Investigation of the Trout Fishery in the Chattahoochee River Below Buford Dam

by

Lisa Klein

Georgia Department of Natural Resources
Wildlife Resources Division
Social Circle, Georgia

January 2003

This study was funded in part with funds obtained through the Federal Aid in Sport Fish Restoration Act

SPORT FISH RESTORATION

Your purchase
of fishing equipment
and motor boat fuels supports
Sport Fish Restoration and
boating access facilities

The Georgia Department of Natural Resources receives Federal Aid in Sport Fish and Wildlife Restoration. Under Title VI of the 1964 Civil Rights Act, Section 504 of the Rehabilitation Act of 1973,Title II of the Americans with Disabilities Act of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972, the U. S. Department of the Interior prohibits discrimination on the basis of race, color, national origin, age, sex, or disability. If you believe that you have been discriminated against in any program, activity, or facility as described above, or if you desire further information please write to:

The Office for Human Resources
U.S. Fish and Wildlife Service
4040 N. Fairfax Drive
Room 300
Arlington, Virginia 22203

Final Report

State: Georgia — Project Number: F-66

Project Title: Walton Experiment Station

Project Type: Research and Survey

Study XXVII Title: Investigation of the Trout Fishery in the Chattahoochee River below Buford Dam

Period Covered: July 1, 1998 - June 30, 2001

Study Objectives: 1) To determine the suitability of the Plymouth Rock strain of brown trout in the Chattahoochee River; 2) To determine total mortality of stocked rainbow and brown trout and ascertain an optimum river stocking rate based on creel and electrofishing data; and 3) To collect current demographic data on river anglers.

Abstract

Hatchery and field performance of Plymouth Rock and Walhalla strain brown trout (BNT; *Salmo trutta*) were evaluated during 1998 to determine suitability for stocking in the Chattahoochee River, Georgia. The Walhalla strain performed better than the Plymouth Rock strain in the hatchery and field.

During 2000, mortality of stocked catchable ($228 millimeters (mm)) rainbow trout (RBT; *Oncorhynchus mykiss*) and BNT was evaluated in the field using marked fish. Condition of both species declined after stocking. Annual mortality for RBT and BNT was 69% and 87%, respectively. Natural mortality was considerably higher than fishing mortality for both species. Exploitation rates for both species were below 17%.

Harvest in the creel survey was dominated by RBT. The typical angler chose to spinfish, used artificial lures, was under 40, fished the river more than 20 times a year and spent a minimum of $100 on river fishing trips each year.

Temperature, turbidity and dissolved oxygen were measured during the creel survey. Correlations were noted between RBT catch per unit effort (CPUE) and these water quality parameters. There was no significant correlation between BNT CPUE and water quality.

INTRODUCTION

A put-and-take fishery for stocked rainbow trout (RBT) and brown trout (BNT) exists for 50 kilometers of reservoir tailwater between Buford Dam (Chattahoochee River kilometer (CRk) 560.8) and Roswell Road (CRk 510.9; Figure 1) near Atlanta, Georgia. Since 1996, the river below Buford Dam has been open to year-round trout fishing.

A previous study on the Chattahoochee River rated field and hatchery performance of RBT, BNT and brook trout strains that were available through the U.S. Fish and Wildlife Service (USFWS) hatchery system (Martin 1985b). Certain strains of trout differ in characteristics such as growth, survival and susceptibility to angling and have been chosen for stocking in specific bodies of water based on these traits (Cordone and Nicola 1970, Behnke 1980, Kincaid 1981, Kincaid et al. 1997).

Some trout strains have shown superiority over others under certain environmental conditions (Miller 1952, Smith 1957, Trojnar and Behnke 1974, Moring 1982, Hudy and Berry 1983, Dwyer and Piper 1984). Fluctuating flows and changing water quality (Minard et al. 2001) define the Chattahoochee River below Buford Dam. Plymouth Rock (PR) is the only BNT strain currently obtainable through the USFWS hatchery system (J. Jones, Erwin National Fish Hatchery, personal communication). This strain has only been studied in northeastern waters (Kincaid et al. 1997) and does not exhibit good growth or survival in Georgia's hatchery system (H. Chestnutt, Georgia Department of Natural Resources (DNR), personal communication). The State of Georgia currently obtains the Walhalla (WAL) strain from South Carolina for

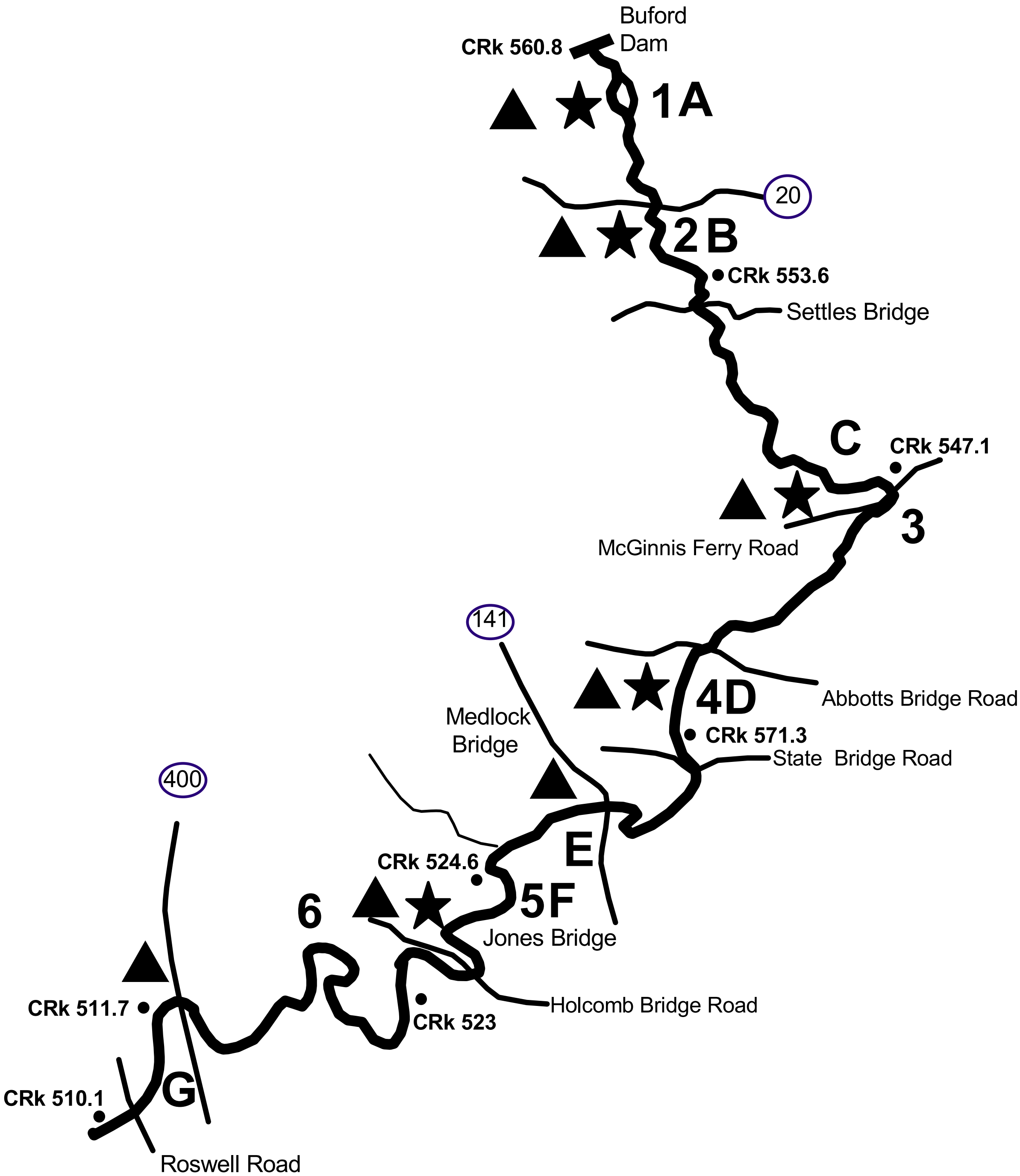


Figure 1. Study area on the Chattahoochee River, Georgia (Buford Dam to Roswell Road). Stocking locations from the 1998 BNT strain evaluation are marked with a star and electrofishing locations are numbered. Stocking locations from 2000 mortality study are marked with a triangle and electrofishing locations are lettered.

stocking into the Chattahoochee River because of their proven performance in both this river (Martin 1985b) and other southeastern waters (Hulbert 1985).

Increased human growth in the metropolitan Atlanta area over the last decade has contributed heavily to declining water quality below Buford Dam (Minard et al. 2001). Excessive sediment loads from tributaries, nutrient loading from wastewater treatment plants, seasonal water quality problems from Lake Lanier (Grizzle 1981), changes in fishing regulations, changes in angler behavior and increased numbers of stocked trout have likely affected trout population dynamics in the Chattahoochee River from Buford Dam to Roswell Road.

Angler use of the Chattahoochee River has been monitored by periodic creel surveys during the last 20 years. Creel surveys in 1983 and 1990 listed harvest of stocked trout at 85% (Martin 1985a) and 63% (Unpublished data), respectively. The number of catchable trout stocked below Buford Dam increased from 181,000 in 1990, to over 300,000 just prior to this study. Exploitation was not measured after this change, but rates were assumed to be high based on past studies, justifying the large increase in stocking.

Management of a put-and-take trout fishery to provide maximum harvest with minimum compensatory mortality requires periodic evaluation of stocking rates. In addition, evaluation of exploitation through tag returns (Beisser 1996), effects on trout growth from increased stocking rates, and changes in water quality are important components of this evaluation.

METHODS AND MATERIALS

Brown Trout Strain Evaluation

Approximately 5,000 each of PR and WAL strain BNT were segregated in two raceways at Buford Fish Hatchery on April 1, 1998. Average fish length was 178 mm. Both strains received equal rations of Zeigler's™ standard 3 millimeter (mm) pellets (38% protein and12% fat) from April 1 to July 20, 1998. During this period, personnel recorded daily mortality, average monthly feed consumption, and average monthly length and weight gain from each raceway.

Both strains of BNT were anaesthetized with MS-222, adipose fin clipped and tagged on June 9-10, 1998. Blank wire microtags were placed in the caudal peduncle of all PR strain trout and at the base of the dorsal fin for all WAL strain trout. Microtags were injected with a Northwest Marine Technology Mark IV automatic tag injector. Subsamples (N=550) of both strains were also marked with a Floy® external anchor tag (#FD-68BC) at the base of the dorsal fin. Each strain received a different dark colored tag to minimize selective predation and poaching. Legends on the tags read, "REWARD GA DNR (770) 918-6418". A reward of $5.00 per tag returned was offered to anglers. Prepaid envelopes for returning the tags were available at stores near the river that sold fishing equipment, through National Park Service (NPS) rangers, from DNR law enforcement personnel, and from metal boxes at nine river access points. Tag number, date caught, name, address, phone number, whether the trout was harvested or released, and the access point at which the trout was caught were collected from each angler who called or returned a tag.

One hundred fish of each BNT strain were individually measured, weighed, and checked for tag retention on July 17, 1998. Mean weights, lengths at stocking, and the Floy® and microtag retention rates were then calculated. All rejected Floy® tags that were recovered from the PR raceway during the holding period were re-inserted ten days prior to stocking. Floy® tags were not re-inserted in the WAL strain prior to stocking because loss was minimal. Raceway mortality and tag retention rates were used to calculate the number of tagged trout stocked.

A total of 4525 PR strain and 5146 WAL strain BNT were stocked on July 20, 1998. Fish were stocked following routine procedures employed by Georgia Wildlife Resources Division hatchery personnel. Stocking occurred at five predetermined sites located between Buford Dam and Roswell Road (Figure 1).

Trout were sampled during the day with direct current (DC) electrofishing gear during low flow conditions. The electrofishing gear consisted of a 2.5 kW generator, Smith-Root GPP 2.5™ electrofisher and boom-mounted electrodes on a 14-ft aluminum boat equipped with a 35-hp jet outboard motor. Maximum generator output was 500V at 4.5A. Frequency was set at 120 pulses per second. Fifteen-minute samples were collected monthly from July through December 1998 at six fixed stations (Figure 1). All stations were sampled on February 11-12, 1999 to assess overwinter survival. All trout collected in electrofishing samples were measured for total length and weight, examined for an adipose clip, Floy ® tag, and presence and location of a microtag.

Rainbow and Brown Trout Mortality Evaluation

Three groups of RBT were tagged with blank wire microtags on January 18-20, 2000 and three groups of BNT (WAL strain) were tagged on April 11-13, 2000. Approximately 10,000 trout were in each group. A subsample (N=1100) from the first group of RBT was tagged with an external Floy® anchor tag (#FD-94) to estimate angler exploitation. Tagging and stocking procedures were identical to those used in the strain evaluation. Anglers who called or sent in Floy® tags were asked questions identical to those in the BNT strain study, and which fishing method they used to catch the trout. Trout were stocked monthly from April through September 2000 (Table 1). Each group was released at predetermined stocking sites between Buford Dam and Roswell Road (Figure 1). Sampling procedures were identical to those in the BNT strain evaluation. Monthly sampling occurred from April 2000 through January 2001 at seven fixed sampling transects (Figure 1). Sampling locations were those used in the BNT strain evaluation, except electrofishing stations E and G were added and station six was removed. All transects were sampled in January 2001 to assess fall survival. Data collection protocol was identical to that used for the BRT strain evaluation.

Creel Survey

A bus-stop creel survey (Robson and Jones 1989; Jones et al. 1990) was conducted from Buford Dam to Roswell Road (50 kilometers) from March 13, 2000 to July 1, 2001. The bus stop method is a modified access survey developed for fisheries with numerous access sites spread over broad geographic regions. This survey was designed to estimate angler effort, harvest, and success information from Buford Dam to Roswell Road.

Anglers were interviewed at 17 access points separated into three different areas (Figure 2). Access point probabilities were determined by surveying angler visitation and were adjusted to account for seasonal changes in angler use. One area was randomly selected each sample day. The 16-month survey was divided into 35 two-week periods with ten sample days in each period. Generally, 14 weekdays

Table 1. Microtag and stocking information for RBT and BNT stocked in the Chattahoochee River (Buford Dam to Roswell Road) from April 3, 2000 to September 11, 2000. Rainbow trout were tagged from January 18-20, 2000 and BNT were tagged from April 11-13, 2000. Tag retention rates were calculated one week prior to stocking.

Species	Total # tagged	Tag Location	Tag Retention Rate (%)	Date Stocked	Number Stocked
Rainbow Trout	10,285	Left Cheek (LC)	86	04/03/2000	8,845
Rainbow Trout	10,017	Tail (T)	93	05/08/2000	9,315
Rainbow Trout	9,736	Dorsal (D)	95	06/12/2000	9,249
Brown Trout	9,864	Left Cheek (LC)	97	07/10/2000	9,568
Brown Trout	10,314	Right Cheek (RC)	98	08/14/2000	10,107
Brown Trout	9,999	Dorsal (D)	87	09/11/2000	8,699

Area	Access Point
1	Buford Dam powerhouse (1) Buford Dam boatramp (2) Buford Trout Hatchery (3) GA 20 Bridge (4) Settles Bridge (5) McGinnis Ferry Bridge (6)
2	Abbotts Bridge NPS (7) State Bridge Road (8) Medlock Bridge Park (9) Jones Bridge Park (10) Jones Bridge NPS (11)
3	Holcomb Bridge Road (12) Island Ford NPS (13) Azalea Park (14) GA 400 Bridge Park (15) Roswell (16) Shoals-Riverside Drive Eves Road (17)

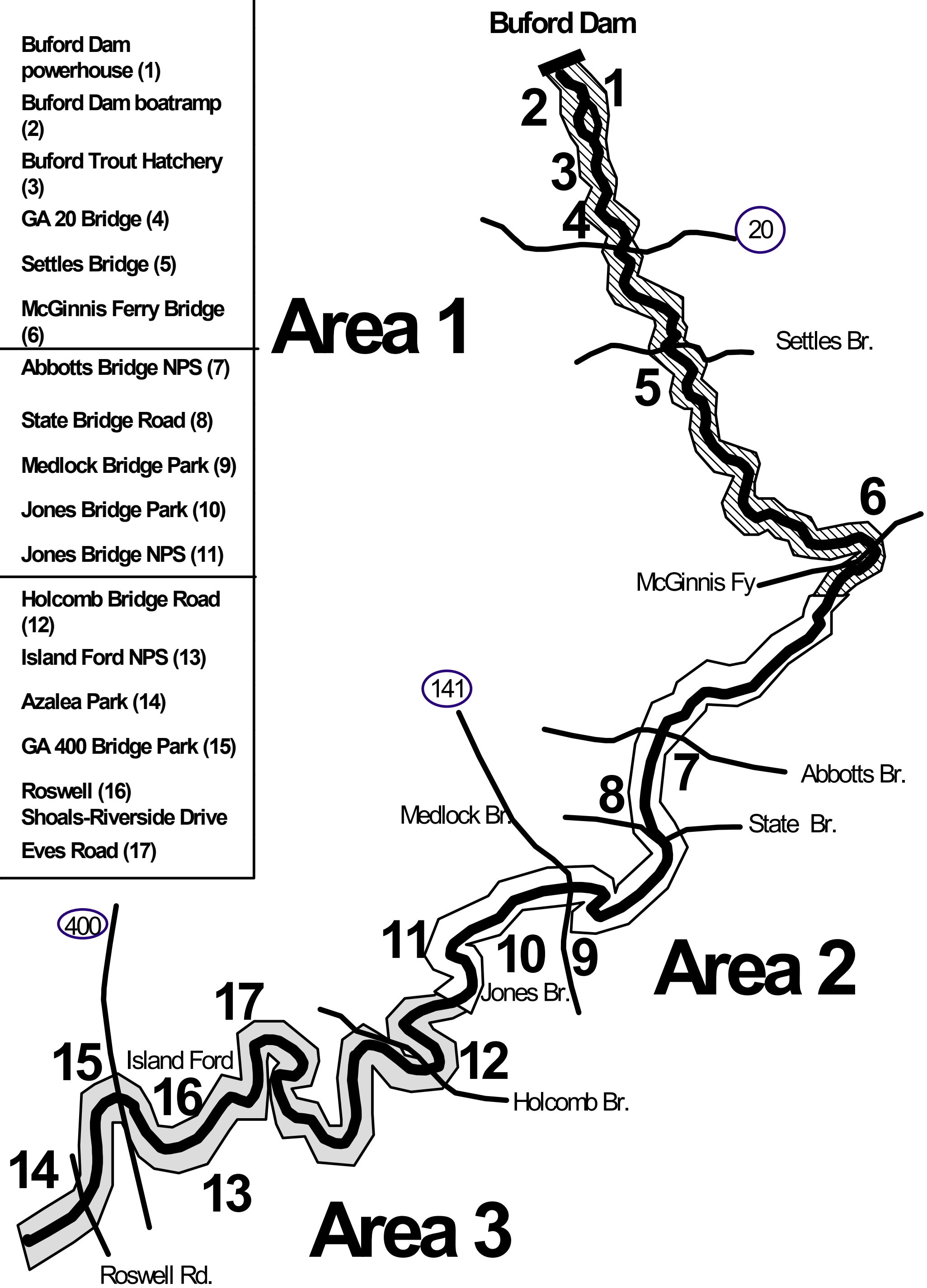


Figure 2. Sample areas and access points used in a creel survey of the Chattahoochee River from Buford Dam to Roswell Road (March 17, 2000 to July 1, 2001).

and six weekend day samples were collected each month. Sampling days were divided into 7.5-hour work shifts. Shifts were either morning (AM) or afternoon (PM). Unequal sampling probabilities were assigned for the time of day the shift would occur because of seasonal generations from Buford Dam and their effects on angling pressure. Probabilities for work shifts from June through August were 60% AM and 40% PM and from December through February they were 40% AM and 60% PM. All other months had equal AM/PM probabilities.

All anglers encountered were asked if they had completed their fishing trip. If the trip was not completed, anglers were only asked the number in their party and demographic questions. If the trip was completed, anglers were asked additional questions about the time they began fishing, species fished for, and the number of trout caught and harvested. The creel clerk examined all harvested trout for adipose fin clips and microtag location. Lengths and weights of all harvested fish were recorded. All anglers were asked their state of residency; Georgia residents were asked their county of residence. Ages of all anglers in a party, fishing method (spinfishing, flyfishing, or still/bait fishing), bait type (artificial or natural), and whether the angler fished from the bank, boat or waded were recorded. Anglers were asked the amount of money they typically spent fishing on the Chattahoochee River each year, the number of times they fished the river each year, and their preference on the size and number of trout they caught.

Water Quality

The creel clerk measured turbidity, temperature and dissolved oxygen at each access point during the sample day. Turbidity was measured in Nephelometric

Turbidity Units (NTU) using a LaMotte® 2020 Turbidimeter and dissolved oxygen (mg/L) and temperature (°C) were measured using a YSI® model 55 meter.

Statistics

Floy® tag returns from the strain evaluation and the mortality segment of this study were used to calculate exploitation and mortality rates. Annual survival and mortality rates of tagged trout were calculated using two methods. Survival (S) and Total (T) were calculated using Robson and Chapman (1961). Annual mortality (A), instantaneous fishing mortality (F), instantaneous natural mortality (M) and the instantaneous rate of total mortality (Z) were calculated using Ricker (1975):

$$S = \frac{T}{N + (T - 1)}$$

T= 1 (number in coded age 1) + 2 (number in coded age 2) + 3 (number in coded age 3)+ n (number in coded age n)

$Z = -(LOG_e\ S)$

$A = 1 - S$

$F = (Z/A)\ U$

$M = Z - F$

Survival calculations were adjusted using post-tagging survival, Floy® tag retention, Floy® tag-reporting rate, and the percentage of trout harvested versus released. The percentage of tags reported by telephone and subsequently returned by mail was considered to be the return (reporting) rate. Instantaneous rates (i.e. Z, F, and M) were used to partition annual mortality into fishing and natural components. Standard errors were calculated according to Robson and Chapman (1961).

An estimate of the trout population was calculated during each study using the change-in-ratio of tagged fish collected from electrofishing samples (Paulik and

Robson 1969). Calculations are similar to the Lincoln-Peterson mark recapture method and monitor changes in the relative abundance of two distinct components of a population. This method uses marked fish that are added to a population instead of collecting and marking fish from the population.

Growth of microtagged trout in both the BNT strain study and the mortality study was evaluated by regression of length and weight of captured trout against days post-stocking. Monthly growth rates of marked trout were determined by averaging growth over time during each phase of the study. Relative weight (Wr; Anderson and Neumann 1996) was used as an index of condition. Differences between WAL and PR BNT strain and between BNT and RBT in the mortality study were examined with two-sample T-tests.

Validity of water quality data collected during the creel survey was assessed by comparison with data collected by the USGS and the Upper Chattahoochee Riverkeeper. All outliers were eliminated from the data set. Water temperature, dissolved oxygen, and turbidity levels measured daily at creel survey sites were compared to angler use and catch. Multiple regression analyses were performed using Statistix® version 7.0 software (Analytical Software 1996) or SYSTAT® version 9.0 software (SPSS Inc. 1999). Statistical significance was determined at p=0.05.

RESULTS

Brown Trout Strain Evaluation

A total of 4,525 PR strain and 5,146 WAL strain BNT were stocked. Microtag retention rates at 36 days for groups of WAL and PR BNT just prior to stocking were 99% and 95%, respectively. Floy® tag retention for the WAL and PR strains just prior to stocking was significantly different at 84% and 36%, respectively (Table 2).

Table 2. Comparison of hatchery and field performance of Plymouth Rock (PR) and Walhalla (WAL) BNT in the Chattahoochee River from Buford Dam to Roswell Road, 1998-1999. T-tests were used to compare means.

Statistical Test	Brown Trout Strain		
Hatchery	PR	WAL	P Value
Mean daily Floy tag loss	11.1	0.7	0.001[a]
Mean daily mortality before tagging	9.3	0.7	0.020[a]
Mean daily mortality after tagging	18.0	1.3	0.009[a]
Mean monthly feed conversion	1.2	1.0	0.800
Mean monthly weight gain (g)	11.6	15.3	0.480
Field	July 1998	Feb 1999	
Length of PR (mm)	207	207	0.270
Length of WAL	212	252	0.020[a]
Weight of PR (g)	86	86	0.320
Weight of WAL	98	115	0.030[a]
Wr of PR	90	93	0.003[a]
Wr of WAL	97	90	0.002[a]
	Brown Trout Strain		
	PR	WAL	
Relative (%) Catchablity with Electrofishing Gear	51	49	0.927
Relative (%) Catchability by Anglers	52	48	0.832

[a] Significantly different (p **#** 0.05)

Hatchery mortality rates for the PR strain were thirteen times higher in the three months before tagging and fourteen times higher after tagging than mortality rates for the WAL strain. There were no significant differences in monthly feed conversions or weight gain between the two strains while in the hatchery.

A total of 130 tags (89 WAL, 41 PR) were reported by telephone (45) or returned directly to the Walton office (85). Thirty-four (76%) of the 45 tags reported by telephone were returned. Rewards were paid for the 119 returned tags. Most BNT were caught near their respective stocking sites. Tag returns were highest during the first two months and dropped abruptly after that period. Reported release rates for both strains were similar and when tags from both strains were combined, nearly 70% were released. There were no differences in catchability by anglers or electrofishing gear between strains. The PR strain collected in electrofishing samples did not show significant growth in either total length or weight after stocking. There was a slight but significant increase in mean relative weight. The WAL strain showed significant growth in both length and weight after stocking, with a slight decrease in mean relative weight (Table 2). Annual mortality of the PR strain was slightly higher than that of the WAL strain. When annual mortality was partitioned into fishing and natural mortality, both strains showed high natural mortality (Table 3).

Rainbow and Brown Trout Mortality Evaluation

Microtag retention rates just prior to stocking were typically high (Table 1). Hatchery mortality rates for all groups of trout in this study were minimal and within normal ranges. Population estimates were calculated for the 1998-1999 and 2000-2001-sample seasons using the change-in-ratio method. All estimates were

Table 3. Trout mortality rates for the 1998 BNT strain and the 2000-2001 mortality evaluations in the Chattahoochee River from Buford Dam to Roswell Road.

Study	Number Stocked	Number Tagged	Exploitation	Survival	Mortality			
					Annual	PSE[1]	Fishing	Natural
BNT Strain Evaluation								
Plymouth Rock	5,412	5,412	7%	13%	87%	0.29%	9%	91%
Walhalla	66,716	4,981	9%	19%	81%	0.17%	12%	88%
Mortality Evaluation								
Rainbow Trout	215,247	30,038	17%	32%	68%	0.14%	25%	75%
Brown Trout	53,618	30,177	8%	18%	82%	0.11%	11%	89%

[1] Proportional standard error.

calculated from samples taken during non-stocking periods, generally September through February. The November 1998 estimate of the trout population was approximately 7,200 (95% CI ±1,250) trout per river km (468/ha), while the February 1999 estimate was approximately 2,880 (95% CI ±1,380) trout per km (187/ha). The September 2000 estimate was approximately 6,080 (95% CI ± 1,900) trout per river km (395/ha) and the January 2001 estimate was approximately 2,880 (±1,990) trout per river km (187/ha).

A low occurrence of microtags in the creel survey and irregular catch rates of microtagged trout in electrofishing samples precluded the use of microtag data for mortality estimates. Therefore, mortality estimates were calculated with Floy®tag data. These estimates do not take into account Type B errors (Ricker 1975) like non-uniform tag loss over time, which may alter survival estimates.

One hundred fifty-one Floy® tagged RBT were either reported by phone (80) or returned directly to the Walton office (71). Fifty-five of 80 tags reported to the Walton office by telephone were returned for a reporting rate of 69%. A reward was paid for the 125 returned tags. Tag returns were highest during the first two months after stocking and then declined rapidly.

Harvest and release rates of RBT and BNT showed significant differences. Over 79% of the Floy tag returns for RBT indicated the fish had been harvested. Annual mortality for both RBT and BNT was high (Table 3). Natural mortality was higher for BNT than it was for RBT and exploitation on both species was low.

None of the groups of microtagged RBT showed significant growth in total length or a change in condition. One group of RBT showed a significant loss of weight (Table 4). One group of BNT grew significantly in length. BNT condition factors decreased significantly in two groups and increased in one group. Growth rates of stocked microtagged BNT and RBT averaged 4.5mm/30 days and 4.9mm/30 days, respectively.

Creel Survey

Estimated fishing pressure for the period of March 2000 through June 2001 totaled 286,266 angler hours and 87,970 trips (Table 5). Average trip length was 3.3 hours. Approximately 60% of effort occurred from March through September.

Angler success was higher for RBT than for BNT (Table 6). The estimated number of RBT harvested by anglers was nearly four times greater than the number of BNT harvested. The creel clerk observed few microtagged trout even though 22% of the total number of trout stocked that year were marked. Of the six groups of RBT and BNT that were microtagged, less than 1% (N=25) were observed in the creel survey. Two groups of RBT (May and June) accounted for 84% of the microtagged trout that were observed in the creel, while two groups of BNT (August and September) accounted for 16% of the microtagged trout that were observed in the creel.

A total of 2,157 anglers provided information for the 1,216 interviews. Completed trips accounted for 29% of the interviews. Nearly 88% of the 2,157 anglers interviewed during the survey period reported that they were fishing specifically for trout.

Most interviewed anglers (67%) were spinfishing. Anglers who were flyfishing or still/bait fishing accounted for 25% and 8%, respectively.

Table 4. Comparison of length, weight and condition of groups of microtagged brown and rainbow trout just prior to stocking (before) and at the end of the study period (after) in the Chattahoochee River from Buford Dam to Roswell Road, 2000 to 2001. T-tests were used to compare means.

Year	Date Stocked	Group	Mean Total Length (mm)			Mean Weight (g)			Mean Condition (Wr)		
			Before	After	P Value	Before	After	P Value	Before	After	P Value
2000	04/03/2000	Rainbow Trout (LC)[1]	255	262	0.320	202	191	0.020[2]	78%	87%	0.090
2000	05/08/2000	Rainbow Trout (T)[1]	275	280	0.310	199	202	0.410	72%	70%	0.390
2000	06/12/2000	Rainbow Trout (D)[1]	253	257	0.300	157	156	0.400	87%	81%	0.330
2000	07/10/2000	Brown Trout (LC)[1]	248	269	0.360	173	191	0.290	95%	78%	0.020[2]
2000	08/14/2000	Brown Trout (RC)[1]	241	252	0.001[2]	159	169	0.100	98%	108%	0.001[2]
2000	09/11/2000	Brown Trout (D)[1]	239	255	0.220	154	167	0.130	101%	90%	0.008[2]

[1] Code for specific microtag location used for group identification.
[2] Significantly different (p # 0.05)

Table 5. Distribution of fishing pressure by period measured on the Chattahoochee River from Buford Dam to Roswell Road, Georgia from March 14, 2000 to July 1, 2001. Weekdays and weekends are combined.

Period					Estimated Angler-hours	Estimated Trips
Mar	12	–	Mar	25	2,867	1,454
Mar	26	–	Apr	8	13,045	3,442
Apr	9	–	Apr	22	8,892	5,024
Apr	23	–	May	6	7,698	2,621
May	7	–	May	20	15,321	4,183
May	21	–	Jun	3	24,904	7,502
Jun	4	–	Jun	17	26,126	8,429
Jun	18	–	Jul	7	25,748	5,837
Jul	2	–	Jul	15	8,732	2,802
Jul	16	–	Jul	29	16,216	5,001
Jul	30	–	Aug	12	13,107	4,127
Aug	13	–	Aug	26	8,142	2,246
Aug	27	–	Sep	9	1,206	403
Sep	10	–	Sep	23	4,642	1,220
Sep	24	–	Oct	7	1,223	774
Oct	8	–	Oct	21	12,630	1,957
Oct	22	–	Nov	4	4,567	1,327
Nov	5	–	Nov	18	1,118	545
Nov	19	–	Dec	2	2,842	936
Dec	3	–	Dec	16	1,980	740
Dec	17	–	Dec	30	2,624	937
Dec	31	–	Jan	13	1,306	632
Jan	14	–	Jan	27	1,425	585
Jan	28	–	Feb	10	1,023	564
Feb	11	–	Feb	24	4,601	1,627
Feb	25	–	Mar	10	2,778	883
Mar	11	–	Mar	24	1,980	955
Mar	25	–	Apr	7	8,446	3,030
Apr	8	–	Apr	21	11,497	3,272
Apr	22	–	May	5	10,998	3,242
May	6	–	May	19	9,594	3,153
May	20	–	Jun	2	1,470	480
Jun	3	–	Jun	16	12,901	3,434
Jun	16	–	Jun	30	18,703	5,775
Total					286,266	87,970
Standard error					25,275	6,676
Proportional standard error					0.09	0.07
95% Confidence interval					260,991-311,541	81,294-94,646

Table 6. Total harvest of fish in numbers and kilograms, number released and total effort in hours from the Chattahoochee River downstream of Buford Dam to Roswell Road, Georgia from March 14, 2000 through July 1, 2001.

	Number			Kilograms		
Species	Estimate	95% C.I.[1]	P.S.E[2]	Estimate	95% C.I.[1]	P.S.E[2]
Harvest						
Rainbow trout	58,472	46,006-70,938	0.21	2,444	853-4,035	0.65
Brown trout	14,910	10,110-19,710	0.32	404	142-666	0.65
Total	73,383	59,676-87,090	0.18	2,849	1135-4,563	0.60
Harvest CPUE						
Rainbow trout	0.201	0.174-0.234	0.15	0.009	0.006	0.33
Brown trout	0.052	0.009-0.095	0.82	0.001	0	1
Total	0.256	N/A	N/A	0.010	N/A	N/A
Released [3]						
Rainbow trout	110,382	90,230-130,534	0.18			
Brown trout	47,130	24,875-69,385	0.47			
Total	157,512	121,697-193,327	0.23			
Total Effort (hours)	286,266	260,991-311,541	0.09			

[1] 95% C.I. denotes confidence interval, estimate " (1.96 X S.E.).
[2] P.S.E denotes proportional standard error.
[3] Released fish estimates developed from angler's recall of species and number released

Sixty-three percent of anglers used artificial lures or flies and 37% used natural bait. Anglers who were still/bait fishing were more successful at catching RBT than anglers using other methods. Fifty percent of the RBT Floy® tags that were returned belonged to anglers who were still/bait fishing, 36% spinfished and 14% flyfished. Based on these differences, still/baitfishing, while not the most popular method, was the most effective way to catch RBT in the Chattahoochee River. Most still/bait fishers and spinfishers kept their catch, while flyfishers released theirs (Figure 3).

Most anglers interviewed were under the age of 40 (68%); and fished in the Chattahoochee River more than 20 times a year (40%, Figure 4). The most popular means for fishing were shoreline (46%) and wading (35%), while 19% of the anglers used boats. Sixty-six percent of anglers preferred catching a few large trout instead of a greater number of small trout.

Of the 17 access points, the four most popular sites accounted for a total of 58% of the angler visits (Figure 5). Chattahoochee River anglers were principally Georgia residents (95%), although anglers from 22 different states (4%) and three different countries (1%) were interviewed.

Water Quality and Catch of Trout

No relationships between total trout CPUE and any of the water quality variables were detected (Table 7). No relationship between CPUE and BNT and any of the water quality variables was detected. RBT CPUE was more sensitive to water quality variables than BNT CPUE.

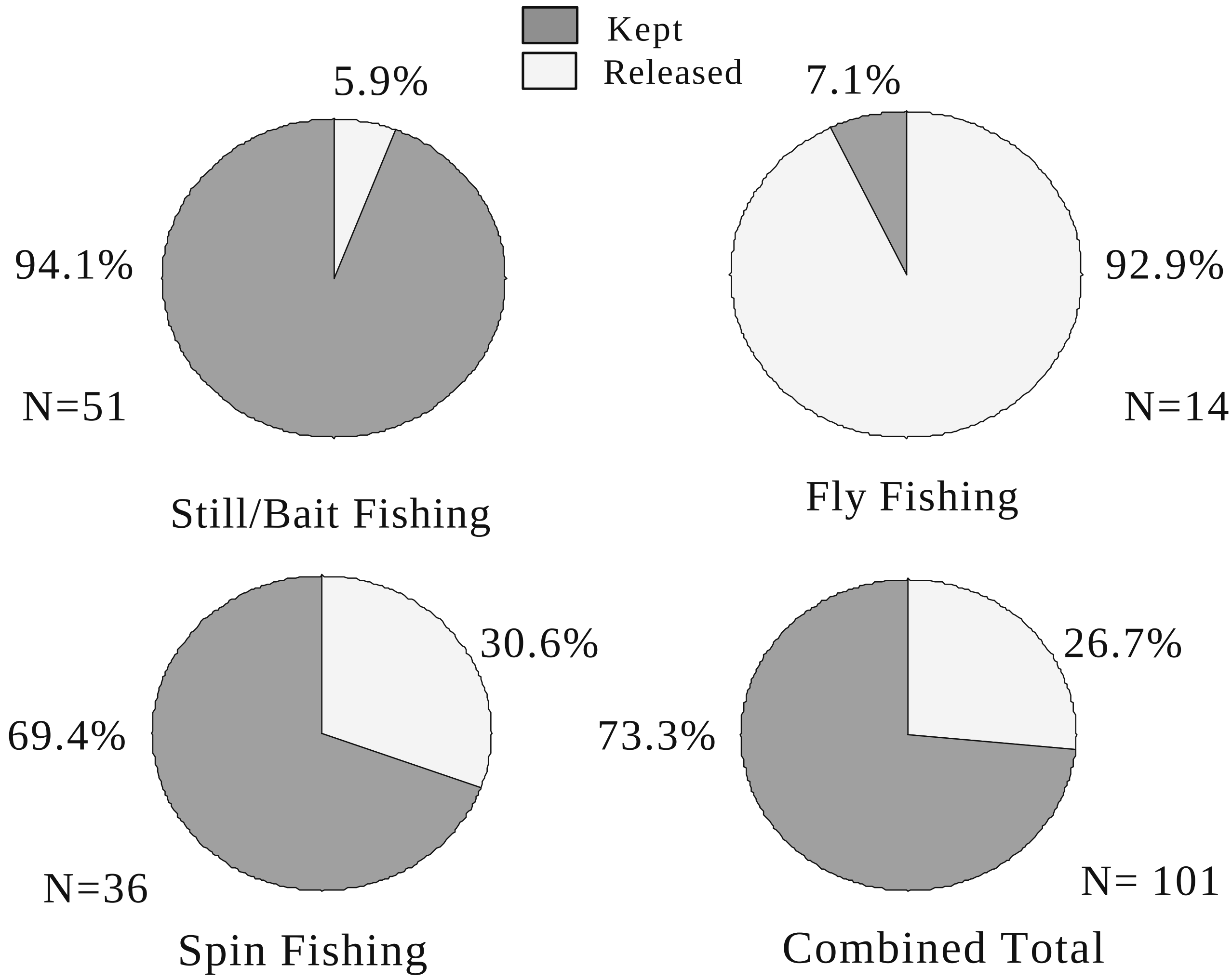


Figure 3. Results from the tag return survey showing fishing method used and whether the fish was kept or released during the RBT and BNT mortality study in the Chattahoochee River from Buford Dam to Roswell Road, Georgia 2000-2001.

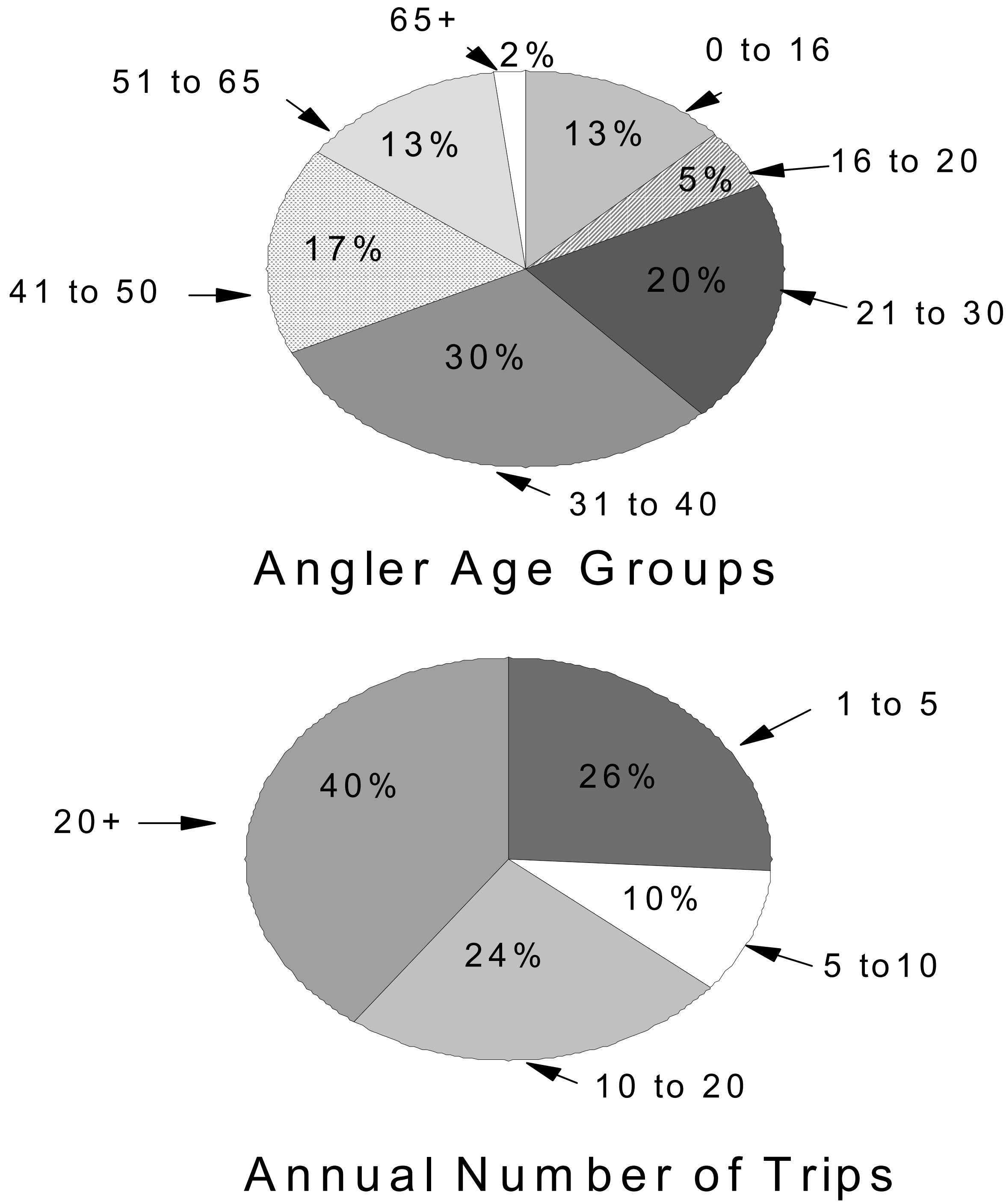


Figure 4. Age group of anglers and the number of times each year anglers fished the Chattahoochee River from Buford Dam to Roswell Road during the March 14, 2000 to July 1, 2001 creel survey.

#	Access Point	% interviews
1	Buford Dam Powerhouse	17%
2	Buford Dam boatramp	5%
3	Buford Trout Hatchery	2%
4	GA 20 Bridge	4%
5	Settles Bridge	1%
6	McGinnis Fy. Bridge	3%
7	Abbotts Bridge NPS	11%
8	State Bridge Rd.	0.3%
9	Medlock Bridge NPS	10%
10	Jones Bridge Park	9%
11	Jones Bridge NPS	20%
12	Holcomb Bridge Rd.	3%
13	Island Ford NPS	1%
14	Azalea Park	7%
15	GA 400 Bridge park	4%
16	Roswell Shoals-Riverside	1%
17	Eves Rd.	2%

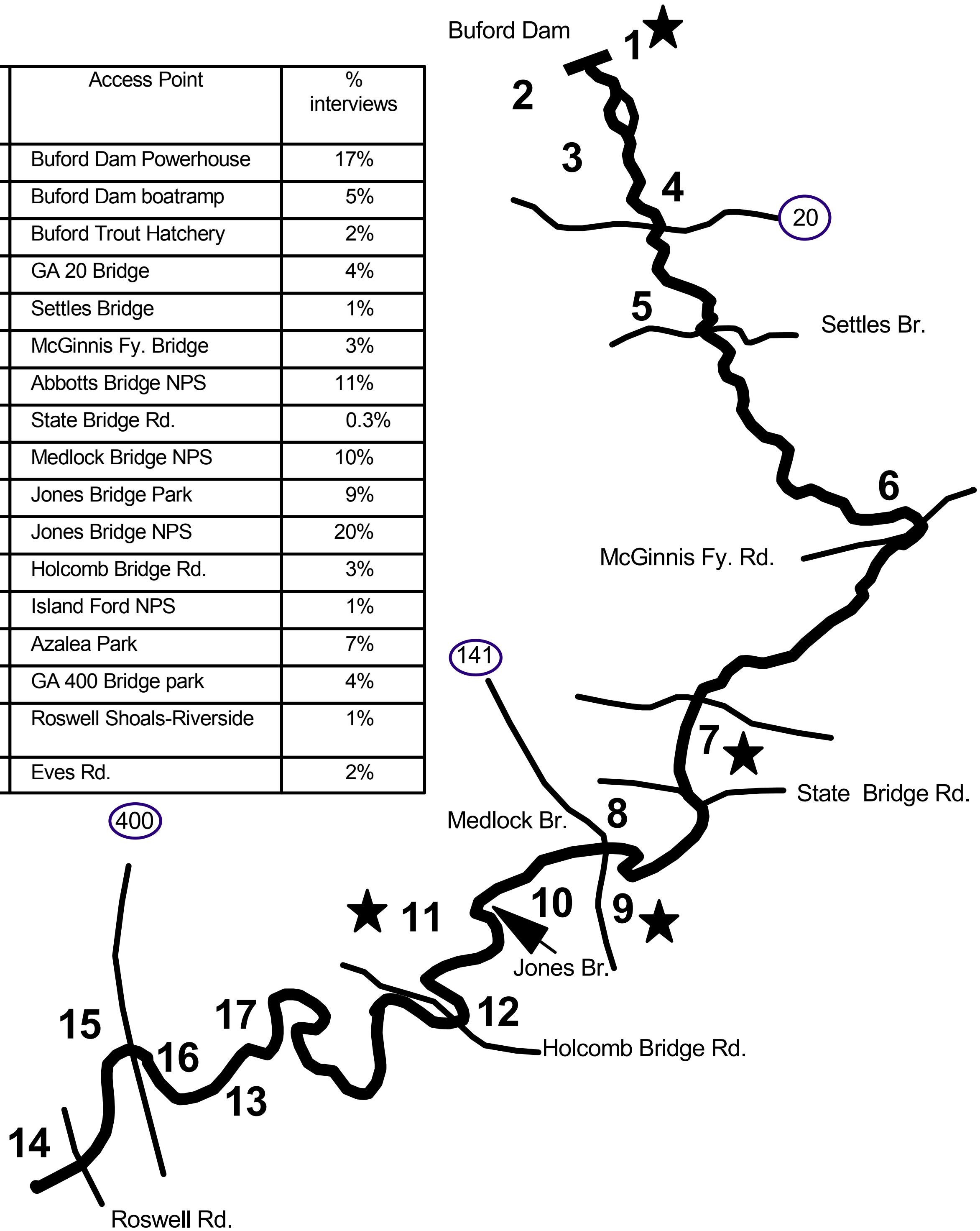


Figure 5. Percent angler interviews by access point on the Chattahoochee River from Buford Dam to Roswell Road, Georgia from March 14, 2000 to July 1, 2001. Access points with stars indicate the most popular angling sites.

Table 7. Interactions between water quality variables, CPUE, and total number of angler interviews (total and sample areas) during the 200-2001 creel survey in the Chattahoochee River from Buford Dam to Roswell Road, Georgia. T-tests were used to compare means. Statistically significant values (P=0.05) are highlighted.

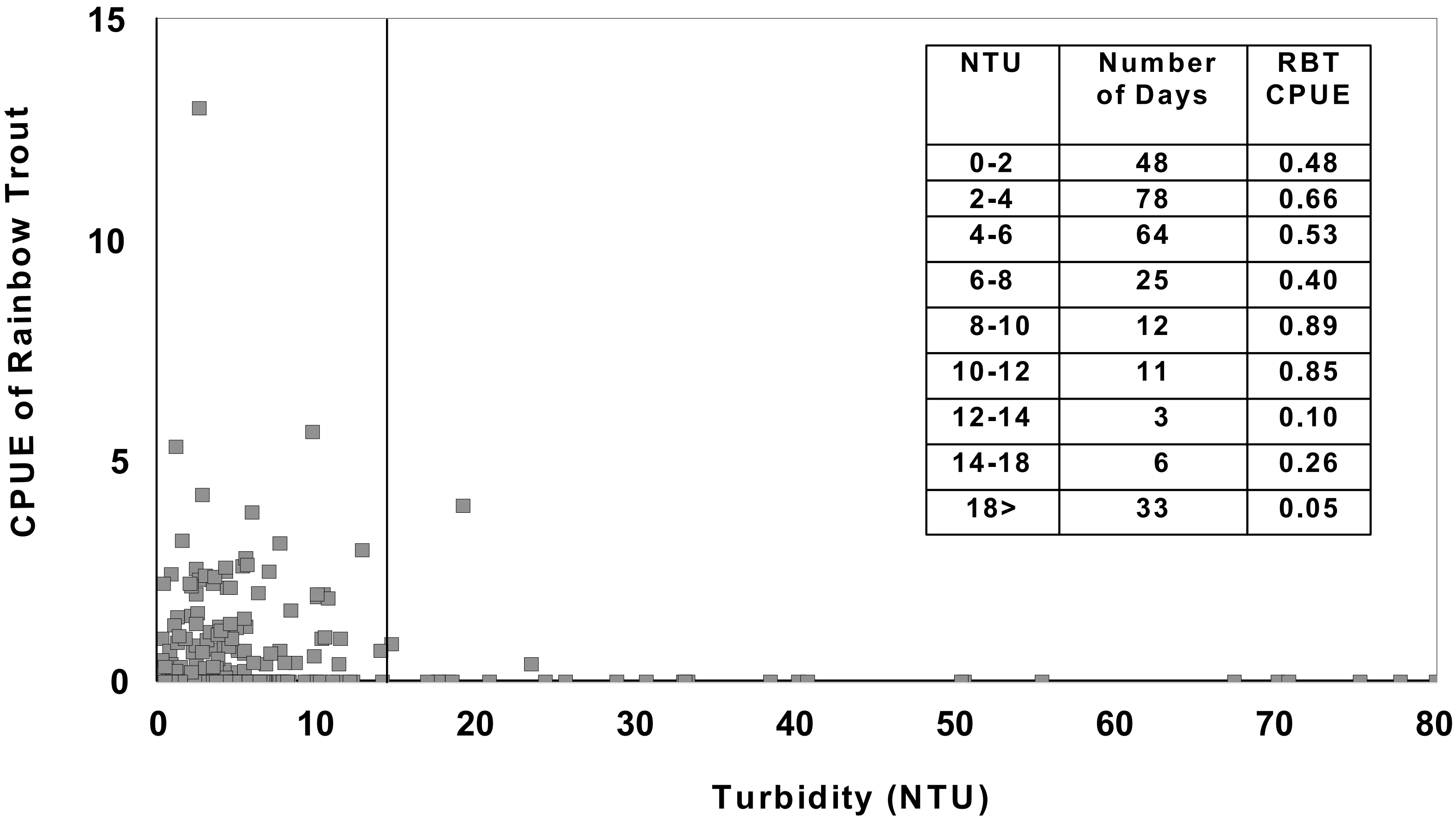
Variables	DO (mg/L)	Temperature (°C)	Turbidity (NTU)	DO/ Temperature	Turbidity/ Temperature	DO/ Temperature/ Turbidity
Trout CPUE	0.916	0.110	0.234			
RBT CPUE	0.495	0.007[a]	0.224	0.065	0.003[a]	0.068
BRT CPUE	0.552	0.938	0.503	0.701		0.842
Total Anglers	0.415	0.001[a]	0.037[a]			
Area 1	0.039[a]	0.001[a]	0.600	0.001[a]		
Area 2			0.066			
Area 3		0.004[a]	0.075		0.001[a]	

[a] Significantly different (p **#** 0.05)

RBT CPUE was highest when turbidity was between 2 and 12 NTU (Figure 6). CPUE declined steadily as turbidity rates rose above 12 NTU. There was also a significant relationship between RBT CPUE and water temperature. As the water temperature increased above 16.5°C, catch rates dropped rapidly (Figure 7). CPUE of RBT was highest when dissolved oxygen levels were between 6 and 11 mg/L (Figure 8).

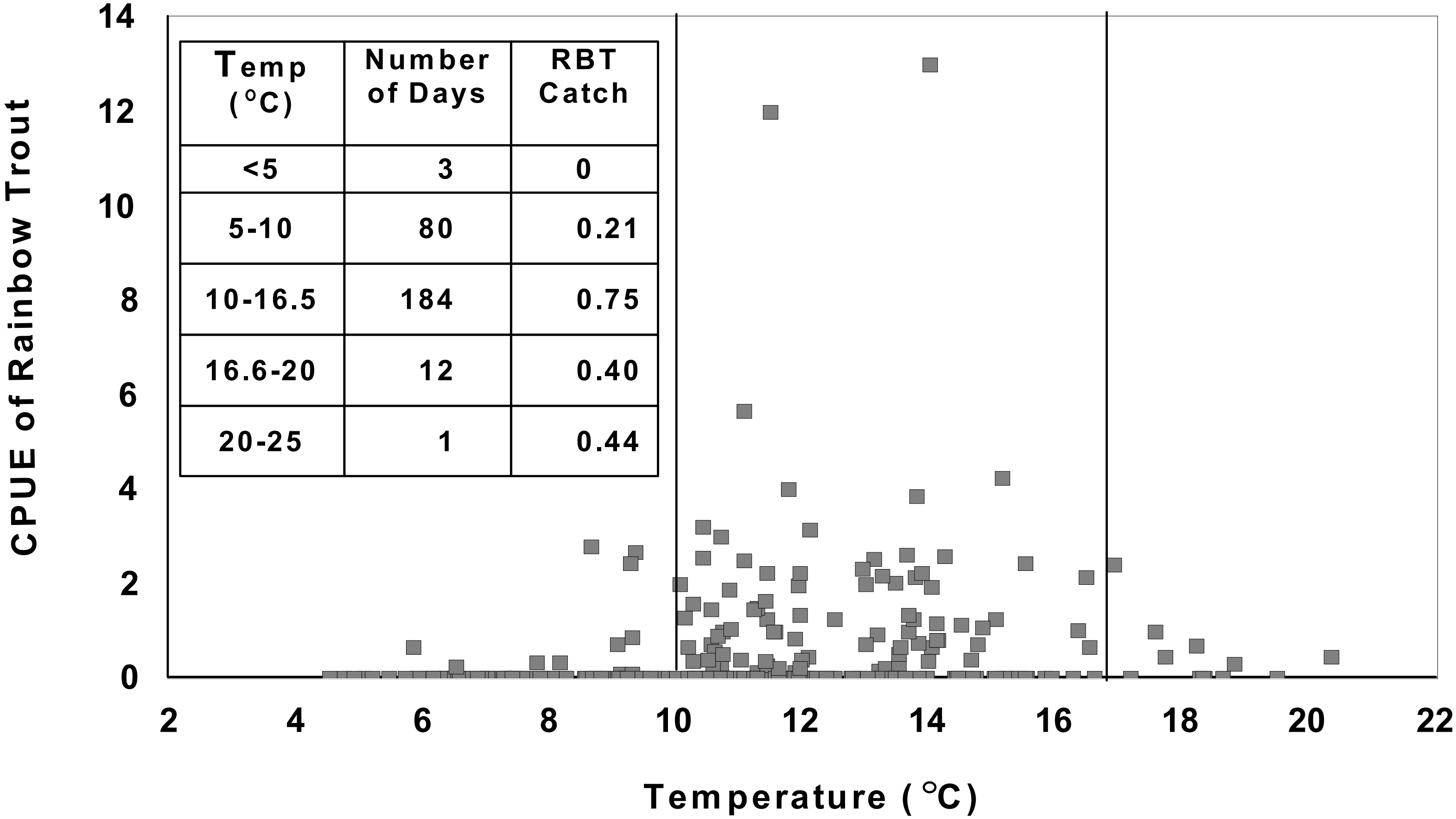
Significant relationships existed between the total number of angler interviews, water temperature and turbidity levels in two of the three survey areas (Table 7). A significant relationship existed between the number of angler in Area 1 and water temperature and a combination of water temperature and dissolved oxygen levels (Figure 9). A significant relationship also existed between the number of angler interviews and water temperatures in Area 3 (Figure 10). This relationship was strengthened when water temperature and turbidity were combined.No significant relationships existed between water quality and number of angler interviews in Area 2.

Data collection occurred on 286 days. Dissolved oxygen readings were below 6 mg/L for a total of 20 days. Water temperatures greater than 20°C, but below lethal limits for trout occurred 14 days. Average water temperatures during the course of the creel survey ranged between 5 and 20°C. Average turbidity readings for the Chattahoochee usually range from 0 to 4 NTU. Measured turbidity levels during the course of the creel survey exceeded 12 NTU for 39 days. Eighteen of those readings exceeded 100 NTU.



NTU	Number of Days	RBT CPUE
0-2	48	0.48
2-4	78	0.66
4-6	64	0.53
6-8	25	0.40
8-10	12	0.89
10-12	11	0.85
12-14	3	0.10
14-18	6	0.26
18>	33	0.05

Figure 6. Relationship of turbidity and catch per unit effort (CPUE) of RBT in the Chattahoochee River from Buford Dam to Roswell Road, Georgia 2000-2001.



Temp (°C)	Number of Days	RBT Catch
<5	3	0
5-10	80	0.21
10-16.5	184	0.75
16.6-20	12	0.40
20-25	1	0.44

Figure 7. Relationship of temperature and catch per unit effort (CPUE) of rainbow trout in the Chattahoochee River from Buford Dam to Roswell Road, Georgia 2000-2001.

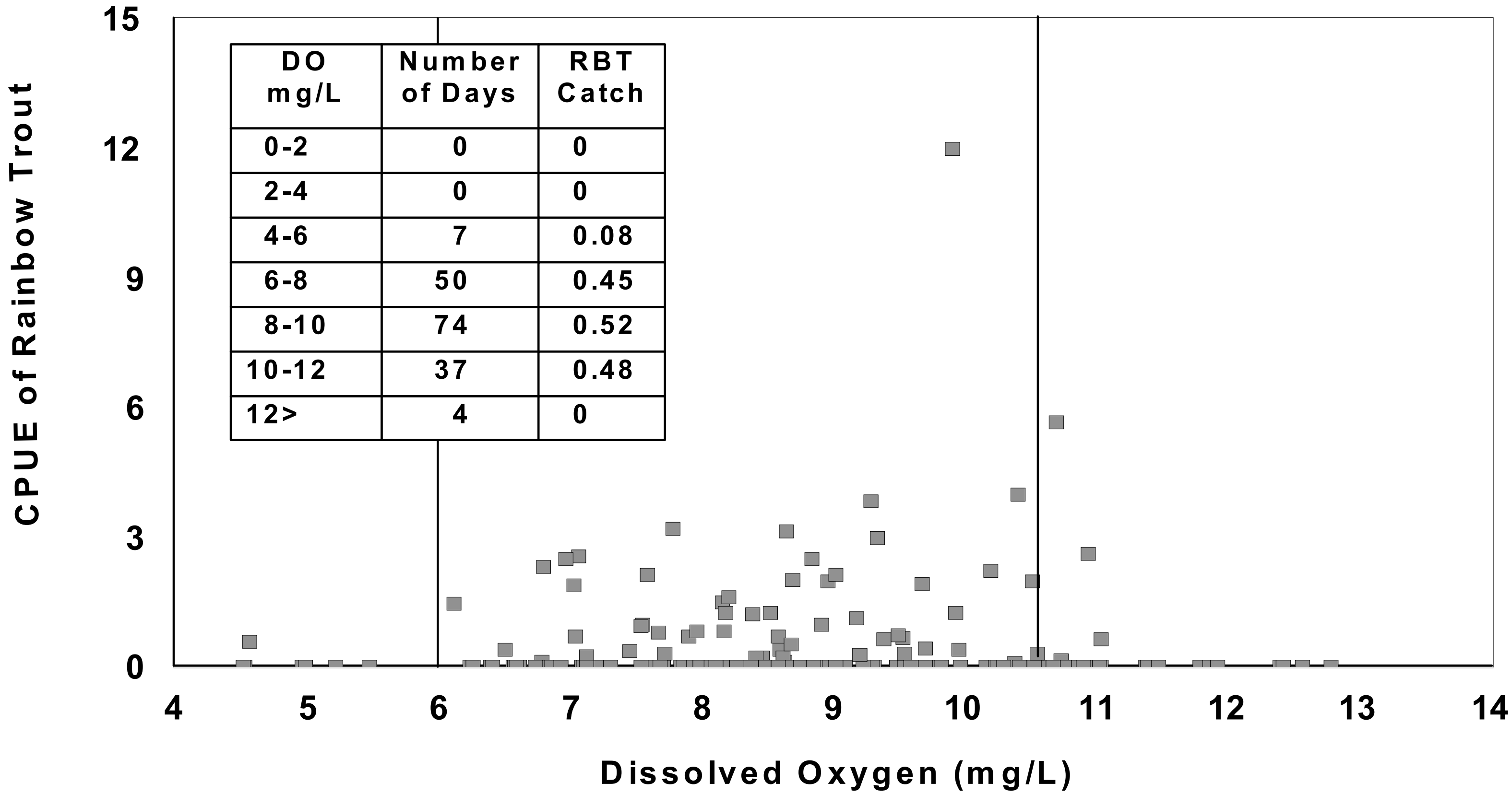


Figure 8. Relationship of dissolved oxygen and catch per unit effort (CPUE) of RBT in the Chattahoochee River from Buford Dam to Roswell Road, Georgia.

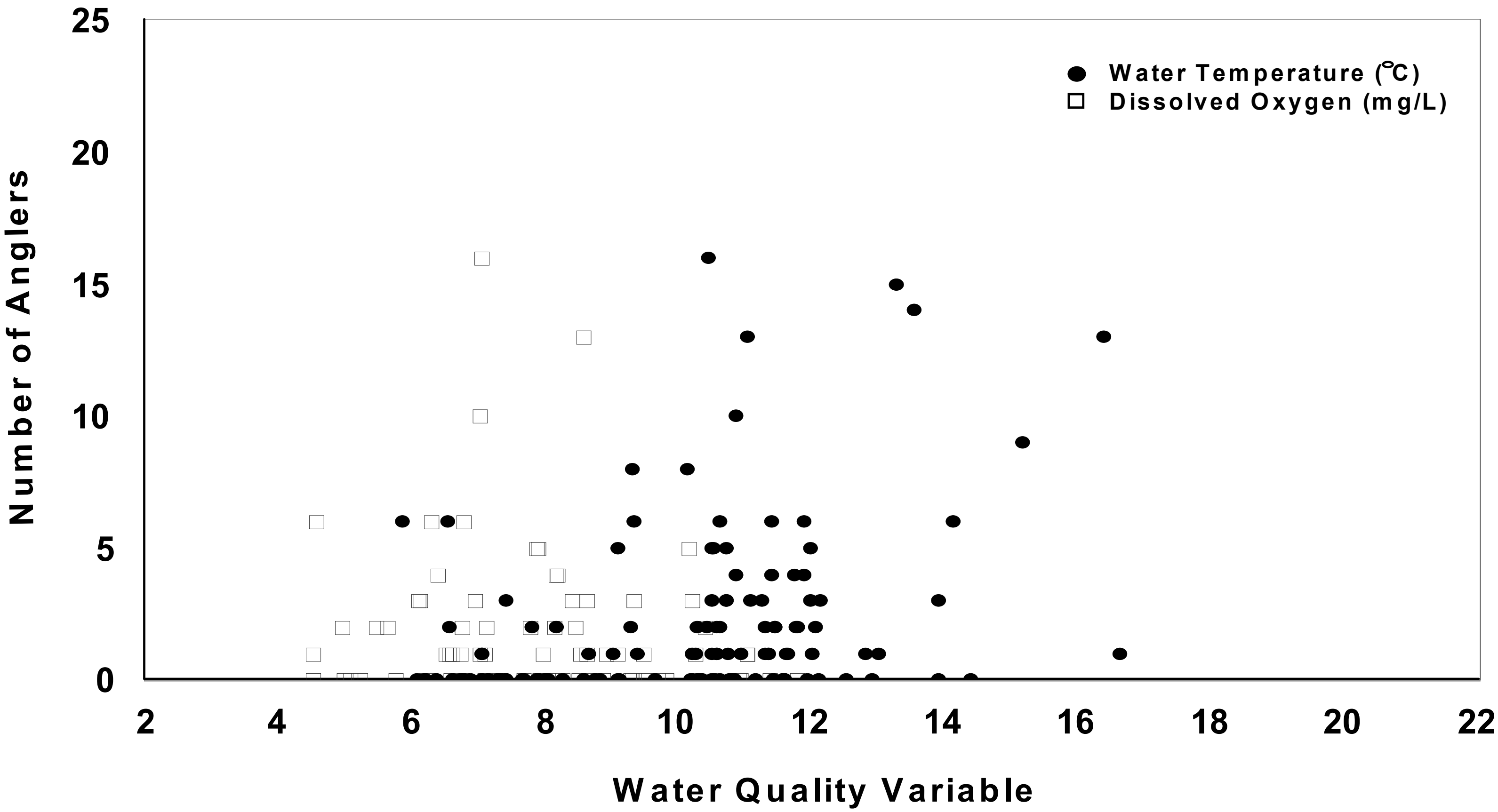


Figure 9. Relationship of dissolved oxygen, water temperature, and the number of angler interviews in Area 1 on the Chattahoochee River from Buford Dam to Roswell Road, Georgia.

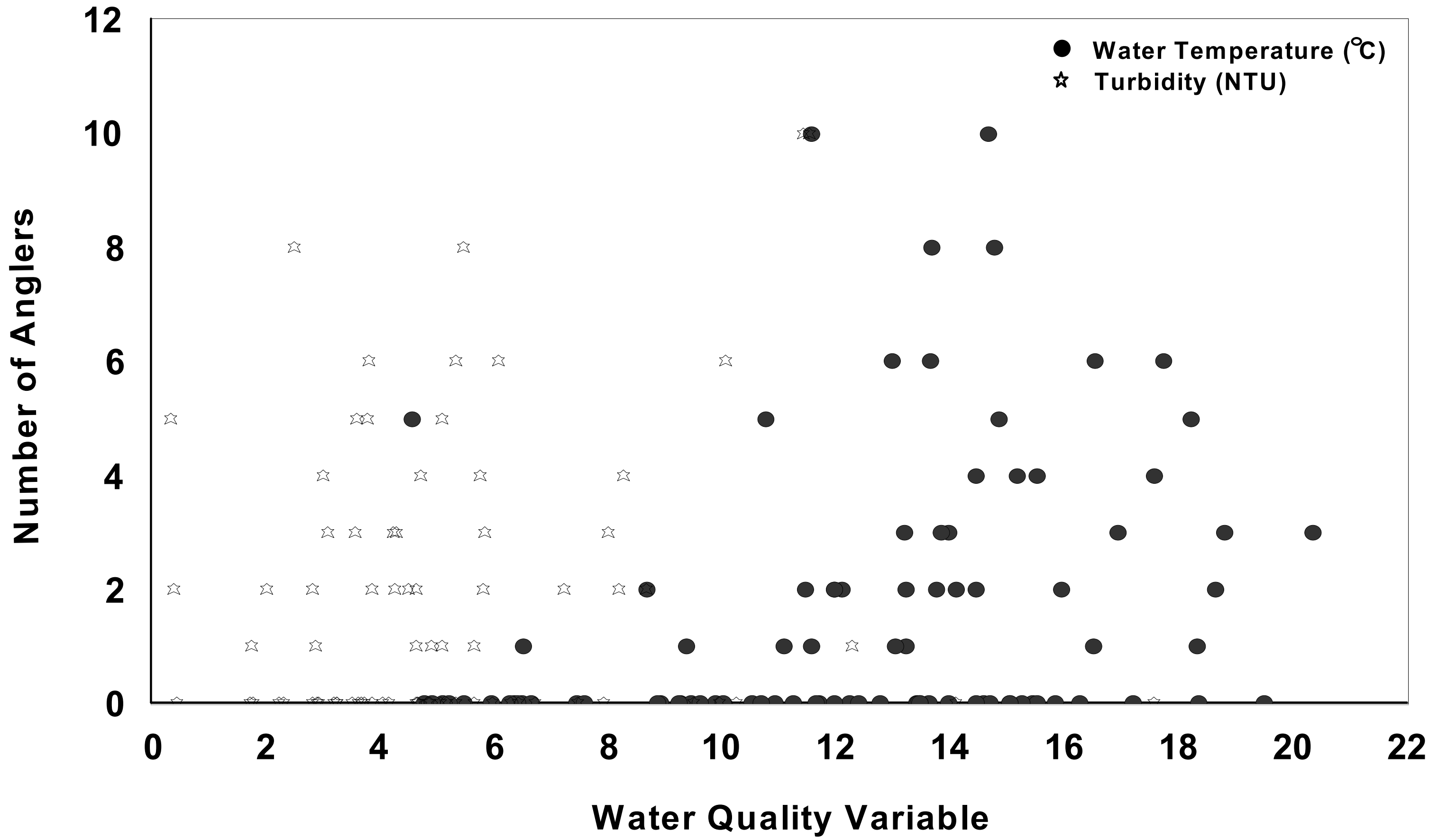


Figure 10. Relationship of turbidity, water temperature, and the number of angler interviews in Area 3 on the Chattahoochee River from Buford Dam to Roswell Road, Georgia.

DISCUSSION

Brown Trout Strain Evaluation

Different strains of trout are developed through selective breeding for special traits, such as increased thermal tolerance, predatory ability, or longevity in the fishery. Selection of certain strains can help meet certain management objectives (Behnke 1972). Georgia DNR currently obtains the WAL strain of BNT from South Carolina because of its superior hatchery and field performance in Georgia.

The WAL strain survived significantly better in the hatchery than the PR strain. Even though both strains of BNT were treated equally throughout the study, the PR strain appeared to be much more susceptible to stress induced mortality. The WAL strain showed significant growth both in length and weight while the PR strain did not. Both hatchery and field tests in the Chattahoochee River have indicated that the PR strain of BNT is inferior in hatchery and field performance to the Walhalla strain. The acquisition of WAL strain eggs from South Carolina instead of those supplied by the federal hatchery system is warranted in this case.

Rainbow and Brown Trout Mortality Evaluation

Estimates of trout survival, exploitation and mortality were calculated for both the BNT strain study and the BNT and RBT mortality study. Floy® tag reporting rates for both BNT and RBT were relatively high at 76% and 69%, respectively. Tagging studies conducted on Georgia reservoirs have had historically low reporting rates ranging from 60-72% for black crappie on Lake Sinclair (Schleiger 1991), 46-57% for largemouth bass on Lakes Richard B. Russell, Clarks Hill and Hartwell (Bettross and Saul 1994) and 50% for rainbow trout in Lake Lanier (Durniak et al.

1987). However, the reporting rates for BNT and RBT found in this study were consistent with findings from past studies on Georgia tailwater trout fisheries of 90% (Martin 1985b) and 97% (Beisser 1991).

Many tailwater fisheries for catchable RBT in the United States are managed as put-and-take, where fish exhibit short residence times and negligible growth after they are stocked (Axon 1975, Swink 1983; Heidinger 1993). This results from quick removal of the fish from the system by heavy fishing pressure (Boles 1969, Aggus et al. 1979, Pawson 1986, Pawson 1991, Heidinger 1993). High stocking densities in tailwater fisheries, which often exceed carrying capacity, are used to support heavy angling pressure (Aggus et al. 1979, Hudy 1990; Heidinger 1993, Leucke et al. 1994). Stocking strategies on the Chattahoochee River have mirrored these philosophies, with annual stockings of approximately 12,800 trout per river km (858/ha).

Stocking rates for the Chattahoochee River were increased after 1990 on the assumption that effort would continue to rise. This assumption was based on several changes, including a regulation change that allowed year-round angling, a large increase in the metropolitan Atlanta population, and vastly improved access through NPS lands. The fishery failed to intensify following these changes and effort remained similar to that measured in 1983 (Martin 1985a) and 1990 (Georgia DNR 1991) (Table 8).

Previous tagging surveys on this tailwater (Hess 1980, Martin 1985a) estimated high harvest rates compared with the number of trout that were stocked (Table 8). Approximately 27% of the quarter million trout stocked into the

Table 8. A comparison of creel statistics from previous surveys conducted on the Chattahoochee River from Buford Dam to Roswell Road, Georgia. All surveys, excluding the present study, were performed during trout season (March 31-October 31).

Year	Number of trout stocked	Trips/ ha	Hours/ha	Trout Harvested	% Return	Average Trip Length (hrs)	% Fishing Pressure	
							Trout	Other
1977[1]	93,588	25	60	42,372	45%	2.5	81.5	18.5
1978[1]	103,487	21	58	37,699	36%	2.9	99.5	0.5
1983[2]	132,305	54	132	112,370	85%	2.6	94	6.0
1990[3]	181,000	41	126	114,591	63%	N/A	N/A	N/A
Present Study	268,865	48	157	73,383	27%	3.3	88	12.0

[1] Hess (1980)
[2] Martin (1985a)
[3] Georgia DNR (1991)

Chattahoochee River were harvested during this study. This resulted in a high density of fish entering the winter season. Change-in-ratio calculations estimated that stocked trout suffered substantial mortality over the fall-winter season, dropping from 7,200 trout per river km (832 trout/ha) in late summer to less than 2,880 trout per river km (187 trout/ha) in early spring.

Similar studies support the concept that changes in harvest rates are responsible for the compensatory changes in growth and natural mortality observed in this fishery (Graham 1974, Kempinger and Carline 1978). Martin (1985b) found much lower natural mortality with higher harvest rates and both Hess (1980) and Martin (1985b) found higher survival (Table 9). Additionally, increases in stocking density would magnify any adverse effects associated with reduced harvest.

The Chattahoochee trout fishery has undergone a substantial shift from high rates of harvest (Martin 1985a, Georgia DNR 1991) to a fishery where approximately 25% (Floy tagged) of all trout caught are released. Release rates #10% usually have negligible effects on a fishery, but higher rates can radically alter the dynamics of a population (Clark 1983). This angler behavior only exacerbates the excessive levels of natural mortality that are present. Benefits that anglers associate with catch and release fishing would be difficult to realize under existing stocking strategies.

Heavier stocking rates in the absence of increased pressure and harvest are believed to be the driving factors associated with the excessive level of natural mortality in this fishery. Similar studies on stocked trout populations support this conclusion (Klak 1941, Riemers 1963, Murphy et al. 1981, Ersbak

Table 9. A comparison of trout mortality statistics from previous studies conducted on the Chattahoochee River from Buford Dam to Roswell Road, Georgia.

Year	Number stocked	% Survival		% Mortality					
		Rainbow Trout	Brown Trout	Rainbow Trout			Brown Trout		
				Annual	Fishing	Natural	Annual	Fishing	Natural
1978[1]	103,487	42%	-----	58%	-----	-----	-----	-----	-----
1983[2]	132,305	52%	46%	48%	79%	21%	54%	65%	35%
Present Study	268,865	31%	17%	69%	25%	75%	83%	11%	89%

[1] Hess (1980)
[2] Martin (1985b)

and Haase 1983, Bachman 1984, Cada et al. 1987, Ensign et al. 1990, Hughes and Dill 1990, Filbert and Hawkins 1995).

Monthly growth rates of microtagged BNT and RBT from this study averaged 4.5 mm and 4.9 mm, respectively. These rates are lower than previous estimates (Hess 1980) of 4.9 mm (BNT) and 8.1 mm (RBT) and much lower than other tailwaters. In comparison, the growth of catchable trout below Norris Dam, Tennessee was 12 mm per month (Bettoli and Bohm 1997), 10 mm per month below Table Rock Dam, Missouri (Fry and Hanson 1968) and as high as 23 mm per month in Bull Shoals Tailwater, Arkansas (Baker 1959). Lower than anticipated rates of effort, high stocking rates and harvest of only a quarter of the yearly stocked trout population are likely causative factors that have reduced the growth and survival of the Chattahoochee River RBT and BNT populations.

Creel Survey

Biologists usually manage put-and-take trout fisheries by stocking trout to yield a desired catch rate (Miko et al. 1995). Catch rates, harvest, and fishing effort have all been used to measure management success. Catch rates, including harvest and release, of 0.80-trout per angler hour on the Chattahoochee River are comparable to other put-and-take trout fisheries. Bettoli and Xenakis (1996) observed catch rates of 0.62-1.44 trout/angler hour and Fatora (1983) observed catch rates from 0.75-1.14 trout/angler hour in intensively stocked Georgia trout streams. Fishing effort remained nearly unchanged when compared with rates from the previous studies in 1983 and 1990. However, harvest rates on the Chattahoochee River dropped from 0.50-trout/angler hour (Martin 1985a, Georgia

DNR 1991) to 0.25 trout per angler hour in this study. This is problematic because stocking rates have nearly doubled since the previous survey.

Because of poor growth and survival of the Chattahoochee River trout population, few stocked trout reach the larger sizes preferred by most anglers. Anglers on the Chattahoochee overwhelmingly preferred quality sized trout over more abundant but smaller trout. Management goals prior to this survey focused on a put-and-take fishery. Put-and-take assumes that catchable trout (228 mm) are stocked into a system and then harvested quickly. Fish growth is not expected because quick harvest is anticipated. The high (75%-89%) natural mortality rates of trout in the Chattahoochee River are considered undesirable in a put-and-take fishery. A change in the Chattahoochee River stocking scheme may be warranted to reduce natural mortality rates.

The demographic information collected from anglers provided valuable information about the Chattahoochee River sport fishery. Nearly 70% of the anglers surveyed were # 40 years old and nearly 40% were # 30 years old. Past surveys have found that the national average of anglers # 40 years was considerably lower at 42% (US Dept. Int. 1996). These findings may indicate an above average recruitment of young anglers using the Chattahoochee River. The fact that the Chattahoochee River is close to Atlanta, Georgia and offers unique recreation in a natural setting with easy accessibility may help draw younger anglers.

The Chattahoochee River trout fishery is valuable to the local economy. Total fishing trip expenditures for freshwater fishing in Georgia averaged $89.28 per trip (US Dept. Int. 1996), was used to estimate the fishery's economic value to the

Atlanta metro area. Anglers spent $7,853,961 in pursuit of the Chattahoochee River trout fishery during the 16-month survey period (87,970 trips).

Water Quality and Catch of Trout

Water quality changes caused by dams are well documented and can have profound effects on the tailwater fish populations. Problems can include hypoxia (Kittrell 1964), low temperature (Pfitzer 1967), dissolved metals (Symons 1969 Grizzle 1981), and depressed fish migration (Raymond 1979). Trout are coldwater specialists that demand a very narrow range of temperature, oxygen, and turbidity standards (Swift 1963, Weithman et al. 1980, Newcombe and Jensen 1996). Water quality in the Chattahoochee River below Buford Dam varies according to season, hydropower demands, and rain events. Water temperatures in early January are cold and the water is well oxygenated. During the summer months the volume of cold water in Lake Lanier's hypolimnion decreases and becomes hypoxic. The U.S. Army Corps of Engineers (USACOE) plans to install two auto-venting turbines in Buford Dam. These vented turbines will provide oxygen during times of the year when water from the dam is normally hypoxic. As an interim measure, the USACOE sluices surface water from Buford Dam during poor water quality periods to augment dissolved oxygen levels.

Some studies have found decreases of up to 0.1 trout per angler hour for every 1 mg/L decrease in dissolved oxygen levels below 6 mg/L (Weithman et al. 1980, Weithman and Haas 1984). In this study, low dissolved oxygen alone did not seem to depress catch rates of either RBT or BNT. Grizzle (1981) hypothesized that trout in the Chattahoochee River were acclimated to low dissolved oxygen concentrations. This phenomenon has also been seen in brook trout (Shepard 1955). Brook trout that were not acclimated to low dissolved oxygen concentrations experienced 50% mortality at 1.75 mg/L, but after acclimation, no significant mortality occurred at levels as low as 1.05 mg/L.

High air temperatures coupled with minimal flows from Buford Dam and run-off from impervious surfaces during summer storms can increase water temperatures to unacceptable levels in the downstream third of designated trout waters below Buford Dam. The creel survey occurred during a drought period, consequently there were very few rain events during this survey that affected water quality. Also, releases from Buford Dam were higher than average, which mitigated any adverse water quality resulting from storm events. Water temperatures stayed within acceptable ranges (5-20°C) during the course of the creel survey.

Chattahoochee River BNT did not exhibit a predictable relationship between catch and temperature, although catch did begin to decline when water temperatures exceeded 18°C. While these findings were initially considered unusual, other studies indicated that BNT are not as sensitive to some water quality variables as RBT (Jowett 1992, Garrett and Bennett 1995, Biagi and Brown 1997). McMichael and Kaya (1991) noted a 50% reduction in catch rates of BNT when temperatures were over 19°C.   Taylor (1978) also found that catch rates for BNT from a small reservoir in England were much lower at temperatures above 18°C than when temperatures were below 13°C. In addition, BNT are more difficult to catch than RBT (Shetter 1962, Anderson and Nehring 1984, Cox and Walters 2002) and as a result, angler success for BNT may not be a good index for determining relationships between catch and water quality.

Highest average CPUE of RBT in the Chattahoochee River occurred when water temperatures were between 10 and 16.5°C. Temperatures above or below this optimum depressed CPUE of RBT significantly. Salmonids subjected to high water temperatures exhibit high metabolic demands that can cause cessation of feeding, growth suppression, and early mortality (Ratledge and Cornell 1952, Baldwin 1956, Elliott 1994, Dickerson and Vinyard 1999). McMichael and Kaya (1991) noted that the highest catch rates for trout in a Montana stream occurred when temperatures were between 8 and 13°C. Hokanson et al. (1977) found that catch of RBT peaked at 17°C and decreased by nearly 60% between 19 and 21°C.

Angler catch and condition of RBT have been tied closely to temperature both in the Chattahoochee River and other locations (Riemers 1963, Cada et al. 1987, Filbert and Hawkins 1995). RBT in the Chattahoochee River appeared to be more sensitive to higher temperatures than BNT. Biagi and Brown (1997) noted this previously in their temperature tolerance study.

Turbidity influenced the Chattahoochee trout fishery by reducing RBT CPUE and possibly angler effort. Numerous and constant land disturbing activities within the watershed contribute substantial sediment to the river. Typical turbidity readings for the Chattahoochee River ranged from 0 to 4 NTU but exceed 200 NTU with run-off from heavy rains (generally $1 inch/day). Catch per unit effort of RBT was lower when turbidity rates exceeded 12 NTU and higher when turbidity levels were within an ideal range of 2 to 12 NTU. These findings support the study by Drenner et al. (1997) and other studies (Noggle 1978, Barrett et al. 1992). Excessive turbidity associated with normal rainfall years has a great potential for adversely affecting the quality of this fishery. High turbidity levels can depress catch rates of trout by causing avoidance of stimuli, depressed feeding rates, and a decreased reaction distance (Servizi and Martens 1992, Bisson and Bilby 1982; Redding et al. 1987, Barrett et al. 1992, Servizi and Martens 1992, Newcombe and Jensen 1996, Sweka and Hartman 2001).

A synergistic effect of high turbidity and warm water temperatures on angler success was noted. When turbidity levels and water temperatures were high, CPUE of RBT was severely depressed. These conditions are prevalent following summer thunderstorms.

High turbidity levels in the river during the summer are almost always associated with elevated water temperatures from rain events. There are also indications that high turbidity levels impair oxygen exchange at the gill surface (Newcomb and Flagg 1983), so fish need additional oxygen when water temperatures and turbidity increase (Brett 1964; Marvin and Heath 1968, Horkel and Pearson 1976).

When catch of trout is depressed due to high turbidity, or a combination of poor water quality factors, anglers are not fishing. Dissolved oxygen, temperature, and turbidity levels fell outside the ideal ranges for catching trout a total of 73 days from March 2000 to July 2001. Data collection occurred on 286 days, while the survey spanned 473 calendar days.

There were significant relationships between number of anglers fishing and all three water quality variables. Trout are known site feeders (Ware 1972, Ringler

1979) so turbidity is a good visual indicator to anglers of potential fishing success. No anglers were present to be interviewed in the lower third of the stream (Area 3) during this survey on days that turbidity exceeded 12 NTU (Figure 10). Turbidity levels exceeded this range on 14% of the 278 sample days and a simple expansion suggests that turbidity exceeded the anglers preferred level on 65 days. Fishing trip expenditures of $89.28 per trip (US Dept. Int. 1996) were used to estimate a lost dollar value of $1,120,017 (193 angler trips per day) associated with excessive turbidity in the Chattahoochee River.

Recommendations

1. Walhalla strain brown trout were superior to Plymouth Rock brown trout in both hatchery and field trials. DNR should continue to emphasize Walhalla strain brown trout in its management system. The federal hatchery system should produce Walhalla strain brown trout for southeastern fisheries.
2. Stocking rates for catchable rainbow and brown trout should be reduced 45-50% to account for existing levels of effort and harvest. The rates should be similar to those used by Martin (1985a), with a target of 140,000-150,000 trout stocked annually. Stocking densities at specific locations should be adjusted to compensate for angler effort.
3. A portion of the available trout from the stocking reductions could be redirected to the Morgan Falls tailwater to extend the catchable trout fishery further downstream.
4. Remaining catchable trout could be redirected back into the statewide stocking program. Consideration should be given to rearing an allotment of

fewer, but larger trout to increase angler satisfaction.

5. Standardized sampling of the Chattahoochee River below Buford Dam should continue on an annual basis to document trends and identify problems. Natural recruitment of trout reproduction should be monitored and considered when making water use and management recommendations.

6. Initial survey findings indicate that there is a local angler base that has a substantial economic impact on the area. A detailed economic survey on the value of the Chattahoochee trout fishery is warranted based on preliminary findings.

Bibliography

Aggus, L.R., D.I. Morais, and R.F. Baker. 1979. Evaluation of the trout fishery in the tailwater of Bull Shoals Reservoir, Arkansas, 1971-73. Proceedings of the Annual Conference Southeastern Association Fish and Wildlife Agencies 31(1977):565-573.

Anderson, R.M., and R.B. Nehring. 1984. Effects of a catch-and-release regulation on a wild trout population in Colorado and its acceptance by anglers. North American Journal of Fisheries Management 4:257-265.

Anderson, R.O., and R.M. Neumann. 1996. Length, weight and associated structural indices. Pages 454-463 in B.R. Murphy and D.W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Analytical Software. 1996. Statistix for Windows users guide. Version 7. Tallahassee, Florida.

Axon, J.R. 1975. Review of coldwater fish management in tailwaters. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 28(1874):351-355.

Bachman, R.A. 1984. Foraging behavior of free-ranging wild and hatchery brown trout in a stream. Transactions of the American Fisheries Society. 113:1-32.

Baker, R.F. 1959. Historical review of the Bull Shoals Dam and Norfolk Dam tailwater fishery. Proc. Annual Conf. Southeast. Assoc. Game Fish Comm. 13:229-236.

Baldwin, N.S. 1956. Food consumption and growth of brook trout at different temperatures. Transactions of the American Fisheries Society 86:323-328.

Barrett, J.C., G.D. Grossman, and J. Rosenfeld. 1992. Turbidity induced changes in reactive distance of rainbow trout. Transactions of the American Fisheries Society 121:437-443.

Behnke, R.J. 1972. The rationale for preserving genetic diversity: Yellowstone National Park, Wyoming. Summary report 1966. U.S. Department of the Interior, Bureau of Sport Fisheries and Wildlife, Washington, D.C.

Behnke, R.J. 1980. Research panel. Pages 8-9 in W. King, editor. Wild trout II. Trout Unlimited and Federation of Fly Fishers, Vienna, Virginia.

Beisser, G.S. 1991. Angler harvest of stocked rainbow trout, *Oncorhynchus mykiss*, in the Blue Ridge Tailwater. Ga. Dept. Nat. Res., Wildlf. Res. Div., Final Report, Fed. Aid Proj. F-36, Study IV.

Beisser, G.S. 1996. Development of a stream classification system for evaluating trout stocking in Georgia. Ga. Dept. Nat. Res., Wildlf. Res. Div., Final Report, Fed. Aid Proj. F-36, Study XII.

Bettoli, P., and L. Bohm. 1997. Interim report and summary of project activities Clinch River trout investigations and creel survey September 1995- June 1997. TN. Coop. Fishery Res. Unit, TN Tech Univ., Cookeville, Tennessee.

Bettoli, P., and S. Xenakis. 1996. An investigation of the trout fishery in the Caney Fork River below Center Hill Dam. TN. Coop. Fishery Res. Unit, TN Tech Univ., Cookeville, Tennessee.

Bettross, E.A., and B.M. Saul. 1994. Dynamics of the largemouth bass fisheries in three mainstem Savannah River reservoirs. Ga. Dept. Nat. Res., Wildlf. Res. Div., Final Report, Fed. Aid Proj. F-26, Study XXII.

Biagi, J., and R.P. Brown. 1997. Upper temperature tolerance of juvenile and adult brown and rainbow trout tested under flowing conditions. Ga. Dept. Nat. Res, Wildlife Resources Div., Final Report., Fed. Aid Proj. F-26. 32p.

Bisson, P.A., and R.E. Bilby. 1982. Avoidance of suspended sediment by juvenile coho salmon. North American Journal of Fisheries Management 4:371-374.

Boles, H.D. 1969. Little Tennessee River investigation. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 22(1968):321-338.

Brett, J.R. 1964. The respiratory metabolism and swimming performance of young sockeye salmon. J. Fish. Res. Board Can. 21:1183-1226.

Cada, F.G., J.M. Loar, and M.J. Sale. 1987. Evidence of food limitation of rainbow and brown trout in Southern Appalachian soft-water streams. Transactions of the American Fisheries Society 116:692-702.

Clark, R.D., Jr. 1983. Potential effects of voluntary catch and release of fish on recreational fisheries. North American Journal of Fisheries Management 3:306-314.

Cordone, A.J., and S.J. Nicola. 1970. Harvest of four strains of rainbow trout, *Salmo gairdneri*, from Beardsley Reservoir, California. Calfornia Fish and Game 56:271-287.

Cox, S.P., and C.Walters. 2002. Modeling exploitation in recreational fisheries and implications for effort management on British Columbia rainbow trout lakes. North American Journal of Fisheries Management 22:21-34.

Dickerson, B.R., and G.L. Vinyard. 1999. Effects of high chronic temperatures and diel temperature cycles on the survival and growth of Lahontan cutthroat trout. Transactions of the American Fisheries Society 128:516-521.

Drenner, R.W., K.L. Gallow, C.M. Edwards, K.E. Rieger, and E.D. Dibble. 1997. Common carp affect turbidity and angler catch rates of largemouth bass in ponds. North American Journal of Fisheries Management. 1997. 17:1010-1013.

Durniak, J.P., W.S. Couch Jr., and O.R. Weaver. 1987. Return of stocked trout from Lake Lanier. Ga. Dept. Nat. Res., Wildlf. Res. Div., Final Report, Fed. Aid Proj. F-25, Study XVIII.

Dwyer, W.P., and R.G. Piper. 1984. Three-year hatchery and field evaluation of four strains of rainbow trout. North American Journal of Fisheries Management 4:216-221.

Elliott, J.M. 1994. Quantitative ecology and the brown trout. Oxford University Press, Oxford, UK.

Ensign, W.E., R.J. Strange, and S.E. Moore. 1990. Summer food limitation reduces brook and rainbow trout biomass in a southern Appalachian stream. Transactions of the American Fisheries Society 119:894-901.

Ersbak, K., and B.L. Haase. 1983. Nutritional deprivation after stocking as a possible mechanism leading to mortality in stream stocked brook trout. North American Journal of Fisheries Management 3:142-151.

Fatora, J.R. 1983. Creel survey in intensively stocked trout streams. Georgia Department of Natural Resources, Game and Fish Division, Federal Aid in Sport Fish Restoration final report, F-25.

Filbert, R.B., and C.P. Hawkins. 1995. Variation in condition of rainbow trout in relation to food, temperature and individual length in the Green River, Utah. Transactions of the American Fisheries Society 124:824-835.

Fry, J.P., and W.D. Hanson. 1968. Lanke Taneycomo: a coldwater reservoir in Missouri. Transactions of the American Fisheries Society 97(2):138-145.

Garrett, J.W., and D.H. Bennett. 1995. Seasonal movements of adult brown trout relative to temperature in a coolwater reservoir. North American Journal of Fisheries Management 105(2):480-487.

Graham, L.K. 1974. Effects of four harvest rates on pond fish populations. Pages 9-38 in J.L. Funk, editor. Symposium on overharvest and management of largemouth bass in small impoundments. Special Publication 3, North Central Division, American Fisheries Sociey, Bethesda, Maryland, USA.

Grizzle, J.M. 1981. Effects of hypolimnetic discharge on fish health below a reservoir. Transactions of the American Fisheries Society 110:29-43.

Heidinger, R.C. 1993. Stocking for sport fisheries enhancement. Pages 309-330 *in* C.C. Kohler and W.A. Hubert, editors. Inland Fisheries Management in North America. American Fisheries Society, Bethesda, Maryland.

Hess , T.B. 1980. An evaluation of the fishery resources of the Chattahoochee River below Buford Dam. Ga. Dept. of Nat. Res., Game and Fish Div., Final Report., Fed. Aid Proj. F-26. 52pp.

Hokanson, K.E.F., C.F. Kleiner, and T.W. Thorsland. 1977. Effects of constant temperature and diel fluctuations on growth, mortality and yield of juvenile rainbow trout, *Salmo gaird*neri (Richardson); Journal of the Fisheries Research Board of Canada 34:639-648.

Horkell, J.D., and W.D. Pearson. 1976. Effects of turbidity on ventilation rates and oxygen consumption of green sunfish, *Lepomis cyanellus*. Transactions of the American Fisheries Society 105(1):107-113.

Hudy, M., and C.R. Berry. 1983. Performance of three strains of rainbow trout in a Utah reservoir. North American Journal of Fisheries Management 3:136-141.

Hudy, M. 1990. Brown trout population structures in White River tailwaters currently managed under no special regulation. Pages 94-97 in J.C. Borawa, editor Brown trout workshop: biology and management. American Fisheries Society, Southern Division, Trout Committee, Asheville, North Carolina.

Hughes, N.F., and L.M. Dill. 1990. Position choice by drift feeding salmonids: model and test for Arctic grayling (*Thymallus arcticus*) in subarctic mountain streams, interior Alaska. Canadian Journal of Fisheries and Aquatic Sciences 47:2039-2048.

Hulbert, P.J. 1985. Post-stocking performance of hatchery-reared yearling brown trout. New York Fish and Game Journal. 32:1-8.

Jobling, M. 1981. Temperature tolerance and the final preferendum-rapid methods for the assessment of optimum growth temperatures. Journal of Fish Biology 19:439-455.

Jones, C.M., D.S. Robson, D. Otis, and S. Gloss. 1990. Use of a computer simulation model to determine the behavior of a new survey estimator of recreational angling. Transactions of the American Fisheries Society 119:41-54.

Jowett, I.G. 1992. Models of the abundance of large brown trout in New Zealand rivers. North American Journal of Fisheries Management 12:417-432.

Kempinger, J.J., and R.F. Carline. 1978. Dynamics of the northern pike populations and changes that occurred with a minimum size limit in Escanaba Lake, Wisconsin. Pages 382-389 in R.L. Kendall, editor. Selected coolwater fishes of North America. American Fisheries Society, Special Publication 11, Bethesda, Maryland, USA.

Kincaid, H.L. 1981. Trout strain registry. U.S. Fish Wildl. Serv., Nat. Fish. Center (Leetown) Rep. No. NFC-L/81-1. 118 pp.

Kincaid, H.L., M.J. Gray, L.J. Mengel, and S. Brimm. 1997. National fish strain registry- trout, species tables of reported strains and broodstocks. U.S. Geological Survey, Research and Development Laboratory, Wellsboro, Pennsylvania, USA.

Kittrel, K.L.E. 1964. Effects of impoundments on dissolved oxygen resources. Sewage and Industrial Wastes 31:1065-1078.

Klak, G.F. 1941. The condition of brook trout and rainbow trout from four eastern streams. Transactions of the American Fisheries Society 70:282-289.

Leucke, C., T.C. Edwards, Jr. M.V. Weingert, Jr. S. Brayton, and R. Schneidervin. 1994. Simulated changes in lake trout yield, trophies, and forage consumption under various slot limits. North American Journal of Fisheries Management 14:14-21.

Martin, C. 1985a. Creel survey of the Chattahoochee River and an evaluation of the effects of poor fall water quality on trout. Ga. Dept. Nat. Res., Game and Fish Div., Final Report, Fed. Aid Proj. F-26-12. 46pp.

Martin, C. 1985b. Hatchery and field performance of six trout strains stocked as catchables in the Chattahoochee River, Georgia. Ga. Dept. Nat. Res., Game and Fish Div., Final Report, Fed. Aid Proj. F-26-12. 27pp.

Marvin, D.E., and A.G. Heath. 1968. Cardiac and respiratory responses to gradual hypoxia in three ecologically distinct species of freshwater fish. Comp. Biochem. Physiol. 27:349-355.

McMichael, G.A. and C.M. Kaya. 1991. Relations among stream temperature, angling success for rainbow trout and brown trout and fisherman satisfaction. North American Journal of Fisheries Management. 11:190-199.

Miko, D.A., H.L. Schramm, Jr., S.D. Arey, J.A. Dennis, and N.E. Mathews. 1995. Determination of stocking densities for satisfactory put-and-take rainbow trout fisheries. North American Journal of Fisheries Management 15:823-829.

Miller, R.B. 1952. Survival of hatchery reared cutthroat trout in an Alberta stream. Transactions of the American Fisheries Society 81:35-42.

Minard, R.A., K. Jones, M. Witten, and S. Thomas. 2001. Policies to prevent erosion in Atlanta's watersheds: accelerating the transition to performance. National Academy of Public Administration, Washington DC. 38pp.

Moring, J.R. 1982. An efficient hatchery strain of rainbow trout for stocking Oregon streams. North American Journal of Fisheries Management 2:209-215.

Murphy, M.L., and J.D. Hall. 1981. Varied effects of clear-cut logging on predators and their habitat in small streams of the Cascade Mountains, Oregon. Canadian Journal of Fisheries and Aquatic Sciences 38:137-145.

Murphy, M.L., C.P. Hawkins, and N.H. Anderson. 1981. Effects of canopy modification and accumulated sediment on stream communities. Transactions of the American Fisheries Society 110:469-478.

Newcomb, T.W., and T.A. Flagg. 1983. Some effects of Mt. St. Helens volcanic ash on juvenile salmon smolts. Mar. Fish. Rev. 45(2):8-12.

Newcombe, C.P., and J.O.T. Jensen. 1996. Channel suspended sediment and fisheries: A synthesis for quantative assessment of risk and impact. North American Journal of Fisheries Management 16:693-727.

Noggle, C.C. 1978. Behavioral, physiological and lethal effects of suspended sediment on juvenile salmonids. Master's thesis. Univerisity of Washington, Seattle.

Paulik, G.J., and D.S. Robson. 1969. Statistical calculations for change-in-ratio estimators of population parameters. Journal of Wildlife Management 33:1-27.

Pawson, M.G. 1986. Performance of rainbow trout, *Salmo gairdneri* Richardson, in a put-and-take fishery, and the influence of anglers' behavior on catchability. Aquaculture and Fisheries Management 17:59-73.

Pawson, M.G. 1991. Comparisons of the performance of brown trout, *Salmo trutta*, L., and rainbow trout, *Oncorhynchus mykiss* (Walbaum), in a put-and-take fishery. Aquaculture and Fisheries Management 22:247-257.

Pfitzer, D.W. 1967. Evaluation of tailwater fishery resources resulting from high dams. Pages 477-488 in Reservoir fishery resources symposium. Reservoir Committee, Southern Division, American Fisheries Society, Washington, District of Colombia, USA.

Ratledge, H.M., and J.H. Cornell. 1952. The effect of trout stocking on the rate of catch. Progressive Fish Culturist 14:117-121.

Raymond, H.L. 1979. Effects of dams and impoundments on migrations of juvenile chinook salmon and steelhead from the Snake River, 1966 to 1975. Transactions of the American Fisheries Society 108:505-529.

Riemers, N. 1963. Body condition, water temperature, and over-winter survival of hatchery reared trout in Convict Creek, California. Transactions of the American Fisheries Society 92:39-49.

Ringler, N.H. 1979. Prey selection by drift-feeding brown trout (*Salmo trutta*). Journal of the Fisheries Research Board of Canada 36:392-403.

Redding, J.M., C.B. Schreck, and G.H. Everest. 1987. Physiological effects on coho salmon and steelhead of exposure to suspended solids. Transactions of the American Fisheries Society 116:737-744.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191.

Robson, D.S., and D.G. Chapman. 1961. Catch curves and mortality rates. Transactions of the American Fisheries Society 90:181-189.

Robson, D.S., and C.M. Jones. 1989. The theoretical basis of an access site angler survey design. Biometrics 45:83-98.

Schleiger, S.L. 1991. A survey of the black crappie population in Lake Sinclair. Ga. Dept. Nat. Res., Wildlf. Res. Div., Final Report, Fed. Aid Proj. F-33, Study IX.

Servizi, J.A., and D.W. Martens. 1992. Sublethal responses of coho salmon (*Oncorhynchus kisutch*) to suspended sediments. Canadian Journal of Fisheries and Aquatic Sciences 49:1389-1395.

Shepard, M.P. 1955. Resistance and tolerance of young speckled trout (*Salvelinus fontinalis*) to oxygen lack, with special reference to low oxygen acclimation. Journal of the Fisheries Research Board of Canada 12:387-433.

Shetter, D.S. 1962. Recoveries by anglers of legal-sized trout stocked during different seasons of the year in Michigan streams. Transactions of the American Fisheries Society 91(2):145-150.

Smith, S.B. 1957. Survival and growth of wild and hatchery rainbow trout (*Salmo gairdneri*) in Corbett Lake, B.C. Canadian Fish Culturist 20:7-12.

SPSS Inc. 1999. SYSTAT® users guide. Version 9. Chicago, Illinois.

Swift, D.R. 1963. Influence of oxygen concentration on growth of brown trout, *Salmo trutta* L. Transactions of the American Fisheries Society 92:300-301.

Sweka, J.A., and K.J. Hartman. 2001. Effects of turbidity on prey consumption and growth in brook trout and implications for bioenergetics modeling. Canadian Journal of Fisheries and Aquatic Sciences 58:386-393.

Swink, W.D. 1983. Survey of stocking policies for tailwater trout fisheries in the southern United States. Progressive Fish Culturist 45:67-71.

Symons, J.M. 1969. Water quality behavior in reservoirs. United States Public Health Service, Publication 1930, Cincinnati, Ohio, USA.

Taylor, A.H. 1978. An analysis of the trout fishing at Eye Brook- a eutrophic reservoir. Journal of Animal Ecology 47:407-423.

Trojnar, J.R., and R.J. Behnke. 1974. Management implications of ecological segregation between two introduced populations of cutthroat trout in a small Colorado lake. Transactions of the American Fisheries Society 103:423-430.

U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census. 1996 National survey of fishing, hunting, and wildlife-associated recreation.

Ware, D.M. 1972. Predation by rainbow trout *Salmo gairdneri*, the influence of hunger, prey density and prey size. Journal of the Fisheries Research Board of Canada 29:1193-1201.

Weithman, A.S., J.R. Whitley, and M.A. Haas. 1980. Table Rock tailwater trout fishery- value, use, and dissolved oxygen problems. Proceedings of a Seminar on Water Quality Evaluation 22-24 January, 1980, Tampa, Florida. Army Corps of Engineers, Committee on Water Quality, Washington, DC, paper 8. 9pp.

Weithman, A.S., and M.A. Haas. 1984. Effects of dissolved oxygen depletion on the rainbow trout fishery in Lake Taneycomo, Missouri. Transactions of the American Fisheries Society 113:109-124.

Appendix

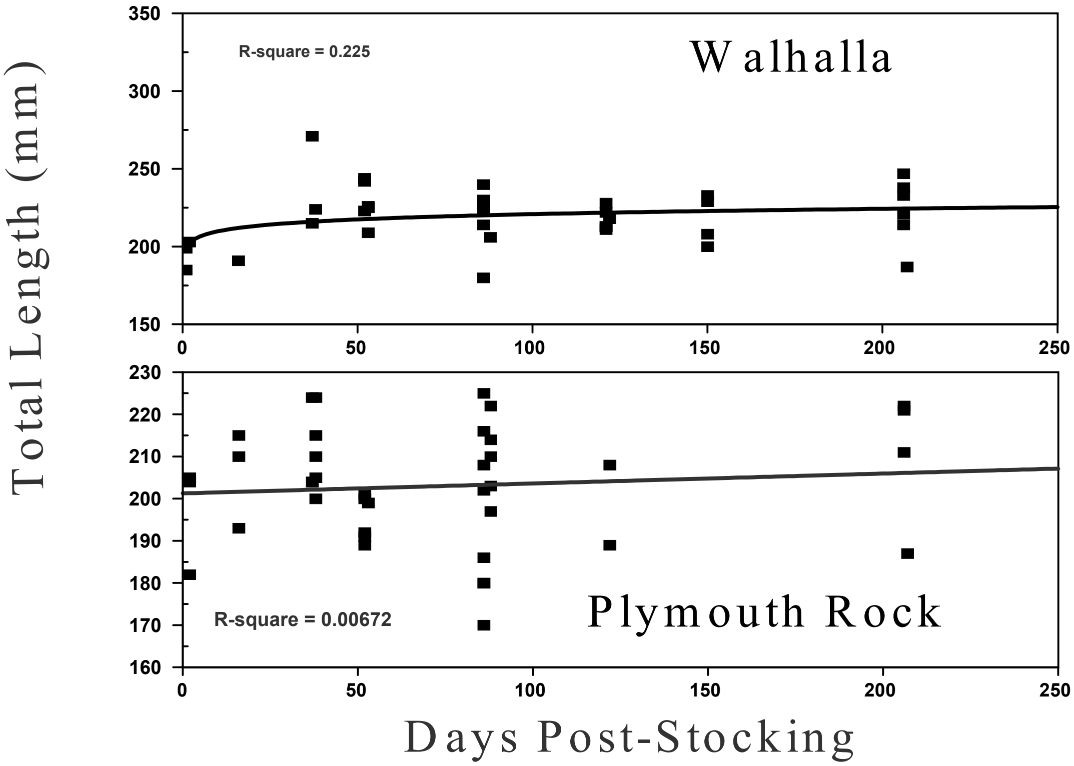


Figure A1. Total length regressed against days post-stocking for Walhalla and Plymouth Rock strain brown trout Chattahoochee River below Buford Dam in 1998-1999.

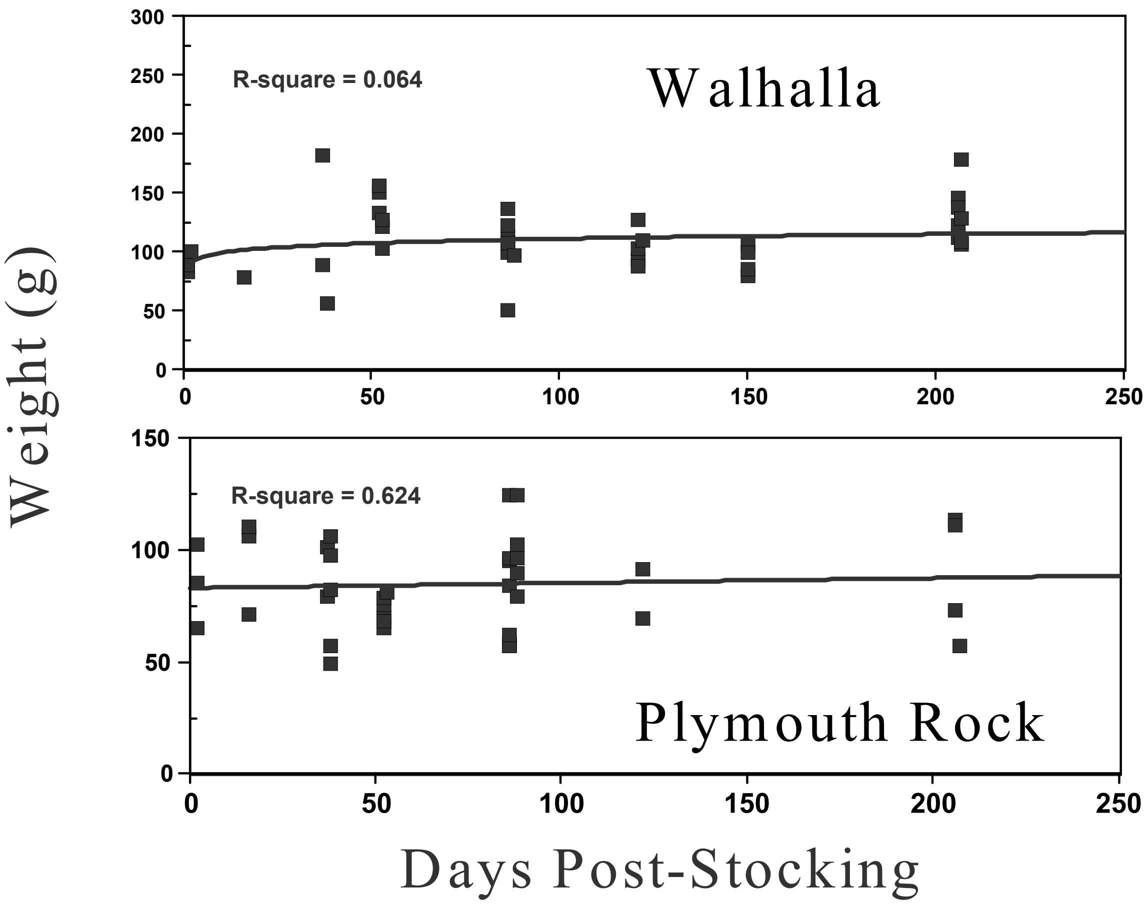


Figure A2. Weight regressed against days post-stocking for Walhalla and Plymouth Rock strain brown trout Chattahoochee River below Buford Dam in 1998-1999.