Survival and Growth of Wild and Domestic Brook Trout (*Salvelinus fontinalis*) in Southwest Wisconsin Streams

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ABSTRACT

Equal numbers of wild- and domestic-strain brook trout (*Salvelinus fontinalis*) were stocked in nine southwest Wisconsin streams during fall 1989. The trout were subsequently sampled by electrofishing during spring and fall 1990 to assess survival and growth. Wild brook trout had significantly greater winter and summer survival rates than domestic brook trout. After an initial stocking ratio of 1:1 in fall 1989, wild trout outnumbered domestic trout by 1.6:1 and 5.8:1 in spring and fall 1990, respectively. Domestic fish were larger than wild fish at the time of stocking and at subsequent sampling periods. Likewise, the instantaneous growth rate during winter was greater for domestic fish than for wild fish. However, instantaneous growth rates during summer were not significantly different between the two strains. These results suggest that wild strains of brook trout should be stocked when long-term survival of fish is an important consideration in management of a stream.

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INTRODUCTION

Historically, trout populations in many Wisconsin streams are not self-perpetuating because of limited spawning substrate. Consequently, the maintenance of viable trout fisheries in streams with marginal habitat has required repeated stocking with hatchery-reared fish. Under these conditions, long-term survival has been of secondary importance to rapid growth of stocked trout.

Wisconsin has recently made concerted efforts to improve fish habitat within trout streams. For example, stream bank stabilization and a narrowing of the stream bed provide overhead cover required by adult trout and increase current velocity, which exposes spawning areas previously covered with silt (Vetrano 1988). As a result of habitat improvement projects, many streams in southwest Wisconsin that were formerly of marginal quality now offer good potential for natural reproduction of trout (Vetrano 1988). Current management objectives have been redirected toward the restoration of self-sustaining trout populations, which often requires the use of hatchery-reared trout to obtain spawning stocks and has increased the emphasis on long-term survival of stocked fish in streams.

Hatchery rearing of salmonids results in selective breeding of fish with specific traits. Many domesticated strains have been intentionally developed with characteristics desirable to fish culturists, such as rapid growth and maturity, uniformity in appearance, and disease resistance (e.g., Wolf 1953; Donaldson and Olson 1955; Toney and Bowen 1968; Gall 1975; Gjedrem 1976). Unintentional genetic selection may also occur because fish that display desirable traits, or are easier to handle, are often subconsciously chosen by fish culturists during brood-stock selection. Subsequent production of large numbers of offspring from a few parents presents conditions that are conducive to rapid genetic change within the population. Because of artificial selection during hatchery rearing, genetic heterogeneity within the salmonid stock is often greatly reduced.

Several studies have used electrophoresis to measure genetic heterogeneity in different stocks of salmonids. Allendorf and Utter (1979) found low genetic variability in a domestic stock of rainbow trout (*Oncorhynchus mykiss*) that had been maintained at a reduced population size for a long period of time and subjected to intentional selection for several traits. Allendorf and Phelps (1980) detected a significant reduction in genetic variation at several isozyme loci in a domestic population of cutthroat trout (*Oncorhynchus clarki*) that had been derived from wild stock 14 years earlier. Ryman and Stahl (1980) demonstrated considerable genetic differences between domestic and wild stocks of brown trout (*Salmo trutta*) previously assumed to represent identical gene pools.

Artificial selection often reduces the ability of domestic strains of fish to compete and survive. Vincent (1960) compared the fitness of wild- and domestic-strain brook trout (*Salvelinus fontinalis*) that had been reared in a hatchery environment. Wild-strain brook trout demonstrated greater stamina and could endure higher water temperatures and greater metabolite concentrations than domestic-strain fish. Wild-strain brook trout also demonstrated greater wariness of humans than domestic-strain fish. Domestic-strain brook trout oriented at the water surface, whereas wild-strain brook trout sought cover near the bottom of the rearing trough. Because both strains of trout were reared under identical conditions, he concluded that the observed behavioral differences were genetically based. Several studies have likewise demonstrated the superiority of wild-strain brook trout over domesticated strains for survival in the wild (e.g., Greene 1952; Flick and Webster 1964, 1976; Mason et al. 1967; Fraser 1981, Webster and Flick 1981; Lachance and Magnan 1990).

Domestic- and wild-strain brook trout differ in their ability to establish self-sustaining populations. For example, Fraser (1989) found that wild-strain brook trout established self-propagating populations in four lakes in which domestic-strain fish had failed to successfully reproduce. He concluded that the failure of domestic-strain brook trout to develop a sustainable population was due to two factors: (1) the domestic-strain fish lost the ability to locate and use suitable spawning areas after 20 generations of domestication, and (2) domestic-strain brook trout had poor survival to sexual maturity.

Most studies that compared the survival of wild- and domestic-strain brook trout were conducted in lakes and ponds of northeastern United States and Canada. Few studies have assessed differences in the survival of these strains in midwestern streams. The increasing need for hatchery-reared trout that survive well in Wisconsin streams warrants an evaluation of different trout strains. Therefore, the objective of this study was to compare first-year survival and growth of wild- and domestic-strain brook trout fingerlings in southwest Wisconsin streams.

METHODS

Strains of Trout

The *Trout Strain Registry* (Kincaid 1981) defines a strain as a fish population that exhibits reproducible physiological, morphological, or cultural performance characteristics that are significantly different from other fish populations. Strain differences are established through substantial changes in the gene pool of a population. A strain is considered domestic if it is maintained in a hatchery environment (e.g., tanks, raceways, or ponds) continuously for more than two generations. A strain is considered native or wild if it is self-perpetuating in a natural environment without recent supplementation by fish reared in hatcheries. The term "F_1 wild" (F denotes filial generation) is used to designate first generation hatchery-reared fish that come from wild parentage. Therefore, the group of wild trout used in this study was F_1 wild. Hereafter, wild-strain will be referred to as wild, and domestic-strain will be referred to as domestic.

The domestic brook trout used in this study was the "St. Croix" strain reared at the St. Croix Falls State Fish Hatchery, Wisconsin. This strain was first propagated at the Paint Bank National Fish Hatchery in Virginia, and was known as the "Paint Bank" strain of brook trout. Although it is not known when the strain was first domesticated, it presumably originated in the Appalachian Mountain region of western Virginia (Guldthwaite, Virginia Department of Conservation; personal communication.). The St. Croix Falls Hatchery obtained the strain in 1973 with a single acquisition of eggs from the Nashua National Fish Hatchery, New Hampshire. It is unknown how the strain was maintained or if it had been subjected to any intentional selection before it was obtained by the St. Croix Falls Hatchery. Selection to improve coloration, body conformity, and egg production of the strain occurred at the St. Croix Falls Hatchery (Claggett and Dehring 1984). Currently, this strain is still undergoing intentional selection for increased egg production (Tabat, Wisconsin Department of Natural Resources; personal communication). Electrophoretic analysis suggested that the St. Croix strain may be genetically unfit for survival in the wild (Callen 1983). This is currently the only domestic strain of brook trout raised in Wisconsin state hatcheries.

The origin of the wild strain of brook trout used in this study was Duncan Creek, Chippewa County, Wisconsin. Duncan Creek had been regularly stocked with domestic brook trout from the Osceola State Fish Hatchery from 1938-1974. Since 1974, the brook trout population in Duncan Creek has been maintained solely through natural reproduction. The most recent census (1978) indicated that Duncan Creek supported a large number of brook trout with densities up to 1,327 fish/ha (Wisconsin Department of Natural Resources, unpublished data).

Five hundred adult brook trout were obtained as brood stock for my study from Duncan Creek by the Wisconsin Department of Natural Resources (WDNR). The brook trout were collected by electrofishing on October 17, 1988, and transferred to La Crosse, Wisconsin, where they were artificially spawned on October 19 and 24, 1988. Eggs from each female were fertilized with milt from two males. A total of 1247 g of fertilized eggs were obtained. The mass of individual eggs was estimated to be approximately 0.109 g/egg. The fertilized eggs were incubated in vertically-stacked tray incubators at a hatchery on Spring Coulee Creek, Vernon County, Wisconsin. After hatching, the fry were transferred to an outside raceway operated by the Coon Valley Conservation Club. The trout were fed the same type and quantity of food as the domestic fish reared at the St. Croix Falls Hatchery. Food was dispensed by an automatic feeding system; however, trout at the St. Croix Falls Hatchery were fed manually.

Study Sites

The experimental study sites were nine streams in Crawford, La Crosse, and Vernon counties of southwest Wisconsin (Fig. 1), which is within the western uplands (Driftless Area) of Wisconsin (Martin 1965). This area is characterized by karst topography with the upper bedrock layer composed of dolomitic limestone. Stream valleys are typically steep-sided with limestone and sandstone outcroppings. The original oak savanna-upland prairie of the region is now primarily used for row crops and pasture.

Most large streams in this area contain large populations of brown trout (*Salmo trutta*), which outcompete brook trout. Therefore, I selected nine small tributary streams for this study. Approximately 300-m stretches of each stream were sampled with a D.C. backpack electroshocker during July 1989 to determine if any stream contained brown trout. Brown trout were found in three of the streams (Fishback Creek, Plum Creek, and Creek 27-3), but their populations were not large enough to warrant eliminating the streams from this study.

The watersheds of the streams were mainly open and wooded pastures. The streams had similar chemical and physical characteristics (Table 1) with slightly basic (pH 7.6-8.3) and well-buffered water (total alkalinity 219-270 ppm as $CaCO_3$). Water temperatures measured during July 1989

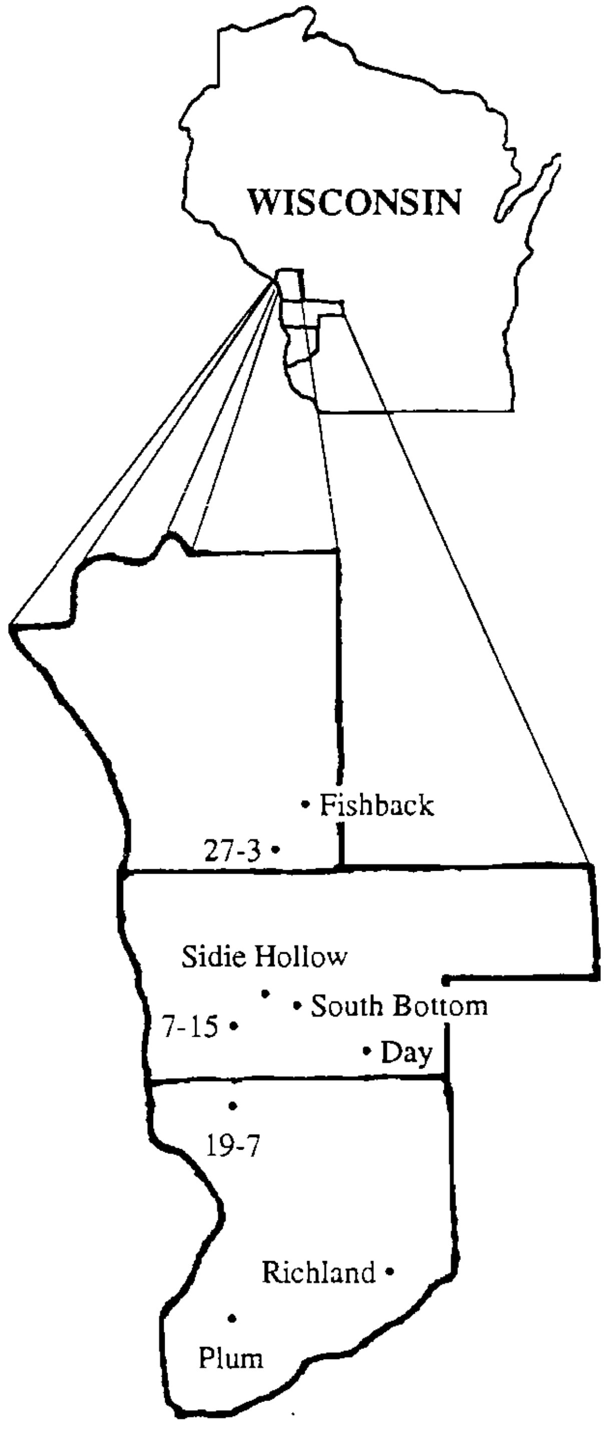

Figure 1. Location of study streams in Crawford, La Crosse, and Vernon counties, Wisconsin.

Table 1. General characterization of the nine study streams.

	Creek 27-3	Creek 7-15	Day	Fish-back	Plum	Rich-land	Rush	South Bottom	Sidie Hollow
Mean width (m)	1.1	1.8	2.5	2.4	4.0	3.0	3.1	3.3	1.4
Gradient (m/km)	25.3	11.3	11.0	18.9	6.7	11.6	4.4	13.1	12.6
Flow (m^3/s)	0.01	0.03	0.05	0.02	0.09	0.04	0.08	0.04	0.01
Total alkalinity (ppm)	219	250	244	230	270	261	238	242	248
pH	8.3	8.1	8.1	7.8	7.6	7.9	8.0	8.1	8.2
Specific conductance (μmhos)	426	424	490	473	500	492	469	471	493
Fish species present									
Brook trout (*Salvelinus fontinalis*)	x		x	x	x			x	x
Brown trout (*Salmo trutta*)	x			x	x		x		
Rainbow trout (*Onchorynchus mykiss*)			x						
White sucker (*Catostomus commersoni*)	x	x	x	x	x	x	x	x	x
Creek chub (*Semotilus atromaculatus*)	x	x	x	x	x	x	x	x	x
Brook stickleback (*Culaea inconstans*)	x	x		x	x	x		x	x

Central stoneroller (*Campostoma anomalum*)	x	x	x	x	x	x	x	x	x
Blacknose dace (*Rhinichthys atratulus*)	x	x	x	x	x	x	x	x	x
Longnose dace (*Rhinichthys cataractae*)		x						x	
Southern redbelly dace (*Chrosomus erythrogaster*)						x			
Bluntnose minnow (*Pimephales notatus*)				x		x			
Golden Shiner (*Notemigonus crysoleucas*)		x							
Johnny darter (*Etheostoma nigrum*)		x	x	x	x	x		x	x
Fantail darter (*Etheostoma flabellare*)		x	x		x			x	
Slimy sculpin (*Cottus cognatus*)							x	x	
Central mudminnow (*Umbra limi*)		x							
American brook lamprey (*Lampetra appendix*)			x						

(14-21 C) were suitable for survival of brook trout (Raleigh 1982). Flow rates during March 1990 ranged from 0.01 to 0.09 m^3/s. The assemblage of fish species present was typical for southwest Wisconsin streams (Table 1).

Stream Stocking

In fall 1989, each stream was stocked with 148 fingerlings of each strain per hectare of stream surface area. Surface area estimates were obtained from stream surveys done by the WDNR. The general WDNR guidelines for fall stocking of streams with "good" and "excellent" habitat is 122 and 162 fingerlings per hectare, respectively.

To enable subsequent identification of fish in the field, The wild and domestic strains of trout were marked prior to stocking by excision of the adipose and left pelvic fins, respectively. The adipose fin, rather than the pelvic fin, was removed from the wild fingerlings because of their small size relative to the domestic fingerlings. Prior to marking, the trout were anaesthetized with ethyl *m*-aminobenzoate methanesulfonate (MS-222) and there was negligible mortality (<1%) 2 days after marking. Wild fingerlings were marked one week prior to stocking; domestic fingerlings were marked at the St. Croix Falls Hatchery.

Streams were stocked with domestic fingerlings on September 20, 1989, and with wild fingerlings on October 4, 1989. Stocking procedures were identical on both dates. A random sample of 100 fingerlings of each strain was measured (± 2.5 mm TL) and weighed (± 1 g). The fingerlings were delivered to the streams in insulated, oxygen-equipped tanks and acclimated to stream conditions by slowly mixing transport water with stream water. The fingerlings were scattered over a 300- to 500-m stretch in each stream, with an attempt to place the fingerlings in areas with suitable cover.

Population Sampling

Brook trout populations in the nine streams were sampled in spring and fall 1990 to compare survival and growth between the two strains. Stream sections sampled during spring and fall were identical. A total stream distance of 12.8 km was sampled among the nine streams representing 1.1 to 1.8 km of each stream (Table 2). The entire lengths of Creek 27-3 and Sidie Hollow Creek were sampled. For the other streams, a single section of stream was sampled, including areas both upstream and downstream of the stocking site. In all streams, sampling extended upstream from the stocking sites until the recovery of stocked trout had ceased or been reduced to a very low level. In Plum Creek and Creek 7-15, the entire stream upstream of the stocking site was sampled. In Day and Fishback Creeks, sampling began at the mouth of the streams

Table 2. Sampling dates and distances. Distances sampled during spring and fall were identical.

	Sampling dates (1990)		
Stream	spring	fall	Sampling distance (km)
Creek 27-3	19 Apr.	28 Sept.	1.52
Creek 7-15	27 May	03 Nov.	1.83
Day	13 May	14 Oct.	1.68
Fishback	20 Apr.	12 Oct.	1.42
Plum	12 May	20 Oct.	1.07
Richland	28 May	27 Oct.	1.49
Rush	25 May	-----[a]	1.12
South Bottom	04 May	01 Oct.	1.08
Sidie Hollow	28 Apr.	22 Oct.	1.60

[a]Rush Creek was not sampled during fall 1990.

and, therefore, included the entire length of stream downstream of the stocking site.

Sampling was done by electrofishing with pulsed D.C. backpack electrofishing gear operating at a duty cycle of 10% and 40 pulses per second. One person operated the backpack electroshocker, and 1 to 2 people transported captured trout. Sampling proceeded in an upstream direction, and captured trout were held and transported in plastic buckets. Captured trout were anaesthetized with MS-222, identified to strain from fin clips, measured ($\pm$ 2.5 mm TL), weighed ($\pm$ 1 g), and given a temporary caudal clip. All trout were allowed to recover from the anaesthetic prior to release back into the stream. To avoid biasing population estimates, trout that did not recover or showed signs of handling stress were not released back into the stream. Streams were sampled again after a minimum of 48 h, and the numbers of resident and stocked trout of both strains with and without caudal clips were recorded.

Statistical Methods

Population estimates were calculated by the Peterson formula:

$$N = MC/R;$$

with variance estimated by the equation:

$$V(N) = M^2C(C-R)/R^3;$$

where M = the number of fish marked, C = total number of fish captured in the second sample, and R = number of marked fish recaptured (Ricker 1975). A non-parametric sign test was used to compare survival between the two strains of brook trout. Separate comparisons of survival were made for two time intervals: (1) date of stocking to spring sampling, and (2) date of spring sampling to fall sampling.

Mean length and weight of the two strains of brook trout were calculated for the following times: stocking, spring sampling, and fall sampling. Statistical comparisons of mean weight between the two strains of trout during spring and fall were not made because wild fingerlings were smaller than the domestic fingerlings at the time of stocking.

An assessment of differences in growth between the two strains of brook trout was made by comparing instantaneous growth (G), which was calculated with the following equation:

$$G = \ln W_{t+1} - \ln W_t;$$

where W = mean weight of a group (strain) of fish at time *t* (Ricker 1975; Newman and Martin 1983). Variance of G was estimated by an approximation of the variance of the natural logarithm of the mean weight (the delta method; Seber 1982):

$$V(\ln W_t) = V(Wt)/W_t^2;$$

The estimate of the variance of G is:

$$V(G) = V(\log_e W_t) + V(\log_e W_{t-1});$$

Comparison of values of G between strains was then made with a *Z* test, in the form of:

$$Z = \frac{G_D - G_W}{\sqrt{V(G_D) + V(G_W)}};$$

where G_D = instantaneous growth rate of the domestic strain and G_W = instantaneous growth rate of the wild strain. Separate comparisons of instantaneous growth were made for the time intervals between stocking and spring sampling, and between spring sampling and fall sampling.

The condition of fish for the two strains was evaluated through least squares regression analysis of length and weight (Cone 1989). Least squares length-weight regressions:

$$\ln W = \ln A + B \ln L;$$

where W = individual fish weight (g), L = total length (cm) were calculated for each strain and for the pooled data of both strains. The slope (B) of the length-weight regression equation was used as a measure of fish condition. Differences in condition between the two strains were evaluated by comparing the (B) values with a *F*-statistic that tests the significance of the pooled variance (Snedecor and Cochran 1980). Separate comparisons of condition between the two strains of trout were made for the spring and fall of the year.

Data were analyzed with the Statistical Analysis System (SAS Institute, Inc. 1986) operating on the VAX computer at the University of Wisconsin-La Crosse. A Type I error (alpha) of 0.05 was used to judge statistical significance.

RESULTS

Survival

Wild brook trout had greater winter survival than domestic brook trout in all nine streams ($p=0.002$; Table 3). Percent winter survival, calculated as the sum of all spring population estimates divided by the total number of trout stocked, was 20.9% for the wild brook trout and 13.3% for the domestic brook trout. For all streams combined, wild brook trout outnumbered the domestic brook trout by a ratio of 1.6:1.

Wild brook trout also had greater summer survival than the domestic brook trout ($p=0.004$; Table 3). Percent summer survival, calculated as the sum of spring population estimates divided by the sum of fall population estimates, was 40.8% for the wild brook trout, and 11.1% for the domestic brook trout. For all streams combined, wild brook trout outnumbered the domestic brook trout by a ratio of 5.8:1.

Growth

At stocking and at subsequent sampling periods, domestic brook trout were larger than wild brook trout. At stocking, the mean weight (g) of the domestic fingerlings ($\bar{x}=21$; sd=5.7; n=100) was 40% greater than that of the wild fingerlings ($\bar{x}=15$; sd=6.4; n=100). The mean total length

Table 3. Number of wild- and domestic-strain brook trout stocked (fall 1989) and estimated abundance ± 95% confidence interval of brook trout in study streams during spring and fall 1990.

Stream	Strain	Number stocked	Spring estimate	% winter survival	Fall estimate	% Summer survival	% Annual survival
Creek 27-3	wild	220	95±15	43.2	22±5	23.2	10.0
	domestic	220	63±12	28.6	6±4	9.5	2.7
Creek 7-15	wild	440	50±8	11.4	35±4	70.0	8.0
	domestic	440	17±3	3.9	6±0	35.3	1.4
Day	wild	940	177±12	18.8	61±9	34.5	6.5
	domestic	940	144±14	15.3	5+0	3.5	0.5
Fishback	wild	730	233±18	31.9	71±30	30.5	9.7
	domestic	730	134±16	18.4	5±0	3.7	0.7
Plum	wild	580	149±17	25.7	61±8	40.9	10.5
	domestic	580	124±13	21.4	34±2	27.4	5.9
Richland	wild	550	108±12	19.6	78±38	72.2	14.2
	domestic	550	68±8	12.4	7±0	10.3	1.3

Rush	wild	180	18±7	10.0	---[a]	---	---
	domestic	180	13±3	7.2	---[a]	---	---
South Bottom	wild	920	101±10	11.0	38±7	37.6	4.1
	domestic	920	35±4	3.8	2±0	5.7	0.2
Sidie Hollow	wild	140	53±10	37.9	28±7	52.8	20.0
	domestic	140	26±2	18.6	3±0	11.5	2.1
All streams[b]	wild	4700	984	20.9	394	40.8	8.7
	domestic	4700	624	13.3	68	11.1	1.5

[a]Rush Creek was not sampled during fall 1990.
[b]Sum of population estimates from all streams.

(cm) of the domestic fish ($\bar{x}$=13.1; sd=1.1; n=100) was also greater than the wild fish ($\bar{x}$=11.0; sd=1.5; n=100). In spring 1990, approximately 7 months after stocking, the mean weight (g) of domestic fish ($\bar{x}$=83; sd=40; n=550) was 250% greater than that of the wild fish ($\bar{x}$=33; sd=18; n=885; Table 4). In fall 1990, approximately one year after stocking, the size difference between the two strains of trout was still great (Table 4). The mean weight (g) of the domestic fish ($\bar{x}$=264; sd=135; n=66) was 236% greater than that of the wild fish ($\bar{x}$=112; sd=67; n=302).

Differences in size between the two strains of trout reflected differences in growth. The instantaneous growth rate (G) of the domestic brook trout for the interval between fall stocking to spring sampling was significantly greater than that of the wild brook trout in all test streams ($P<0.0001$, Table 5). However, the instantaneous growth rates of the two strains of brook trout for the interval between spring sampling to fall sampling were not significantly different.

<u>Condition</u>

In addition to differences in weight and growth, differences in condition also existed between the two strains of fish. During spring, the condition of the domestic brook trout ($B=3.28$, $r^2=0.94$, $SE=0.04$) was

Table 4. Mean (±sd) total length, mean (±sd) weight , and sample sizes (N) of stocked wild- and domestic-strain brook trout during spring (April-May) and fall (October-November) 1990.

		Spring			Fall		
Stream	Strain	Mean (±sd) length (cm)	Mean (±sd) weight (g)	N	Mean (±sd) length (cm)	Mean (±sd) weight (g)	N
Creek 27-3	wild	13.1 (1.7)	25 (10)	75	19.9 (1.6)	105 (27)	19
	domestic	16.9 (1.5)	55 (16)	51	24.3 (2.1)	176 (36)	5
Creek 7-15	wild	16.8 (1.8)	57 (21)	43	23.4 (2.9)	150 (65)	33
	domestic	23.6 (2.4)	176 (69)	18	28.4 (5.0)	298 (182)	6
Day	wild	14.1 (1.9)	30 (13)	194	18.2 (1.8)	71 (24)	54
	domestic	17.7 (1.7)	67 (21)	132	20.7 (1.1)	99 (15)	5
Fishback	wild	13.0 (1.9)	22 (11)	208	18.6 (1.9)	76 (24)	43
	domestic	17.3 (1.7)	56 (20)	111	23.3 (2.0)	135 (39)	5
Plum	wild	16.7 (1.8)	51 (16)	124	25.0 (2.8)	211 (67)	54
	domestic	21.5 (1.4)	120 (25)	108	30.1 (3.1)	360 (86)	33
Richland	wild	16.6 (1.9)	48 (18)	94	19.9 (2.4)	78 (32)	42
	domestic	21.1 (1.5)	112 (29)	61	24.9 (2.3)	152 (53)	7
Rush	wild	16.0 (2.2)	47 (21)	12	-----[a]	-----	-
	domestic	20.4 (1.7)	93 (25)	11	-----[a]	-----	-

South Bottom	wild	13.5 (1.8)	26 (12)	90	19.2 (3.1)	86 (42)	33
	domestic	18.2 (1.2)	70 (18)	33	24.4 (2.2)	167 (21)	2
Sidie Hollow	wild	12.6 (1.5)	21 (8)	45	20.7 (1.4)	97 (23)	24
	domestic	17.2 (1.3)	64 (14)	25	20.5 (1.0)	111 (15)	3
All streams[b]	wild	14.4 (2.4)	33 (18)	885	20.7 (3.4)	112 (67)	302
	domestic	18.9 (2.6)	83 (40)	550	27.1 (4.5)	264 (135)	66

[a]Rush Creek was not sampled during fall 1990.
[b]Sum of growth data from all streams.

Table 5. Daily instantaneous growth rates (G) of the wild- and domestic-strain brook trout.

	Winter		Summer	
Stream	wild	domestic	wild	domestic
Creek 27-3	0.0026	0.0045	0.0089	0.0072
Creek 7-15	0.0057	0.0085	0.0060	0.0033
Day	0.0031	0.0049	0.0056	0.0025
Fishback	0.0019	0.0046	0.0071	0.0050
Plum	0.0055	0.0074	0.0088	0.0068
Richland	0.0049	0.0067	0.0032	0.0020
Rush	0.0049	0.0066	----[a]	----[a]
South Bottom	0.0026	0.0053	0.0080	0.0058
Sidie Hollow	0.0016	0.0050	0.0086	0.0031

[a]Rush Creek was not sampled during fall 1990.

significantly greater ($F=20.86$, $P<0.0001$) than that of the wild brook trout ($B=3.09$, $r^2=0.95$, $SE=0.02$). However, during the fall sampling period, the condition of the two strains of brook trout were not significantly different (domestic: $B=3.18$, $r^2=0.92$, $SE=0.12$; wild: $B=3.19$, $r^2=0.92$, $SE=0.05$).

The condition of the two strains of fish changed between sampling intervals. The condition of domestic brook trout decreased significantly from spring to fall ($F=9.14$, $P<0.001$); the condition of wild brook trout increased significantly from spring to fall ($F=11.36$, $P<0.001$).

DISCUSSION

Survival

Wild brook trout had greater winter and summer survival than domestic brook trout in all nine streams. These results are similar to those in studies by Greene (1952), Flick and Webster (1964, 1976), Mason et al. (1967), Webster and Flick (1981), Fraser (1981), and Lachance and Magnan (1990). Several hypotheses may explain the observed patterns in survival, including: differences in culture methods, size differences between the two strains of fish at stocking, physiological tolerance to environmental conditions, ability to compete for food, and mortality due to angling and predators.

Differences in survival between strains were not likely due to differences in culture methods. Webster and Flick (1981) found that wild strains of brook trout reared in a hatchery had greater survival than domestic strains of brook trout reared in a natural environment; differences in survival were probably genetically based. Mason et al. (1967) found no significant difference in survival between wild strains of brook trout that had been reared in a hatchery and those reared in a natural environment.

Differences in survival between the two strains of brook trout probably were not due to the size of the fish at stocking. If initial size had a significant effect on survival, then domestic trout, which were larger at stocking than the wild fish, would have been expected to have the highest survival. Other studies of brook trout (Flick and Webster 1976; Fraser 1981; Lachance and Magnan 1990) corroborate my findings that wild brook trout survived better than domestic brook trout, even though wild fish were smaller than domestic fish at stocking.

Physiologically, wild trout may tolerate stress and environmental conditions better than domestic fish. Phillips et al. (1957) found that the chemical composition of a wild strain of brook trout was superior to that of a domestic strain of brook trout. For example, the tissue of wild fish contained more protein, ash, and iodine, and less fat and water than domestic fish. Vincent (1960) reported that wild brook trout demonstrated greater stamina, and could endure higher water temperatures and greater metabolite concentrations than domestic brook trout.

Some studies have suggested that high mortality of domestic salmonids may be due to inefficient feeding and subsequent starvation (Miller 1952; Ersbak and Haase 1983). However, in my study, domestic fish had greater winter growth rates than wild fish, suggesting that starvation did not significantly contribute to winter mortality of domestic fish.

Because brook trout are highly vulnerable to angling, fishing mortality is a major factor that affects their overall survival (Cooper 1952; Alexander and Shetter 1969). Domestic fish may be more susceptible to anglers and consequently have greater angling mortality than wild fish. For example, Dwyer and Piper (1984) found that two strains of domesticated rainbow trout were much more susceptible to angling than wild strains. Similarly, Dwyer (1990) found that susceptibility to angling among strains of cutthroat trout was directly related to the degree of domestication. Flick and Webster (1962) reported that domestic brook trout in an Adirondack pond were more vulnerable to fly-fishing than wild strains, even though all fish were approximately the same length. During the first summer following stocking, over 30% of the domesticated fish were removed by fly-fishing; only 12% of the fish from the two wild stocks were removed. Mason et al. (1967) conducted a creel survey on two southern Wisconsin streams that had been stocked with wild and domestic strains of brook trout. They found that, during the first month of the fishing season, the harvest of domestic fish was 13.9 to 26.2% of the population but that harvest of wild fish was only 0.2 to 1.2%.

Angling was probably not a significant source of mortality in this study. The fishing season was closed from October 1 to April 30 each year; hence angling was not responsible for winter mortality. Because of severe drought during 1989, catch-and-release fishing was allowed from May 1 to September 30, 1990 with artificial lures only. Consequently, even if differential vulnerability to angling occurred between strains, these fishing regulations probably minimized its effect on fish mortality.

Differences in mortality between strains may have been due to behaviors that could have made the domestic brook trout more vulnerable than wild fish to predation. Vincent (1960) found that domestic trout showed little avoidance of humans in the laboratory and oriented at the surface of the water column, whereas wild trout sought cover near the bottom of the rearing trough. I observed similar behavior in the field when the fish were stocked into the streams. Upon release into the streams, domestic trout swam near the surface of the water for several minutes, but wild trout quickly sought cover and disappeared from sight. A continuation of this behavior would render domestic brook trout more susceptible than wild brook trout to avian predation. Predation by great blue heron (*Ardea herodias*) on trout during this study was probably substantial. During spring sampling, I observed great blue herons at all nine streams. Several of the stocked brook trout that I captured had large dorsal wounds--probably the result of attacks by avian predators. During the spring, 11 domestic and 3 wild brook trout were observed with dorsal wounds. During the fall, 6 domestic and 0 wild brook trout were observed with dorsal wounds. This suggests that the domestic brook trout may have been more vulnerable to avian predation than the wild brook trout.

Growth

The condition of the domestic brook trout decreased and the condition of the wild brook trout increased during summer 1990. Ersback and Haase (1983) similarly found that the condition of domestic brook trout declined after stocking, whereas the condition of resident wild trout remained constant.

Domestic brook trout were larger at stocking and throughout this one year study and also had a greater winter instantaneous growth rate than the wild trout. Summer instantaneous growth rates were not significantly different between the two strains. My results are similar to other studies that compare growth between wild and domestic brook trout. For example, Flick and Webster (1964) found that domestic brook trout remained larger than wild brook trout throughout the first year after stocking in ponds. In a similar study, Flick and Webster (1976) found that domestic brook trout consistently reached maximum size a year earlier than wild brook trout. Lachance and Magnan (1990) reported that following stocking in Quebec lakes, domestic brook trout remained larger than wild brook trout throughout the two-year period of the study.

Measured growth rates of trout in the wild are biased by fishing and natural mortality because only individuals still alive at the time of sampling are used to estimate growth. Great fishing pressure and natural mortality that selectively remove large fish would probably reduce the apparent growth differences between two strains of trout. Consequently, the best estimates of growth would be derived from populations protected from angling and with low levels of natural mortality.

The data in this study demonstrate a positive relationship between growth and condition. The domestic brook trout had a significantly greater winter growth rate than the wild fish and also had significantly greater condition during the spring. Summer instantaneous growth rates and condition were not significantly different between the two strains.

In conclusion, wild brook trout had greater winter and summer survival than domestic brook trout. Domestic brook trout had greater winter growth; summer growth rates were not significantly different between the two strains. Domestic brook trout had greater condition during the spring; condition was not significantly different between the two strains during the fall. The condition of the domestic brook trout decreased significantly from spring to fall; condition of the wild brook trout increased significantly during the same period. Differences in survival were probably due to predation and not to competition.

MANAGEMENT IMPLICATIONS

This study suggests that wild brook trout should be stocked in southwest Wisconsin streams when long-term survival of the fish is important. These results also reinforce the importance of maintaining genetic heterogeneity within domestic salmonid stocks. Any type of selection, either intentional or inadvertent, can greatly accelerate the loss of genetic variability and result in strains unsuitable for survival in the wild (Allendorf and Phelps 1980). Ryman and Stahl (1980) suggested that continued surveillance of the genetic composition of domesticated stocks should be done through electrophoretic analysis. This would allow fish culturists to detect inadvertent reductions in genetic variability within the stock. Allendorf and Phelps (1980) recommended that genetic material from local wild stocks should be periodically introduced into domesticated strains to help preserve genetic variability. Interstrain hybrid brook trout of wild x domestic crosses have survival rates either equivalent to F_1 wild strains (Fraser 1981; Webster and Flick 1981) or intermediate to wild and domestic strains (Mason et al. 1967; Lachance and Magnan 1990).

Rather than stocking domestic fish, the re-establishment of self-sustaining trout populations might also be accomplished through the transfer of fish from local streams with large standing stocks of adult wild trout. This method has the advantage of relying on locally-adapted gene pools (Krueger et al. 1981). Adult wild trout could also be used, as in this study, to obtain F_1 wild fish, which could be raised in the hatchery prior to stocking. Through the use of automatic feeding systems, many of the problems of raising wild trout in a hatchery can be avoided, and the amount of work can be greatly reduced. This approach also provides a good opportunity for local conservation and sportsman's groups to work together with state management agencies in the rearing of trout in small local hatcheries.

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Appendix 1. Peterson population estimates ± 95% confidence intervals for resident trout during spring and fall 1990. Richland Creek and Creek 7-15 did not have any resident trout populations.

Stream	Season	Brook Trout	Brown Trout	Rainbow Trout
Creek 27-3	Spring	1±0	93±14	---
	Fall	1±0	69±16	---
Day	Spring	83±14	---	7±3
	Fall	12±3	---	---
Fishback	Spring	81±15	289±48	---
	Fall	20±8	89±53	---
Plum	Spring	11±5	27±8	---
	Fall	5±3	11±5	---
Rush	Spring	---	67±9	---
	Fall	---[a]	---[a]	---[a]
South Bottom	Spring	43±8	---	---
	Fall	23±14	---	---
Sidie Hollow	Spring	46±12	2±0	---
	Fall	13±5	4±0	---

[a]Rush Creek was not sampled during fall 1990.