FISHERIES REPORT
17-02

REGION IV
TROUT FISHERIES REPORT
2016

Prepared by:

James W. Habera
Rick D. Bivens
Bart D. Carter
Carl E. Williams

Tennessee Wildlife Resources Agency

Visit our website at ***http://twra4streams.homestead.com/troutres.html***, where you can download this report and learn more about TWRA Region IV's trout resources. You can also link to this site (or the general Region IV site) through the main TWRA website at ***www.tnwildlife.org***.

Cover: The brook trout pond at 4,000' on upper Birchfield Camp Branch in the Cherokee National Forest (Unicoi County). This pond (~3 acres) is located within the Higgins Creek / South Indian Creek watershed and was sampled in 2016 to verify the presence of brook trout (photo at left, courtesy of M. Carter, USFS) and obtain DNA samples for genetic analyses. Cover photo by J. Habera.

TROUT FISHERIES REPORT
2017

Prepared by:

James W. Habera
Rick D. Bivens
Bart D. Carter
and
Carl E. Williams

TENNESSEE WILDLIFE RESOURCES AGENCY

April 2017

This report contains progress and accomplishments for the following TWRA Projects: "Stream Survey".

Development of this report was financed in part by funds from Federal Aid in Fish and Wildlife Restoration (Public Law 91-503) as documented in Federal Aid Project FW-6 (4350 and 4351)

Executive Summary

Wild trout streams: Fourteen stations on 10 wild trout monitoring streams in the Nolichucky, Watauga, and South Fork Holston river watersheds in Region IV were quantitatively sampled during 2016. Assistance was also provided to Region III with sampling efforts at three monitoring stations on North River and Bald River in Monroe County. Drought conditions prevailed during spring and fall 2016, with rainfall for the Tennessee Valley above Chattanooga 35% below average for March-May and 50% below average for September-November (A. Ramsey, TVA, personal communication). By the end of November, most of Region 4 had a “severe” or “extreme” drought classification with the United States Drought Monitor. Few age-0 brown trout and brook trout (below 3,000’ elevation) were observed across the region, indicating poor reproductive success. Biomass estimates decreased at most monitoring stations relative to 2015 and fewer adults in the larger size classes were present.

Sympatric brook/rainbow trout streams: Relative brook trout biomass increased or remained relatively stable at two of the four monitoring stations in 2016 and declined somewhat at the others. Relative brook trout biomass in all streams except Briar Creek currently exceeds the level present when monitoring began 21-25 years ago. Data from these stations continue to document long-term co-existence of brook and rainbow trout under sympatric conditions and that drier periods (particularly 1998-2002; 2007-2008) favor brook trout while wetter periods (e.g., 2003-2005, and 2013) or floods (e.g., 1994) favor rainbows.

Brook trout DNA sampling: Forty-five Region IV brook trout populations were sampled by electrofishing in 2016 to obtain DNA samples (fin clips) for microsatellite DNA analyses (U.S. Geological Survey Leetown Science Center Lab, Kearneysville, WV). Overall, DNA samples were obtained from 1,099 fish, with sample sizes ranging from 2-35 and averaging 24 (29 samples included ≥30 fish). Mean length of the collection zone in each stream was 900 m. All 26 extant populations in the French Broad and Nolichucky basins were completed, including one inhabiting the Birchfield Camp pond in Unicoi County. Important results of these new analyses will be verification of the identity of existing native brook trout populations, along with more detailed information (including effective population sizes) for selecting appropriate source populations as part of restoration and enhancement projects. The remaining 41 populations in Region IV will be sampled primarily during 2017. Most of these populations are in the Doe River (19), Roan Creek (8), and Beaverdam Creek (9) watersheds.

Little Jacob Creek brook trout enhancement: The Little Jacob Creek brook trout population in Sullivan County (established in 2000) was electrofished during the summer and fall of 2016 to remove sympatric rainbow trout upstream from a cascade at 689 m elevation (2,260’). This will convert a 1.6-km reach of this stream to an allopatric, native brook trout population. Overall, about 400 rainbow trout were removed and nearly 50 brook trout now occupy this area. Another electrofishing pass upstream of the barrier will be made in 2017 to remove any remaining rainbow trout and to assess brook trout abundance. Rainbow trout may also be removed in the reach between the cascade and the road crossing culvert 290 m downstream, followed by translocation of some brook trout from upstream of the cascade to that area.

Norris tailwater: The mean electrofishing catch rate for trout within the PLR (356-508 mm) exceeded 80 fish/h in 2014 (there was no 2015 sample) and remained at 80 fish/h in 2016. The current Norris tailwater management plan (2014-2019) provides a mean PLR catch rate objective of 28 fish/h and is certainly being achieved. The relative stock density of trout 356 mm (14 in.) and larger (RSD-14) has increased from 12 (2009) to over 50 and indicates that trout population size structures have been shifted toward larger fish and maintained, as CPUE for trout ≥178 mm has been relatively stable (150-200 fish/h) and annual stocking rates have been relatively consistent. An RSD-14 value of 50 indicates that 50% of all stock-size trout—those at least 254 mm (10 in.) in length—are 356 mm (14 in.) or larger. No brook trout were stocked in 2015 and none were collected during the 2016 sampling efforts.

Cherokee tailwater: Water temperatures in the Cherokee tailwater were warmer during 2016 than in any year since monitoring began (2005 near the dam and 2003 at Blue Spring). Minimum daily water temperature near the dam exceeded 21° C for 55 consecutive days beginning on 1 September—the longest period with no coldwater habitat observed since 2005. Mean maximum water temperature at the Blue Spring site (13 km below Cherokee Dam) during 15 September through 15 October was 25.0° C—1.3° warmer than the next-highest mean for the same one-month period since 2003. There were also substantially more days at this site in 2016 with maximum temperature >24° C (40) and >25° C (20) than were recorded during any previous monitoring year. Minimum daily water temperature at Blue Spring reached 21° C on 30 August and remained above 21° C for 53 consecutive days (no coldwater habitat). Water temperatures in the Cherokee tailwater typically return to trout-tolerant levels (<21° C) by mid- to late October, although they did not do so until late October in 2016. Consequently, only 5 trout (3 rainbows, 2 browns) were captured during monitoring efforts in October 2016, yielding the lowest overall mean catch rate (2.5 fish/h ≥178 mm) since 2003 (1.0 fish/h).

Wilbur tailwater: The 2016 mean catch rate for all trout in the ≥178 mm size class increased slightly (to 210 fish/h) since 2015 and has remained above 200 fish/h during the past three years, primarily as a result of the increasing wild brown trout population in the half of the tailwater. The new management plan (2015-2020) prescribes developing a wild brown trout fishery throughout the tailwater with a mean catch rate of 40 fish/h (≥178 mm) for the lower portion. The 2016 brown trout catch rate for that area (36 fish/h) approached that objective. A 2016 TWRA creel survey asked 273 Wilbur tailwater anglers if they fished in the Quality Zone (QZ) during the past three years and if so, whether or not they caught more large trout (≥356 mm) there than elsewhere in the tailwater. Anglers who fished the QZ were asked if they were in favor of changing regulations there to a protected “slot limit” (e.g., 356-457 mm or 14-18 in.) with no bait restrictions and a 7-fish creel (with one >457 mm). Ninety anglers (33%) indicated that they had fished in the QZ since 2013, with slightly less than half of those (44%) reporting that they also caught more large trout there. Even though a majority of QZ anglers did not experience a higher catch rate for larger trout, most (81%) did not support the proposed regulation change. This opinion differed little between those who caught more large fish in the QZ (83% unsupportive) and those who did not (80% unsupportive). Monitoring data provide no clear indication that the QZ regulations are enhancing abundance of larger trout there, although they do suggest a general increase in the abundance of trout ≥356 mm throughout the tailwater since 2005. Based on current angler opinions, however, ensuring that the QZ is actually providing anglers the opportunity to experience higher catch rates for larger trout may be relatively unimportant. Additional results of the 2016 angler survey will be provided in the 2017 Region IV Trout Fisheries Report.

Ft. Patrick Henry tailwater: The mean catch rate for all trout ≥178 mm decreased slightly (to 94 fish/h) in 2016, although the catch rate for larger trout (≥356 mm) increased to 67 fish/h—the highest catch rate for trout in this size class obtained since monitoring began in 2002. Additionally, more rainbow trout ≥508 mm (20 in.) were captured in 2016 (16) than in any earlier sample (maximum was 8 in 2015). The abundance of trout ≥457 mm had been depressed during 2004-2010 (0 to 4 fish/h), but has improved substantially since then, averaging over 17 fish/h (31 fish/h during the past two years). The Ft. Patrick Henry tailwater—like the Boone tailwater upstream—produces extremely well-conditioned trout with relative weights (W_r), often well in excess of 100.

Boone tailwater: The mean electrofishing catch rate for all trout ≥178 mm in the Boone tailwater sample increased to 91 fish/h in 2016, reversing a general downward trend since 2009 and exceeding the long-term average of 74 fish/h. The catch rate for fish ≥356 mm also improved to 38 fish/h in 2016, which exceeds the long-term average of 30 fish/h. Interestingly, the 2016 catch rate for trout ≥457 mm decreased to 6 fish/h, which was—uncharacteristically—at the lower end of the range for Region IV tailwaters in 2016 (0-28 fish/h). Repairs at Boone Dam continued in 2016 and require the drawdown of Boone Lake to an elevation of 412 m (1,352')—3.1 m (10') below winter pool (possibly until 2022). TVA water quality monitoring data from the tailwater near the dam indicated no significant water temperature increases. Dissolved oxygen (DO) often fell below 6 mg/l (TDEC's criterion for trout waters) during May-July 2016 (occasionally for over 12 h) and on most days in October, but always remained above 3.0 mg/l. The 2017 monitoring efforts should help determine if these lower DO levels (likely related to drought conditions and reduced flows during summer and fall 2016) had any chronic effect on the Boone tailwater trout fishery.

South Holston tailwater: The mean catch rate for trout ≥178 mm (total) was slightly below 300 fish/h for only the second time since 2009, although the long-term average of 250 fish/h continues to be the highest overall catch rate for any Region IV trout tailwater. Brown trout in the 229-330 mm (9-13 in.) size classes decreased to 59% of the total sample for that species in 2016, an improvement from the peak average of 69% during 2011-2015. There was also better recruitment into the size classes approaching the PLR (356 and 381 mm) than in any year since 2006, as well as into the PLR. However, only 21 trout within the PLR (406-559 mm) were captured in 2016 (11 fish/h). The average PLR catch rate during 2004-2009 was twice as high (24 fish/h). Relative stock density for all trout ≥406 mm (RSD-16) —based on a stock size of 254 mm—improved from 3 in 2015 to 6 in 2016, but averaged 16 prior to any influence from the PLR regulations (1997, 1999-2000). Following establishment of the PLR, RSD-16 averaged 19 during 2004-2007, but has declined since then as total CPUE has generally reached and exceeded 250-300 fish/h (≥178 mm). Current trout population size structures, therefore, do not indicate a shift toward larger fish—one of the original intents of the PRL—as the result of density-dependent limits on growth, condition, and recruitment. Harvesting fish below the lower boundary of a PLR is necessary to prevent overcrowding and without sufficient exploitation, stockpiling can occur rendering the regulation ineffective. Angler catch rates for brown trout (~6 fish/trip) seem high enough that harvest could help control population size, but the harvest rate for brown trout is extremely low (3.5%). Therefore, other management actions that can decrease brown trout recruitment when necessary, such as altering dam operations (i.e., to produce high flows) could help maintain more stable trout populations with larger adults through relaxed intraspecific competition.

TABLE OF CONTENTS

1. INTRODUCTION

The Tennessee Wildlife Resources Agency (TWRA) manages trout fisheries in a variety of waters in Tennessee including streams, tailwater rivers, and reservoirs. Together, these fisheries provide a popular and important set of angling opportunities. A recent nationwide analysis of trout fishing by the U.S. Fish and Wildlife Service (USFWS; Harris 2010) estimated that there were 95,000 Tennessee trout anglers (age 16 or older) who fished 989,000 days in 2006. A subsequent statewide survey by the University of Tennessee in 2012 indicated that 15% of Tennessee's anglers fished for trout, making an average of 15 trips (averaging 4 hours) that year (Schexnayder et al. 2014). Most of those anglers targeted trout in hatchery-supported fisheries. Accordingly, while Agency management emphasizes habitat preservation and maintenance of wild stocks where they occur, artificially propagated trout are essential for managing substantial portions of the coldwater resource. In 2016, 563,000 pounds of trout (~2.1 million fish) produced or grown primarily at five state (TWRA), one municipal (Gatlinburg), and two federal (USFWS) facilities were stocked to manage Tennessee's hatchery-supported fisheries (Roddy 2017). Nearly half (254,000 pounds) was stocked in Region IV waters, with 35% of those trout used to support tailwater fisheries and another 25% used to provide reservoir fisheries.

The Blue Ridge physiographic province of eastern Tennessee contains about 1,000 km (621 mi) of coldwater streams inhabited by wild (self-sustaining) populations of rainbow trout *Oncorhynchus mykiss*, brook trout *Salvelinus fontinalis*, and brown trout *Salmo trutta*. Wild trout occur in 9 of Region IV's 21 counties (primarily those that border North Carolina; Figure 1-1). The Tennessee portion of Great Smoky Mountains National Park (GSMNP) in Cocke, Sevier, and Blount counties contains another 395 km (245 mi) of wild trout streams. Most of Region IV's wild trout resource outside GSMNP is located within the U.S. Forest Service's (USFS) 253,000-hectare (625,000-acre) Cherokee National Forest (CNF). However, a substantial portion (~30%) occurs on privately owned lands and includes some of the State's best wild trout streams.

Rainbow trout, native to Pacific-drainage streams of the western U.S., and brown trout, native to Europe, were widely introduced into coldwater habitats during the past century and have become naturalized in many Tennessee streams. Brook trout are Tennessee's only native salmonid and once occurred at elevations as low as 490 m (1,600 ft.) in some streams (King 1937). They currently occupy about 226 km (141 mi) in 111 streams (and one small lake), or about 24% of the stream length supporting wild trout outside GSMNP. Brook trout occur allopatrically (no other trout species are present) in 42 streams totaling 72 km (45 mi.), representing 32% of the brook trout resource. Another 13 streams have waterfalls or man-made barriers that maintain brook trout allopatry in most of the 37 km (23 mi.) of habitat they provide.

Wild trout populations reflect the quality and stability of the aquatic systems they inhabit, as well as associated terrestrial systems. TWRA recognizes the ecological importance of Tennessee's wild trout resources (particularly native, southern Appalachian brook trout), their value to anglers, and the special management opportunities they offer. The Agency's current statewide trout management plan (Fiss and Habera 2006) features management goals and strategies designed to conserve wild trout and their habitat while providing a variety of angling experiences.

Many streams with unregulated flows can support trout fisheries, but are limited by marginal summer habitat or levels of natural production insufficient to meet existing fishing pressure. TWRA provides or supplements trout fisheries in 34 such streams in Region IV by annually stocking hatchery-produced (adult) rainbow trout. Some stocked steams (e.g., Beaverdam Creek, Doe Creek, Laurel Fork, and Doe River) do support excellent wild trout populations as well, but the moderate stocking rates employed are considered to pose no population-level problems for the resident fish (Meyer et al. 2012).

Cold, hypolimnetic releases from five Tennessee Valley Authority (TVA) dams in Region IV (Norris, Ft. Patrick Henry, South Holston, Wilbur, and Boone) also support year-round trout fisheries in the tailwaters downstream (Figure 1-1). The habitat and food resources that characterize these tailwaters provide for higher carrying capacities and allow trout to grow larger than they normally do in other streams. Tailwaters are typically stocked with fingerlings (~102 mm) in the early spring and adult fish (229-305 mm) throughout the summer. Stocked adult trout supplement the catch during peak angling season and by fall, fingerlings have begun to enter these fisheries. Recruitment of natural reproduction (mostly by brown trout) contributes substantially to the fisheries in the South Holston and Wilbur (Watauga River) tailwaters. The Holston River below Cherokee Reservoir (Figure 1-1) also supports a tailwater trout fishery, although high water temperatures (>21° C) during late summer and early fall limit survival. No fingerlings are stocked there, as few would survive the thermal bottleneck to recruit to the fishery.

Reservoirs that stratify during summer months but have habitat suitable for trout below depths normally occupied by warmwater species are termed ‘two-story’ fisheries. These reservoirs must have a zone with water below 21° C and a minimum dissolved oxygen concentration of 3.0 mg/L (Wilkins et al. 1967). Seven two-story reservoirs in Region IV (Calderwood, Chilhowee, Tellico, Ft. Patrick Henry, South Holston, Wilbur, and Watauga) have such zones and create an additional trout resource (Figure 1-1). These reservoirs are stocked with adult-size trout (typically rainbows) during the late fall and winter when reservoir temperatures are uniformly cold and piscivorous warmwater predators are less active. Watauga and South Holston reservoirs are annually stocked with lake trout *Salvelinus namaycush* and currently provide excellent fisheries for this species. Chilhowee Reservoir also occasionally receives lake trout.

One of TWRA’s core functions identified in its Strategic Plan (TWRA 2014) is outdoor recreation, and a primary objective is to maintain or improve programs that promote high user satisfaction for hunters, anglers, and boaters. Tennessee’s trout anglers recently expressed a high level of satisfaction (89%) with the Agency’s management of the State’s trout fisheries (Schexnayder et al. 2014). Maintaining this level of satisfaction will require effective management of existing resources and opportunities—as well as development of new ones. TWRA’s statewide trout management plan (Fiss and Habera 2006) is currently being updated for the next 10 years to address how these goals can be accomplished. This new plan will include management guidelines for Tennessee's native, southern Appalachian brook trout, particularly in light of new genetics data being acquired for all brook trout populations. Acquisition of trout population status and dynamics data from streams and tailwaters through standardized stream survey techniques (e.g., abundance trends and size structures, etc.) will also continue to be an important strategy for managing these fisheries.

Region IV Trout Streams, Tailwaters, and Reservoirs

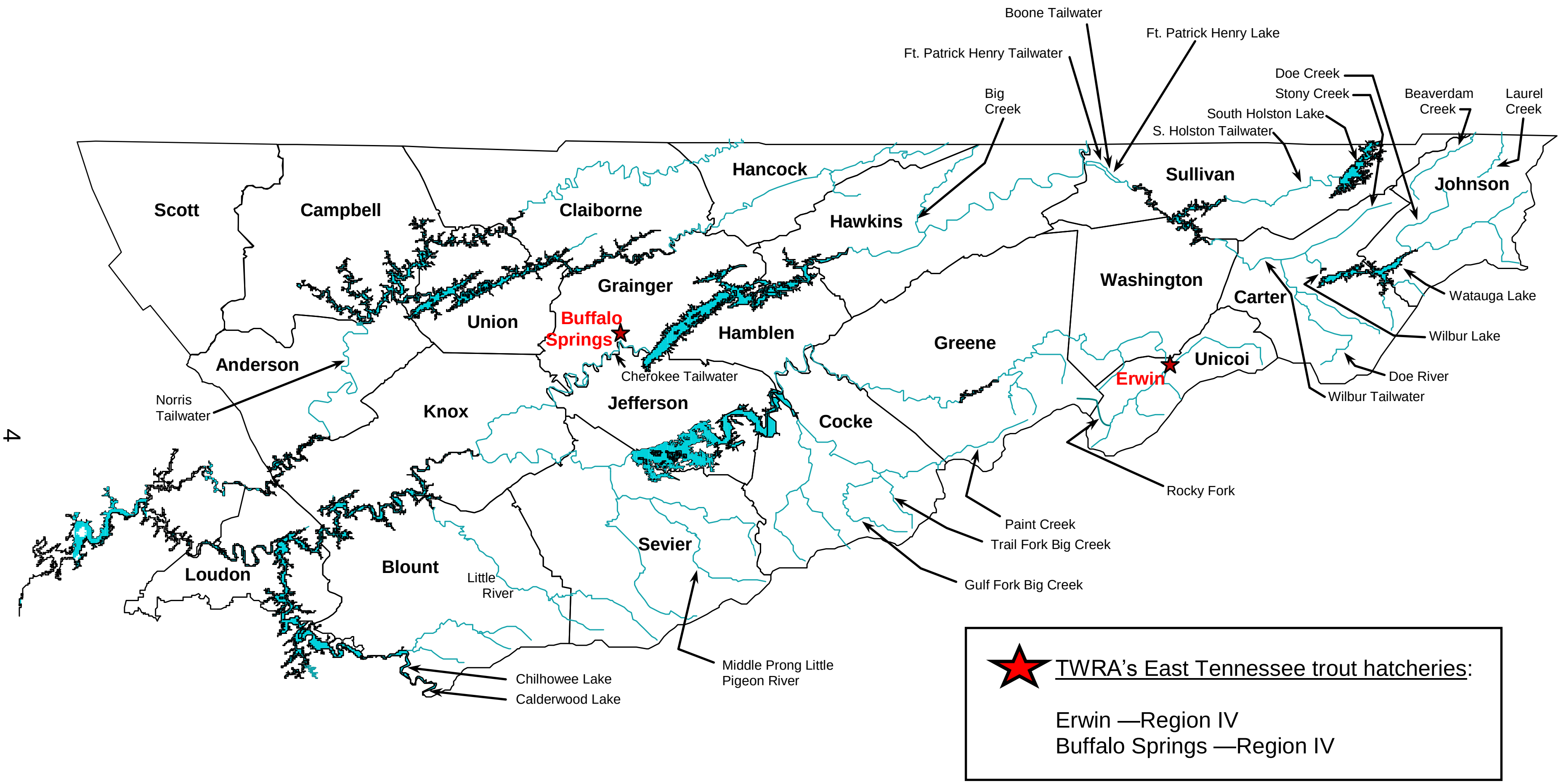


Figure 1-1. Locations of selected Region IV trout fisheries managed by TWRA.

2. WILD TROUT STREAM ACCOUNTS

Ten trout streams in the Nolichucky, Watauga, and South Fork Holston river watersheds were quantitatively sampled during the 2016 field season (June - October). The 14 stations sampled on these streams were located in Greene, Washington, Unicoi, Carter, and Johnson counties. These stations were located on privately-owned and State-owned lands, as well as the CNF. Brook trout DNA samples (fin clips) were obtained from 45 populations (including all those in the French Broad and Nolichucky basins) to update and broaden existing genetics information based on allozyme electrophoresis data from the 1990s. Additionally, assistance was provided with sampling efforts at the monitoring stations on North River and Bald River in Monroe County (Region III). Region III personnel also collected DNA samples from all brook trout populations in the Little Tennessee River basin (6 populations) during 2016.

Drought conditions prevailed in east Tennessee during 2016, particularly during spring and fall. Rainfall for the Tennessee Valley above Chattanooga (39.90 in.) was 20% below average for the year, but 35% below average for March-May and 50% below average for September-November (A. Ramsey, TVA, personal communication). This led, by the end of November, to most of east Tennessee (Region 4) having a "severe" or "extreme" drought classification with the United States Drought Monitor (http://droughtmonitor.unl.edu/Home.aspx). Consequently, stream flows during 2016 were some of the lowest observed in several years.

Individual accounts for all wild trout streams sampled during 2016 are provided below. A list of all streams sampled quantitatively during 1991-2016 is provided in Appendix A.

2.1 SAMPLING METHODS

Wild trout stream sampling was conducted with battery-powered backpack electrofishing units employing inverters to produce AC outputs. Output voltages were 125-600 VAC, depending upon water conductivity. All quantitative (three-pass depletion) sampling followed TWRA's standard protocols (TWRA 1998). Three-pass depletion sampling provides accurate trout abundance estimates in typical southern Appalachian streams (Habera et al. 2010), is endorsed by the Southern Division, American Fisheries Society's (SDAFS) Trout Committee, and is widely used by other state and federal agencies in the region. Stocked rainbow trout, distinguishable by dull coloration, eroded fins, atypical body proportions, and large size (usually >229 mm), were noted on data sheets but were not included in any analyses. A list of the common and scientific names of all fish collected during 2016 sampling efforts in wild trout streams is provided in Table 2-1.

Removal-depletion data were analyzed with *MicroFish 3.0* for Windows (http://microfish.org/) developed by Jack Van Deventer in cooperation with the SDAFS Trout Committee. Trout ≤90 mm in length were analyzed separately from those >90 mm. Trout in the smaller size group tend to have lower catchabilities (Lohr and West 1992; Thompson and Rahel 1996; Peterson et al. 2004; Habera et al. 2010), making separate analysis necessary to avoid bias. These two groups also roughly correspond to young-of-the-year (YOY or age-0) and adults.

Table 2-1. Common and scientific names of fishes collected during 2016 quantitative trout stream surveys[1].

Common Name	Scientific Name
Minnows	Cyprinidae
Central stoneroller	*Campostoma anomalum*
Rosyside dace	*Clinostomus funduloides*
Warpaint shiner	*Luxilus coccogenis*
River chub	*Nocomis micropogon*
Saffron shiner	*Notropis rubricroceus*
Tennessee shiner	*N. leuciodus*
Blacknose dace	*Rhinichthys atratulus*
Longnose dace	*R. cataractae*
Creek chub	*Semotilus atromaculatus*
Suckers	Catostomidae
White sucker	*Catostomus commersonii*
Northern hog sucker	*Hypentelium nigricans*
Black redhorse	*Moxostoma duquesnei*
Trouts	Salmonidae
Rainbow trout	*Oncorhynchus mykiss*
Brown trout	*Salmo trutta*
Brook trout	*Salvelinus fontinalis*
Sculpins	Cottidae
Mottled sculpin	*Cottus bairdii*
Sunfishes	Centrarchidae
Green sunfish	*Lepomis cyanellus*
Bluegill	*L. macrochirus*
Largemouth bass	*Micropterus salmoides*
Perches	Percidae
Greenside darter	*Etheostoma blennioides*
Greenfin darter	*E. chlorobranchium*
Fantail darter	*E. flabellare*
Snubnose darter	*E. simoterum*
Swannanoa darter	*E. swannanoa*

[1]Nomenclature follows Page et al. (2013).
.

2.2 LONG-TERM MONITORING STREAMS

Long-term monitoring stations established on Rocky Fork, Left Prong Hampton Creek, Right Prong of Middle Branch, Stony Creek, Doe Creek, Laurel Creek, and Beaverdam Creek were sampled during 2016. Some of the more important information obtained from the long-term monitoring efforts includes documentation of annual variability in wild trout abundance, estimates of annual mortality (total), and evaluation of the effects of droughts, floods, and other events. National Park Service (NPS), USFS, U.S. Fish and Wildlife Service, and Trout Unlimited (TU) personnel helped sample several of these streams. Such cooperation permits larger projects to be undertaken and serves as an important means for communication among the agencies managing wild trout populations and habitat in Tennessee.

2.2.1 Rocky Fork

Study Area

Rocky Fork is a tributary of South Indian Creek in the Nolichucky River basin and is located within Greene and Unicoi counties. The watershed is mountainous and forested, with some recent (although limited) logging activity. The lower portion of the stream is contained within the 825-ha (2,036-acre) Rocky Fork State Park. Planning continues for development of the Park's access roads, trail system, welcome center, picnic shelters, and campground. The remaining 3,000 ha (7,600 acres) of the formerly privately-owned Rocky Fork tract were added to the CNF. The middle and lower reaches of Rocky Fork support an excellent wild rainbow trout population. The upper portion of (above 2,890') has both brook and rainbow trout. Three tributaries (Blockstand Creek, Broad Branch, and Fort Davie Creek) also contain brook trout, but all four populations have been substantially introgressed with hatchery ("northern") genes (Strange and Habera 1997) from numerous stockings that occurred into the 1980s.

Shields (1950) noted that rainbow trout growth and production in Rocky Fork was quite good and described the portion from Fort Davie Creek downstream (12.9 km) as carrying a large crop of fish. Despite the Rocky Fork's capacity for wild trout production, it was intensively managed as a put-and-take fishery with hatchery-produced rainbow and brook trout for many years (Bivens et al. 1998). That strategy was changed in 1988 to feature wild trout by discontinuing stocking except in the 1.7-km segment upstream of the confluence with South Indian Creek. The annual stocking rate for that portion of Rocky Fork has averaged ~4,800 adult rainbow trout for the past three years. A three-fish creel limit was also added to the 229-mm minimum length limit and single-hook, artificial-lures only regulations already in place. Regulations were changed again in 1991 to focus harvest on rainbow trout by removing their size limit and raising the creel limit to seven fish (to include only three brook trout). Subsequently, as more data from Rocky Fork and other wild trout streams have become available, regulations were changed again in 2013 to make them more biologically relevant. Accordingly, the creel limit was increased to five fish and minimum size limits were removed (including the 152-mm statewide size limit for brook trout).

TWRA qualitatively sampled Rocky Fork in the 1980s (Bivens 1989; Bivens and Williams 1990), then began the current quantitative sampling program in 1991 with the establishment of two long-term monitoring stations (Figure 2-1). These stations have been sampled annually since 1991. Site location and effort details, along with habitat and water quality information are summarized in Table 2-2.

Results and Discussion

Catch data and abundance estimates for trout and all other species sampled at the Rocky Fork stations in 2016 are given in Table 2-3. Total trout abundance estimates for Station 1 decreased relative to 2015 (Figure 2-2), with biomass falling below the long-term average (about 42 kg/ha). The total trout density estimate at Station 2 decreased somewhat relative to 2015, primarily as the result of decreased abundance of age-0 brook trout (Figure 2-2). However, total trout biomass at Station 2 (39 kg/ha) increased to the highest level observed since 2011, although it still remained below the long-term average (45 kg/ha; Figure 2-2). A more detailed discussion of the relative abundance of brook and rainbow trout at Station 2 is provided in Section 2.3.2.

The 2016 rainbow trout cohort at Station 1 (age-0 fish, <100 mm; Figure 2-3) was about above average in terms of abundance. Seven fish ≥203 mm were captured in 2015 (the most since 1993), but fewer were present in 2016 (5; Figure 2-3)—probably as the result of low stream flows associated with the drought conditions that prevailed during 2016. Size distributions for rainbow and brook trout at Station 2 are provided and discussed in Section 2.3.2.

Management Recommendations

Rocky Fork provides a good fishery for wild rainbow and brook trout which future management should emphasize. Because the stream is relatively long (>13 km) and access is limited to foot travel, it provides an ideal setting for anglers seeking a more solitary experience. Monitoring of the Rocky Fork stations should be conducted annually to maintain the continuity of this important wild trout database and document any effects related to development of the road/trail system in the new State Park and upstream areas in the CNF. DNA samples were obtained from all four brook trout populations in the Rocky Fork watershed in 2016 (see Section 2.4).

Rocky Fork Monitoring Stations

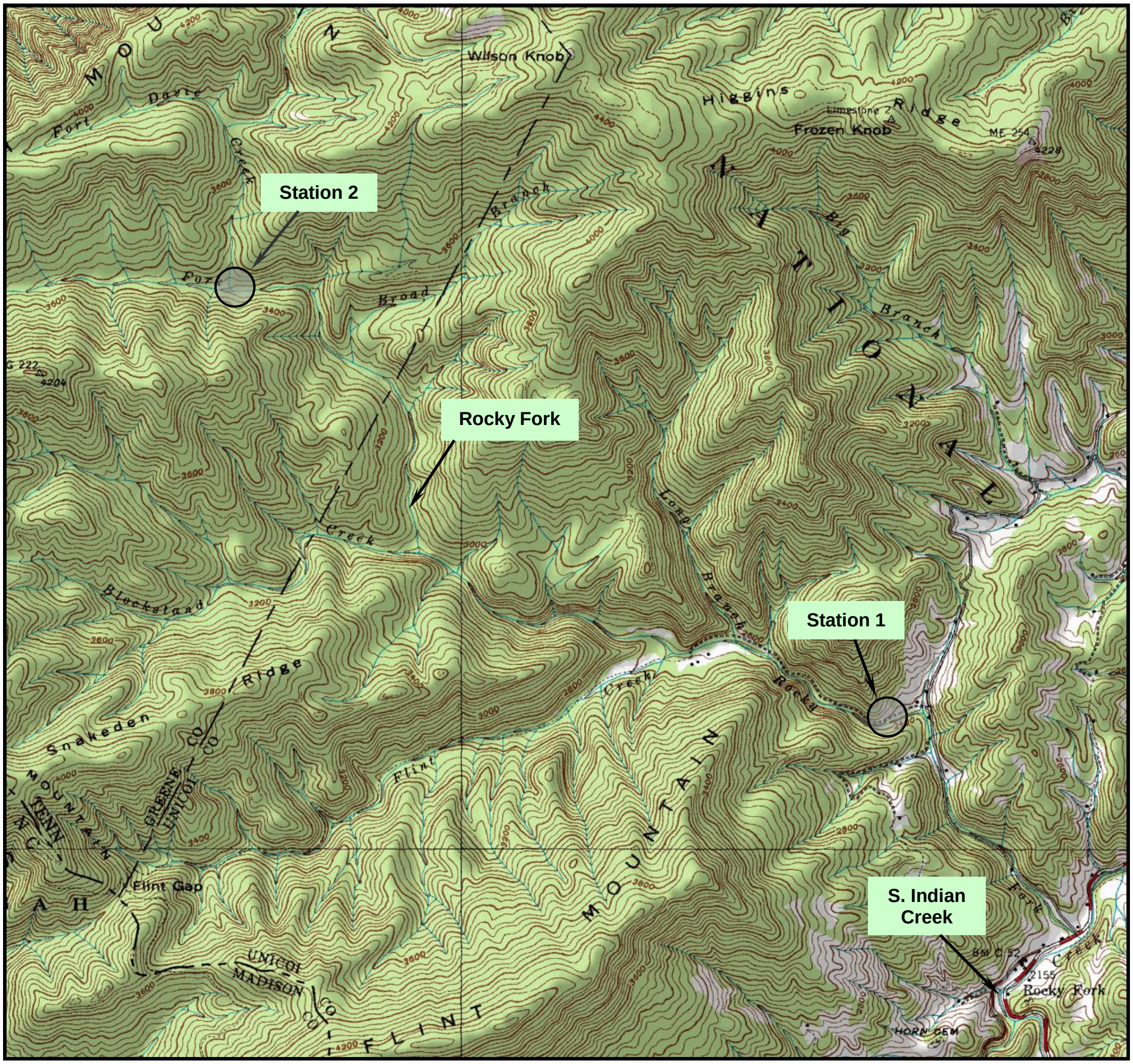


Figure 2-1. Locations of the two long-term monitoring stations on Rocky Fork.

Table 2-2.   Site and sampling information for Rocky Fork in 2016.

Location	**Station 1**		**Station 2**	
Site code	420162601		420162602	
Sample date	20 September		20 September	
Watershed	Nolichucky River		Nolichucky River	
County	Unicoi		Greene	
Quadrangle	Flag Pond 190 SE		Flag Pond 190 SE	
Lat-Long	36.04801 N, -82.55889 W		36.06758 N, -82.59608 W	
Reach number	06010108		06010108	
Elevation (ft)	2,360		3,230	
Stream order	4		3	
Land ownership	State of TN (TDEC)		USFS	
Fishing access	Good		Limited	
Description	Begins ~100 m upstream of the blue gate.		Ends ~10 m upstream of confl. with Ft. Davie Ck.	
Effort				
Station length (m)	130		100	
Sample area (m²)	806		320	
Personnel	13		4	
Electrofishing units	2		1	
Voltage (AC)	450		600	
Removal passes	3		3	
Habitat				
Mean width (m)	6.2		3.2	
Maximum depth (cm)	93		70	
Canopy cover (%)	90		95	
Aquatic vegetation	scarce		scarce	
Estimated % of site in pools	64		48	
Estimated % of site in riffles	36		52	
Habitat assessment score	160 (optimal)		164 (optimal)	
Substrate Composition	**Pool (%)**	**Riffle (%)**	**Pool (%)**	**Riffle (%)**
Silt	5		5	
Sand	10	5	10	5
Gravel	20	15	25	35
Rubble	30	35	30	40
Boulder	20	40	25	20
Bedrock	15	5	5	
Water Quality				
Flow (cfs; visual)	2.6; low		0.9; low	
Temperature (C)	17.5		16.7	
pH	6.9		6.7	
Conductivity (µS/cm)	24		14	
Dissolved oxygen (mg/L)	N/M		N/M	
Alkalinity (mg/L $CaCO_3$)	20		15	

Table 2-3 Fish population abundance estimates (with 95% confidence limits) for the monitoring stations on Rocky Fork sampled 20 September 2016.

		Population Size			Est.	Mean	Biomass (kg/ha)			Density (fish/ha)		
Species	Total Catch	Est.	Lower C.L.	Upper C.L.	Weight (g)	Fish Wt. (g)	Est.	Lower C.L.	Upper C.L.	Est.	Lower C.L.	Upper C.L.
Station 1												
RBT ≤90 mm	75	86	75	100	217	2.5	2.69	2.33	3.10	1,067	931	1,241
RBT >90 mm	102	106	102	112	2,697	25.4	33.46	32.14	35.30	1,315	1,266	1,390
BKT >90 mm	2	2	2	15	24	11.8	0.29	0.29	2.20	25	25	186
Longnose dace	14	14	14	14	189	13.5	2.34	2.34	2.34	174	174	174
Blacknose dace	93	99	93	107	384	3.9	4.77	4.50	5.18	1,228	1,154	1,328
Mottled sculpin	87	100	87	116	700	7.0	8.68	7.56	10.07	1,241	1,079	1,439
Totals	**373**	**407**	**373**	**464**	**4,211**		**52.23**	**49.16**	**58.19**	**5,050**	**4,629**	**5,758**
Station 2												
RBT ≤90 mm	9	9	9	10	30	3.3	0.94	0.93	1.03	281	281	313
RBT >90 mm	17	17	17	18	376	22.1	11.75	11.74	12.43	531	531	563
BKT ≤90 mm	14	14	14	14	40	2.9	1.25	1.27	1.27	438	438	438
BKT >90 mm	45	46	45	49	816	17.7	25.49	24.89	27.10	1,438	1,406	1,531
Totals	**85**	**86**	**85**	**91**	**1,262**		**39.43**	**38.83**	**41.83**	**2,688**	**2,656**	**2,845**

Note: RBT = rainbow trout and BKT = brook trout.

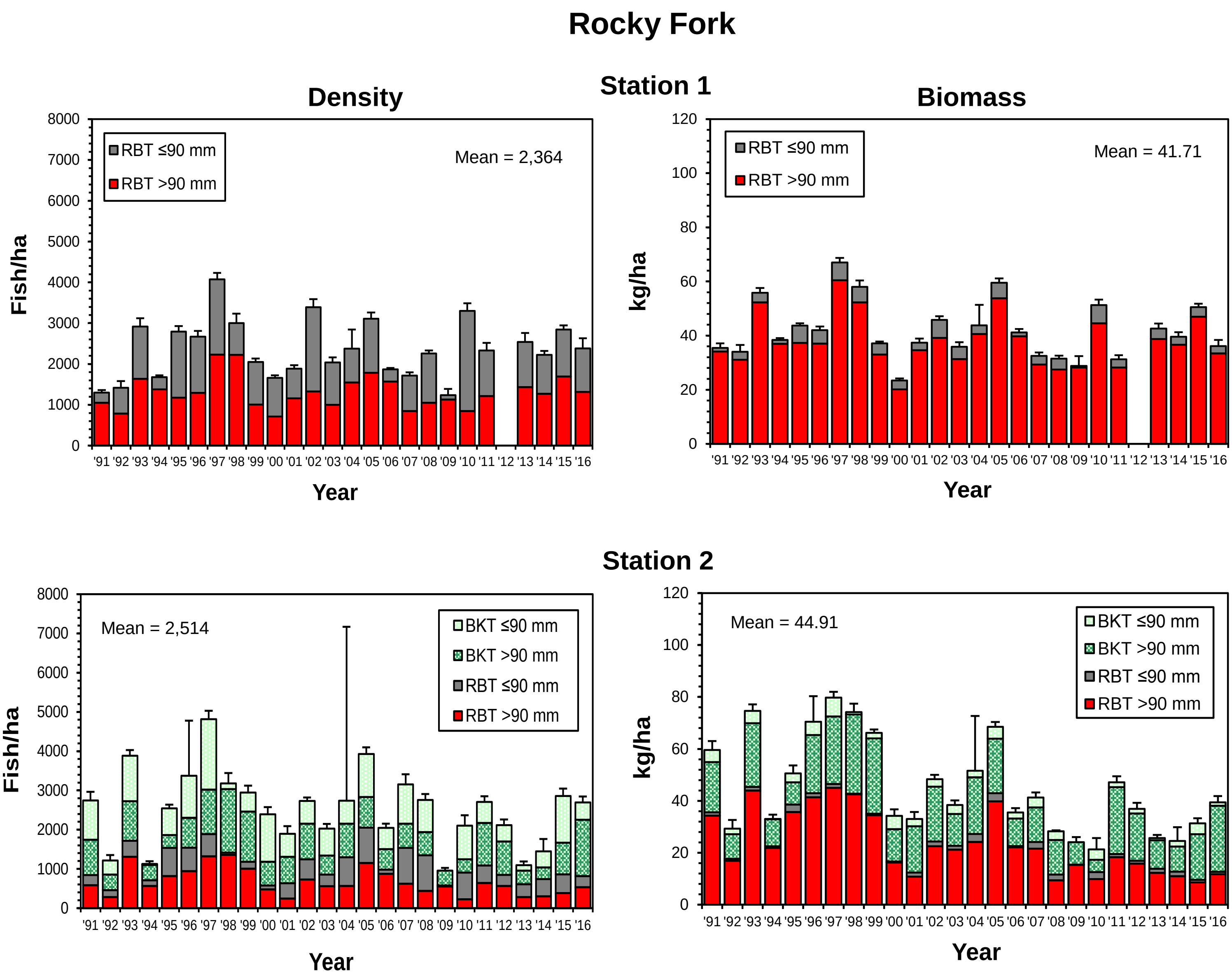


Figure 2-2. Trout abundance estimates for the Rocky Fork monitoring stations. RBT = rainbow trout and BKT = brook trout. Bars indicate upper 95% confidence limits (total).

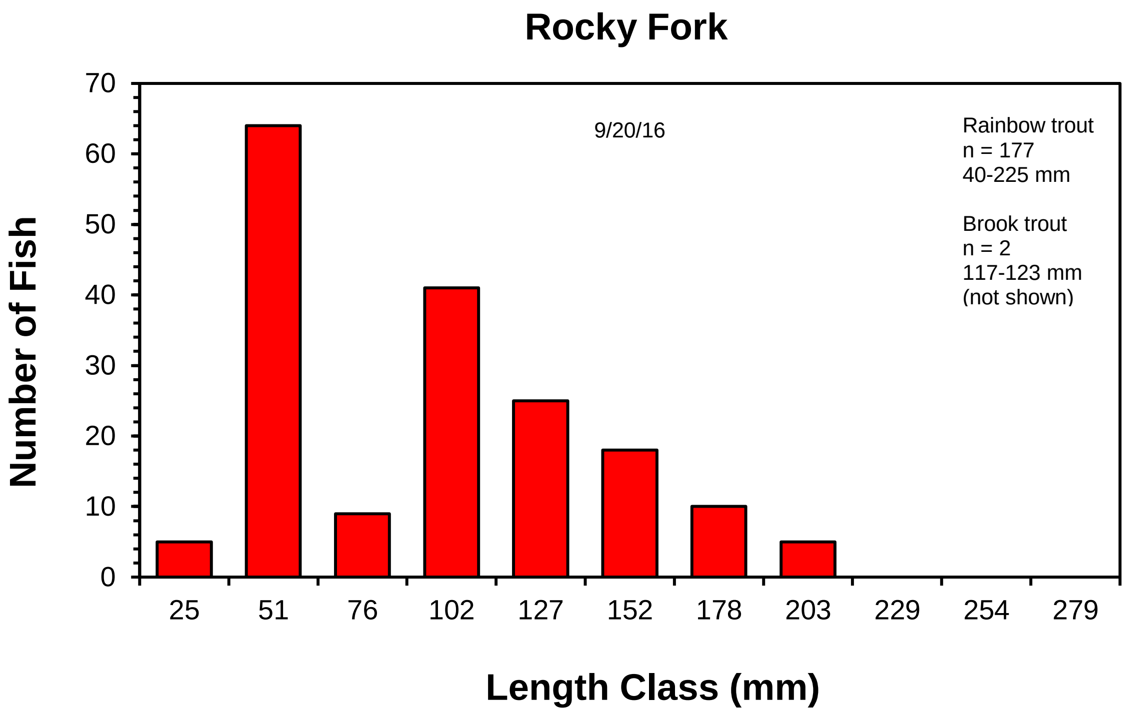


Figure 2-3. Length frequency distribution for rainbow trout from the 2016 Rocky Fork sample at Station 1 (Station 2 data are provided in Section 2.3.2).

2.2.2 Left Prong Hampton Creek

Study Area

Left Prong of Hampton Creek flows through the 281-ha (693-acre) Hampton Creek Cove State Natural Area in Carter County and is a tributary to the Doe and Watauga rivers. A substantial portion of this area remains in use as livestock pasture, although fencing prevents livestock access to the stream. Rhododendron (*Rhododendron* spp.), which often dominates the riparian vegetation of other wild trout streams, is absent along Left Prong. Historically, the stream would have been inhabited by brook trout, but TWRA found only an abundant wild rainbow trout population during a 1988 survey (Bivens 1989). Subsequently, brook trout were successfully restored to the upper 2 km of Left Prong during 1999-2000 through a cooperative, multi-agency effort involving TWRA, Overmountain Chapter TU, USFS, NPS, Tennessee Department of Environment and Conservation (TDEC), and the Southern Appalachian Highlands Conservancy. The ineffective modified-culvert fish barrier at the downstream end of the brook trout re-establishment zone was replaced in 2007 with a 2.7 m (9 ft.) waterfall (Habera and Carter 2008; Habera et al. 2008). Maintenance on this structure was completed in 2015 by Overmountain TU and TWRA. Left Prong was placed under special regulations (three-fish creel limit for brook trout; single-hook, artificial lures only) during establishment the new brook trout population. It is now managed under TWRA's special wild trout regulations, which include a 5-fish creel limit and no minimum size limit.

A long-term monitoring station (Station 1) was established on lower Left Prong in 1994 (Figure 2-4). Stations 2 and 3 were added in 1996 to better represent the upper portion of the stream, which has a higher gradient and more canopy cover, but have also served to monitor the brook trout population since 2000. All three stations have been sampled annually since 1996. Sample site location and effort details, along with habitat and water quality information are summarized in Table 2-4.

Results and Discussion

Catch data and abundance estimates for trout and all other species sampled at the three stations on Left Prong in 2016 are given in Table 2-5. The 2016 density estimate for rainbow trout >90 mm (i.e., adults) improved again somewhat from its low in 2014, but remains well below the levels observed for most years prior to 2010 (Figure 2-5). Total rainbow trout density at Station 1 declined relative to 2015 because of the much smaller 2016 cohort (fish ≤90 mm, Figure 2-5). The total rainbow trout biomass estimate at Station 1 also decreased relative to 2015 (Figure 2-5) and remains about 40% below the long-term average (58.07 kg/ha; Figure 2-5).

Previously (1990s), biomass estimates at Station 1 averaged nearly 100 kg/ha and were among the highest obtained for wild rainbow trout anywhere in Tennessee. However, biomass has generally declined since 2000 (Figure 2-5). This was likely in response to the various droughts that prevailed during that time, although the trend reversed briefly during 2003-2005 with more normal stream flows. Winter floods in this watershed (particularly in 1998) have also substantially reduced pool habitat at this site (e.g., by partial or complete filling) and the 2016 habitat assessment documented a further decline. Roghair et al. (2002) and Carline and McCullough (2003) found that flooding in trout streams caused substantial substrate movement which decreased pool lengths, surface areas, and depths. Consequently, unless pool quality improves, it is unlikely that this site will ever be capable of supporting the trout biomass it once did. Pool depth and quality are correlated with trout abundance (Lewis 1969; Bowlby and Roff 1986), and pools are important trout habitat features (Matthews et al. 1994; Anglin and Grossman 2013; Davis and Wagner 2016), particularly during low flows (Elliott 2000; Sotiropoulos et al. 2006) and for adult brook trout (Johnson and Dropkin 1996).

Brook trout abundance estimates at Station 2 decreased somewhat compared to the 2015 sample, while there were corresponding increases at Station 3 (Figure 2-5). Brook trout density estimates at both stations were near the corresponding long-term averages in 2016; however, biomass estimates remain well below average. Altered pool habitat at Station 2 caused by the 1998 flood (as at Station 1) will likely prevent brook trout abundance from reaching the level previously attained by rainbow trout there (78 kg/ha). Sedimentation of the pools at Station 3 is also becoming increasingly evident and may be responsible for declining abundance there. No rainbows have been captured at these stations since construction of the new fish barrier in 2007, indicating that it is effectively preventing encroachment by rainbow trout from downstream.

The rainbow trout population size structure at Station 1 indicated a relatively abundant 2016 cohort, but continued limited recruitment to the adult size classes, particularly ≥178 mm (no fish; Figure 2-6). Poor recruitment to the larger size classes has been typical of the rainbow trout population at Station 1 during recent years. It is unlikely that the lack of larger fish is a result of harvest, as fishing pressure on this stream (particularly the rainbow trout zone) would be considered relatively light. Some brook trout are typically captured at Station 1, and are likely transients from upstream of the barrier. Six were captured in 2016, but only two were adults (108-158 mm), indicating little recruitment from the 13 age-0 brook trout present in 2015. It will be interesting to determine if a small brook trout population can eventually become established below the barrier, especially given the reduced level of rainbow trout biomass there now. Size structures for the brook trout populations at Stations 2 and 3 also indicated the presence of relatively abundant 2016 cohort (Figure 2-6), although this was not true of many brook trout populations sampled during 2016 as part of DNA collection efforts (Section 2.4). There was no recruitment into the larger brook trout size classes (≥178 mm) at Stations 2 and 3 in 2016 (no fish, Figure 2-6)—the first time that has occurred since monitoring began in 2000.

Management Recommendations

Upper Left Prong's brook trout population has made it one of Tennessee's premier brook trout fisheries. Since fully established in 2003, mean brook trout biomass for the upper station (79 kg/ha) has substantially exceeded the statewide average for other streams (about 21 kg/ha), and is comparable to the mean biomass for the previous rainbow trout population (81 kg/ha). Benjamin and Baxter (2010) found that nonnative salmonids (brook trout in Idaho streams) exhibited 1.7 times the biomass of the native species they replaced (cutthroat trout). This appears to be less evident in Left Prong, although brook trout biomass at Station 3 has averaged about 1.1 times higher than the previous mean rainbow trout biomass, even with drought conditions. Native southern Appalachian brook trout may better adapted to and more tolerant of drought conditions (common during the past decade) than are nonnative rainbow trout. Monitoring data from other streams such as Rocky Fork (Section 2.3.2) and Gentry Creek (Section 2.3.4) also indicate brook trout have greater drought tolerance compared to rainbows. Management of Left Prong should feature its brook trout fishery and development of this important database should continue through annual monitoring at all three sites.

Cook and Johnson (2016) evaluated post-stocking performance in Left Prong for two cohorts (2013 and 2014) of southern Appalachian brook trout fingerlings produced the Tellico brook trout hatchery and at the Tennessee Aquarium (re-circulating system). They found that the overall annual survival rate for these fish was lower in Left Prong (16.7%) than in Region 3's Sycamore Creek (34.7%) and for seven pooled wild brook trout populations from GSMNP (29.3%; Kulp 1994). A possible explanation for the lower survival of stocked fingerlings in Left Prong is that this stream's higher brook trout density reduced growth—and ultimately survival—of the stocked fish (Cook and Johnson 2016).

Left Prong is also part of the ongoing multi-agency Tennessee's Ecologically At-Risk Streams—Appalachian Mountains (TEARS-AM) project to collect baseline chemical, physical and biological data on stream sections with naturally reproducing brook trout populations within the CNF and GSMNP.   The project goal is to investigate global, regional and/or local influences on stream health such as climate change and atmospheric deposition of mercury. Food chain dynamics is being assessed by analyzing contaminant concentrations and stable isotopes of carbon and nitrogen in seven matrices: sediment, periphyton, emergent insects, crayfish, salamanders, eastern brook trout, and tetragnathid spiders.

Left Prong Hampton Creek Monitoring Stations

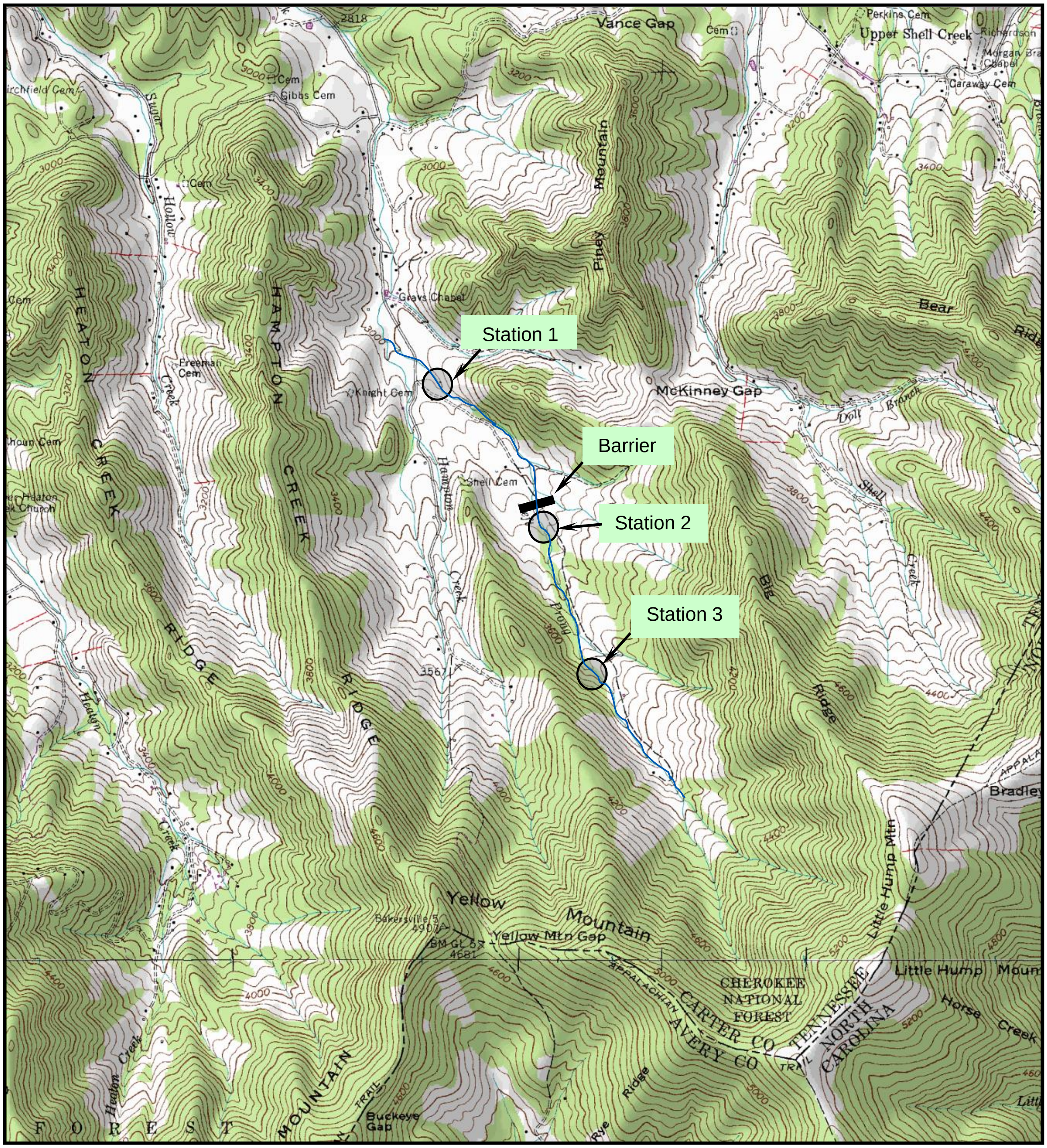


Figure 2-4. Locations of the three monitoring stations on Left Prong Hampton Creek.

Table 2-4. Site and sampling information for Left Prong Hampton Creek in 2016.

Location	**Station 1**		**Station 2**		**Station 3**	
Site code	420161801		420161802		420161803	
Sample date	14 July		14 July		14 July	
Watershed	Watauga River		Watauga River		Watauga River	
County	Carter		Carter		Carter	
Quadrangle	White Rocks Mtn. 208 NE		White Rocks Mtn. 208 NE		White Rocks Mtn. 208 NE	
Lat-Long	36.15132 N, -82.05324 W		36.14673 N, -82.04917 W		36.13811 N, -82.04473 W	
Reach number	06010103		06010103		06010103	
Elevation (ft)	3,080		3,240		3,560	
Stream order	2		2		2	
Land ownership	State (Hampton Cove)		State (Hampton Cove)		State (Hampton Cove)	
Fishing access	Good		Good		Good	
Description	Begins ~10 m upstream of the first foot bridge.		Begins 50 m upstream of the fish barrier.		Begins 880 m upstream of the upper end of Site 2.	
Effort						
Station length (m)	106		94		100	
Sample area (m²)	254		395		270	
Personnel	3		4		4	
Electrofishing units	1		1		1	
Voltage (AC)	350		400		500	
Removal passes	3		3		3	
Habitat						
Mean width (m)	2.4		4.2		2.7	
Maximum depth (cm)	40		N/M		N/M	
Canopy cover (%)	70		90		95	
Aquatic vegetation	scarce		scarce		scarce	
Estimated % of site in pools	26		45		N/M	
Estimated % of site in riffles	74		55		N/M	
Habitat assessment score	157 (suboptimal)		157 (suboptimal)		159 (suboptimal)	
Substrate Composition	**Pool (%)**	**Riffle (%)**				
Silt	15		5		25	
Sand	10	5	10	10	10	5
Gravel	35	40	40	25	20	30
Rubble	35	45	20	45	15	35
Boulder	5	10	25	20	25	25
Bedrock					5	5
Water Quality						
Flow (cfs; visual)	N/M; low		N/M; low		N/M; low	
Temperature (C)	19.0		18.2		16.1	
pH	7.0		7.0		6.9	
Conductivity (µS/cm)	36		33		N/M	
Dissolved oxygen (mg/L)	N/M		N/M		N/M	
Alkalinity (mg/L $CaCO_3$)	20		15		15	

Table 2-5. Fish population abundance estimates (with 95% confidence limits) for the monitoring stations on Left Prong Hampton Creek sampled 14 July 2016.

Species	Total Catch	Population Size Est.	Population Size Lower C.L.	Population Size Upper C.L.	Est. Weight (g)	Mean Fish Wt. (g)	Biomass (kg/ha) Est.	Biomass (kg/ha) Lower C.L.	Biomass (kg/ha) Upper C.L.	Density (fish/ha) Est.	Density (fish/ha) Lower C.L.	Density (fish/ha) Upper C.L.
Station 1												
RBT ≤90 mm	52	53	52	56	158	3	6.22	6.14	6.61	2,087	2,047	2,205
RBT >90 mm	19	19	19	19	415	21.8	16.33	16.33	16.33	748	748	748
BKT ≤90 mm	4	4	4	4	15	3.8	0.60	0.60	0.60	157	157	157
BKT >90 mm	2	2	2	2	49	24.5	1.93	1.93	1.93	79	79	79
Blacknose dace	65	67	65	72	280	4.2	11.04	10.75	11.91	2,638	2,559	2,835
Fantail darter	5	13	5	95	23	1.8	0.91	0.35	6.73	512	197	3,740
Totals	**147**	**158**	**147**	**248**	**940**		**37.03**	**36.10**	**44.11**	**6,221**	**5,787**	**9,764**
Station 2												
BKT ≤90 mm	49	50	49	53	154	3.1	3.90	3.85	4.16	1,266	1,241	1,342
BKT >90 mm	32	32	32	33	629	19.7	15.92	15.96	16.46	810	810	835
Totals	**81**	**82**	**81**	**86**	**783**		**19.82**	**19.81**	**20.62**	**2,076**	**2,051**	**2,177**
Station 3												
BKT ≤90 mm	55	59	55	66	164	2.8	6.08	5.70	6.84	2,185	2,037	2,444
BKT >90 mm	72	73	72	76	1,574	21.6	58.28	57.60	60.80	2,704	2,667	2,815
Totals	**127**	**132**	**127**	**142**	**1,738**		**64.36**	**63.30**	**67.64**	**4,889**	**4,704**	**5,259**

Note: RBT = rainbow trout and BKT = brook trout.

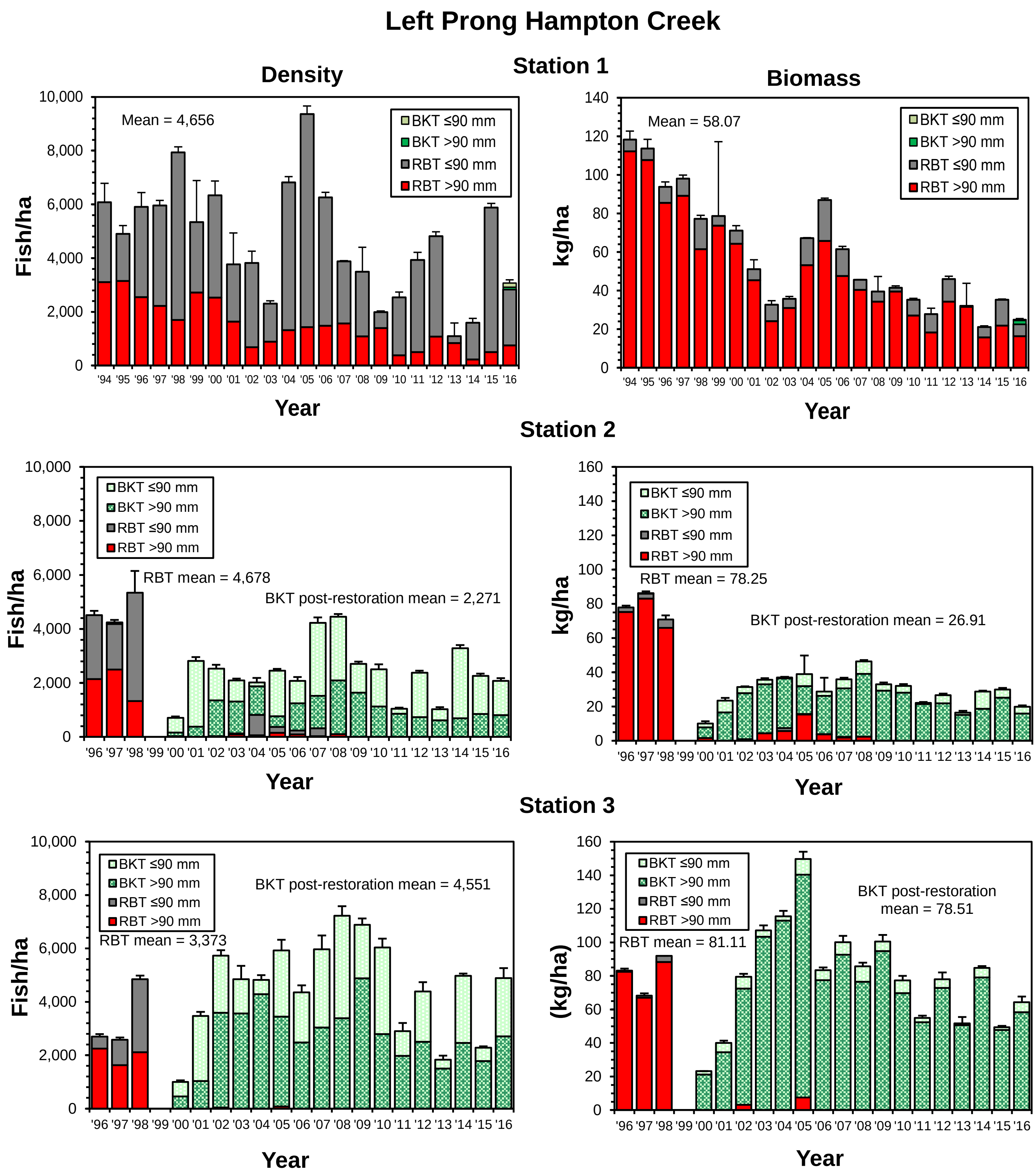


Figure 2-5. Trout abundance estimates for the Left Prong Hampton Creek monitoring stations. RBT = rainbow trout and BKT = brook trout. Bars indicate upper 95% confidence limits.

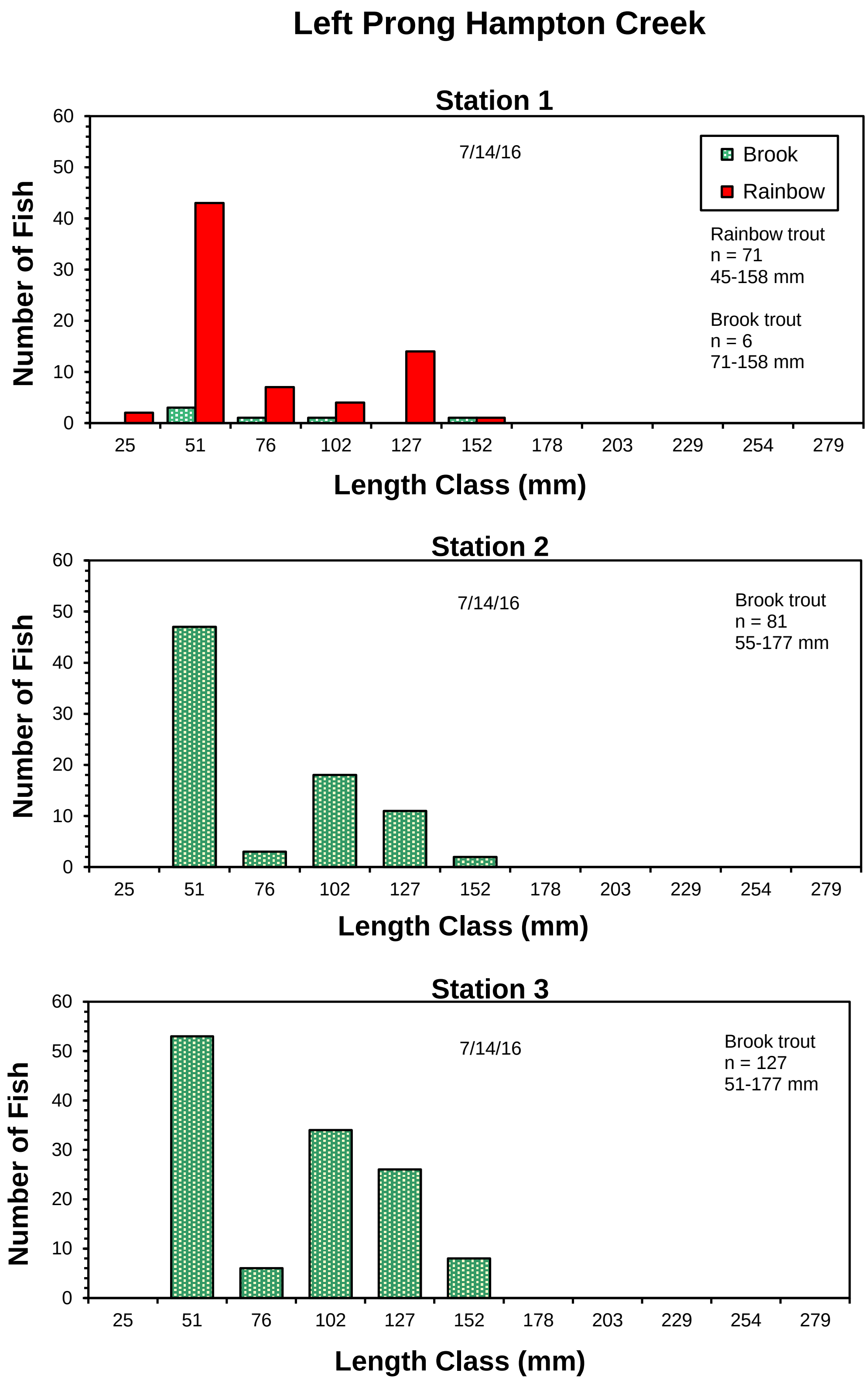


Figure 2-6. Length frequency distributions for trout from the 2016 Left Prong Hampton Creek samples.

2.2.3 Right Prong Middle Branch

Study Area

Right Prong Middle Branch is a headwater tributary to the Doe and Watauga rivers. Its Roan Mountain watershed is forested and located largely within the CNF in Carter County. It supports an allopatric population of native, southern Appalachian brook trout upstream of State Route 143. Bivens (1979) surveyed the stream and provided the first documentation of its brook trout population. The current monitoring station (Figure 2-7) was first sampled in 1994 (Strange and Habera 1995) and was added to the monitoring program in 1997 to represent a high-elevation (above 4,000' or 1,220 m) native brook trout population. Sample site location and effort details, along with habitat and water quality information are summarized in Table 2-6.

Results and Discussion

Catch data and abundance estimates for brook trout sampled at the Right Prong Middle Branch station in 2016 are given in Table 2-7. Despite some relatively strong cohorts in Right Prong Middle Branch in recent years, biomass has decreased 58% since 2012 (from 76 kg/ha to 32 kg/ha in 2016; Figure 2-8). Consequently, biomass is now below the long-term mean of about 49 kg/ha (Figure 2-8).

The biomass decline since 2015 can largely be related to the presence of only three brook trout ≥152 mm in the 2016 sample (Figure 2-9). The number of brook trout ≥152 mm captured during 2014-2016 (3-6 fish) has declined compared to the 2011-2013 samples (13 to19 fish), suggesting that recruitment to the larger size classes has also declined recently. However, no particular habitat changes at this site are apparent (e.g., pool quality degradation), thus other factors (including increased harvest) may be involved. The 2016 brook trout cohort (age-0 fish) was relatively strong in this higher-elevation stream (Figure 2-9), but this was not the case for lower-elevation (below 3,000') populations (Section 2.4).

DNA samples were collected from 27 Right Prong Middle Branch brook trout during the 2016 monitoring efforts to confirm the genetic identity of this population and examine relationships with other populations.

Management Recommendations

No special management of Right Prong Middle Branch is suggested at this time other than protection of the resource. Because of the small size of this stream and its relative obscurity, angling pressure is probably light. Sampling at the monitoring station should continue in order to increase our understanding of brook trout population dynamics, particular in higher-elevation streams.

Right Prong Middle Branch Monitoring Station

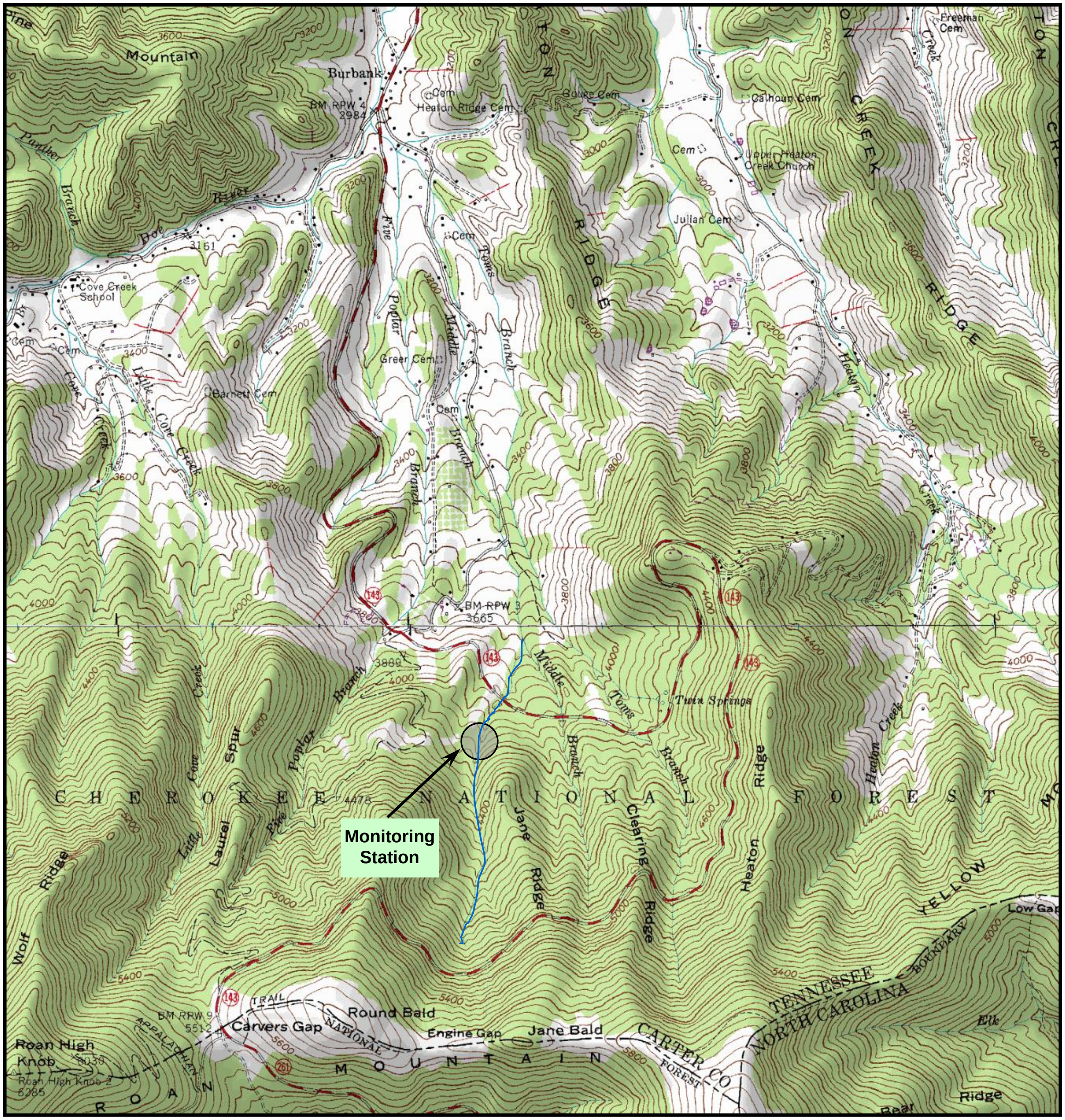


Figure 2-7. Location of the long-term monitoring station on Right Prong Middle Branch.

Table 2-6. Site and sampling information for Right Prong Middle Branch in 2016.

Location	Station 1
Site code	420162101
Sample date	18 August
Watershed	Watauga River
County	Carter
Quadrangle	Carvers Gap 208 SE
Lat-Long	36.12007 N, -82.09574 W
Reach number	06010103
Elevation (ft)	4,070
Stream order	1
Land ownership	USFS
Fishing access	Limited
Description	Begins at head of small island ~270 m upstream of Rt. 143.

Effort	
Station length (m)	90
Sample area (m²)	288
Personnel	2
Electrofishing units	1
Voltage (AC)	150
Removal passes	3

Habitat	
Mean width (m)	3.2
Maximum depth (cm)	70
Canopy cover (%)	95
Aquatic vegetation	scarce
Estimated % of site in pools	37
Estimated % of site in riffles	63
Habitat assessment score	160 (optimal)

Substrate Composition	Pool (%)	Riffle (%)
Silt	25	
Sand	5	5
Gravel	30	30
Rubble	15	30
Boulder	20	35
Bedrock	5	

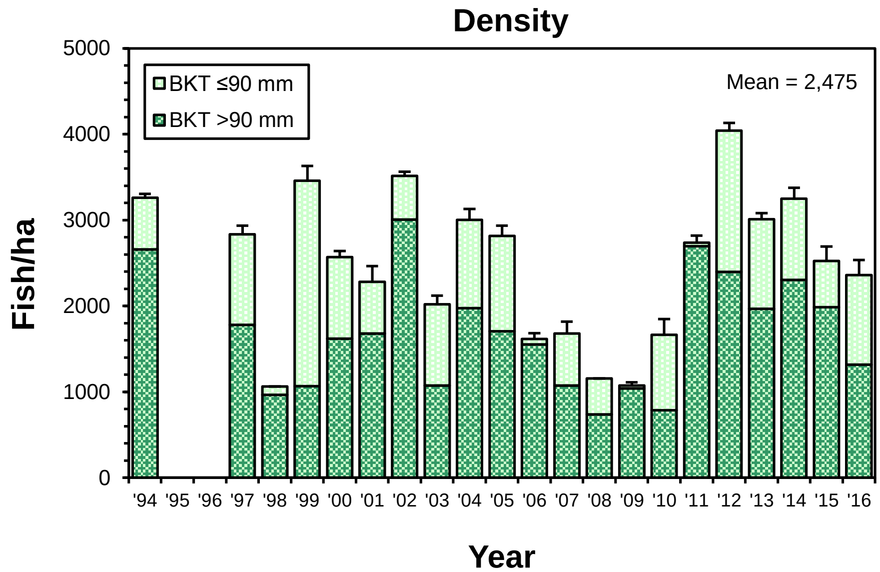
Water Quality	
Flow (cfs; visual)	N/M; low
Temperature (C)	15.4
pH	6.8
Conductivity (µS/cm)	68
Dissolved oxygen (mg/L)	N/M
Alkalinity (mg/L $CaCO_3$)	15

Table 2-7. Fish population abundance estimates (with 95% confidence limits) for the monitoring station on Right Prong Middle Branch sampled 18 August 2016.

		Population Size			Est.	Mean	Biomass (kg/ha)			Density (fish/ha)		
Species	Total Catch	Est.	Lower C.L.	Upper C.L.	Weight (g)	Fish Wt. (g)	Est.	Lower C.L.	Upper C.L.	Est.	Lower C.L.	Upper C.L.
BKT ≤90 mm	29	30	29	34	85	2.8	2.96	2.82	3.31	1,042	1,007	1,181
BKT >90 mm	38	38	38	39	829	21.8	28.78	28.78	29.52	1,319	1,319	1,354
Totals	**67**	**68**	**67**	**73**	**914**		**31.74**	**31.60**	**32.83**	**2,361**	**2,326**	**2,535**

Note: BKT = brook trout.

Right Prong Middle Branch



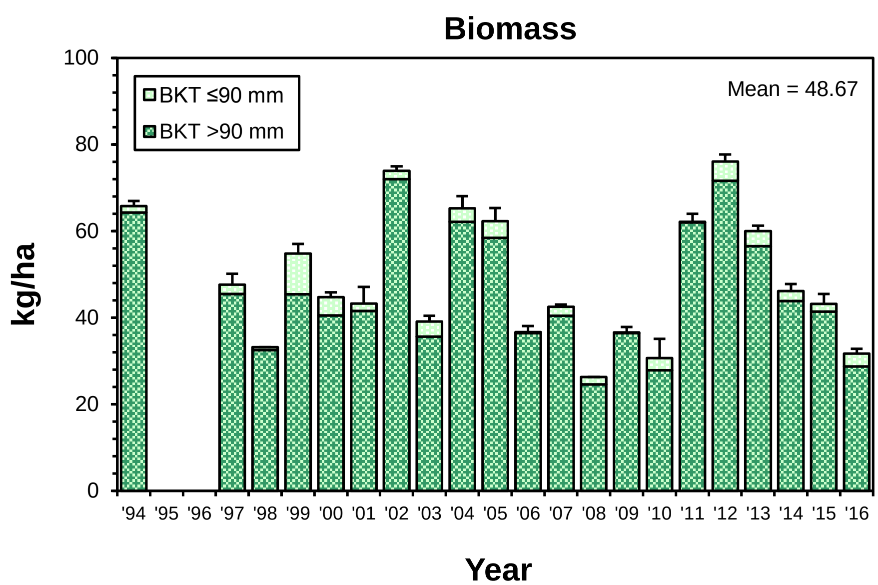


Figure 2-8. Trout abundance estimates for the Right Prong Middle Branch monitoring station. BKT = brook trout. Bars indicate upper 95% confidence limits (total).

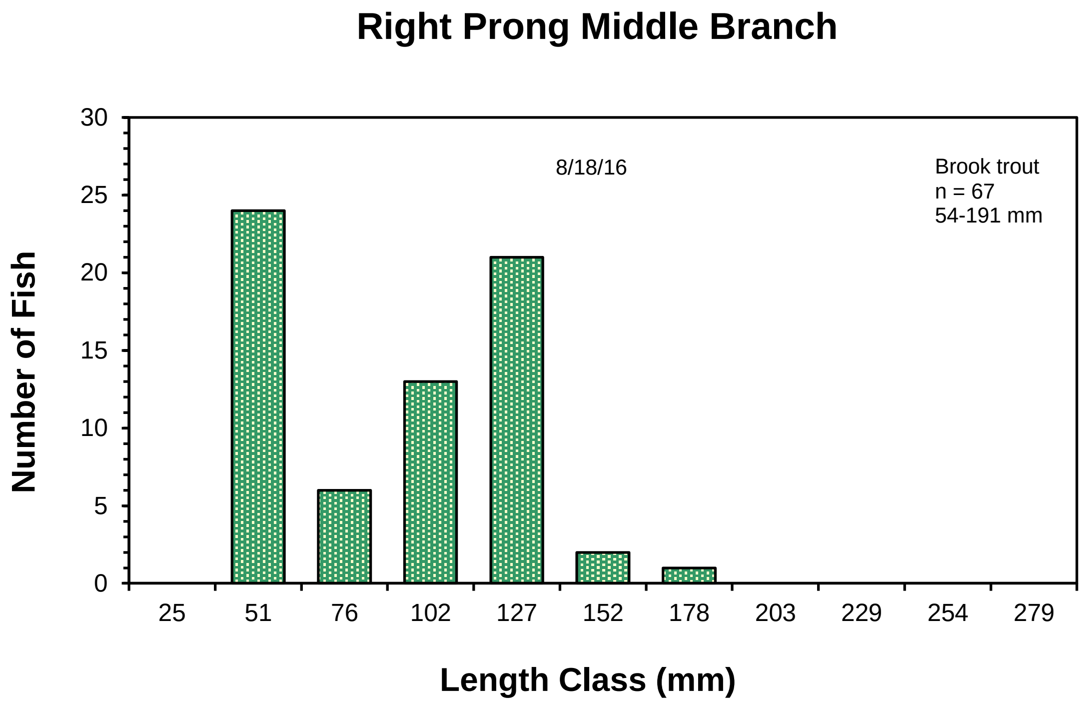


Figure 2-9. Length frequency distribution for brook trout from the 2016 Right Prong Middle Branch sample.

2.2.4 Stony Creek

Study Area

Stony Creek originates on Cross Mountain along the border of Johnson and Carter counties and flows nearly 30 km along the southeast edge of Holston Mountain to become a tributary to the Watauga River (Wilbur tailwater) in Carter County at Hunter (near Elizabethton). Except for the upper 5.3 km, which are on the CNF, Stony Creek flows through privately owned land, much of which is being used for small-scale agricultural and residential purposes. Ten tributaries to Stony Creek, as well as 3.5 km of upper Stony Creek itself (beginning at 2,348' or 716 m), support brook trout, with nearly 21 km (13 mi.) of brook trout water in the entire watershed. Four of the tributary populations (Right Fork Mill Creek, Big Spur Branch, Water Hollow Branch, and Baker Ridge Branch) were identified in 2015 during distribution surveys and subsequent microsatellite DNA analyses indicated that all of these except Right Fork Mill Creel are of native, southern Appalachian origin. DNA samples from the other six populations in the Stony Creek watershed were collected in 2016 to verify their genetic origin and examine relationships with other populations (Section 2.4). The brook trout population in Furnace Branch (Stony Creek tributary) extended down to 1,775' (541 m) in 2016, one of the lowest known elevations at which brook trout occur in Tennessee.

Shields (1950) considered Stony Creek to provide a fair trout fishery for stocked fish and a much more marginal one for wild fish. He noted that carry over was potentially good, although reproduction was limited, confined to the extreme headwaters, and not sufficient to contribute much to the fish yield. Stony Creek now supports, in addition to the brook trout in its headwaters, excellent populations of wild rainbow and brown trout which extend downstream nearly to the confluence with the Watauga River. It has also been stocked annually since 1951 with various combinations of fingerling and catchable brook, brown, and rainbow trout. The most recent brook trout stocking occurred in 1961 and browns were last stocked in 1997. The current stocking program in Stony Creek involves only adult (254-356 mm) rainbow trout, which have been stocked at the rate of 3,900/year (March-June) since 2014. Fingerling rainbows were last stocked in 1991.

A 2015 TWRA creel survey documented angler activity during only June, July, August, and November (Black 2016). Stony Creek anglers (94% were from Carter Co.) made 293 trips totaling 854 hours during those four months, caught an estimated 1,056 trout (80% rainbows), and harvested 402 of those (88% rainbows). Catch and harvest rates were 1.23 fish/h and 0.47 fish/h, respectively. TWRA's previous creel survey of Stony Creek in 2003 (Habera et al. 2004) estimated more effort (3,148 h), although catch (590 fish) and harvest (91 fish) estimates were much smaller. Stony Creek had the lowest catch (0.19 fish/h) and harvest (0.03 fish/h) rates among the five wild trout streams surveyed in 2003 (Habera et al. 2004), but these rates have increased since then.

Previous quantitative sampling efforts on Stony Creek are limited to three sites dating to 1992. A station within the brook trout zone on upper Stony Creek was quantitatively sampled in that year (Strange and Habera 1993) and two sites further downstream were established and sampled in 1995 (Strange and Habera 1996). The middle site of these three (located behind the

Stony Creek Volunteer Fire Department; Figure 2-10) is now the current monitoring station and has been sampled in 1995, 2004-2006, and on a three-year rotation beginning in 2010. Sample site location and effort details, along with habitat and water quality information are given in Table 2-8.

Results and Discussion

Catch data and abundance estimates for trout and all other species sampled at the Stony Creek station in 2016 are given in Table 2-9. Age-0 trout, particularly rainbows, have been exceptionally abundant in previous Stony Creek monitoring station samples since 2004, and this was the case again in 2016 (78% of 617 rainbows were ≤90 mm; Table 2-9). The last three samples (2010, 2013, and 2016) have produced 1,024 rainbow trout ≤90 mm. Consequently, Shields' previously-mentioned assessment of Stony Creek's capacity for trout reproduction obviously does not currently apply. Recruitment of all this reproduction, however, appears to be limited and declining, particularly during periods of drought and lower stream flows. The 2013 sample produced 52 rainbow trout ≥152 mm, while only 22 were present in 2016. It seems questionable whether such relatively small numbers of adults could produce such large cohorts, as similarly large cohorts have not been observed in other monitoring streams. Perhaps rainbow trout from the Wilbur tailwater use this portion of Stony Creek, about 10 km (6.3 mi.) upstream from the confluence, as spawning habitat.

Total trout density in 2016 increased relative to the 2013 estimate as a result of the large number of age-0 rainbow trout, but both adult trout density and biomass declined to near the lowest levels observed since 1995 (Figure 2-11). Brown trout also appear to be declining at the Stony Creek monitoring station, as only two adults were collected in 2016 (biomass <3 kg/ha; Figure 2-11). No age-0 brown trout were collected and similar results were observed in other 2016 monitoring streams where brown trout are present (Beaverdam Creek and Laurel Creek).

The size structure of the rainbow trout population was less well-balanced than in 2013, with only eight fish in the 178-mm size class and larger (Figure 2-12). Only two brown trout (271-281 mm) were present (Figure 2-12).

Management Recommendations

Stony Creek supports an excellent population of wild rainbow trout, along with good populations of brown trout and brook trout (in the upper reaches). Its above-average fertility (alkalinity of 95 mg/L as $CaCO_3$ in 2016) also enables it to produce some of Tennessee's larger wild rainbows and browns. Accordingly, management of this fishery resource should emphasize wild trout. The current level of stocking with adult rainbows is not incompatible with wild trout management or native fishes (Weaver and Kwak 2013) but should not be expanded in scope or scale, particularly given the limited angler use observed in the 2015 creel survey. The Stony Creek monitoring station is on a three-year sampling rotation and is next scheduled to be sampled during 2019. A qualitative survey during December-March might help determine if rainbow trout spawners from the Wilbur tailwater are using this portion of Stony Creek and contributing to the high abundance of age-0 fish in monitoring samples there.

Stony Creek Monitoring Station

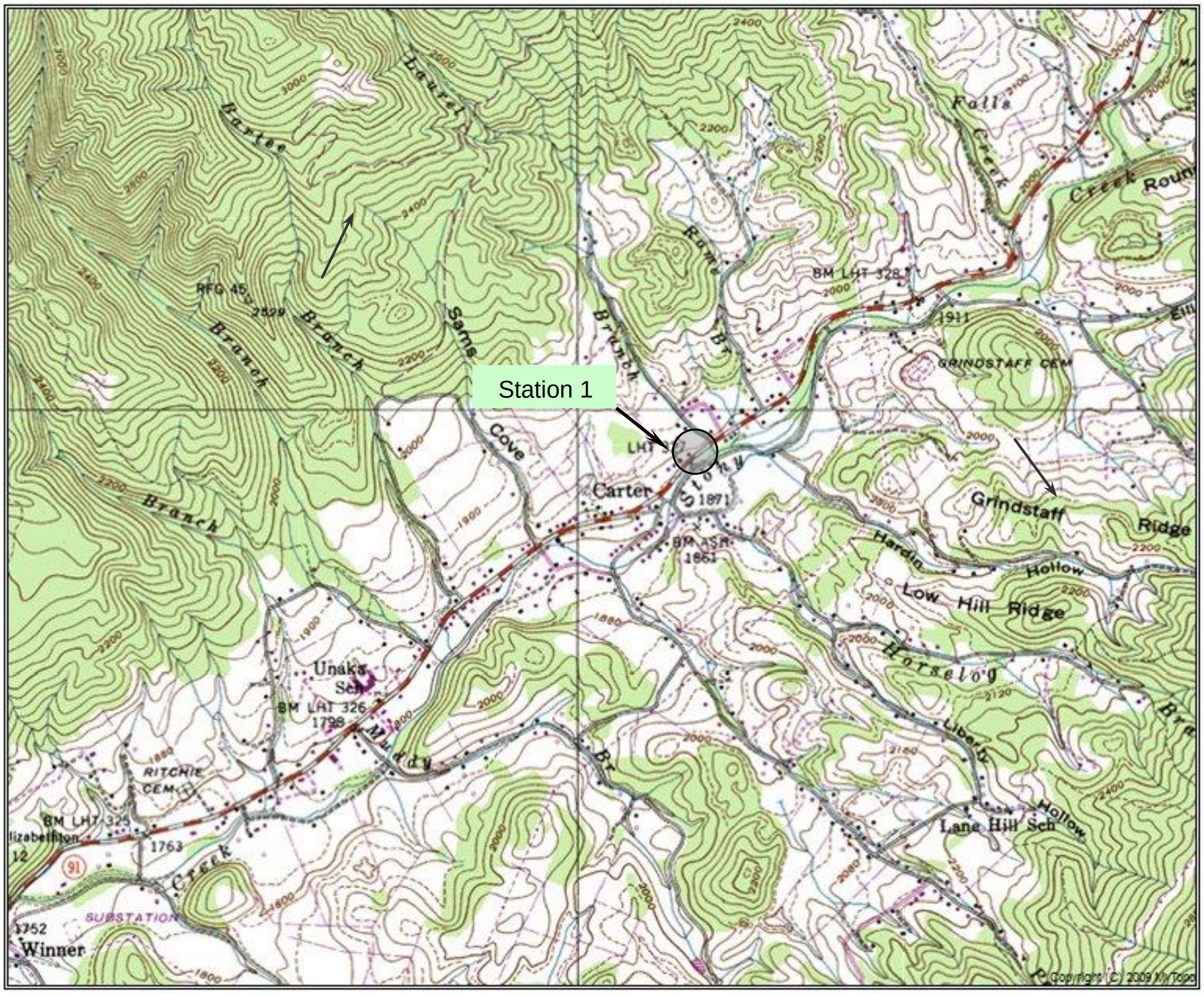


Figure 2-10. Location of the monitoring station on Stony Creek.

Table 2-8. Site and sampling information for Stony Creek in 2016.

Location	**Station 1**
Site Code	420162501
Sample Date	15 September
Watershed	Watauga River
County	Carter
Quadrangle	Carter 207 NE
Lat-Long	36.41442 N, 82.07841 W
Reach Number	06010103-39,0
Elevation (ft)	1,860
Stream Order	4
Land Ownership	Private
Fishing Access	Good
Description	Begins ~50 m upstream of bridge at Stony Ck. VFD
Effort	
Station Length (m)	211
Sample Area (m²)	1,583
Personnel	10
Electrofishing Units	3
Voltage (AC)	125
Removal Passes	3
Habitat	
Mean width (m)	7.5
Maximum depth (cm)	70
Canopy cover (%)	40
Aquatic vegetation	scarce
Estimated % of site in pools	54
Estimated % of site in riffles	46
Visual Hab. Assess. Score	141 (suboptimal)

Substrate Composition	**Pool (%)**	**Riffle (%)**
Silt	10	
Sand	10	5
Gravel	25	25
Rubble	45	35
Boulder	15	35
Bedrock		

Water Quality	
Flow (cfs; visual)	6.0; low
Temperature (C)	20.5
pH	7.4
Conductivity (µS/cm)	136
Dissolved Oxygen (mg/L)	N/M
Alkalinity (mg/L $CaCO_3$)	95

Table 2-9. Estimated fish population sizes, standing crops, and densities (with 95% confidence limits) for the monitoring station on Stony Creek sampled 15 September 2016.

Species	Total Catch	Population Size Est.	Population Size Lower C.L.	Population Size Upper C.L.	Est. Biomass (g)	Mean Fish Wt. (g)	Standing Crop (kg/ha) Est.	Standing Crop (kg/ha) Lower C.L.	Standing Crop (kg/ha) Upper C.L.	Density (Fish/ha) Est.	Density (Fish/ha) Lower C.L.	Density (Fish/ha) Upper C.L.
Station 1												
RBT ≤90 mm	480	529	504	554	2,062	3.9	13.03	12.42	13.65	3,342	3,184	3,500
RBT >90 mm	137	148	137	160	2,613	17.7	16.51	15.32	17.89	935	865	1,011
BNT >90 mm	2	2	2	2	406	203.0	2.56	2.56	2.56	13	13	13
Blacknose dace	585	632	609	655	2,302	3.6	14.54	13.85	14.90	3,992	3,847	4,138
Fantail darter	185	287	196	378	504	1.8	3.19	2.23	4.30	1,813	1,238	2,388
Snubnose darter	35	42	35	56	107	2.5	0.67	0.55	0.88	265	221	354
Mottled sculpin	563	867	714	1,020	6,951	8.0	43.91	36.08	51.55	5,477	4,510	6,443
Stoneroller	239	251	240	262	6,017	24.0	38.01	36.39	39.72	1,586	1,516	1,655
N. hogsucker	9	9	9	12	1,001	111.2	6.32	6.32	10.26	57	57	76
White sucker	2	2	2	2	35	17.5	0.22	0.22	0.22	13	13	13
Totals	**2,237**	**2,769**	**2,448**	**3,101**	**21,998**		**138.96**	**125.94**	**155.93**	**17,493**	**15,464**	**19,591**

Note: RBT = rainbow trout and BNT = brown trout.

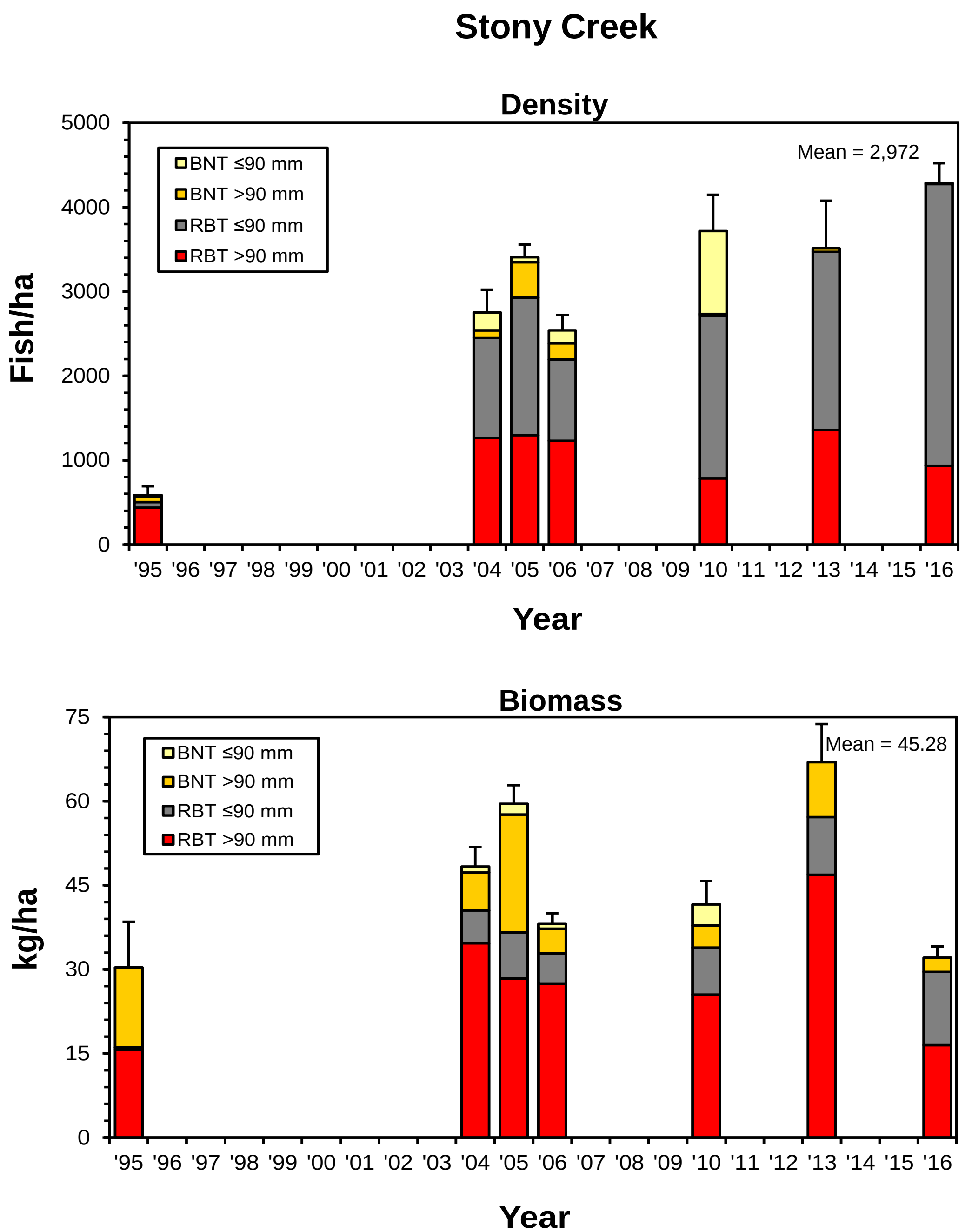


Figure 2-11 Trout abundance estimates for the Stony Creek monitoring station. RBT = rainbow trout and BNT = brown trout. Bars indicate upper 95% confidence limits (total).

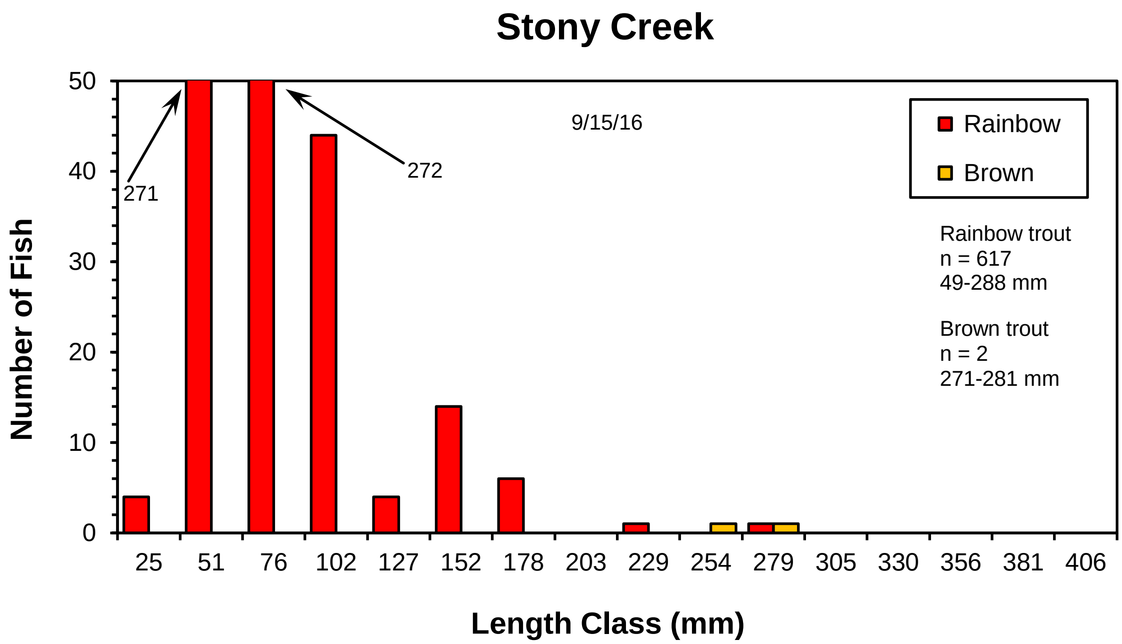


Figure 2-12. Length frequency distributions for rainbow and brown trout from the 2016 Stony Creek sample.

2.2.5 Doe Creek

Study Area

Doe Creek is a large spring-fed tributary to Watauga Reservoir in Johnson County. It flows through privately-owned land, much of which is being used for agricultural and residential purposes. Doe Creek is probably best known for the trophy rainbow trout fishery it supported during the 1950s and 1960s. That fishery consisted of an annual run of fall-spawning rainbows from Watauga Reservoir and probably originated from eggs planted at the mouth of the stream in 1954 (Bivens et al. 1998).

Although the trophy fishery disappeared in the early 1970s, Doe Creek still supports one of Tennessee's finest populations of wild rainbow trout and some large (>500 mm) rainbow trout still enter Doe Creek each winter from the lake. Adult rainbow trout are also stocked during March-June (about 2,800/year) and general (statewide) trout fishing regulations apply. Doe Creek was surveyed for TWRA by Shields (1950) and later qualitatively sampled by Bivens (1989). Ironically, Shields (1950) recommended removal of Doe Creek from the trout stream list because of its limited trout carrying capacity and lack of potential for reproduction at that time. A 2003 creel survey indicated that Doe Creek had the highest estimated trout catch and harvest rates among the five streams surveyed and was second only to Doe River (much of which is in Roan Mountain State Park) in terms of estimated angler effort for trout (Habera et al. 2004).

The current long-term monitoring station on Doe Creek (Figure 2-13) was established in 1993 and has been sampled annually since then. It is located along Highway 67 and ends at the old dam just below the confluence with the outflow from Lowe Spring, which is an important source of cold water for Doe Creek. Sample site location and effort details, along with habitat and water quality information are given in Table 2-10.

Results and Discussion

Catch data and abundance estimates for all species sampled at the Doe Creek station in 2016 are given in Table 2-11. Estimated rainbow trout density and biomass decreased relative to 2015, and both measures of abundance fell below the corresponding long-term averages for this site (Figure 2-14). Doe Creek previously produced wild rainbow trout biomass estimates >100 kg/ha (1993, 1997, and 2004) and averaging 75 kg/ha through 2006 (Figure 2-13). However, biomass has averaged just below 60 kg/ha since then, indicating that wild trout production in Doe Creek is not typically attaining this former potential.

A relatively strong rainbow trout cohort was present in the 2016 Doe Creek sample (Figure 2-14), as 60% (136) of the 224 rainbows captured were in the 70-110 mm size range (age 0). Recruitment into the larger (≥208 mm) adult size classes (5 fish; Figure 2-14) declined from 2015 (16 fish), and no trout ≥229 mm were present (Figure 2-14).

Management Recommendations

Doe Creek remains one of Tennessee's most productive wild trout streams and TWRA is committed to protecting its quality. The most recent angler survey data indicate that the hatchery-supported trout fishery in Doe Creek is also popular (Habera et al. 2004). Management of this stream should feature the outstanding wild trout population, and while the current stocking program is not incompatible with wild trout management or native fish assemblages (Weaver and Kwak 2013), it should not be expanded in scope or scale. Annual monitoring at the station near Lowe Spring should continue and may help identify any impacts related to Mountain City's water withdrawals (0.5 million gallons per day) from the spring, which began in 2002. Additionally, a new angler survey would help determine if current stocking levels are appropriate.

Doe Creek Monitoring Station

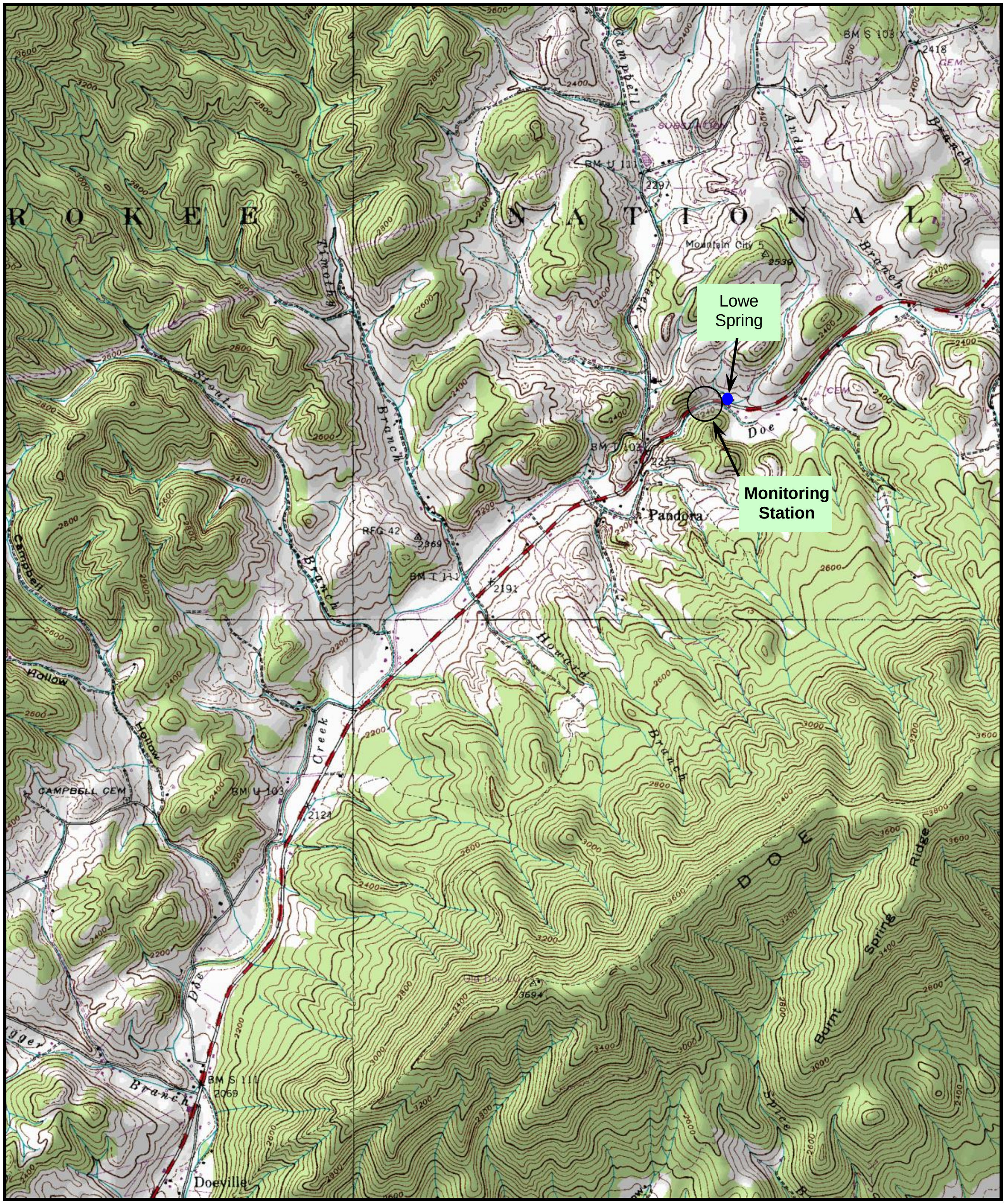


Figure 2-13. Location of the long-term monitoring station on Doe Creek.

Table 2-10. Site and sampling information for Doe Creek in 2016.

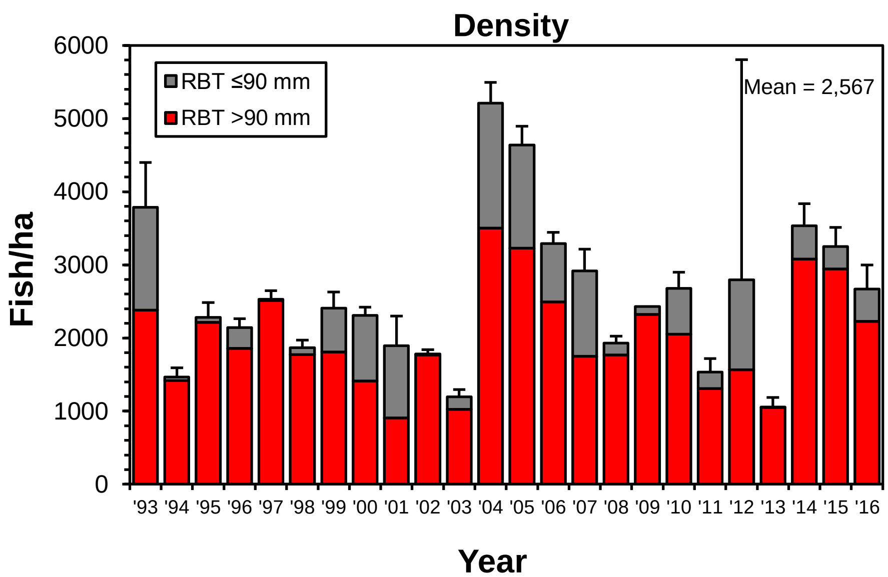
Location	Station 1	
Site code	420162401	
Sample date	13 September	
Watershed	Watauga River	
County	Johnson	
Quadrangle	Doe 214 NW	
Lat-Long	36.42709 N, -81.93725 W	
Reach number	06010103-37,0	
Elevation (ft)	2,210	
Stream order	4	
Land ownership	Private	
Fishing access	Good	
Description	Site ends at small dam just below Lowe spring.	
Effort		
Station length (m)	134	
Sample area (m²)	951	
Personnel	9	
Electrofishing units	3	
Voltage (AC)	125	
Removal passes	3	
Habitat		
Mean width (m)	7.1	
Maximum depth (cm)	75	
Canopy cover (%)	45	
Aquatic vegetation	common	
Estimated % of site in pools	40	
Estimated % of site in riffles	60	
Habitat assessment score	157 (suboptimal)	
Substrate Composition	**Pool (%)**	**Riffle (%)**
Silt	5	
Sand	5	5
Gravel	25	25
Rubble	20	35
Boulder	20	25
Bedrock	25	10
Water Quality		
Flow (cfs; visual)	16.4; normal	
Temperature (C)	15.4	
pH	7.4	
Conductivity (µS/cm)	152	
Dissolved oxygen (mg/L)	N/M	
Alkalinity (mg/L $CaCO_3$)	90	

Table 2-11. Fish population abundance estimates (with 95% confidence limits) for the monitoring station on Doe Creek sampled 13 September 2016.

Species	Total Catch	Population Size Est.	Population Size Lower C.L.	Population Size Upper C.L.	Est. Weight (g)	Mean Fish Wt. (g)	Biomass (kg/ha) Est.	Biomass (kg/ha) Lower C.L.	Biomass (kg/ha) Upper C.L.	Density (fish/ha) Est.	Density (fish/ha) Lower C.L.	Density (fish/ha) Upper C.L.
RBT ≤90 mm	36	42	36	54	252	6.0	2.65	2.27	3.41	442	379	568
RBT >90 mm	188	212	193	231	4,522	21.3	47.55	43.23	51.74	2,229	2,029	2,429
Creek chub	8	8	8	10	27	3.4	0.28	0.28	0.36	84	84	105
Blacknose dace	261	281	266	296	1,227	4.4	12.91	12.31	13.70	2,955	2,797	3,113
Fantail darter	69	92	69	123	156	1.7	1.64	1.23	2.20	967	726	1,293
Mottled sculpin	415	763	527	999	2,657	3.5	27.94	19.40	36.77	8,023	5,542	10,505
C. stoneroller	54	75	54	108	2,532	33.8	26.62	19.19	38.38	789	568	1,136
N. hog sucker	4	4	4	5	82	20.5	0.86	0.86	1.08	42	42	53
White sucker	1	1	1	1	2	2.0	0.02	0.02	0.02	11	11	11
Totals	**1,036**	**1,478**	**1,158**	**1,827**	**11,457**		**120.47**	**98.79**	**147.66**	**15,542**	**12,178**	**19,213**

Note: RBT = rainbow trout.

Doe Creek



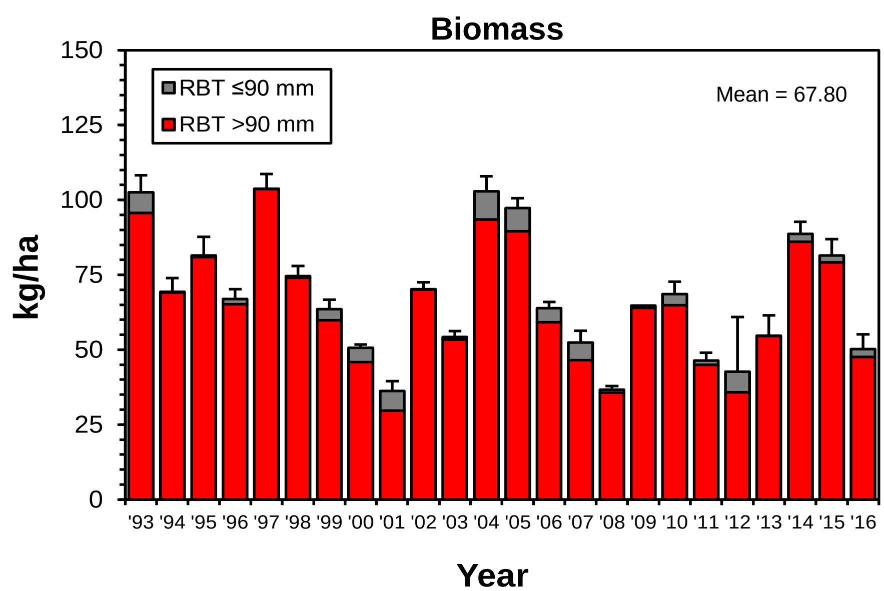


Figure 2-14. Trout abundance estimates for the Doe Creek monitoring station. RBT = rainbow trout. Bars indicate upper 95% confidence limits (total).

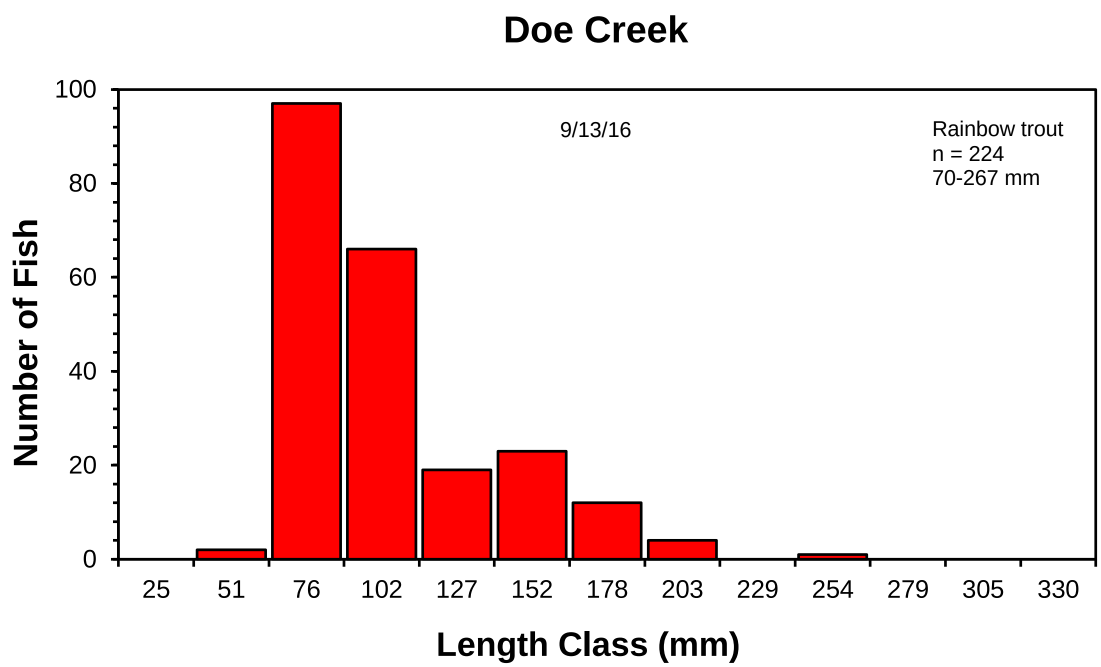


Figure 2-15. Length frequency distribution for rainbow trout from the 2016 Doe Creek sample.

2.2.6 Laurel Creek

Study Area

Laurel Creek is located in Johnson County, just across the Iron Mountains from Beaverdam Creek. It flows northeast into Virginia where it is joined by Beaverdam Creek in Damascus and becomes a major tributary to the South Fork Holston River. The 3.1-km segment extending upstream from the state line lies within the CNF. The watershed consists of a mixture of forested, agricultural, and residential lands upstream of the portion on the CNF. Laurel Creek is similar to Beaverdam Creek in terms of its size, flow, water quality, fish community, and the excellent wild rainbow and brown trout fishery it supports. Nine tributaries contain brook trout populations and three of these have been confirmed to be of native, southern Appalachian heritage through microsatellite DNA analyses. Brook trout DNA samples from all five streams in the Gentry Creek watershed were collected in 2016 for further genetic analyses (Section 2.4) and the remaining stream (Valley Creek) will be sampled in 2017.

Management of Laurel Creek includes a put-and-take fishery for rainbow trout. An average of 3,300 adult rainbow trout has been stocked each year (March-June) since 2014. Unlike most of Beaverdam Creek, Laurel Creek and its tributaries are subject to general, statewide trout angling regulations, which include a seven-fish creel limit, no bait restrictions, and no size limits for rainbow or brown trout.

Shields' (1950) assessment of Laurel Creek was that it carried more large trout than Beaverdam Creek despite heavy fishing pressure, but natural reproduction was poor, especially for brown trout. Bivens and Williams (1990) qualitatively surveyed Laurel Creek for TWRA in 1989 (just upstream of the state line) and reported good populations of wild rainbow and brown trout with adequate reproduction. Later, quantitative samples were conducted near the confluence with Elliot Branch (on the CNF) in 1993 and further upstream near the confluence of Atchison Branch (private land) in 1994 (Bivens et al. 1994; Strange and Habera 1994, 1995). Excellent wild trout populations were present in each case, and brown trout standing crop exceeded 100 kg/ha at the upstream site (Strange and Habera 1994). The 1993 Laurel Creek site near Elliot Branch (Figure 2-16) was shortened by 10 m, a fifth electrofishing unit was added, and it was included in the long-term monitoring program in 2001 to obtain more information about this important wild trout fishery. Since then, it (Station 1) has been sampled in 2002, 2004, and 2010. A second monitoring station (3.1 km upstream of Station 1) was established and sampled in 2007 (Habera et al. 2008) and 2013 (Habera et al. 2014a) to better represent the upper portion of the stream. Sample site location and effort details for Station 1 on Laurel Creek, along with habitat and water quality information are summarized in Table 2-12.

Results and Discussion

Catch data and abundance estimates for trout and all other species sampled at the Laurel Creek station in 2016 are given in Table 2-13. Total trout density was somewhat lower than previous estimates, primarily because of the scarcity of age-0 brown trout (Figure 2-17). The 2016 brown trout cohort was extremely weak at other monitoring stations as well (e.g., Stony Creek and

Beaverdam Creek). Total trout biomass estimates at this station have been relatively stable since monitoring began, ranging from 31-42 kg/ha and averaging 37 kg/ha (Figure 2-17). Brown trout have typically had a higher relative biomass than rainbow trout, and this was again the case in 2016 (61%). Mean trout abundances for this station (Figure 2-17) are very similar to those for the two monitoring stations on nearby Beaverdam Creek (Section 2.7), as are the nonsalmonid species present. The largemouth bass *Micropterus salmoides,* bluegill *Lepomis macrochirus*, and green sunfish *L. cyanellus* in the 2016 Laurel Creek sample likely originated from ponds in the watershed.

Length frequency distributions for rainbow and brown trout (Figure 2-18) were relatively well-balanced, although the 2016 brown trout cohort was weak in Laurel Creek as it was elsewhere in 2016. Additionally, no rainbow trout ≥254 mm were present in 2016 (Figure 2-18) and none have been captured at this station since 2004.

Management Recommendations

Laurel Creek supports an excellent wild trout fishery that is comparable to the one present in nearby Beaverdam Creek. While future management of Laurel Creek should maintain and feature wild trout, the current level of stocking with catchable-size rainbows that is not incompatible with wild trout management and native fish assemblages (Weaver and Kwak 2013). However, stocking should not be expanded in scope or scale. The general angling regulations currently in place can also be maintained. Station 2 might be sampled along with Station 1 when Laurel Creek rotates onto the schedule again (2019) in order to further develop the Laurel Creek database.

Laurel Creek Monitoring Station

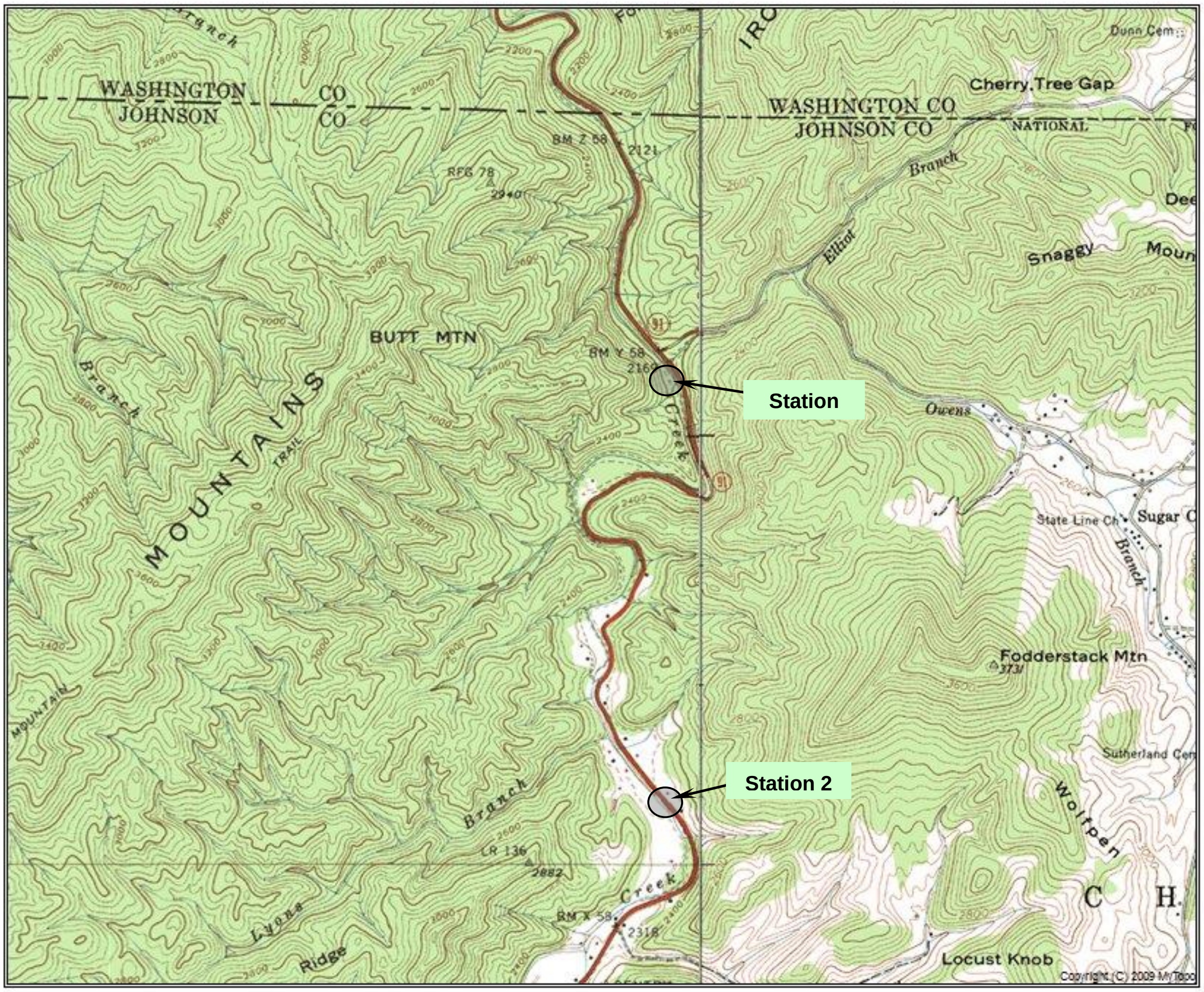


Figure 2-16. Location of the monitoring station on Laurel Creek.

Table 2-12. Site and sampling information for Laurel Creek in 2016.

Location	Station 1	
Site Code	420162301	
Sample Date	8 September	
Watershed	S. Fork Holston River	
County	Johnson	
Quadrangle	Laurel Bloomery 214 SE	
Lat-Long	36.60163 N, 81.75058 W	
Reach Number	06010102-25,0	
Elevation (ft)	2,210	
Stream Order	4	
Land Ownership	USFS	
Fishing Access	Excellent	
Description	Site begins ~10 m upstream of confluence with Elliot Branch (at wood duck box on LBD).	
Effort		
Station Length (m)	165	
Sample Area (m²)	2,294	
Personnel	18	
Electrofishing Units	5	
Voltage (AC)	200	
Removal Passes	3	
Habitat		
Mean width (m)	13.9	
Maximum depth (cm)	130	
Canopy cover (%)	45	
Aquatic vegetation	scarce	
Estimated % of site in pools	42	
Estimated % of site in riffles	58	
Visual Hab. Assess. Score	150 (suboptimal)	
Substrate Composition	**Pool (%)**	**Riffle (%)**
Silt	15	
Sand	15	10
Gravel	15	25
Rubble	15	35
Boulder	20	25
Bedrock	20	5
Water Quality		
Flow (cfs; visual)	29.9; normal	
Temperature (C)	18.5	
pH	7.7	
Conductivity (µS/cm)	136	
Dissolved Oxygen (mg/L)	N/M	
Alkalinity (mg/L $CaCO_3$)	85	

Table 2-13. Estimated fish population sizes, standing crops, and densities (with 95% confidence limits) for monitoring Station 1 on Laurel Creek sampled 8 September 2016.

Species	Total Catch	Population Size Est.	Lower C.L.	Upper C.L.	Est. Biomass (g)	Mean Fish Wt. (g)	Standing Crop (kg/ha) Est.	Lower C.L.	Upper C.L.	Density (Fish/ha) Est.	Lower C.L.	Upper C.L.
Station 1												
RBT ≤90 mm	71	75	71	82	331	4.4	1.44	1.36	1.57	327	310	357
RBT >90 mm	73	73	73	75	3,360	46.0	14.65	14.65	15.04	318	318	327
BNT ≤90 mm	2	2	2	15	12	6.0	0.05	0.05	0.39	9	9	65
BNT >90 mm	50	50	50	52	5,780	115.6	25.20	25.20	26.20	218	218	227
Creek chub	4	4	4	5	25	6.3	0.11	0.11	0.14	17	17	22
River chub	167	178	167	189	2,334	13.1	10.18	9.54	2.38	776	728	824
Blacknose dace	64	65	64	68	292	4.5	1.27	1.26	1.33	283	279	296
Fantail darter	54	128	54	306	254	2.0	1.11	0.47	2.67	558	235	1,334
Snubnose darter	25	33	25	52	82	2.5	0.36	0.27	0.57	144	109	227
Swannanoa darter	2	2	2	15	25	12.5	0.11	0.11	0.82	9	9	65
Mottled sculpin	733	1,354	1,036	1,672	4,812	3.6	20.98	16.26	26.24	5,902	4,516	7,289
Saffron shiner	56	59	56	65	82	1.4	0.36	0.34	0.40	257	244	283
Tennessee shiner	1	1	1	1	4	4.0	0.02	0.02	0.02	4	4	4
Warpaint shiner	7	7	7	10	73	10.4	0.32	0.32	0.45	31	31	44
Stoneroller	183	192	183	201	5,524	28.8	24.08	22.97	25.23	837	798	876
N. hogsucker	45	45	45	46	5,128	114.0	22.35	22.35	22.86	196	196	201
White sucker	9	10	9	16	648	64.8	2.82	2.54	4.52	44	39	70
Bluegill	4	4	4	5	19	4.8	0.08	0.08	0.10	17	17	22
Largemouth bass	2	2	2	2	10	5.0	0.04	0.04	0.04	9	9	9
Green sunfish	5	5	5	8	83	16.6	0.36	0.36	0.58	22	22	35
Totals	**1,557**	**2,289**	**1,860**	**2,885**	**28,878**		**125.89**	**118.30**	**131.55**	**9,978**	**8,108**	**12,577**

Note: RBT = rainbow trout; BNT = brown trout.

Laurel Creek

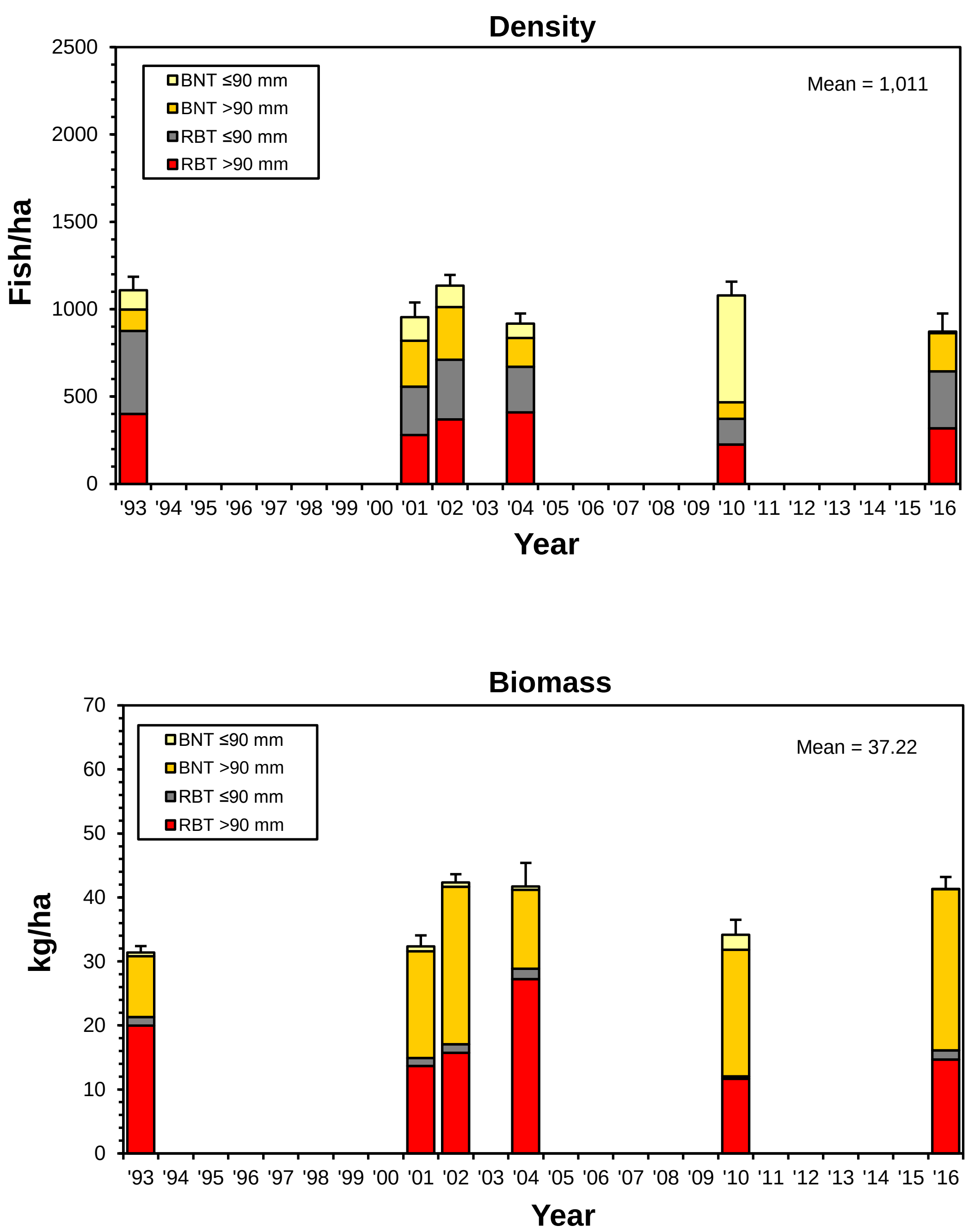


Figure 2-17. Trout abundance estimates for monitoring Station 1 on Laurel Creek. RBT = rainbow trout and BNT = brown trout. Bars indicate upper 95% confidence limits (total).

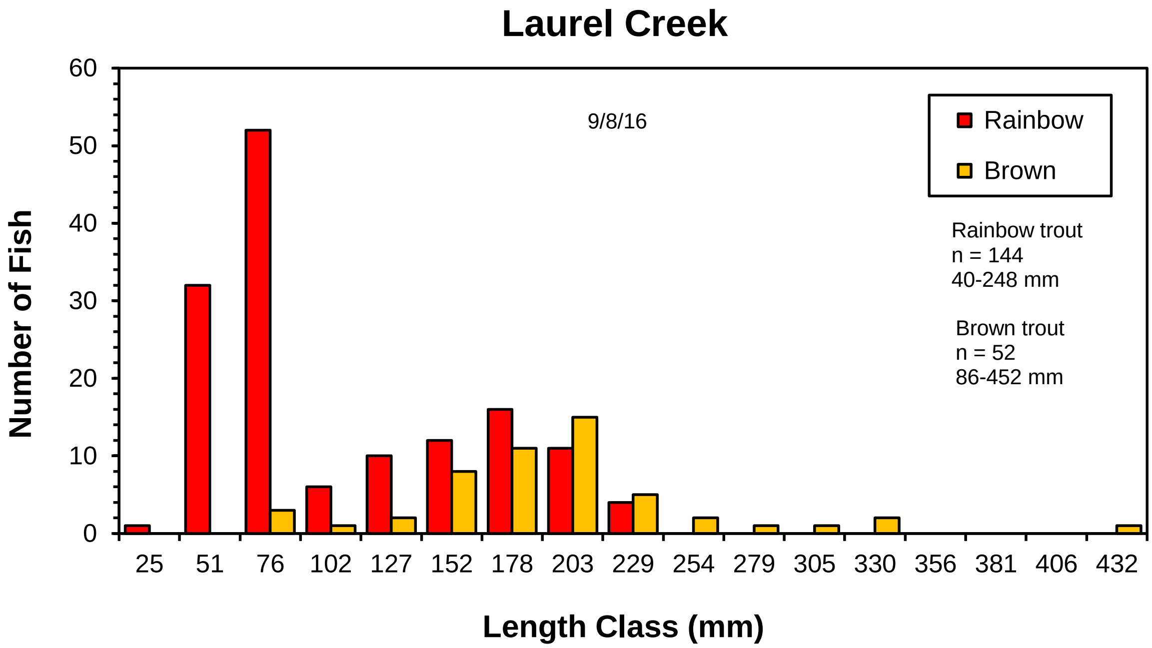


Figure 2-18. Length frequency distributions for rainbow and brown trout from the 2016 Laurel Creek sample (Station 1).

2.2.7 Beaverdam Creek

Study Area

Beaverdam Creek is one of Tennessee's best-known wild trout streams. It originates in Johnson County's Iron Mountains and flows northeast into Virginia as part of the South Fork Holston drainage. The watershed is largely forested (much is CNF), although there is substantial agricultural and residential land use in the Shady Valley area. Shields (1950) described Beaverdam Creek as providing excellent rainbow trout water. However, because there was no reproduction (except in the tributaries), he recommended a stocking program that included fall fingerlings in the Shady Valley section and a permit system for managing this stream. He made no mention of a brown trout fishery at that time. Later, Bivens (1988) and Bivens and Williams (1990) conducted qualitative surveys of Beaverdam Creek for TWRA and documented excellent wild rainbow and brown trout populations. Brook trout currently inhabit over 29 km in 12 Beaverdam Creek tributaries and most were determined to be of native, southern Appalachian heritage based on previous genetic analyses using allozymes (Strange and Habera 1997). Fin clips from three of these populations were collected in 2016 for more robust microsatellite DNA analyses (Section 2-4) and the remaining populations will be sampled in 2017.

The 10-km section of Beaverdam Creek between Tank Hollow Road and Birch Branch (located in the CNF) was managed under a 229-mm minimum length limit, three-fish creel limit, and single-hook, artificial-lures-only restriction during 1988-2012 to emphasize the wild trout fishery. Stocking was also discontinued within this area after 1988. The 229-mm length limit was removed and the creel limit was increased to five fish in 2013 as part of the revision of special wild trout regulations to make them more biologically sound. Outside the special regulations zone, about 5,600 catchable rainbow trout are stocked each year during March-June. Brown trout fingerlings have occasionally been stocked in upper Beaverdam Creek (vicinity of Hwy. 421 crossing and upstream) to supplement the wild brown trout population in that area, which has limited spawning habitat (Habera et al. 2006).

Two long-term monitoring stations (Figure 2-19) were established in 1991 within the special regulations zone and have been sampled annually since then. Sample site location and effort details, along with habitat and water quality information are summarized in Table 2-14.

Results and Discussion

Catch data and abundance estimates for trout and all other species collected at the Beaverdam Creek stations in 2016 are given in Table 2-15. Total trout density at both stations decreased again in 2016 (Figure 2-20), primarily as the result of decreased abundance brown trout—particularly fish ≤90 mm (i.e., age 0). Density estimates for brown trout ≤90 mm at both stations were among the lowest observed to date (Figure 2-20). Total trout biomass also decreased at both stations in 2016, with the declines being attributable to lower adult rainbow trout biomass at Station 1 and lower adult brown trout biomass at Station 2 (Figure 2-20). Abundance estimates were below the corresponding long-term averages at both stations (Figure 2-20).

The 2016 rainbow cohort was relatively abundant at both stations, while the corresponding brown trout cohort was exceptionally weak (Figure 2-21). Otherwise, length-frequency distributions at both sites were relatively well-balanced, with numerous (38 total) trout exceeding 229 mm, including a brown trout >400 mm at Station 2 (Figure 2-21). Beaverdam Creek is well known for its large (>400 mm) brown trout, and these have been present in 20 of 26 annual surveys—including all but one since 2003 (2012).

A 2015 TWRA creel survey (Black 2016) documented that Beaverdam Creek anglers made 685 trips totaling 2,611 hours, caught an estimated 4,517 trout (65% rainbows), and harvested 1,586 of those (93% rainbows). Catch and harvest rates were 1.73 fish/h and 0.35 fish/h, respectively. Most effort (85%) occurred during April-July and, interestingly, most anglers (53%) were from Virginia (36% were from Tennessee). TWRA's previous creel survey of Beaverdam Creek in 2003 (Habera et al. 2004) estimated more effort (3,210 h), although catch (723 fish) and harvest (163 fish) estimates were much smaller. Consequently, catch (0.22 fish/h) and harvest (0.05 fish/h) rates were much lower.

Beaverdam Creek anglers were asked some attitude/opinion questions regarding the fishery and their harvest tendencies during the 2015 survey. Responses (n=38) to these questions indicated that most anglers (66%) were primarily targeting stocked trout, while 29% were fishing for wild trout and 5% had no preference. Overall, majorities supported the current regulations (60%), had not changed the number of fish kept per trip since 2013 (76%), and never kept trout <229 mm (65%). The results were similar for each angler sub-group (stocked trout or wild trout). Only six anglers (16%; three from each group) said that they now harvested more trout per trip and only two (5%; one from each group) said that they regularly harvested trout <229 mm.

Management Recommendations

Beaverdam Creek supports one of Tennessee's best wild trout fisheries, which management should continue to maintain and emphasize. The current stocking program is not incompatible with wild trout management or native fish assemblages (Weaver and Kwak 2013), but there should be no expansion of the area or number of catchable trout currently stocked. Based on responses to the 2015 attitude/opinion survey questions, most anglers support the current regulations (which liberalized creel and size limits), but have not changed their harvest tendencies as a result of them. Annual monitoring should continue at both stations to increase our understanding of this important wild trout fishery.

Beaverdam Creek Monitoring Stations

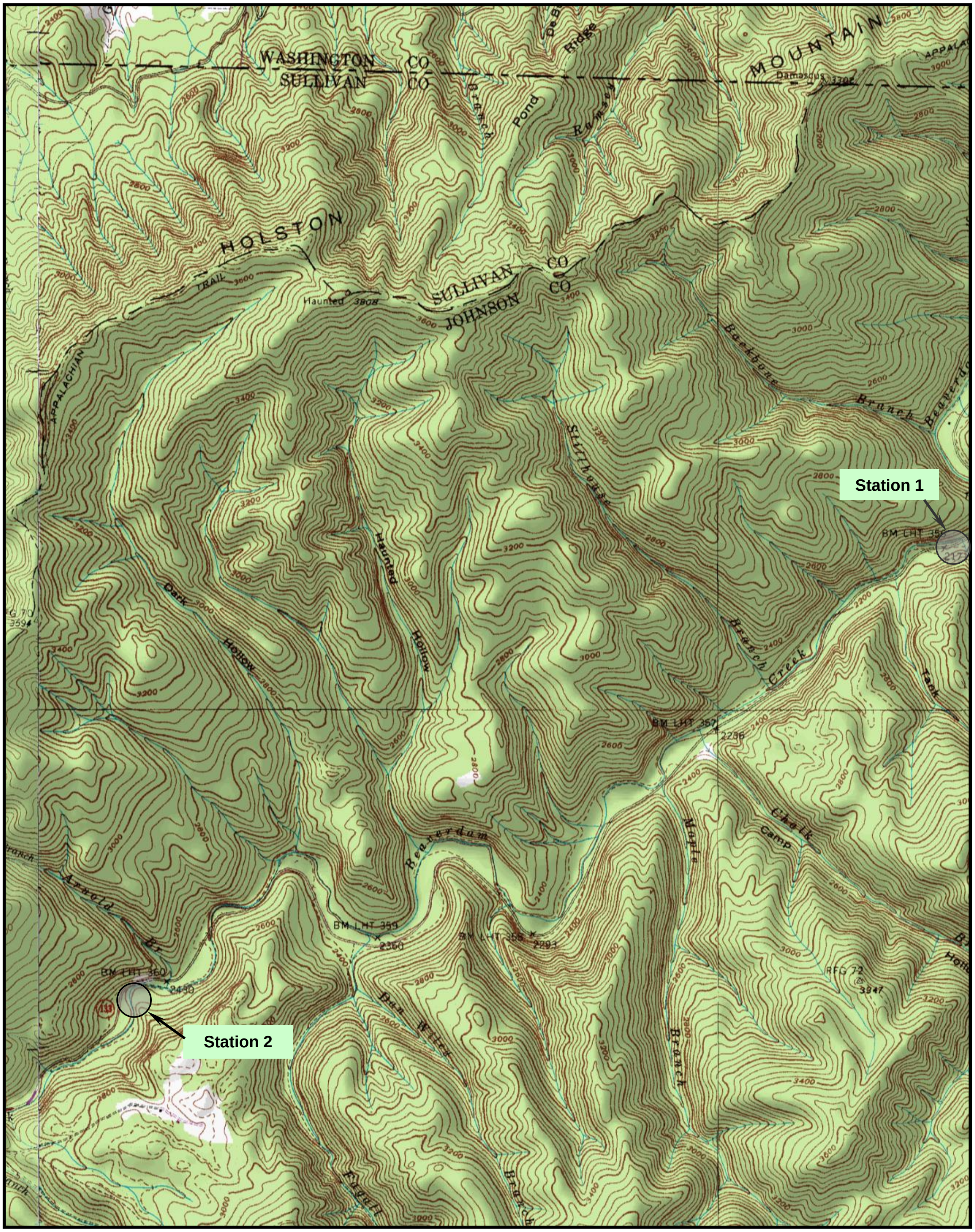


Figure 2-19. Locations of the two long-term monitoring stations on Beaverdam Creek.

Table 2-14. Site and sampling information for Beaverdam Creek in 2016.

Location	**Station 1**		**Station 2**	
Site code	420162201		420162202	
Sample date	30 August		31 August	
Watershed	S. Fork Holston River		S. Fork Holston River	
County	Johnson		Johnson	
Quadrangle	Laurel Bloomery 213 SE		Laurel Bloomery 213 SE	
Lat-Long	36.59176 N, -81.81847 W		36.56576 N, -81.87315 W	
Reach number	06010102-23,0		06010102-23,0	
Elevation (ft)	2,160		2,440	
Stream order	4		4	
Land ownership	USFS		USFS	
Fishing access	Excellent		Excellent	
Description	Begins at Tank Hollow Rd. near Backbone Rock.		Begins at Hwy. 133 mile marker 5 near Arnold Br.	
Effort				
Station length (m)	200		177	
Sample area (m²)	2,540		2,319	
Personnel	21		20	
Electrofishing units	4		4	
Voltage (AC)	250		250	
Removal passes	3		3	
Habitat				
Mean width (m)	12.7		13.1	
Maximum depth (cm)	120		130	
Canopy cover (%)	70		60	
Aquatic vegetation	scarce		scarce	
Estimated % of site in pools	58		47	
Estimated % of site in riffles	42		53	
Habitat assessment score	165 (optimal)		162 (optimal)	
Substrate Composition	**Pool (%)**	**Riffle (%)**	**Pool (%)**	**Riffle (%)**
Silt	10		10	
Sand	5	5	10	5
Gravel	20	25	20	30
Rubble	30	35	20	30
Boulder	15	30	30	30
Bedrock	20	5	10	5
Water Quality				
Flow (cfs; visual)	12.6; low		21.8; normal	
Temperature (C)	19.3		18.2	
pH	7.2		7.2	
Conductivity (µS/cm)	71		83	
Dissolved oxygen (mg/L)	N/M		N/M	
Alkalinity (mg/L $CaCO_3$)	40		45	

Table 2-15. Fish population abundance estimates (with 95% confidence limits) for the monitoring stations on Beaverdam Creek sampled 30 and 31 August 2016.

Species	Total Catch	Population Size Est.	Population Size Lower C.L.	Population Size Upper C.L.	Est. Weight (g)	Mean Fish Wt. (g)	Biomass (kg/ha) Est.	Biomass (kg/ha) Lower C.L.	Biomass (kg/ha) Upper C.L.	Density (fish/ha) Est.	Density (fish/ha) Lower C.L.	Density (fish/ha) Upper C.L.
Station 1												
RBT ≤90 mm	88	95	88	104	321	3.4	1.26	1.18	1.39	374	346	409
RBT >90 mm	53	54	53	57	2,502	46.3	9.85	9.66	10.39	213	209	224
BNT ≤90 mm	3	3	3	8	17	5.5	0.07	0.07	0.17	12	12	31
BNT >90 mm	40	41	40	44	3,370	82.2	13.27	12.94	14.24	161	157	173
Creek chub	2	2	2	15	2	1.0	0.01	0.01	0.06	8	8	59
River chub	141	167	143	191	3,071	18.4	12.09	10.36	13.84	657	563	752
Longnose dace	5	5	5	6	48	9.6	0.19	0.19	0.23	20	20	24
Blacknose dace	1	1	1	1	4	4.0	0.02	0.02	0.02	4	4	4
Fantail darter[1]	36	54	54	81	87	1.6	0.34	--	--	213	--	--
Greenfin darter	8	10	8	21	129	12.9	0.51	0.41	1.07	39	31	83
Snubnose darter	1	1	1	1	2	2.0	0.01	0.01	0.01	4	4	4
Swannanoa darter	5	5	5	7	12	2.4	0.05	0.05	0.07	20	20	28
Black redhorse	1	1	1	1	2	2.0	0.01	0.01	0.01	4	4	4
Mottled sculpin[1]	496	744	--	--	2,837	3.8	11.17	--	--	2,929	--	--
Saffron shiner	39	66	39	124	115	1.7	0.45	0.26	0.83	260	154	488
Warpaint shiner	15	22	22	33	194	8.8	0.76	0.76	1.14	87	87	130
C. stoneroller	111	118	111	127	3,704	31.4	14.58	13.72	15.70	465	437	500
N. hog sucker	14	14	14	15	1,815	129.6	7.15	7.15	7.65	55	55	59
Totals	**1,059**	**1,403**	**--**	**--**	**18,230**		**71.79**	**--**	**--**	**5,525**	**--**	**--**
Station 2												
RBT ≤90 mm	67	72	67	80	269	3.7	1.16	1.07	1.28	310	289	345
RBT >90 mm	68	71	68	77	3,961	55.8	17.08	16.36	18.53	306	293	332
BNT ≤90 mm	2	2	2	26	7	3.6	0.03	0.03	0.40	9	9	112
BNT >90 mm	29	29	29	31	3,857	133.0	16.63	16.63	17.78	125	125	134
Creek chub	2	2	2	2	22	11.0	0.09	0.09	0.09	9	9	9
River chub	166	184	168	200	927	5.0	4.00	3.62	4.31	793	724	862
Longnose dace	5	13	5	95	325	25.0	1.40	0.54	10.24	56	22	410
Blacknose dace	8	8	8	9	21	2.6	0.09	0.09	0.10	34	34	39
Rosyside dace	1	1	1	1	4	4.0	0.02	0.02	0.02	4	4	4
Fantail darter	62	94	62	143	144	1.5	0.62	0.40	0.92	405	267	617
Snubnose darter	21	24	21	32	34	1.4	0.15	0.13	0.19	103	91	138
Swannanoa darter	8	8	8	10	29	3.6	0.13	0.12	0.16	34	34	43
Mottled sculpin	494	906	650	1,162	3,916	4.3	16.88	12.05	21.55	3,907	2,803	5,011
Saffron shiner	58	59	58	62	90	1.5	0.39	0.38	0.40	254	250	267
Warpaint shiner	5	5	5	8	22	4.4	0.09	0.09	0.15	22	22	34
C. stoneroller	52	55	52	61	1,103	20.1	4.76	4.51	5.29	237	224	263
N. hog sucker	4	4	4	4	400	100.0	1.72	1.72	1.72	17	17	17
Totals	**1,052**	**1,537**	**1,210**	**2,003**	**15,131**		**65.24**	**57.85**	**83.13**	**6,625**	**5,217**	**8,637**

[1]Non-descending removal pattern. Population estimate set equal to 1.5 times total catch (95% confidence limits not calculated).

Note: RBT = rainbow trout; BNT = brown trout.

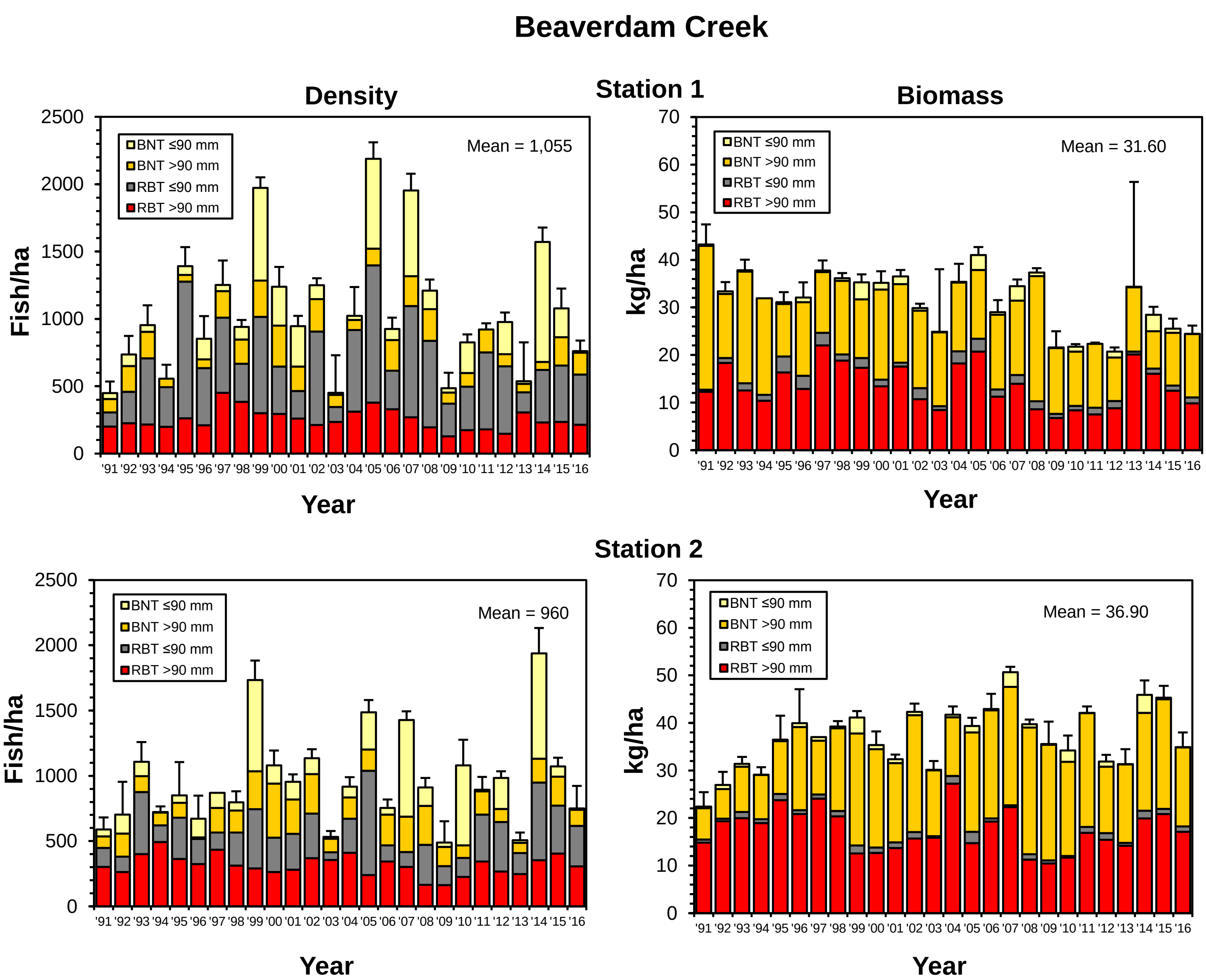


Figure 2-20. Trout abundance estimates for the Beaverdam Creek monitoring stations. RBT = rainbow trout and BNT = brown trout. Bars indicate upper 95% confidence limits (total).

Beaverdam Creek

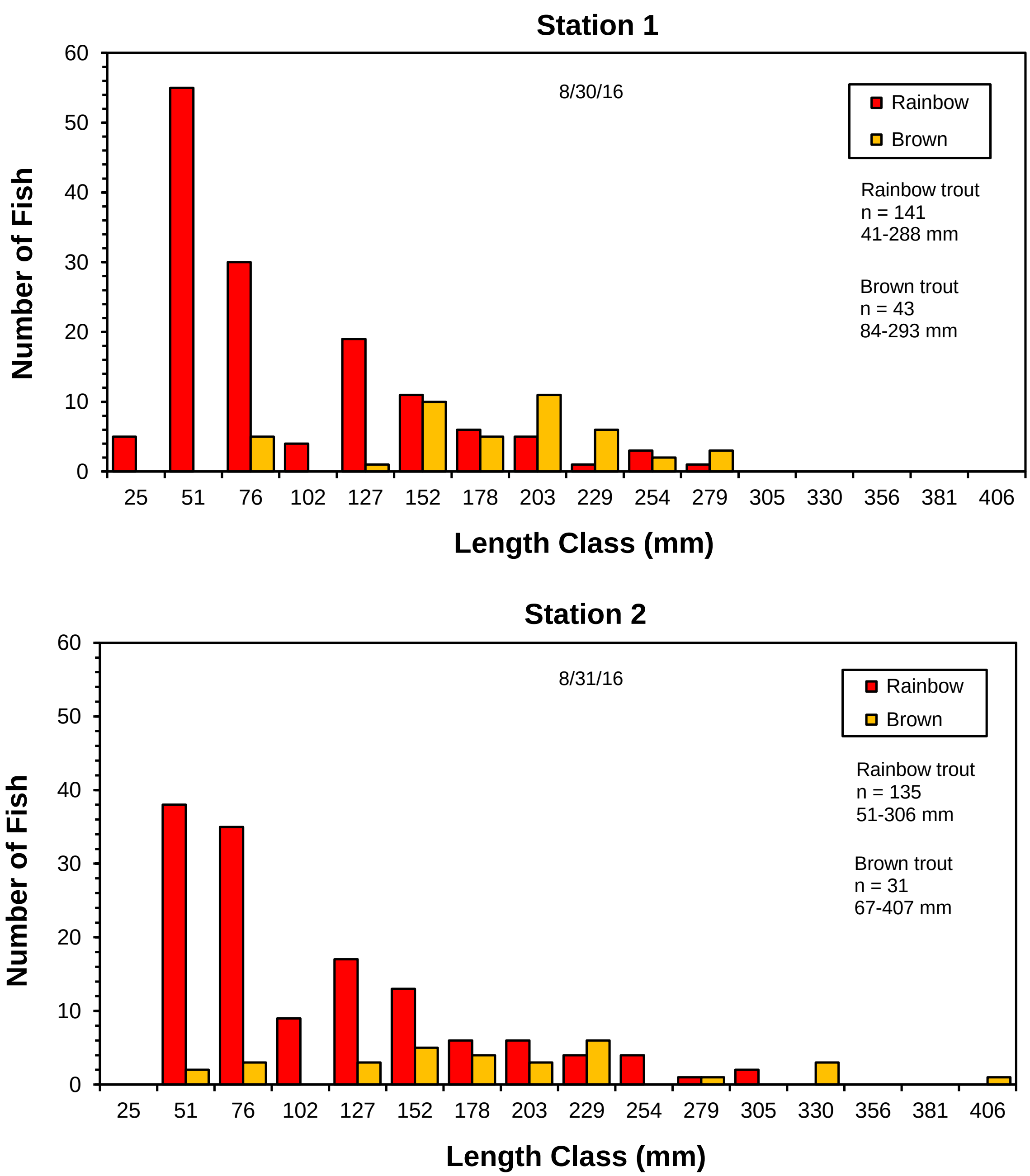


Figure 2-21. Length frequency distributions for rainbow and brown trout from the 2016 Beaverdam Creek samples.

2.3 SYMPATRIC BROOK/RAINBOW TROUT MONITORING STREAMS

Four streams (upper Rocky Fork, Briar Creek, Birch Branch, and Gentry Creek) are currently being monitored annually with the objective of documenting how (or if) rainbow trout eventually replace brook trout in areas where the two species occur sympatrically. These streams were sampled again in 2016 to continue tracking changes and trends in the relative abundance of each species over time. The information obtained through these sympatric-population monitoring efforts should document the extent to which brook and rainbow trout are capable of long-term coexistence.

2.3.1 Briar Creek

Study Area

Briar Creek is a Nolichucky River tributary in Washington County that flows from Buffalo Mountain through a forested watershed located within the CNF. It contains 4.7 km of brook trout water (southern Appalachian) beginning at an elevation of about 657 m (2,140'). Rainbow trout are present throughout the stream to its confluence with Dry Creek. Brook trout were re-introduced to Briar Creek in 1983 and the existing rainbow trout population was thinned in the 1.37-km introduction zone during 1983-1986 (Nagel 1986). A total of 114 southern Appalachian brook trout (mixed ages) were translocated from East Fork Beaverdam Creek, George Creek, and Tiger Creek during 1983-1984 (Nagel 1986). A reproducing brook trout population became established in the introduction zone by 1986, then expanded into areas from which no rainbow trout were removed (Nagel 1991). Currently, brook trout inhabit 4.7 km of Briar Creek, all of which remains sympatric with rainbow trout. DNA samples were obtained from 30 fish in 2016 to confirm their genetic identity and obtain other population genetics information (Section 2.4). Briar Creek is currently subject to general, statewide trout angling regulations.

A station at 662 m (2,170') was quantitatively sampled in 1992 to check the brook trout population status in the original introduction zone (Strange and Habera 1993). This site contained 27% brook trout, but several were removed for genetic analyses (Kriegler et al. 1995). Therefore, a new site (Figure 2-22) was established at 671 m (2,200') and annual monitoring began in 1995 (Strange and Habera 1996). Site location and effort details, along with habitat and water quality information are summarized in Table 2-16.

Results and Discussion

Catch data and abundance estimates for trout and all other species sampled at the Briar Creek station in 2016 are given in Table 2-17. Briar Creek has been impacted by droughts since 1998, with August flows typically well below 1 cfs). Only six fish (two brook trout) were captured in 2010 (Habera et al. 2011), but better flow conditions by 2014 and 2015 led to a substantial increase in trout abundance (>100 fish) with numerous age-0 fish of both species (Habera et al. 2015a and 2016). However, trout numbers were reduced again in 2016 under the extremely dry conditions and low stream flow (Figure 2-23). Only six brook trout were present, including no age-0 fish (Figure 2-23).

Total trout biomass at the Briar Creek monitoring station generally declined from the late 1990s through 2013 in conjunction with the previously-mentioned droughts during that time (Figure 2-24). Following the improvement to 32 kg/ha in 2014, biomass declined again to 26 kg/ha in 2015 and 19 kg/ha in 2016 (Figure 2-24), with the 2016 estimate now below the long-term average for this site (25 kg/ha).

Brook trout relative abundance (biomass) generally increased at the Briar Creek monitoring station during 1997-2002, exceeding 50% during the drought years of 1998-2002 (Figure 2-24). However, it has generally declined since then, falling to 12% in 2010 and 14% in 2016 (Figure 2-24). Given its persistence over the past three decades, this brook trout population is obviously resilient and has been capable of withstanding a combination of environmental and competitive challenges.

Management Recommendations

Upper Briar Creek typically supports a good wild trout fishery featuring brook trout except when reduced by droughts. Fortunately, wild trout populations (particularly brook trout in Briar Creek) tend to be resilient and this fishery will likely recover from recent drought-related impacts. Annual sampling at the monitoring station should continue in order to learn more about brook and rainbow trout populations under sympatric conditions, particularly their responses to abiotic events (droughts and floods). No efforts to remove rainbow trout or enhance brook trout should occur in upper Briar Creek while this monitoring is underway so that only natural processes can be studied.

The culvert at the upper road crossing (FR 188) has a perched downstream lip and is currently being replaced by the USFS with a new structure that will improve connectivity with the brook trout population upstream. Brook trout were more abundant in the vicinity of this culvert (elevation ~731 m or 2,400') than they were downstream at the monitoring station during sampling to collect DNA samples in 2016 (and age-0 fish were present).

Briar Creek Monitoring Station

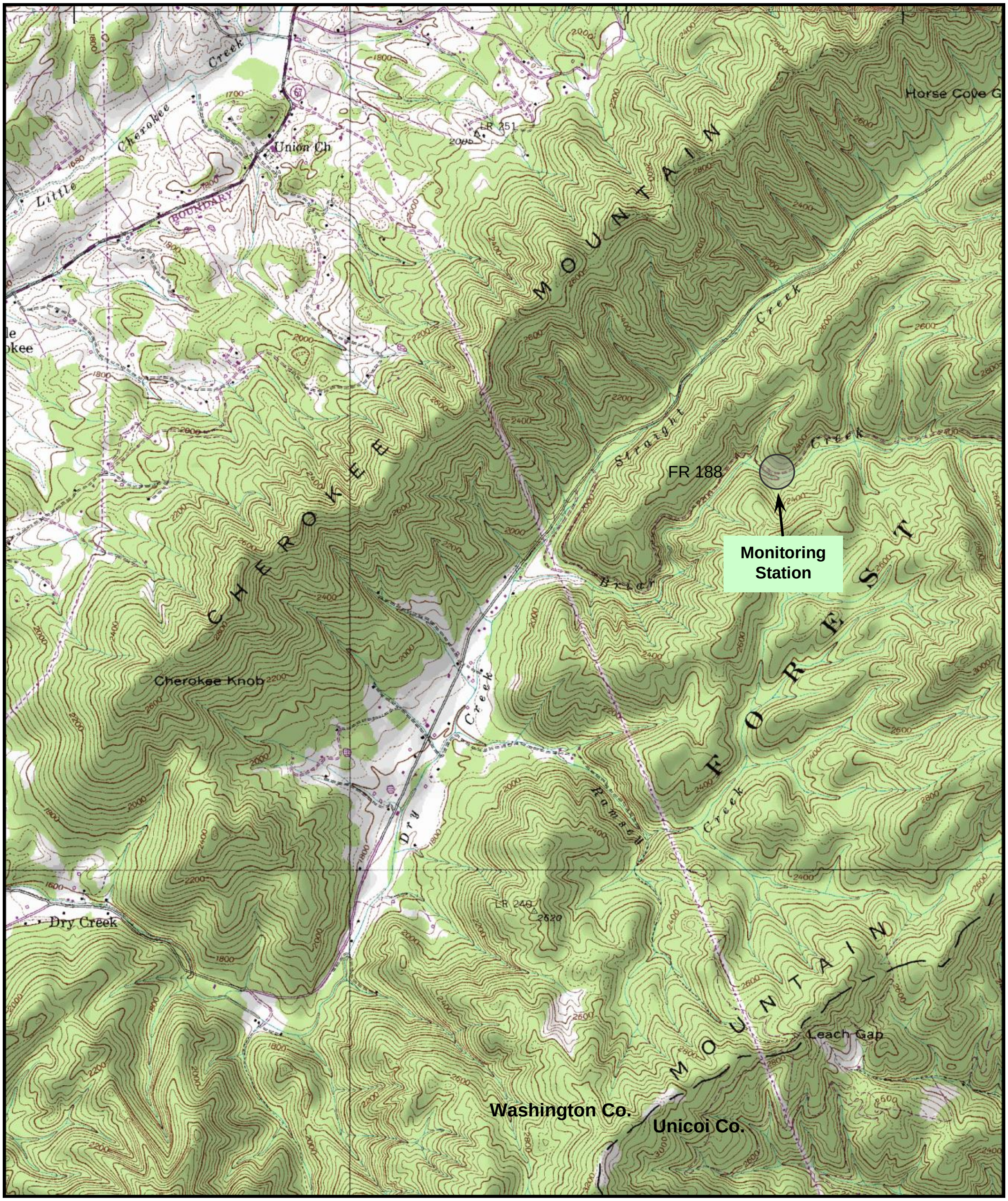


Figure 2-22. Location of the long-term monitoring station in the brook/rainbow trout sympatric zone on Briar Creek.

Table 2-16. Site and sampling information for Briar Creek in 2016.

Location	**Station 1**	
Site code	420162001	
Sample date	1 August	
Watershed	Nolichucky River	
County	Washington	
Quadrangle	Erwin 199 NW	
Lat-Long	36.22825 N, -82.38883 W	
Reach number	06010108	
Elevation (ft)	2,200	
Stream order	3	
Land ownership	USFS	
Fishing access	Good	
Description	This site is located along the adjacent road (USFS 188). The lower end is marked with a tag on a hemlock on the right descending stream bank.	
Effort		
Station length (m)	145	
Sample area (m²)	435	
Personnel	4	
Electrofishing units	1	
Voltage (AC)	450	
Removal passes	3	
Habitat		
Mean width (m)	3.0	
Maximum depth (cm)	80	
Canopy cover (%)	85	
Aquatic vegetation	scarce	
Estimated % of site in pools	34	
Estimated % of site in riffles	66	
Habitat assessment score	155 (suboptimal)	
Substrate Composition	**Pool (%)**	**Riffle (%)**
Silt		
Sand	15	5
Gravel	40	35
Rubble	30	45
Boulder	10	15
Bedrock	5	
Water Quality		
Flow (cfs; visual)	N/M; low	
Temperature (C)	20.0	
pH	6.9	
Conductivity (µS/cm)	36	
Dissolved oxygen (mg/L)	N/M	
Alkalinity (mg/L $CaCO_3$)	25	

Table 2-17. Fish population abundance estimates (with 95% confidence limits) for the monitoring station on Briar Creek sampled 1 August 2016.

		Population Size			Est.	Mean	Biomass (kg/ha)			Density (fish/ha)		
Species	Total Catch	Est.	Lower C.L.	Upper C.L.	Weight (g)	Fish Wt. (g)	Est.	Lower C.L.	Upper C.L.	Est.	Lower C.L.	Upper C.L.
RBT ≤90 mm	32	33	32	36	93	2.8	2.13	2.06	2.32	759	736	828
RBT >90 mm	26	26	26	27	631	24.3	14.51	14.51	15.08	598	598	621
BKT >90 mm	6	6	6	6	116	19.3	2.67	2.67	2.66	138	138	138
Blacknose dace	332	335	332	339	270	0.8	6.22	6.11	6.23	7,701	7,632	7,793
Totals	**396**	**400**	**396**	**408**	**1,110**		**25.53**	**25.35**	**26.29**	**9,196**	**9,104**	**9,380**

Note: RBT = rainbow trout and BKT = brook trout.

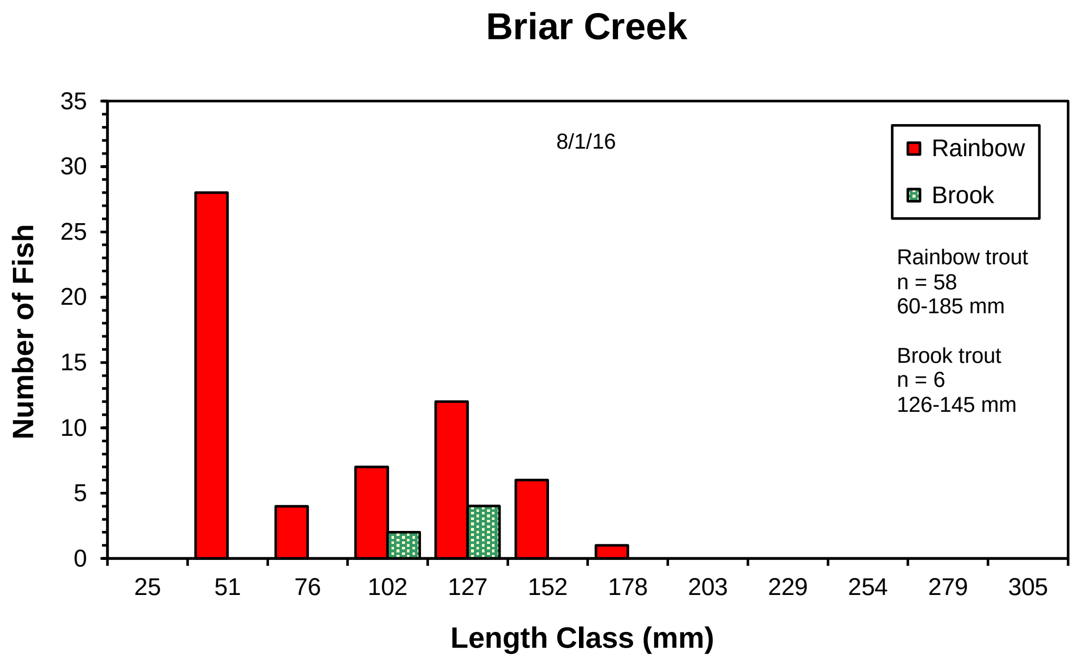


Figure 2-23. Length frequency distributions for brook and rainbow trout from the 2016 Briar Creek sample.

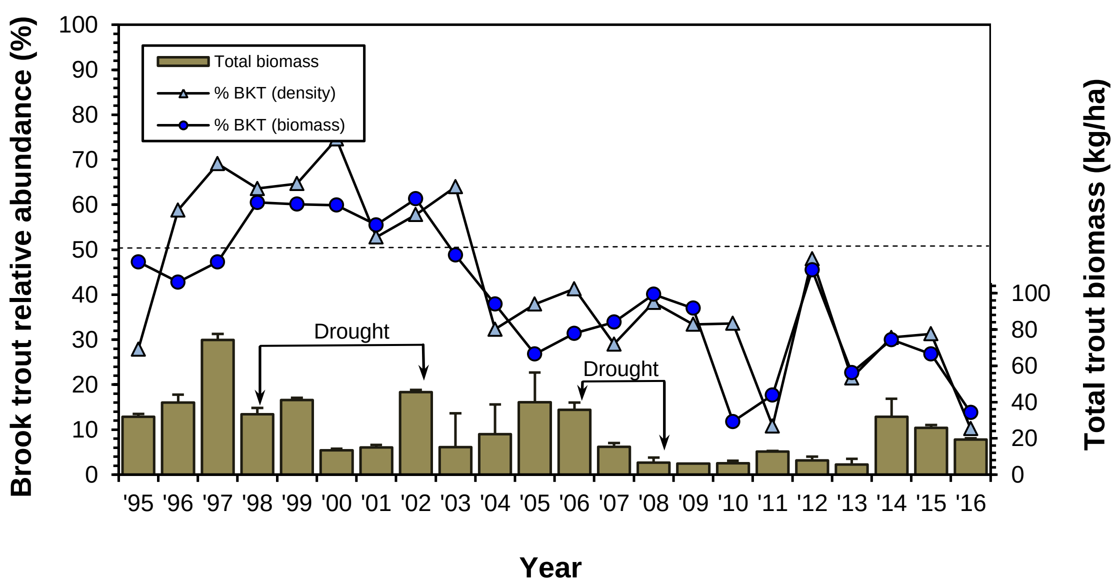


Figure 2-24. Total biomass and relative brook trout abundance at the Briar Creek monitoring station. Bars indicate upper 95% confidence limits.

2.3.2 Rocky Fork

Study Area

Rocky Fork is a tributary of South Indian Creek in the Nolichucky River basin and is located in Greene and Unicoi counties. Most of the 4,000 ha (10,000 acre) tract containing Rocky Fork and its tributaries is now owned by the USFS. About 800 ha (2,000 acres) in the lower portion of the watershed comprises Rocky Fork State Park. The watershed is mountainous and forested, with some recent (although relatively limited) logging activity. The middle and lower reaches of Rocky Fork support an excellent wild rainbow trout population. The upper portion (~3.8 km above an elevation of 881 m or 2,890') has both brook and rainbow trout. Three tributaries (Blockstand Creek, Broad Branch, and Fort Davie Creek) provide another 2.3 km of brook trout water, but all four populations are substantially introgressed with genes from hatchery (“northern”) fish introduced over the years (Strange and Habera 1997). Brook trout DNA samples from Rocky Fork and the three tributaries were collected in 2016 to upgrade the current genetic information available for these populations (Section 2.4).

Shields (1950) noted that rainbow trout growth and production in Rocky Fork was quite good and described the portion from Fort Davie Creek downstream (12.9 km) as carrying a large crop of fish. He also indicated that upper Rocky Fork, Fort Davie Creek, and Blockstand Creek carried large populations of small brook trout. All subsequent surveys of upper Rocky Fork during the 1960s and 1970s (reviewed by Bivens 1984) documented the presence of excellent brook trout populations, along with wild rainbow trout.

Rocky Fork was intensively managed as a put-and-take fishery with hatchery-produced rainbow and brook trout for many years (Bivens et al. 1998). Later, (1988-1990), Rocky Fork was managed under a 229-mm minimum length limit, three-fish creel limit, and single-hook, artificial-lures-only restriction to emphasize the wild trout fishery. These regulations were modified in 1991 to focus harvest on rainbow trout by removing their size limit and raising the creel limit to seven fish (including only three brook trout). The 152-mm statewide size limit for brook trout was removed and the creel limit was increased to five fish in 2013 as part of the revision of special wild trout regulations to align them more closely with the biological characteristics of these populations.

TWRA qualitatively sampled Rocky Fork in the 1980s (Bivens 1989; Bivens and Williams 1990). Quantitative sampling began in 1991 when two long-term monitoring stations (Figure 2-1, Section 2.2.1) were established. These stations have been sampled annually since 1991, except for Station 1 in 2012 (high flow). Site location and effort details, along with habitat and water quality information are summarized in Table 2-2 (Section 2.2.1).

Results and Discussion

Catch data and abundance estimates for trout sampled at Station 2 on Rocky Fork in 2016 are given in Table 2-3 (Section 2.2.1). The density of both rainbow and brook trout adults (>90 mm) increased at Station 2 relative to 2015 (Figure 2-2, Section 2.2.1), thus the total biomass estimate also increased (Figure 2-2; Section 2.2.1). Brook trout density and biomass increases in particular at Station 2 were evidence of good recruitment from the strong 2015 cohort. Total trout biomass remained below the long-term average at Station 2 in 2015 (Figure 2-2; Section 2.2.1).

Rainbow trout are typically more abundant than brook trout in the larger size classes (≥178 mm), but this was not the case at Station 2 in 2016 (Figure 2-25). Nagel and Deaton (1989) questioned the size advantage rainbow trout were thought to hold over brook trout in Rocky Fork's headwaters (Whitworth and Strange 1983) and elsewhere. However, monitoring data from Rocky Fork and other streams have generally verified the tendency of rainbow trout to grow larger than brook trout in a variety of sympatric situations. This advantage may be lost at times during droughts such as in 2008 (Habera et al. 2009a) and 2016, when survival and recruitment appear to be impacted more for rainbow trout than for brook trout.

Brook trout relative abundance (biomass) was quite stable at about 40% from 1991 through 1993, but declined rapidly after the flood in early 1994 (Figure 2-26) and associated brook trout year-class failure (Strange and Habera 1995). Brook trout relative abundance recovered to the pre-flood level in 1996, then surpassed 50% in 2000 and 60% in 2001 (Figure 2-26) during the dry years of 1998-2002 (Habera et al. 2003). Brook trout relative abundance (biomass) generally increased again with the next drought, surpassing 60% in 2015 and 2016 (Figure 2-26). In fact, brook trout relative abundance (biomass) in 2015 and 2016 was the highest observed during the 26 years this station has been monitored. Consequently, it is clearly evident in Rocky Fork (and elsewhere) that brook trout can exist—and even thrive—in sympatry with rainbow trout for long periods of time. Brook trout appear to be favored during droughts in the sense that competitive pressure is reduced as rainbow trout are more markedly impacted. However, cumulative drought effects on recruitment may reach a level where the abundance of both species is reduced to the point that relative abundance percentages have little meaning. This occurred in Briar Creek in 2009-2011 (Section 2.3.1), Rocky Fork in 2010, and Birch Branch in 2008-2010 (Section 2.3.3).

Management Recommendations

Upper Rocky Fork continues to provide an example of the resiliency of wild trout populations (particularly brook trout) in southern Appalachian streams. Despite large reductions in abundance related to droughts and floods, the brook trout population has demonstrated the ability to recover, even in the presence of rainbow trout. Future management should protect and emphasize this important fishery. Annual monitoring should continue at Station 2 to further develop our understanding of sympatric brook and rainbow trout interactions and assess the ability of rainbows to replace brook trout over time. It is recommended that no efforts to remove rainbow trout or enhance brook trout be initiated in upper Rocky Fork while this monitoring is underway so that only natural processes can be studied.

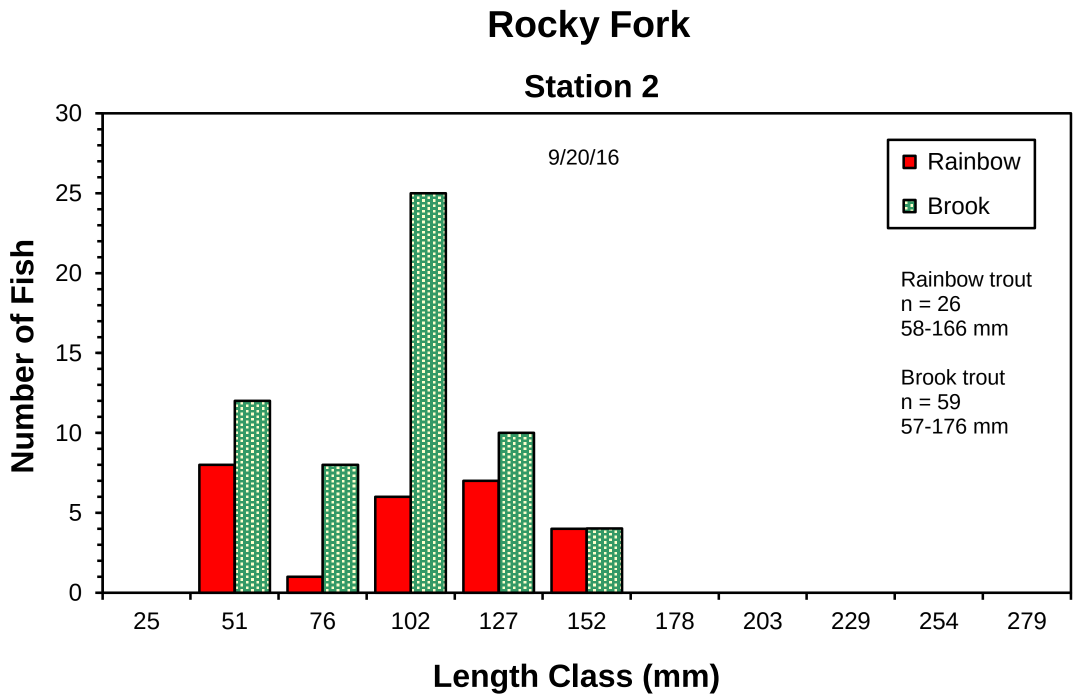


Figure 2-25. Length frequency distributions for brook and rainbow trout from the 2016 sample at the upper monitoring station (2) on Rocky Fork.

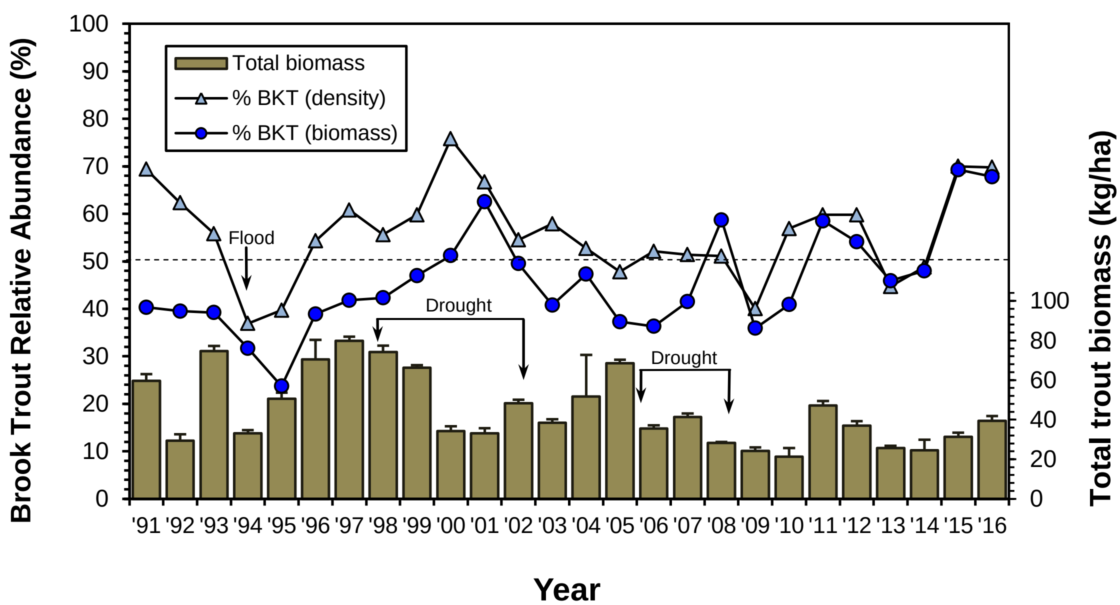


Figure 2-26. Total biomass and relative brook trout abundance at the upper monitoring station (2) on Rocky Fork. Bars indicate upper 95% confidence limits.

2.3.3 Birch Branch

Study Area

Birch Branch is a Beaverdam Creek tributary in Johnson County that flows through a mountainous, forested watershed primarily within the CNF (the lower 0.8 km is on private land). It contains 4.6 km of native, southern Appalachian brook trout water beginning at an elevation of 779 m (2,555'). Wild rainbow trout are sympatric with brook trout in the lower half of this distribution (Bivens et al. 1985), and some brown trout are also occasionally present, particularly near the confluence with Beaverdam Creek. Birch Branch is subject to general, statewide trout angling regulations.

Birch Branch was surveyed by TWRA (1960s) and the USFS (1970s) to document the presence of brook trout (Bivens 1984) and later, Bivens (1984) recommended construction of a barrier in the lower portion of the stream and removal of the encroaching rainbow trout. However, this was not done, providing an opportunity to monitor brook and rainbow trout population trends in the sympatric zone. A station at 872 m (2,860') containing 97% brook trout was quantitatively sampled in 1991 (Strange and Habera 1992), then a site further downstream (at 823 m or 2,700'; Figure 2-27) was established as a monitoring station in 1995 (Strange and Habera 1996). Sample site location and effort details, along with habitat and water quality information are summarized in Table 2-18.

Results and Discussion

Catch data and abundance estimates for trout sampled at the Birch Branch station in 2016 are given in Table 2-19. Recruitment has typically been depressed in Birch Branch, with few (<10) adult trout ≥127 mm present during recent years. It was only slightly better in 2016, with five rainbow trout and eight brook trout ≥127 mm present (Figure 2-28), despite the relatively abundant 2015 cohorts. This was enough, however, to increase total trout biomass for 2016 (15 kg/ha) above the long-term average of 13 kg/ha (Figure 2-29).

Brook trout relative abundance in terms of biomass generally increased from about 30% in 1995 to over 70% in 2002, with much of the change occurring during the 1998-2002 drought (Figure 2-29). Since then, brook trout relative abundance (biomass) has generally declined, although it has remained near or above 50% since 2010 (Figure 2-29).

Management Recommendations

The wild trout fishery in Birch Branch is not particularly noteworthy, although it does include native, southern Appalachian brook trout and is one of 12 Beaverdam Creek tributaries supporting brook trout populations. Brook trout DNA samples from Birch Branch and two other Beaverdam tributaries were collected in 2016 to upgrade the current genetic information available for these populations (Section 2.4). Continued monitoring at the Birch Branch will help further our understanding of brook and rainbow trout interactions in sympatry and evaluate the ability of rainbows to replace brook trout. It is recommended that no efforts to remove rainbow trout or enhance brook trout be undertaken in Birch Branch while this monitoring is underway so that only natural processes can be studied.

Birch Branch Monitoring Station

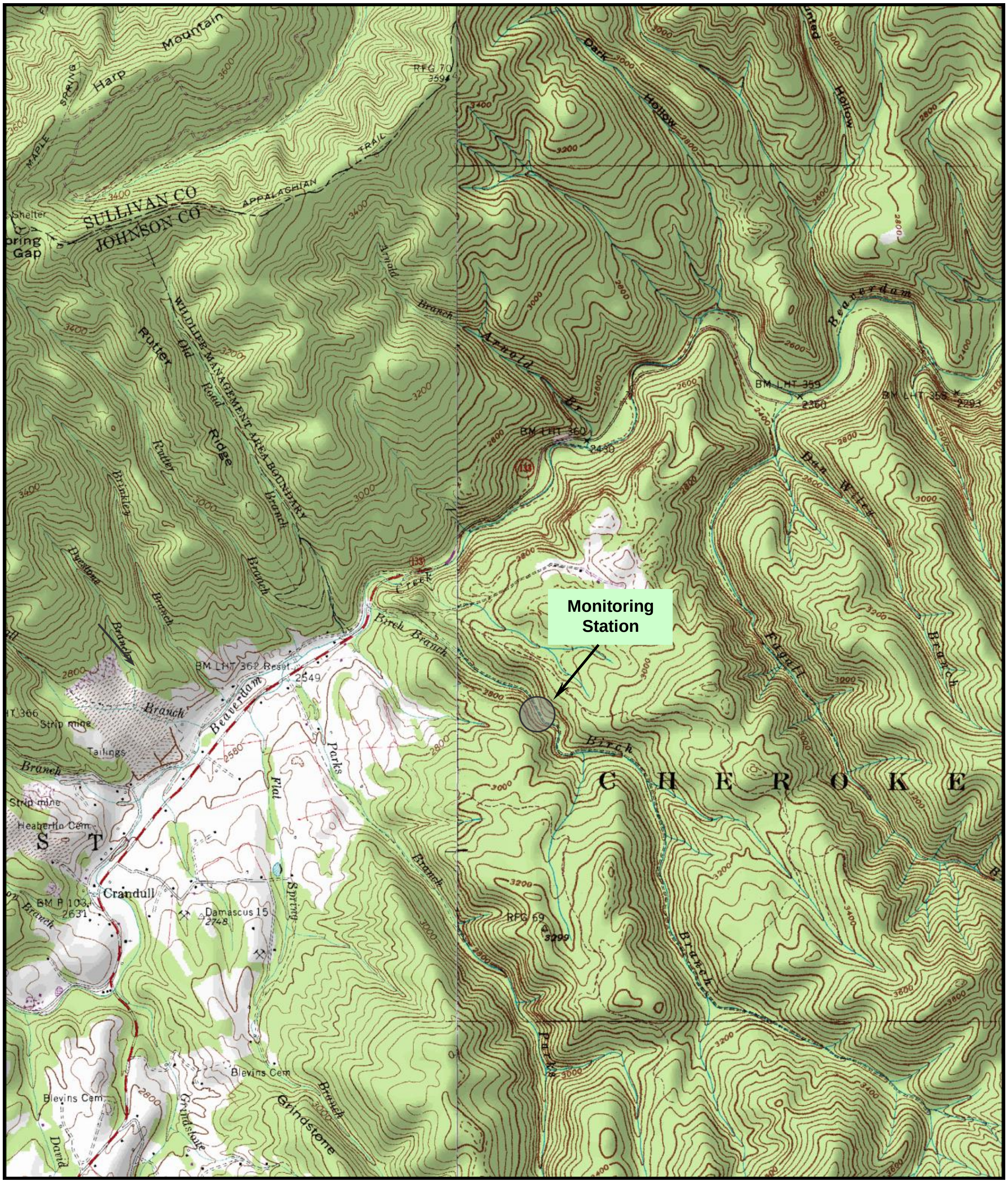


Figure 2-27. Location of the long-term monitoring station in the brook/rainbow trout sympatric zone on Birch Branch.

Table 2-18. Site and sampling information for Birch Branch in 2016.

Location	Station 1
Site code	420161901
Sample date	25 July
Watershed	S. Fork Holston River
County	Johnson
Quadrangle	Laurel Bloomery 213 SE
Lat-Long	36.55629 N, -81.86941 W
Reach number	06010102
Elevation (ft)	2,700
Stream order	2
Land ownership	Private
Fishing access	Good
Description	This monitoring station ends at the USFS boundary markers (at first trail crossing).

Effort	
Station length (m)	144
Sample area (m²)	446
Personnel	2
Electrofishing units	1
Voltage (AC)	500
Removal passes	3

Habitat	
Mean width (m)	3.1
Maximum depth (cm)	100
Canopy cover (%)	95
Aquatic vegetation	scarce
Estimated % of site in pools	34
Estimated % of site in riffles	66
Habitat assessment score	157 (suboptimal)

Substrate Composition	Pool (%)	Riffle (%)
Silt	5	
Sand	10	5
Gravel	30	25
Rubble	40	50
Boulder	15	20
Bedrock		

Water Quality	
Flow (cfs; visual)	N/M; low
Temperature (C)	18.7
pH	6.7
Conductivity (µS/cm)	11
Dissolved oxygen (mg/L)	N/M
Alkalinity (mg/L $CaCO_3$)	10

Table 2-19. Fish population abundance estimates (with 95% confidence limits) for the monitoring station on Birch Branch sampled 25 July 2016.

		Population Size			Est.	Mean	Biomass (kg/ha)			Density (fish/ha)		
Species	Total Catch	Est.	Lower C.L.	Upper C.L.	Weight (g)	Fish Wt. (g)	Est.	Lower C.L.	Upper C.L.	Est.	Lower C.L.	Upper C.L.
RBT ≤90 mm	50	57	56	68	93	1.6	2.09	2.01	2.44	1,278	1,256	1,525
RBT >90 mm	10	10	10	13	210	21.0	4.71	4.71	6.12	224	224	291
BKT ≤90 mm	5	5	5	6	16	3.2	0.36	0.36	0.43	112	112	135
BKT >90 mm	18	18	18	19	350	19.4	7.85	7.85	8.26	404	404	426
Totals	**83**	**90**	**89**	**106**	**669**		**15.01**	**14.93**	**17.25**	**2,018**	**1,996**	**2,377**

Note: RBT = rainbow trout; BKT = brook trout

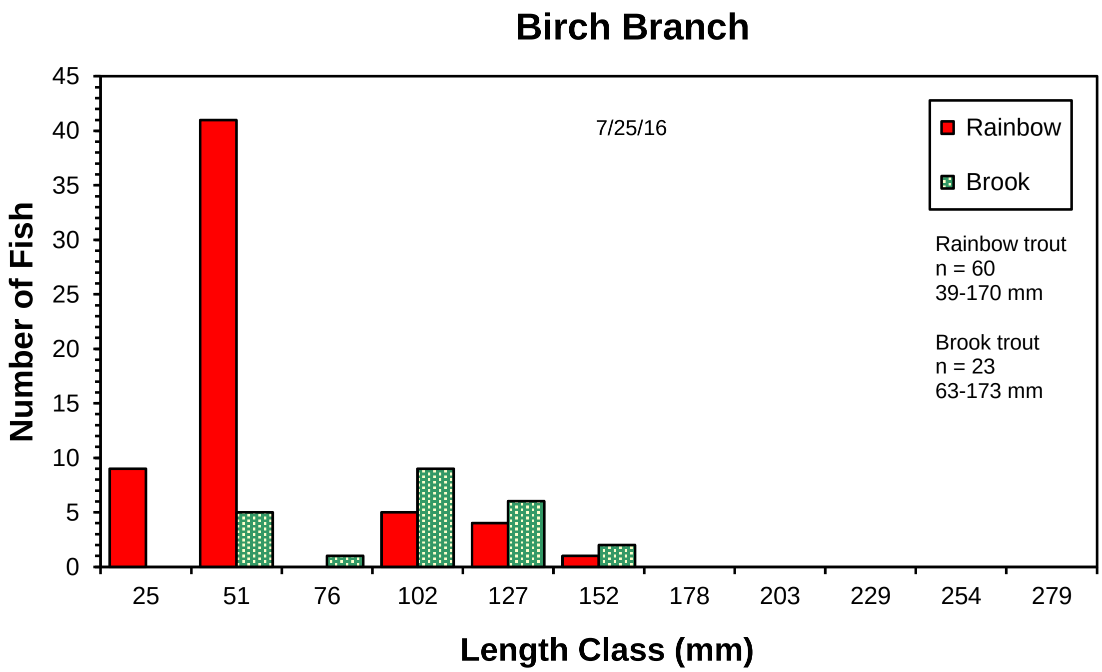


Figure 2-28. Length frequency distributions for brook and rainbow trout from the 2016 Birch Branch sample.

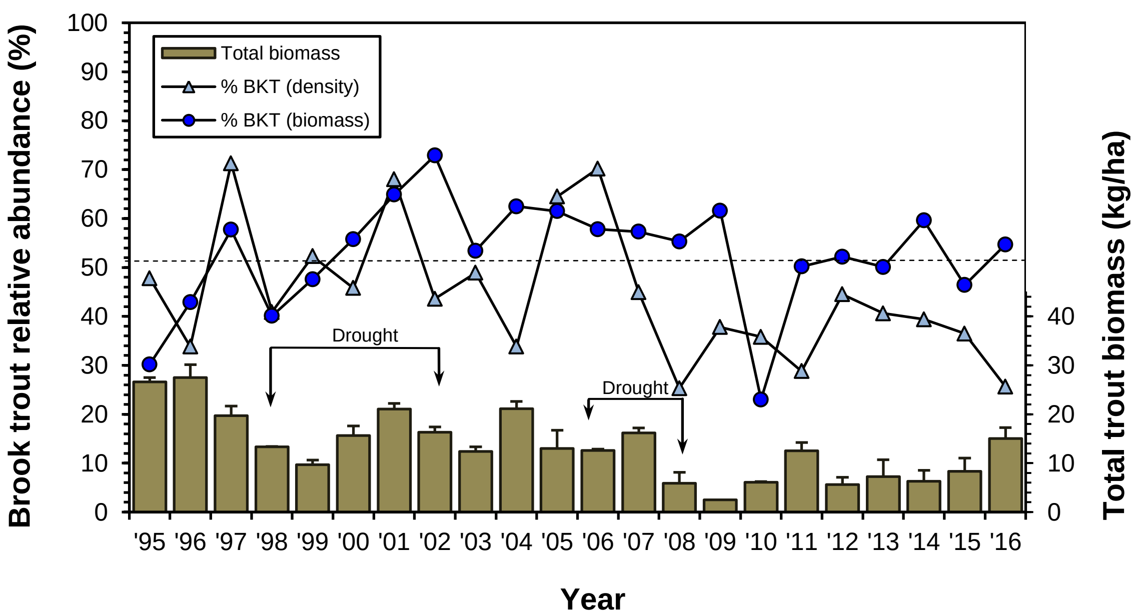


Figure 2-29. Total biomass and relative brook trout abundance at the Birch Branch monitoring station. Bars indicate upper 95% confidence limits.

2.3.4 Gentry Creek

Study Area

Gentry Creek is a tributary of Laurel Creek in Johnson County and flows through a mountainous, forested watershed primarily within the CNF. It has about 8 km of brook trout distribution beginning at 768 m (2,520') elevation. Allopatric, southern Appalachian brook trout inhabit the stream above a large two-tiered falls at about 1,024 m (3,360'). Below the falls is a 5.8-km section containing both brook and rainbow trout. Downstream of that reach (to the confluence with Laurel Creek), rainbow trout predominate, although some brown trout are also present. Four Gentry Creek tributaries (Grindstone Branch, Cut Laurel Branch, Kate Branch, and Gilbert Branch) provide another 6.8 km of native, southern Appalachian brook trout water. Brook trout DNA samples from Gentry Creek (including upstream of the falls) and the four tributary populations were collected in 2016 to upgrade current genetic information (based on allozymes). The entire watershed is currently under general statewide trout angling regulations.

This large waterfall on upper Gentry Creek limits the upstream distribution of rainbow trout.

Gentry Creek was surveyed by TWRA in the 1960s and by the USFS in the 1970s to document the presence of brook trout (reviewed by Bivens 1984). Bivens (1984) recommended that a barrier be constructed below Grindstone Branch and rainbow trout removed from the area upstream. No action has been taken to date, thus providing an opportunity to monitor trout population trends in the sympatric zone. A station at 963 m elevation (3,160') in the sympatric zone was sampled in 1992 (Figure 2-30; Strange and Habera 1993) and was added to the annual monitoring program in 1996. Sample site location and effort details, along with habitat and water quality information are summarized in Table 2-20.

Results and Discussion

Catch data and abundance estimates for trout and other species sampled at the Gentry Creek station in 2016 are given in Table 2-21. The 2016 brook trout cohort was relatively strong (Figure 2-31) as in 2015; however, recruitment from the 2015 cohort declined, as the catch for the 102- and 127-mm size classes dropped from 23 (2015) to 12 (Figure 2-31). Brook trout biomass and total trout biomass decreased again in 2016 (30% relative to 2015; Figure 2-31) but both (20 kg/ha; 27 kg/ha) are near the corresponding long-term averages (21 kg/ha; 28 kg/ha). A brown trout (154 mm) was captured for the first time in this part of Gentry Creek.

Floods can alter species composition in favor of rainbow trout where they occur sympatrically with brook trout (Seegrist and Gard 1972; Nagel 1991; Warren et al. 2009). This occurred in Gentry Creek as trout abundance changed from predominantly brook trout to predominantly rainbow trout after two floods during 1992-1994 (Figure 2-32). Droughts can have the opposite effect, however, as brook trout relative abundance (biomass) exceeded 90% in 2002 following low flows during 1998-2002 (Figure 2-32). As more normal flows returned after 2002, rainbow trout recovered and brook trout relative abundance began a general decline similar to that observed in Briar Creek, Rocky Fork, and Birch Branch. Brook trout relative abundance increased again as drought conditions resumed in 2006, reaching 100% in 2009 (Figure 2-32). Some age-0 rainbow trout were present near the monitoring station in 2009, however, since yearlings were captured in 2010. Relative brook trout abundance (biomass) has trended downward somewhat since 2009, but remained above 75% in 2016 (Figure 2-32). Clearly, Gentry Creek's brook trout, like those in the other monitoring streams, are capable of long-term coexistence with rainbow trout and competition from rainbows can be substantially diminished during droughts.

Management Recommendations

Gentry Creek supports a quality wild trout fishery featuring brook trout that management should maintain and emphasize. Continued monitoring at the Gentry Creek station will be important to further understand brook and rainbow trout interactions in sympatry (particularly their responses to droughts and floods) and to evaluate the ability of rainbows to replace brook trout. It is recommended that no efforts to remove rainbow trout or enhance brook trout be initiated in Gentry Creek while this monitoring is underway so that only natural processes can be studied.

A native, Southern Appalachian brook trout from upper Gentry Creek.

Gentry Creek is part of the multi-agency TEARS-AM (Tennessee's Ecologically At-Risk Streams—Appalachian Mountains) project to obtain baseline chemical, physical and biological data on streams with naturally-reproducing brook trout within the CNF and GSMNP. The project goal is to investigate global, regional and/or local influences on stream health such as climate change and atmospheric deposition of mercury. Food chain dynamics are being assessed by examining contaminant concentrations and stable isotopes of carbon and nitrogen in seven matrices: sediment, periphyton, emergent insects, crayfish, salamanders, eastern brook trout, and tetragnathid spiders.

Gentry Creek Monitoring Station

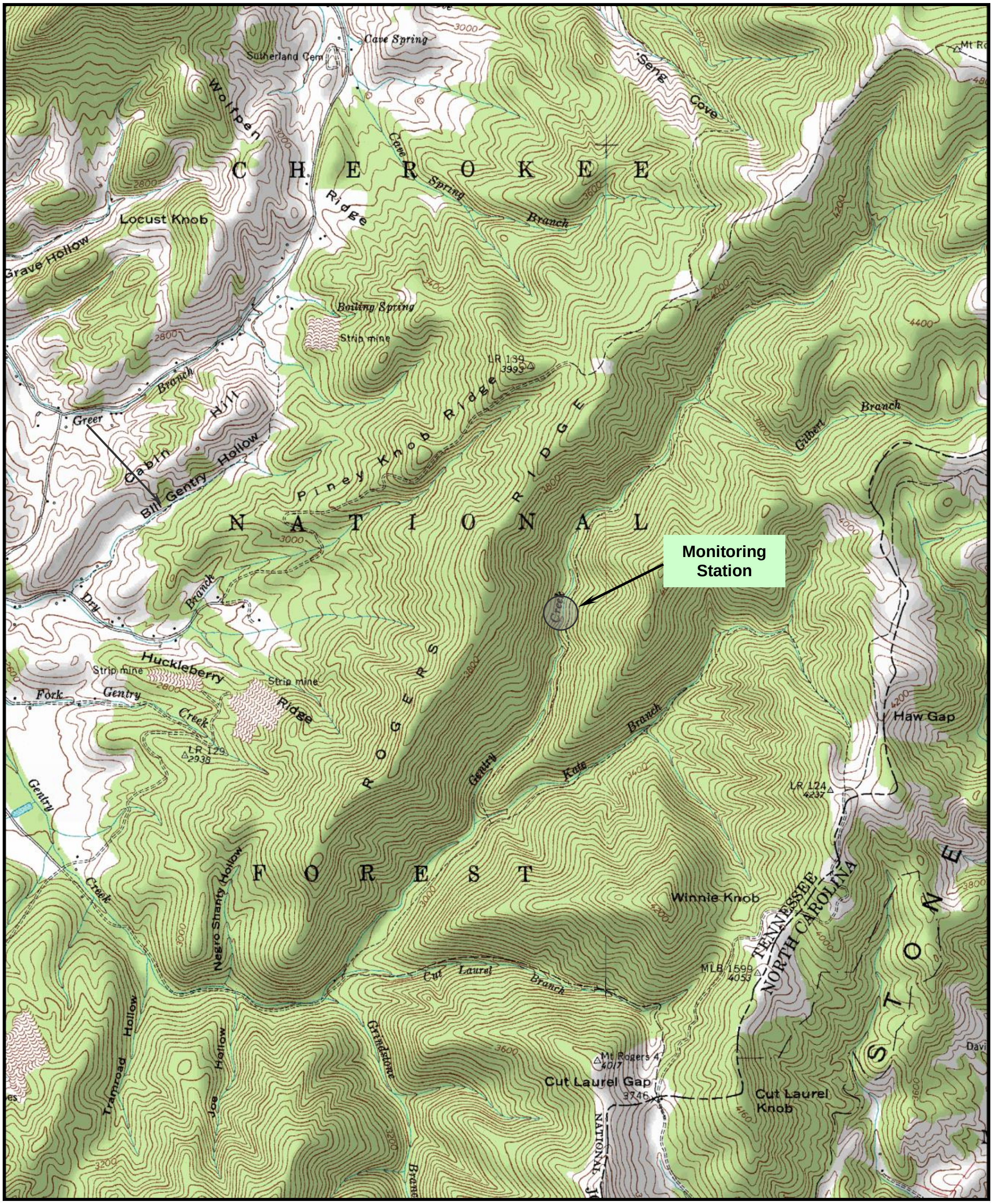


Figure 2-30. Location of the long-term monitoring station in the brook/rainbow trout sympatric zone on Gentry Creek.

Table 2-20. Site and sampling information for Gentry Creek in 2016.

Location	Station 1	
Site code	420161701	
Sample date	21 June	
Watershed	S. Fork Holston River	
County	Johnson	
Quadrangle	Grayson 219 SW	
Lat-Long	36.55928 N, -81.71131 W	
Reach number	06010102-27,0	
Elevation (ft)	3,180	
Stream order	2	
Land ownership	USFS	
Fishing access	Excellent	
Description	This monitoring station ends at the eighth crossing by the adjacent trail (beginning at the parking area near Cut Laurel Branch).	
Effort		
Station length (m)	122	
Sample area (m²)	354	
Personnel	2	
Electrofishing units	1	
Voltage (AC)	400	
Removal passes	3	
Habitat		
Mean width (m)	2.9	
Maximum depth (cm)	N/M	
Canopy cover (%)	90	
Aquatic vegetation	scarce	
Estimated % of site in pools	37	
Estimated % of site in riffles	63	
Habitat assessment score	166 (optimal)	
Substrate Composition	**Pool (%)**	**Riffle (%)**
Silt	5	5
Sand	15	30
Gravel	35	40
Rubble	25	20
Boulder	15	5
Bedrock	5	
Water Quality		
Flow (cfs; visual)	N/M; low	
Temperature (C)	14.5	
pH	6.7	
Conductivity (µS/cm)	N/M	
Dissolved oxygen (mg/L)	N/M	
Alkalinity (mg/L $CaCO_3$)	N/M	

Table 2-21. Fish population abundance estimates (with 95% confidence limits) for the monitoring station on Gentry Creek sampled 21 June 2016.

Species	Total Catch	Population Size Est.	Population Size Lower C.L.	Population Size Upper C.L.	Est. Weight (g)	Mean Fish Wt. (g)	Biomass (kg/ha) Est.	Biomass (kg/ha) Lower C.L.	Biomass (kg/ha) Upper C.L.	Density (fish/ha) Est.	Density (fish/ha) Lower C.L.	Density (fish/ha) Upper C.L.
RBT ≤90 mm	7	7	7	10	8	1.1	0.21	0.21	0.31	198	198	282
RBT >90 mm	4	4	4	4	188	46.9	5.30	5.30	5.30	113	113	113
BKT ≤90 mm	21	21	21	23	64	3.1	1.82	1.82	2.01	593	593	650
BKT >90 mm	25	25	25	27	651	26.0	18.39	18.39	19.83	706	706	763
BNT >90 mm	1	1	1	1	32	32.0	0.90	0.90	0.90	28	28	28
Mottled sculpin	30	37	30	52	216	5.8	6.10	4.92	8.52	1,045	847	1,469
Totals	**88**	**95**	**88**	**117**	**1,159**		**32.72**	**31.54**	**36.87**	**2,683**	**2,485**	**3,305**

Note: RBT = rainbow trout; BKT = brook trout; BNT = brown trout.

Gentry Creek

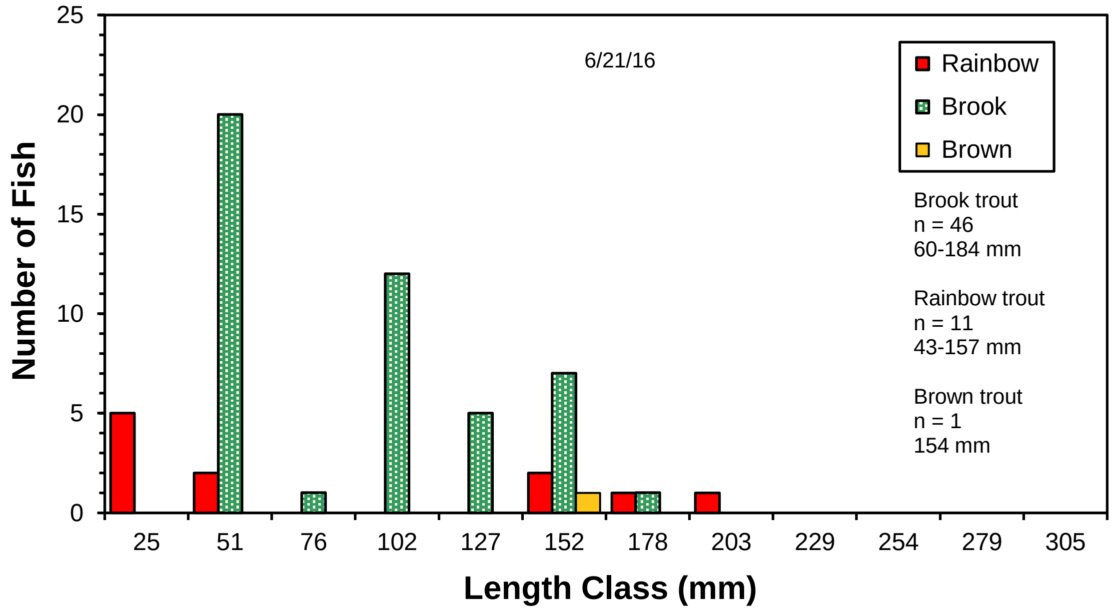


Figure 2-31. Length frequency distributions for brook and rainbow trout from the 2016 Gentry Creek sample.

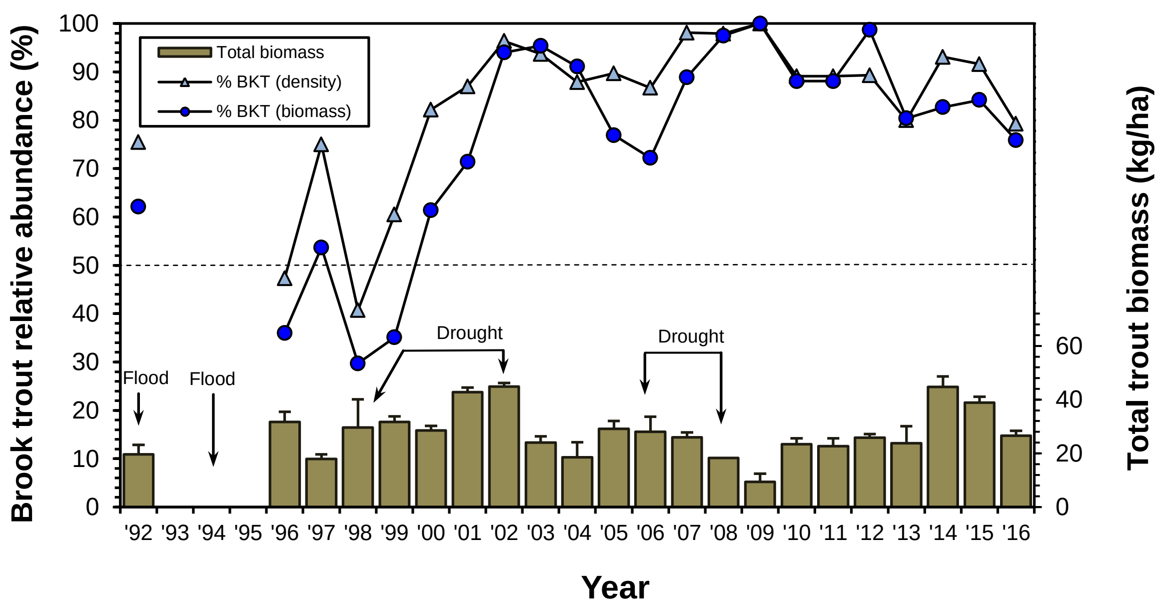


Figure 2-32. Total biomass and relative brook trout abundance at the Gentry Creek monitoring station. Bars indicate upper 95% confidence limits.

2.3.5 Summary

Nagel (1991) predicted high extinction probabilities (56% for 2.5-km streams, 92% for 0.5-km streams) for small, isolated brook trout populations over 30-year periods with year class failures at 5-year intervals and no sympatric rainbow trout. Most brook trout year class failures would be flood-induced, but TWRA's monitoring indicates that such failures currently occur at average intervals of greater than 5 years. Consequently, the local extinction probabilities projected by Nagel (1991) have not been confirmed by Strange and Habera (1998), Habera et al. (2001a) or Habera et al. (2014a). Additionally, few recent (since 2000) brook trout population losses can be attributed to rainbow trout replacement (Habera et al. 2014a).

Clark and Rose (1997) may have been the first to recognize that conventional theory—a niche shift induced by the presence of a superior competitor—did not explain replacement of brook trout by rainbow trout. Their modeling emphasized the importance of year-class failures (e.g., those caused by floods), but predicted that rainbows would not replace brook trout if such failures occurred infrequently (intervals of 10-20 years). Even with much more frequent year-class failures (3-year intervals), it still required 80 years for a simulated brook trout population to be eliminated. Simulated year-class failures included both species, even though typical late-winter/early-spring floods could impact year-class strength of brook trout (fall spawners) much more severely than rainbow trout (Strange and Habera 1995, 1996; Warren et al. 2009). Additionally, these and subsequent (Clark et al. 2001) model simulations did not include droughts, which can be frequent and are clearly more detrimental to rainbow trout survival and recruitment in sympatric Tennessee populations. However, both floods and droughts would be expected to occur over several decades and their effects on relative abundance can be offsetting.

Larson et al. (1995) observed rainbow trout density fluctuations over a 14-year period (including a large flood) and while rainbows occasionally displaced sympatric brook trout as the most abundant species, they never eliminated them. Adams et al. (2002) observed similar results for invading populations of nonnative brook trout in Idaho trout streams. However, larger and longer-lived brown trout have been shown to limit brook trout growth, recruitment, and abundance (Hoxmeier and Dieterman 2013; 2016) or essentially replace them (Waters 1999) in Minnesota streams. Complete replacement of brook trout by rainbows in Tennessee streams might be possible only through unusual circumstances, such as a succession of late winter/early spring floods that severely weaken or eliminate multiple brook trout year classes. Conversely, data from all four monitoring streams indicate that droughts (particularly 1998-2002 and 2006-2008) can offset brook trout declines related to previous floods by reducing rainbow trout relative abundance. Extended drought, however, may eliminate brook trout populations in marginal habitats regardless of the presence of any sympatric salmonids (Habera et al. 2014a).

Although brook trout relative abundance has fluctuated over the years at the monitoring stations, it appears that rainbow trout have no particular competitive advantage, thus these species can coexist for many years at some general equilibrium. Strange and Habera (1998) and Habera et al. (2001a; 2014a) found no broad-scale loss of distribution or inexorable replacement by rainbow trout in sympatric populations. Furthermore, brook trout have gained distribution (2 km or more in some cases) in the presence of rainbow trout in several streams since the 1990s (Habera et al. 2014a; Section 2.5). Additional monitoring data will be useful for identifying any conditions that may eventually enable rainbow trout to eliminate brook trout. These could include landscape alterations (Hudy et al. 2008; Stranko et al. 2008) and climate change (Trumbo et al. 2010; Myers et al. 2014; DeWeber and Wagner 2015). Interestingly, Trumbo et al. (2010) found that their direct measurement of paired air and water temperatures in Virginia identified more brook trout watersheds that would be resistant to predicted air temperature increases—and with potential refugia existing at lower elevations—than predicted by previous modelling. Additionally, Stitt et al. (2014) found that among brook trout strains, thermal tolerance was highest for the one with the most southern ancestry. Verhille et al. (2016) observed the same characteristic for wild rainbow trout at the southern limit of distribution within their native range. This would potentially provide brook trout additional flexibility for adjusting to changing climatic conditions and some resistance to replacement by rainbow trout in thermally stressed environments. In mainstem habitats, competition for thermal refugia, rather than food, is likely more important for brook trout and would be heightened under current climate change scenarios, especially in the presence of exotic salmonids (Huntsman and Petty 2014).

2.4 BROOK TROUT DNA SAMPLE COLLECTION

Tennessee's Current Allozyme-based Brook Trout Genetics Information

Genetic information (primarily origin) for most of Tennessee's brook trout populations is currently based on samples collected during the 1990s and analyzed by allozyme electrophoresis (Kriegler et al. 1995; Saidak 1995). Populations were surveyed for eight muscle tissue enzymes encoded by 17 presumptive loci (Kriegler et al. 1995), with frequencies for the two alleles at one creatine kinase locus (*CK-A2*100* and *CK-A2*78)* being generally considered diagnostic for identifying native southern Appalachian, hatchery-derived, and mixed populations. Just over half (53%) of the 106 brook trout populations recognized by end of the 1990s were considered to be of native, southern Appalachian origin based allozyme data (Habera et al. 2001a). Genetic distance indices based on these data indicated that there was structuring among the native populations based on geographic location—especially north and south of the French Broad River (Kriegler et al. 1995). Additionally, substantial genetic diversity was observed among populations within watersheds, as well as among watersheds (Kriegler et al. 1995). All of this information has guided brook trout management during the past two decades (particularly restoration and enhancement projects) in Tennessee and throughout the southern Appalachian region (Habera and Moore 2005).

Microsatellite DNA Analyses and Range-wide Brook Trout Population Genetics[1]

The single allozyme *CK-A2** marker, however, was based on only two hatchery strains and was not tested extensively in wild populations. Recently, microsatellite DNA analyses (King et al. 2012) of archived tissue samples from North Carolina brook trout initially genotyped with allozymes revealed classification errors. In particular, some populations classified as native with microsatellite markers were designated as being hatchery-influenced based on allozymes (primarily *CK-A2**). Brook trout genetic diversity characterization with microsatellite DNA involves 12 markers (loci) across 84 chromosomes (the most among any charr). These markers are selectively neutral or non-adaptive (not acted on by selection) and are best for phylogeographic and population-level differentiation, not taxonomic distinction. Range-wide, the number of associated alleles varies from 2-54 (mean = 21), permitting much finer resolution than allozymes.

Currently, 27,000 brook trout representing 850 collections from throughout their historic range have been genotyped using microsatellite DNA (including >8,000 from the southern Appalachian region). Additionally, 17 hatchery brook trout stains have also been analyzed. Results indicate that genotypes are more complex than northern vs. southern, and there is no clear evidence supporting a phylogeographic break at the New River (VA). Six clades are recognized: sea run, northern Atlantic Slope, St. Lawrence River/Great Lakes, upper interior basin (Ohio River), southern Atlantic Slope, and lower interior basin (Ohio River). The mid-Atlantic area is the zone of most allelic diversity (Hall et al. 2002), with diversity declining to the north (younger populations because of post-glacial recolonization) and south (isolation). Southern Atlantic Slope populations

[1] Details regarding microsatellite DNA analyses and range-wide results are from presentations by T. King (US Geological Survey Leetown Science Center lab) at the Southern Division American Fisheries Society Trout Committee meeting in Wheeling, WV (February 18, 2016) and the joint North Carolina Wildlife Resources Commission / TWRA Brook Trout Genetics conference in Asheville, NC (August 15, 2016).

are more similar to those from the lower interior basin than to those from the northern Atlantic Slope, potentially as a result of stream capture or translocation of fish. Northern Atlantic Slope brook trout were the source for most hatchery strains; their genetic profiles are now well known and their signal (outside northern Atlantic Slope watersheds) indicates stocking.

Overall brook trout allelic richness and heterozygosity are low to moderate, while heterogeneity is extremely high. Genetic differentiation or population subdivision (F_{ST}) is also high, even over relatively short geographic distances—to be expected given the fragmented occurrence patterns. Considerable "heritage diversity" remains, as most streams appear to have little to no hatchery influence. Kazyak et al. (2016) found evidence of a "cryptic metapopulation" in the Maryland system they studied: two adjoining tributary brook trout populations and the downstream main stem. They detected limited genetic exchange or physical movement between the tributaries, although fish from both streams used the mainstem. Metapopulations can be considered geographically and/or genetically structured subpopulations that are in contact but have migration rates insufficient to homogenize the entire group (Hastings and Harrison 1994). Kazyak et al. (2016) described a cryptic metapopulation as a spatially continuous distribution of organisms with metapopulation-like characteristics, and that these may not be uncommon—even in relatively small watersheds (D. Kazyak, USGS, personal communication).

Metapopulations should receive management emphasis as they are most likely to persist and their subpopulations may represent local adaptation and repositories of genetic diversity (Kazyak et al. 2016). Consequently, efforts to improve connectivity may be of limited importance if populations have evolved to persist in small patches even though they are continuous with wider areas of habitat (Kazyak et al. 2016). Ultimately, a management paradigm shift away from river- or drainage-specific management is indicated, as assumptions of a linear (interconnected) system are incorrect. Distributions are punctuated with genetically divergent populations with little to no connectivity (not a continuum).

2016 Brook Trout DNA Sample Collection for Microsatellite DNA Analyses

Because of the potential error associated with allozyme-derived genotype designations and the limited information available regarding allelic diversity, effective population size (N_e), relatedness to other populations, etc., an upgrade to Tennessee's brook trout genetics database is necessary. Genotype verification of all 112 extant brook trout populations, along with acquiring other population genetics characteristics (e.g., N_e and relatedness to other populations), is also an important goal of Tennessee's forthcoming Native Brook Trout Management Plan and ultimately addresses objectives and strategies relative to brook trout in TWRA's 2014-2020 Strategic Plan (TWRA 2014). This work began during the brook trout distribution survey efforts that got underway in 2011 (Habera et al. 2012). Twelve brook trout populations that were either previously undocumented or were not located during the 1990s were identified during those distribution surveys. Additionally, brook trout populations in Turkeypen Cove in Greene Co. and Birchfield Camp pond in Unicoi Co. were verified in 2016. Eight of these 14 'new' or re-located populations, along with four that were not included in the original allozyme analyses, have recently been genotyped using microsatellite DNA at the U.S. Geological Survey (USGS) Leetown Science Center lab in Kearneysville, WV. Additionally, seven populations that were initially genotyped using allozymes in the 1990s have also been re-analyzed using microsatellite DNA: Left Prong Hampton Creek and its three source populations; Sycamore Creek (Region 3) and one of its source populations (Bald River), and Brookshire Creek (Region 3). Allozyme genotype designations were confirmed in each case. The remaining 93 populations (87 in Region IV) were scheduled for DNA sample collection in 2016 and 2017 following the establishment of an agreement by TWRA with the USGS Leetown Science Center lab for providing the microsatellite DNA analyses.

Deploying a gill net in Birchfield Camp pond to collect brook trout for DNA samples, November 2016. *(Photo by M. Carter, USFS)*

Collecting brook trout fin clips from Birchfield Camp pond. *(Photo by M. Carter, USFS)*

Forty-six Region IV trout brook populations were sampled by electrofishing in 2016 to obtain DNA samples (Table 2-22). Brook trout were present in Straight Creek (Washington Co.) in 2012, but none were captured or observed in 2016, thus this stream was removed from the current inventory. Target sample size for the other 45 populations was 30 fish representing as much of the existing distribution as possible. A single pelvic fin clip was taken from each fish and stored in 95% ethanol. Age-0 fish were avoided if possible and efforts were made to avoid siblings by taking only one fish per pool. In many populations throughout Region IV (particularly below 915 m or 3,000' elevation), age-0 brook trout abundance was exceptionally low. Recently, Kanno et al. (2015) have shown that abiotic factors (i.e., seasonal weather patterns) have more pronounced effects on age-0 brook trout abundance than biotic factors such as spawner abundance. Mean winter precipitation had the largest impact (negative) on age-0 abundance, mean autumn temperature also had a significant negative effect, and these impacts produced synchrony in age-0 abundance across a large spatial scale (Shenandoah National Park, VA; Kanno et al. 2015). These factors may have reduced age-0 brook trout abundance across Region IV in 2016, and may have affected fall-spawning brown trout in Stony Creek (Section 2.2.4), Laurel Creek (Section 2.2.6) and Beaverdam Creek (Section 2.2.7) as well.

Overall, DNA samples were obtained from 1,099 fish, with sample sizes ranging from 2-35 and averaging 24 (29 samples included ≥30 fish). Mean length of the collection zone in each stream was 900 m and samples were collected upstream of major waterfalls where present. Streams with short distributions and low abundances produced the smaller samples sizes (<10), although in these cases a high percentage of the existing population was sampled. Sampling in 2016 focused on the French Broad and Nolichucky basins and collections from all 26 extant populations located there were completed, including one inhabiting the Birchfield Camp pond in Unicoi County (Table 2-22). Bivens (1984) mentioned the presence of this population, but no subsequent agency sampling efforts had been made to verify it. Electrofishing with a small boat-mounted system in October produced one brook trout (~150 mm) and later (November), two 30-m (100') gill nets with 2.54 cm (1 in.) and 3.18-cm (1.25 in.) mesh produced three additional fish in the 250-280 mm range. Sampling of the six remaining populations in Region 3 (Little Tennessee River basin) was also completed (149 fish total). All samples collected in 2016 (51 populations) have been sent to the USGS Leetown Science Center lab for microsatellite DNA analysis.

A brook trout from Birchfield Camp pond in Unicoi County, November 2016.
(Photo by M. Carter, USFS)

The remaining 41 populations in Region IV will be sampled primarily during May-July 2017. Most of these populations are in the Doe River (19), Roan Creek (8), and Beaverdam Creek (9) watersheds. Important results of these new analyses will be verification of the identity of existing native brook trout populations, along with more detailed information (including effective population size) for selecting appropriate source populations as part of restoration and enhancement projects. Effective population size (N_e) is the number of individuals from a population required to represent the genetic diversity present—usually much smaller than census size. Managers should consider N_e when selecting brook trout populations as sources for restoration projects. Populations with larger N_e have more genetic diversity and a higher probability of long-term survival. Range-wide, N_e averages about 50, while 50 of 68 populations from GSMNP had N_e <50 (range, 2-1,241) and 8 of 11 Tennessee populations (outside GSMNP) had N_e <20 (range, 1-58).

Population Genetics of Southern Appalachian Brook Trout

A manuscript summarizing the most current brook trout population genetics data across the southern Appalachian and mid-Atlantic range (including Tennessee's) is now being prepared (led by USGS Leetown Science Center lab staff). Basic goals and objectives of this paper will be to:

1. Describe baseline genetic attributes of brook trout populations across the southern portion of their distribution.

   Compare/contrast differences:
   i. of genetic diversity within and genetic differentiation among drainages,
   ii. relative to population size, spatial distance, drainage,
   iii. related to stocked and unstocked populations,
   iv. in population segments with/without movement barriers,
   v. between genetic attributes of populations found north and south of New River watershed, VA/NC.

2. Describe the evolutionary relationships among brook trout populations at the population and phylogeographic scale across their range.

3. Identify patterns in most recent common ancestry within/among streams, drainages, and regions.

4. Determine if there is evidence of effective genetic migration of populations within/among watershed(s) (i.e., panmictic populations vs. isolated gene flow vs. isolated fragmented populations).

5. Assess genetic signature and degree of introgression within/among hybrid populations exposed to single vs. repeated stocking of hatchery-strain brook trout.

6. Determine if repeated removals of brook trout from source streams for translocation to restored stream segments has caused significant declines in genetic metrics.

7. Define management units based upon genetic metrics and hydrological patterns.

The SDAFS Trout Committee will then use this information to update their position statement on managing southern Appalachian brook trout (Habera and Moore 2005). Consequently, brook trout conservation and management strategies throughout the region can be refined, particularly with respect to brook trout restoration and enhancement projects.

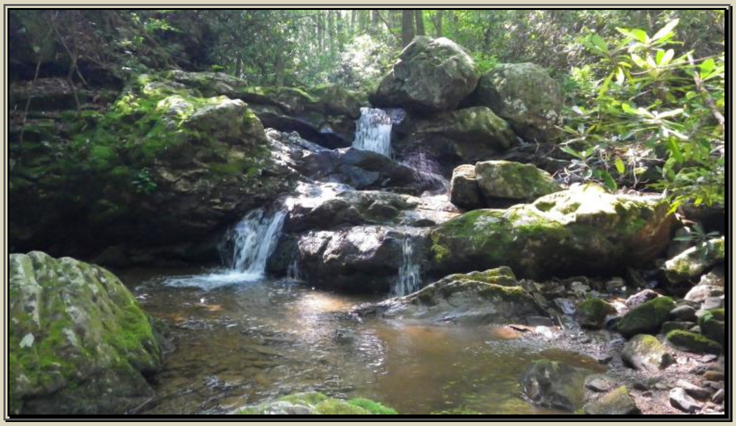
Table 2-22. Region IV brook trout populations from which DNA samples were collected during 2016 (June-November).

Stream[1]	County	Basin	Samples	Sample collection zone Lower Lat.	Lower Long.	Upper Lat.	Upper Long.	Distance (km)
Gulf Fork Big Creek	Cocke	French Broad	5	35.79745	-83.01175	35.79532	-83.01172	0.24
Mid. Prong Gulf Ck.	Cocke	French Broad	30	35.80050	-83.00027	35.79599	-82.99602	0.66
Brown Gap Creek	Cocke	French Broad	30	35.79340	-83.00793	35.78769	-83.00217	0.85
Dry Fork	Cocke	French Broad	30	35.88346	-82.95904	35.87620	-82.95590	1.00
Wolf Creek	Cocke	French Broad	30	35.86268	82.92706	35.85596	-82.93049	0.89
Sawmill Branch	Greene	French Broad	30	35.95855	-82.82770	35.94513	-82.82695	1.75
Norton Creek	Sevier	French Broad	21	35.71136	-83.56931	35.70290	-83.57630	1.23
Round Knob Branch	Greene	Nolichucky	30	36.08926	-82.68086	36.08220	-82.68120	0.78
Davis Creek	Greene	Nolichucky	30	36.07015	-82.70171	36.06494	-82.69268	1.13
West Fork Dry Creek	Greene	Nolichucky	15	36.06074	-82.71383	36.05680	-82.71714	0.57
Sarvis Cove	Greene	Nolichucky	30	36.09476	-82.65665	36.08748	-82.65670	0.96
Squibb Creek	Greene	Nolichucky	30	36.10322	-82.65339	36.09435	-82.64339	1.41
Turkeypen Cove	Greene	Nolichucky	5	36.10136	-82.64642	36.10035	-82.64510	0.17
Long Branch	Unicoi	Nolichucky	24	36.09076	-82.42665	36.08605	-82.43068	0.65
Jones Branch	Unicoi	Nolichucky	3	36.10700	-82.41823	36.10575	-82.41609	0.26
Red Fork	Unicoi	Nolichucky	14	36.15739	-82.25484	36.14832	-82.26159	1.62
Clear Fork	Unicoi	Nolichucky	30	36.14808	-82.26069	36.13868	-82.26400	1.14
Higgins Creek	Unicoi	Nolichucky	30	36.08992	-82.53488	36.09362	-82.54535	1.13
Birchfield Camp Br.	Unicoi	Nolichucky	2	36.09033	-82.53579	36.07788	-82.55138	1.22
Briar Creek	Washington	Nolichucky	30	36.22825	-82.38883	36.22937	-82.37509	1.32
Straight Creek	Washington	Nolichucky	No Fish	36.23146	-82.39643	36.23729	-82.38991	0.90
Rocky Fork	Uni./Greene	Nolichucky	30	36.05955	-82.58607	36.06760	-82.59817	1.73
Broad Branch	Greene	Nolichucky	6	36.06438	-82.59005	36.06676	-82.58768	0.34
Ft. Davie Creek	Greene	Nolichucky	30	36.06788	-82.59643	36.07055	-82.59648	0.30
Blockstand Creek	Uni./Greene	Nolichucky	36	36.05539	-82.58566	36.05400	-82.59645	1.24
Rock Creek	Unicoi	Nolichucky	19	36.13409	-82.33594	36.13380	-82.33112	0.49
Birchfield Camp Pond	Unicoi	Nolichucky	4	36.07772	-82.55176	--	--	--
Camp Ten Branch	Carter	Watauga	11	36.22619	-82.04382	36.22680	-82.04338	0.09
Stony Creek	Carter	Watauga	30	36.46864	-81.98374	36.47561	-81.97655	1.26
N. Fork Stony Creek	Carter	Watauga	30	36.46886	-82.00246	36.48114	-81.99525	1.66
Pole Branch	Carter	Watauga	30	36.47321	-81.99947	36.47644	-81.99989	0.37
Mill Creek	Carter	Watauga	30	36.43135	-82.07072	36.43888	-82.08194	1.37
Furnace Branch	Carter	Watauga	30	36.39837	-82.11581	36.40295	-82.11857	0.59
Little Stony Creek	Carter	Watauga	30	36.38934	-82.15692	36.39642	-82.16105	1.02
R. Prong Middle Br.	Carter	Watauga	27	36.12262	-82.09393	36.11918	-82.09602	0.43
Little Laurel Fork	Carter	Watauga	7	36.24770	-82.08698	36.24917	-82.08645	0.18
Firescald Branch	Carter	Watauga	27	36.24920	-82.08700	36.25174	-82.08824	0.34
Gentry Creek	Johnson	S. Fork Holston	30	36.55005	-81.71624	36.57000	-81.70361	2.70
Gilbert Branch	Johnson	S. Fork Holston	25	36.57484	-81.69987	36.56963	-81.70002	0.28
Birch Branch	Johnson	S. Fork Holston	30	36.56077	-81.87634	36.55100	-81.86210	1.87
Kate Branch	Johnson	S. Fork Holston	30	36.55017	-81.71547	36.55424	-81.70656	0.93
Cut Laurel Branch	Johnson	S. Fork Holston	30	36.54296	-81.72401	36.54254	-81.72036	0.34
Grindstone Branch	Johnson	S. Fork Holston	30	36.54138	-81.72522	36.53683	-81.72120	0.67
Heaberlin Branch	Johnson	S. Fork Holston	35	36.55461	-81.90506	36.55704	-81.90966	0.53
Marshall Branch	Johnson	S. Fork Holston	30	36.56265	-81.90466	36.56787	-81.90885	0.70
Little Jacob Creek	Sullivan	S. Fork Holston	33	36.54832	-81.96416	36.54540	-81.95570	1.08

[1]The last 10 fish from Gentry Creeek were collected upstream of the waterfall; the first 21 from Blockstand Creek were from upstream of the falls.

2.5 LITTLE JACOB CREEK BROOK TROUT ENHANCEMENT

Brook trout were reintroduced into Little Jacob Creek—a South Holston Lake tributary on the CNF in Sullivan Co.—in September 2000 by translocating 180 native, southern Appalachian fish from Fagall Branch, Heaberlin Branch, and East Fork Beaverdam Creek (Habera et al. 2001b). All three source populations are Beaverdam Creek tributaries in the South Fork Holston River watershed. Brook trout were introduced into the 970-m stream reach between 756 m and 817 m (2,480 ft. to 2,680 ft.) elevation. The wild rainbow trout population existing in this area (2,735 fish/ha; 31 kg/ha) was not removed or thinned prior to reintroducing the brook trout. Successful brook trout reproduction was verified in August 2001 (22 age-0 fish collected) and again in August 2003. The 2003 survey produced 24 brook trout (including 12 age-0 fish) within the introduction zone, as well as six age-0 brook trout further downstream, thus brook trout were considered to be successfully established in Little Jacob Creek at a that time (Habera et al. 2004). The next qualitative survey was conducted in November 2010, following the drought years of 2006-2008. Brook trout were again present throughout the introduction zone, with 17 adults and 43 age-0 fish collected at five sample points. The five rainbow trout (all adults) captured were removed. A follow-up survey in July 2011 determined that brook trout extended down to an elevation of 730 m (2,390’) and had colonized ~260 m of Little Jacob Creek downstream of the introduction zone since 2000. Total brook trout distribution in Little Jacob Creek in 2011 was 1.2 km, with most of that being dominated by rainbow trout. A cascade series (see photo) at 689 m (2,260’) was also located in 2011 that could serve as a rainbow trout barrier and permit the conversion of the 1.6-km trout population upstream to allopatric, native southern Appalachian brook trout.



Rainbow trout were removed from 1.6 km of Little Jacob Creek upstream of this series of cascades in 2016.

The extremely low stream flows during the summer and fall of 2016 provided an excellent opportunity to enhance the Little Jacob Creek brook trout population by extending it down to the potential barrier at 689 m and removing sympatric rainbow trout. Therefore, rainbow trout were removed throughout the upper 1.1 km while brook trout DNA samples were being collected during October 2016 (Section 2.4). Approximately 50 rainbow trout (age 0 to 254-mm adults) were removed from this reach and fin clips were obtained from all 25 brook trout present (no age-0 brook trout were captured) during a single electrofishing pass. Capture efficiency was considered to be very high because of the exceptionally low stream flow.

Another effort consisting of two electrofishing passes was made through the remaining 0.5-km reach beginning at the cascade later in October 2016 and removed 352 rainbow trout (including

190 age-0 fish). The first pass captured 85% of all rainbow trout and 90% of adult rainbow trout removed during this effort, emphasizing the high capture efficiency made possible by the low stream flow conditions. Brook trout were present within 100 m of the cascade and 21 (including five age-0 fish) were captured along with the rainbows and released. DNA samples from an additional eight brook trout from this area were collected, bringing the total sample size to 33. Overall, about 400 rainbow trout were removed from Little Jacob Creek upstream of the barrier and nearly 50 brook trout now occupy this area. Another electrofishing pass upstream of the barrier will be made in 2017 to remove any remaining rainbow trout and assess brook trout abundance. Abundance and biomass of allopatric brook trout should reach pre-enhancement levels (primarily composed of rainbow trout) in three years as has been observed in Left Prong Hampton Creek (Section 2.2.2) and several streams in GSMNP (Kanno et al. 2016).

The cave or “rockhouse” along Little Jacob Creek (elevation 735 m or 2,410’) within the brook trout enhancement zone.

Little Jacob Creek Brook Trout Enhancement

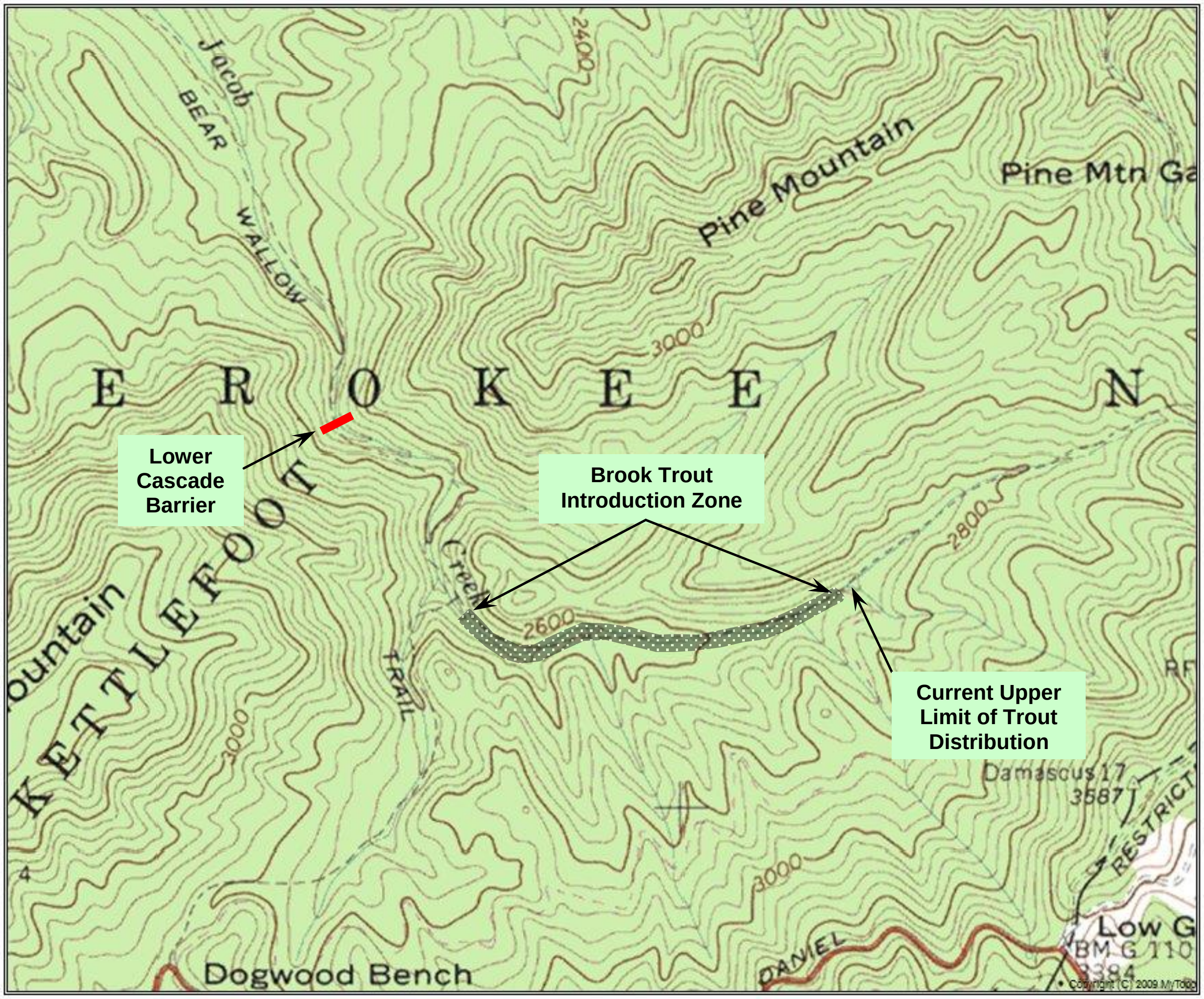


Figure 2-32. Location of the 2016 brook trout enhancement zone on Little Jacob Creek (1.6 km between the lower cascade barrier and the upper limit of trout distribution).

3. TAILWATER ACCOUNTS

Region IV's tailwater trout fisheries present unique fishery management problems and opportunities for which no standard solutions or practices apply (Hill 1978). The problems inherent in sampling tailwaters, such as their large size, fluctuating flows, and the lack of any practical means for maintaining closed populations, make it difficult at best to collect quantitative data from these systems. Additionally, natural reproduction is typically insignificant, so most tailwater trout populations are also largely hatchery-supported, with abundances and size/age-class densities related to stocking rates. In some cases however (e.g., the South Holston and Wilbur tailwaters), natural reproduction is substantial, which presents a different set of management issues and options. Annual tailwater monitoring in Region IV began in 1991 (Bivens et al. 1992), but the initial efforts (prior to 1999) provided limited information. Consequently, TWRA sponsored more intensive studies focusing on assessment of trout abundance, the fate of stocked fish, natural reproduction, movements, and angler use in the Norris, South Holston, and Wilbur tailwaters (e.g., Bettoli and Bohm 1997; Bettoli 1999; Bettoli et al. 1999; Bettinger and Bettoli 2000; Bettoli 2002; Bettoli 2003a; Bettoli 2003b; Hutt and Bettoli 2003; Meerbeek and Bettoli 2005; Bettoli 2006; Holbrook and Bettoli 2006; Bettoli 2007; Damer and Bettoli 2008).

3.1 SAMPLING METHODS AND CONDITIONS

Sampling effort for the Norris, Cherokee, South Holston, and Wilbur tailwaters annually consists of 600-s (pedal time) runs at each of 12 monitoring stations with boat-mounted electrofishing systems (120 pulses/s DC, 4-5 amps). The smaller Ft. Patrick Henry and Boone tailwaters are sampled using 900-s runs at 4 stations. Electrofishing on these tailwaters (except Norris) is conducted during the day with generation by one unit (turbine). Only trout are collected during these efforts. Tailwater sampling conditions and effort are summarized below:

Tailwater	Year annual monitoring began	Sample time	Stations	Approximate flow	Total effort (h)
Norris	1999	Night	12	114 m^3/s (4,000 cfs)	2.0
Cherokee	2003	Day	12	114 m^3/s (4,000 cfs)	2.0
Ft. Patrick Henry	2002	Day	4	88 m^3/s (3,100 cfs)	1.0
Wilbur	1999	Day	13[1]	71 m^3/s (2,500 cfs)	2.0[2]
Boone	2009	Day	4	88 m^3/s (3,100 cfs)	1.0
South Holston	1999	Day	12	71 m^3/s (2,500 cfs)	2.0

[1]An extra site was added in 2010 to help evaluate the Quality Zone.
2Does not include effort (600 s) at the additional QZ site.

3.2 TAILWATER MONITORING

Six Region IV tailwater trout fisheries (Norris, Cherokee, Wilbur, Ft. Patrick Henry, Boone, South Holston; Figure 1-2) are part of the annual monitoring program. Updated management plans have been finalized for the Norris, Wilbur, and South Holston tailwaters (Habera et al. 2014b; 2015b; 2015c). Sampling is conducted each year in late February or March (except Cherokee) to provide an assessment of the overwintering trout populations present before stocking begins. The Cherokee tailwater (Holston River) stations are sampled in the fall (October), as trout survival over the summer is a more important issue for that fishery. Catch per unit effort (CPUE) for each species at each site (fish/h), as well as means for each tailwater, are calculated annually to monitor trout abundance trends.

3.2.1 Norris (Clinch River)

Study Area

The Clinch River originates in southwestern Virginia and enters Tennessee in Hancock County. Norris Dam impounds the Clinch River 197 km (122 mi) downstream in Anderson County, forming 13,846-ha (34,213-acre) Norris Reservoir. Hypolimnetic discharges created coldwater habitat and rainbow trout were stocked in the tailwater shortly after completion of the dam in 1936 (Tarzwell 1939). The Tennessee Game and Fish Commission stocked trout during 1950-1970 and managed the river as a year-round fishery (Swink 1983). Chronic low dissolved oxygen levels and a lack of minimum flow limited development of the trout fishery (Boles 1980; Yeager et al. 1987) and were addressed by TVA’s Reservoir Release Improvements Program (TVA 1980). Dissolved oxygen concentrations were improved initially by fitting the turbines with a hub baffle system (Yeager et al. 1987). Later (1995 and 1996), both turbines were replaced with a more efficient autoventing system (Scott et al. 1996), which maintains dissolved oxygen around 6 mg/L. A minimum flow of 5.7 m^3/s (200 CFS) was established in 1984 and has been maintained since then by a re-regulation weir located about 3.2 km (2 mi) downstream of the dam (Yeager et al. 1987). The weir was upgraded in 1995 to increase its holding capacity and improve public access (Bettoli and Bohm 1997).

Improvements in dissolved oxygen and minimum flows increased the abundance and distribution of benthic invertebrates, as well as trout carrying capacity and trout condition (Yeager et al. 1987; Scott et al. 1996). The Norris tailwater currently supports a 20-km (12.5-mi) fishery for rainbow and brown trout that is one of the most heavily fished in Tennessee (Bettoli 2006). Put-and-take and put-and-grow management is accomplished by annually stocking both fingerling and adult trout. Bettoli and Bohm (1997) documented a small amount of natural reproduction by rainbow trout, but recruitment to the tailwater fishery was considered to be minimal. Some of this natural reproduction may come from Clear Creek, which large rainbow trout enter to spawn each winter. Banks and Bettoli (2000) and Holbrook and Bettoli (2006) attributed the lack of brown trout reproduction in the Norris tailwater to poor or dewatered spawning substrate and unsuitable flows and water temperatures during spawning season. Some of these factors probably limit successful rainbow trout reproduction as well.

The first intensive study of the Norris tailwater trout fishery (1995-1997) produced an overwinter biomass estimate of 112 kg/ha composed of about 80% rainbow trout and 20% brown trout (Bettoli and Bohm 1997). Tennessee's only other tailwaters with higher trout biomass estimates at that time were South Holston and Wilbur (Bettoli 1999). Bettoli and Bohm (1997) also reported a relatively low return rate for stocked rainbow trout (19%) and very few brown trout were observed in the creel. Most adult (208-330 mm) rainbow trout cohorts stocked in the tailwater were found to be limited more by natural mortality than by angler harvest. Trout stocked as adults exhibited energetically inefficient behaviors (e.g., rapid, long-range movements) which led to poor creel-return rates and survival (Bettinger and Bettoli 2002). Consequently, the fishery is primarily supported by fingerling rainbow trout stocking (Bettoli and Bohm 1997; Bettinger and Bettoli 2000). High growth rates of fingerling-stocked rainbow trout (about 20 mm/month) allow the tailwater to produce quality-sized fish within a relatively short time (Bettoli and Bohm 1997). Growth of stocked brown trout is slower (12 mm/month; Meerbeek and Bettoli 2005).

Norris tailwater anglers (photo by Paul Shaw).

A 2013 TWRA roving creel survey (Black 2014) indicated that pressure (48,317 h), trips (12,249), catch (52,114), and harvest (11,946) were all lower relative to the previous 2005 survey (Bettoli 2006). About 80% of 2013 pressure, trips, catch, and harvest occurred during April-October (the months covered by the 2005 survey). The average trout catch rate was 1.08 fish/h during 2013, with an average catch per trip of over 4 fish. Catch rates over 0.7 fish/h are generally considered representative of good fishing (McMichael and Kaya 1991; Wiley et al. 1993). Average harvest was low in 2013 (0.98 fish/trip) and has been below 2 fish/ trip during all previous surveys, with most trips harvesting no fish. Norris tailwater anglers overwhelmingly (76%) supported the PLR regulation and 85% rated TWRA's management of this fishery as good or excellent during the 2013 survey. A new angler survey will be conducted on the Norris tailwater in 2017.

The locations of TWRA's 12 monitoring stations on the Norris tailwater, sampled on 9 March 2016, are provided in Figure 3-1. Additional sample location and effort details are summarized in Table 3-1.

Results and Discussion

The Norris tailwater was not sampled in 2015 because of poor weather conditions in late February and extended high flows during March. Samplings resumed in 2016 and 443 trout weighing over 190 kg were captured at the 12 monitoring stations (Table 3-2), exceeding the biomass from any previous year. The catch included 369 rainbows (83%) and 74 browns (17%); no brook trout were captured, although none were available for stocking in 2015. Relative abundances of rainbow and brown trout by weight were 75% and 25%, respectively. Rainbow trout biomass increased to 143 kg in 2016—the highest observed to date—and mean weight for rainbow trout was 388 g/fish, which exceeded all previous samples except 2014. Brown trout biomass (47 kg) declined relative to the 2014 sample (63 kg), which included the two largest fish (6.3 and 6.6 kg) collected to date. Mean weight for brown trout in 2016 was 641 g/fish.

Rainbow trout ranged from 155-527 mm and brown trout ranged from 104-742 mm (Table 3-2). Rainbow trout had a bimodal length distribution, with fish in the 178 mm (7 in.) and 305-381 mm (12-15 in.) size classes most abundant (Figure 3-2). Nearly half (43%) of the rainbow trout >178 mm were in the 356-508 mm (14-20 in.) protected length range or PLR (Figure 3-2). Brown length distribution was also relatively bimodal, with fish in the 152 mm (6 in.) and 305-330 mm (12-13 in.) size classes most abundant (Figure 3-2). Only 19% of the catch >178 mm (11 fish) was within the PLR (similar to the 2013 and 2014 samples). Ten brown trout >508 mm were captured and, along with three rainbows in this size range, were primarily present at stations 7-10.

The 2016 mean electrofishing catch rate for all trout ≥178 mm (201 fish/h) was the highest obtained since 2009 (Figure 3-3) is about 20% higher than the average for the previous five samples (167 fish/h). The increase was attributable to rainbow trout, for which the mean catch rate increased to 172 fish/h (Figure 3-3)—the highest observed since monitoring began in 1996. The mean catch rate for brown trout ≥178 mm has relatively stable at 25-30 fish/h since 2012 (Figure 3-3). The mean electrofishing catch rate for trout within the PLR (356-508 mm) exceeded 80 fish/h in 2014 and remained at 80 fish/h in 2016 (Figure 3-3). The current Norris tailwater management plan (Habera et al. 2014b) maintains a mean PLR catch rate objective of 28 fish/h for 2014-2019, and this objective is certainly being achieved. The increasing relative stock density of trout 356 mm (14 in.) and larger (RSD-14) indicates that trout population size structures have been shifted toward larger fish since 2010 (Figure 3-4), as CPUE for trout ≥178 mm has been relatively stable (150-200 fish/h) and annual stocking rates have been relatively consistent (see below). An RSD-14 value of 50 indicates that 50% of all stock-size trout—those at least 254 mm (10 in.) in length—are 356 mm (14 in.) or larger and would be double the pre-PLR average of 25.

The Norris tailwater was stocked with 379,000 trout during calendar year 2016 (Figure 3-5). Typically, Norris has the highest stocking rate of any Tennessee tailwater. About 89% (337,000) of these were rainbow trout, most of which (293,000) were fingerlings. The remainder was brown trout (40,000; 10.5%) and brook trout (2,100). The fingerling rainbow trout stocking rate in 2016 was well above that prescribed in the Norris tailwater management plan (160,000; Habera et al. 2014b) because deteriorating water quality conditions in November at Dale Hollow National Fish Hatchery (related to the drought) made it necessary to stock much of the 2017 allocation early. The 2017 fingerling rainbow trout stocking rate will be adjusted accordingly. Only 20,000 brook trout were available for Norris in 2016 because of shortages at Dale Hollow. Generally, though, stocking rates have been consistent since 2010 (Figure 3-5).

Management Actions and Recommendations

TWRA's management goal for the Norris tailwater continues to focus on maintaining the quality trout fishery that has developed there since 2008 (Habera et al. 2014b). Accordingly, the primary strategy for attaining this goal is to enhance the abundance of quality-sized (≥356 mm or 14 in.) trout through the 356-508 mm (14-20 in.) protected length range (PLR or 'slot limit') regulation. Slot limits have been shown to improve size structures of sport fish populations including largemouth bass *Micropterus salmoides* (Wilde 1997) and trout (Luecke et al. 1994; Power and Power 1996). The Norris tailwater PLR regulation has successfully increased the abundance of fish in the protected size range and anglers have recognized this by overwhelmingly expressing their support for the PLR during the 2013 survey. Slot limits are also expected to promote growth of smaller fish by reducing competition through angler harvest (Anderson 1976), which may be more easily accomplished in tailwater fisheries maintained by stocking (e.g., Norris), where 'year class strength' can be controlled.

Norris Tailwater

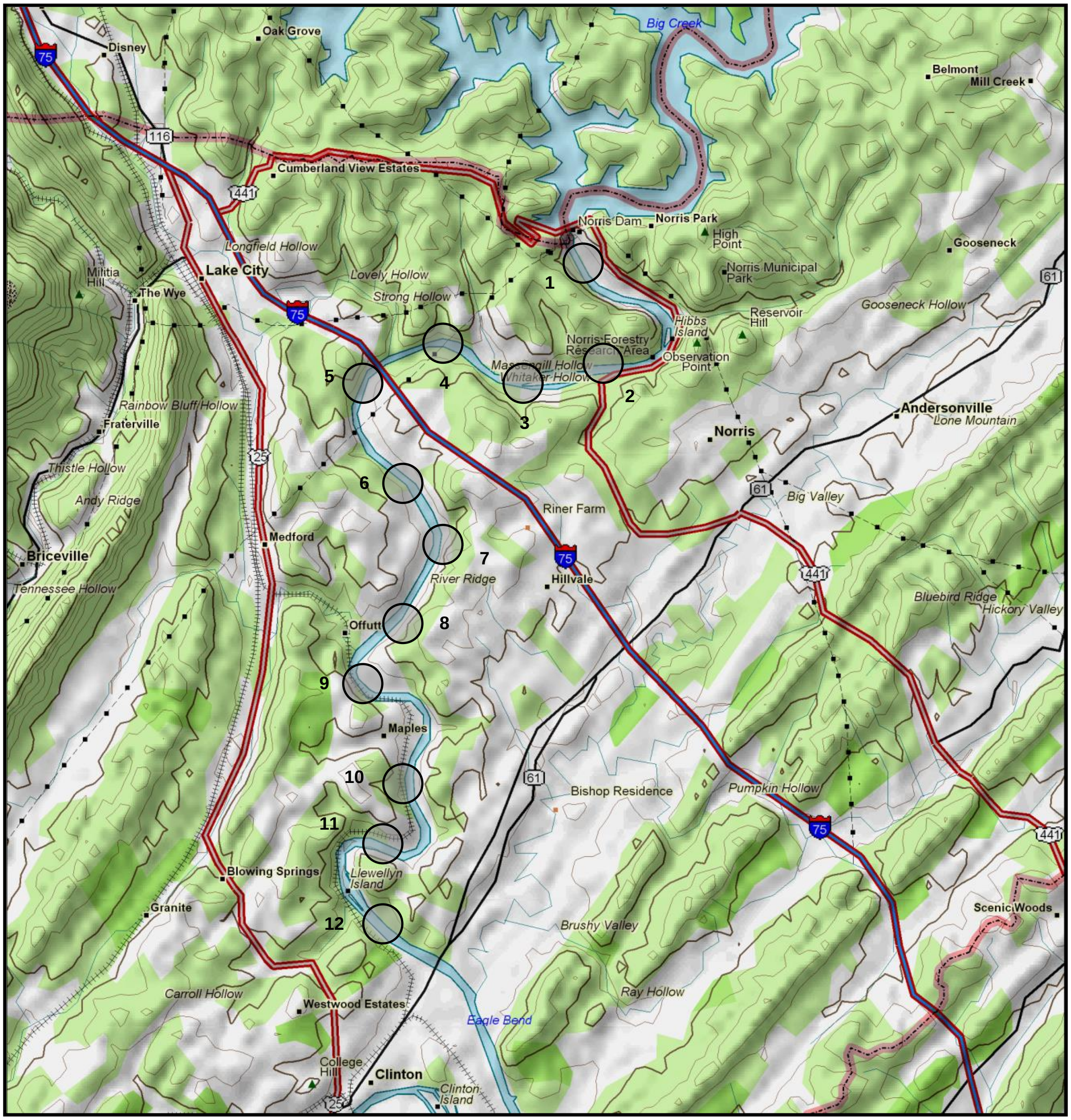


Figure 3-1. Locations of the Norris tailwater (Clinch River) monitoring stations.

Table 3-1. Location and sampling information for the 12 stations on the Norris tailwater, 9 March 2016.

Station	Site Code	County	Quadrangle	Coordinates	Reach Number	River Mile	Effort (s)	Output
1	420160301	Anderson	Norris 137 NE	36.22222N-84.09250W	06010207-19,1	79.7	600	150 V DC 120 PPS, 4 A
2	420160302	Anderson	Norris 137 NE	36.20466N-84.08651W	06010207-19,1	77.2	600	707 V DC 120 PPS, 4-5 A
3	420160303	Anderson	Norris 137 NE	36.20370N-84.10006W	06010207-19,1	76.3	600	707 V DC 120 PPS, 4-5 A
4	420160304	Anderson	Norris 137 NE	36.20654N-84.12265W	06010207-19,1	75.6	600	707 V DC 120 PPS, 4-5 A
5	420160305	Anderson	Lake City 137 NW	36.20433N-84.12580W	06010207-19,0	74.4	600	707 V DC 120 PPS, 4-5 A
6	420160306	Anderson	Lake City 137 NW	36.19722N-84.12778W	06010207-19,0	74.1	600	150 V DC 120 PPS, 4 A
7	420160307	Anderson	Norris 137 NE	36.18611N-84.11667W	06010207-19,0	73	602	150 V DC 120 PPS, 5 A
8	420160308	Anderson	Norris 137 NE	36.17500N-84.11806W	06010207-19,0	72.2	604	150 V DC 120 PPS, 4 A
9	420160309	Anderson	Norris 137 NE	36.16028N-84.12028W	06010207-19,0	70.4	601	150 V DC 120 PPS, 4 A
10	420160310	Anderson	Norris 137 NE	36.14681N-84.11853W	06010207-19,0	69.5	600	707 V DC 120 PPS, 4-5 A
11	420160311	Anderson	Norris 137 NE	36.14306N-84.11750W	06010207-19,0	69.1	601	150 V DC 120 PPS, 4 A
12	420160312	Anderson	Lake City 137 NW	36.13151N-84.12628W	06010207-19,0	67.2	600	707 V DC 120 PPS, 4-5 A

Table 3-2. Catch data for the12 electrofishing stations on the Norris tailwater sampled 9 March 2016.

Station	Species	Total catch	Size range (mm)	Total weight (g)	% Abundance (number)	% Abundance (weight)
1	Rainbow	14	166-409	3,558	40	30
	Brown	21	306-448	8,246	60	70
Totals		**35**		**11,804**	**100**	**100**
2	Rainbow	52	155-470	15,087	78	90
	Brown	15	128-325	1,637	22	10
Totals		**67**		**16,724**	**100**	**100**
3	Rainbow	42	160-443	13,497	74	84
	Brown	15	104-346	2,613	26	16
Totals		**57**		**16,110**	**100**	**100**
4	Rainbow	22	175-440	9,937	96	99
	Brown	1	254	149	4	1
Totals		**23**		**10,086**	**100**	**100**
5	Rainbow	32	171-477	12,762	91	89
	Brown	3	154-525	1,611	9	11
Totals		**35**		**14,373**	**100**	**100**
6	Rainbow	17	270-472	7,931	100	100
Totals		**17**		**7,931**	**100**	**100**
7	Rainbow	33	166-514	16,007	73	47
	Brown	12	256-660	18,149	27	53
Totals		**45**		**34,156**	**100**	**100**
8	Rainbow	28	162-527	10,908	97	93
	Brown	1	439	870	3	7
Totals		**29**		**11,778**	**100**	**100**
9	Rainbow	46	170-497	22,573	96	90
	Brown	2	460-532	2,620	4	10
Totals		**48**		**25,193**	**100**	**100**
10	Rainbow	15	180-495	6,297	79	35
	Brown	4	400-742	11,575	21	65
Totals		**19**		**17,872**	**100**	**100**
11	Rainbow	20	169-492	7,216	100	100
Totals		**20**		**7,216**	**100**	**100**
12	Rainbow	48	172-470	17,581	100	100
Totals		**48**		**17,581**	**100**	**100**
Total Rainbows		369	155-527	143,354	83	75
Total Browns		74	104-742	47,470	17	25
Overall		**443**		**190,824**	**100**	**100**

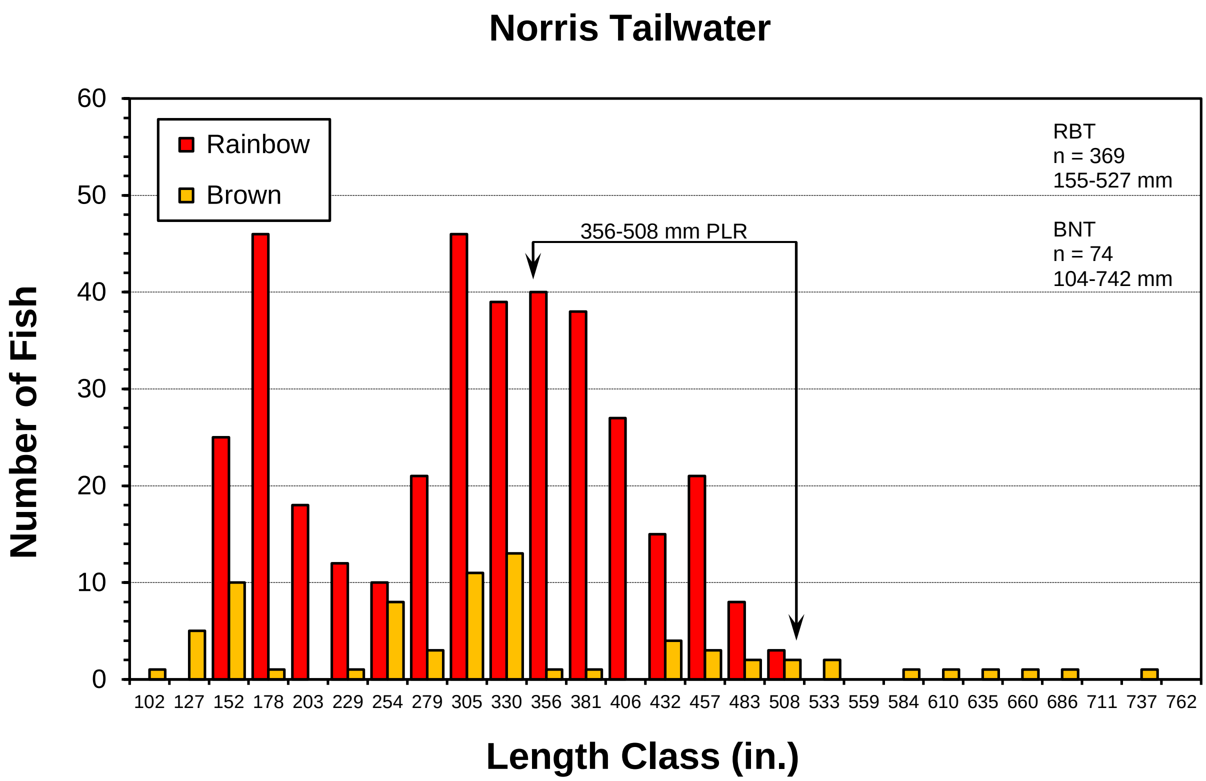
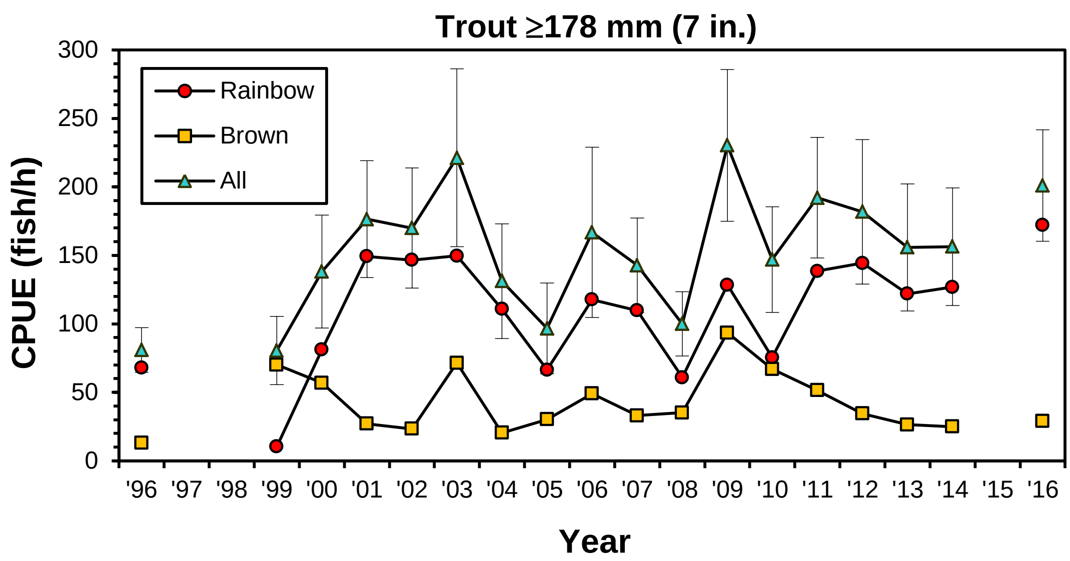


Figure 3-2. Length frequency distributions for trout from the Norris tailwater monitoring stations in 2016.

Norris Tailwater



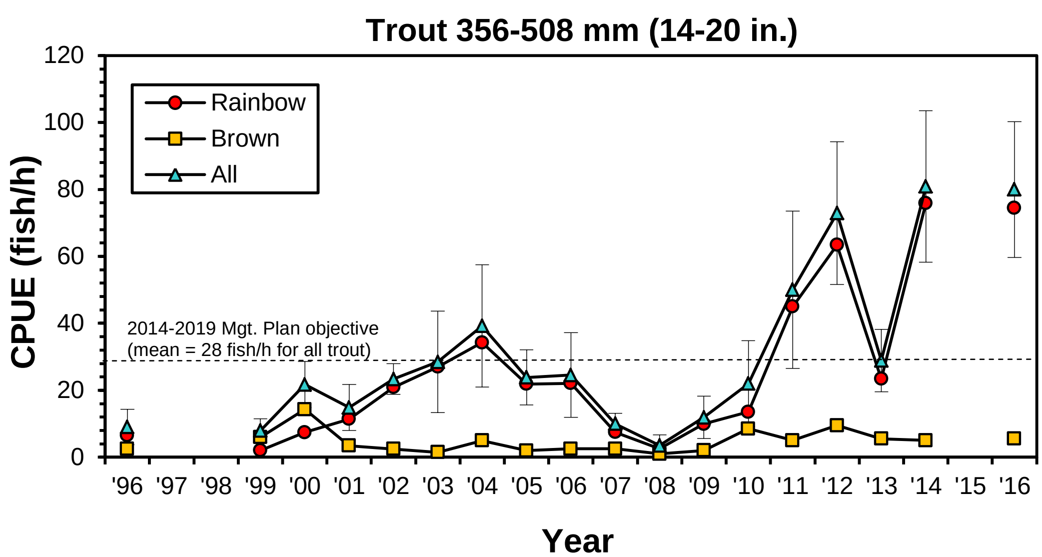


Figure 3-3. Mean trout CPUEs for the Norris tailwater samples. Bars indicate 90% confidence intervals.

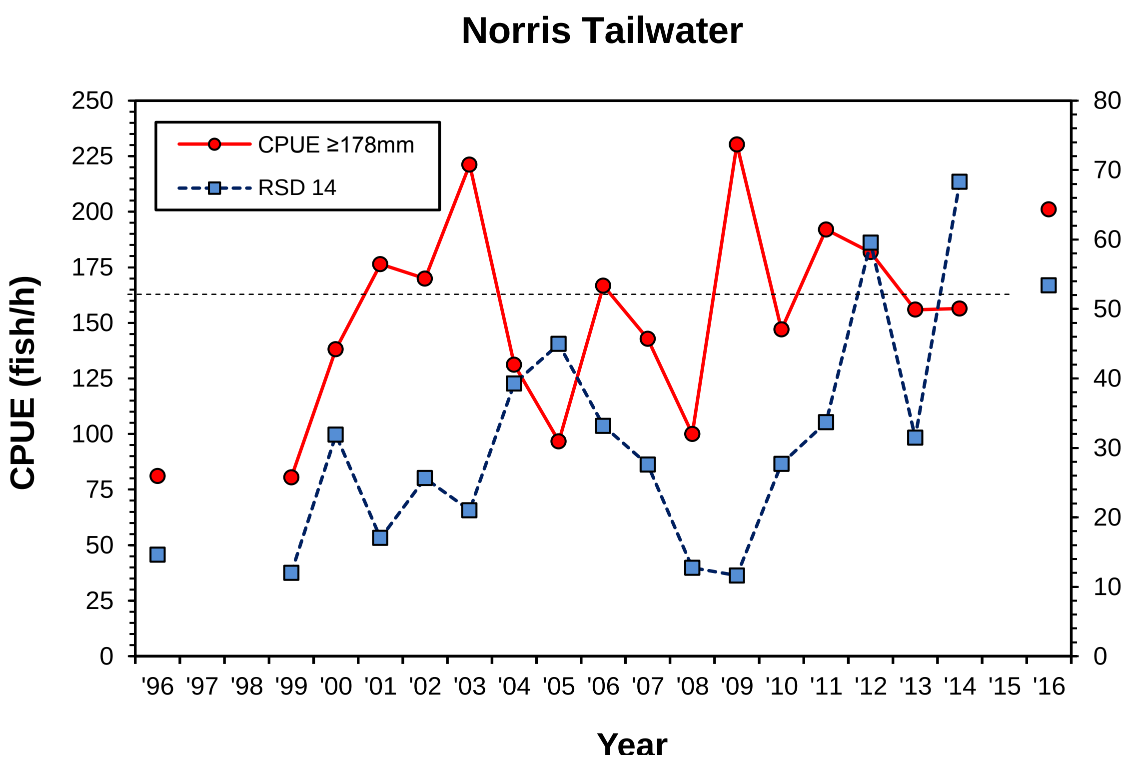


Figure 3-4. RSD-14 Norris tailwater trout compared with corresponding CPUE for fish ≥178 mm.

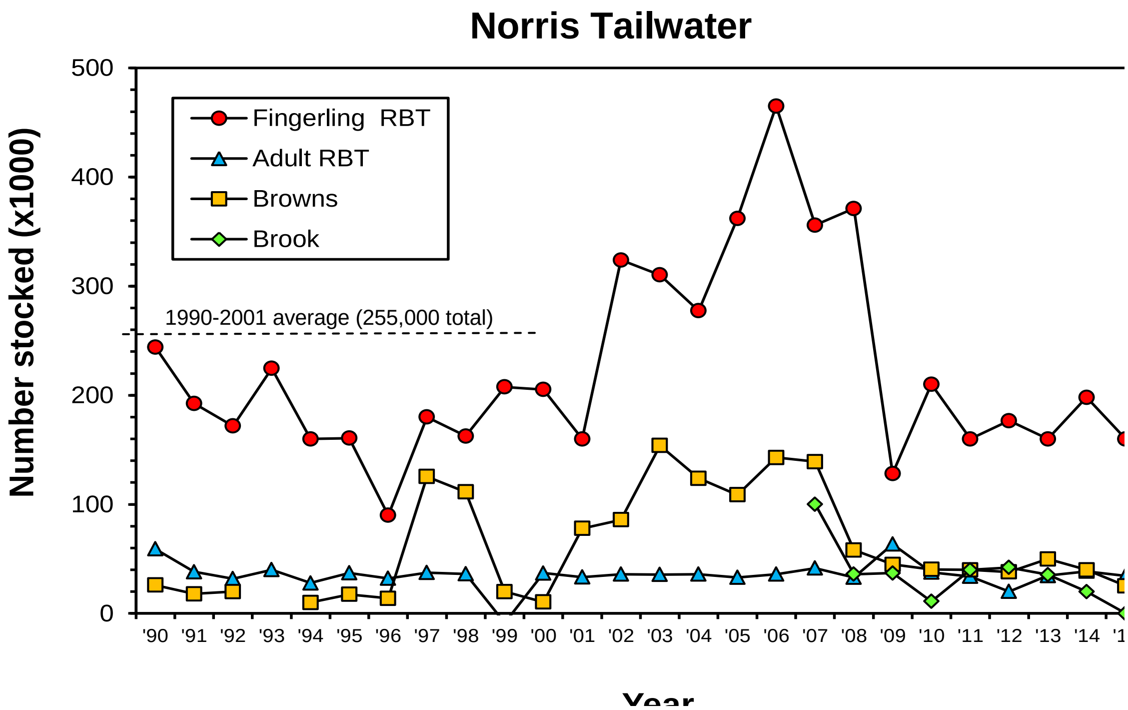


Figure 3-5. Recent trout stocking rates for the Norris tailwater. Currently, about 160,000 fingerlings rainbows, 37,000 adult rainbows, 20,000-40,000 brown trout, and 20,000 brook trout are stocked annually (~237,000 trout/year). Much of the 2017 fingerling rainbow trout allocation was stocked in November 2016 (133,000) because of deteriorating water quality conditions at Dale Hollow National Fish Hatchery. The 2017 stocking rate will be adjusted accordingly.

3.2.2 Cherokee (Holston River)

Study Area

Cherokee Dam impounds 12,272-ha (30,300-acre) Cherokee Reservoir on the Holston River near Jefferson City. The dam is located about 83 km (52 mi.) upstream of the confluence of the Holston and French Broad rivers in Knoxville and the reservoir has an 8,879-km^2 (3,428-mi.^{2}) watershed. Historically, low dissolved oxygen (DO) levels (Higgins 1978) and the lack of a minimum flow in the Cherokee tailwater impacted its aquatic communities. TVA established a minimum flow of 9.2 m^3/s (325 cfs) in 1988 as part of its release improvements program, then began to address low DO levels in 1995 (Scott et al. 1996). Dissolved oxygen levels in the tailwater were improved by installation of a liquid oxygen injection system in the forebay area of the reservoir and through turbine venting aided with hub baffles (Scott et al. 1996). These improvements have helped TVA meet the DO target of 4.0 mg/L in the tailwater and as a result, fish and macroinvertebrate communities have substantially improved.

Cherokee tailwater.

Seasonal temperature regimes, in addition to water quality and quantity problems, were an impediment to fisheries management in the Cherokee tailwater for many years (Hill and Brown 1980). Pfitzer (1962) characterized temperatures as being too cold for warmwater fishes in the spring and too warm for trout in the summer. However, it was generally regarded as supporting a warmwater fish community (Scott et al. 1996; Hill and Brown 1980). TWRA stocked trout infrequently, releasing 39,000 rainbow, brown, and brook trout (fingerlings and adults) during 1951-1955, and 16,000 browns in 1974. All of these efforts likely had limited success as they took place prior to TVA's water quality improvements. Trout stocking became more consistent after 1995 and stocking rates were increased as water quality improved.

The upper 30 km (18.8 mi.) of the Cherokee tailwater, from the dam downstream to the vicinity of Nance Ferry, is now being managed as a put-and-take and put-and-grow trout fishery. It has become popular among area anglers and has drawn some pressure away from other Region IV tailwaters (particularly the Clinch River). Because of the warmer water and abundant food supply (particularly caddis flies), trout grow extremely well, providing the potential for a quality fishery. However, late summer temperatures can exceed and remain above 21° C (70° F) for weeks, creating a thermal 'bottleneck' that severely limits trout survival (i.e., carryover). Along with the relative scarcity of trout in October electrofishing surveys, the abundance of warmwater species (e.g., buffalo *Ictiobus* sp., gizzard shad *Dorosoma cepedianum*, and channel catfish *Ictalurus punctatus)* indicate that the Cherokee tailwater provides marginal trout habitat during summer and early fall.

The 12 electrofishing monitoring stations on the Cherokee tailwater (Figure 3-6) were sampled again in November 2016 to evaluate the trout fishery following the elevated temperatures of late summer and early fall. Sample site locations and effort details are summarized in Table 3-3. Temperature data were also collected (measured hourly by Onset TidbiT® *v2* loggers) near Cherokee Dam and at Blue Spring during May-November 2015.

Results and Discussion

The 12 Cherokee tailwater electrofishing stations produced only 5 trout (3 rainbows, 2 browns) from three stations (4, 6, and 7) in 2016 (Table 3-4). This was the smallest total sample size since 2003 (two fish)—the year annual monitoring began. Consequently, the overall mean catch rate of 2.5 fish/h (≥178 mm) was also the lowest since 2003 (1.0 fish/h; Figure 3-7). The mean catch rate for trout ≥356 mm decreased to 1.0 fish/h, the lowest since 2007 (Figure 3-7), and no fish ≥457 mm, which also had not occurred since 2007 (Figure 3-7). Most rainbows (70%) collected during monitoring efforts in the Cherokee tailwater have been in the 330-406 mm (13-16 in.) size classes (including the 2016 sample), while most browns (70%) have been in the 229-279 mm (9-11 in.) range (Figure 3-8).

Water temperatures near Cherokee Dam in 2016 were warmer than in any year since monitoring began (2005). Maximum daily water temperature reached 21° C on 25 August (two weeks later than in 2015), but remained above 21° C for 75 consecutive days (through 7 November; Figure 3-9)—more than any previous monitoring year except 2013 (79). Mean maximum temperature during 15 September through 15 October 2016 was 25.2° C—1.7° warmer than the next-highest mean for the same one-month period. On average, (2005-2016), mean maximum temperature at this site reached 21° C on 27 August and remained above 21° C for 60 days (through mid-October; Figure 3-9). Minimum water temperature exceeded 21° C for 55 consecutive days beginning on 1 September (Figure 3-9), thus there was no coldwater habitat during that period—the longest since monitoring began at this site in 2005. During 2005-2016, minimum temperature exceeded 21° C an average of 21 days each year. Mean minimum temperature for the 12-year period reached or closely approached 21° C during a 17-day period (21 September through 7 October; Figure 3-9).

Water temperatures were also warmer at the Blue Spring site (13 km below Cherokee Dam) in 2016. Maximum daily water temperature reached 21° C on 23 August and remained above 21° C for 74 consecutive days (through 4 November; Figure 3-10). Mean maximum temperature during 15 September through 15 October 2016 was 25.0° C—1.3° warmer than the next-highest mean for the same one-month period since 2003. There were substantially more days in 2016 with maximum temperature >24° C (40) and >25° C (20) than were recorded in any previous monitoring year (24 days and 4 days, respectively). During 2005-2016, maximum daily temperature at this site reached 21° C on 16 August and remained above 21° C for an average of

70 days (through 21 October; Figure 3-10). Minimum water temperature reached 21° C on 30 August—11 days later than in 2015—and remained above 21° C for 53 consecutive days (through October 21; Figure 3-10), thus there was no coldwater habitat during that period. Minimum daily temperature exceeded 22° C on 42 days, more than any year since 2003 (45). On average, (2003-2016), the Blue Spring area typically has no coldwater habitat (daily minimum water temperature is >21° C) during September and the first week of October (Figure 3-10). Water temperatures in the Cherokee tailwater typically return to trout-tolerant levels (<21° C) by mid- to late October, although they did not do so until late October in 2016 (Figures 3-9 and 3-10).

The Cherokee tailwater received 18,800 adult rainbow trout and 35,000 brown trout in 2016 (Figure 3-11). Stocking rates have averaged 25,000 adult rainbows and 21,700 browns (159-214 mm) annually during the past three years. Although rainbow trout stocking rates were lower in 2015 and 2016 (Figure 3-11), electrofishing catch rates appear to be generally correlated with water temperature, which in turn is related to variability in flow from Cherokee Dam during June-October. Above average precipitation in some years (e.g., 2003) results in higher average flows from Cherokee Dam, earlier depletion of cold water stored in the reservoir, and unsuitably warm tailwater temperatures for long periods of time. The reverse is true during dry years such as 2007 and 2008. Consequently, there is a relatively strong (R^2 = 0.67) inverse relationship (2^{nd} order polynomial) between water temperature (expressed as the number of days where the minimum was ≥22° C at the Blue Spring site) and the electrofishing catch rate (log_{10}-transformed +1; Figure 3-12). There is also a relatively strong (R^2 = 0.45) positive relationship (2^{nd} order polynomial) between water temperature (expressed as the number of days where the minimum was ≥21° C at Blue Spring) and mean flow for June – October (Figure 3-13). The low catch rate in 2016 would seem to indicate a relatively high mean flow for June – October (e.g., ≥5,000 cfs), but the actual mean was 3,076 cfs. In fact, only the corresponding mean flow for 2008 was lower (3,014 cfs). Perhaps there is also a relationship (e.g., in 2016) where extended low flows in late summer and high air temperatures combine to raise water temperatures to levels that impact trout survival.

Management Recommendations

Trout in the Cherokee tailwater are subject to, on average, about a month (typically September) each year without coldwater habitat: minimum temperatures exceed 21° C and maximums often reach 24-25° C. Consequently, most survive less than a year, even with the relatively low harvest rate. However, some trout are able to find thermal refugia such as groundwater upwellings or cooler tributaries (Baird and Krueger 2003) and survive through at least one summer/early fall—evident by the large (≥457 mm) fish that are captured in most years (Figure 3-8). Current stocking policy excludes the use of fingerling rainbows because of their low recruitment potential and avoids July-October because of high water temperatures (>21° C) during those months.

Despite limited trout carry-over caused by extended periods with water temperatures exceeding 21° C, the Cherokee tailwater is well worth managing as a trout fishery. Even with the summer/fall thermal bottleneck, trout angling opportunities are available during most months. The thermal regime and benthic community of the Cherokee tailwater make it more like a natural trout stream than other Tennessee tailwaters. The abundance of trichopterans (particularly *Cheumatopsyche* spp.; Habera et al. 2004) undoubtedly enhances trout growth and prolific mayfly and caddis hatches during the spring provide excellent flyfishing opportunities. Cherokee tailwater trout anglers caught an estimated 0.63 fish/h and 2.89 fish/trip in 2014, while harvesting 0.27 fish/h and 1.21 fish/trip (Black 2015).

Current angling regulations (i.e., general statewide for trout) are appropriate for maintaining this fishery. A majority of Cherokee tailwater anglers (72%) rated TWRA's management of this fishery as good or excellent during the 2014 survey (Habera et al. 2016). Anglers occasionally request special regulations (minimum size or slot limits), but they would be of little value as few fish protected by such measures would survive the summer thermal bottleneck. The 12 existing monitoring stations should be sampled annually to further develop the trout fishery database and annual water temperature monitoring should also continue, as this will provide additional understanding of the relationship among temperature, flow, and trout abundance. These basic recommendations, along with stocking rate annual stocking rates, will be incorporated into a management plan for this tailwater (in preparation during 2017) to ensure its potential as a trout fishery is maximized.

Cherokee tailwater angler.

Cherokee Tailwater

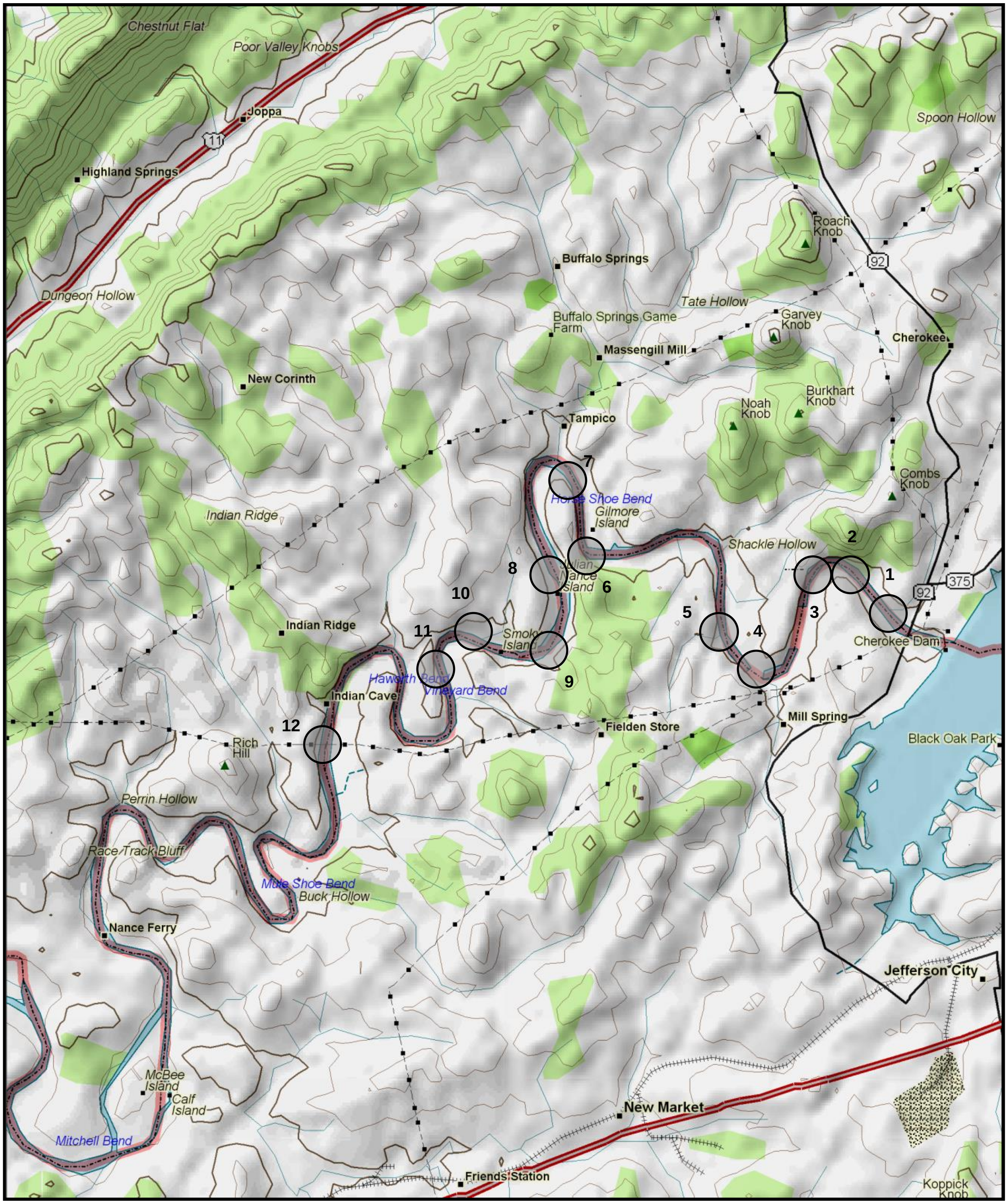


Figure 3-6. Locations of the Cherokee tailwater (Holston River) monitoring stations.

Table 3-3 Location and sampling information for the 12 stations on the Cherokee tailwater, 4 November 2016.

Station	Site Code	County	Quadrangle	Coordinates	Reach Number	River Mile	Effort (s)	Output
1	420162701	Grainger/ Jefferson	Joppa 155 NE	36.16864N-83.50461W	06010104-3,4	51.8	600	707 V DC 120 PPS, 6-8 A
2	420162702	Grainger	Joppa 155 NE	36.17589N-83.51183W	06010104-3,4	51.2	600	175 V DC 120 PPS, 4-6 A
3	420162703	Grainger	Joppa 155 NE	36.17858N-83.51667W	06010104-3,4	50.9	600	707 V DC 120 PPS, 6-8 A
4	420162704	Grainger/ Jefferson	Joppa 155 NE	36.16244N-83.52933W	06010104-3,4	49.5	600	175 V DC 120 PPS, 4-6 A
5	420162705	Jefferson	Joppa 155 NE	36.16767N-83.53564W	06010104-3,4	49.0	600	707 V DC 120 PPS, 6-8 A
6	420162706	Grainger/ Jefferson	Joppa 155 NE	36.17978N-83.55542W	06010104-3,4	47.0	600	175 V DC 120 PPS, 4-6 A
7	420162707	Jefferson	Joppa 155 NE	36.18825N-83.56036W	06010104-3,4	46.2	600	707 V DC 120 PPS, 6-8 A
8	420162708	Jefferson	Joppa 155 NE	36.17658N-83.56161W	06010104-3,4	44.7	600	175 V DC 120 PPS, 4-6 A
9	420162709	Jefferson	Joppa 155 NE	36.16733N-83.56281W	06010104-3,4	44.0	600	707 V DC 120 PPS, 6-8 A
10	420162710	Grainger/ Jefferson	Joppa 155 NE	36.16633N-83.57314W	06010104-3,4	43.5	600	175 V DC 120 PPS, 4-6 A
11	420162711	Grainger	Joppa 155 NE	36.16458N-83.58286W	06010104-3,4	42.7	600	707 V DC 120 PPS, 6-8 A
12	420162712	Grainger	Joppa 155 NE	36.15339N-83.60217W	06010104-3,4	39.5	600	175 V DC 120 PPS, 4-6 A

Table 3-4. Catch data for the12 electrofishing stations on the Cherokee tailwater sampled 4 November 2016.

Station	Species	Total Catch	Size Range (mm)	Total Weight (g)	% Abundance (number)	% Abundance (weight)
1	Rainbow	0	--	0	0	0
	Brown	0	--	0	0	0
Totals		**0**		**0**	**0**	**0**
2	Rainbow	0	--	0	0	0
	Brown	0	--	0	0	0
Totals		**0**		**0**	**0**	**0**
3	Rainbow	0	--	0	0	0
	Brown	0	--	0	0	0
Totals		**0**		**0**	**0**	**0**
4	Rainbow	1	384	464	100	100
	Brown	0	--	0	0	0
Totals		**1**		**464**	**100**	**100**
5	Rainbow	0	--	0	0	0
	Brown	0	--	0	0	0
Totals		**0**		**0**	**0**	**0**
6	Rainbow	2	378-390	1,095	100	100
	Brown	0	--	0	0	0
Totals		**2**		**1,095**	**100**	**100**
7	Rainbow	0	--	0	0	0
	Brown	2	281-304	454	100	100
Totals		**2**		**454**	**100**	**100**
8	Rainbow	0	--	0	0	0
	Brown	0	--	0	0	0
Totals		**0**		**0**	**0**	**0**
9	Rainbow	0	--	0	0	0
	Brown	0	--	0	0	0
Totals		**0**		**0**	**0**	**0**
10	Rainbow	0	--	0	0	0
	Brown	0	--	0	0	0
Totals		**0**		**0**	**0**	**0**
11	Rainbow	0	--	0	0	0
	Brown	0	--	0	0	0
Totals		**0**		**0**	**0**	**0**
12	Rainbow	0	--	0	0	0
	Brown	0	--	0	0	0
Totals		**0**		**0**	**0**	**0**
Total Rainbows		3	378-390	1,559	60	77
Total Browns		2	281-304	454	40	23
Overall		**5**		**2,013**	**100**	**100**

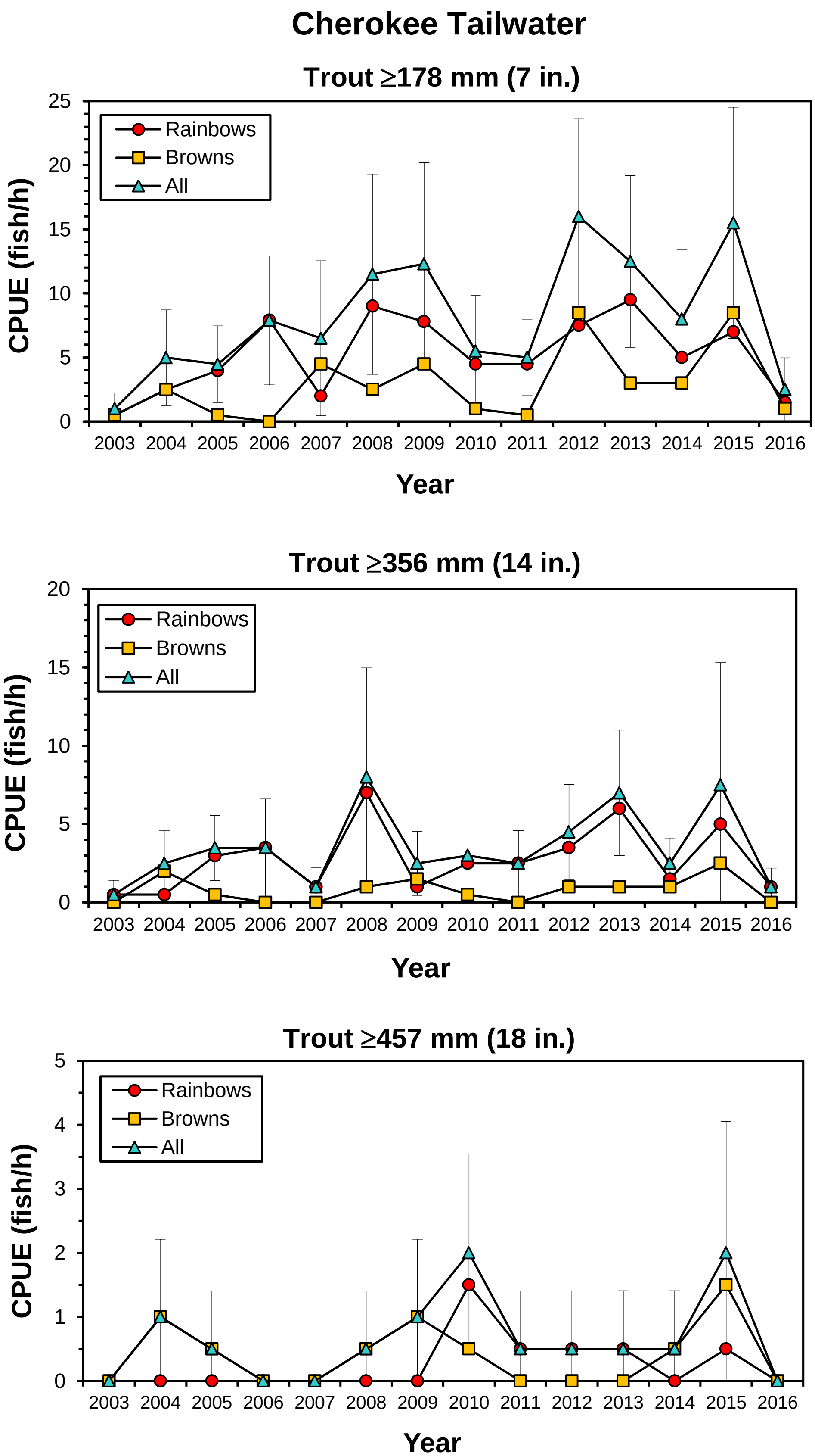
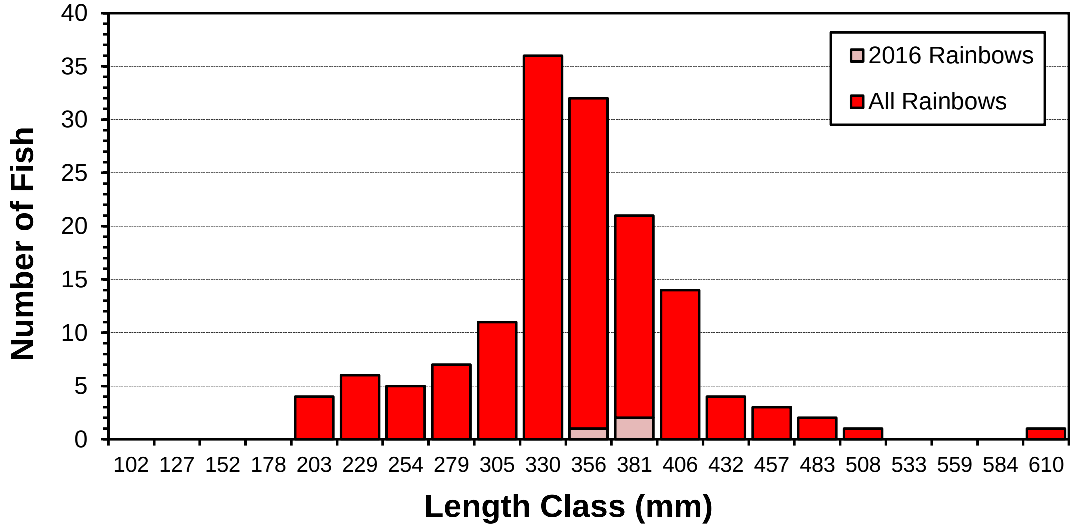


Figure 3-7. Mean trout CPUEs for the Cherokee tailwater samples. Bars indicate 90% confidence intervals.

Cherokee Tailwater



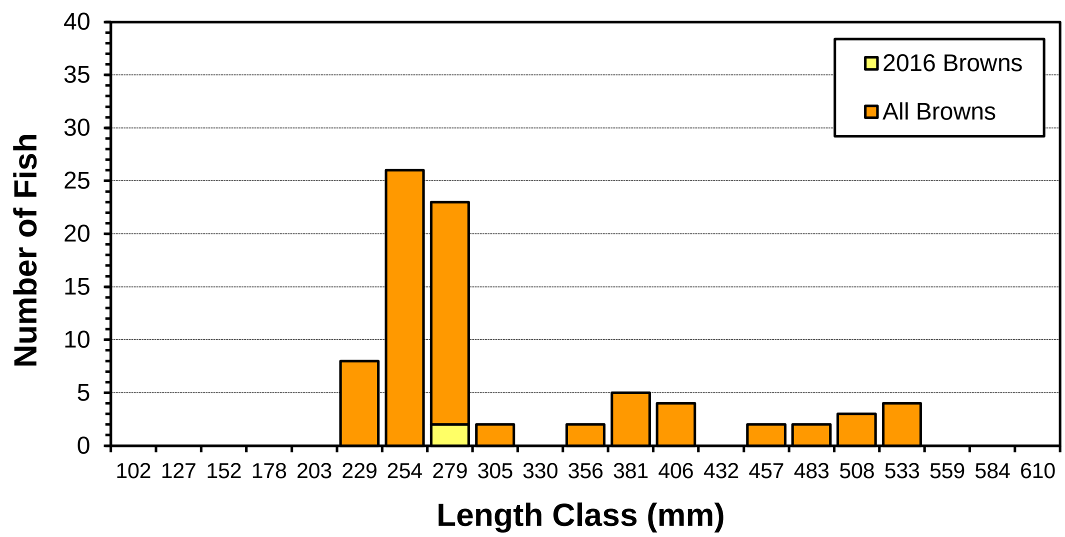
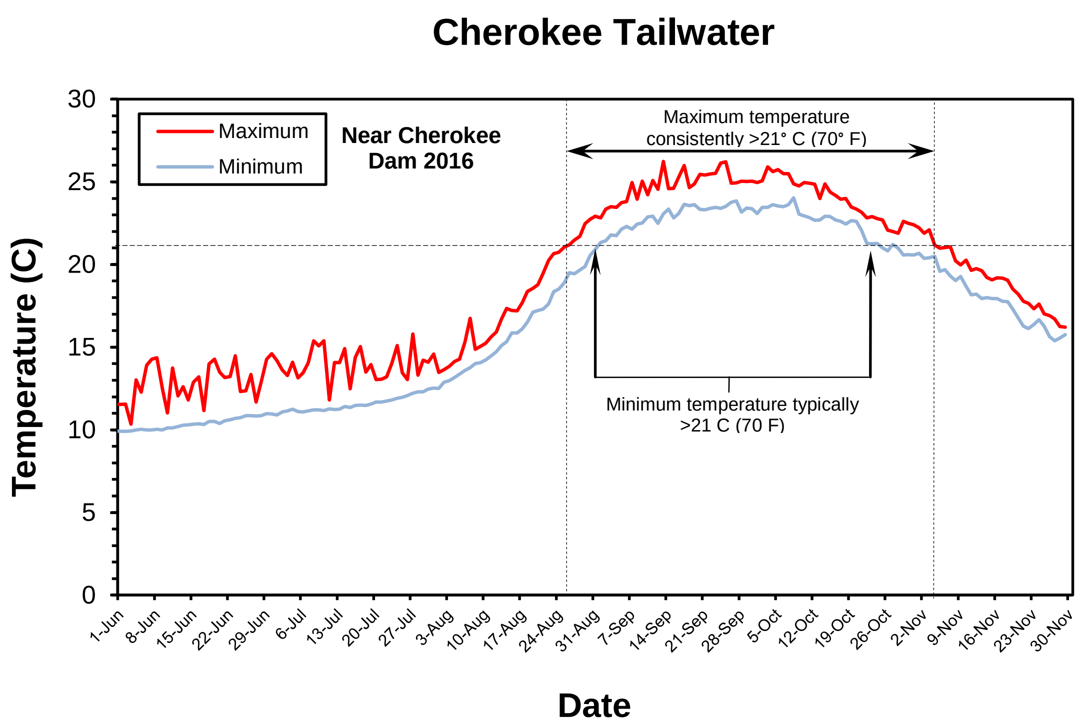


Figure 3-8. Length frequency distributions for trout from the Cherokee tailwater monitoring stations (2003-2016).



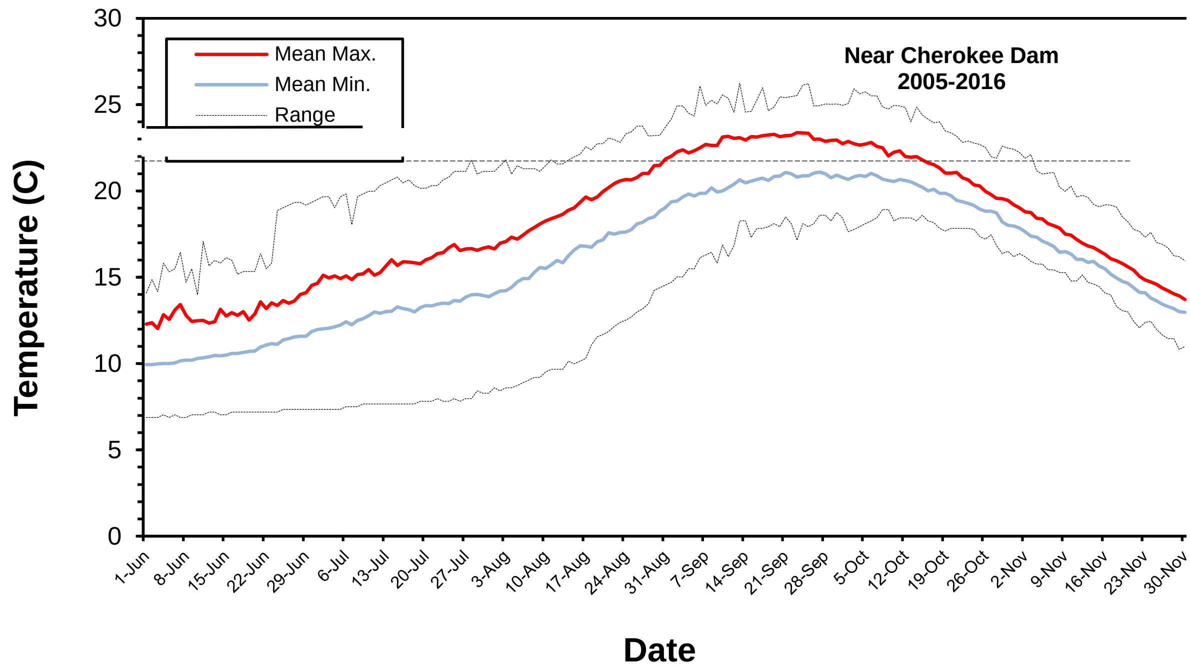
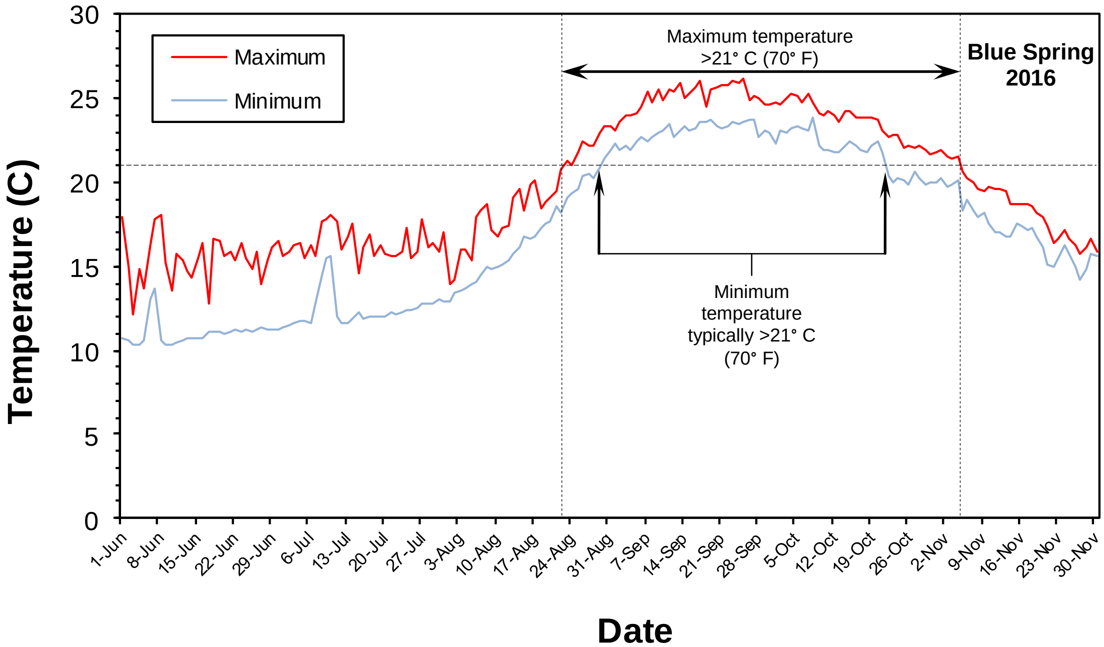


Figure 3-9. Daily temperature maxima and minima for June-November near Cherokee Dam (~1.6 km below the dam) in 2016 (upper graph) and 2005-2016 means (lower graph, with range).

Cherokee Tailwater



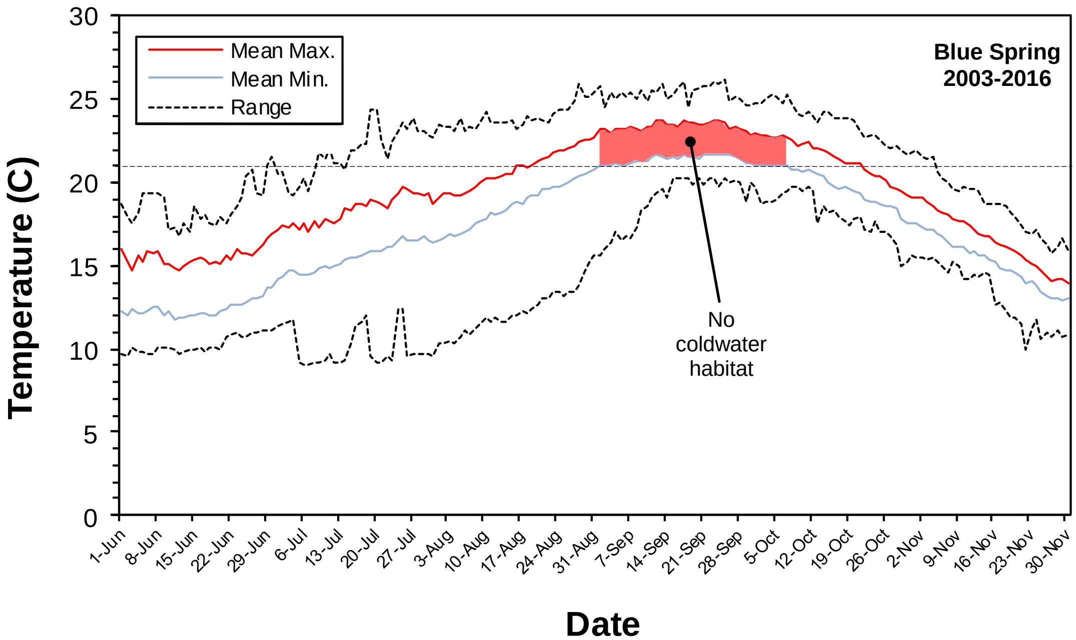


Figure 3-10. Daily temperature maxima and minima for June-November at Blue Spring (~13 km below the dam) in 2016 (upper graph) and 2003-2016 means (lower graph, with range).

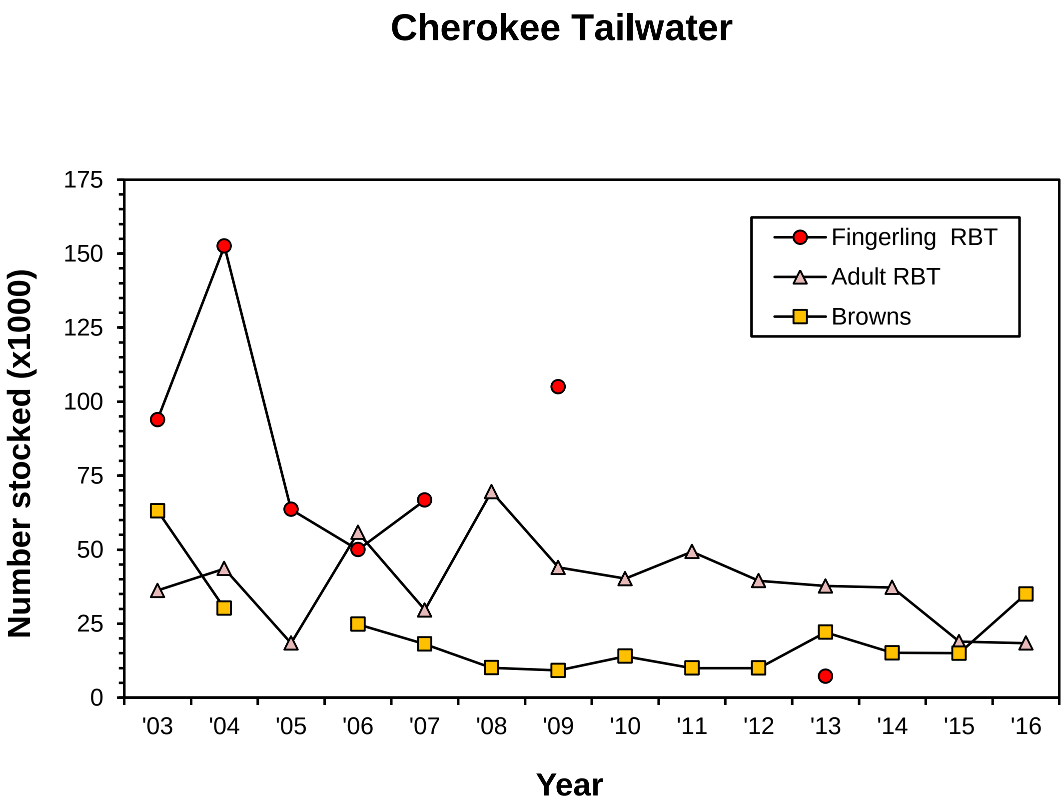


Figure 3-11. Recent trout stocking rates for the Cherokee tailwater. About 25,000 adult rainbow trout and 21,700 brown trout have been stocked annually since 2014.

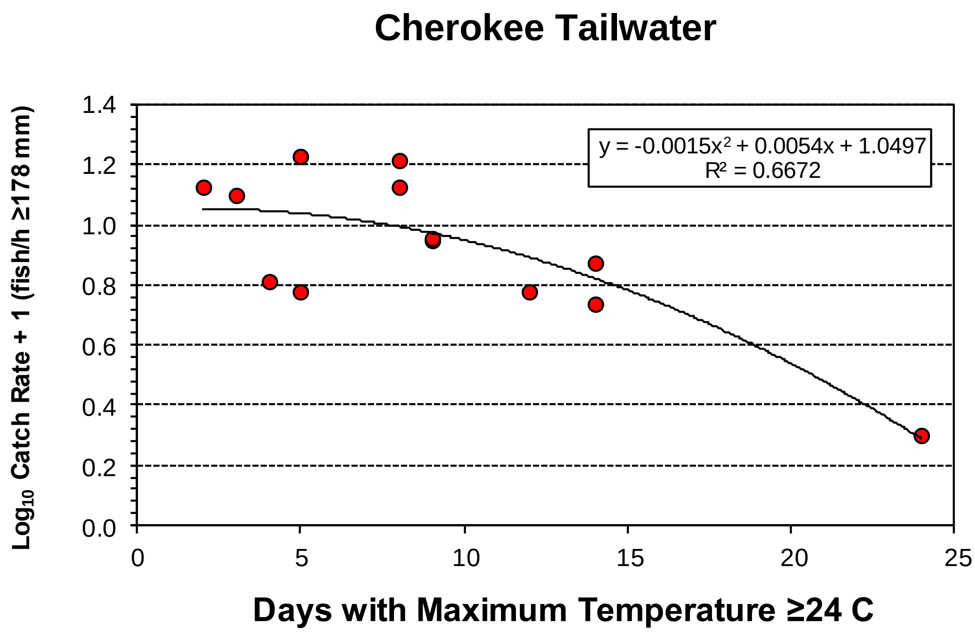


Figure 3-12. Inverse relationship between temperature (days during June-Oct. with maximum ≥24 C at Blue Spring) and October electrofishing catch rate for the Cherokee tailwater.

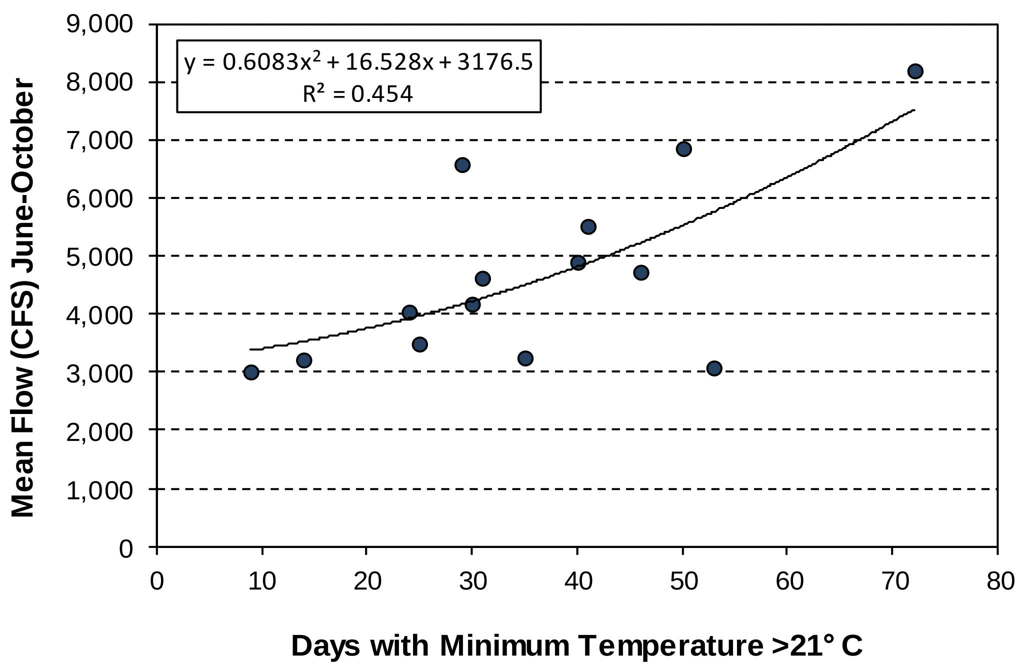


Figure 3-13. Relationship between mean flow (June-October) and temperature (days during June-October with minimum ≥21 C at Blue Spring) for the Cherokee tailwater.

3.2.3 Wilbur (Watauga River)

Study Area

The Watauga River originates in the mountains of northwestern North Carolina and is impounded near Hampton, Tennessee (Carter County), forming Watauga Reservoir (2,603 ha). Most of the reservoir's watershed (1,213 km^2) is forested and much of the Tennessee portion lies within the CNF. Wilbur Dam is located 4.2 km (~2.6 mi.) downstream of Watauga Dam and impounds a small (29 ha or 72 acre) reservoir. The dam was completed in 1912 and is the second oldest in the TVA system (Ocoee No. 1 is the oldest). Despite its long history of degradation (Bivens 1988), the Watauga River between Elizabethton and Boone Reservoir supported one of the finest trout fisheries in the state by the 1990's through a combination of TVA's water quality improvements and TWRA's stocking program.

Bettoli (1999) estimated that the capacity of the Wilbur tailwater to overwinter trout (122 kg/ha) was second only to the South Holston tailwater. The trout fishery in the 16-km (10-mile) river section downstream of Elizabethton was severely damaged by toxic runoff associated with a fire at the North American Corporation in February 2000 (Habera et al. 2001b). Restoration of the trout fishery began immediately and was complete by 2005 (Habera et al. 2006).

The Wilbur tailwater currently supports a 26-km (16-mi.) fishery for rainbow and brown trout. Surface area of the tailwater at base flow is 135 ha (Bettoli 1999). Put-and-take and put-and-grow fisheries are provided by annually stocking fingerling and adult rainbow trout. Additionally, successful natural reproduction (Banks and Bettoli 2000; Holbrook and Bettoli 2006) has led to the development of a substantial wild brown trout fishery, particularly in the upper half of the tailwater. Brown trout stocking was discontinued throughout the tailwater in 2015. General trout angling regulations apply except in a 'Quality Zone' (QZ) extending 4.2 km (2.6 mi.) between Smalling Bridge and the CSX Railroad Bridge near Watauga (Figure 3-9). A two-fish creel limit and 356-mm minimum size limit are in effect within the QZ and only artificial lures are permitted. A 2013 TWRA creel survey indicated that Wilbur tailwater trout anglers catch an average of 1.68 fish/h and 6 fish/trip, while harvesting 0.89 fish/trip. (Black 2014).

Wilbur tailwater Quality Zone.

The 13 monitoring stations on the Wilbur tailwater (Figure 3-14) were sampled on 29 February 2015. The purpose of the additional station (10.5; Figure 3-14) is to help evaluate the

QZ as prescribed in the previous Wilbur tailwater management plan (Habera et al. 2009b). Data from this station are used only for comparing electrofishing catch rates inside and outside the QZ. Location and sampling effort details for all stations are provided in Table 3-5.

Results and Discussion

The 12 Wilbur tailwater monitoring stations produced 537 trout weighing over 108 kg in 2016 (Table 3-6). Total catch increased 28% relative to 2015 as the result of increases in the number of brown trout captured throughout the tailwater, but particularly at stations 1-6 (Table 3-6). Total biomass for the 2016 sample actually decreased slightly (3%), reflecting declines in the number of larger trout (≥356 mm and ≥457 mm) captured. The 2016 catch included 411 browns (77%, Table 3-4) and 126 rainbows. Brown trout have been the predominant species in all Wilbur tailwater monitoring samples except during 2001 (immediately following the fish kill). Bettoli (1999) estimated that browns represented 60% of overwintering trout density in the Wilbur tailwater during 1998-1999. Since 2001, the relative abundance of brown trout has been in the 66-78% range. Most brown trout in 2016 were in the 125-125 mm (probably age-1) and 229-279 mm (probably age-2) size groups. Most rainbow trout (75%) were in the 203-279 mm size groups (Figure 3-15).

The 2016 mean catch rate for all trout in the ≥178 mm size class increased slightly (to 210 fish/h; Figure 3-16) and has remained above 200 fish/h during the past three years, primarily as a result of the increasing wild brown trout population (Figure 3-15). The new Wilbur tailwater management plan (Habera et al. 2015b) prescribes developing a wild brown trout fishery throughout the tailwater by discontinuing all brown trout stocking (effective in 2015). This strategy will be considered successful if a mean brown trout catch rate of 40 fish/h (≥178 mm) can be maintained in the lower portion of the tailwater (Stations 8-12) during 2015-2020 (Habera et al. 2015b). The 2016 brown trout catch rate in that area was 36 fish/h (35 fish/h in 2015).

The mean catch rate for larger trout (≥356 mm) decreased slightly again but remains near 20 fish/h (Figure 3-16)—the long-term average since restoration was considered complete in 2005. The mean catch rate for the largest trout (≥457 mm) also decreased from 5.0 fish/h in 2015 to 4.0 fish/h in 2016 (Figure 3-16). Most of the trout in this size range are browns, as few (7) rainbow trout ≥457 mm have been captured to date. However, rainbow trout in this size range have been relatively uncommon in other Region IV tailwaters such as South Holston and Cherokee:

Tailwater	Effort (total monitoring hours)	Rainbow trout ≥457 mm	Mean catch rate (fish/h)
South Holston	36	8	0.22
Cherokee	28	7	0.25
Wilbur	30	7	0.23

Weiland and Hayward (1997) observed that failure of rainbow trout to reach large sizes in some tailwaters may be related to diet overlap among size class and limited capacity to intraspecifically partition food resources (in contrast to brown trout). Dodrill et al. (2016) found that prey size, as well as abundance and quality, limits maximum size for drift-foraging rainbow trout in tailwaters. Bioenergetically, larger rainbow trout would prefer to select larger prey items, but these can be scarce in tailwater systems (Dodrill et al. 2016).

A Wilbur tailwater brown trout.

The 2016 catch rate for trout ≥356 mm throughout the Wilbur tailwater (20 fish/h) was near the lower end of the current range for other Region IV tailwaters (1–87 fish/h). Recently, mean catch rates for trout ≥356 mm in the QZ (Stations 10, 10.5, and 11) have been somewhat higher than corresponding catch rates at the other 10 stations. (Figure 3-17). However, there has been substantial overlap of the 90% confidence limits for both areas in most years (Figure 3-17) because of substantial catch rate variability among the QZ sites related to habitat quality. While not conclusive, these data provide no clear indication that the QZ regulations are enhancing abundance of larger trout in that area, although they do suggest a general increase in the electrofishing catch rate of trout ≥356 mm throughout the tailwater since 2005. The most recent angler harvest rate for the Wilbur tailwater was relatively low (0.89 fish/trip), but separate data were not available for the QZ. However, focusing harvest on larger trout size classes through minimum length limits (rather than protecting them) may actually promote recruitment and growth overfishing (Sánchez-Hernández 2016) and thereby limit attainment of management objectives.

The Wilbur tailwater was stocked with 50,000 fingerling and 43,000 adult rainbow trout during 2016 (Figure 3-18) as basically directed in the current management plan (Habera et al. 2015b). No brown trout were stocked and brook trout stocking was discontinued in 2009 (after eight years) because of extremely low survival (0.1 – 4.4% over 100 d), slow growth (4-15 mm per month), and excessive predation by brown trout (Damer and Bettoli 2008).

Management Recommendations

The goal of the current (2015-2020) Wilbur tailwater management plan is to maintain a quality trout fishery throughout the tailwater capable of providing a variety of opportunities to the anglers who enjoy this resource (Habera et al. 2015b). The basic objectives of the previous plan—to maintain (or improve) the overall trout population abundance/size structure and manage for a wild brown trout fishery in the upper half of the tailwater—were accomplished. Attainment of a third objective—ensuring that the QZ is actually providing anglers the opportunity to experience higher catch rates for trout ≥356 mm (14 in.)—remains uncertain, but may now be less important.

A new creel survey conducted by TWRA in 2016 specifically asked 273 Wilbur tailwater anglers if they fished in the QZ during the past three years and if so, whether or not they caught more trout ≥356 mm there than elsewhere in the tailwater. Anglers who fished the QZ were also asked if they were in favor of changing regulations there to a PLR (e.g., 356-457 mm or 14-18 in.) with no bait restrictions and a 7-fish creel (with one >457 mm). Ninety anglers (33%) indicated that they had fished in the QZ since 2013, with slightly less than half of those (44%) reporting that they did catch more trout ≥356 mm there. Even though a majority of anglers did not experience a higher catch rate for larger trout in the QZ, most (81%) did not support the proposed regulation change. This opinion differed little between those who caught more large fish in the QZ (83% unsupportive) and those who did not (80% unsupportive). Previously (2013), a majority of all Wilbur tailwater anglers (67%) also expressed their support for the existing QZ regulations and 60% opposed replacing it with a tailwater-wide PLR (slot limit) with no bait restrictions (Habera et al. 2015a). A substantial majority (98%) rated TWRA's management of the Wilbur tailwater trout fishery as good or excellent at that time. Additional results of the 2016 angler survey will be provided in the 2017 Region IV Trout Fisheries Report.

Because of the detection of whirling disease in nearby North Carolina trout fisheries and the popularity of the Wilbur tailwater with anglers from that area, rainbow and brown trout from the Wilbur tailwater will be collected and screened for this pathogen during 2017.

Wilbur Tailwater

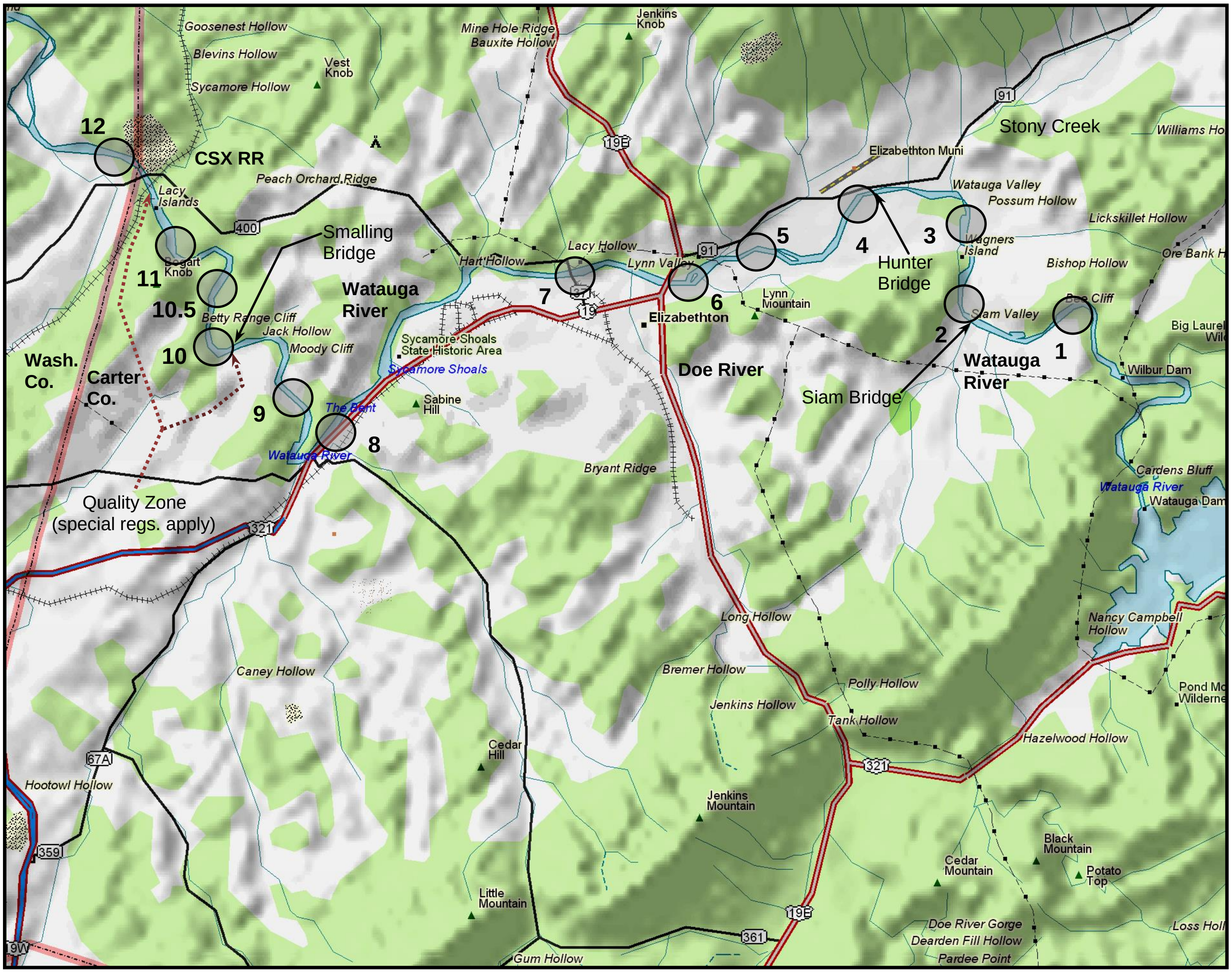


Figure 3-14. Locations of the Wilbur tailwater (Watauga River) monitoring stations. Station 10.5 was added in 2010 to help evaluate the Quality Zone (which also includes stations 10 and 11).

Table 3-5. Location and sampling information for the 13 electrofishing stations on the Wilbur tailwater, 29 February 2016.

Station	Site Code	County	Quadrangle	Coordinates	Reach Number	River Mile	Effort (s)	Output
1	420160101	Carter	Elizabethton 207 SW	36.35194N-82.13306W	06010103-19,0	33.0	600	400 V DC 120 PPS, 4 A
2	420160102	Carter	Elizabethton 207 SW	36.34806N-82.14861W	06010103-19,0	32.0	600	884 V DC 120 PPS, 4 A
3	420160103	Carter	Elizabethton 207 SW	36.36361N-82.15444W	06010103-19,0	30.3	600	400 V DC 120 PPS, 4 A
4	420160104	Carter	Elizabethton 207 SW	36.36833N-82.16861W	06010103-18,0	29.5	600	884 V DC 120 PPS, 4 A
5	420160105	Carter	Elizabethton 207 SW	36.35833N-82.17944W	06010103-18,0	28.4	600	400 V DC 120 PPS, 4 A
6	420160106	Carter	Elizabethton 207 SW	36.35500N-82.20333W	06010103-18,0	27.0	600	884 V DC 120 PPS, 4 A
7	420160107	Carter	Elizabethton 207 SW	36.36028N-82.22694W	06010103-12,2	25.9	600	400 V DC 120 PPS, 4 A
8	420160108	Carter	Johnson City 198 SE	36.33222N-82.26694W	06010103-12,2	22.4	600	884 V DC 120 PPS, 4 A
9	420160109	Carter	Johnson City 198 SE	36.33389N-82.26917W	06010103-12,0	21.8	600	400 V DC 120 PPS, 4 A
10	420160110	Carter	Johnson City 198 SE	36.34556N-82.28306W	06010103-12,0	20.0	600	884 V DC 120 PPS, 4 A
10.5	420160111	Carter	Johnson City 198 SE	36.35150N-82.28730W	06010103-12,0	19.4	600	400 V DC 120 PPS, 4 A
11	420160112	Carter	Johnson City 198 SE	36.35750N-82.29056W	06010103-10,0	18.7	600	400 V DC 120 PPS, 4 A
12	420160113	Carter	Johnson City 198 SE	36.37361N-82.30250W	06010103-10,0	17.3	600	884 V DC 120 PPS, 4 A

Station 10.5 was added in 2010 to help evaluate the Quality Zone (also includes Stations 10 and 11).

Table 3-6. Catch data for the 13 electrofishing stations on the Wilbur tailwater sampled 29 February 2016.

Station	Species	Total Catch	Size Range (mm)	Total Weight (g)	% Abundance (number)	% Abundance (weight)
1	Rainbow	9	193-302	1,202	15	10
	Brown	53	111-377	11,154	85	90
Totals		**62**		**12,356**	**100**	**100**
2	Rainbow	12	193-359	2,474	19	16
	Brown	52	119-403	13,223	81	84
Totals		**64**		**15,697**	**100**	**100**
3	Rainbow	3	232-287	434	8	6
	Brown	34	147-409	7,179	92	94
Totals		**37**		**7,613**	**100**	**100**
4	Rainbow	11	216-290	1,725	12	13
	Brown	80	110-408	11,653	88	87
Totals		**91**		**13,378**	**100**	**100**
5	Rainbow	15	203-420	3,246	14	25
	Brown	89	90-344	9,745	86	75
Totals		**104**		**12,991**	**100**	**100**
6	Rainbow	20	217-351	3,502	32	35
	Brown	42	125-380	6,600	68	65
Totals		**62**		**10,102**	**100**	**100**
7	Rainbow	3	220-314	577	11	8
	Brown	24	145-625	6,283	89	92
Totals		**27**		**6,860**	**100**	**100**
8	Rainbow	18	148-383	3,629	64	45
	Brown	10	145-555	4,385	36	55
Totals		**28**		**8,014**	**100**	**100**
9	Rainbow	13	213-344	2,720	68	62
	Brown	6	175-422	1,655	32	38
Totals		**19**		**4,375**	**100**	**100**
10	Rainbow	11	205-366	2,805	48	34
	Brown	12	166-543	5,465	52	66
Totals		**23**		**8,270**	**100**	**100**
10.5	Rainbow	7	233-366	2,230	30	27
	Brown	6	176-469	3,083	26	37
Totals		**13**		**5,313**	**57**	**64**
11	Rainbow	10	231-422	3,733	63	52
	Brown	6	167-480	3,507	38	48
Totals		**16**		**7,240**	**100**	**100**
12	Rainbow	1	397	649	25	50
	Brown	3	132-334	662	75	50
Totals		**4**		**1,311**	**100**	**100**
Total Rainbows[1]		126	148-422	26,696	23	25
Total Browns[1]		411	90-625	81,511	77	75
Overall totals[1]		**537**		**108,207**	**100**	**100**

[1]Overall totals do not include Station 10.5, which was added in 2010 to help evaluate the Quality Zone (stations 10, 10.5, and 11 are in the QZ).

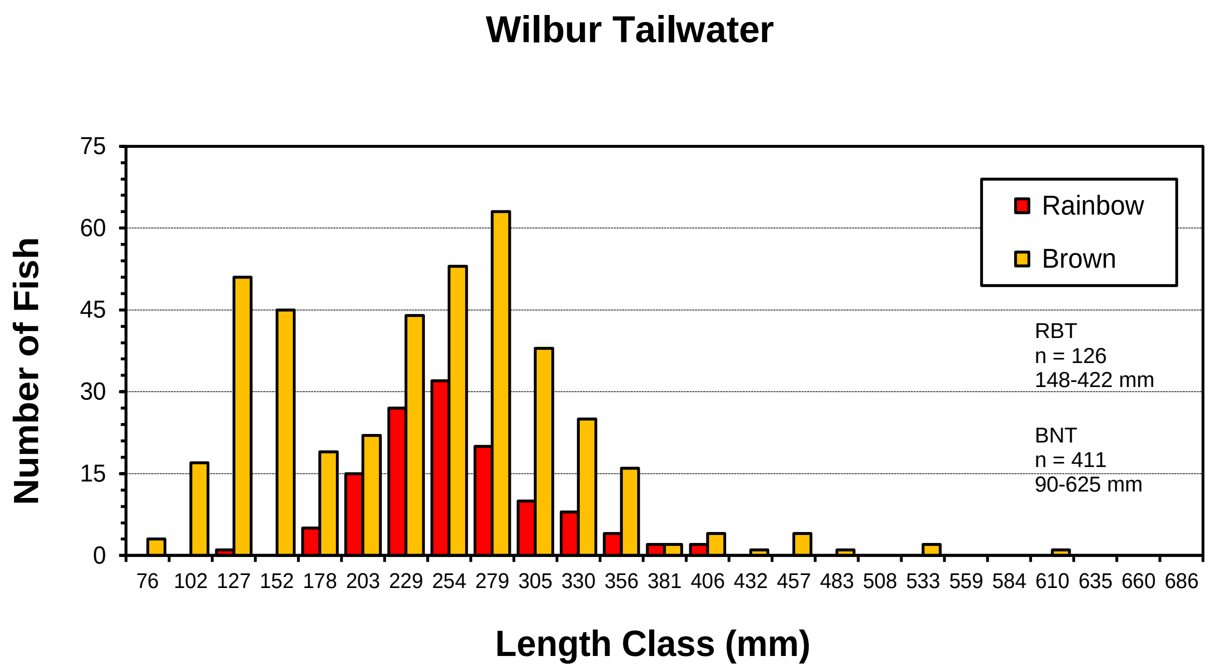


Figure 3-15. Length frequency distributions for trout from the Wilbur tailwater monitoring stations in 2016 (excluding Station 10.5).

Wilbur Tailwater

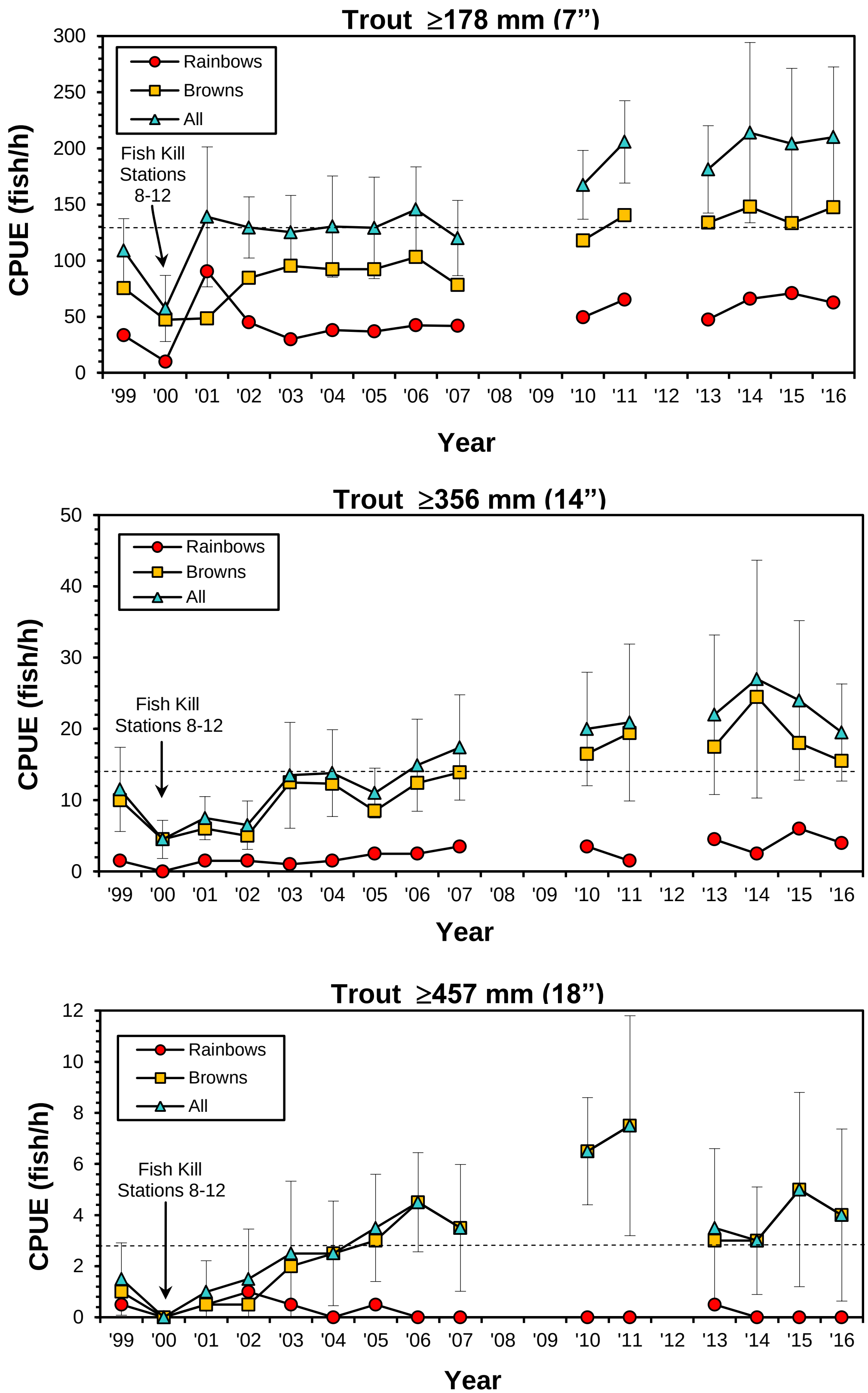


Figure 3-16. Mean trout CPUEs for the Wilbur tailwater samples. Bars indicate 90% confidence intervals.

Wilbur Tailwater

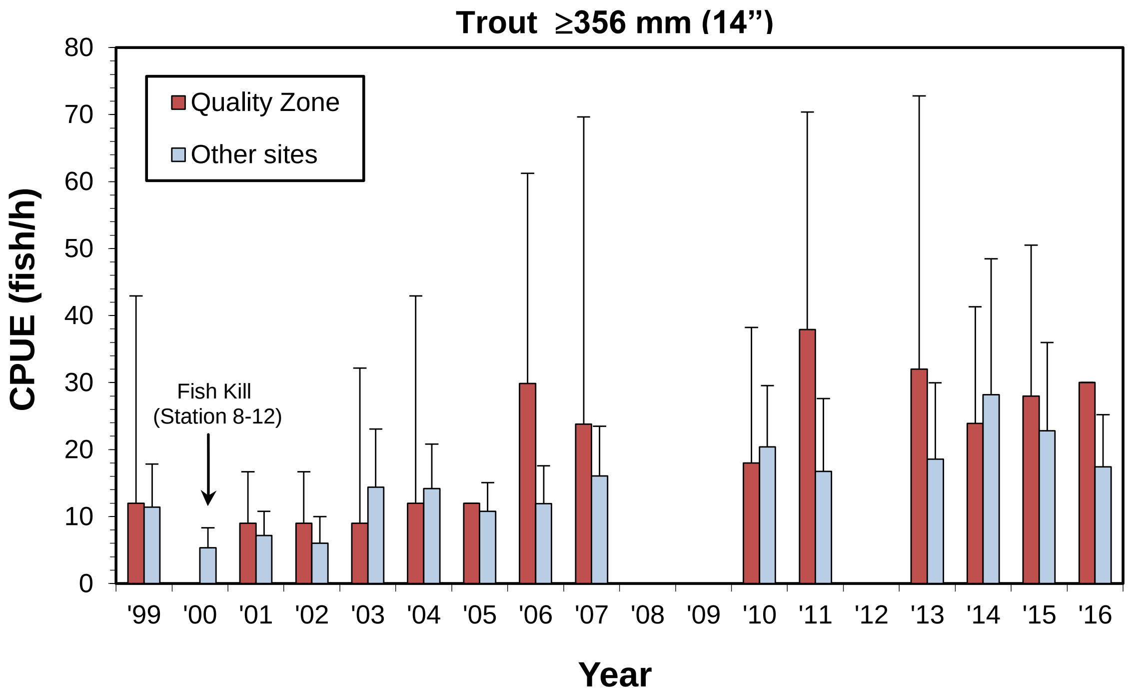


Figure 3-17. Mean trout CPUEs for trout ≥356 mm from the Quality Zone (QZ; sites 10, 10.5, and 11) and the other ten sites on the Wilbur tailwater. Bars indicate 90% upper confidence limits.

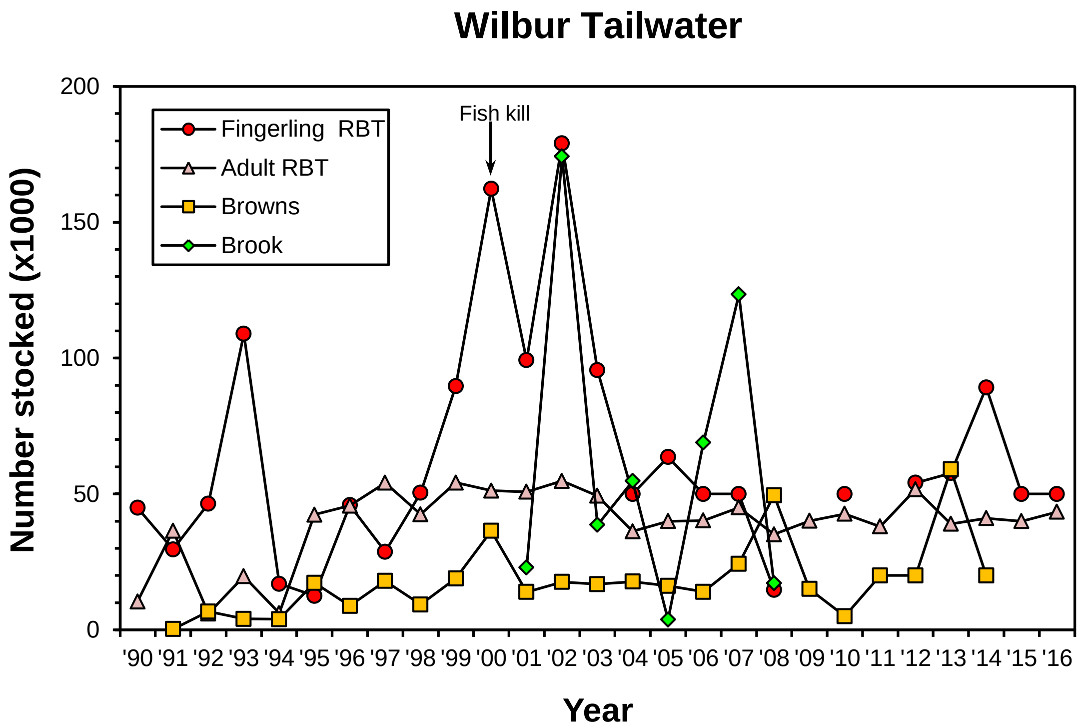


Figure 3-18. Recent trout stocking rates for the Wilbur tailwater. Annual stocking rates under the new management plan (2015-2020) are 40,000 adult rainbow trout and 50,000 fingerling rainbows.

.

3.2.4 Fort Patrick Henry (South Fork Holston River)

Study Area

Ft. Patrick Henry Dam impounds a small (362 ha) reservoir (Ft. Patrick Henry Lake) on the South Fork of the Holston River near Kingsport. TVA maintains a minimum flow of 11.3 m^3/s (400 cfs) downstream of the dam, where the river provides an important industrial water supply. The upper 4.7 km (2.9 mi.) of the Ft. Patrick Henry tailwater (Figure 3-19) is managed as a put-and-take and put-and-grow trout fishery with annual stockings of adult and fingerling rainbow trout and sub-adult (152-178 mm) brown trout. Sample site locations and effort details are summarized in Table 3-7.

Results and Discussion

The catch from the four Ft. Patrick Henry tailwater electrofishing stations comprised 102 trout weighing over 79 kg in 2016 (Table 3-8). Trout biomass for 2016 exceeded all previous monitoring samples. Higher rainbow trout abundance, particularly larger fish (≥356 mm), produced this increase. Rainbow trout ranged from 139-573 mm and fish in the 279 mm (11 in.) and 381-432 mm (15-17 in.) size classes were most abundant (Figure 3-20). Rainbow trout ≥432 mm (17 in.) were about twice as abundant in the 2015 (44) and 2016 (36) samples as in any previous monitoring year. Additionally, more rainbow trout ≥508 mm (20 in.) were captured in 2016 (16) than in any earlier sample (maximum was 8 in 2015). The seven brown trout captured in 2016 ranged from 135-370 mm and made up only 2% of the sample biomass (Table 3-8). The mean catch rate for all trout ≥178 mm decreased slightly to 94 fish/h in 2016 (Figure 3-21), but remained well above the long-term (2002-2015) average of 74 fish/h. However, the catch rate for larger trout (≥356 mm) increased again to 67 fish/h (Figure 3-21)—the highest catch rate for trout in this size class obtained since monitoring began in 2002. The mean catch rate for the largest trout (≥457 mm or 18 in.), which had been at its highest level in 2015, decreased somewhat to 28 fish/h (Figure 3-21)—still well above the 2002-2015 average of 14 fish/h. The abundance of trout ≥457 mm had been depressed during 2004-2010 (0 to 4 fish/h), but has improved substantially since then, averaging over 17 fish/h (Figure 3-21). Stocking rates have been more stable since 2009 (Figure 3-22), with 15,800 adult rainbow trout, 3,700 fingerling rainbows, and 22,300 brown trout stocked in 2016. Overall, an

Ft. Patrick Henry tailwater.

average of 19,300 rainbow trout (including 7,500 fingerlings) and 17,500 browns has been stocked during the previous three years (Figure 3-22).

Management Recommendations

Despite its relatively small size, the Ft. Patrick Henry tailwater provides an excellent trout fishery that consistently produces large, extremely well-conditioned trout. Mean relative weight (W_r) is 107 (SE=0.49) for rainbow trout and 109 (SE=1.03) for brown trout, with numerous fish of both species exceeding 130. This fishery is currently subject to statewide trout angling regulations and no changes are recommended at this time. The current adult rainbow trout and brown trout stocking rates should at least be maintained (about 15,000 of each per year). Also, the four sampling stations should be sampled annually to obtain information useful for the future management of this fishery. These basic recommendations will be incorporated into a trout fishery management plan for the Ft. Patrick Henry and Boone tailwaters (in preparation during 2017) to ensure that they continue to achieve their potential for providing exceptional angling opportunities for quality trout.

A large rainbow trout from the Ft. Patrick Henry tailwater.

Ft. Patrick Henry Tailwater

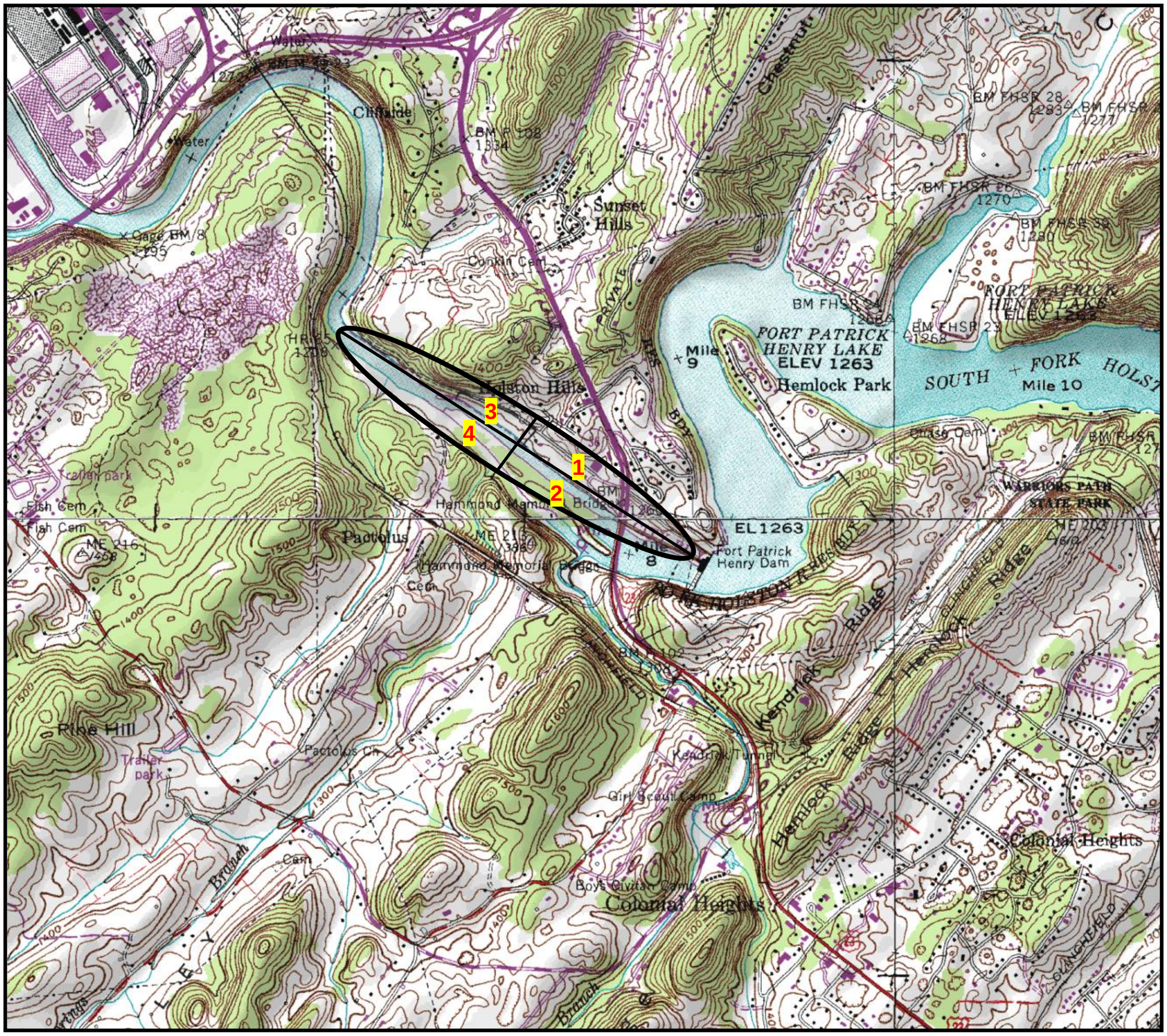


Figure 3-19. Location of the Ft. Patrick Henry tailwater (South Fork Holston River) monitoring stations.

Table 3-7. Location and sampling information for the four stations on the Ft. Patrick Henry tailwater, 11 March 2016.

Station	Site Code	County	Quadrangle	Coordinates	Reach Number	River Mile	Effort (s)	Output
1	420160501	Sullivan	Kingsport 188 SE	36.49972N-82.51278W	06010102-4,1	8.0	900	200 V DC 120 PPS, 4 A
2	420160502	Sullivan	Kingsport 188 SE	36.49917N-82.51278W	06010102-4,1	8.0	902	884 V DC 120 PPS, 4-5 A
3	420160503	Sullivan	Kingsport 188 SE	36.50583N-82.52306W	06010102-4,0	7.4	900	200 V DC 120 PPS, 4 A
4	420160504	Sullivan	Kingsport 188 SE	36.50556N-82.52333W	06010102-4,0	7.4	927	884 V DC 120 PPS, 4-5 A

Table 3-8. Catch data for the four electrofishing stations on the Ft. Patrick Henry tailwater sampled 11 March 2016.

Station	Species	Total Catch	Size Range (mm)	Total Weight (g)	% Abundance (number)	% Abundance (weight)
1	Rainbow	26	139-572	16,750	93	96
	Brown	2	171-350	675	7	4
Totals		**28**		**17,425**	**100**	**100**
2	Rainbow	23	235-573	21,258	85	95
	Brown	4	135-370	1,042	15	5
Totals		**27**		**22,300**	**100**	**100**
3	Rainbow	21	235-571	17,645	95	100
	Brown	1	149	35	5	0
Totals		**22**		**17,680**	**100**	**100**
4	Rainbow	25	293-572	21,697	100	100
	Brown	0	--	0	0	0
Totals		**25**		**21,697**	**100**	**100**
Total Rainbows		**95**	139-573	**77,350**	93	98
Total Browns		**7**	135-370	**1,752**	7	2
Overall totals		**102**		**79,102**	**100**	**100**

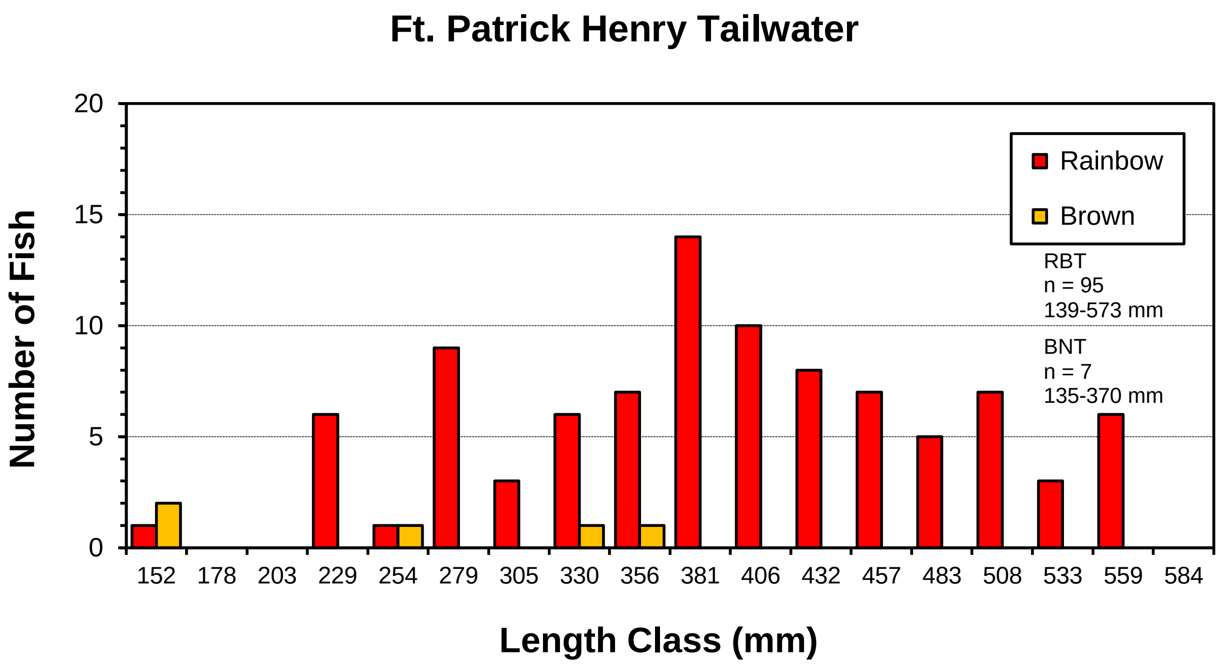


Figure 3-20. Length frequency distributions for trout from the Ft. Patrick Henry tailwater monitoring stations in 2016.

Ft. Patrick Henry Tailwater

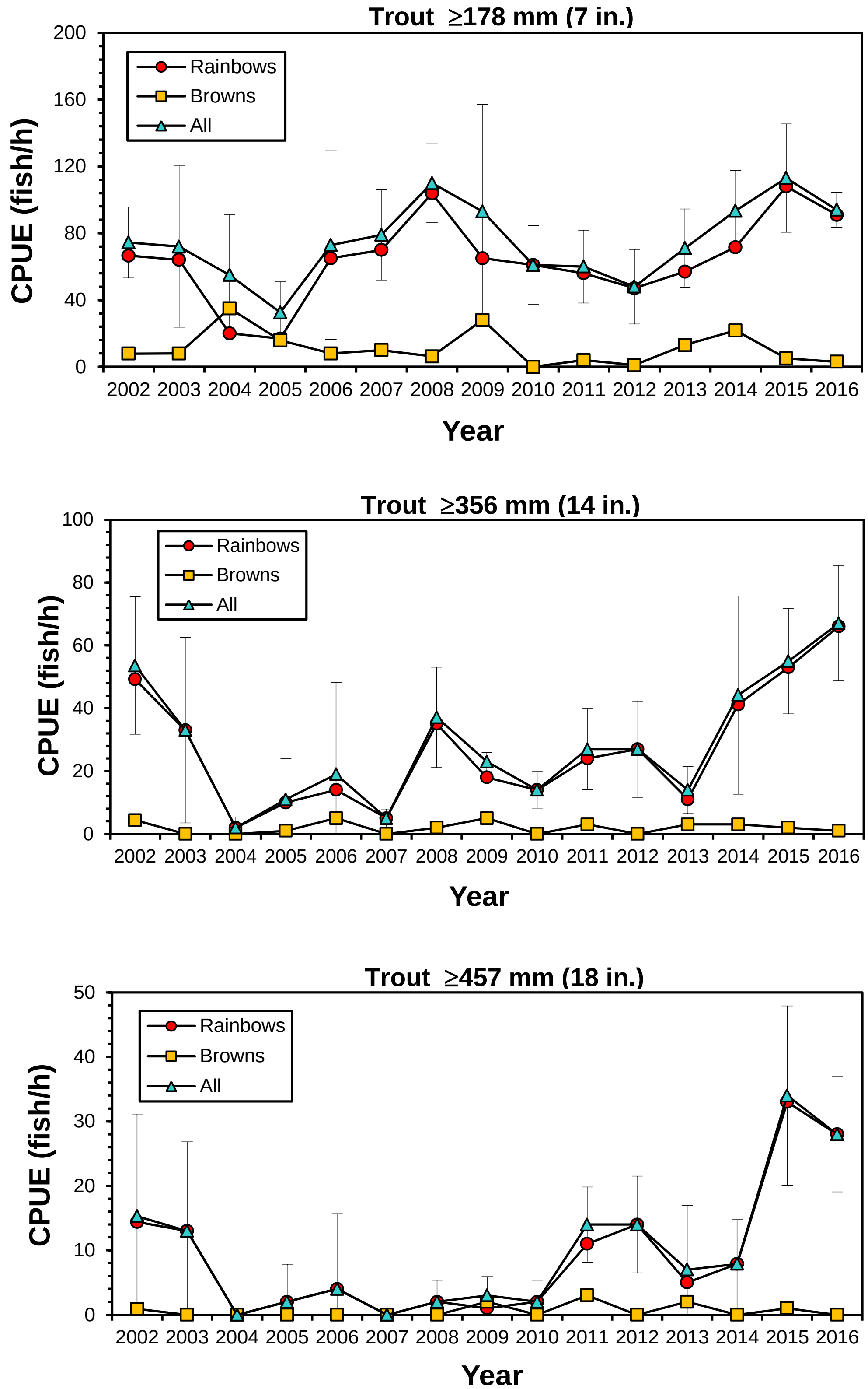


Figure 3-21. Mean trout CPUEs for the Ft. Patrick Henry tailwater samples. Bars indicate 90% confidence intervals.

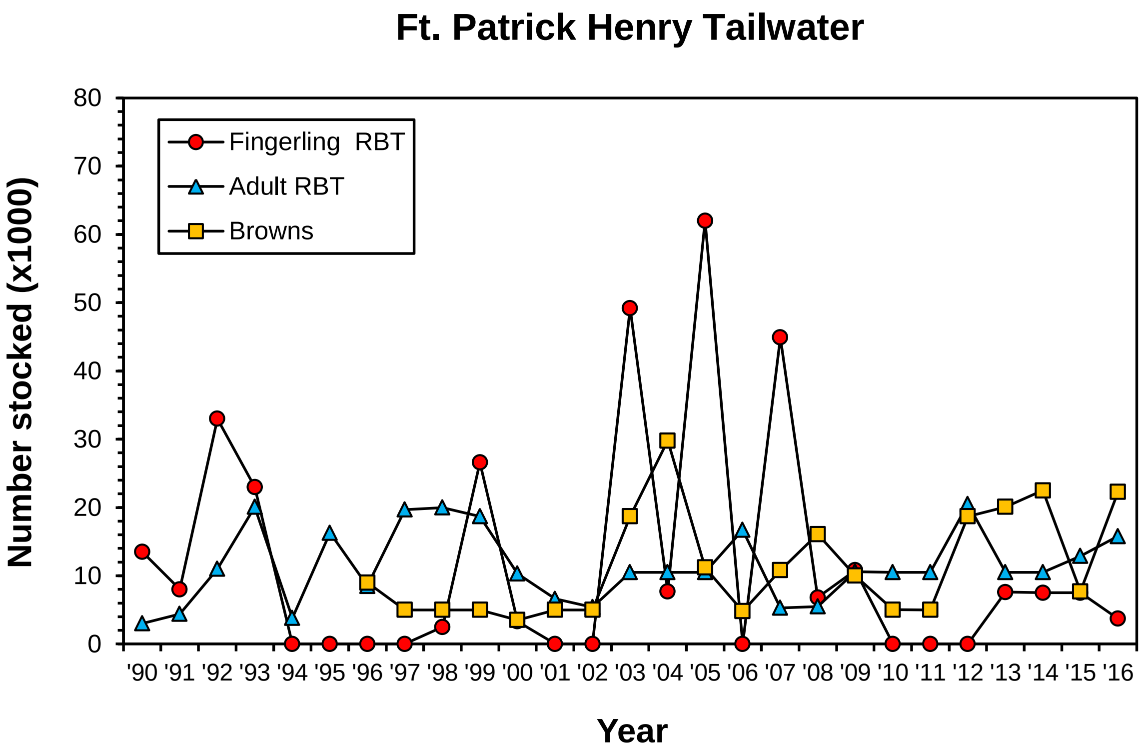


Figure 3-22. Recent trout stocking rates for the Ft. Patrick Henry tailwater. The average annual stocking rate during the past three years (2014-2016) was 19,300 rainbows and 17,500 brown trout.

3.2.5 Boone (South Fork Holston River)

Study Area

Boone Dam impounds a 1,782 ha (4,400 acre) reservoir (Boone Lake) on the South Fork of the Holston and Watauga rivers in Sullivan and Washington counties near Johnson City and Kingsport. Both the South Holston and Wilbur tailwaters, which support two of Tennessee's premier trout fisheries, flow into Boone Lake. A short (~1 km) tailwater exists downstream of Boone Dam at the upper end of Ft. Patrick Henry Lake. The dam has three autoventing turbines which help improve dissolved oxygen levels in the water released from Boone Dam. This tailwater and Ft. Patrick Henry Lake provide coldwater habitat that was historically been stocked with adult rainbow trout. TWRA's preliminary investigations of this tailwater in 2008 indicated the presence of a good rainbow trout fishery along with a few brown trout, which likely were migrants from the South Holston or Wilbur tailwaters upstream. Evidence of some natural reproduction by rainbow trout (58-85 mm fish) was also detected in 2008 during sampling at base flow. Accordingly, four electrofishing stations (Figure 3-23) were established in 2008 and the Boone tailwater was added to the annual monitoring program in 2009. Sample site locations and effort details are summarized in Table 3-9.


Boone tailwater trout fishery monitoring.

Results and Discussion

The four Boone tailwater monitoring stations produced 91 trout (75 rainbows and 16 browns) weighing 40 kg in 2016 (Table 3-10). Although the total trout catch doubled relative to 2015, catch biomass remained relatively stable, indicating lower mean weights (and in this case presence of fewer large fish ≥457 mm). Rainbow trout have typically exhibited a bimodal size distribution, and the 229 mm (9 in.) and 356-381 mm (14-15 in.) size classes were most abundant in 2016 (Figure 3-24). Brown trout were added to the stocking program in 2008 and while they have not become abundant, several fish over 600 mm (23.6 in.) have been captured in previous samples, indicating that those browns that do survive have excellent growth potential in this tailwater. Most browns captured in 2016 were in the 305-356 mm (12-14 in.) size range (Figure 3-24). Brook trout, stocked in 2009, 2012, and 2014, have also grown exceptionally well (three fish >356 mm or 14 in. have been captured), but none were present in 2016.

The mean electrofishing catch rate for all trout ≥178 mm from the Boone tailwater increased to 91 fish/h in 2016 (Figure 3-25), reversing a general downward trend since 2009 and exceeding the long-term average of 74 fish/h. The catch rate for fish ≥356 mm improved to 38 fish/h in 2016 (Figure 3-25), which is also above the long-term average of 30 fish/h. Interestingly, the 2016 catch rate for trout ≥457 mm decreased to 6 fish/h (Figure 3-25), which is below the long-term average of 8 fish/h and—uncharacteristically—at the lower end of the range for Region IV tailwaters in 2016 (0-28 fish/h). The catch rate for this size group also decreased in the Ft. Patrick Henry tailwater downstream, but not nearly as much (Section 3.2.4). Except for 2014 and 2016, catch rates for larger trout (≥356 mm and ≥457 mm) from the Boone tailwater have typically been at or near the upper end of the corresponding ranges for all Region IV tailwaters.


A large brown trout from the Boone tailwater.

Historically, only adult rainbow trout were stocked in the Ft. Patrick Henry Lake (Boone tailwater) at annually-variable rates, averaging 9,700/year during 1990-2007 (Figure 3-26). Since then, adult rainbow trout stocking rates have generally been higher, although 9,300 were stocked in 2016 (Figure 3-26). Fingerling rainbow trout were not stocked in 2015, but 3,700 were stocked in 2016 about 8,100 per year were stocked during 2008-2014. Given the Boone tailwater's potential to produce large fish, brown trout were added to the program in 2008 and since then, ~12,000 browns (primarily 203 mm) have been stocked annually, including 22,200 in 2016 (Figure 3-26). Brook trout have been stocked occasionally since 2009 (Figure 3-26) and have shown limited survival, but good growth potential. About 11,000 rainbow trout (including fingerlings) and 13,000 brown trout have been stocked annually in the Boone tailwater during the past three years (Figure 3-26).

Repairs to address seepage at the earthen portion of Boone Dam continued in 2016 and require the extended drawdown of Boone Lake to an elevation of 412 m (1,352')—3.1 m (10') below winter pool. TVA maintains a monitoring station in the tailwater near the dam that records several water quality parameters at 5-min. intervals. There were no issues with elevated temperature or depressed dissolved oxygen (DO) levels in 2015 (Habera et al. 2015a). Brief (<30 min.) water temperature increases to 21-22° C on seven days during July-September 2016 are not considered significant. The Boone tailwater reach of the South Fork Holston River is listed under TDEC's water usage classifications (Chapter 0400-40-04; TDEC 2013) and water quality standards (Chapter 0400-40-03; TDEC 2015) as trout water with a minimum DO criterion of 6 mg/l. DO levels in the tailwater were below 6.0 mg/l on all but 7 days during May-July 2016 (often for over 12

h) and on most days in October. Although DO did not fall below 3.0 mg/l, it was in the 4 mg/l range on 46 days during May-July. The 2017 monitoring efforts should help determine if these lower DO levels (likely related to drought conditions and reduced flows during summer and fall 2016) had any chronic effect on the Boone tailwater trout fishery. TVA projects that repairs to the dam will be completed sometime during 2020-2022.

Management Recommendations

The Boone tailwater is a relatively small trout fishery, but one that consistently—like the Ft. Patrick Henry tailwater downstream—produces large, well-conditioned trout. Mean W_r is 105 for rainbow trout (SE=0.62), 112 for brown trout (SE=1.93), and 119 for brook trout (SE= 6.51). This fishery is currently subject to statewide trout angling regulations and no changes are recommended at this time. The current trout stocking rates might be adjusted somewhat as more is learned about this tailwater, then standardized. Brook trout should also be included occasionally, as trophy-sized fish can clearly be produced—an option not available with most other brook trout fisheries available to the public. Additionally, the four monitoring stations should be sampled annually to obtain information necessary for the future management of this fishery. These basic recommendations will be incorporated into a trout management plan for the Boone and Ft. Patrick Henry tailwaters (in preparation during 2017) to ensure that they continue to achieve their potential to provide exceptional angling opportunities. TWRA will also continue to work cooperatively with TVA to ensure that the Boone Lake drawdown does not impact the tailwater trout fishery (or the other sport fisheries in the lake).

Boone Tailwater

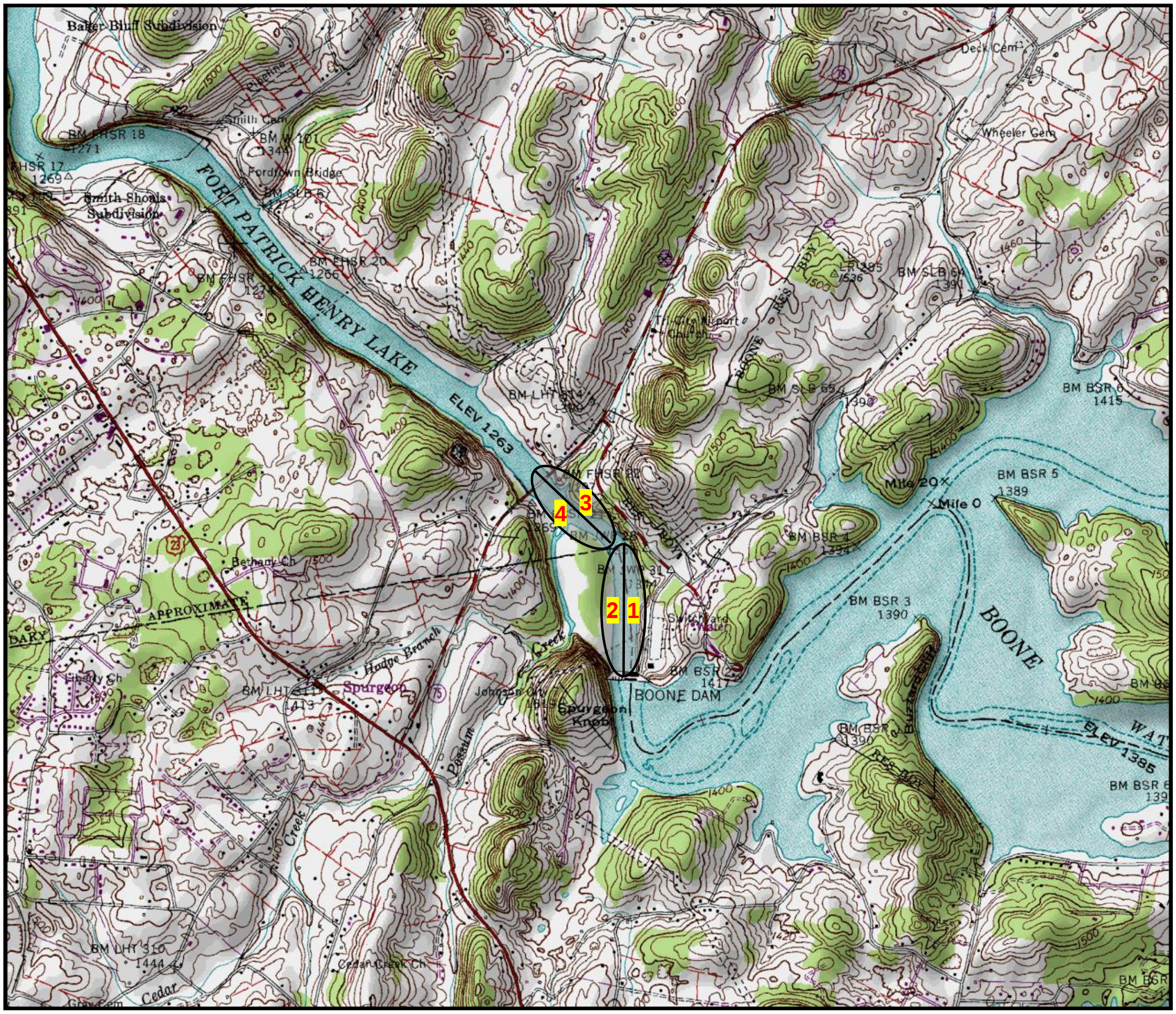


Figure 3-23. Location of the Boone tailwater (South Fork Holston River) monitoring stations.

Table 3-9 Location and sampling information for the four stations on the Boone tailwater, 11 March 2016.

Station	Site Code	County	Quadrangle	Coordinates	Reach Number	River Mile	Effort (s)	Output
1	420160401	Sullivan	Boone Dam 198 NW	36.44302N-82.43746W	06010102-5,1	18.5	929	200 V DC 120 PPS, 4 A
2	420160402	Washington	Boone Dam 198 NW	36.44344N-82.43823W	06010102-5,1	18.5	900	884 V DC 120 PPS, 5 A
3	420160403	Sullivan	Boone Dam 198 NW	36.44589N-82.43883W	06010102-5,1	18.2	900	200 V DC 120 PPS, 4 A
4	420160404	Sullivan	Boone Dam 198 NW	36.44589N-82.43887W	06010102-5,1	18.2	900	884 V DC 120 PPS, 5 A

Table 3-10. Catch data for the four electrofishing stations on the Boone tailwater sampled 11 March 2016.

Station	Species	Total Catch	Size Range (mm)	Total Weight (g)	% Abundance (number)	% Abundance (weight)
1	Rainbow	9	207-478	3,210	60	45
	Brown	6	249-472	3,985	40	55
Totals		**15**		**7,195**	**100**	**100**
2	Rainbow	36	209-425	9,055	97	96
	Brown	1	327	356	3	4
Totals		**37**		**9,411**	**100**	**100**
3	Rainbow	5	232-525	3,880	71	80
	Brown	2	350-361	950	29	20
Totals		**7**		**4,830**	**100**	**100**
4	Rainbow	25	230-515	14,894	78	81
	Brown	7	320-462	3,601	22	19
Totals		**32**		**18,495**	**100**	**100**
Total Rainbows		**75**	207-525	**31,039**	82	78
Total Browns		**16**	249-472	**8,892**	18	22
Overall totals		**91**		**39,931**	**100**	**100**

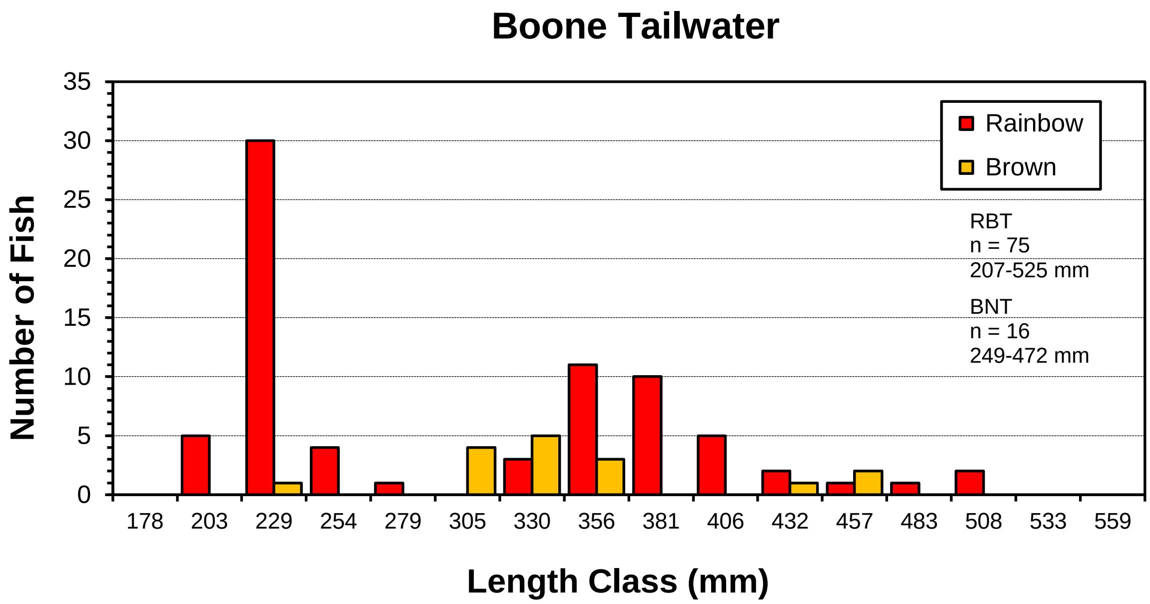


Figure 3-24. Length frequency distributions for trout from the Boone tailwater monitoring stations in 2016.

Boone Tailwater

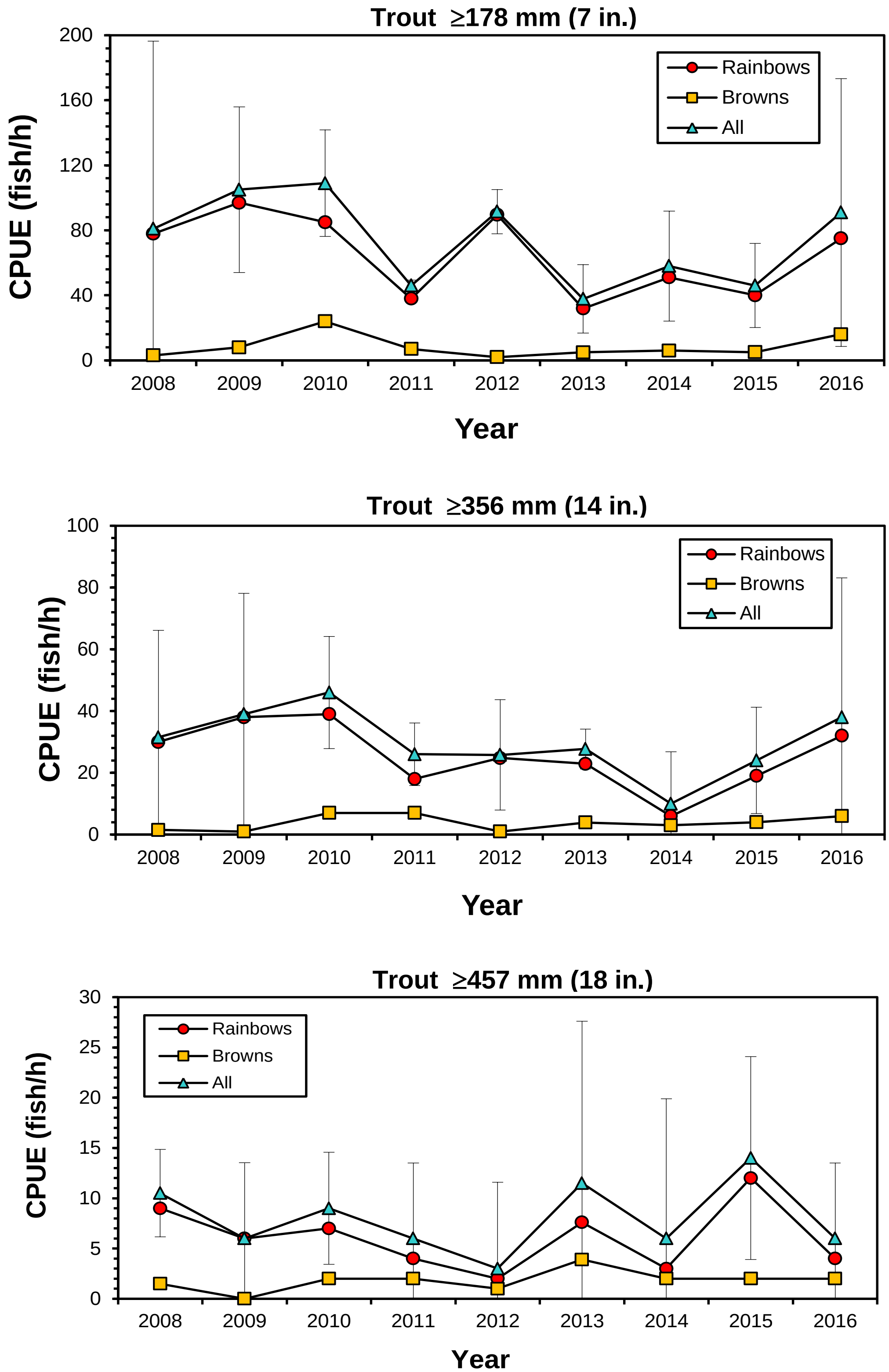


Figure 3-25. Mean trout CPUEs for the Boone tailwater samples. Bars indicate 90% confidence intervals.

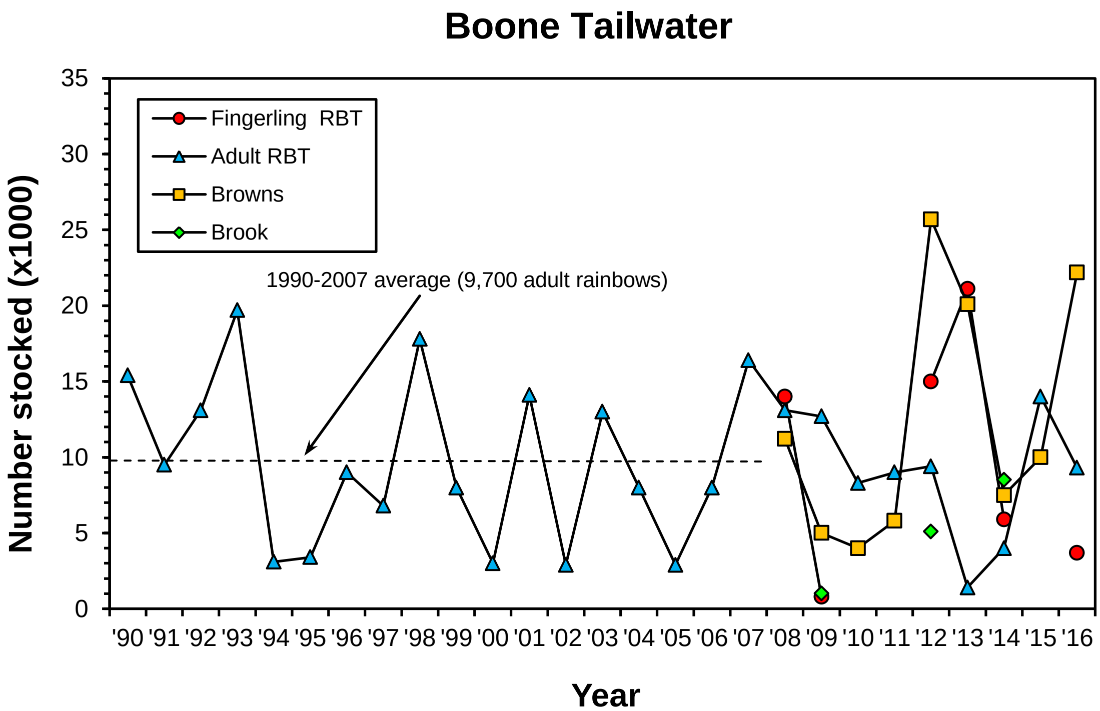


Figure 3-26. Recent trout stocking rates for Ft. Patrick Henry Lake / Boone tailwater. An average of 12,400 rainbow trout and 13,200 brown trout was stocked during 2014-2016.

3.2.6 South Holston (South Fork Holston River)

Study Area

The South Holston tailwater extends ~22.5 km (13.7 mi.) from South Holston Dam to Boone Reservoir. The tailwater was created in 1951 when the Tennessee Valley Authority (TVA) completed construction of the dam at South Fork Holston River Mile (SFHRM) 49.8 in Sullivan County, Tennessee. The reservoir upstream of the dam has a drainage area of 1,821 km^2 and extends upstream for 38.1 km into Washington County, Virginia. Much of the watershed is forested and includes portions of the CNF (Tennessee) and the Jefferson National Forest (Virginia). The tailwater has an average width of 61 m and a surface area of about 137 ha.

TVA addressed low DO levels during summer and fall and a lack of minimum flow in the tailwater by constructing an aerating labyrinth weir at SFHRM 48.5 in 1991 as part of its Reservoir Releases Improvement Program. The weir maintains a minimum flow of 2.55 m^2/s (90 CFS) and recovers approximately 40-50% of the oxygen deficit as water passes over it (Yeager et al. 1993). The turbine is typically pulsed twice daily to maintain the weir pool and these releases are aerated via turbine venting aided with hub baffles. The weir and turbine improvements combine to help maintain the target DO concentration of 6 ppm.

The first trout stockings in the South Holston tailwater occurred in 1952 and included fingerling and adult rainbow and brook trout. Subsequently, annual stockings of adult rainbow trout and fingerling rainbow and brown trout maintained put-and-take and put-and-grow fisheries. Investigations conducted for TWRA by Bettoli et al. (1999) documented substantial natural reproduction (particularly by brown trout) and an overwintering biomass (80% brown trout) of 170-232 kg/ha. Later, Meerbeek and Bettoli (2005) measured an overwintering brown trout biomass of 207 kg/ha during 2003-2004 (highest among all Tennessee tailwaters). Mork's (2011) study of large (>460 mm) brown trout movement in the Boone Lake system verified that some South Holston fish use the reservoir in winter and spring (but not fish from the Wilbur tailwater) and that there was no intermingling of browns from those two populations. No brown trout are stocked in the South Holston tailwater because of the excellent wild brown trout fishery it now provides. Rainbow trout continue to be managed as both a put-and-take and put-and-grow fishery by stocking 40,000 adults and 50,000 fingerlings annually (Habera et al. 2015c).

Establishment of a 'quality zone' with special angling regulations was considered during 1992-1993, but never officially proposed. Subsequently, better biological information (along with angler support) led to a management strategy focused on wild brown trout. All snagging was banned in 1999 and two major trout spawning areas were closed to fishing during November-January. These measures were taken to protect large brown trout during the spawning season and to facilitate development of a self-sustaining fishery. A 406-559 mm (16-22 in.) protected length range (PLR) or "slot limit" was established for the entire tailwater in 2000 with the goal of shifting population structure toward larger fish and protecting spawners (primarily brown trout). Slot limits of this type have been shown to be effective at improving trout population size structures (Luecke et al. 1994; Power and Power 1996).

TWRA established two monitoring sites on the South Holston tailwater in 1995 (Bivens et al. 1996) and sampled these annually during the summer (at base flow) to begin compiling a database on the existing trout fishery. These sites were replaced in 1999 with the 12 stations (Figure 3-27) and protocol established by Bettoli et al. (1999). Current sample site location and effort details are summarized in Table 3-11.

Results and Discussion

The 12 South Holston tailwater monitoring stations produced 640 trout weighing 179 kg in 2016 (Table 3-12). Brown trout catch declined slightly (4%) relative to 2015, while their biomass increased 17%—indicating an improvement in average weight. Brown trout represented 90% of the sample by number and 88% by biomass in 2015, which is similar to samples from recent years. Fifty sub-adult brown trout ≤178 mm were captured in 2016, and along with the 2015 catch (24) are the fewest observed since 2005-2006. This relatively crude indicator of year class strength (for the preceding year) suggests that several large cohorts have entered the population during the past decade, likely producing density-dependent effects on growth and recruitment, particularly given the low levels of angler exploitation.

Brown trout exhibited a bimodal length frequency distribution, with modes at the 178- and 305-mm classes (Figure 3-28). Fish in the 229-330 mm (9-13 in.) size classes represented 59% of the total brown trout sample in 2016 (Figure 3-28), which is down from the peak average of 69% during 2011-2015. There was also better recruitment into the size classes approaching the PLR (356 and 381 mm) than in any year since 2006, as well as into the PLR. Only 12 trout within the PLR were captured in 2015, but this increased to 21 in 2016 (Figure 3-28)—which is also the 2010-2016 average PLR catch. During 2004-2009, the average PLR catch was twice as high (48).

Relative stock density for all trout ≥406 mm (RSD-16) —based on a stock size of 254 mm (Willis et al. 1993)—was 3 in 2015 but improved to 6 in 2016 (Figure 2-29). Prior to any influence from the PLR regulations (1997, 1999-2000) RSD-16 averaged 16 with a corresponding mean CPUE of 106 fish/h (≥178 mm). Following establishment of the PLR, RSD-16 averaged 19 during 2004-2007 (Figure 2-29), but has declined since then (range, 3-11; mean 7) as total CPUE has generally exceeded 250-300 fish/h (≥178 mm). Current trout population size structures, therefore, do not indicate a shift toward larger fish—one of the original intents of the PRL. The Norris tailwater PLR (356-508 mm or 14-20 in.), by comparison, has successfully altered trout population size structures in favor of lager fish and maintained that shift (see Section 3.2.1). Recent angler surveys indicate that the trout harvest rate for both tailwaters is low (Norris, 0.98 fish/trip; South Holston, 1.04 fish/trip), with pressure at Norris (12,249 trips) about half that estimated for South Holston (24,285 trips; Black 2014, 2015).

Mean CPUE for trout ≥178 mm (total) was 293 fish/h in 2016, dropping below 300 fish/h for only the second time since 2009 (Figure 3-30). The long-term average of 250 fish/h continues to be the highest overall catch rate for any Region IV trout tailwater. The mean catch rate for brown trout ≥178 mm (263 fish/h; Figure 3-30) decreased again, but still exceeds the range considered in the new management plan to be more conducive to recruitment into the PLR (150-200 fish/h;

Habera et al. 2015c). The mean catch rate for rainbow trout ≥178 mm was 30 fish/h in 2016 (Figure 3-30) and 48 fish/h for the past two years. The current management plan objective is ≥50 fish/h (Habera et al. 2015c). Trout ≥356 mm are considered to be "quality"-sized fish and the mean catch rate for these fish peaked at 72 fish/h in 2005, but has generally declined since, although there was an increase from 23 to 41 fish/h during the past year (Figure 3-30). The catch rate for trout in the PLR (406-559 mm) has also declined from its peak of 29 fish/h in 2006, but there was an improvement from 6 to 11 fish/h since 2015 (Figure 3-30)—possibly in response to the decrease in overall abundance.

The substantial (3- to 4-fold) increase in trout abundance since the late 1990s (particularly for wild browns) appears to have affected growth (Bohlin et al. 2002; Vøllestad et al. 2002; Lobon-Cervia 2007) and recruitment (Walters and Post 1993)—particularly to larger size classes—as increasing numbers of fish compete for food resources that tend to limit salmonid populations in tailwaters and unregulated streams (e.g., Filbert and Hawkins 1995; Ensign et al. 1990). Although mean relative weights (W_r) for brown trout in the size classes immediately below the PLR (305-405 mm) were typically >90 prior to 2007, there was a general decline as overall abundance increased (Figure 3-31). The effect of overcrowding is particularly evident for fish in the 300-400 mm size range based on the relationship of W_r and total length (Figure 3-32). Mean W_r for brown trout in the PLR also generally declined since 2005, reaching its lowest level in 2015 (Figure 3-31). This suggests that the abundance of trout in the river has affected condition and thereby limited growth and recruitment into the PLR. Yard et al. (2015) observed that the highest growth and relative condition for rainbow trout in Glen Canyon tailwater (AZ) occurred in areas with lower densities. Similarly, McKinney et al. (2001) reported that increased abundance of rainbow trout in the Lee's Ferry tailwater, AZ (resulting from higher, more stable flows) was accompanied by reduced relative condition, particularly for fish ≥305 mm. Dibble et al. (2015) also found that brown trout length declined when large cohorts recruited to adult size in western tailwaters. Additionally, Fox and Neal (2011) saw depressed largemouth bass *Micropterus salmoides* W_r at intermediate sizes as the population—managed with a 356-508 mm PLR—became overcrowded.

Management Recommendations

The South Holston's exceptional wild brown trout fishery provides the primary means for attaining the tailwater's management goal, which continues to be providing a high-quality trout fishery and the variety of angling opportunities it offers (Habera et al. 2015c). These fish have undoubtedly helped produce the high angler catch rates and satisfaction levels mentioned above. Rainbow trout are also an important part of the fishery, which is being sustained through consistent annual stocking rates for adults and fingerlings.

The previous catch rate objective for trout within the PLR (mean of 25 fish/h during 2009-2014; Habera et al. 2009c) was not achieved, as the actual mean PLR catch rate was 13 fish/h. There currently is no improvement in population size structure relative to pre-PLR conditions, as density-dependent factors now appear to be limiting brown trout growth, condition, and recruitment into the larger size classes (i.e., the PLR). Dreves et al. (2016) used a 508-mm (20-in.) minimum size limit and 1 fish/day creel limit to improve the size structure of brown trout (particularly for fish

≥381 mm) in the Lake Cumberland tailwater (KY) without incurring density-dependent impacts to growth and condition. Although overall brown trout CPUE there increased 3-fold over 10 years, it remained relatively low (89 fish/h) and most likely below the carrying capacity of the tailwater (Dreves et al. 2016); density-dependent responses, therefore, were not triggered. Additionally, the Cumberland Lake tailwater brown trout fishery is hatchery supported, thus providing essentially stable recruitment annually (as in the Norris tailwater).

As long as overall trout abundance in the South Holston tailwater remains high (CPUE near 300 fish/h) and the angler harvest rate for brown trout remains extremely low (only 3.5% of 136,000 fish caught in 2014), it is unlikely that RSD-16 will improve much. In fact, current trout abundance would require an increase in the PLR (and above) catch rate to 20 fish/h to raise RSD-16 to 10—a relatively modest improvement. Although RSD target values have not been defined for balanced brown trout populations (Pedicillo et al. 2010), RSD-16 for South Holston tailwater brown trout has reached the 21-23 range both before and after (2005-2007) establishment of the PLR regulation. Achieving and maintaining an RSD-16 of ~20 (mostly composed of brown trout) would more closely align with the basic management goal of providing a high-quality trout fishery (Habera et al. 2015c).

Factors that impact trout year-class strength, such as high flows, can reduce density-dependent effects on growth, condition, and recruitment. Any such events in the South Holston tailwater have had minimal effects on brown trout year-class strength, as cohorts produced during the past several years have been sufficient to substantially increase abundance—even with declining numbers of large spawners. Brown trout spawning activity in the South Holston tailwater begins during early November and peaks in mid to late-December (Banks and Bettoli 2000). A somewhat earlier spawning season (mid-October through November) was observed for brown trout in the White River (AR) tailwater, with emergence there beginning at the end of February (Pender and Kwak 2002). Fry emergence in the South Holston tailwater has not been studied, but likely occurs in March or early April. Dibble et al. (2015) observed that brown trout recruitment was affected most by flow velocity, and that high levels of recruitment indirectly reduce fish size. Therefore, management actions that can decrease brown trout recruitment when necessary, such as altering dam operations (i.e., to produce high flows) could help maintain more stable trout populations with larger adults through relaxed intraspecific competition (Dibble et al. 2015). Pender and Kwak (2002) observed age-0 tailwater brown trout using gravel interstices as refugia from high velocities at the onset of water releases, so velocities would have to be high enough or the fish vulnerable enough for high flows to be effective. This timeframe would likely occur just after emergence (March-April) in the South Holston tailwater, although it coincides with the refill period on TVA’s guide curve for South Holston Lake. Interestingly, extended marginally-high flows (20-50% above average) actually improved development of large cohorts or rainbow trout in the Glen Canyon tailwater (Avery et al. 2015).

Angler catch rates for brown trout (137,000 total, 5.6/trip in 2014; Black 2015) appear high enough that harvest could help control population size and improve growth, condition, and recruitment into the PLR, thus anglers are encouraged to harvest 254-305 mm (10-12 in.) brown trout. Harvesting fish below the lower boundary of a PLR is necessary to prevent overcrowding;

without sufficient exploitation, stockpiling occurs and the regulation becomes ineffective (Wilde 1997; Noble and Jones 1999; Fox and Neal 2011). However, if anglers are generally satisfied with the increased brown trout abundance and higher associated catch rates that exist now, then they may not be concerned by the current ineffectiveness of the South Holston PLR.

Because of the detection of whirling disease in nearby North Carolina trout fisheries and the popularity of the South Holston tailwater with anglers from that area, rainbow and brown trout from the South Holston tailwater will be collected and screened for this pathogen during 2017.

South Holston Tailwater

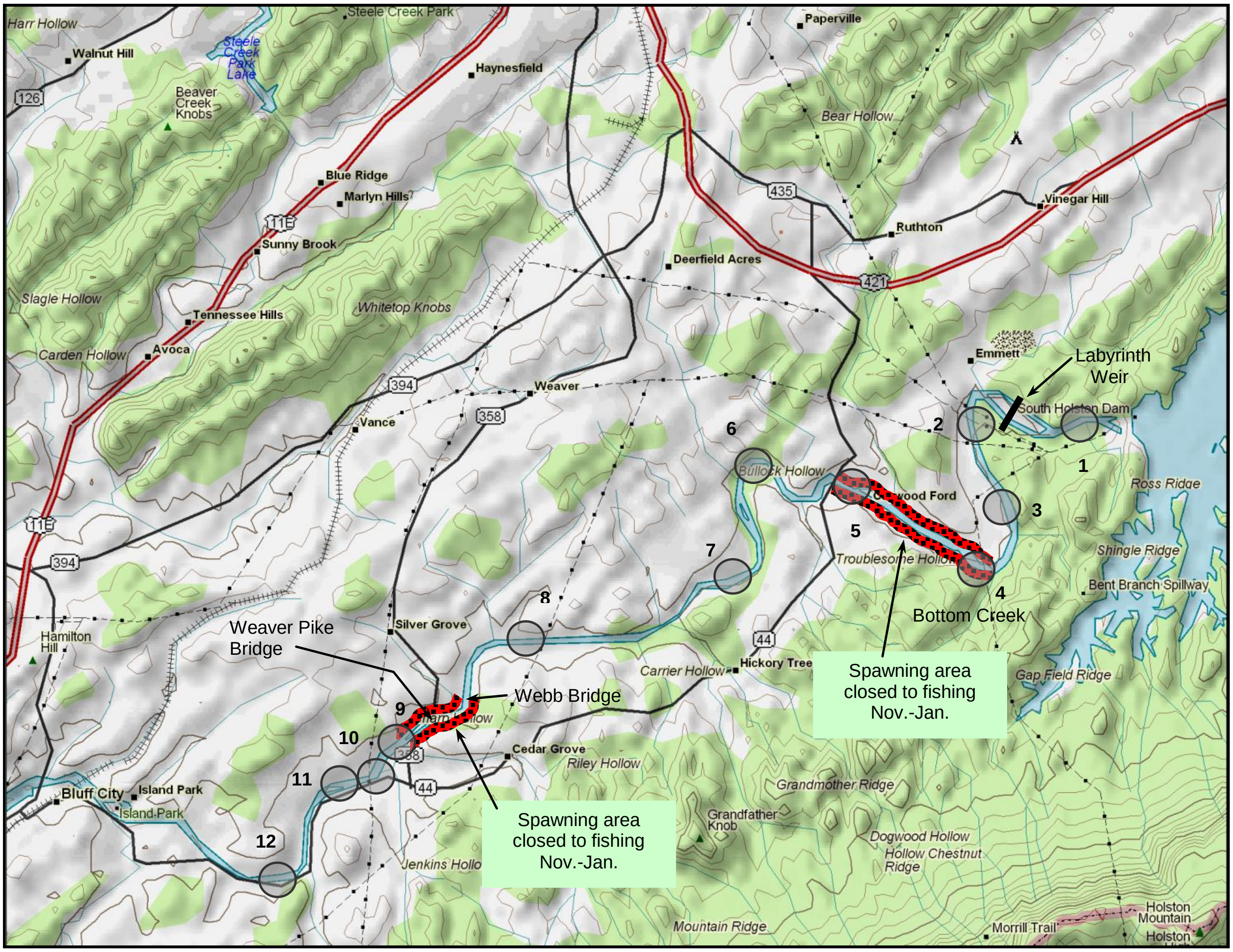


Figure 3-27. Locations of the South Holston tailwater (South Fork Holston River) monitoring stations.

Table 3-11. Location and sampling information for the 12 stations on the South Holston tailwater, 7 March 2016.

Station	Site Code	County	Quadrangle	Coordinates	Reach Number	River Mile	Effort (s)	Output
1	420160201	Sullivan	Holston Valley 206 SE	36.5236N-82.09306W	06010102-14,0	49.5	600	884 V DC 120 PPS, 4-5 A
2	420160202	Sullivan	Holston Valley 206 SE	36.52500N-82.11528W	06010102-14,0	48	600	884 V DC 120 PPS, 4-5 A
3	420160203	Sullivan	Holston Valley 206 SE	36.50972N-82.10694W	06010102-14,0	46.8	600	884 V DC 120 PPS, 4-5 A
4	420160204	Sullivan	Holston Valley 206 SE	36.50417N-82.11111W	06010102-13,2	46.4	600	884 V DC 120 PPS, 4-5 A
5	420160205	Sullivan	Bristol 206 SW	36.51250N-82.12778W	06010102-13,2	45.3	600	884 V DC 120 PPS, 4-5 A
6	420160206	Sullivan	Bristol 206 SW	36.51389N-82.14444W	06010102-13,2	44.2	600	884 V DC 120 PPS, 4-5 A
7	420160207	Sullivan	Bristol 206 SW	36.50972N-82.14861W	06010102-13,2	43	600	30-40% low range 120 PPS DC, 4 A
8	420160208	Sullivan	Bristol 206 SW	36.49528N-82.18056W	06010102-13,2	40.6	600	30-40% low range 120 PPS DC, 4 A
9	420160209	Sullivan	Keenburg 207 NW	36.48194N-82.20556W	06010102-13,2	38.6	600	30-40% low range 120 PPS DC, 4 A
10	420160210	Sullivan	Keenburg 207 NW	36.47917N-82.20833W	06010102-13,2	38.4	600	30-40% low range 120 PPS DC, 4 A
11	420160211	Sullivan	Keenburg 207 NW	36.47778N-82.21528W	06010102-13,1	38	600	30-40% low range 120 PPS DC, 4 A
12	420160212	Sullivan	Keenburg 207 NW	36.46556N-82.22083W	06010102-13,1	37.1	600	30-40% low range 120 PPS DC, 4 A

Table 3-12. Catch data for the12 electrofishing stations on the South Holston tailwater sampled 7 March 2016.

Station	Species	Total Catch	Size Range (mm)	Total Weight (g)	% Abundance (number)	% Abundance (weight)
1	Rainbow	13	269-402	5,369	100	100
	Brown	0	--	--	0	0
Totals		**13**		**5,369**	**100**	**100**
2	Rainbow	10	167-518	3,433	12	19
	Brown	75	116-365	14,580	88	81
Totals		**85**		**18,013**	**100**	**100**
3	Rainbow	5	99-352	1,013	5	5
	Brown	96	140-523	18,861	95	95
Totals		**101**		**19,874**	**100**	**100**
4	Rainbow	3	308-358	1,053	7	8
	Brown	38	169-550	12,833	93	92
Totals		**41**		**13,886**	**100**	**100**
5	Rainbow	11	175-324	2,622	18	22
	Brown	50	139-490	9,117	82	78
Totals		**61**		**11,739**	**100**	**100**
6	Rainbow	8	110-338	1,845	14	13
	Brown	49	143-389	12,234	86	87
Totals		**57**		**14,079**	**100**	**100**
7	Rainbow	2	338-342	732	3	3
	Brown	63	128-493	20,806	97	97
Totals		**65**		**21,538**	**100**	**100**
8	Rainbow	3	113-332	738	8	5
	Brown	34	192-505	15,078	92	95
Totals		**37**		**15,816**	**100**	**100**
9	Rainbow	1	283	249	2	1
	Brown	65	160-507	17,348	98	99
Totals		**66**		**17,597**	**100**	**100**
10	Rainbow	2	337-347	805	9	9
	Brown	21	138-472	8,630	91	91
Totals		**23**		**9,435**	**100**	**100**
11	Rainbow	2	314-380	861	5	6
	Brown	42	160-521	14,306	95	94
Totals		**44**		**15,167**	**100**	**100**
12	Rainbow	5	310-367	1,995	11	12
	Brown	42	169-432	14,510	89	88
Totals		**47**		**16,505**	**100**	**100**
Total Rainbows		65	99-518	20,715	10	12
Total Browns		575	116-550	158,303	90	88
Overall totals		**640**		**179,018**	**100**	**100**

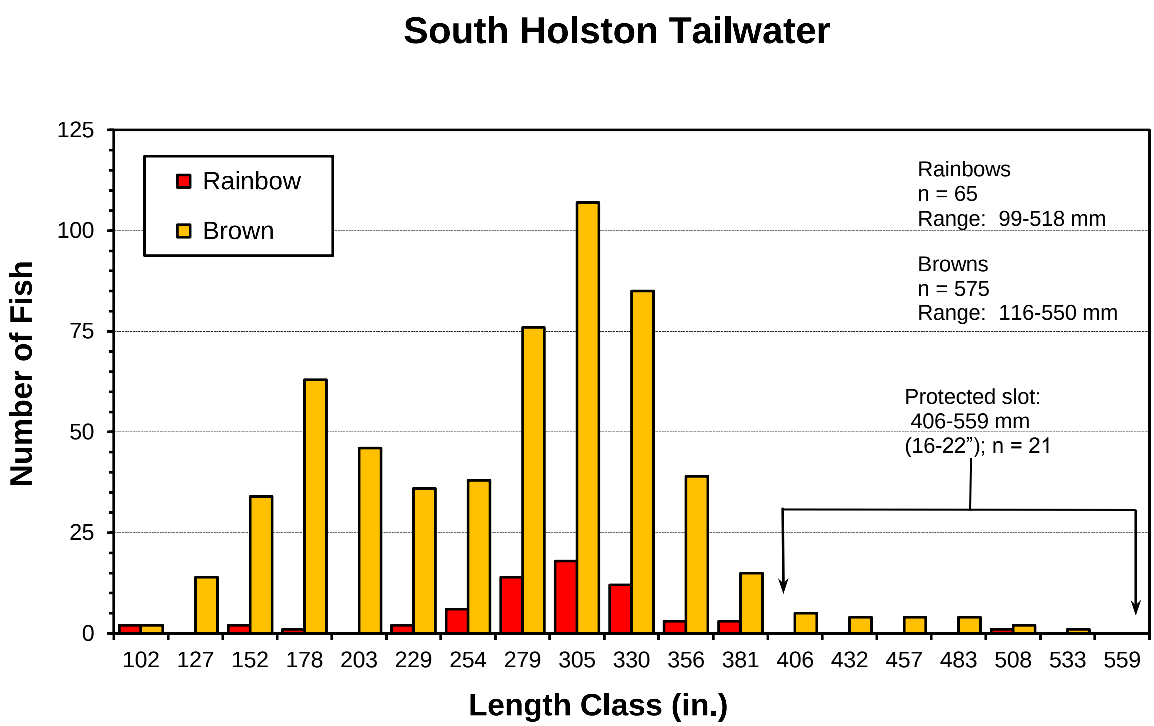


Figure 3-28. Length frequency distributions for trout from the South Holston tailwater monitoring stations in 2016.

South Holston Tailwater

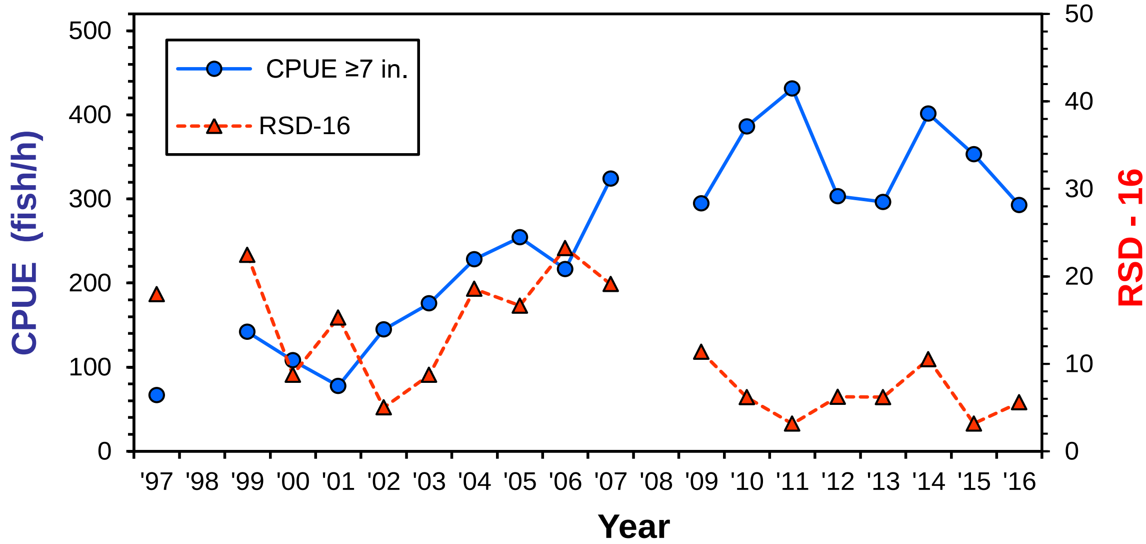


Figure 3-29. Comparison of mean CPUE (fish/h) for all trout ≥178 mm and RSD-16 for the South Holston tailwater.

South Holston Tailwater

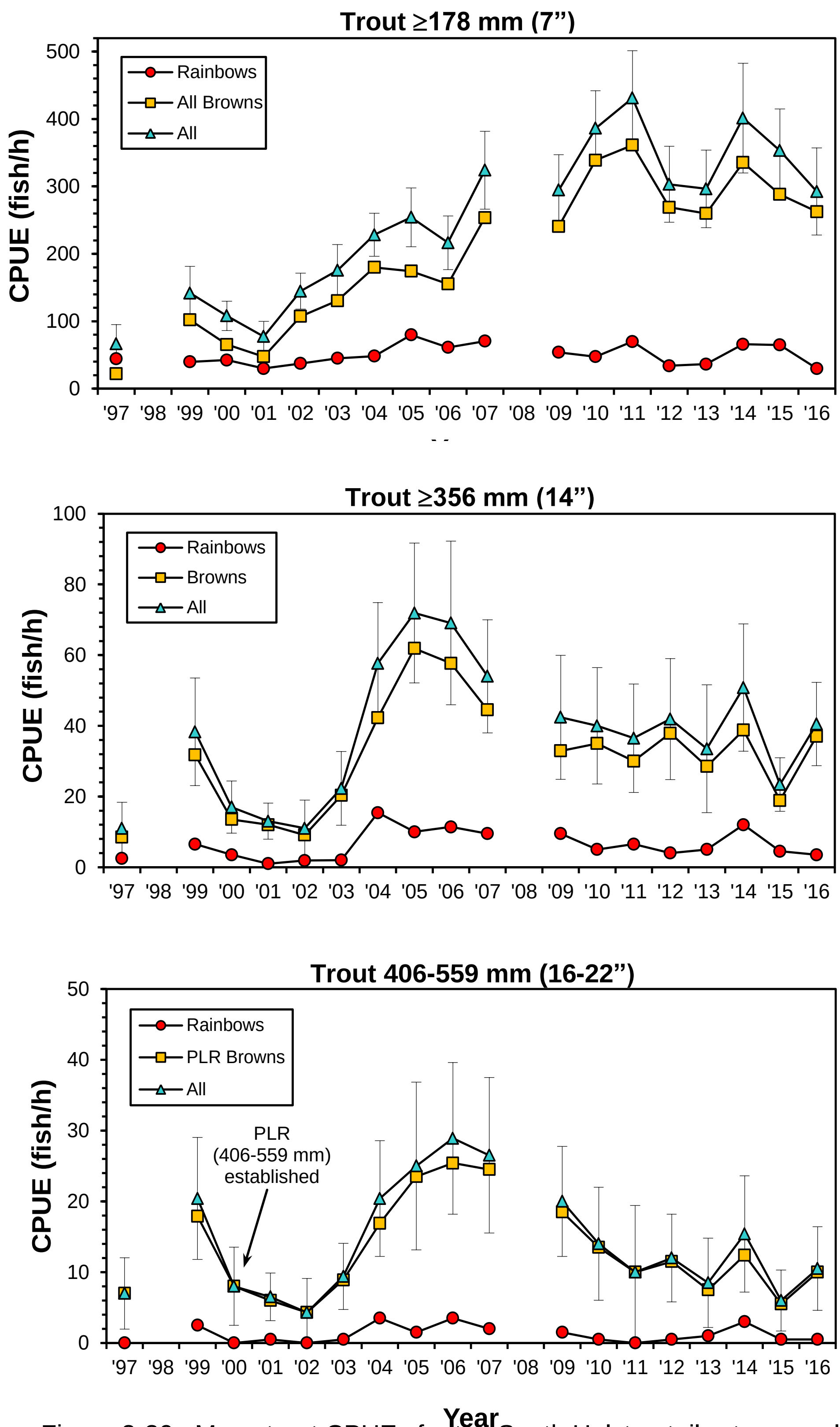


Figure 3-30. Mean trout CPUEs for the South Holston tailwater samples. Bars indicate 90% confidence intervals.

South Holston Tailwater

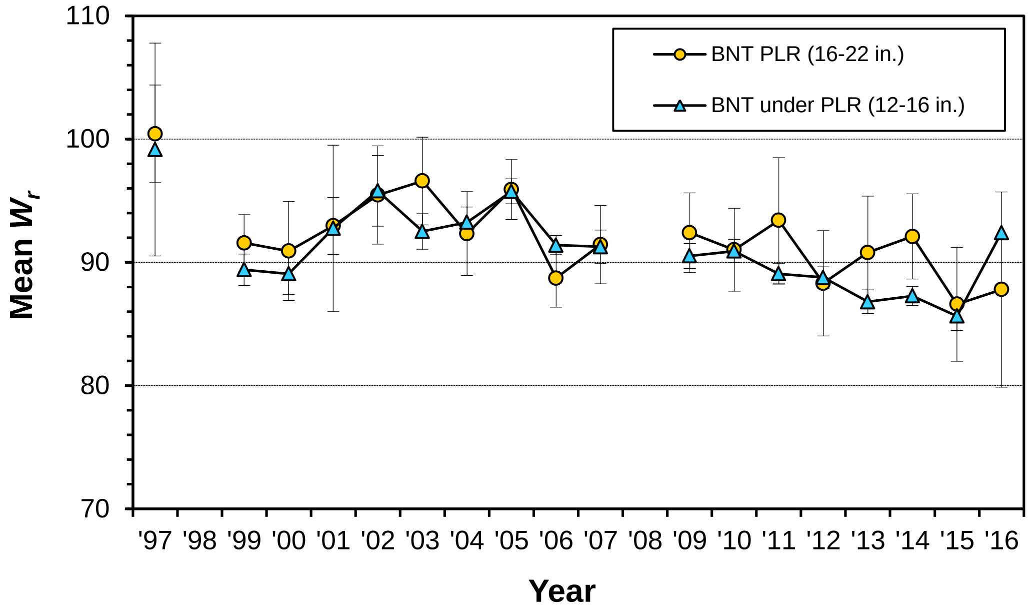


Figure 3-31. Mean relative weights (W_r) for brown trout from the South Holston tailwater. Bars indicate 90% confidence intervals.

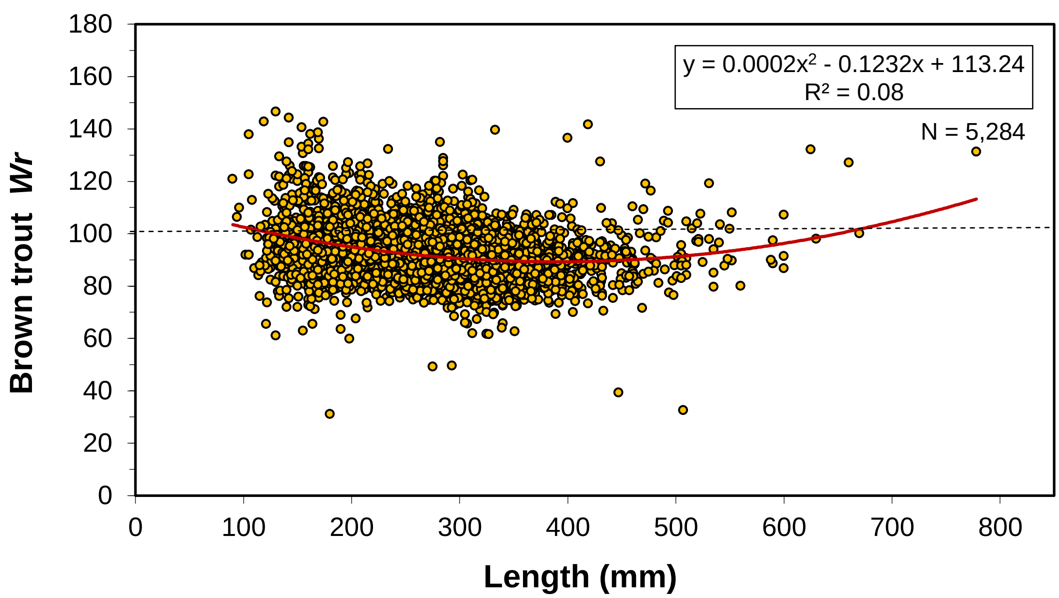


Figure 3-32. Relative weights (W_r) for brown trout from the South Holston Tailwater (2009-2016). Solid curved line is polynomial trend line and dashed line is optimum W_r of 100.

REFERENCES

Adams, S. B., C. A. Frissell, and B. E. Rieman. 2002. Changes in distribution of nonnative brook trout in an Idaho drainage over two decades. Transactions of the American Fisheries Society 131:561-568.

Anderson, R. O. 1976. Management of small warm water impoundments. Fisheries 1(6):561-568.

Anglin, Z. W., and G. D. Grossman. 2013. Microhabitat use by southern brook trout (Salvelinus fontinalis) in a headwater North Carolina stream. Ecology of Freshwater Fish 22:567-577.

Avery, L. A., J. Korman, and W. R. Persons. 2015. Effects of increased discharge on spawning and age-0 recruitment of rainbow trout in the Colorado River at Lees Ferry, Arizona. North American Journal of Fisheries Management 35:671-680.

Baird, O. E., and C. C. Krueger. 2003. Behavioral thermoregulation of brook and rainbow trout: comparison of summer habitat use in an Adirondack river, New York. Transactions of the American Fisheries Society 132:1194-1206.

Banks, S. M., and P. W. Bettoli. 2000. Reproductive potential of brown trout in Tennessee tailwaters. Fisheries Report No. 00-19. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Benjamin, J. R., and C. V. Baxter. 2010. Do nonnative salmonines exhibit greater density and production than the natives they replace? A comparison of nonnative brook trout with native cutthroat trout. Transactions of the American Fisheries Society 139:641-651.

Bettinger, J. M., and P. W. Bettoli. 2000. Movements and activity of rainbow trout and brown trout in the Clinch River, Tennessee, as determined by radio-telemetry. Fisheries Report No. 00-14. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Bettoli, P. W. 1999. Creel survey and population dynamics of salmonids stocked into the Watauga River below Wilbur Dam. Fisheries Report No. 99-41. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Bettoli, P. W. 2002. Clinch River creel survey results: March-October 2001. Fisheries Report No. 02-01. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Bettoli, P. W. 2003a. Survey of the trout fishery in the Watauga River: March-October 2002. Fisheries Report No. 03-05. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Bettoli, P. W. 2003b. Survey of the trout fishery in the South Fork of the Holston River, March-October 2002. Fisheries Report No. 03-06. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Bettoli, P. W. 2006. Clinch River creel survey results: April-October 2005. Fisheries Report No. 06-08. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Bettoli, P. W. 2007. Surveys of the trout fisheries in the Watauga River and South Fork of the Holston River: March-October 2005. Fisheries Report No. 07-07. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Bettoli, P. W., and L. A. Bohm. 1997. Clinch River trout investigations and creel survey. Fisheries Report No. 97-39. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Bettoli, P. W., S. J. Owens, and M. Nemeth. 1999. Trout habitat, reproduction, survival, and growth in the South Fork of the Holston River. Fisheries Report No. 99-3. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Bivens, R. D. 1979. Survey of brook trout streams on the Unaka and Nolichucky Ranger Districts, Cherokee National Forest. Internal project report, U.S. Department of Agriculture Forest Service, Cleveland, Tennessee.

Bivens, R. D. 1984. History and distribution of brook trout in the Appalachian region of Tennessee. MS thesis, University of Tennessee, Knoxville, Tennessee.

Bivens, R. D. 1988. Region IV stream fishery data collection report: 1986-1987. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Bivens, R. D. 1989. Region IV stream fishery data collection report: 1988. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Bivens, R. D., R. J. Strange, and D. C. Peterson. 1985. Current distribution of the native brook trout in the Appalachian region of Tennessee. Journal of the Tennessee Academy of Science 60:101-105.

Bivens, R. D., and C. E. Williams. 1990. Region IV stream fishery data collection report: 1989. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Bivens, R. D., M. T. Fagg, and C. E. Williams. 1992. Region IV trout fishery data collection report: 1991. Fisheries Report No. 93-17. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Bivens, R. D., B. D. Carter, and C. E. Williams. 1994. Region IV trout fisheries report: 1993. Fisheries Report No. 94-21. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Bivens, R. D., B. D. Carter, and C. E. Williams. 1996. Region IV trout fisheries report: 1995. Fisheries Report No. 96-5. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Bivens, R. D., B. D. Carter, and C. E. Williams. 1998. Region IV trout fisheries report: 1997. Fisheries Report 98-3. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Black, W. P. 2014. Tennessee Statewide Creel Survey: 2013 Results. Final report, Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Black, W. P. 2015. Tennessee Statewide Creel Survey: 2014 Results. Final report, Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Black, W. P. 2016. Tennessee Statewide Creel Survey: 2015 Results. Fisheries Report 16-09. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Bohlin, T., L. F. Sundström, J. I. Johnsson, J. Höjesjö, and J. Pettersson. 2002. Density-dependent growth in brown trout: effects of introducing wild and hatchery fish. Journal of Animal Ecology 71:683-692.

Boles, H. D. 1980. Clinch River (Norris tailwater) trout fishery investigations 1971-1977. Fisheries Resources Internal Report (Interim Summary Report). U. S. Department of Interior, Fish and Wildlife Service.

Bowlby, J. N., and J. C. Roff. 1986. Trout biomass and habitat relationships in southern Ontario streams. Transactions of the American Fisheries Society 115:503-514.

Carline, R. F., and B. J. McCullough. 2003. Effects of floods on brook trout populations in the Monongahela National Forest, West Virginia. Transactions of the American Fisheries Society 132:1014-1020.

Clark, M. E., and K. A. Rose. 1997. Factors affecting competitive dominance of rainbow trout over brook trout in southern Appalachian streams: implications of an individual-based model. Transactions of the American Fisheries Society 126:1-20.

Clark, M. E., K. A. Rose, D. A. Levine, and W. W. Hargrove. 2001. Predicting climate change effects on Appalachian trout: combining GIS and individual-based modeling. Ecological Applications 11(1):161-178.

Cook, S. B. and T. C. Johnson. 2016. Assessment of southern Appalachian brook trout propagation as a tool for restoring Tennessee populations. Final report, Department of Biology and the Center for the Management, Protection and Utilization of Water Resources, Tennessee Technological University, Cookeville, Tennessee.

Damer, J., and P. W. Bettoli. 2008. The fate of brook trout stocked in the Watauga River below Wilbur Dam. Fisheries Report No. 08-03. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Davis, L., and T. Wagner. 2016. Scale-dependent seasonal pool habitat use by sympatric wild brook trout and brown trout populations. Transactions of the American Fisheries Society 145:888-902.

DeWeber, J. T., and T. Wagner. 2015. Predicting brook trout occurrence in stream reaches throughout their native range in the eastern United States. Transactions of the American Fisheries Society 144:11-24.

Dibble, K. L., C. B. Yackulic, T. A. Kennedy, and P. Budy. 2015. Flow management and fish density regulate salmonid recruitment and adult size in tailwaters across western North America. Ecological Applications 25:2168-2179.

Dodrill, M. J., C. B. Yackulic, T. A. Kennedy, and J. W. Hayes. 2016. Prey size and availability limits maximum size of rainbow trout in a large tailwater: insights from a drift-foraging bioenergetics model. Canadian Journal of Fisheries and Aquatic Sciences 73(5):1-14.

Dreves, D. P., J. R. Ross, and J. T. Kosa. 2016. Effect of trophy regulations and reservoir discharge on a population of stocked brown trout in a large, southeastern United States tailwater. Journal of the Southeastern Association of Fish and Wildlife Agencies 3:167-177.

Elliott, J. M. 2000. Pools as refugia for brown trout during two summer droughts: trout responses to thermal and oxygen stress. Journal of Fish Biology 56:938-948.

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.

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.

Fiss, F. C., and J. W. Habera, editors. 2006. Trout management plan for Tennessee 2006-2016. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Fox, C. N., and J. W. Neal. 2011. Development of a crowded largemouth bass population in a tropical reservoir. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies. 65:98-104.

Habera, J. W., R. J. Strange, and R. D. Bivens. 2001a. A revised outlook for Tennessee's brook trout. Journal of the Tennessee Academy of Science 76:68-73.

Habera, J. W., R. D. Bivens, B. D. Carter, and C. E. Williams. 2001b. Region IV trout fisheries report: 2000. Fisheries Report No. 01-03. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Habera, J. W., R. D. Bivens, B. D. Carter, and C. E. Williams. 2003. Region IV trout fisheries report: 2002. Fisheries Report No. 03-03. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Habera, J. W., R. D. Bivens, B. D. Carter, and C. E. Williams. 2004. Region IV trout fisheries report: 2003. Fisheries Report No. 04-04. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Habera, J. W., R. D. Bivens, B. D. Carter, and C. E. Williams. 2006. Region IV trout fisheries report: 2005. Fisheries Report No. 06-01. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Habera, J. W., R. D. Bivens, B. D. Carter, and C. E. Williams. 2008. Region IV trout fisheries report: 2007. Fisheries Report No. 08-01. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Habera, J. W., R. D. Bivens, B. D. Carter, and C. E. Williams. 2009a. Region IV trout fisheries report: 2008. Fisheries Report No. 09-01. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Habera, J. W., R. D. Bivens, and B. D. Carter. 2009b. Management plan for the Wilbur tailwater trout fishery 2009-2014. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Habera, J. W., R. D. Bivens, and B. D. Carter. 2009c. Management plan for the South Holston tailwater trout fishery 2009-2014. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Habera, J. W., M. A. Kulp, S. E. Moore, and T. B. Henry. 2010. Three-pass depletion sampling accuracy of two electric fields for estimating trout abundance in a low-conductivity stream with limited habitat complexity. North American Journal of Fisheries Management 30:757-766.

Habera, J. W., R. D. Bivens, B. D. Carter, and C. E. Williams. 2011. Region IV trout fisheries report: 2010. Fisheries Report No. 11-01. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Habera, J. W., R. D. Bivens, B. D. Carter, and C. E. Williams. 2012. Region IV trout fisheries report: 2011. Fisheries Report No. 12-01. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Habera, J. W., R. D. Bivens, B. D. Carter, and C. E. Williams. 2014a. Region IV trout fisheries report: 2013. Fisheries Report No. 14-01. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Habera, J. W., R. D. Bivens, and B. D. Carter. 2014b. Management plan for the Norris Tailwater trout fishery 2014-2019. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Habera, J. W., R. D. Bivens, B. D. Carter, and C. E. Williams. 2015a. Region IV trout fisheries report: 2014. Fisheries Report No. 15-01. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Habera, J. W., R. D. Bivens, and B. D. Carter. 2015b. Management plan for the Wilbur Tailwater trout fishery 2015-2020. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Habera, J. W., R. D. Bivens, and B. D. Carter. 2015c. Management plan for the South Holston Tailwater trout fishery 2015-2020. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Habera, J. W., R. D. Bivens, B. D. Carter, and C. E. Williams. 2016. Region IV trout fisheries report: 2015. Fisheries Report No. 16-04. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Habera, J. W., and B. D. Carter. 2008. Access denied: keeping the rainbows out of Left Prong. Tennessee Wildlife 31(6):21-24.

Habera, J. W. and S. E. Moore. 2005. Managing southern Appalachian brook trout: a position statement. Fisheries 30(7):10-20.

Hall, M. R., R. P. Morgan II, and R. G. Danzmann. 2002. Mitochondrial DNA analysis of mid-Atlantic populations of brook trout: the zone of contact for major historical lineages. Transactions of the American Fisheries Society 131:1140-1151.

Harris, A. 2010. Trout fishing in 2006: a demographic description and economic analysis (addendum to the 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation). Report 2006-6. U.S. Fish and Wildlife Service, Arlington, Virginia.

Hastings, A., and S. Harrison. 1994. Metapopulation dynamics and genetics. Annual Review of Ecology and Systematics 25:167-188.

Higgins, J. M. 1978. Water quality progress in the Holston River basin. TVA Division of Environmental Planning, Chattanooga, Tennessee. TVA/EP-78/08.

Hill, D. M. 1978. Tailwater trout management. Pages 66-75 in Southeastern trout resource: ecology and management symposium proceedings. USDA Forest Service, Southeastern Forest Experiment Station, Asheville, North Carolina.

Hill, D. M., and S. R. Brown. 1980. The fishery resource of Tennessee Valley tailwaters—Cherokee. TVA Division of Water Resources, Norris, Tennessee.

Holbrook, C., and P. W. Bettoli. 2006. Spawning habitat, length at maturity, and fecundity of brown trout in Tennessee tailwaters. Fisheries Report No. 06-11. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Hoxmeier, R. J. H., and D. J. Dieterman. 2013. Seasonal movement, growth and survival of brook trout in sympatry with brown trout in Midwestern US streams. Ecology of Freshwater Fish 22:530-542.

Hoxmeier, R. J. H., and D. J. Dieterman. 2016. Long-term population demographics of native brook trout following manipulative reduction of an invader. Biological Invasions 18(10).

Hudy, M., T. M. Thieling, N. Gillespie, and E. P. Smith. 2008. Distribution, status, and land use characteristics of subwatersheds within the native range of brook trout in the eastern United States. North American Journal of Fisheries Management 28:1069-1085.

Huntsman, B. M. and J. T. Petty. 2014. Density-dependent regulation of brook trout population dynamics along a core-periphery distribution gradient in a central Appalachian watershed. PLoS One 9(3): e91673. doi:10.1371/journal.pone.0091673

Hutt, C. P., and Bettoli, P. W. 2003. Recreational specialization, preferences, and management attitudes of trout anglers utilizing Tennessee tailwaters. Fisheries Report No. 03-01. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Johnson, J. H., and D. S. Dropkin. 1996. Seasonal habitat use by brook trout, *Salvelinus fontinalis* (Mitchill), in a second-order stream. Fisheries Management and Ecology 3:1-11.

Kanno, Y., K. C. Pregler, N. P. Hitt, B. H. Letcher, D. J. Hocking, J. E. B. Wofford. 2015. Seasonal temperature and precipitation regulate brook trout young-of-the-year abundance and population dynamics. Freshwater Biology 61(1):88-99.

Kanno, Y., M. A. Kulp, and S. E. Moore. 2016. Recovery of native brook trout populations following the eradication of nonnative rainbow trout in southern Appalachian Mountains streams. North American Journal of Fisheries Management 36:1325-1335.

Kazyak D. C., R. H. Hilderbrand, T. L. King, S. R. Keller, and V. E. Chhatre. 2016. Hiding in plain sight: a case for cryptic metapopulations of brook trout (*Salvelinus fontinalis*). PLoS One 11(1): e0146295. doi:10.1371/journal.pone.0146295

King, T. L., B. A. Lubinski, M. K. Burnham-Curtis, W. Stott, and R. P. Morgan II. 2012. Tools for the management and conservation of genetic diversity in brook trout (*Salvelinus fontinalis*): tri- and tetranucleotide microsatellite markers for the assessment of genetic diversity, phylogeography, and historical demographics. Conservation Genetics Resources 4:539-543.

King, W. 1937. Notes on the distribution of native speckled and rainbow trout in the streams of Great Smoky Mountains National Park. Journal of the Tennessee Academy of Science 12:351-361.

Kriegler, F. J., G. F. McCracken, J. W. Habera, and R. J. Strange. 1995. Genetic characterization of Tennessee's brook trout populations and associated management implications. North American Journal of Fisheries Management 15:804-813.

Kulp, M. A. 1994. A comparative ecology study of two strains of brook trout in Great Smoky Mountains National Park. MS thesis, Tennessee Technological University, Cookeville, Tennessee.

Larson, G. L., S. E. Moore, and B. Carter. 1995. Ebb and flow of encroachment by nonnative rainbow trout in a small stream in the southern Appalachian Mountains. Transactions of the American Fisheries Society 124:613-622.

Lewis, S. L. 1969. Physical factors influencing fish populations in pools of a trout stream. Transactions of the American Fisheries Society 98:14-19.

Lobon-Cervia, J. 2007. Density-dependent growth in stream-living brown trout *Salmo trutta* L. Functional Ecology 21:117-124.

Lohr, S. C., and J. L. West. 1992. Microhabitat selection by brook and rainbow trout in a southern Appalachian stream. Transactions of the American Fisheries Society 121:729-736.

Luecke, C., T. C. Edwards, Jr., M. W. Wengert, 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.

Matthews, K. R., N. H. Berg, D. L. Azuma, and T. R. Lambert. 1994. Cool water formation and trout habitat use in a deep pool in the Sierra Nevada, California. Transactions of the American Fisheries Society 123:549-564.

McKinney, T., D. W. Speas, R. S. Rogers, and W. R. Persons. 2001. Rainbow trout in a regulated river below Glen Canyon Dam, Arizona, following increased minimum flows and reduced discharge variability. North American Journal of Fisheries Management 21:216-222.

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

Meerbeek, J., and P. W. Bettoli. 2005. Survival, growth, condition, and diet of stocked brown trout in five Tennessee tailwaters. Fisheries Report No. 05-05. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Meyer, K. A., B. High, and F. S. Elle. 2012. Effects of stocking catchable-sized hatchery rainbow trout on wild rainbow trout abundance, survival, growth, and recruitment. Transactions of the American Fisheries Society 141:224-237.

Mork, M. D. 2011. Survival and movements of large brown trout in a regulated river system in east Tennessee. MS thesis, Tennessee Technological University, Cookeville, Tennessee.

Myers, B. J. E., C. A. Dolloff, and A. L. Rypel. 2014. Rainbow trout versus brook trout biomass and production under varied climate regimes in small southern Appalachian streams. Pages 127-134 *in* R. F. Carline, editor. Wild Trout IX: Looking back and moving forward. Wild Trout Symposium, Bozeman, Montana.

Nagel, J. W. 1986. Brook trout / rainbow trout headwaters competition studies. Research progress report submitted to Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Nagel, J. W. 1991. Is the decline of brook trout in the southern Appalachians resulting from competitive exclusion and/or extinction due to habitat fragmentation? Journal of the Tennessee Academy of Science 66:141-143.

Nagel, J. W., and J. E. Deaton. 1989. Growth and longevity of rainbow trout in two headwater streams in northeastern Tennessee. Journal of the Tennessee Academy of Science 64:9-12.

Noble, R. L., and T. W. Jones. 1999. Managing fisheries with regulations. Pages 455-480 *in* C. C. Kohler and W. A. Hubert, editors. Inland fisheries management in North America, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Page, L. M., H. Espinosa-Pèrez, L. T. Findley, C. R. Gilbert, R. N. Lea, N. E. Mandrak, R. L. Mayden, and J. S. Nelson. 2013. Common and scientific names of fishes from the United States, Canada, and Mexico, 7th edition. American Fisheries Society, Special Publication 34, Bethesda, Maryland.

Pedicillo, G, A. Carosi, L. Ghetti, and M. Lorenzoni. 2010. Population size structure indices and growth standards for *Salmo (trutta) trutta* Linnaeus, 1758 in central Italy. Knowledge and Management of Aquatic Ecosystems 399(02). doi:10.1051/kmae/2010030.

Pender, D. R., and T. J. Kwak. 2002. Factors influencing brown trout reproductive success in Ozark tailwater rivers. Transactions of the American Fisheries Society 131:698-717.

Peterson, J. T., R. F. Thurow, and J. W. Guzevich. 2004. An evaluation of multipass electrofishing for estimating the abundance of stream-dwelling salmonids. Transactions of the American Fisheries Society 113:462-475.

Pfitzer, D. W. 1962. Investigations of waters below large storage reservoirs in Tennessee. D-J-R Project F-1-R. Tennessee Game and Fish Commission, Nashville, Tennessee.

Power, M., and G. Power. 1996. Comparing minimum-size and slot limits for brook trout management. North American Journal of Fisheries Management 16:49-62.

Roddy, D., editor. 2017. Coldwater fish production—statewide hatchery report: 2016. Fisheries Report No. 17-04. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Roghair, C. N., C. A. Dolloff, and M. K. Underwood. 2002. Response of a brook trout population and instream habitat to a catastrophic flood and debris flow. Transactions of the American Fisheries Society 131:718-730.

Saidak, L. R. 1995. Brook trout (Salvelinus fontinalis) in Tennessee: an ecological genetics study using allozyme electrophoresis and random amplified polymorphic DNA. MS thesis, University of Tennessee, Knoxville, Tennessee.

Sánchez-Hernández, J., S. L. Shaw, F. Cobo, and M. S. Allen. 2016. Influence of a minimum-length limit regulation on wild brown trout: an example of recruitment and growth overfishing. North American Journal of Fisheries Management 36:1024-1035.

Schexnayder, S. M., A. Griffin, and J. M. Fly. 2014. Fishing participation and attitudes of anglers in Tennessee, 2012. Human Dimensions Research Lab, Department of Forestry, Wildlife and Fisheries. University of Tennessee, Knoxville, Tennessee.

Scott, E. M., K. D. Gardner, D. S. Baxter, and B. L. Yeager. 1996. Biological and water quality responses in tributary tailwaters to dissolved oxygen and minimum flow improvements. Tennessee Valley Authority, Water Management Services, Norris, Tennessee.

Seegrist, D. W., and R. Gard. 1972. Effects of floods on trout in Sagehen Creek, California. Transactions of the American Fisheries Society 101:478-482.

Shields, R. A. 1950. A survey of east Tennessee trout streams with recommendations for management. Internal report, Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Sotiropoulos, J. C., K. H. Nislow, and M. R. Ross. 2006. Brook trout, *Salvelinus fontinalis*, microhabitat selection and diet under low summer stream flows. Fisheries Management and Ecology 13:149-155.

Stitt, B. C., G. Burness, K. A. Burgonmaster, S. Currie, J. L. McDermid, and C. C. Wilson. 2014. Intraspecific variation in thermal tolerance and acclimation capacity in brook trout (*Salvelinus fontinalis*): Physiological implications for climate change. Physiological and Biochemical Zoology 87:15-29.

Strange, R. J., and J. W. Habera. 1992. Wild trout project: 1991 annual report. Publication No. R11-2216-76-001-92. University of Tennessee, Knoxville, Tennessee.

Strange, R. J., and J. W. Habera. 1993. Wild trout project: 1992 annual report. Publication No. R11-2216-76-001-93. University of Tennessee, Knoxville, Tennessee.

Strange, R. J., and J. W. Habera. 1994. Wild trout project: 1993 annual report. Publication No. R11-2216-18-001-94. University of Tennessee, Knoxville, Tennessee.

Strange, R. J., and J. W. Habera. 1995. Wild trout project: 1994 annual report. Publication No. R11-2217-18-001-95. University of Tennessee, Knoxville, Tennessee.

Strange, R. J., and J. W. Habera. 1996. Wild trout project: 1995 annual report. Publication No. R11-2217-93-001-96. University of Tennessee, Knoxville, Tennessee.

Strange, R. J., and J. W. Habera. 1997. Wild trout project: 1996 annual report. Publication No. R11-2217-93-001-97. University of Tennessee, Knoxville, Tennessee.

Strange, R. J., and J. W. Habera. 1998. No net loss of brook trout distribution in areas of sympatry with rainbow trout in Tennessee streams. Transactions of the American Fisheries Society 127:434-440.

Stranko, S. A., R. H. Hilderbrand, R. P. Morgan II, M. W. Staley, A. J. Becker, A. Roseberry-Linclon, E. S. Perry, and P. T. Jacobson. 2008. Brook trout declines with land cover and temperature changes in Maryland. North American Journal of Fisheries Management 28:1223-1232.

Swink, W. D. 1983. Survey of stocking of tailwater trout fisheries in the southern United States. Progressive Fish-Culturist 45(2):67-71.

Tarzwell, C. M. 1939. Changing the Clinch River into a trout stream. Transactions of the American Fisheries Society 68:228-233.

TDEC (Tennessee Department of Environment and Conservation). 2013. State of Tennessee water quality standards: use classifications for surface waters, chapter 0400-40-04. Water Quality Control Board, Nashville.

TDEC (Tennessee Department of Environment and Conservation). 2015. State of Tennessee water quality standards: general water quality criteria, chapter 0400-40-03. Water Quality Control Board, Nashville.

TWRA (Tennessee Wildlife Resources Agency). 1998. Stream survey protocols. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

TWRA (Tennessee Wildlife Resources Agency). 2014. Protecting, preserving, and perpetuating Tennessee’s wildlife and ecosystems: Strategic plan 2014-2020. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

TVA (Tennessee Valley Authority). 1980. Improving reservoir releases. TVA Office of Natural Resources and Environmental Development, Knoxville, Tennessee.

Thompson, P. D., and F. J. Rahel. 1996. Evaluation of depletion-removal electrofishing of brook trout in small Rocky Mountain streams. North American Journal of Fisheries Management 16:332-339.

Trumbo, B., M. Hudy, E. P. Smith, D.-Y. Kim, B. A. Wiggins, K. H. Nislow, and C. A. Dolloff. 2010. Sensitivity and vulnerability of brook trout populations to climate change. Pages 62-68 *in* R. F. Carline and C. LoSapio, editors. Wild Trout X: Conserving wild trout. Wild Trout Symposium, Bozeman, Montana.

Verhille, C. E, K. K. English, D. E. Cocherell, A. P. Farrell, and N. A. Fangue. 2016. High thermal tolerance of a rainbow trout population near its southern range limit suggests local thermal adjustment. Conservation Physiology 4(1):1-12.

Vøllestad, L. A., E. M. Olsen, and T. Forseth. 2002. Growth-rate variation in brown trout in small neighbouring streams: evidence for density-dependence? Journal of Fish Biology 61:1513-1527.

Walters, C. J., and J. R. Post. 1993. Density-dependent growth and competitive asymmetries in size-structured fish populations: a theoretical model and recommendations for field experiments. Transaction of the American Fisheries Society 122:34-45.

Warren, D. R., A. G. Ernst, and B. P. Baldigo. 2009. Influence of spring floods on year-class strength of fall- and spring-spawning salmonids in Catskill Mountain streams. Transaction of the American Fisheries Society 138:200-210.

Waters, T. F. 1999. Long-term trout production in Valley Creek, Minnesota. Transaction of the American Fisheries Society 128:1151-1162.

Weaver, D. M., and T. J. Kwak. 2013. Assessing effects of stocked trout on nongame fish assemblages in southern Appalachian Mountain streams. Transaction of the American Fisheries Society 142:1495-1507.

Weiland, M. A., and R. S. Hayward. 1997. Cause for the decline of large rainbow trout in a tailwater fishery: too much putting or too much taking? Transaction of the American Fisheries Society 126:758-773.

Whitworth, W. E., and R. J. Strange. 1983. Growth and production of sympatric brook and rainbow trout in an Appalachian stream. Transaction of the American Fisheries Society 112:469-475.

Wilde, G. R. 1997. Largemouth bass fishery responses to length limits. Fisheries 22:14-23.

Wiley, R. W., R. A. Whaley, J. B. Satake, and M. Fowden. 1993. Assessment of stocking hatchery trout: a Wyoming perspective. North American Journal of Fisheries Management 13:160-170.

Wilkins, L. P., L. Kirkland, and A. Hulsey. 1967. The management of trout fisheries in reservoirs having a self-sustaining warm water fishery. Pages 444-452 *in* C. E. Lane, symposium chairman. Reservoir Fishery Resources Symposium, Reservoir Committee, Southern Division, American Fisheries Society, Bethesda, Maryland.

Willis, D. W., B. R. Murphy, and C. S. Guy. 1993. Stock densities: development, use, and limitations. Reviews in Fisheries Science 1(3):203-222.

Yard, M. D., J. Korman, C. J. Walters, and T. A. Kennedy. 2015. Seasonal and spatial patterns of growth of rainbow trout in the Colorado River in Grand Canyon, Arizona. Canadian Journal of Fisheries and Aquatic Sciences 73:125-139.

Yeager, B. L., D. M. Hill, W. M. Seawell, C. M. Alexander, and R. Wallus. 1987. Effects of aeration and minimum flow enhancement on the biota of Norris tailwater. TVA Office of Natural Resources and Environmental Development, Knoxville, Tennessee.

Yeager, B. L., T. A. McDonough, and D. A. Kenny. 1993. Growth, feeding and movement of trout in South Holston tailwater. Water Management Services, WM-94-003. Tennessee Valley Authority, Norris, Tennessee.

APPENDIX A

Quantitative Wild Trout Stream Samples
1991-2016

Table A-1. Wild trout streams sampled quantitatively during 1991-2016.

Stream	Watershed	County	Location	Year	Primary species[1]	Total samples
Gee Creek	Hiwassee	Polk	CNF	1993	RBT	1
Rymer Camp Branch	Hiwassee	Polk	CNF	1994	RBT	1
Sulphur Springs Branch	Hiwassee	Polk	CNF	1992	RBT	1
East Fork Wolf Creek	Hiwassee	Polk	CNF	1995	RBT	1
Big Creek	Ocoee	Polk	CNF	1996	RBT	1
Goforth Creek	Ocoee	Polk	CNF	1993	RBT	1
Rough Creek	Ocoee	Polk	CNF	1995	RBT	1
Tellico River[2]	L. Tennessee	Monroe	CNF	1993,95-02, 06, 11, 14	RBT/BNT	32
Bald River[3]	Tellico	Monroe	CNF	1991-00, 05, 07, 10, 13	RBT/BNT/BKT	39
Kirkland Creek	Tellico	Monroe	CNF	1991	RBT	1
Henderson Branch	Tellico	Monroe	CNF	1996	RBT/BNT/BKT	2
Brookshire Creek	Tellico	Monroe	CNF	1996	BKT	3
North River[2]	Tellico	Monroe	CNF	1991-14	RBT/BNT	72
Laurel Branch	Tellico	Monroe	CNF	1997	RBT/BNT	1
Sugar Cove Creek	Tellico	Monroe	CNF	1995-96	RBT/BKT	3
Meadow Branch	Tellico	Monroe	CNF	1991,95, 04	BKT	6
Sycamore Creek	Tellico	Monroe	CNF	1994-95,97-98	RBT/BKT	6
Rough Ridge Creek	Tellico	Monroe	CNF	1995	RBT/BKT	2
Citico Creek	L. Tennessee	Monroe	CNF	1996	RBT/BNT	1
Doublecamp Creek	L. Tennessee	Monroe	CNF	1992	RBT/BNT	2
S. Fork Citico Creek	L. Tennessee	Monroe	CNF	2004	RBT	1
N. Fork Citico Creek	L. Tennessee	Monroe	CNF	2003	RBT	1
Parson Branch	L. Tennessee	Blount	Private	1993	RBT	1
Slickrock Creek	L. Tennessee	Monroe	CNF	2007	BNT	2
Little Slickrock Creek	L. Tennessee	Monroe	CNF	2007	BNT	1
Dunn Creek	French Broad	Sevier	Private	1993	RBT	1
Indian Camp Creek	French Broad	Cocke	Private	2007	RBT	1
Sinking Creek	French Broad	Cocke	Private	1999	RBT	1
Tobes Creek	French Broad	Cocke	Private	2006	RBT	1
Gulf Fork Big Creek	French Broad	Cocke	Private	1993, 04, 08	RBT/BNT	3
Deep Gap Creek	French Broad	Cocke	State Forest	2005	RBT	1
Laurel Creek	French Broad	Cocke	State Forest	2013	RBT	1
M. Prong Gulf Creek	French Broad	Cocke	Private	1991	BKT	1
Brown Gap Creek	French Broad	Cocke	Private	1991	BKT	1
Trail Fork Big Creek	French Broad	Cocke	CNF	1996, 2001	RBT	2
Dry Fork	French Broad	Cocke	CNF	1994	BKT/RBT	2
Wolf Creek	French Broad	Cocke	CNF	1993	RBT	2
Paint Creek[2]	French Broad	Greene	CNF	92, 94, 95, 02-04, 08, 11, 14	BNT/RBT	15
Sawmill Branch	French Broad	Greene	CNF	1999	BKT/BNT	1
Little Paint Creek	French Broad	Greene	CNF	1993	BKT	1

Table A-1 (cont.). Wild trout streams sampled quantitatively during 1991-2016.

Stream	Watershed	County	Location	Year	Primary species[1]	Total samples
Camp Creek	Nolichucky	Greene	Private	2004	RBT	1
Jennings Creek	Nolichucky	Greene	CNF	1992, 14	RBT	2
Round Knob Branch	Nolichucky	Greene	CNF	1996	BKT	1
Dry Creek	Nolichucky	Greene	CNF	1992	RBT	1
Davis Creek	Nolichucky	Greene	CNF	1992, 2003	RBT/BKT	2
W. Fork Dry Creek	Nolichucky	Greene	CNF	1992	BKT	1
Horse Creek	Nolichucky	Greene	CNF	1994	RBT	1
Squibb Creek	Nolichucky	Greene	CNF	1991, 2003	RBT/BKT	2
Sarvis Cove Creek	Nolichucky	Greene	CNF	1991, 2003	RBT/BKT	2
Cassi Creek	Nolichucky	Greene	CNF	2003	RBT	1
Painter Creek	Nolichucky	Washington	Private	1993	RBT	1
Clark Creek	Nolichucky	Unicoi	CNF	1991	RBT	1
Sill Branch	Nolichucky	Unicoi	CNF	1994	RBT	1
Devil Fork	Nolichucky	Unicoi	CNF	1999	RBT	1
Longarm Branch	Nolichucky	Unicoi	CNF	1997	RBT	1
Dry Creek	Nolichucky	Washington	CNF	1997	RBT	1
Ramsey Creek	Nolichucky	Washington	Private	1996	RBT	1
Briar Creek[2]	Nolichucky	Washington	CNF	1992,95-16	RBT/BKT	23
Straight Creek	Nolichucky	Washington	CNF	2003	BKT	1
Broad Shoal Creek	Nolichucky	Unicoi	CNF	1991	RBT	1
N. Indian Creek	Nolichucky	Unicoi	CNF	1994-95, 03	RBT/BNT	3
Rock Creek	Nolichucky	Unicoi	CNF	1991	RBT/BKT	1
R. Prong Rock Creek	Nolichucky	Unicoi	CNF	1998	RBT	1
Red Fork	Nolichucky	Unicoi	CNF	1998	RBT	1
Clear Fork	Nolichucky	Unicoi	CNF	1993	BKT	1
South Indian Creek	Nolichucky	Unicoi	Private	2009	RBT	1
Mill Creek	Nolichucky	Unicoi	CNF	1996	RBT	1
Granny Lewis Creek	Nolichucky	Unicoi	CNF	1991	RBT	2
Higgins Creek (Lower)	Nolichucky	Unicoi	Private	1992,95	BKT/RBT	2
Spivey Creek	Nolichucky	Unicoi	Private	2007	RBT	1
Coffee Ridge	Nolichucky	Unicoi	Private	2011	RBT	1
Big Bald Creek	Nolichucky	Unicoi	Private	1996	RBT	1
Tumbling Creek	Nolichucky	Unicoi	Private	1995	RBT	1
Little Bald Creek	Nolichucky	Unicoi	Private	2007	RBT	1
Big Branch	Nolichucky	Unicoi	Private	1996	RBT	1
Rocky Fork[2]	Nolichucky	Unicoi/Greene	Private	1991-16	RBT/BKT	51
Rice Creek	Nolichucky	Unicoi	Private	1995	RBT	1
Higgins Creek (Upper)	Nolichucky	Unicoi	Private	2006	RBT	1
Sams Creek	Nolichucky	Unicoi	Private	2002	RBT	1
Jones Branch	Nolichucky	Unicoi	CNF	1991	BKT	1

Table A-1 (cont.). Wild trout streams sampled quantitatively during 1991-2016.

Stream	Watershed	County	Location	Year	Primary species[1]	Total samples
Sinking Creek	Watauga	Washington	Private	2007	RBT/BNT	1
Buffalo Creek	Watauga	Unicoi/Carter	Private	1998, 02	RBT	2
Doe River[2]	Watauga	Carter	Private	1995-99, 02-04, 09, 12, 15	RBT/BKT/BNT	14
Laurel Fork[2]	Watauga	Carter	CNF	1991-01, 03, 06, 09, 12, 15	BNT	32
Little Laurel Fork	Watauga	Carter	CNF	1994	BKT	1
Leonard Branch	Watauga	Carter	CNF	2011	BKT/BNT	1
Wagner Branch	Watauga	Carter	CNF	1993	BKT/BNT	1
Cook Branch	Watauga	Carter	CNF	2008	BNT	1
Camp 15 Branch	Watauga	Carter	CNF	2011	BKT/BNT	1
Camp 10 Branch	Watauga	Carter	CNF	1995	BKT	1
Little Doe River	Watauga	Carter	Private	2010	RBT/BNT	1
Simerly Creek	Watauga	Carter	Private	1994, 2010	RBT/BNT	2
Sally Cove Creek	Watauga	Carter	Private	1995	RBT	1
Clarke Creek	Watauga	Carter	Private	1992	BKT	1
McKinney Branch	Watauga	Carter	Private	2010	RBT/BNT	1
Tiger Creek	Watauga	Carter	CNF	1991, 99	RBT/BKT	2
Roberts Hollow	Watauga	Carter	Private	2014	RBT/BKT	1
Bill Creek	Watauga	Carter	CNF	1991	BKT	1
Roaring Creek	Watauga	Carter	Private	2011	RBT	1
George Creek	Watauga	Carter	CNF	1991	BKT	1
Buck Creek	Watauga	Carter	CNF/Private	1997	RBT	2
Shell Creek	Watauga	Carter	Private	2004	RBT	1
L. Pr. Hampton Creek[2]	Watauga	Carter	State	1994-16	RBT/BKT	63
Heaton Creek	Watauga	Carter	Private	2000	RBT	1
Toms Branch	Watauga	Carter	Private/CNF	1991, 09	BKT	2
Five Poplar Branch	Watauga	Carter	Private	2000	RBT	1
Middle Branch	Watauga	Carter	Private	1991	BKT	1
R. Pr. Middle Branch[2]	Watauga	Carter	CNF	1994, 97-15	BKT	20
Panther Branch	Watauga	Carter	CNF	1996	BKT	1
Cove Creek	Watauga	Carter	Private	1991, 12	BKT/RBT	2
Little Cove Creek	Watauga	Carter	Private	2008	RBT/BKT	1
Stony Creek	Watauga	Carter	CNF	1992, 95, 04-06, 10, 13, 16	RBT/BKT/BNT	9
Little Stony Creek	Watauga	Carter	CNF	1992	BKT	1
Furnace Branch	Watauga	Carter	CNF	2003	BKT	1
Mill Creek	Watauga	Carter	Private	1994	BKT	1
North Fork Stony Creek	Watauga	Carter	CNF	1991	BKT	1
Lindy Camp Branch	Watauga	Carter	CNF	2008	BKT	1
Little Stony Creek[4]	Watauga	Carter	CNF	1993, 2014	RBT/BKT	2
Roan Creek	Watauga	Johnson	Private	1997	RBT/BKT	2
Doe Creek[2]	Watauga	Johnson	Private	1993-16	RBT	25

Table A-1 (cont.). Wild trout streams sampled quantitatively during 1991-2016.

Stream	Watershed	County	Location	Year	Primary species[1]	Total samples
Campbell Creek	Watauga	Johnson	Private	1993	RBT	1
Slabtown Branch	Watauga	Johnson	Private	1995	RBT	1
Vaught Creek	Watauga	Johnson	Private	2005	RBT	1
Furnace Creek	Watauga	Johnson	Private	1992	BKT	1
Goose Creek	Watauga	Johnson	Private	2006	RBT/BNT	1
Forge Creek	Watauga	Johnson	Private	1993	RBT/BKT	2
Roaring Creek	Watauga	Johnson	Private	2001	RBT	1
Bulldog Creek	Watauga	Johnson	Private	2009	RBT	1
Big Dry Run	Watauga	Johnson	Private	1994	RBT	1
Heaton Branch	Watauga	Carter	Private	1994	RBT	1
Little Laurel Branch	Watauga	Carter	CNF	1992	BKT	1
Trivett Branch	Watauga	Carter	Private	1996	BNT	1
Big Creek	S. F. Holston	Sullivan	CNF	1994	RBT	1
Fishdam Creek	S. F. Holston	Sullivan	CNF	1991, 2005	RBT	2
Sharps Creek	S. F. Holston	Sullivan	CNF	2012	RBT	1
Little Jacob Creek	S. F. Holston	Sullivan	CNF	1991, 2000	RBT	2
Rockhouse Run	S. F. Holston	Sullivan	CNF	1993	BKT	1
Laurel Creek[2]	S. F. Holston	Johnson	CNF	1993-94, 01-02, 04, 07, 10, 13, 16	RBT/BNT	9
Beaverdam Creek[2]	S. F. Holston	Johnson	CNF	1991-16	RBT/BNT	52
Tank Hollow	S. F. Holston	Johnson	CNF	2003	BKT	1
Chalk Branch	S. F. Holston	Johnson	CNF	1994	BKT	1
Maple Branch	S. F. Holston	Johnson	CNF	1994	BKT	1
Fagall Branch	S. F. Holston	Johnson	CNF	1995	BKT	1
Birch Branch[2]	S. F. Holston	Johnson	CNF/Private	1991,95-16	BKT/RBT	23
Marshall Branch	S. F. Holston	Johnson	CNF	1999	BKT	1
Heaberlin Branch	S. F. Holston	Johnson	CNF	1993	BKT	1
Johnson Blevins Br.	S. F. Holston	Johnson	Private	1991	BKT	1
Jim Wright Branch	S. F. Holston	Johnson	Private	1991	BKT	1
E. Fk. Beaverdam Ck.	S. F. Holston	Johnson	CNF	1992	BKT	1
Valley Creek	S. F. Holston	Johnson	CNF	1993	BKT	1
Owens Branch	S. F. Holston	Johnson	CNF	1995	RBT/BNT	1
Lyons Branch	S. F. Holston	Johnson	CNF	1992	RBT	1
Gentry Creek[2]	S. F. Holston	Johnson	CNF	1992,96-16	RBT/BKT	23
Grindstone Branch	S. F. Holston	Johnson	CNF	1996	BKT	1
Kate Branch	S. F. Holston	Johnson	CNF	2000	BKT	1
Atchison Branch	S. F. Holston	Johnson	Private	2006	RBT	1

[1]RBT = rainbow trout; BNT = brown trout; BKT = brook trout.

[2]Monitoring stream. TWRA Region III began monitoring streams in the Tellico and Little Tennessee watersheds in 2014.

[3]Includes a site sampled in the allopatric brook trout zone in 1992; monitoring Site 2 was discontinued in 2010.

[4]Watauga Lake tributary.

APPENDIX B

Qualitative Stream Surveys
1991-2016

Table B-1. Streams sampled qualitatively during 1991-2016 to determine the presence of wild trout.

Stream	Watershed	County	Location	Coordinates	Survey date	Wild trout present[1]
Smith Creek	Hiwassee	Polk	CNF	35.15135, -84.42420	Nov-99	RBT
Coker Creek	Hiwassee	Monroe	Private	35.26978, -84.26283	Jul-96	None
Wolf Creek	Hiwassee	Polk	CNF	35.16522, -84.38135	May-99	RBT/BNT
Wildcat Creek	Tellico	Monroe	CNF	35.29894, -84.25793	Jul-96	None
Natty Creek	Tellico	Monroe	CNF	35.31705, -84.22875	Jul-96	None
Tobe Creek	Tellico	Monroe	CNF	35.29990, -84.22923	Jul-96	None
Laurel Branch	French Broad	Sevier	Private	35.77184, -83.39841	Jul-15	None
Wilhite Creek	French Broad	Sevier	Private	35.87333, -83.32037	Jul-15	None
Lin Creek	French Broad	Sevier	Private	35.86744, -83.32864	Jul-15	None
Mill Creek	French Broad	Sevier	Private	35.73479, -83.57456	Jul-15	RBT
Indian Camp Creek (lower)	French Broad	Cocke	Private	35.77938, -83.26361	Jun-06	RBT
Indian Camp Creek (lower)	French Broad	Cocke	Private	35.77622, -83.26537	Jun-06	RBT, BKT
Indian Camp Creek (lower)	French Broad	Cocke	Private	37.77337, -83.26657	Jun-06	RBT, BKT
Greenbrier Creek	French Broad	Cocke	Private	35.78278, -83.24322	Jun-06	RBT
Groundhog Creek	French Broad	Cocke	Private	35.78918, -83.18387	Jul-15	RBT
Robinson Creek	French Broad	Cocke	Private	35.79097, -83.19433	Jul-15	RBT
John Creek	French Broad	Cocke	Private	35.86611, -83.03250	Jun-01	None
Baker Branch	French Broad	Cocke	Private	35.86306, -83.03083	Jun-01	None
Tom Creek	French Broad	Cocke	Private	35.85306, -83.01806	Jun-01	RBT[3]
Gulf Fork Big Creek	French Broad	Cocke	Private	35.82385, -83.09162	May-07	RBT/BNT
Gulf Fork Big Creek	French Broad	Cocke	Private	35.83037, -83.05730	May-07	RBT/BNT
Gulf Fork Big Creek	French Broad	Cocke	Private	35.82064, -83.04665	May-07	RBT/BNT
Gulf Fork Big Creek	French Broad	Cocke	Private	35.81805, -83.04191	May-07	RBT/BNT
Laurel Fork (upper)	French Broad	Cocke	CNF	35.88146, -83.06236	Jun-14	None
Laurel Fork (lower)	French Broad	Cocke	Private	35.89220, -83.06274	Jun-14	None
Grassy Fork	French Broad	Cocke	Private	35.81585, -83.08673	Jun-03	RBT[4]
Deep Gap Creek	French Broad	Cocke	State	35.79321, -83.02074	Oct-06	BKT
Brush Creek	French Broad	Cocke	CNF	35.95817, -82.93442	Jun-15	None
Paint Creek	French Broad	Greene	Private	36.00702, -82.77679	Jun-15	RBT/BNT
Paint Creek	French Broad	Greene	CNF	36.02082, -82.74602	Jun-15	RBT
Cove Creek	Nolichucky	Greene	Private	35.97882, -82.86960	Jun-15	None
Back Creek	Nolichucky	Greene	Private	36.01896, -82.80796	Jun-08	None
Camp Creek	Nolichucky	Greene	Private	36.07811, -82.76464	Jul-03	RBT
Bumpus Cove Creek	Nolichucky	Unicoi	Private	36.16941, -82.47134	Jul-07	RBT
Bumpus Cove Creek	Nolichucky	Washington	Private	36.15227, -82.49503	Jul-07	RBT/BNT
Broad Shoal Creek	Nolichucky	Unicoi	CNF	36.15229, -82.44492	Jun-08	RBT
Dry Creek	Nolichucky	Unicoi	Private	36.17448, -82.35113	Jun-10	None (dry)
Dick Creek	Nolichucky	Unicoi	CNF	36.17326, -82.31647	May-11	No fish
Rocky Branch	Nolichucky	Unicoi	Private	36.17589, -82.29530	Jun-10	None
Simerly Creek	Nolichucky	Unicoi	Private	36.18453, -82.25218	Jun-10	None[2]

Table B-1 (cont.). Streams sampled qualitatively during 1991-2016 to determine the presence of wild trout.

Stream	Watershed	County	Location	Coordinates	Survey date	Wild trout present[1]
Birchlog Creek	Nolichucky	Unicoi	Private	36.15263, -82.24237	Jun-10	None
South Indian Creek (upper)	Nolichucky	Unicoi	Private	36.03568, -82.55163	Jun-05	RBT
South Indian Creek (middle)	Nolichucky	Unicoi	Private	36.05937, -82.52198	Jun-05	RBT[4]
South Indian Creek (lower)	Nolichucky	Unicoi	Private	36.12065, -82.44834	Jul-08	RBT[4]
Spivey Creek (lower)	Nolichucky	Unicoi	Private	36.06566, -82.50199	Jun-06	RBT
Spivey Creek (middle)	Nolichucky	Unicoi	Private	36.05169, -82.50063	Jun-06	RBT
Spivey Creek (middle)	Nolichucky	Unicoi	Private	36.03955, -82.48652	Jun-06	RBT
Spivey Creek (upper)	Nolichucky	Unicoi	Private	36.04042, -82.47109	Jun-06	RBT
Murray Branch	Nolichucky	Unicoi	Private	36.04610, -82.51080	May-11	RBT[4]
Murray Branch	Nolichucky	Unicoi	Private	36.04348, -82.51683	May-11	None
Slip Creek	Nolichucky	Unicoi	Private	36.02103, -82.50891	Jun-06	RBT[4]
Little Bald Creek	Nolichucky	Unicoi	Private	36.03993, -82.46505	Jun-06	RBT
Pete Creek	Nolichucky	Unicoi	CNF	36.01286, -82.58934	Jun-05	None[2]
E. Fork Higgins Creek	Nolichucky	Unicoi	CNF	35.99601, -82.53006	Jun-05	None[2]
Long Branch	Nolichucky	Unicoi	CNF	36.08811, -82.42917	Jun-08	BKT
Sinking Creek (upper)	Watauga	Carter	Private	36.25559, -82.36470	Jun-06	RBT, BKT, BNT
Sinking Creek (upper)	Watauga	Carter	Private	36.25192, -82.36493	Jun-06	RBT, BKT, BNT
Sinking Creek (middle)	Watauga	Carter	Private	36.26143, -82.36430	Jun-06	RBT, BKT
Sinking Creek (lower)	Watauga	Carter	Private	36.27966, -82.36838	Jun-06	RBT
Basil Hollow	Watauga	Washington	Private	36.25134, -82.36456	May-07	RBT
Dry Creek	Watauga	Carter	Private	36.25910, -82.28150	Jun-09	BNT[4]
Honeycomb Creek	Watauga	Carter	Private	36.24304, -82.26767	Jun-09	RBT[4]
Gap Creek	Watauga	Carter	CNF	36.26756, -82.23016	Jun-09	None
Upper Gap Creek	Watauga	Carter	Private	36.25850, -82.23574	Jun-09	None[2]
Little Doe River	Watauga	Carter	Private	36.24629, -82.19464	Jun-09	RBT/BNT
Little Doe River	Watauga	Carter	Private	36.22870, -82.18899	Jun-09	RBT/BNT
Simerly Creek (lower)	Watauga	Carter	Private	36.22769, -82.18925	Jun-09	RBT/BNT
Big Flats Branch	Watauga	Carter	Private	36.24634, -82.14575	Aug-06	RBT
Firescald Branch	Watauga	Carter	CNF	36.24920, -82.08700	Nov-15	BKT
Doll Branch	Watauga	Carter	Private	36.15115, -82.02994	Jun-04	RBT
Morgan Branch	Watauga	Carter	Private	36.17449, -82.02072	Jun-08	RBT[4]
Bear Branch	Watauga	Carter	CNF	36.18106, -82.01066	Jun-08	RBT[4]
State Line Branch	Watauga	Carter	Private	36.16797, -82.00265	Jun-08	RBT[4]
Hampton Creek (upper)	Watauga	Carter	Private	36.14939, -82.05561	Jun-08	RBT[4]
Sugar Hollow Creek	Watauga	Carter	Private	36.15694, -82.07053	Jun-08	RBT[4]
Bearwallow Hollow	Watauga	Carter	State	36.15899, -82.10180	Jul-14	None
Nidifer Branch	Watauga	Carter	Private	36.39768, -82.09988	May-95	None[2]
Hinkle Branch	Watauga	Carter	Private	36.40950, -82.09707	May-95	None[2]
Peters Branch	Watauga	Carter	Private	36.40696, -82.07738	Jun-11	None (nearly dry)
Horselog Branch	Watauga	Carter	Private	36.40822, -82.06854	Jun-11	None (nearly dry)
Laurel Branch	Watauga	Carter	Private	36.41660, -82.07871	May-95	None[2]
Grindstaff Branch	Watauga	Carter	Private	36.41442, -82.05386	Jun-11	None

Table B-1 (cont.). Streams sampled qualitatively during 1991-2016 to determine the presence of wild trout.

Stream	Watershed	County	Location	Coordinates	Survey date	Wild trout present[1]
Stover Branch	Watauga	Carter	Private	36.42096, -82.05016	Jun-11	RBT[4]
Right Fork Mill Creek	Watauga	Carter	CNF	36.43993, -82.07787	Jun-15	BKT
Hurley Branch	Watauga	Carter	Private	36.43600, -82.04804	Jun-11	RBT/BNT
Hurley Branch	Watauga	Carter	Private	36.43150, -82.03231	Jun-11	RBT
Richardson Branch	Watauga	Carter	Private	36.45740, -82.01002	Jun-11	None (dry)
Bowen Branch	Watauga	Carter	Private	36.46105, -82.00719	Jun-11	None (dry)
Upper Hinkle Branch	Watauga	Carter	Private	36.46905, -82.00466	Jul-07	None
Big Spur Branch	Watauga	Carter	CNF	36.46786, -81.97704	Jun-15	BKT
Lindy Camp Branch	Watauga	Carter	CNF	36.47081, -81.96968	Jul-07	BKT
Baker Ridge Branch	Watauga	Carter	CNF	36.48095, -81.97507	Jun-15	BKT
Water Hollow Branch	Watauga	Carter	CNF	36.47822, -81.97452	Jun-15	BKT
Sink Branch	Watauga	Johnson	Private	36.36305, -81.99222	Jun-09	None[2]
Doe Creek	Watauga	Johnson	Private	36.45667, -81.87556	Oct-01	None
Doe Creek	Watauga	Johnson	Private	36.44889, -81.89889	Oct-01	RBT[4]
Doe Creek	Watauga	Johnson	Private	36.44194, -81.90806	Oct-01	RBT[4]
Dugger Branch	Watauga	Johnson	Private	36.39397, -81.96911	Jun-95	None[2]
Campbell Hollow	Watauga	Johnson	Private	36.40306, -81.96558	Jun-95	None[2]
Campbell Creek	Watauga	Johnson	CNF	36.45734, -81.95157	Sep-14	Barrier—no fish above
Spruce Branch	Watauga	Johnson	Private	36.45630, -81.88100	Jun-15	RBT
Stout Branch	Watauga	Johnson	Private	36.47544, -81.87173	Jun-15	None
Shaw Branch	Watauga	Johnson	Private	36.48240, -81.85836	Jun-15	None[2]
Little Dry Run	Watauga	Johnson	Private	36.35489, -81.93736	Jun-09	None[2]
Avery Branch	Watauga	Johnson	Private	36.36972, -81.87307	Jun-09	None[2]
Stout Branch	Watauga	Johnson	Private	36.36716, -81.83291	Jun-08	RBT[4]
Slimp Branch	Watauga	Johnson	Private	36.38751, -81.84609	Jun-08	None
Lunt Branch	Watauga	Johnson	Private	36.40488, -81.85349	Jun-08	None (dry)
Big Sandy Creek	Watauga	Johnson	Private	36.39884, -81.80691	Jun-08	None (dry)
Furnace Creek	Watauga	Johnson	Private	36.48419, -81.79864	Jun-06	RBT
East Fork (Furnace Creek)	Watauga	Johnson	Private	36.36681, -81.80068	Jun-94, Jun-15	None
Cabbage Creek	Watauga	Johnson	Private	36.40792, -81.80150	Jun-08	None (dry)
Stout Branch	Watauga	Johnson	Private	36.42797, -81.74439	Jul-97	None
E.H. Phillippi Branch	Watauga	Johnson	Private	36.49089, -81.84778	Jun-15	None[2]
Patrick Branch	Watauga	Johnson	Private	36.50505, -81.82793	Jun-15	None[2]
Thomas Branch	Watauga	Johnson	Private	36.51315, -81.83235	Jun-15	None[2]
Fenner Branch	Watauga	Johnson	Private	36.51606, -81.83144	Jun-15	None[2]
Gentry Branch	Watauga	Johnson	Private	36.51816, -81.82568	Jun-15	None[2]
Hall Branch	Watauga	Johnson	Private	36.51850, -81.81934	Jun-15	None[2]
Stone Branch	Watauga	Johnson	Private	36.52243, -81.81736	Jun-15	None[2]
Fall Branch	Watauga	Johnson	Private	36.42452, -81.74489	Jun-99	RBT
Woodward Branch	Watauga	Johnson	Private	36.47442, -81.72249	Jun-10	RBT[4]
Drake Branch	Watauga	Johnson	Private	36.36566, -81.74845	Jun-09	RBT[4]
Egger Branch	Watauga	Johnson	Private	36.36543, -81.76789	Jun-15	RBT[4]
Buttermilk Branch	Watauga	Johnson	Private	36.35035, -81.75234	Jun-15	RBT[4]

Table B-1 (cont.). Streams sampled qualitatively during 1991-2016 to determine the presence of wild trout.

Stream	Watershed	County	Location	Coordinates	Survey date	Wild trout present[1]
W. Fork Buttermilk Br.	Watauga	Johnson	Private	36.34703, -81.75228	Jun-15	None
Jenkins Creek	Watauga	Johnson	Private	36.35215, -81.73884	Jun-10	RBT[4]
'Poplar Ridge' Branch[5]	Watauga	Johnson	Private	36.36566, -81.74845	Jun-15	RBT
Black Branch	Watauga	Carter	Private	36.28758, -82.01163	Jul-07	RBT/BNT[4]
Row Branch	Watauga	Carter	Private	36.28869, -82.01325	Jul-07	RBT[4]
Jones Branch	Watauga	Carter	Private/CNF	36.20195, -81.98815	Jul-02	None
Baker Branch	Watauga	Johnson	Private	36.34010, -81.92116	May-96	None[2]
Morgan Branch	Watauga	Johnson	Private	36.32769, -81.90590	Jun-09	None
Dye Leaf Branch	Watauga	Johnson	Private	36.33538, -81.89473	Jun-09	None
Little Creek	S. Fork Holston	Sullivan	CNF	36.47529, -82.08702	Jul-15	BNT (1)
Roaring Creek	S. Fork Holston	Sullivan	CNF	36.48538, -82.08930	Jul-15	None
Josiah Creek	S. Fork Holston	Sullivan	CNF	36.49992, -82.04397	Jul-15	None[2]
Sulphur Springs Branch	S. Fork Holston	Sullivan	CNF	36.52238, -82.02516	Jun-05	RBT
Sharps Creek	S. Fork Holston	Sullivan	Private	36.54608, -82.01824	Jun-11	RBT[4]
Sharps Creek	S. Fork Holston	Sullivan	Private	32.53868, -81.99159	Jun-11	RBT
Cave Spring Branch	S. Fork Holston	Sullivan	Private	36.59283, -81.98427	Jun-11	None
Laurel Creek	S. Fork Holston	Johnson	CNF	36.52622, -81.80172	Jun-04	None
Beaverdam Creek	S. Fork Holston	Johnson	Private	36.53244, -81.92330	May-03, Jun-05	RBT/BNT
Beaverdam Creek	S. Fork Holston	Johnson	Private	36.52050, -81.93219	May-03, Jun-05	RBT/BNT
Beaverdam Creek	S. Fork Holston	Johnson	Private	36.51664, -81.93763	May-03, Jun-05	RBT/BNT
Reservoir Branch	S. Fork Holston	Johnson	Private	36.60295, -81.81103	May-96	None[2]
Reservoir Branch	S. Fork Holston	Johnson	Private	36.60264, -81.81086	Oct-15	RBT/BNT
Reservoir Branch	S. Fork Holston	Johnson	Private	36.59858, -81.80787	Oct-15	None
Stillhouse Branch	S. Fork Holston	Johnson	CNF	36.58489, -81.83032	Jun-04	RBT/BNT
Haunted Hollow	S. Fork Holston	Johnson	CNF	36.57662, -81.85151	Jun-04	None
Dan Wiley Branch	S. Fork Holston	Johnson	CNF	36.56981, -81.85512	Oct-15	None
Dark Hollow	S. Fork Holston	Johnson	CNF	36.57683, -81.85896	Jun-04	None
Flat Springs Branch	S. Fork Holston	Johnson	Private	36.54886, -81.88531	Aug-05	RBT/BNT
Grindstone Branch	S. Fork Holston	Johnson	Private	36.53513, -81.88837	Jun-15	None[2]
David Blevins Branch	S. Fork Holston	Johnson	Private	36.53357, -81.89964	Jun-06	None
McQueen Branch	S. Fork Holston	Johnson	Private	36.54262, -81.90921	Jun-06	RBT[4]
Green Mountain Branch	S. Fork Holston	Johnson	Private	36.50915, -81.91061	Jun-06	RBT
Buck Ridge Branch	S. Fork Holston	Johnson	Private	36.49639, -81.96272	Jul-04	RBT/BNT
W. Fork Beaverdam Creek	S. Fork Holston	Johnson	Private	36.49064, -81.94230	Jun-06	BKT
M. Fork Beaverdam Creek	S. Fork Holston	Johnson	Private	36.49661, -81.93719	Jun-06	RBT, BKT, BNT
Seng Cove Branch	S. Fork Holston	Johnson	Private	36.59219, -81.72168	Jun-10	None
Cave Spring Branch	S. Fork Holston	Johnson	Private	36.59002, -81.72465	Jun-10	RBT[4]
Shingletown Branch	S. Fork Holston	Johnson	Private	36.54533, -81.77751	Jun-04	None[2]
Drystone Branch	S. Fork Holston	Johnson	Private	36.52833, -81.77521	May-96	None[2]
Flatwood Branch	S. Fork Holston	Johnson	Private	36.52680, -81.80280	Jun-04	None[2]
Corum Branch	S. Fork Holston	Johnson	Private	36.52636, -81.81085	Jun-15	None[2]
Richardson Branch	S. Fork Holston	Johnson	CNF	36.61033, -81.67962	Jun-93	None
Richardson Branch	S. Fork Holston	Johnson	CNF	36.61046, -81.68022	Jun-15	BKT

Table B-1 (cont.). Streams sampled qualitatively during 1991-2016 to determine the presence of wild trout.

Stream	Watershed	County	Location	Coordinates	Survey date	Wild trout present[1]
Whetstone Branch	S. Fork Holston	Johnson	CNF	36.60731, -81.68474	Jun-15	BKT

[1]RBT = rainbow trout; BNT = brown trout; BKT = brook trout.

[2]Visually inspected and judged too small (<1 m wide) or without appropriate habitat to support wild trout.

[3]Trout present, but origin questionable; could be the result of fingerling stocking by private individuals.

[4]Low abundance.

[5]Unnamed tributary to Roan Creek on Zionville quad. map.