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[Article]

Growth, Movement, and Catch of Brook, Rainbow, and Brown Trout after Stocking into a Large, Marginally Suitable Adirondack River

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Abstract.—Poststocking growth, movement, and catch were compared among hatchery brook trout *Salvelinus fontinalis*, rainbow trout *Oncorhynchus mykiss*, and brown trout *Salmo trutta* in a fifth-order river. Associations of species, size, and stocking date with angler catch were also examined. The river is episodically acidified, and during summer it approaches lethal maximum temperatures for trout. Catchable-sized brook and rainbow trout (168–458 mm total length) were stocked in the late spring of 1996 and 1997. Brown trout were stocked only in 1997. Fish were marked with visible implant tags and were recovered through October of each year. All three species had negative daily growth rates in weight over the summer and early fall. Rainbow trout stocked in 1997 tended to move downstream after stocking, whereas the other groups showed no strong movement trend. Recovery rates significantly differed between brook and brown trouts stocked in early June and those fish stocked in late May. Large (>300-mm) rainbow trout were caught at higher rates than small (<260-mm) fish were. Anglers were estimated to have caught 72% of the stocked brook trout, 51% of the rainbow trout, and 18% of the brown trout. High summer water temperatures (>20°C) did not affect angler catch rates because cool refuges within the river concentrated and made the stocked fish—especially brook trout—vulnerable to angling. By stocking more than one species, we were able to create diversified angling opportunities and sustain a fishery in this thermally marginal river over the entire summer season.

Hatchery brook trout *Salvelinus fontinalis*, rainbow trout *Oncorhynchus mykiss*, and brown trout *Salmo trutta* are often stocked into rivers for put-and-take management programs. Stocking variables such as species, age, size, and time of stocking can affect fish survival or angler catch. Differences among species or strains in terms of behavior (e.g., movement and habitat use: Helfrich and Kendall 1982) or physiology (e.g., optimal and lethal temperatures: Brauhn and Kincaid 1982) can also influence the performance of stocked trout. Comparisons of domestic and wild strains have been conducted for brook trout (e.g., Van Offelen et al. 1993), rainbow trout (e.g., Babey and Berry 1989), and brown trout (e.g., Hulbert 1985). However, few studies have concurrently compared all three trout species.

Spring stocking of catchable-sized trout can be used as a management strategy to create a put-and-take fishery in streams that are marginally suitable for year-round trout survival. Year-round survival may be prevented by high summer water temperatures or lethal episodic pH depressions associated with spring snow-melt (e.g., Wigington et al. 1996). Although acidified streams may be lethal for trout during a few weeks in the springtime, suitable conditions may occur for the remainder of the year. Summer water temperatures can limit salmonid populations if the temperatures exceed upper lethal limits (about 25°C; MacCrimmon and Campbell 1969; McCormick et al. 1972), and negative effects such as reduced growth can occur at warm, but sub-lethal, temperatures (Hokanson et al. 1977; Drake and Taylor 1996). The evaluation of species and stocking variables (e.g., size and date) and their effect on angler catch can provide information that will guide stocking programs in matching fish to the conditions of rivers and in creating seasonal put-and-take fisheries.

The purpose of this study was to compare the fishery performance of three trout species stocked into a large, fifth-order river that is prone to lethal episodic acidification and warm summer water temperatures. The objectives of this study were (1) to compare growth, movement, and survival among brook, rainbow, and brown trout and (2) to determine the effects of size at stocking, date of stocking, and water temperature on angler catch.

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Study Area

This study was conducted on the South Branch of the Moose River (hereafter referred to as the SB Moose River), a fifth-order stream located in Hamilton and Herkimer counties, New York, in the southwestern region of the Adirondack Mountains. The SB Moose River drains an area of 450 km^2. The study site was a 12-km middle reach of the river (Figure 1), located about 32 km downstream from the source and 10 km upstream from the river mouth. The study reach had an average gradient of 0.3%; low-gradient sections had sand, gravel, and cobble substrates and were interspersed with steeper-gradient sections containing boulder, cobble, and bedrock substrates. The watershed is forested with mature, second-growth northern hardwoods and mixed northern hardwood–conifer forests. Naturally reproducing brook trout are common in some tributaries and are present in the SB Moose River.

Summertime water temperatures in the SB Moose River can approach or exceed reported maximum upper limits for salmonid survival. The maximum daily mean temperature was 23.1°C in 1996 and 24.8°C in 1997. The mean daily water temperature was over 20°C for 36 d in 1996 and 32 d in 1997. During high-discharge events, the SB Moose River is subject to episodic pH depressions that can result in conditions lethal to salmonids. During the summers of 1996 and 1997, base flow pH was approximately 6.0. However, during spring runoff in those same years, pH was as low as 4.7 and inorganic monomeric aluminum concentrations were at lethal levels for brook trout (Baird 2000).

Stocking of brook trout of various sizes into the study section of the SB Moose River began in 1936. Annual stockings of catchable-sized brook and rainbow trout began in 1958 to compensate for declines in wild brook trout abundance. Historically, the river reportedly had abundant brook trout populations (Webster 1979). Over the past two decades, approximately 1,000 brook and rainbow trout were stocked annually into the study reach in late May and early June to create a put-and-take fishery. Brown trout were not stocked until 1997. Wild brook trout were present in all six major tributaries that enter the study section, and these fish comprise a portion of the angler catch in the main river. In the study area, anglers are restricted to fly fishing only; the open season runs from April 1 to November 30, and the creel limit is 5 trout/d. The study reach was not open to the general public. Only the property owners and their guests had access to the river.

Methods

Individually marked trout were stocked in the study reach in late May and early June of 1996 and 1997 (Table 1). Poststocking performance was evaluated by

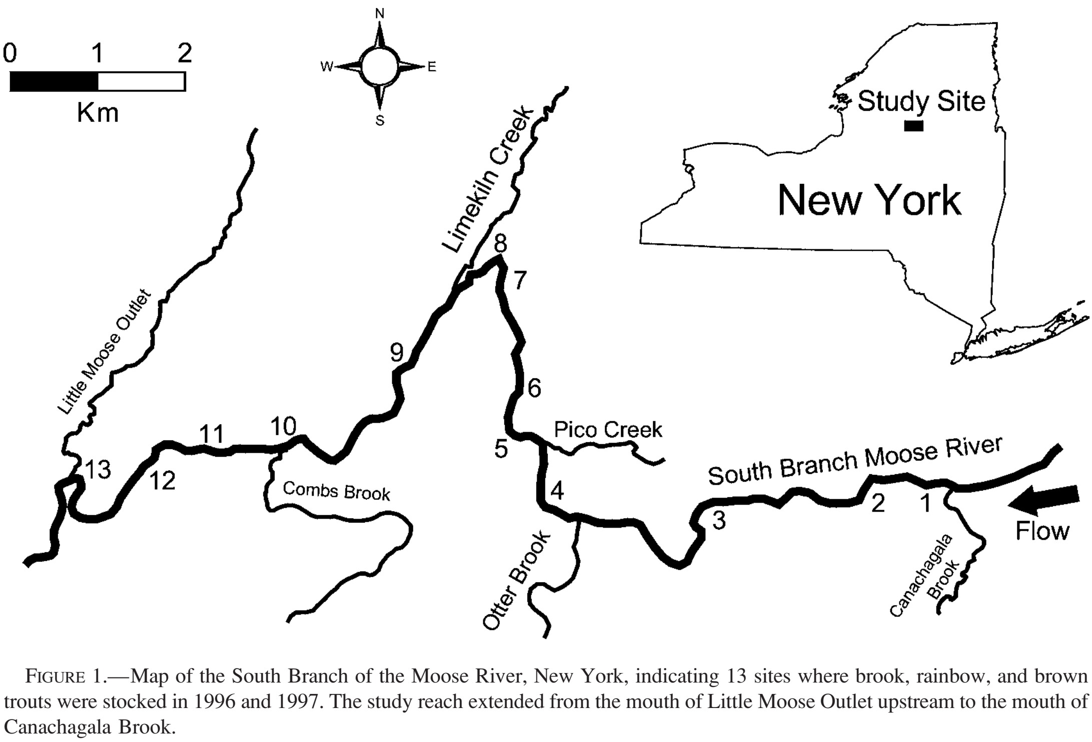

FIGURE 1.—Map of the South Branch of the Moose River, New York, indicating 13 sites where brook, rainbow, and brown trouts were stocked in 1996 and 1997. The study reach extended from the mouth of Little Moose Outlet upstream to the mouth of Canachagala Brook.

TABLE 1.—Total length (TL) and weight of the trout stocked into the South Branch of the Moose River, New York, in the spring of 1996 and 1997; N = number stocked.

		TL (mm)			Weight (g)		
Stocking date	N	Mean (SE)	Median	Range	Mean (SE)	Median	Range
Brook trout							
May 1996	497	289 (1.34)	282	253–427	286 (6.74)	242	161–1,100
Jun 1996	495	293 (1.15)	288	254–426	289 (5.39)	260	180–1,038
May 1997	507	265 (1.66)	254	225–426	229 (7.18)	182.5	118–1,111
Jun 1997	505	269 (1.95)	255	199–447	252 (9.24)	185	74–1,281
Rainbow trout							
May 1996	500	246 (2.55)	226	202–445	176 (7.68)	114	69–832
Jun 1996	501	265 (2.87)	234	201–459	234 (9.29)	130	68–1,026
May 1997	486	285 (2.06)	280	198–458	261 (7.12)	225.5	70–1,040
Jun 1997	446	233 (2.59)	211	179–446	152 (7.92)	89	57–1,017
Brown trout							
May 1997	460	260 (2.50)	235	175–368	234 (7.75)	135	51–685
Jun 1997	396	266 (2.74)	240	168–376	254 (8.56)	150	36–701

capturing fish in the summer and fall by means of angling, trap-netting, and electrofishing. Angler catch data were collected through volunteer catch reporting by the property owners and project staff.

Fish sources.—Catchable-sized brook trout stocked in both years were obtained from Fernwood Trout Hatchery, Gansevoort, New York. The Fernwood strain of brook trout originated from the Shy Beaver Hatchery, West Buxton, Maine, in 1978 (Kincaid et al. 1997; Thomas C. Field, Fernwood–Limne, Inc., personal communication). Ninety-five percent of the brook trout stocked in 1996 were age 1, and the other 5% were age 2. In 1997, 90% of the fish were age 1 and 10% were age 2.

Catchable-sized rainbow trout of three different strains were used in this study. Rainbow trout were received as eyed eggs and were reared at Fernwood Trout Hatchery. In 1996, stocked rainbow trout originated from a broodstock at the Cold Spring Harbor Hatchery, Long Island, New York; this stock originated from the Connetquot Hatchery strain (T. C. Field, Fernwood–Limne, personal communication). In 1997, 10% of the stocked rainbow trout were age-1 fish from the Cold Spring Harbor strain, and 77% were age-1 fish from Mount Lassen Trout Farm, Red Bluff, California, broodstock. The latter group of fish was derived from crosses between Kamloops and Mount Shasta strains in the 1950s (Kincaid et al. 1997; T. C. Field, Fernwood–Limne, personal communication). The balance (13%) of rainbow trout stocked in 1997 was composed of age-2 fish that were the progeny of Hinchenbrook Hatchery, New York, broodstock, which were originally derived from Warren County Hatchery, Warrensburg, New York, broodstock.

Catchable-sized brown trout were stocked only in 1997 and were from the Rome State Fish Hatchery operated by the New York State Department of Environmental Conservation (NYDEC). The Rome strain was derived from Germany and the United Kingdom starting in the 1880s (Luton 1985) and was subsequently bred for resistance to furunculosis (Ehlinger 1977). Some brown trout stocked were 2-year-olds that were transferred as yearlings from the Rome State Fish Hatchery in May 1996 and reared until spring 1997 at the Little Moose Field Station, Old Forge, New York, located on Little Moose Outlet (Figure 1) about 8 km upstream of the SB Moose River. Sixty percent of the brown trout stocked were age 1, and 40% were age 2.

Spring stocking.—Trout transported by truck from either the Fernwood or Rome hatchery were held at the Little Moose Field Station for 1–24 d before marking and for 5–14 d after marking but before stocking. All trout were anesthetized (tricaine methanesulfonate [MS-222]; 100–200 mg of MS-222 per liter of water), tagged in the left postorbital eyelid tissue with a visible implant (VI) tag that enabled identification of individual fish with a three-digit alphanumeric code (Haw et al. 1990), and marked with an adipose fin clip. Total length (nearest mm) and wet weight (nearest g) were recorded at the time of marking (Table 1).

Fish were stocked in late May and early June at 12 locations in 1996 and 13 locations in 1997 (site 3 was not stocked in 1996; Figure 1). Each site was stocked with 5–13% of the total number stocked. Tag numbers were recorded by stocking site. In 1996, 5 brook trout and 33 rainbow trout were stocked without tags. In 1997, all stocked fish had tags when stocked.

Minimal differences in the size of stocked trout occurred between years, except in two instances. Brook trout stocked in 1996 were larger than those stocked in 1997; the median length of fish in 1996 was 30 mm more than the 1997 median (Wilcoxon rank-sum test: $z = 26.9$, $P < 0.001$; Table 1). Stocked rainbow trout were longer in 1997 than in 1996 (median length was 22 mm more; Wilcoxon rank-sum test: $z = 2.9$, $P = 0.004$).

Data collection.—Trout were recovered after stocking by use of angling, trap-netting, and electrofishing. Most data came from angler-caught trout. Trap-netting was limited to September 1996 and September and October 1997. A few stocked trout were caught by electrofishing, primarily in the tributaries to the SB Moose River. Electrofishing and angling were conducted in SB Moose River tributaries to detect whether the stocked trout moved into these streams. Most of the tag recovery effort occurred within the 12-km study reach by angling during May–October of each year. Some angling was done in a section about 5 km downstream of the study reach. Location, date of capture, and VI tag code were recorded from all fish caught. Length and weight were recorded from some of the fish caught by angling and all of the trout caught by electrofishing and trap-netting.

Data were collected from anglers at seven access sites along the study reach. Anglers were required to record location and date fished, the number of each species released and kept, and the number of anglers in the group. An additional group of 11 anglers in 1996 and 7 anglers in 1997 participated in an angler diary program. Angler diary participants recorded location and date fished, the number of each species caught, fin clips, tag numbers, and whether fish were kept or released. Angling was also conducted by project staff. In 1996, anglers were asked to place the heads of any retained fish into collection containers located at the reporting stations so that VI tag numbers could be read and recorded by project personnel. In 1997, anglers were asked to record the tag numbers themselves on the reporting cards. Angler reports probably constituted more than 75% of the angling effort within the study reach due to the property owners' high interest in the fishery.

Water temperature was measured with Onset Corp. (Pocasset, Massachusetts) Optic Stowaway and Hobo Temp temperature loggers and with Hydrolab Corp. (Austin, Texas) DataSonde 3 multiloggers. Temperature loggers generally recorded temperature at hourly intervals throughout the study period.

Data analysis.—The difference between size at capture and size at marking for individual fish was used to determine growth in length and weight. Mean growth rates (g/d) were compared among brook, rainbow, and brown trout with a one-way analysis of variance (ANOVA). If the ANOVA was significant, Tukey's tests with an overall significance level of 0.05 were used to compare means of the species–year groups. Correlations of individual fish growth rates with length at stocking and the number of days after stocking were used to determine whether fish size and time after stocking affected growth rates. Some fish were caught and measured multiple times over the several months after stocking; only the weight or length at first capture was used in comparisons between species, years, and sizes. Size at second or third capture was excluded to maintain the independence of samples. Brook trout included in the growth analysis were caught from 20 to 161 d after stocking. Rainbow trout used in the growth analysis were caught from 14 to 154 d after stocking, and brown trout were captured from 56 to 153 d after stocking. Fish captured by all methods were included in the growth analysis.

Movement data (up to 160 d poststocking) were analyzed based on the site of capture relative to the stocking location for only those fish stocked at sites 6–9 (Figure 1), located in the middle of the study reach. Recovery data from fish stocked at the middle four sites were used to analyze poststocking movement to reduce the bias that can occur due to the geographic distribution of recovery effort upstream or downstream of where the fish were stocked. Fish capture locations were located to within 100 m on 1:25,000-scale topographic maps. Movement was compared among the five groups by use of a one-way ANOVA. Fish captured by all methods were used in the analysis of movement.

To determine whether all sizes of stocked fish contributed equally to the catch, we used a Wilcoxon rank-sum test to compare the stocking length of all fish with the stocking length of captured fish for each species stocked in each year. To determine whether the May or June stocking contributed more fish to the total catch (all gears combined), a chi-square goodness-of-fit test was used to compare catch to a uniform distribution with equal contribution from the May and June dates. This analysis was done for all fish caught and for only those fish caught during July–October each year. Fish caught in May or June were excluded to remove the possible effect of angling vulnerability differences between the first few weeks poststocking and later periods in the season. Fish captured by all methods were used in this analysis.

Data collected from the diary program, the angler cards, and research staff angling were combined for angling catch analysis. Angler catch per trip for the general anglers was determined by dividing the number of fish caught by the number of anglers reported on cards. The catch of brook trout reported by anglers was comprised of wild and stocked fish. Wild and stocked brook trout were not reported separately by anglers, so stocked brook trout catch was estimated based on the ratio of wild to stocked brook trout caught by angling

TABLE 2.—Recovery of tagged brook, rainbow, and brown trout captured by angling, trap-netting, or electrofishing for fish stocked with tags. Some fish without tags were stocked in 1996. Thus, the total numbers stocked in 1996 for brook trout and rainbow trout are larger in Tables 1 and 5 than in this table. Asterisks indicate that recovery of trout was significantly different between the May and June stockings within a year ($P < 0.05$).

Date stocked	Number stocked with tags	Total captured	Jul–Oct captures
	Brook trout		
22 May 1996	494	130	75
4–5 Jun 1996	493	138	84
19–20 May 1997	507	75*	44*
2–3 Jun 1997	505	128*	88*
	Rainbow trout		
22 May 1996	475	45*	26
4–5 Jun 1996	493	70*	39
19–20 May 1997	486	42	21
2–3 Jun 1997	446	27	17
	Brown trout		
19–20 May 1997	460	18	8*
2–3 Jun 1997	396	25	16*

by project staff. Stocked brook trout were identifiable because all stocked trout had an adipose fin clip.

Comparisons of angling catch per trip were made among species with ANOVA. Comparisons of angling catch and effort were made for trips from the beginning of the fishing season through September; little angling occurred after September. The effect of water temperature on angler catch was determined by regression of catch per trip on mean water temperature for the day of each angling trip.

Results

Recovery of Tagged Fish

About 5–27% of the trout stocked in 1996 and 1997 were recovered from the river by angling, trap-netting, and electrofishing. Total recovery of tagged fish from all sources included 268 brook trout and 115 rainbow trout from the 1996 stocking and 203 brook trout, 69 rainbow trout, and 43 brown trout from the 1997 stocking (Table 2). Angler diaries and angler catch reports contributed tagged fish data for 97 brook trout and 23 rainbow trout in 1996 and 19 brook trout, 5 rainbow trout, and 9 brown trout in 1997. The balance of the data was from fish caught by project staff, primarily by angling.

Growth

Most trout lost weight between stocking and recovery (Table 3). No difference occurred in growth rate among the five groups of fish (May–June lots combined; ANOVA: $F_{4,193} = 1.05$, $P = 0.40$). The few individuals that had positive growth rates were generally small fish (<275 mm). Growth rate (g/d) was negatively related to fish size for brook trout in 1996 ($r = -0.85$) and 1997 ($r = -0.90$), rainbow trout in 1996 ($r = -0.87$) and 1997 ($r = -0.78$), and brown trout in 1997 ($r = -0.91$; all $P \leq 0.001$). The growth rate in weight increased as the number of days after stocking increased for brook trout (1996: $r = 0.37$, $P < 0.001$; 1997: $r = 0.45$, $P < 0.001$). Brook trout that were caught and weighed multiple times generally showed a weight decrease immediately after stocking,

TABLE 3.—Growth rates in weight (g/d) and total length (mm/d) of three trout species from stocking to first capture in the South Branch of the Moose River, New York, in 1996 and 1997. No brown trout were stocked in 1996.

Length or weight variable	Brook trout		Rainbow trout		Brown trout
	1996	1997	1996	1997	1997
			Weight		
Mean	−0.56	−0.48	−0.64	−0.55	−0.10
SE	0.073	0.066	0.172	0.285	0.158
Minimum	−4.2	−2.5	−2.9	−3.8	−0.8
Maximum	0.30	0.21	0.36	0.44	0.40
N	87	59	29	15	8
			Total length		
Mean	0.054	0.052	0.140	0.210	0.170
SE	0.0088	0.0061	0.0210	0.0450	0.0280
Minimum	0.000	0.000	0.000	0.000	0.088
Maximum	0.360	0.200	0.440	0.640	0.310
N	77	54	28	14	8

TABLE 4.—Distance (km) moved by three species of stocked trout from release sites 6–9 (Figure 1) to the location of first capture in the South Branch of the Moose River, New York, in 1996 and 1997. Positive values indicate upstream movement and negative values indicate downstream movement.

	Brook trout		Rainbow trout		Brown trout
Movement variable	1996	1997	1996	1997	1997
Mean	1.1	0.5	0.8	−3.9	0.4
SE	0.32	0.36	0.56	1.51	1.12
Greatest downstream	−7.5	−5.6	−6.7	−16.1	−5.6
Greatest upstream	5.2	7.1	7.1	0.4	5.7
N	60	52	27	13	8

followed by a stabilization or slight increase in weight by September or October.

All groups of trout had positive mean daily growth rates in length after stocking (Table 3). Daily growth rates were not equal among the five groups of fish (ANOVA: $F_{4,176} = 17.8$, $P < 0.001$). Brook trout grew less than rainbow or brown trout did. The growth rate in length declined as fish size increased for brook trout stocked in 1997 ($r = -0.32$, $P = 0.007$). The number of days from stocking to capture was related to the growth rate in length for brook trout stocked in 1997 ($r = 0.58$, $P < 0.001$) and for brown trout ($r = 0.75$, $P = 0.03$).

Movement

The average distance between site of capture and stocking locations 6–9 was 1 km or less for all groups stocked except the rainbow trout stocked in 1997, which showed significant downstream movement ($F_{4,155} = 7.65$, $P < 0.001$; Table 4). The percentage of trout caught within 1.0 km of their stocking locations ranged from a low of 25% for brook trout in 1996 to a maximum of 46% for rainbow trout in 1997.

Few stocked trout were recovered in the tributaries to the SB Moose River. Five brook trout and three rainbow trout were caught in tributaries in 1996. In 1997, three brook trout, one rainbow trout, and two brown trout were caught in tributaries. Movement into the tributaries ranged from a few meters above their confluences to 3.8 km upstream from the main river.

Effect of Size at Stocking on Catch

Large (>280-mm) rainbow trout were more likely to be caught than small (<250-mm) fish in both 1996 and 1997. The median stocking length of rainbow trout caught in 1996 was 7 mm greater than the median stocking length of all rainbow trout (Wilcoxon rank-sum test: $z = 3.86$, $P = 0.0001$). The median stocking length of rainbow trout caught in 1997 was 31 mm greater than the median stocking length of all rainbow trout (Wilcoxon rank-sum test: $z = 3.32$, $P = 0.0009$). Size at stocking did not affect the catch of brook trout (1996: $z = -0.78$, $P = 0.40$; 1997: $z = 1.0$, $P = 0.30$) or brown trout ($z = 1.0$, $P = 0.30$). All sizes of brook and brown trout contributed to the catch in proportion to the number stocked.

Effect of Stocking Date on Catch

For three of the five groups, the trout stocked in June were more likely to be caught than the fish stocked in May ($P < 0.05$; Table 2). Brook, rainbow, and brown trout each represented one of the three groups. No significant differences in catch occurred between the May and June stocking groups for brook trout in 1996 and rainbow trout in 1997.

Species Vulnerability to Angling

More brook trout (in proportion to numbers stocked) were caught by anglers than rainbow or brown trout (Table 5). The total catch of stocked brook trout was estimated to be 82% of the fish stocked in 1996 and 62% of those stocked in 1997 (adjusted for wild brook trout contribution). The proportion of stocked rainbow trout caught was 62% in 1996 and 40% in 1997, or approximately 20% less than that of brook trout during each year. Catch of brown trout was only 18% of the number stocked. Wild brook trout were estimated to have contributed 28% to the total brook trout angling catch in 1996 and 32% in 1997.

Although similar numbers of each species were stocked in each year, the average catch of stocked brook trout per trip was greater than the catch rates for rainbow and brown trout (Table 5; 1996: $t = 5.53$, df = 744, $P < 0.001$; 1997: $F_{2,879} = 119$, $P < 0.001$). Brown trout catch per trip was the lowest among the three species at 0.4 fish per trip.

In 1997, brown trout catch rates were similar among months ($F_{4,289} = 0.3$, $P = 0.9$), in contrast to the catch rates for brook and rainbow trout (Figure 2). Brook and rainbow trout generally showed declines in catch rates between June and July or August during both years. For example, stocked brook trout catch per trip in 1996 was greater in June than July ($F_{4,368} = 3.5$, $P = 0.008$). Similarly, in 1997, the catch per trip of stocked brook trout was greater in June than August (Figure 2; $F_{4,289} = 3.5$, $P = 0.008$).

TABLE 5.—Total reported trout catch in number (from volunteer angler report cards, angler diaries, and researcher angling) and in percent of the total number stocked in the South Branch of the Moose River, New York. The reported catch exceeds the number stocked and the number of tagged fish contributing to the fishery because these catch numbers include wild brook trout, unmarked stocked trout captured in 1996, and trout caught more than once. Wild brook trout were estimated to contribute 28% to the total brook trout catch in 1996 and 32% in 1997.

	Brook trout		Rainbow trout		Brown trout
Variable	1996	1997	1996	1997	1997
Total reported catch (including wild brook trout)	1,131	921	618	335	153
Stocked trout catch per trip	1.6	1.5	1.2	0.8	0.4
SE	0.15	0.12	0.10	0.06	0.04
Estimated catch of wild trout	317	295			
Number stocked	992	1,012	1,001	932	856
Catch of stocked fish (%)	82	62	62	40	18

No relationship existed between angling catch and water temperature for brook, brown, or rainbow trout ($P \geq 0.3$ for slopes) except for rainbow trout in 1996, which showed a slight positive relationship (slope = 0.11, $t = 2.2$, $P = 0.03$). High catch rates (>1 fish/trip) occurred even when mean daily water temperature approached the upper lethal limit for salmonids.

Discussion

Growth

All three trout species stocked into the SB Moose River typically showed a loss of weight after stocking. Individual fish that gained weight were usually smaller than 275 mm. In other studies, growth of large brook trout (age $\geq$ 2) was reduced by warm summer temperatures, while the growth of small brook trout (ages 0 and 1) was unaffected (Schofield et al. 1993; Drake and Taylor 1996). Large brook trout have higher metabolic demands than small fish and have increasingly higher metabolic costs at temperatures greater than 16°C than do small fish. Similarly, the lack of growth by large rainbow and brown trout may have occurred because large fish prefer cooler water than do small individuals (Coutant 1977). Thus, the warm summer temperatures in the SB Moose River may have affected growth of large trout more than small trout. Hatchery brook trout and cutthroat trout *O. clarkii* have been reported to lose weight immediately after stocking (Miller 1953; Ersbak and Haase 1983). Weight loss after stocking could also be due to food limitations and extensive movement and activity after stocking. Recently stocked rainbow trout in a Tennessee River showed higher activity, movement, and mortality than fish that had resided in the river for more than 4 months (Bettinger and Bettoli 2002).

Movement

Most trout stocked in the SB Moose River were caught within 1 km of their stocking location, which was consistent with the poststocking movement reported in other studies. For example, brook and rainbow trout stocked into a Pennsylvania stream tended to move downstream, whereas brown trout moved upstream; however, most movement was less than 1.6 km (Trembley 1943). In a second-order stream in Virginia, stocked brook and rainbow trout moved downstream, and brown trout moved upstream; however, all species tended to stay within 1 km of the stocking site (Helfrich and Kendall 1982). In Michigan streams, the majority of stocked brook, rainbow, and brown trout were caught within 5–8 km of the stocking site; most movement greater than this was in a downstream direction (Shetter and Hazzard 1940; Shetter 1944).

The effort to recover tagged fish in this study occurred over a limited geographic area, and therefore movement patterns must be interpreted cautiously. Any fish that moved beyond our study area had a low probability of capture relative to those that remained within the study area. Angling that occurred 5 km downstream from the 12-km study section recovered some tagged trout. Description of movement based on our tag recoveries reflects only movement within the 12-km study section. Although some limited effort was expended to recover marked trout outside the area, conclusions cannot be made regarding large-scale movements beyond the study reach. The value of our observations lies in the fact that many put-and-take fisheries are managed as limited river sections that are similar in length to our study section. Large-scale movements out of such sections are equivalent to mortality, as the fish are unavailable to the intended fishery.

Angling Catch

Brook trout provided the greatest angler catch for the number stocked and had the greatest catch per angler trip; hence, this was the most vulnerable of the three species (Table 5; Figure 2). The vulnerability of brook trout relative to the other trout species has been

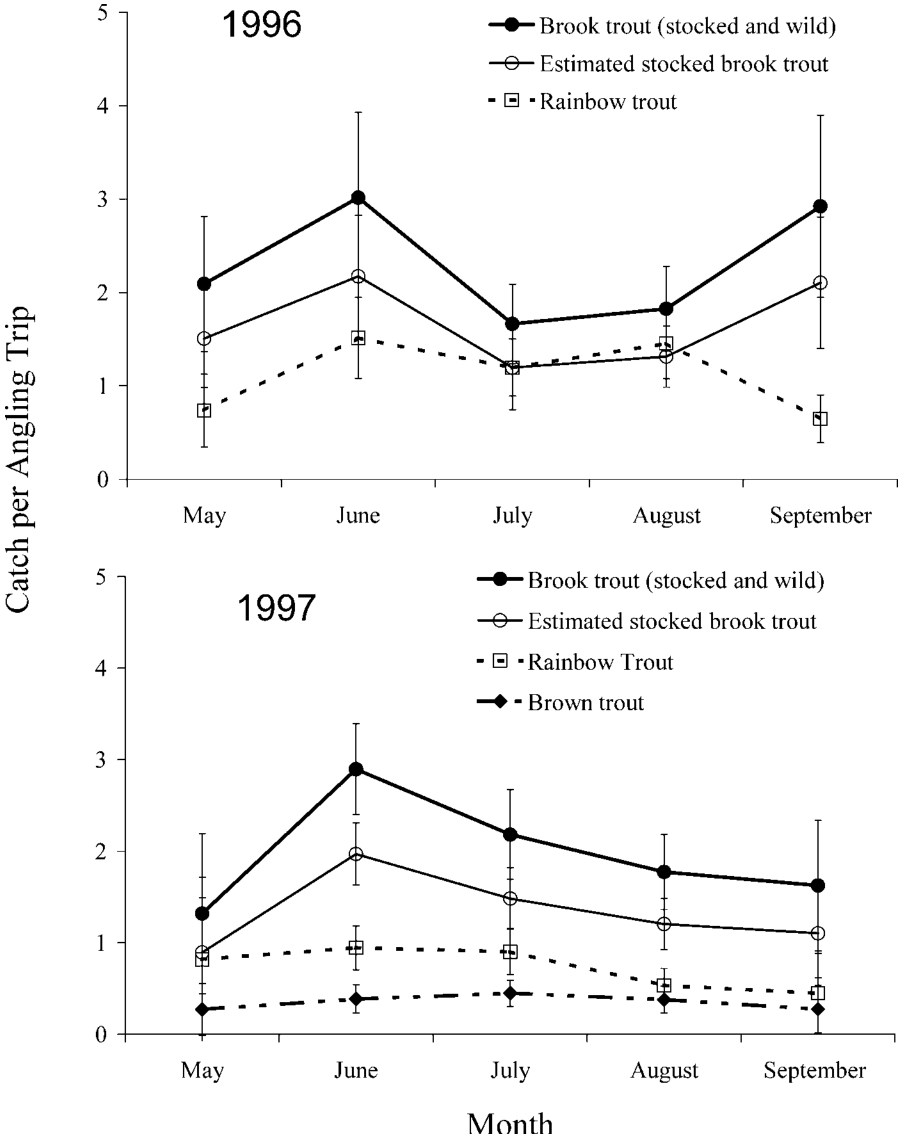

FIGURE 2.—Mean (±SE) catch per angling trip for brook, rainbow, and brown trout by month in the South Branch Moose River, New York, during 1996 and 1997. Fish were stocked in late May and early June in 1996 and 1997.

reported in other studies. For example, in a comparison of catchable-sized brook, brown, and rainbow trout stocked in a Pennsylvania stream, brook and rainbow trout were caught in similar proportions (56% and 60% of the number stocked), while brown trout had the lowest return of 47% (Trembley 1943). In a river in Michigan, rainbow and brook trout had higher catches (45% and 40% of the number stocked) than did brown trout (26%; Cooper 1952). In a second-order stream in Virginia, brook trout had the highest return (37% of the number stocked) and brown trout had the lowest (16%), while the rainbow trout return rate was nearly as great as that of the brook trout (32%; Helfrich and Kendall 1982). Recapture of stocked brook trout in a Minnesota stream was twice (20%) that of brown trout (9%; Smith and Smith 1943).

Another factor that contributed to the greater catch of brook trout than the other two species was the extensive use and concentration in cool thermal refuges created by tributary confluences or groundwater discharge areas during warm periods in the summer. Rainbow and brown trout did not use these areas to the extent that brook trout did (Baird and Krueger 2003). Few rainbow and brown trout were observed by snorkeling or were caught from these coolwater areas. Anglers targeted these coolwater areas where brook trout congregated. Thus, the use of these unique thermal habitats made brook trout much more vulnerable to angling than rainbow and brown trout. The use of cool thermal refuges by brook trout caused angler catch rates to remain high even when water temperatures in the main flow of the SB Moose River were near lethal levels for trout (≥23°C). In contrast to the SB Moose River, angler catch rates for rainbow and brown trout in the Madison River, Montana, declined when water temperatures were 19°C or greater (McMichael and Kaya 1991).

Size at stocking influenced the recovery of rainbow trout but not brook and brown trout. Large rainbow trout (>280 mm) contributed much more to the total rainbow trout catch than small (<250 mm) fish did. The health of the small rainbow trout stocked in 1996 and 1997 was worse than that of the large fish. A number of small rainbow trout died after transportation to Little Moose Field Station and during tagging, and also may have suffered greater poststocking mortality than large rainbow and brook trout.

Management Implications

Stocking catchable-sized brook, rainbow, and brown trout provided a diversity of angling opportunities throughout the SB Moose River over the summer season. The coolwater refuge areas used by brook trout in the SB Moose River helped to maintain high angler catch rates during the warmest periods. Rainbow and brown trout were not as concentrated in coolwater areas as were brook trout and thus provided an important opportunity for anglers to catch fish in other areas of the river during July and August, rather than at a few localized areas. Though brown trout catch was generally low, the consistency of brown trout catch per angling trip among all months resulted in brown trout contributing proportionally more to anglers' catch as the season progressed. Thus, the stocking of more than one species enhanced the spatial characteristics and catch rates of the fishery during the summer.

The stocking program we describe poses important social and ecological tradeoffs in its management. The stocking of catchable-sized trout created a put-and-take fishery in a river that was marginally suitable for trout. However, the stocking program could have negative effects on the relatively small native brook trout populations in the SB Moose River and its tributaries through ecological and genetic effects (e.g., Krueger and May 1991). These remnant wild populations could be an important source of fish for re-colonization if the episodic acidification of the SB Moose River declines. However, wild brook trout have persisted and rainbow trout have not naturalized after the decades-long stocking program. Thus, current management may be having a minor influence on the wild brook trout population. The stocking of only rainbow trout would be an alternative strategy to create a fishery while minimizing the risk to wild brook trout. Lower ecological and genetic risks would result from this strategy than from current management because rainbow trout cannot successfully interbreed with the wild brook trout and do not use the cool thermal refuge areas as much as stocked brook trout do (Baird and Krueger 2003).

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