Survival of Rainbow Trout Fingerlings Stocked into the Special Regulation Zone of the Canyon Reservoir Tailrace

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Management Data Series
No. 247
2007

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ACKNOWLEDGMENTS

The author acknowledges Texas Parks and Wildlife Department (TPWD) Inland Fisheries Management employees Craig Bonds, Josh Duty, Greg Cummings and Drew Rickman for their assistance in the field collection and tagging; Josh Duty for his work on the sampling map; Marcos DeJesus, Mark Howell, Raphael Brock, Brian Van Zee and Bob Betsill for review of the manuscript. Thanks to the TPWD A.E. Wood State Fish Hatchery staff for help with tagging, anesthetizing fingerlings and monitoring tagged control fish. This research was funded by the Federal Aid in Sport Fish Restoration Act, Grant F-30-R to the TPWD.

ABSTRACT

The Canyon Reservoir tailrace is a 22.2-km, hypolimnetic release tailrace trout fishery located below Canyon Reservoir on the Guadalupe River in Comal County, Texas. The section of the tailrace from 6.3 to 22.2 km has a 457-mm minimum length and one fish daily bag limit (rainbow and brown trout). Fingerling (62-130 mm) rainbow trout were stocked in the tailrace by the Texas Parks and Wildlife Department (TPWD) from 1996 to 2000. Rationale for these stockings was that fingerlings stocked in the tailrace special regulation zone would be protected from harvest and might grow to a quality size. If fingerling stockings were successful, a high quality catch-and-release fishery might develop, eliminating or decreasing the need to stock catchable size (203–304 mm) trout in this stretch of the tailrace. Catchable size trout stockings could then be concentrated at sites where harvest oriented fishing effort was high. In three of the five years stocked fingerlings oversummered, although almost all survival was in the first 6.3 km downstream from Canyon Dam. Beyond 6.3 km, water temperature frequently exceeded recommended (< 21.1 C), and even lethal (25 C), levels when flow from Canyon Reservoir was decreased during the summer months (May-October). The potential for mortality associated with high water temperature justified discontinuation of fingerling stocking after 2000.

In May 2003, a water release contract between Guadalupe River Trout Unlimited (GRTU) and the Guadalupe River Blanco Authority (GBRA) was implemented with the specific objective of keeping water temperatures < 21.1 C in sections of the tailrace > 6.3 km downstream from the dam. Given the new water release agreement, TPWD decided to once again test the efficacy of fingerling rainbow trout stockings, and in June, 2005 approximately ten thousand rainbow trout fingerlings (mean length = 135 mm) were marked and stocked into the special regulation zone to evaluate survival. Boat electrofishing surveys (2.42 hours effort/survey) were conducted from Canyon Dam to approximately 17.2 km downstream once per month from August to November in 2005 to collect tagged fingerlings. Backpack electrofishing was also conducted in August, 2005.

No marked fingerlings were recaptured, though unmarked rainbow trout were collected in all surveys. As in electrofishing surveys of the 1990's, total catch rate decreased with successive collections. Water temperatures greater than recommended (21.1 C), but less than lethal (25 C), were recorded in the special regulation zone during the study period. Stress caused by elevated water temperature may have been a factor influencing mortality of stocked fingerlings and unmarked rainbow trout. Based on results of this study, the practice of stocking fingerlings into the special regulation zone should be discontinued. Water temperature in the 6.3-km stretch upstream of the special regulation zone almost always remains below 21.1 C. Stocking in this area may increase survival; however, trout in this area are not currently protected by a minimum length limit. Future studies should focus on increasing survival of stocked catchable trout in the special regulation zone.

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INTRODUCTION

Tailrace trout fisheries are an important part of many state fisheries programs in the southern United States (Baker 1959, Fry and Hanson 1968, Axon 1975, Wiley and Dufek 1980). Hypolimnetic releases often keep water temperatures below optimal levels for endemic warmwater fish populations (Hickman and Hevel 1986, Ruane et al. 1986) making rainbow trout (*Oncorhynchus mykiss*) an acceptable replacement sport fish (Fry and Hanson 1968, Axon 1975, Hess 1980, Harper 1994). Tailrace trout fisheries can provide local economic benefits that greatly outweigh costs associated with stocking (Axon 1975, Forshage 1976, Weithman and Haas 1982, Choi et al. 1993, Harper 1994, Bradle et al. 2006) and provide diversified fishing opportunities.

Rainbow trout were first stocked in the Canyon Reservoir tailrace, a hypolimnetic reservoir release tailrace, in 1966 by the Texas Parks and Wildlife Department (TPWD) (White 1968). It is one of the most popular winter trout fisheries in Texas (TPWD, unpublished data) and catchable size (>203 mm) rainbow trout are stocked each winter (December-February) at public and Guadalupe River Trout Unlimited (GRTU) access sites. Harvest of the trout stocked at public access points with no minimum length limit can be high (83-91%) (Magnelia 2004).

Because of its location in south-central Texas, water temperatures in the tailrace during the summer (June through September) were thought to exceed lethal levels for rainbow trout. However, oversummer survival of trout (White 1968, Magnelia 2004) and acceptable growth (White 1968) sparked interest in developing a portion of the fishery into a put-grow-and-take section. On September 1, 1997, a 457-mm minimum length limit and one trout (rainbow and brown trout) daily bag limit was initiated in the section from 6.3 to 22.2 km downstream from the dam. Trout harvested in this special regulation zone must be caught on an artificial lure, although anglers may fish with any bait type. Catchable size rainbow trout (N = 10,605) were stocked by TPWD and GRTU in this area from December 2004 to February 2005. In addition, TPWD stocked

approximately 53,000 unmarked fingerlings (mean TL = 49 mm) in March 2005 and 13,000 (mean TL = 76 mm) in April 2005.

Rainbow trout fingerlings (mean size range = 62-130 mm) were first introduced by TPWD into this section of the tailrace in 1996 (Magnelia 2004). This practice continued annually through 2000. Justification for these stockings was that fingerlings would be protected from harvest and might grow to a quality size. If fingerling stockings were successful, a high quality catch-and-release fishery might develop, eliminating or decreasing the need to stock catchable size (>203 mm) trout in this stretch. Stockings of catchable size trout could then be concentrated at sites where anglers were primarily interested in harvest. From 1996 to 2000, stocked fingerlings oversummered in the Canyon Reservoir Tailrace during three years, although almost all survival was in the first 6.3 km of the tailrace (Magnelia 2004). Downstream of 6.3 km, water temperature frequently exceeded recommended (< 21.1 C) and/or lethal levels (25 C), when flow from Canyon Reservoir was decreased during the summer months (Magnelia 2004). Growth of fingerlings was documented in four of the five years stocked (Magnelia 2004). However, because of concerns with water temperature induced mortality, fingerling stockings were discontinued.

Elevated water temperature has limited the scope of other tailrace trout fisheries until adequate reservoir releases were made for maintaining suitable downstream water temperature. Axon (1974) reported water temperature in the White River below Bull Shoals Reservoir, Arkansas was a factor limiting that rainbow trout fishery, until the U.S. Army Corp of Engineers (USACE) agreed to provide adequate flows for keeping water temperatures below 21.1 C. Similarly, the Oklahoma Department of Wildlife Conservation made reservoir release recommendations for maintaining downstream water temperature at or below 21.1 C on the Mountain Fork River below Broken Bow Reservoir (Harper 1994). Although 25 C is considered an upper lethal temperature for rainbow trout (United States Fish and Wildlife Service (USFWS)

1984), 21.1 C can be considered a maximum threshold water temperature for maintaining tailrace trout fisheries. In May 2003, a water release contract between GRTU and the Guadalupe Blanco River Authority (GBRA) was implemented with the objective of keeping water temperature below 21.1 C from May through September in sections of the tailrace >6.3 km downstream. The stocking of fingerlings was reinitiated under this new water release policy in 2005.

In 2003, water temperatures were <21.1 C in much of the special regulation zone throughout the summer (TPWD, unpublished data). Despite protection under a 457-mm minimum length limit, water temperatures below the maximum threshold, and a stocking of 17,000 catchable size rainbow trout (mean TL = 302 mm) the preceding winter, the October 2003 total electrofishing CPUE in the special regulation zone was disappointing (8.0/hour, effort = 1.75 hours). This catch rate was only slightly better than fall 2001 (prior to the GRTU/GBRA water release agreement) (5.6/hour, effort = 1.25 hours) when water temperature 17.1 km downstream exceeded 21.1 C from June through August and 25 C in August (Magnelia 2004) and 11,724 catchable size rainbow trout were stocked in the special regulation zone. In comparison, fingerling rainbow trout stocked in the Canyon Reservoir tailrace from April through June (1996-2000) were electrofished in October through December at a mean CPUE of 42/hour in years when survival occurred (Magnelia 2004), although almost all fingerling were collected within 6.3 km downstream of the dam where water temperature almost always remains below 21.1 C (Magnelia 2004). Other factors besides harvest and water temperature induced mortality may be limiting density of stocked catchable size trout in the special regulation zone.

On the Clinch River in Tennessee, below Norris Reservoir, annual survival rates for rainbow and brown trout (*Salmo trutta*) stocked as fingerlings were much higher (26-52% annual survival) than rainbow trout stocked as catchables (2-6% annual survival) (Bettoli and Bohm 1997). Poor survival of rainbow trout stocked as catchables suggested that the quality of the

fishery was due to fingerling stockings (Bettinger and Bettoli 2002). In the Clinch River, few rainbow trout stocked as catchables were harvested or survived long enough to contribute to the fishery (Bettinger and Bettolli 2002). The authors attributed low survival of rainbow trout stocked as catchables to rapid, long-range movements and high levels of activity, which were energetically inefficient and probably rendered them more vulnerable to predation. They suggested stocking catchable size trout in the Clinch River might only be cost effective at access areas with high fishing pressure. Low electrofishing catch rate of stocked catchable size trout in the Canyon Reservoir Tailrace in 2003 may be due to similar factors. Striped bass (*Morone saxatilis*) were present in the tailrace in low densities (Terre and Magnelia 1996) and probably preyed on stocked trout. Specific objectives of this study were to evaluate survival and growth for tagged rainbow trout fingerlings stocked in the special regulation zone of the Canyon Reservoir tailrace.

METHODS

Study Area

Canyon Reservoir, a 3,335-ha flood control reservoir located in Comal County, Texas, was created in 1964 when the Guadalupe River was impounded. It is classified as an oligo-mesotrophic, hard water, deep storage, bottom draining reservoir (Hannan et al. 1979). Thermal stratification is normally present from May through November with anoxic conditions existing in the hypolimnion from July through November (Hannan and Young 1974).

The Canyon Reservoir tailrace is a section of the Guadalupe River extending 22.2 km below the stilling basin of Canyon Reservoir. The lower boundary was set because it was assumed this would be the furthest distance downstream where oversummer survival of stocked trout might occur. A bridge at this point also provided a landmark for enforcement of fishing regulations. The tailrace was regulated under the statewide 5 trout daily bag limit (rainbow and brown trout) in any

combination) and no minimum length limit regulation until September 1, 1997, at which time a 457-mm minimum length and one trout (rainbow and brown trout) daily bag limits were initiated in the stretch from 6.3 to 22.2 km below the dam. Trout harvested in this area must be caught on an artificial lure, although anglers may fish with any bait type.

Water from Canyon Reservoir is discharged from a fixed depth of 41 m below the surface, at a conservation pool elevation of 277 m msl. In 1989, a 6-megawatt hydropower plant constructed at the stilling basin by the GBRA became operational. Under the Federal Regulatory Energy Commission (FERC) hydropower permit, minimum outflow into the tailrace during non-drought periods was 2.5 m^3/sec, but under drought conditions outflow may be reduced to reservoir inflow. When the reservoir was in the flood pool, the United States Army Corp of Engineers (USACE) dictated reservoir releases. Outflow rate, when the reservoir was below conservation pool, was determined by inflow into the reservoir and downstream water rights (GBRA, personal communication).

A minimum dissolved oxygen level of 6 mg/l was also required as part of the FERC permit. This level of dissolved oxygen meets minimum standards for tailrace trout fisheries (Weithman and Haas 1984). Meeting requirements of the FERC permit was mandatory only when the reservoir was below conservation pool and water releases were regulated by GBRA.

Lethal hydrogen sulfide levels (> 0.025 mg/L for trout, Environmental Protection Agency (EPA) 1976) are often present at the outflow from Canyon Dam from July through October (TPWD, unpublished data). In September 1997, when hydrogen sulfide was measured, it was non-detectable 1.6-km downstream (TPWD, unpublished data). Water temperature at the discharge during this period was high compared to other years (Magnelia 2004), which probably decreased the length of the plume as aqueous solubility of hydrogen sulfide gas decreases with increasing temperature (Morel and Herring 1993). How this plume changes in response to flow and water temperature, and affects the distribution, mortality or movement of trout in the tailrace is unknown.

Beginning in January 2003, if the reservoir was below conservation pool between May and September, releases were subject to a contractual agreement between GRTU and GBRA. However, this agreement would be implemented only if Canyon Reservoir had reached conservation pool for any length of time prior to the effective date during the period between January 1 and September 30. Minimum reservoir releases were; May 1-15 (3.96 m^3/sec), May 16-31 (4.81 m^3/sec), June 1-14 (5.95 m^3/sec), June 15-30 (6.80 m^3/sec), July 1-31 (5.66 m^3/sec), August 1-31 (5.66 m^3/sec), September 1-30 (5.66 m^3/sec). These releases were recommended to maintain water temperatures below 21.1 C in sections of the tailrace greater than 6.3 km from the outflow.

Water Temperature and Flow

ONSET^{TM} water temperature loggers were deployed at 1.0, 6.3, 11.7, 17.1 and 22.2 km downstream of Canyon Dam (Figure 1). Water temperature was recorded every 30 minutes. Water temperature loggers were deployed attached to the inside of a 305-mm length of 76-mm diameter plastic pipe with 8-10, 18-mm holes. Each end of the pipe was closed using 76-mm plastic end-cap grates. A 1.8-kg lead weight was attached to the lower end of the pipe to anchor it. Pipe and logger were chained and locked to suitable anchor points in an area of good flow. Release rate (m^3/s) at Canyon Dam was provided by the USACE.

Fingerling Tagging and Stocking

On June 20, 2005 rainbow trout fingerlings from Crystal Lake Fisheries Inc. Ava, Missouri were transported by truck to the A.E. Wood State Fish Hatchery in San Marcos, Texas. Upon arrival, fingerlings were placed in chilled water (18 C) circular flow-through holding tanks and a sample (N=200) was measured (mean length = 135 mm, STD = 9 mm). On June 21 and 22 fingerlings were removed from the tanks with a dip net (20-30 per net), anaesthetized with a buffered 15 mg/L tricaine solution and tagged (N = 10,697) with Northwest Marine Technology blank wire micro-tags. Tags were injected into the snout using a Northwest Marine Technology rainbow trout head mold and

automatic tag injector. Dissolved oxygen in the tricaine solution was monitored throughout the tagging process and a new solution was made when dissolved oxygen fell below 6 mg/l. Presence of tags immediately after tagging was verified using a Northwest Marine Technology Tunnel Detector Quality Control Device. After being tagged, individuals were immediately placed in a recovery tank. When tagging operations ceased for the day, fingerlings (N = 300) were checked for tags using a Northwest Marine Technology Handheld Wand Detector. At the end of each tagging day tagged fish were loaded into a 2700 L fish hauling unit and transported 30-40 minutes to stocking sites on the Canyon Reservoir tailrace (Figure 1). Appropriate water quality was maintained as fingerlings were transported. All stocking sites were located > 6.3 km downstream from the outflow in the special regulation zone of the Canyon Reservoir tailrace (Figure 1). Over a two-day period, 10,597 tagged fingerlings were stocked at 9 sites (approximately 1,100 to 1,200/site). Where practical, fingerlings were stocked directly off the bank at the access site. At remote locations fingerlings were stocked from boats. Boat-stocked fingerlings were netted from the hauling unit into 95 L round containers approximately half full of river water. Compressed oxygen was bubbled into each container using a commercial grade oxygen diffuser en route to the stocking site. Upon reaching the stocking location fingerlings were poured directly from the container.

To verify tag retention, tagged fingerlings (N = 106) were held for 32 days in a chilled (<21.1 C) water circular tank at the A.E. Wood State Fish Hatchery. If wire micro tags are shed, they do so by 30 days post-stocking (Northwest Marine Technology, personal communication). At the end of 32 days these fingerlings were checked for tags using a Northwest Marine Technology Handheld Wand Detector. Fish held at the hatchery were monitored daily by fish hatchery personnel and fed a maintenance diet. Surface water temperature, dissolved oxygen and pH were checked on 23 of the 32 days. Individuals which died before the end of 32 days were removed from the tank and frozen.

Recapture of Tagged Fingerlings

From August to November 2005, electrofishing surveys were conducted once per month to collect marked fingerlings. Twenty-nine sites (5 minutes electrofishing effort/site; total effort of 2.42 hours) were electrofished on each survey using a Smith Root™ model GPP 15 pulsator (Figure 1). High voltage and low amperage (approximately 4-6 amps) 15 HZ pulsed direct current (DC) was used. Pulsed DC electrofishing has been found to cause spinal injuries (Sharber and Carothers 1988, Reynolds and Kolz 1988, Holmes et al. 1990, Taube 1992) and mortality (Taube 1992) in rainbow trout. Electrofishing-induced mortality of marked fingerling could bias estimates of survival, growth (Gatz et al. 1986, Dalby et al. 1996, Ainslie et al 1998) and body condition (Thompson et al. 1997). However, using direct current with pulse rates of 30 or less (low pulse DC) is thought to reduce the overall injury rate (Sharber et al. 1994). A pulse rate of 7.5 pulses per second (pps) direct current (DC) has been found to decrease electrofishing induced mortality when compared to continuous DC and other pulse DC frequencies (Henry 2002), however when that pulse rate was used in this study it was ineffective at stunning trout. Pulsator settings were held constant between collections. Additional electrofishing pulse frequencies (30-60 pps) were used at each site in the last survey (November) after first electrofishing with 15 pps. This was done to check that the pulse rate was not influencing collection of tagged fingerlings. Electrofishing sites were distributed from directly below the Canyon Dam hydropower plant to approximately 17.2 km downstream (Figure 1). No sites were further downstream than 17.2 km because there was no suitable access for launching a boat. Sites inaccessible to boat electrofishing in the first 17.2 km were sampled in the August 2005 survey using a Smith Root™ model 12-A POW backpack electrofisher (Total effort = 1.2 hour) (Figure 1). Backpack electrofishing was discontinued after this survey as no tagged fingerlings were collected (i.e. no more effective than boat electrofishing). Backpack pulse settings were the same as those used in the boat electrofisher. Captured trout were placed in an aerated livewell (boat electrofishing) or

placed in a bucket with river water (backpack electrofishing), checked for tags using the handheld wand detector, measured (TL, mm), weighed (gm) and released. Water temperature and dissolved oxygen were recorded at each site.

RESULTS AND DISCUSSION

Water Temperature and Flow

Water temperature exceeded 21.1C at all water temperature stations except at the station closest to the dam (1-km) (Figure 2). Reservoir outflow remained at or above values set in the GRTU/GBRA flow agreement until October 1 and then remained above 3.13 m^3/s throughout the remainder of the study period (Figure 2). These flows maintained water temperature very near 21.1 C as far as 6.3 km, but were not adequate for maintaining temperatures less than 21.1 C in areas further downstream (Figure 2).

Tag Retention

Of the fingerlings tagged, 97.7% (293 of 300 checked) had retained tags when they were placed in the hatchery hauling unit. Of the fingerlings held at the hatchery (N = 106), none lost tags, though only 48% survived the 32 days. Between day 26 and day 32, hatchery staff collected 55 dead fingerlings. Mortality may have been the result of stress caused by a temperature spike on day 9, when an afternoon surface water temperature of 32.3 C was recorded. Temperature below the surface must have been cooler, as this temperature far exceeded the lethal level of 25 C. This was a short-lived event as surface water temperature was 18.9 C (Day 8) just 24 hours before and was 19.6 C by the afternoon of day 10. Tag retention at 30 days was 86-89% for similarly tagged rainbow trout fingerlings (mean TL range = 148-155 mm) stocked in the Clinch River, Tennessee (Bettoli and Bohm 1997).

Recapture of Tagged Fingerlings

No tagged fingerlings were recovered using either boat or backpack electrofishing. The inability to collect marked fingerlings is puzzling since they should have been large enough to be sampled with boat electrofishing gear. On the Clinch River tailrace trout fishery in Tennessee, both rainbow and brown trout recruited to boat electrofishing gear at 100 mm; although 60 pps electrofishing was used in all those surveys (Bettoli and Bohm 1997). Fingerlings stocked in this study (mean length = 135 mm) exceeded that length. Water temperatures exceeding 21.1 C were recorded at the two temperature monitoring sites in the special regulation area (Figure 2). Although water temperature at these sites never reached lethal temperature (25 C), stress from tagging and stocking, and additional stress from water temperatures above 21.1 C may have induced mortality. In another study, specific mortality rates ranged from 11.5 to 21.5 percent per day during a ten-day period for juvenile rainbow trout (mean length = 30.2 mm) acclimated to 16 C and then exposed to water temperature fluctuating 3.8 C around a daily mean of 21 C (Hokanson et al. 1977). In the current study, mean water temperature at the 11.7-km monitoring station was 19.4 C on stocking days and 20.8 C (SD = 1.3 C) from the day of stocking (June 21) through September; this station is approximately in the middle of the special regulation zone). Forty-eight percent of fingerlings held at the A.E. Wood Fish Hatchery lived 30 days after tagging. Except for the temperature spike previously mentioned water temperature in the tank remained below 21.3 C.

Capture of Untagged Trout

Untagged trout were collected in all surveys (Figure 3) and indications are that mortality substantially reduced their numbers during the study period. These were larger individuals (mean length = 387.5 mm, STD = 53.1 mm) than tagged fingerlings, with 14% exceeding the 457-mm minimum length limit. Total electrofishing catch rate of untagged trout decreased with each

successive electrofishing survey (Table 1), decreasing to only 1.6/hour in November 2005. Similarly, total electrofishing catch rate decreased between June and October surveys in 1993 and 1994 (Magnelia 2004). Mortality from water temperature above 21.1 C, harvest, or predation may have singularly, or in combination, been responsible for this decrease. A July-September 1994 creel survey documented no harvest or catch of trout, although anglers seeking trout were interviewed (Magnelia 2004). Striped bass have been implicated as potential predators of stocked trout on tailrace trout fisheries (Bettoli 2000). Large (mean length = 742 mm) striped bass were collected on three of the four electrofishing surveys, but catch rate was extremely low (CPUE = 1.7/hour, Effort = 9.7 hours, N = 16,). One striped bass was collected with a 457 mm rainbow trout in its esophagus. However, almost all striped bass (81%) were found at electrofishing sites 15 and 16 (Figure 1), directly below a low water dam, and 50% (N = 4) of the striped bass collected in the October and November surveys were recaptures (marked with a fin clip) from previous surveys. This indicated the population was concentrated in one area and population density was low.

CONCLUSIONS

The stocking of fingerlings for grow-out in the special regulation zone of the Canyon Reservoir tailrace should be discontinued. While larger untagged trout were collected throughout the study, it appears conditions were not suitable for fingerling survival in this area. Decreasing electrofishing catch of unmarked trout through the summer, observed during this study, was similar to earlier studies (Magnelia 2004), indicating mortality or harvest is decreasing population density by October or November. Specific factors causing mortality are unknown, but may relate to ongoing stress caused by water temperatures above 21.1 C. A paucity of invertebrate food items in the tailrace (Halloran and Arsuffi 2000) may also be responsible for mortality. While the

GBRA/GRTU agreement was put in place to provide water temperature less than 21.1 C, water temperatures in 2005 still exceeded this level in the special regulation zone. Previous stockings of fingerlings into the Canyon Reservoir Tailrace (1996, 1999 and 2000) met with some success; however these fish were collected within 6.3 km of the outflow where water temperature generally remains below 21.1 C (Magnelia 2004). Fingerlings stocked in this area would not be protected by harvest restrictions and would likely be harvested if caught. Results of a creel survey conducted in 1993 and 1994 indicated most (82.8%) of the catchable size trout stocked at a site directly below Canyon Dam were harvested almost immediately (Magnelia 2004). Future studies should concentrate on determining factors responsible for mortality of stocked catchable size trout in the special regulation zone. If no other factor except water temperature can be identified, angler opinions should be polled regarding movement of the upstream boundary of the special regulation zone closer to Canyon Dam where water temperature almost always remains below 21.1 C. Survival in this area, with adequate harvest protection, might be higher.

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Table 1. Number of rainbow trout collected with boat electrofishing on four sampling dates at 29 sites in the Canyon Reservoir Tailrace, August through November, 2005. Sampling effort on each date was 2.42 hours; the catch rate (fish/hour) is given for each sampling date.

Site[a]	Date			
	8/4/2005	9/8/2005	10/17/2005	11/17/2005
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	2	2	0	1
5	0	0	0	0
6	6	1	0	0
7	1	0	0	0
8	2	2	0	0
9	1	1	1	0
10	3	2	3	0
11	0	0	1	0
12	0	0	1	1
13	7	0	0	0
14	4	2	0	0
15	1	0	0	0
16	0	1	3	0
17	13	4	3	2
18	1	1	1	0
19	0	0	0	0
20	0	0	0	0
21	0	0	0	0
22	1	1	0	0
23	0	0	0	0
24	0	3	2	0
25	0	1	0	0
26	1	0	0	0
27	3	0	0	0
28	4	4	0	0
29	0	0	0	0
Fish/hour	20.6	10.3	6.2	1.6

[a] Electrofishing sites are shown in Figure 1. Sites were numbered sequentially beginning nearest Canyon Dam and moving downstream. Sites 7 through 29 were located in the Special Regulation Zone

Figure 1. Location of water temperature monitoring, electrofishing, and tagged fingerling stocking sites, June through November, 2005 in the Canyon Reservoir Tailrace, Comal County, Texas. Backpack electrofishing sites were in close proximity to each other and the number of stations is noted. Boat electrofishing sites were numbered sequentially starting at Canyon Reservoir Dam. Map is to scale.

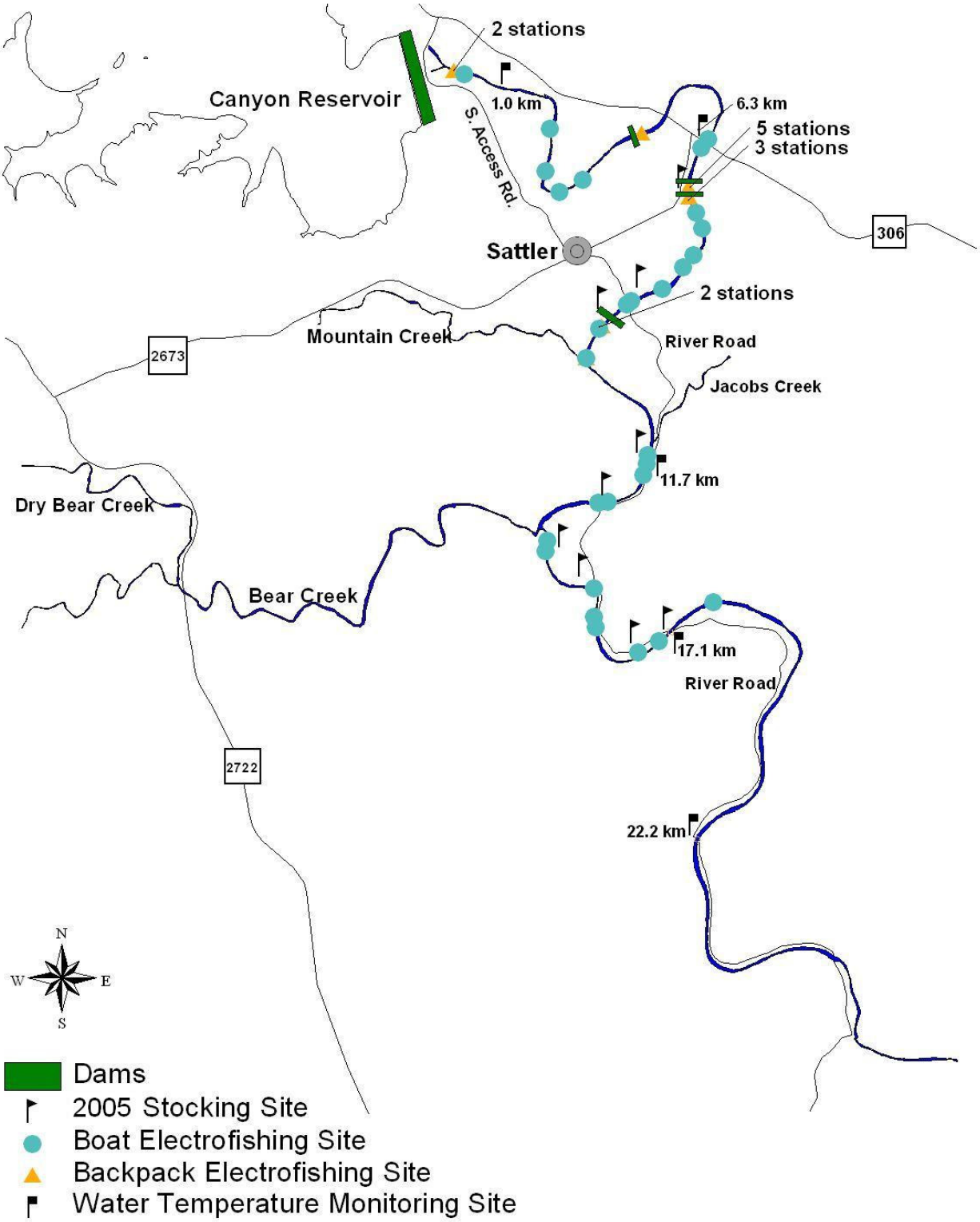
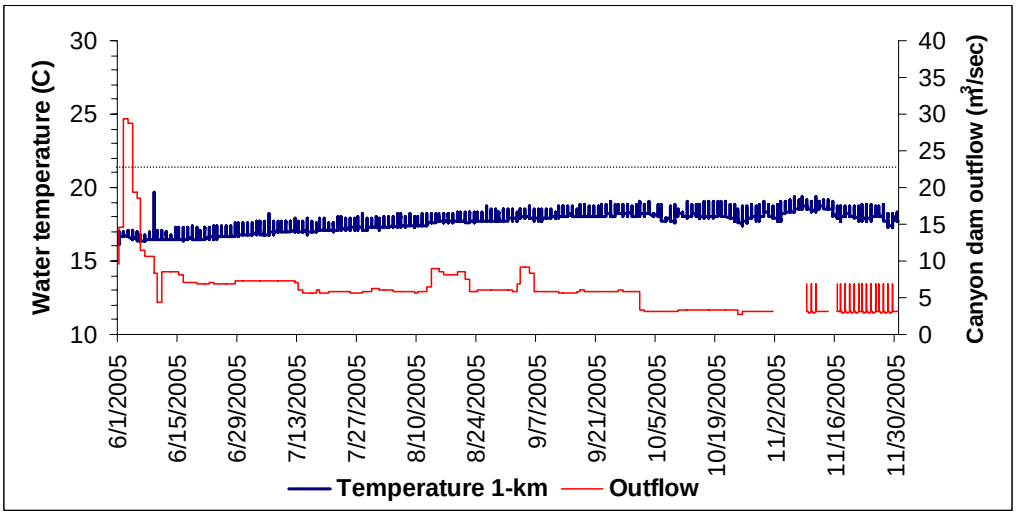
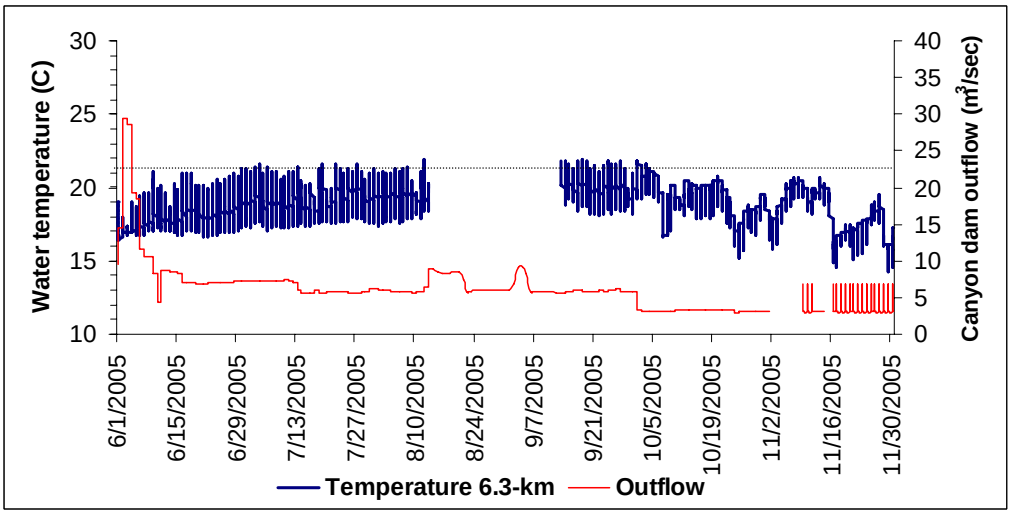

2 stations
Canyon Reservoir
1.0 km
S. Access Rd.
6.3 km
5 stations
3 stations
306
Sattler
2 stations
Mountain Creek
2673
River Road
Jacobs Creek
11.7 km
Dry Bear Creek
Bear Creek
17.1 km
River Road
2722
22.2 km
N
W
E
S
Dams
2005 Stocking Site
Boat Electrofishing Site
Backpack Electrofishing Site
Water Temperature Monitoring Site

Figure 2. Water temperature at 1.0 km, 6.3 km, 11.7 km, 17.1 km and 22.2 km downstream of the outflow of Canyon Reservoir, June through November, 2005. Flow was recorded at Canyon Dam. A horizontal reference line is placed at 21.1 C, the maximum recommended water temperature for tailrace trout fisheries (Axon 1975, Harper 1994).


Water temperature (C)
Canyon dam outflow (m3/sec)
30
25
20
15
10
40
35
30
25
20
15
10
5
0
6/1/2005
6/15/2005
6/29/2005
7/13/2005
7/27/2005
8/10/2005
8/24/2005
9/7/2005
9/21/2005
10/5/2005
10/19/2005
11/2/2005
11/16/2005
11/30/2005
Temperature 1-km
Outflow


Water temperature (C)
Canyon dam outflow (m3/sec)
30
25
20
15
10
40
35
30
25
20
15
10
5
0
6/1/2005
6/15/2005
6/29/2005
7/13/2005
7/27/2005
8/10/2005
8/24/2005
9/7/2005
9/21/2005
10/5/2005
10/19/2005
11/2/2005
11/16/2005
11/30/2005
Temperature 6.3-km
Outflow

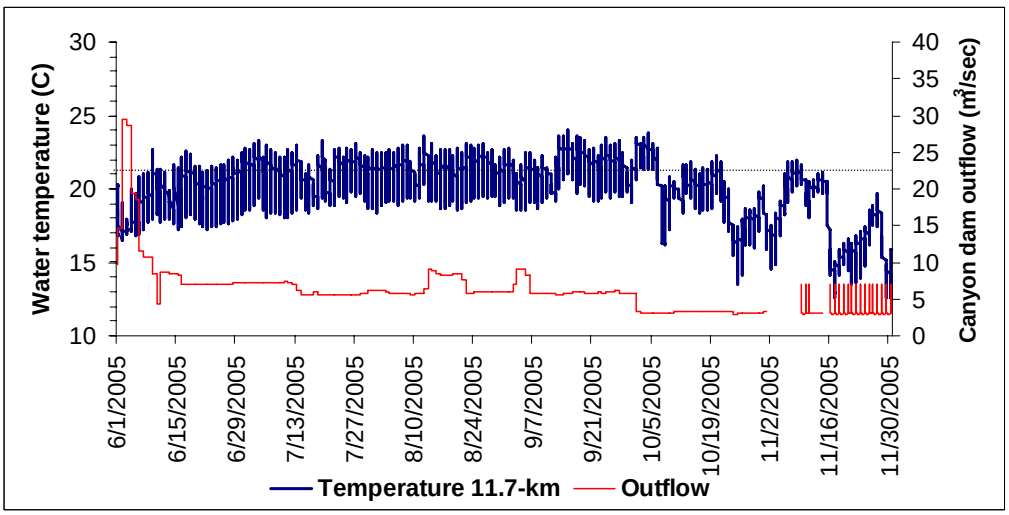
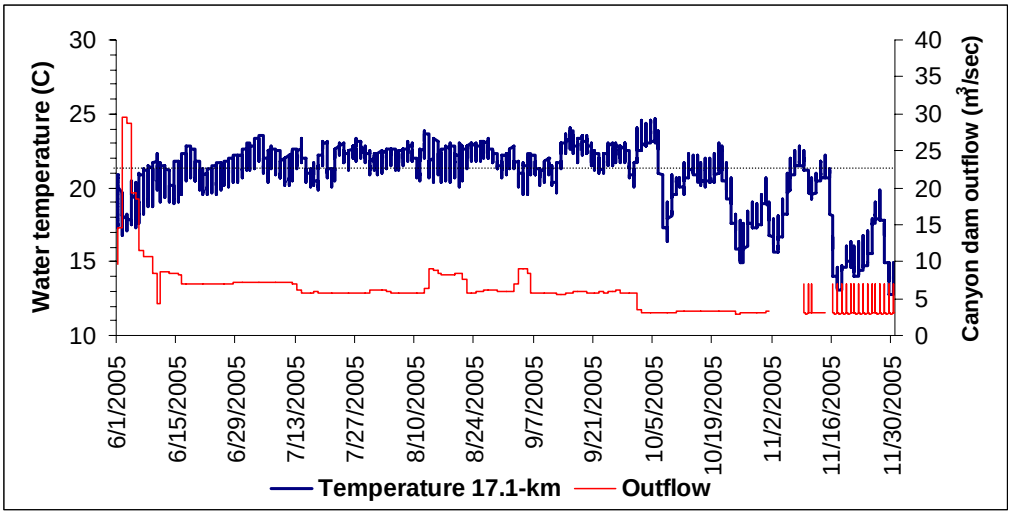

Water temperature (C)
Canyon dam outflow (m3/sec)
30
25
20
15
10
40
35
30
25
20
15
10
5
0
6/1/2005
6/15/2005
6/29/2005
7/13/2005
7/27/2005
8/10/2005
8/24/2005
9/7/2005
9/21/2005
10/5/2005
10/19/2005
11/2/2005
11/16/2005
11/30/2005
Temperature 11.7-km
Outflow

Figure 2. Continued


Water temperature (C)
Canyon dam outflow (m3/sec)
30
25
20
15
10
40
35
30
25
20
15
10
5
0
6/1/2005
6/15/2005
6/29/2005
7/13/2005
7/27/2005
8/10/2005
8/24/2005
9/7/2005
9/21/2005
10/5/2005
10/19/2005
11/2/2005
11/16/2005
11/30/2005
Temperature 17.1-km
Outflow

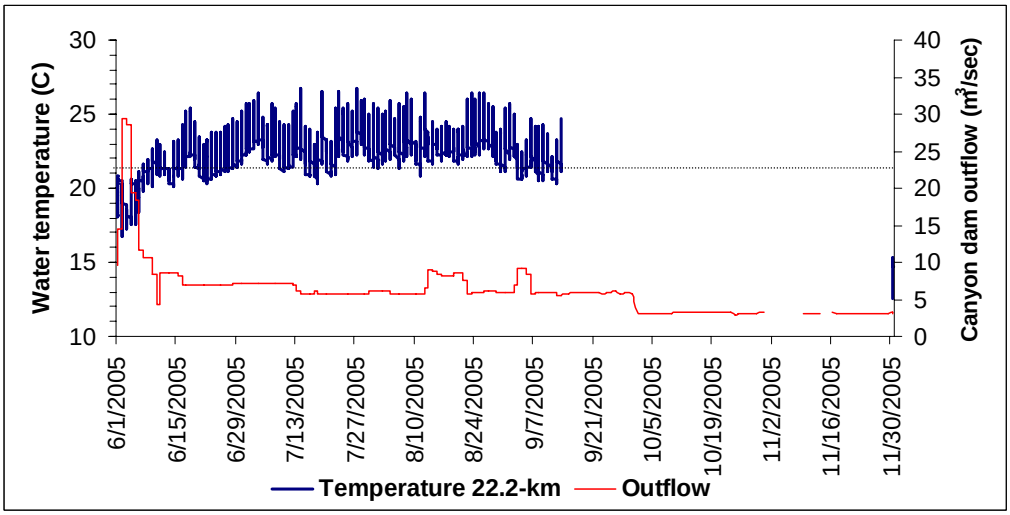
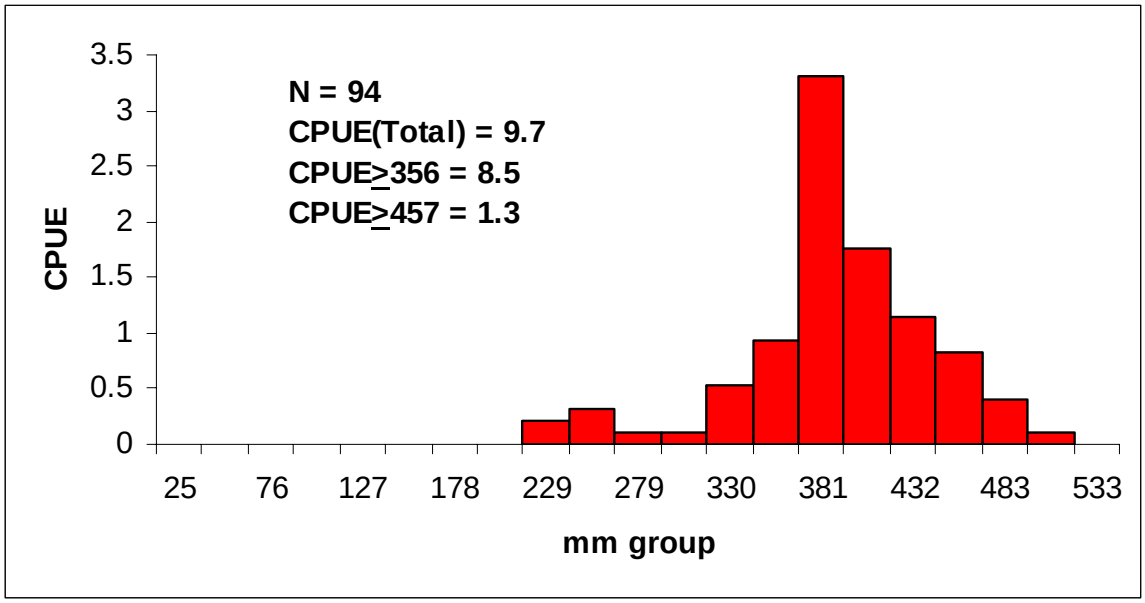

Water temperature (C)
Canyon dam outflow (m3/sec)
30
25
20
15
10
40
35
30
25
20
15
10
5
0
6/1/2005
6/15/2005
6/29/2005
7/13/2005
7/27/2005
8/10/2005
8/24/2005
9/7/2005
9/21/2005
10/5/2005
10/19/2005
11/2/2005
11/16/2005
11/30/2005
Temperature 22.2-km
Outflow

Figure 3. Length (25.4-mm groups) frequency histogram and catch rates (CPUE; fish/h) for all rainbow trout collected boat electrofishing on the Canyon Reservoir Tailrace, August to November 2005. On the x-axis, labels are the upper limit of the length group, rounded to the nearest whole number.


N = 94
CPUE(Total) = 9.7
CPUE≥356 = 8.5
CPUE≥457 = 1.3
CPUE
3.5
3
2.5
2
1.5
1
0.5
0
25
76
127
178
229
279
330
381
432
483
533
mm group

PWD RP T3200-1557 (3/08)

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