Evaluation of 3 Small-scale, Put-and-take Rainbow Trout Fisheries in Tennessee

Christopher J. O'Bara, *Center for the Management, Utilization, and Protection of Water Resources, Tennessee Technological University, Box 5033, Cookeville, TN 38505*

Michael A. Eggleton, *Center for the Management, Utilization, and Protection of Water Resources, Tennessee Technological University, Box 5033, Cookeville, TN 38505*

Abstract: Percent return, survival, and harvest rates of stocked rainbow trout (*Oncorhynchus mykiss*) were evaluated in 3 Tennessee streams from 1991 through 1994. Harvestable-size trout were stocked 2–4 times during spring at densities of 29–188/km. Subharvestable (fingerling) trout were stocked only during fall at densities of 69–286/km. Mean annual returns ranged from 13% to 29% over the 4 years of the study and averaged 23% for all 3 streams. Returns for fall-stocked trout were negligible. Survival of spring-stocked (March–May) trout was low, ranging from 2% to 7% by July of each year. Similarly, survival of fall-stocked trout was also low and ranged from 1% to 3% by the following March. No significant relationship ($P > 0.05$) was detected between stocking densities and mean harvest rates or percent returns of individual stockings. Thus, altering stocking densities and periods did not achieve a greater return to the angler in these streams.

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The Tennessee Wildlife Resources Agency stocks 2 million salmonids annually at a cost of just over $700,000/year (F. Fiss, pers. commun.). This program provides put-and-take and put-grow-and-take recreational fisheries. Put-and-take fisheries are generally established in waters that are marginal for wild trout production, or are in close proximity to urban or suburban areas (Fay and Pardue 1986). Fingerling trout stocked during fall provide put-grow-and-take fisheries in some streams. However, of the more than 75 streams stocked annually in Tennessee, little or no definitive data exists regarding the fate of stocked trout, returns, or harvest rates. In some streams, returns are high and harvest-related mortality may exceed 75% (U.S. Army Corps Eng. 1985). In others, returns are lower and natural mortality of non-harvested fish is also high. Long-term survival of these fish is often not a management priority, but such extreme natural mortality rates reduce stocking efficiency. Thus, these "lost" fish represent a significant recreational and economic loss. Determination of appropriate stocking rates relative to anticipated angling effort and survival in a given stream would be a valuable management tool for fishery managers.

Considering this information gap for Tennessee streams, the primary objectives of this study were: 1) to evaluate the return of stocked rainbow trout relative to stocking densities, and 2) to assess post-stocking trout abundance and survival.

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Methods

Three representative streams were selected for evaluation. Mill Creek (Hickman County) has traditionally been considered a high use trout fishery (D. Scott, pers. commun.). It is a third order stream fed by numerous springs and has suitable water quality for trout. Natural reproduction of trout does occur, but is far too low to provide a self-sustaining fishery. Battle Creek (Marion County) is a third order stream and receives inflows from numerous springs and caves. The upper portion frequently de-waters during summer; however, discharge from Martin Springs Cave maintains year-round flow to the lower reaches. No natural trout reproduction has ever been observed. Big Creek (Polk County), located in the Cherokee National Forest, is a second order stream fed by several first order tributaries. Water quality is suitable for trout and low levels of natural reproduction do occur.

Trout Stockings and Creel Surveys

Trout were obtained from TWRA hatcheries in Flintville and Tellico Plains. Fall-stocked trout (fingerlings) averaged 135 mm (range 100–170 mm) total length and 25 g (range 12–52 g). Spring-stocked trout (harvestable-size) averaged 275 mm total length (range 200–350 mm) and 250 g (range 130–365 g). All trout were distinctly fin-clipped at the hatchery prior to each stocking to allow differentiation of trout in the field (Table 1). Field examinations verified that fin clips (or the resulting scar) could be recognized in the field for over 1 year.

Fifteen separate stockings were evaluated. In Mill Creek, 2 spring stockings of 1,500–2,700 trout (104–188/km) were conducted each April and May from 1991 through 1993; in 1994, 4 stockings of 900–1,200 trout (63–83 trout/km) were conducted between late March and mid-May (Table 1). Battle Creek was stocked with 100–400 trout (29–114/km) on 3 occasions in 1991 (Table 1). Big Creek was stocked with a total of 850 trout (83–94/km) on 2 occasions in 1992 (Table 1).

Creel surveys were begun the day of stockings and conducted for up to 7

Table 1. Dates and associated information of rainbow trout stockings in 3 Tennessee streams, 1991–1994.

Stream	Dates stocked	*N* stocked	Size stocked	Fin clip[a]
Mill Creek	Sep 90	3,500	Fingerling	A
	09 Apr 91	2,000	Harvestable	LV
	02 May 91	1,500	Harvestable	RV
	Sep 91	3,500	Fingerling	A
	28 Apr 92	2,700	Harvestable	RV
	27 May 92	2,000	Harvestable	LV
	Sep 92	3,500	Fingerling	A
	27 Apr 93	2,000	Harvestable	LV
	26 May 93	1,500	Harvestable	RV
	Sep 93	3,500	Fingerling	A
	09 Mar 94	1,200	Harvestable	NC
	28 Apr 94	900	Harvestable	LV
	04 May 94	1,200	Harvestable	RV
	17 May 94	900	Harvestable	NC
Battle Creek	Sep 90	1,500	Fingerling	A
	27 Mar 91	300	Harvestable	UC
	24 Apr 91	400	Harvestable	LC
	23 May 91	100	Harvestable	NC
Big Creek	Sep 91	1,000	Fingerling	A
	22 Apr 92	400	Harvestable	RV
	06 May 92	450	Harvestable	LV

[a]A = adipose; LV = left ventral; RV = right ventral; NC = no clip; UC = upper caudal; LC = lower caudal.

days thereafter. Survey effort was stratified among all reaches of the streams supporting trout. Because Mill Creek anglers utilized over 14 km of stream and used several access points, all anglers could not be interviewed by 1 clerk. In 1991, a 94% efficiency was determined for Mill Creek surveys using several clerks at upper and lower accesses to the stream. This efficiency factor was assumed for all subsequent surveys. Access was limited in Battle Creek and Big Creek, thus, 1 clerk could survey all anglers thereby achieving 100% efficiency.

Total harvest (ETH) of trout was estimated for all streams following spring stockings. Total harvest was estimated for each survey day and summed for all survey periods using the following information: *N* surveyed trips (ENT), estimated total effort (in angler-hours) (ETE), mean length of completed angling trips (in angler-hours) (MLT), mean *N* anglers/party (MNA), and mean harvest/unit of effort (as *N* trout harvested/angler-hour) (MHPUE). The algorithms are as follows: ETE = ENT X MLT X MNA and ETH = ETE X MHPUE. All estimates for Mill Creek were adjusted for 94% efficiency. Approximate standard errors were computed using the mean-square-successive-difference-between-periods procedure for roving creel analysis (N.C. State Univ. 1986). Angler returns of stocked trout were calculated by dividing ETH by the total *N* trout stocked. Returns were calculated by individual stocking, and averaged by year.

Statistical differences among harvest rates and effort across dates were determined using a completely randomized analysis of variance with statistical differences declared at $P \leq 0.05$. Relationships among stocking densities, mean harvest rates, and percent returns were evaluated using correlation analysis (Pearson product-moment).

Population Surveys and Survival Estimation

Trout population surveys were conducted annually in November (fall), March (pre-stocking), and July (post-stocking). Daytime sampling was conducted using backpack electrofishing units at 6 sites in Mill Creek, 4 sites in Battle Creek, and 5 sites in Big Creek. One pass was made at each site with density computed as *N* trout/km of stream.

Survival was estimated by integrating mean densities (from population surveys) with harvest information (from creel surveys). Estimates of total *N* trout in each stream were determined by extrapolation of mean densities (across sites) to total stream lengths which supported trout. Based on supplemental electrofishing in 1991 and 1992 and discussions with wildlife officers, an estimated 14.4 km of Mill Creek, 3.5 km of Battle Creek, and 4.8 km of Big Creek supported trout. In all 3 streams, downstream reaches became too warm to support trout.

Results

Mill Creek

Clerks creeled 2,533 trout during the 10 surveys over 4 years. Of these, 94% were stocked that spring with 6% stocked during a previous stocking period. Of these, 2% were stocked the previous fall, 0.4% were from previous years' spring stockings, and 4% were unclassified (Fig. 1). Angling effort during the survey periods did not differ significantly ($P > 0.05$) among years and ranged from 516.9 angler-hours in 1993 to 695.6 angler-hours in 1994 (Table 2). Harvest rates also were similar among years ranging from 1.2 trout/hour in 1992 to 1.9 trout/hour in 1993 (Table 2). Return of stocked trout ranged from 10% to 28% over the 4-year period and averaged 21% (Table 2).

Estimated survival of fall-stocked trout through spring the following year was 1%–3% (Table 3). Survival through July was 1%–2% (Table 3). Survival of spring-stocked trout through July was also low at 2%–7% (Table 3). July mean densities translate to 86–245 trout on average surviving 2–3 months after stockings in Mill Creek. Spring-stocked trout were never collected in any significant numbers during subsequent samples. Thus, survival of these fish was negligible after 3 months.

Between 1991 and 1994, 76% of the spring-stocked trout were unaccounted for in either electrofishing or creel surveys in Mill Creek. Percentages by year

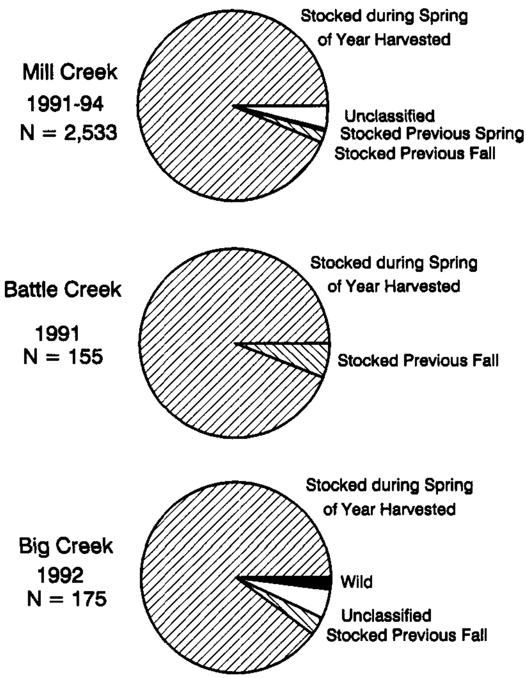

Figure 1. Relative abundance of harvested trout by stocking in 3 Tennessee streams.

were 71% in 1991, 86% in 1992, 72% in 1993, and 82% in 1994. These trout were presumed lost to the fishery.

Battle Creek

An estimated total of 236 trout were harvested over the 3 stocking periods (Table 2). Of the 155 trout actually creeled, 94% were stocked during the spring of 1991 out, in with the remaining 6% stocked in the fall of 1990 (Fig. 1). Estimated total effort was 222.8 angler-hours over the 3 stocking periods with a mean harvest rate of 1.3 trout/hour (Table 2). Despite the difference in stocking densities, mean harvest rates and total effort were similar among periods. Angler returns for the 3 stockings ranged from 18 to 45% and averaged 29% (Table 2).

Estimated survival of 1990 fall-stocked trout was 0.1% through March 1991, and 0.2% through July 1991 (Table 3). Of the 1,500 subharvestable trout stocked in September, only an estimated 6% survived until November (Table 3). Too few spring-stocked trout were collected in subsequent surveys to obtain survival estimates. Seventy-one percent of the spring-stocked trout were unaccounted for in either creel or electrofishing surveys.

Big Creek

An estimated total of 184.2 angler-hours was expended with an estimated total harvest of 237 trout (Table 2). Of the 175 trout actually creeled, 89% were

Table 2. Effort and creel summary for the trout stockings in 3 Tennessee streams, 1991–1994.

Stream	Survey date	Estimated effort (hr)[a] (±SE)	Estimated harvest (*N*) (±SE)	Mean harvest (trout/hr)[a]	Estimated return (%)
Mill Creek					
	Apr 91	369.0 (±90.8)	610 (±213)	1.8	27
	May 91	288.9 (±39.9)	441 (±70)	1.6	26
	Total	657.9 (±102.0)	1,050 (±212)		
	Mean			1.7	27
	Apr 92	389.7 (±53.7)	493 (±120)	1.3	16
	May 92	227.1 (±70.8)	221 (±62)	1.0	10
	Total	616.8 (±98.8)	714 (±130)		
	Mean			1.2	13
	Apr 93	257.7 (±69.1)	495 (±108)	1.9	22
	May 93	259.2 (±50.5)	483 (±72)	1.9	28
	Total	516.9 (±88.5)	978 (±157)		
	Mean			1.9	25
	Mar 94	211.3 (±99.3)	241 (±121)	1.1	18
	Apr 94	134.3 (±69.2)	166 (±89)	1.3	16
	May 94[b]	130.3 (±36.1)	224 (±60)	1.7	17
	May 94[c]	219.7 (±68.4)	258 (±59)	1.3	19
	Total	695.6 (±141.0)	890 (±170)		
	Mean			1.3	19
Battle Creek					
	Mar 91	60.5 (±44.4)	80 (±76)	1.3	23
	Apr 91	100.4 (±35.0)	78 (±24)	1.2	18
	May 91	61.9 (±45.3)	78 (±30)	1.8	45
	Total	222.8 (±61.4)	236 (±88)		
	Mean			1.3	29
Big Creek					
	Apr 92	107.0 (±26.7)	121 (±40)	1.0	28
	May 92	77.2 (±28.6)	117 (±68)	1.4	20
	Total	184.2 (±43.7)	238 (±69)		
	Mean			1.2	24

[a]HR = angler-hour.
[b]Stocking date 4 May 1994.
[c]Stocking date 17 May 1994.

stocked during the spring of 1992. Additional creeled fish included 3% stocked in the fall of 1991, 2% wild trout, and 6% unclassified (Fig. 1). Unclassified individuals were either stocked prior to the study, or in most cases had already been cleaned by anglers and no fin clips could be determined. Return was 28% and 20% for the April and May stockings, respectively (Table 2). Mean harvest rate over the 2 periods was 1.2 trout/hour. No significant differences were detected for harvest rates or total effort between stocking periods.

Estimated survival of fall-stocked trout was 61% through October 1991, but only 6% by March 1992 (Table 3). Too few spring-stocked trout were collected in subsequent surveys to obtain survival estimates. Seventy-five percent of the spring-stocked trout were unaccounted for in either creel or electrofishing surveys.

Table 3. Estimated density and survival of trout stocked in 3 Tennessee streams, 1991–1993.

Stocking season	Creel period	Estimated mean density (trout/km) (±SE)	Estimated survival (%) (SE range)	Estimated *N* in system (±SE)
		Mill Creek[a]		
Fall	Fall 90	50 (±18)	20 (14–28)	716 (±253)
	Spring 91	5 (±2)	2 (2–3)	78 (±25)
	Summer 91	4 (±1)	2 (1–2)	53 (±20)
	Fall 91	4 (±3)	2 (0–3)	58 (±43)
	Spring 92	7 (±5)	3 (1–5)	101 (±72)
	Summer 92	2 (±1)	1 (0–1)	29 (±14)
	Fall 92	14 (±5)	6 (4–8)	202 (±72)
	Spring 93	2 (±1)	1 (0–1)	29 (±14)
	Summer 93	2 (±1)	1 (0–1)	29 (±14)
Spring	Summer 91	6 (±3)	2 (1–4)	81 (±43)
	Summer 92	8 (±4)	3 (2–4)	121 (±58)
	Summer 93	17 (±8)	7 (4–10)	244 (±115)
		Battle Creek[b]		
Fall	Fall 90	17 (±8)	6 (3–9)	89 (±43)
	Spring 91	0.4 (±0.4)	0.1 (0–0.2)	2 (±2)
	Summer 91	1 (±1)	0.2 (0–0.4)	3 (±3)
		Big Creek[bc]		
Fall	Fall 91	126 (±65)	61 (29–92)	605 (±312)
	Spring 92	13 (±7)	6 (3–10)	62 (±34)

[a]No electrofishing done in 1994.
[b]Too few spring-stocked trout collected in later sampling for survival estimates.
[c]No electrofishing done in summer 1992.

Overview

Among the 3 study areas, both total harvest and total angler effort were significantly correlated to stocking densities (Table 4). Total harvest was significantly correlated to total effort (Table 4). Angler harvest rates showed no relationship with stocking densities, but showed significant correlation with percent angler returns (Table 4). Return of stocked trout showed no relationship with angler effort, total harvest, or stocking densities (Table 4).

Discussion

Low survival of unharvested trout was consistent across all streams and suggested that trout either experienced extreme natural mortality and/or rapidly migrated out of the systems. Movement patterns were not assessed in this study. However, several authors have reported that post-stocking rainbow trout movements were usually minimal (<5 km) and typically in a downstream direction. Bjornn and Mallet (1964) reported limited movement (90% of the trout <3.2 km from stocking location) of stocked trout (mainly rainbow trout) in Idaho streams the year following stocking. Heimer et al. (1985) observed most of the

Table 4. Correlation coefficients among creel and stocking parameters in 3 Tennessee streams, 1991–1994.

Comparison[a]	*r*	*P*
Total harvest: Stocking density	0.64	0.0098
Total effort: Stocking density	0.73	0.0022
Total effort: Total harvest	0.93	0.0001
Mean harvest rate: Stocking density	−0.01	0.9588
Percent return: Mean harvest rate	0.52	0.0426
Percent return: Stocking density	−0.46	0.0812
Percent return: Total effort	−0.20	0.4716
Percent return: Total harvest	−0.03	0.9293

[a]$N = 15$.

stocked rainbow trout they recovered in the Portneuf River, Idaho, were still within close proximity of the stocking location. Helfrich and Kendall (1982) reported similar findings in a Virginia stream for rainbow and brook trout (*Salvelinus fontinalis*). In a review, Cresswell (1981) reported low, and typically downstream, movement of stocked brook and rainbow trout. Less movement was observed with brown trout (*Salmo trutta*), but all species showed higher dispersion after overwintering in the stream environment. In the present study, all 3 streams supported warmwater fisheries in lower reaches. Thus, the potential for extensive downstream movement of trout was limited.

Another factor which may have influenced findings was harvest which occurred outside of scheduled creel periods. However, trout anglers were not observed at other times of the year by project investigators in any of the 3 streams. Furthermore, creel information indicated that few anglers fished at times other than after stockings. In Mill Creek and Battle Creek, angling had almost ceased by the fourth or fifth day after stockings. In Big Creek, the fishery was utilized more during summer, but harvest was considered minor due to the low abundance of harvestable-size trout during electrofishing surveys. Although some harvest undoubtedly occurred outside of the scheduled creel period, harvest would have been negligible due to minimal stream use and low abundance of harvestable-size trout.

Returns of fall-stocked trout in all 3 streams were negligible when compared to other studies. Cresswell (1981) reported in a review (mostly of research in the United States) that as little as 3% of stocked small trout (i.e., fingerlings) will survive and actually be harvested due to high overwinter mortality. Research in Wyoming yielded similar findings with return rates of subharvestables ranging from 0.6% to 23.0% in streams, and 0.03%–63.0% in lakes (Wiley et al. 1993). Although results were variable, mean returns from these studies were 28% and 48% for streams and lakes, respectively.

Returns of harvestable-size trout tend to be greater because fish are usually exposed to immediate angling pressure. Wiley et al. (1993) reported that Wyoming returns ranged from 8% to 65% in 34 streams and 4%-90% in 20 lakes between 1953 and 1989. Rohrer (1987) reported 3%–46% return on stocked harvestable-size rainbow trout in an Idaho stream. Similarly, Cresswell (1981) reported a mean return of 32% for stocked harvestable-size rainbow trout from several studies. The present study included fewer streams, but the 23% average return was similar to those in other studies.

Rohrer (1987) reported the percent of stocked fish harvested was correlated with angling pressure. In Henry's Fork, Idaho, angling pressure exceeded 3,000 angler-hours/km annually, and was greatest in the section where the highest harvests occurred. In general, this paralleled findings in all 3 streams as effort and harvest were undoubtedly concentrated at easy access areas and stocking locations. Returns by stream reach could not be evaluated from this study, but the insignificant relationship between return and effort suggests that returns were not affected by angling pressure. Other factors influencing catchability (and ultimately harvest) such as stream temperatures (McMichael and Kaya 1991), water quality (Wiley et al. 1993), presence of wild trout (Vincent 1987, Moring 1993), and strain-based characteristics (Fay and Pardue 1986) could not be evaluated in this study.

Moring (1985) reported that angler catch rates declined significantly when stocking rates were decreased in 5 Oregon streams, but anglers still harvested a similar percentage of the stocked fish (62%–82% in several streams). Although our returns were lower (13%–29%), angler catch rates and returns showed no significant relationship with stocking densities. Thus, stocking more (or less) trout in a given stream had no effect on harvest rates or returns at levels of angling effort observed.

Management Recommendations

Based on the findings of this study, the following recommendations are appropriate for put-and-take and put-grow-and-take trout fisheries in Tennessee streams. First, the stocking of juvenile rainbow trout during fall should be eliminated due to extremely poor survival. Annual carryover may occur in some streams, but recruitment to the fishery appears to be insignificant. Second, further altering of stocking densities in 1 or more streams will better define the relationship between returns and stocking densities. More precisely, by establishing upper and lower thresholds of returns relative to variable stocking densities, a stronger basis for future stocking strategies and more efficient use of hatchery resources will be achieved.

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