with standard-total length equations from Harrington et al. 1979).

Annual survival (minimum-variance unbiased estimate) was calculated from age-frequency catch curves (Robson and Chapman 1961) of gill-net collected red drum from 1982, 1983, and 1984. Stocking rates, 1981–1984, were relatively constant, and, without natural reproduction in Braunig Reservoir, relatively constant recruitment resulting in a homeostatic population was assumed on an annual basis. Differences ($P \leq 0.05$) in annual survival rates were tested for by *t*-test between means of independent samples (Snedecor and Cochran 1967).

Access point angler creel surveys were conducted on a total of 224 days to determine directed pressure, harvest, catch, and angler acceptance on Braunig Reservoir from March to November (1982–1990) as described by Luebke (1987). Creel surveys were conducted from 1000 hours to 1800 hours each day. Angler interviews (for harvest and catch estimates) and roving angler counts (for pressure estimates) were conducted on approximately 10% of all available days during the 9-month survey period each year, which was divided into 3 sampling seasons as described by Luebke (1987), except that information on fishes caught but released (catch) was not obtained until 1985 through 1990. Weighted least-squares analysis of covariance (Freund and Littell 1981) was used to test for significant relationships ($P \leq 0.05$) among angler effort, fishing success, harvest, and distance traveled to fish versus creel year. Annual means were weighted by the inverse of variance for each mean. Angler class (boat or shoreline and anglers seeking red drum or anglers seeking any other species, respectively) was included as a covariable to test for differences ($P \leq 0.05$) in harvest and mean weight of red drum caught, and in distance traveled to fish between angler class.

During 1982–1984, anglers were asked to estimate their total expense for the immediate fishing trip based on variable costs including entrance fees, fuel, food, and baits. Combined costs for procurement, rearing, and stocking red drum and the expenditure estimates obtained from anglers fishing for red drum were used to calculate cost:benefit ratios of the Braunig Reservoir red drum fishery. Because no swimming or water skiing was allowed at Braunig Reservoir, the assumption was made that boating or picnicking activities were minor and part of the angling experience. Therefore, total annual attendance figures at Braunig Reservoir obtained from SARA allowed estimation of total fishing effort related to red drum (after adjusting for percent seeking red drum and mean trip length from creel surveys) for cost:benefit calculations.

Results and Discussion

Scales from 170 red drum (TL range = 76–932 mm) were aged by independent readers. Consistent ages between readers were found for 74.3% of the scales by 1 set of readings, but 4.7% of the scales did not get consistent ages after 3 sets of readings. Confusion occurred in larger individuals (≥406 mm TL). Also, most red drum collected could be assigned known-age with length-frequency analysis (Table 1 and Fig. 1). Comparison of scale age to known age revealed 49.4% and 65.7% that did not agree for the total sample and the total sample with 0^+ fish removed (N = 108), respectively. Of the 84 scale ages for the total sample that disagreed with known age, 1 was 1 year older, 55 were 1 year younger, 20 were 2 years younger, and 8 could not be compared because no consistent scale readings were obtained. Similar results aging red drum by scales have been noted by others (Wakefield and Colura 1983, Prentice and Dean 1991). McKee (1980) found scales unreliable for aging red drum from a Texas coast power-plant cooling reservoir. Because of scale-age questions, Braunig Reservoir red drum growth was determined by length-frequency-determined age.

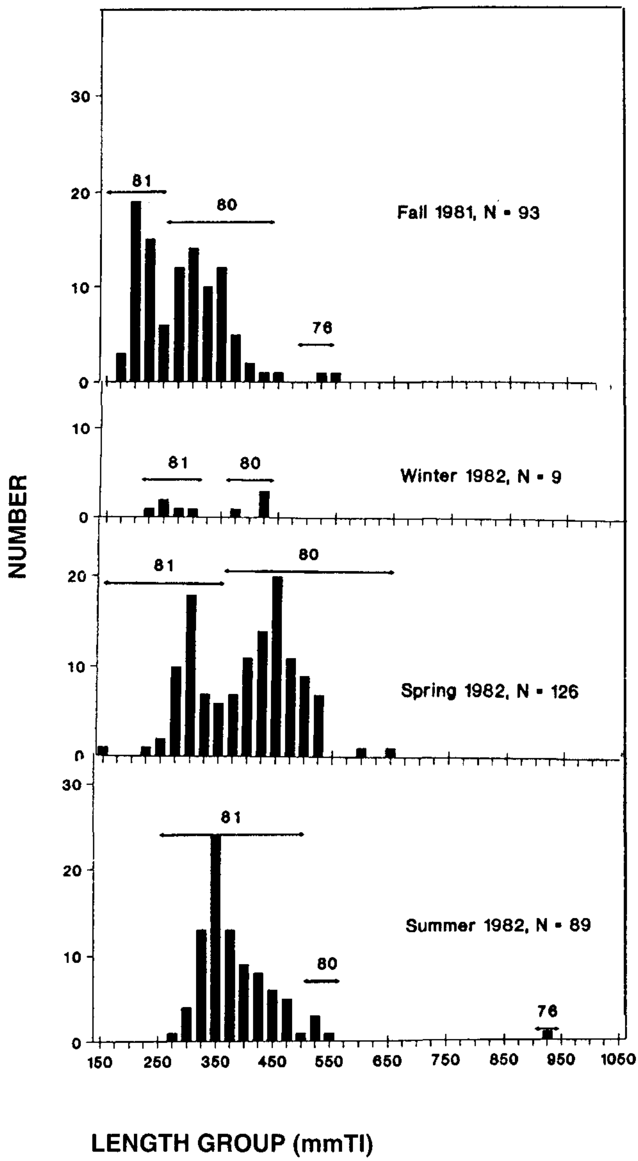
Red drum growth in Braunig Reservoir was rapid, reaching approximately 412, 592, 683, and 728 mm TL by 12, 24, 36, and 48 months, respectively (Table 2). However, the first-year growth increment was much larger than increments in later years, similar to the growth pattern found for Calaveras Reservoir red drum (Prentice and Dean 1991). The large first-year increment presaged larger Braunig red drum in years 2 and 3 than were reported for Texas saltwater red drum populations (Table 2). This rapid growth rate also provided legal-sized (51 cm TL) fish for angler harvest within 2 years of each stocking in Braunig Reservoir.

No significant difference ($P = 0.9651$) was found in Braunig Reservoir red drum weight-length relationships between sexes. The weight-length relationship (sexes combined) for 1,153 red drum (TL range 76–1,029 mm) collected from Braunig Reservoir ($\log_{10} W = -5.0054 + 3.0142\log_{10} [TL]$; $R^2 = 0.98$) was similar to those reported for other red drum populations (Harrington et al. 1979, Matlock 1984, Prentice and Dean 1991) and indicated 51-cm TL fish in Braunig Reservoir would weigh 1,431 g. The standard-length condition factor (K_{SL}) of Braunig Reservoir red drum (1.95 ± 0.01, range = 1.33–3.13) was similar to values reported for other freshwater (Henderson 1972) and saltwater (Boothby and Avault 1971, Luebke 1973, Bass and Avault 1975, McKee 1980) red drum populations. These observations indicate red drum adapted well to environmental conditions and life in this freshwater reservoir.

Annual survival rates of Braunig Reservoir red drum (40.4 ± 5.5, 31.9 ± 6.8, and $34.9 \pm 8.4\%$ estimated for 1982, 1983, and 1984, respectively) provided a mean survival rate ($35.7 \pm 4.1\%$) that was higher than those reported for red drum in Texas coastal waters. Matlock and Weaver (1979) found mean monthly red drum survival in Texas bays that equalled an annual survival rate of 32%. Annual red drum survival in Texas bays, based on length-frequencies, ranged from 11% to 31% (Matlock 1984) and from 12% to 20%, averaging $15 \pm 2\%$ (Green et al. 1985). Lower survival rates for Texas coast red drum populations may have been a result of high fishing mortality due to both recreational and commercial activities. There was no significant difference ($P > 0.4$) found among Braunig Reservoir annual survival rates indicating stability and that red drum year-class strength could be expected to decrease rapidly after each stocking.

Creel surveys completed 18,571 angler interviews, during March through November from 1982 to 1990. Red drum harvest in Braunig Reservoir was first reported by anglers during 1979 (3 fish, total weight = 7.53 kg; unpubl. data, SARA). By 1982, red drum were well represented in the creel (Tables 3, 4). Angler effort (hours/ha) for red drum followed a significant ($R^2 = 0.82$, $P = 0.0062$) curvilinear trend across years. This relationship indicated angler effort increased from 1982 to 1986, remained high from 1986 to 1988, and decreased after 1988 (Table 3). Angler effort seeking red drum was generally higher throughout this study than for any other major sport fish (Table 3). Red drum angler success rate remained fairly stable throughout this study ranging from 16.8% to 27.4% (Table 3); catch rates were generally <0.1 fish/hour (Table 5). Also, few anglers harvested the daily bag limit (Table 5).

Red drum harvest in *N*/ha and kg/ha also illustrated significant ($R^2 = 0.76$, $P = 0.0133$, and $R^2 = 0.86$, $P = 0.0025$, respectively) curvilinear relationships across years. These relationships indicated harvest increased from 1982 to 1986 and remained high through 1988 (Table 4). Despite increasingly restrictive harvest regulations imposed in 1986, large annual stockings (Table 1) and a strong fishery,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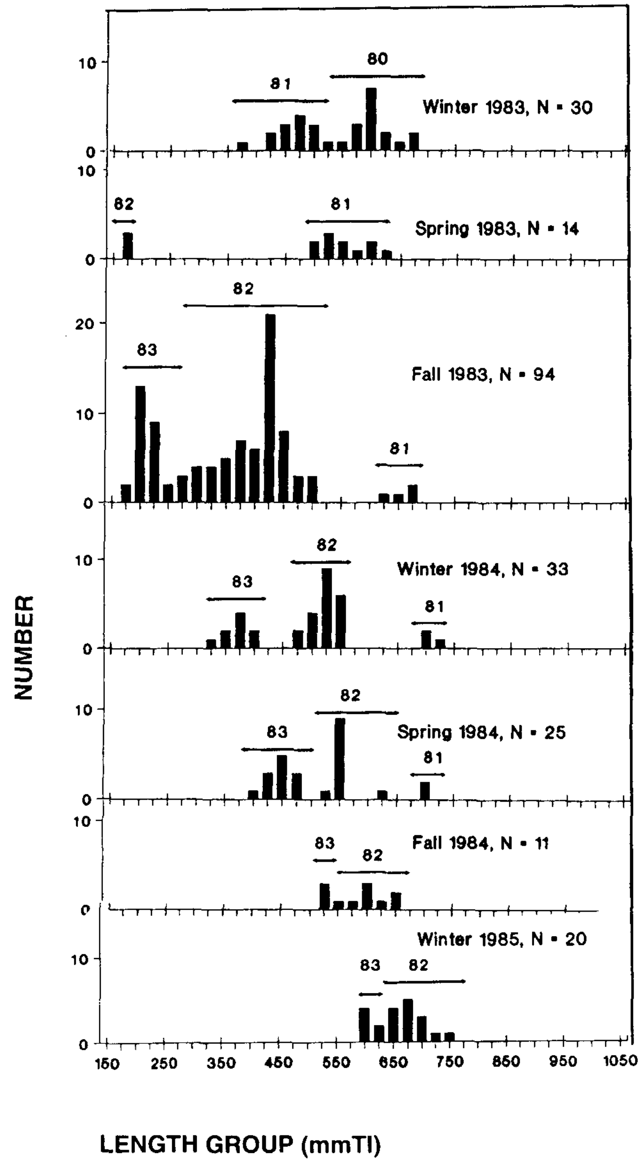

Figure 1. Seasonal length-frequencies of red drum collected in gill nets, Braunig Reservoir, Texas. Length groups are in 25-mm TL increments (e.g. 150 = 150–174 mm, 175 = 175–199 mm, etc.). Horizontal lines above length distributions indicate year classes. Collections with no red drum are not included.

Table 2. Estimates of von Bertalanffy growth model parameters and calculated mean total lengths-at-age for red drum populations from various locations in Texas.

			von Bertalanffy growth parameters			Calculated total length (mm)-at-age				
Location	Aging method[a]	*N*	L_{inf}(TL, mm±SE)	K(±SE)	t_0(years±SE)	1	2	3	4	5
Braunig Reservoir	LF	352	775(31.3)	0.69(0.071)	−0.11(0.042)	412	592	683	728	751
Calaveras Reservoir[b]	KA	37	749(14.8)	0.82(0.070)	0.05(0.065)	404	597	682	720	
Lower Laguna Madre[c]	S	30	717	0.52	−0.01	293	465	567		
Matagorda Bay[c]	S	339	835	0.35	−0.02	251	423	545	631	691
Galveston Bay[c]	S	23	804	0.41	−0.01	273	451	570	649	
Aransas and Corpus Christi Bays[d]	LF	695	1,068	0.30	0.14	239	451	609	726	813
Total Texas Coast[e]	TR	2,010	918(21.0)	0.42(0.023)	f	315	522	658	747	806

[a]LF = length-frequency, KA = known age, S = scales, TR = tag recovery.
[b]From Prentice and Dean (1991).
[c]From Doerzbacher et al. (1988) based on data from Wakefield and Colura (1983).
[d]From Matlock (1984) based on data from Pearson (1929).
[e]From Doerzbacher et al. (1988).
[f]Calculations of t_0 was not possible, but was assumed 0.0 to calculate comparative lengths-at-age.

Table 3. Summary of annual creel (March–November) estimates comparing any species, red drum (RD), channel catfish (CC), largemouth bass (LMB), and striped X white hybrid bass (SH) at Braunig Reservoir, Texas, 1982–1990. Standard errors are in parenthesis.

	Fishing effort (hours/ha) directed at					Percent success[a] for parties seeking				
Year	Any spp.	RD	CC	LMB[b]	SH	Any spp.	RD	CC	LMB[b]	SH
1982	331.2 (25.3)	57.9 (7.7)	100.8(13.1)	97.3(13.0)	15.6 (4.1)	21.1(1.8)	20.2(2.4)	26.4(2.3)	26.1(4.1)	13.6(4.6)
1983	371.9 (28.1)	89.0(10.7)	157.8(14.9)	74.3(11.4)	11.4 (2.7)	20.1(1.4)	17.6(3.0)	30.8(1.9)	14.2(2.5)	10.6(4.2)
1984	556.1 (45.6)	229.0(27.3)	158.8(18.2)	42.6 (7.6)	17.5 (4.8)	18.9(1.0)	17.8(1.7)	27.0(2.8)	26.4(4.8)	30.0(5.3)
1985	598.3 (54.7)	250.3(29.5)	131.9(15.1)	15.5 (3.1)	44.4 (9.7)	17.6(1.7)	17.0(2.3)	28.0(3.8)	4.9(3.8)	46.2(4.3)
1986	1,185.9(176.4)	418.0(83.3)	168.8(33.5)	51.5(12.1)	201.1(56.9)	21.4(2.3)	24.8(2.5)	24.2(4.6)	3.0(1.9)	49.1(8.2)
1987	938.8 (95.0)	303.1(40.1)	89.3(11.4)	41.6 (8.5)	102.4(28.1)	12.2(1.0)	16.8(2.5)	22.4(2.7)	1.1(1.1)	34.3(3.0)
1988	1,003.0(131.4)	274.5(45.0)	94.6(18.1)	54.1(10.4)	167.4(36.8)	15.3(1.9)	27.4(2.7)	19.9(3.0)	5.4(0.8)	43.2(6.0)
1989	529.9 (53.8)	140.3(16.6)	69.8(10.0)	27.7 (4.3)	42.5 (8.2)	8.5(0.8)	26.5(1.6)	13.5(2.4)	5.2(0.6)	22.5(5.0)
1990	529.9 (50.4)	123.9(15.6)	75.2(11.1)	30.1 (5.3)	26.2 (5.1)	8.1(0.7)	23.4(1.9)	18.5(4.5)	5.7(0.8)	12.2(4.0)

[a]Parties harvesting at least 1 fish/trip.
[b]LMB regulations changed from 10 fish/day bag and minimum harvest length (MHL) of 24.5 cmTL 1982–1984 to 2 fish/day and MHL of 53 cmTL 1985–1990.

Table 4. Annual (March–November) harvest estimates for boat and shoreline anglers seeking red drum, Braunig Reservoir, Texas, 1982–1990. Standard errors are in parentheses.

Harvest type	1982	1983	1984	1985	1986	1987	1988	1989	1990
Boat anglers									
fish/ha	6.0 (1.9)	6.3 (1.5)	11.0 (2.1)	14.5 (5.5)	33.5 (7.3)	25.4 (5.0)	19.7 (4.2)	7.5 (2.0)	2.7 (1.0)
kg/ha	5.6 (2.0)	11.2.(2.5)	25.5 (5.0)	59.9(24.3)	97.4(20.7)	99.6(21.8)	75.2(16.5)	34.0 (8.2)	11.3 (4.7)
kg/fish	0.9 (0.1)	1.7 (0.2)	2.3 (0.04)	4.1 (0.3)	2.9 (0.2)	4.1 (0.2)	3.8 (0.2)	4.5 (0.5)	4.2 (0.4)
Shoreline anglers									
fish/ha	2.9 (2.2)	2.1 (0.9)	2.5 (0.7)	3.3 (1.5)	3.7 (1.2)	1.3 (0.5)	2.3 (1.1)	4.0 (0.9)	2.8 (0.9)
kg/ha	0.6 (0.2)	4.1 (2.2)	5.9 (1.7)	17.5 (8.0)	13.1 (4.5)	4.0 (2.1)	10.7 (5.3)	9.5 (1.8)	8.7 (3.0)
kg/fish	0.7 (0.0)	1.8 (0.3)	2.4 (0.2)	5.3 (0.1)	3.7 (0.6)	2.6 (1.0)	4.8 (0.3)	2.3 (0.4)	3.1 (0.6)

Table 5. Annual (Mar–Nov) catch and harvest estimates for anglers seeking red drum and proportion of anglers harvesting the bag limit, Braunig Reservoir, Texas, 1985–1990. Standard errors are in parentheses.

Year	*N* red drum			Red drum harvest by weight (kg/hour)	% anglers with full bag[a]
	Harvest/hour	Release/hour	Total catch/hour		
1985	0.067 (0.006)	0.062 (0.004)	0.129 (0.006)	0.263 (0.026)	0.98
1986	0.077 (0.003)	0.021 (0.002)	0.098 (0.002)	0.203 (0.008)	2.03
1987	0.041 (0.009)	0.026 (0.006)	0.067 (0.012)	0.165 (0.039)	0.00
1988	0.042 (0.006)	0.022 (0.008)	0.063 (0.011)	0.162 (0.025)	0.00
1989	0.040 (0.006)	0.027 (0.007)	0.067 (0.010)	0.149 (0.023)	6.99
1990	0.072 (0.015)	0.006 (0.002)	0.078 (0.016)	0.288 (0.071)	3.31

[a] 10 fish/day and minimum harvest length (MHL) of 41 cmTL, 1982–1985; 5 fish/day and MHL of 46 cmTL, 1986–1988; 3 fish/day and MHL of 51 cmTL, 1989–1990.

harvest declined after 1988 (Table 4). However, rapid growth (Table 2) and large individual size (Table 4) created a trophy fishery for red drum that was utilized by both boat and shoreline anglers.

Braunig Reservoir red drum annual directed harvest (Table 4) was much higher than annual (1986 through 1989) statewide average directed harvest for 2 of Texas' major sport fishes. These sport fishes, largemouth bass and channel catfish, had directed harvest which ranged from 2.2 fish/ha (1.98 kg/ha) to 5.2 fish/ha (3.67 kg/ha) and from 4.5 fish/ha (2.39 kg/ha) to 9.5 fish/ha (3.64 kg/ha) respectively (TPWD creel survey data files). Braunig Reservoir red drum harvest rates (Table 5) and mean fish weight (Table 4) also were generally high when compared to Texas coastwide red drum estimates, 1974 through 1989, of 0.01–0.05 fish/hour and 0.74–2.39 kg/fish (Green et al. 1991).

The average distance traveled to fish at Braunig Reservoir (1985–1990) was approximately 38.9 km. Although a few angler parties each year claimed to have traveled >950 km seeking red drum, there was no significant relationship indicating difference in trip distances among years ($P = 0.9426$). However, anglers seeking red drum traveled significantly ($P = 0.0001$) greater distances than anglers seeking any other species. Angler satisfaction with fishing trips also did not improve among years or among anglers seeking red drum or other fishes. The percentage of red drum anglers rating their fishing as good or very good was largest (17.9 and 19.6% in 1985 and 1986, respectively) when catch rate was highest (Table 5). During 1987–1990, 9.9% to 17.3% of red drum anglers rated fishing as good or very good. Perhaps presence of this unusual red drum fishery resulted in unusually high angler expectations.

Mean spending of anglers seeking red drum at Braunig Reservoir, 1982–1984, was $1.69/angler-hour. Red drum procurement, rearing, and stocking costs in 1984 were approximately $17/1,000 fish. Cost:benefit ratios were 1:65, 1:147 and 1:382 for 1982, 1983, and 1984, respectively. Low spending/hour fished at Braunig Reservoir, compared to the estimated (U.S. Dep. Int. 1989) $6.23/hour fishing in Texas freshwaters during 1985, was probably due to the close proximity to San Antonio and its essential conversion into an urban fishery. Based on the $6.23 spent/hour fishing estimate, freshwater red drum fisheries created in other reservoirs could have higher cost:benefit ratios.

Shoreline anglers at Braunig Reservoir were able to participate in the red drum fishery. Analysis of covariance indicated boat anglers harvested significantly more red drum by *N*/ha ($P = 0.0115$) and kg/ha ($P = 0.0001$) than shoreline anglers. Although harvest by boat anglers was greater (ranging 1.9 to 19.9 times more by numbers, except in 1990 when shoreline anglers actually harvested more than boat anglers; and ranging 1.3 to 24.6 times more by weight, Table 4) than by shoreline anglers, shoreline anglers harvested many red drum. However, there was no statistical difference ($P = 0.3523$) between boat and shoreline anglers in mean size (kg/fish) of red drum harvested. There was higher mean size of red drum harvested by shoreline than boat anglers in 5 of the 9 years measured (Table 4). Therefore, this fishery provided shoreline anglers an opportunity to catch "trophy-sized" fish similar to that provided to boat anglers.

Red drum adapted well to environmental conditions and provided a successful fishery when introduced into Braunig Reservoir. When minimal levels of dissolved solids and temperature (Miranda and Sonski 1985) are met in other target waters for introduction, red drum can be expected to provide a quality fishery. Stocked red drum exhibited rapid growth which provided harvestable fish in <2 years. Braunig Reservoir red drum also created a fishery that offered the opportunity for both shoreline and boat anglers to catch "trophy-sized" fish. High cost:benefit ratios found for this fishery, considered with the high angler utilization observed, indicated freshwater red drum fishery creation is also economically feasible. Finally, red drum is an exotic species in freshwater reservoirs; however, concern over their escapement into streams or rivers in the southeastern United States due to water release or flooding is unwarranted because those waters either would not support red drum survival due to low dissolved solids or temperature or would lead to red drum native habitats.

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