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Field Performance of Wild and Domestic Brown Trout Strains in Two Wisconsin Rivers

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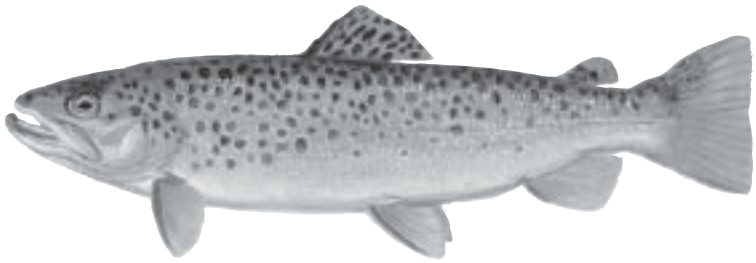
Photo: Ed L. Avery



Abstract

We evaluated whether improvement in survival and growth of stocked brown trout could be accomplished by using first-generation wild strains instead of domestic strains. We also examined whether improvement in survival and growth of domestic strains might result from improving the hatchery rearing environment rather than changing the genetic lineage.

We stocked three cohorts of brown trout as fall fingerlings in 1993 and 1994 in the Waupaca River and three additional cohorts of brown trout as spring yearlings in the West Fork Kickapoo River in 1994 and 1995. The 3 cohorts stocked in each stream consisted of a wild trout strain and a domestic trout strain, both reared under “optimum” hatchery conditions, and a domestic trout strain reared under “standard” hatchery conditions. The survival and growth of the 3 trout cohorts were followed for 2 years in each stream. A creel survey on the Waupaca River in 1995 provided information on angler harvest. Catch-and-release fishing only was permitted on the West Fork Kickapoo River.

Wild-strain brown trout dramatically outperformed domestic-strain trout in both rivers. Survival of wild trout was 1.3-4.5 times higher than domestic strains after 1 year and 4-42 times higher than domestic strains after 2 years. Differential angling mortality in the Waupaca River did not substantially alter survival comparisons. Growth of wild trout was similar to that of domestic trout in the moderately fertile Waupaca River, and domestic trout maintained their initial size advantage present at planting. Growth of wild trout in the fertile West Fork Kickapoo River exceeded the growth of and reduced noticeably the initial size advantage of the domestic trout strains.

No significant differences in survival and growth of domestic trout strains reared under “optimum” and “standard” hatchery conditions occurred in the Waupaca River, but significant differences did occur in the West Fork Kickapoo River. Improvements in growth and survival of domestic trout reared under “optimum” conditions were far less than the field performance improvements realized by rearing wild trout strains.

Contents

Photo: Ed L. Avery

Introduction

Domesticated trout strains stocked in Wisconsin streams usually provide good early season fisheries; but, those individuals not harvested frequently exhibit survival rates too low to sustain good fisheries throughout the first and subsequent fishing seasons or to contribute to subsequent natural reproduction (Mason et al.1967, Johnson 1983). Many fisheries managers speculate that poor poststocking survival is a direct consequence of years of inbreeding and selection of domestic stocks to achieve high year-class survival, accelerated growth, and early spawning during their existence in hatchery environments. Such selection processes leave domesticated trout ill-equipped to handle environmental extremes and avoid natural predators in the wild.

In 1990 and 1991, when harvest of trout was prohibited due to emergency responses to a prolonged severe drought, poor survival of domesticated strains of brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) was observed in numerous Wisconsin streams (Vetrano 1991, Meyers and Kerr 1992). This prompted renewed support for either crossbreeding wild genetics back into Wisconsin's domesticated trout strains or using entirely new wild trout strains to improve field performance (i.e. better survival and growth). Voluminous literature documents the better survival of both F1 (wild X domestic) hybrids and first generation wild salmonid strains compared with domesticated salmonid strains (Alexander 1985, Borawa 1988, Flick and Webster 1964, Fraser 1981, Green 1952, Keller and Plosila 1981, Lachane and Magnan 1990, Mason et al. 1967, Webster and Flick 1981).

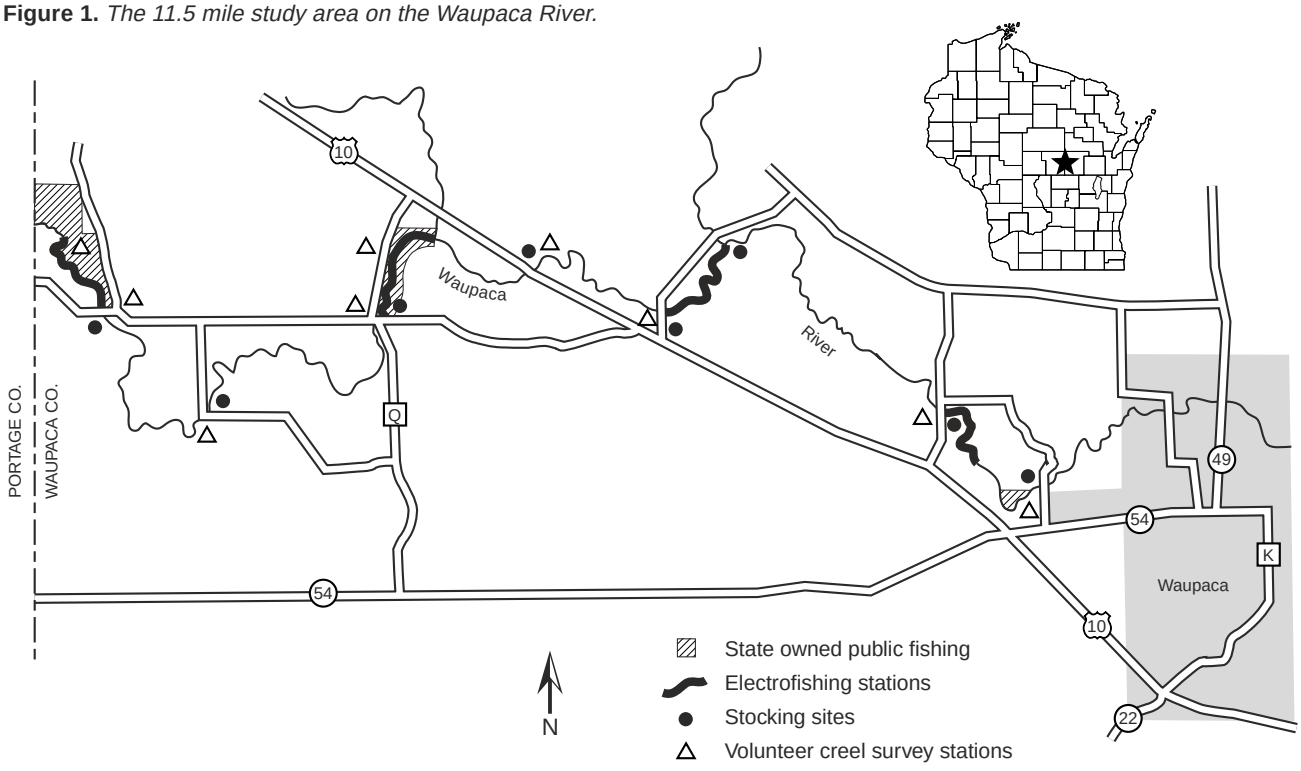
In November 1991, the Wisconsin Department of Natural Resources' (DNR) Bureau of Fisheries Management and Habitat Protection (FH) coordinated a meeting of fisheries managers with the ad hoc Trout Stocking Committee[1] to address the problem of poor field performance of stocked trout. Participants in this meeting and a subsequent meeting of FH staff in January 1992 reached consensus that, despite previously reported evaluations of poststocking performances of wild vs. domestic strains, further clarification on two issues was needed before major changes in Wisconsin's propagation program would occur. First, there was a need to further quantify the field performance of wild trout strains vs. domestic trout strains specifically in Wisconsin streams. Second, there was a need to examine the effect of improving the rearing environment in Wisconsin hatcheries (rather than changing the genetic lineage) on field performance of domestic trout strains. This study was initiated to address both needs.

[1] The Ad Hoc Trout Stocking Committee is a DNR committee of fishery managers, hatchery supervisors, a trout researcher, a fish health specialist, and several FH staff. It was formed in November 1988 to recommend a plan for developing, maintaining, and providing salmonid stocks/strains to meet management and propagation needs that would improve the quality of salmonid fisheries in Wisconsin.

Study Streams

The Waupaca River originates as the Tomorrow River in central Wisconsin's Portage County and flows southeasterly approximately 69 miles before entering the Wolf River in Waupaca County. The Tomorrow River becomes the Waupaca River when it crosses the Waupaca County line. The Waupaca River flows 24.7 miles, has an average width of 66 ft, a summer discharge of 180 cfs, a pH of 8.5, an alkalinity of 180 mg/L $CaC0_3$, and is Waupaca County's largest trout stream (Fassbender et al. 1971). Approximately 11.5 miles of the Waupaca River from the Portage/Waupaca County line downstream to the Highway 49 bridge was selected for study (Fig. 1). This reach is designated as Class II trout water (i.e. annual stocking of domestic brown trout is necessary to augment the population of wild trout; Wisconsin DNR 1980) and managed under Category 4 trout angling regulations (i.e. a

Figure 1. *The 11.5 mile study area on the Waupaca River.*



PHOTOS BY ED L. AVERY

The Waupaca River near Waupaca, Wisconsin.

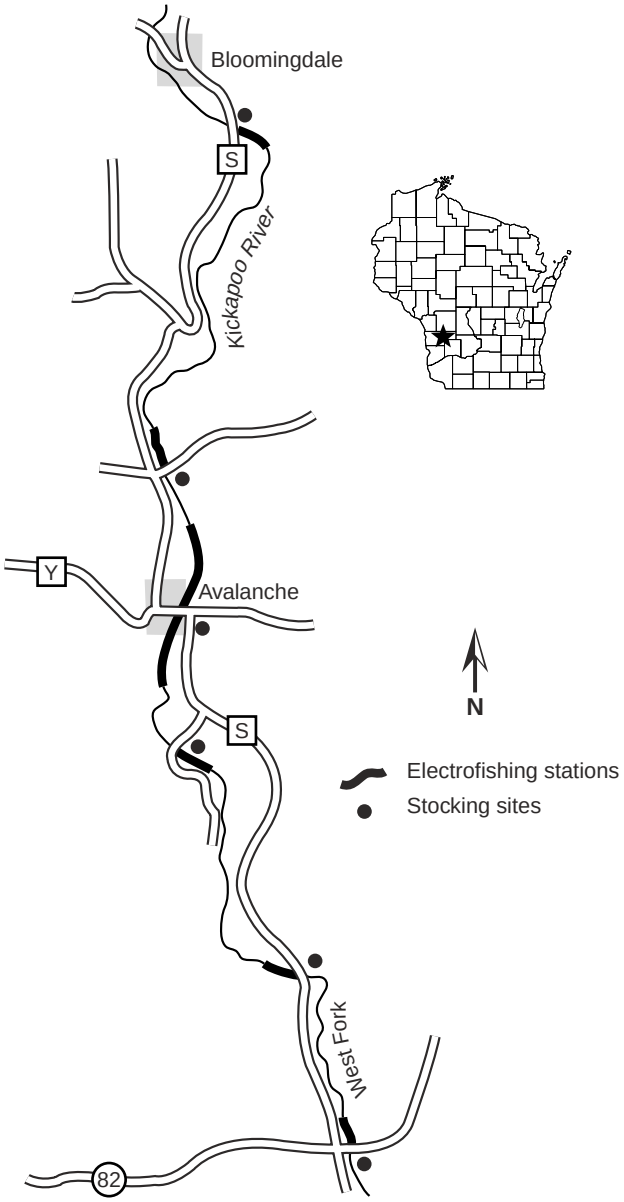
daily bag of 3 trout; minimum size of 12 inches for brown trout and 8 inches for brook trout).

The West Fork Kickapoo River originates in Monroe County in the “Driftless Area” of southwest Wisconsin. It flows south into Vernon County and continues for 24 miles before joining the Kickapoo River just north of Readstown. It is a clear stream with an average width of 27 ft, a discharge of 27.5 cfs, a pH of 7.8, and an alkalinity of 242 mg/L $CaCO_3$ (Klick and Threinen 1973). A 7.5-mile reach of the West Fork Kickapoo River from the County Highway S bridge south of the town of Bloomingdale downstream to the State Highway 82 bridge was selected for study (Fig. 2). This reach is also a Class II trout water that is stocked annually with brown trout. The river is managed as a Category 5 fishery (i.e. catch and release, artificial lures only fishing).

The West Fork Kickapoo River near Avalanche, Wisconsin.

PHOTOS BY ED L. AVERY

Figure 2. *The 7.5 mile study area on the West Fork Kickapoo River.*



Methods

Brown Trout Strains, Rearing, and Stocking

Radley Creek, a trout stream located in the Tomorrow\Waupaca River watershed, was selected as the source for the wild brown trout that would be evaluated in the Waupaca River. Approximately 120 wild, adult, brown trout (male:female ratio = 1:2) were collected from Radley Creek in late October and early November during both 1992 and 1993, taken to the DNR's Wild Rose Fish Hatchery in Waushara County and held for up to 6 weeks. Trout were spawned on 4-6 occasions, usually once per week. "Spawned-out" fish were immediately returned to their natal stream. During both years, peak egg collection occurred during mid- to late November. Wild eggs were incubated at 48° F.

Spawning of domesticated brown trout reared at the Wild Rose hatchery occurred from late July through mid-October in 1992 and 1993, with peak egg collection occurring during August. Annually, beginning in May, photoperiod was progressively reduced on the domesticated trout to force early maturation and spawning. Fertilized eggs were incubated at elevated water temperatures, 2-3° F warmer than the 48° F groundwater source, to further accelerate development and hatching.

Following the incubation and hatching of wild brown trout eggs, the fry were transferred to a separate building where they were reared on a separate water supply with little human contact (automatic feeders; normal photoperiods) and at approximately half the density of standard hatchery protocol. This was necessary to reduce stress and mortality as well as to protect against potential transmission of disease to other trout being reared at the hatchery. A cohort of domesticated brown trout fry from eggs spawned late in the hatchery cycle (early October) were transferred to the same building and reared under the same conditions as the wild fry. These wild and domesticated cohorts of brown trout are referred to as wild (W) and optimum domestic (OD) trout. A second cohort of domesticated brown trout fry from eggs spawned during the peak of the hatchery cycle (late August) were incubated and reared under standard hatchery protocols. These trout are designated as domestics (D).

Roullands Coulee Creek, a brown trout stream located in Monroe County and part of the Coon Creek watershed, was selected as the source for the wild brown trout that would be evaluated in the West Fork Kickapoo River. Wild brown trout adults were collected from Roullands Coulee Creek on 28 October and 2 November during both 1992 and 1993, transported to a DNR egg incubation facility on upper Spring Coulee Creek, spawned immediately, and returned to their natal stream. Also in early November of 1992 and 1993, a cohort of "eyed-up" domesticated brown trout eggs from the DNR's St. Croix Falls Fish hatchery in Polk County was transferred to the egg incubation facility on Spring Coulee Creek, incubated, and hatched along-side the wild (W) brown trout eggs. The domesticated eggs/fry are referred to as optimum domestics (OD). Both W and OD eggs were incubated and hatched at water temperatures near 48° F.

Following egg incubation and hatching in 1993, W and OD fry were transported to the Coon Valley Cooperative Trout Rearing Facility (CVCTRF) east of Coon Valley in Vernon County. There, fry were reared with little human contact (automatic feeders, normal photoperiods) and at approximately half the density of standard hatchery protocol. A second cohort of domesticated brown trout fry, referred to as domestics (D), was reared under standard hatchery protocols at the DNR's St. Croix Falls Fish Hatchery. In 1994, W fry were again reared at the CVCTRF while OD fry were reared at the Living Waters Bible Camp Cooperative Trout Rearing Facility located below Jersey Valley Lake in Vernon County. Rearing protocols for W, OD, and D trout were similar to those followed in 1993.

The St. Croix Falls strain of domesticated brown trout was developed from the Wild Rose strain of brown trout in the early 1970s (Claggett and Dehring 1984). Spawning of domesticated brown trout at the St. Croix Falls Fish Hatchery occurs from late September through mid-October, with peak egg collection occurring in early October. Photoperiod is adjusted to promote early spawning. Egg incubation and hatching occurs at 47°-48° F.

Similar numbers of W, OD, and D brown trout were stocked as fall fingerlings (age 0) in the Waupaca River in 1993 and 1994. Numbers of W, OD, and D brown trout stocked in the West Fork Kickapoo River varied by as much as 47% and were stocked as spring yearlings (age I) in 1994 and 1995 (Table 1). A few days prior to stocking, trout in each cohort were counted, weighed, measured, and given a permanent, characteristic finclip to facilitate subsequent identification. In the Waupaca River, similar numbers of the 3 cohorts of fall fingerlings were transferred to floating, wire-mesh, fish boxes at 8 access points (Fig. 1) and scatter-planted by members of the Central Wisconsin and Fox Valley chapters of Trout Unlimited. In the West Fork Kickapoo River, similar numbers of

the 3 cohorts of spring yearlings were released at each of 6 bridge crossings (Fig. 2).

Trout Population Assessment

Marking and recapture electrofishing surveys were conducted each spring and fall in 4 sections, totaling 2.5 miles in length, of the Waupaca River (Fig. 1). Surveys began in the fall of 1993 and ended in the fall of 1995. Fall electrofishing surveys were conducted prior to the fall stocking of fingerling trout. Two stream-shocker boats, each equipped with a 220 v DC generator and 3 positive electrodes, were used. Electrofishing proceeded upstream with each boat crew responsible for half the stream width. In straight reaches, the two crews generally moved upstream parallel to one another; in wide areas the crews were often separated by as much as 30-60 ft. Each crew often zigzagged within its half of the stream to cover as much of the river as possible. On bends, one crew would often work ahead on the shallow side of the river, cut across the river to the head of the bend, and electrofish downstream to the second crew as they continued to electrofish upstream on the deeper side of the river. Electrofishing crews stopped to process captured trout every 150-250 yds of streamthread. Marking and recapture surveys were separated by 24-48 hours. Trout captured on the marking run were measured to the nearest 0.1 inch, weighed to the nearest 1 g, examined for finclips, given a temporary caudal finclip, and released near the midpoint of each reach of stream sampled. Trout captured on the recapture survey were examined for finclips, measured to the nearest 0.5-inch group, and released.

Marking and recapture electrofishing surveys were conducted each spring and fall in 6 sections of the West Fork Kickapoo River that totaled 1.7 miles in length (Fig. 2). Surveys began in the spring of 1994 and ended in the spring of 1996. Spring electrofishing surveys were conducted prior to spring stocking of yearling trout. One electrofishing boat was used during each survey with the boat crew responsible for sampling the entire stream width. Other sampling protocols were similar to those used in the Waupaca River.

The Bailey modification of the Petersen mark/recapture formula (Ricker 1958) was used to estimate the population of W, OD, D, and "other" trout in all electrofishing stations combined on each stream during each sampling period. Population estimates of "other" trout < 6 inches and $\geq$ 6 inches were made and totaled. Confidence intervals at the 95% level for each population estimate were determined as $\pm$2 times the square root of the variance (Spiegel 1961). Significant differences between cohorts of trout were assumed when 95% confidence intervals did not overlap. Population estimates of each cohort were apportioned into inch groups based upon the corresponding proportions of unmarked trout captured in each inch group on both marking and recapture electrofishing runs. Average lengths and weights of trout in each inch group were determined based upon measurements and weights of trout from all electrofishing stations. Total numbers of trout present during each sampling period on each stream was the sum of the individual population estimates for W, OD, D, and "other" trout. Confidence intervals at the 95% level were determined as $\pm$2 times the square root of the sum of the population variances of each cohort. Trout biomass present in each stream was computed as the sum of the biomass per inch group per individual cohort.

Table 1. *Characteristics of brown trout strains stocked in the Waupaca and West Fork Kickapoo Rivers, 1993-1995.*

Strain[1]	Date Stocked	Age (months)	Ave. Size (inches)	Number Stocked	Density (No. /mile)
		Waupaca River			
W	2 Oct. 1993	10.5	3.1	6,690	582
OD	2 Oct. 1993	11.8	4.7	6,799	584
D	2 Oct. 1993	13.5	6.8	6,740	586
W	8 Oct. 1994	10.8	3.5	6,771	589
OD	8 Oct. 1994	12.0	5.9	6,826	594
D	8 Oct. 1994	13.8	6.6	6,824	593
		West Fork Kickapoo River			
W[2]	20 Apr. 1994	17.5	6.0	2,270	303
OD[2]	20 Apr. 1994	18.5	10.3	2,158	288
D	20 Apr. 1994	18.5	9.9	2,600	347
W	2 May 1995	18.0	6.8	1,850	247
OD	2 May 1995	19.0	8.6	1,384	185
D	2 May 1995	19.0	9.3	2,600	347

[1] W = wild, OD = optimum domestic, D = domestic.
[2] Stocked only at middle 4 sites (see Fig. 2).

Fishing Pressure and Trout Harvest Assessments

A partial creel survey (40 hours/week) was conducted on the Waupaca River throughout the 1995 trout fishing season to determine contributions of various cohorts of trout to the sport fishery and thus help fully assess survival and mortality comparisons between the trout cohorts. A creel survey was not conducted on the West Fork Kickapoo River because catch-and-release, artificial lure only regulations were in effect.

The 1995 trout season opened the first Saturday in May and ended September 30. Excluding opening weekend, the creel survey was stratified so that 50% of the survey effort was exerted on weekends and holidays and 50% was exerted on weekdays. A creel clerk worked a double shift (5:30 a.m. to 9:30 p.m.) each day of opening weekend to approximate a complete census and to accommodate the heavy fishing pressure. Thereafter, a creel clerk generally worked an 8-hour shift on each census day (either 5:30 a.m. to 1:30 p.m. or 1:30 p.m. to 9:30 p.m.). Survey days and 8-hour shifts were randomly selected within the constraints of a 40-hour workweek to best represent all days as well as a.m. and p.m. shifts.

Vehicles at or near bridge crossings and other common access points were counted at 2-hour intervals on each census day. The first vehicle count on the morning shift was at 6:30 a.m. The last vehicle count on the afternoon shift was at 8:30 p.m. Vehicle counts represented the midpoint of 2-hour time intervals with the exceptions of the 6:30 a.m. and 8:30 p.m. counts. Time intervals represented by these 2 counts were determined by the earliest car on the stream and the last car leaving the stream, respectively, during each month. The mean number of anglers per vehicle was based only on interviews with anglers who had driven to the stream.

On each survey day, a creel clerk interviewed anglers to gather information on the number of anglers in the angling party, angler residence, the length of time fished, fishing methods, and their catch. Most anglers were interviewed as they returned to their cars at the end of their fishing trip. All creeled trout were measured to the nearest 0.1 inch and examined for finclips to determine their origins.

In addition to angler interviews, 9 unattended creel survey stations were established at prominent access points along the Waupaca River (Fig. 1). Pencils and specially designed creel survey cards were provided at each of these sites, along with a map of the study area and an explanation of the purpose of the requested information. Fishing diaries were also distributed to riparian homeowners, if a member(s) of the household anticipated fishing the river. Completed creel cards and diaries could be left in a drop box at any of the 9 survey stations or mailed to a DNR address provided on each form. Avery (1981,1983,1990) describes the formulae and specific protocols for estimating fishing pressure and trout harvest.

Results

Brown trout and brook trout were captured during spring and fall electrofishing surveys on the Waupaca River in 1993-1995. Brown trout, brook trout, and rainbow trout (*Onchorynchus mykiss*) were captured during spring and fall electrofishing surveys on the West Fork Kickapoo River in 1994-1996. Brown trout comprised from 96% to 98% of the trout present in both streams and are the only species to which this report refers.

Waupaca River

Trout populations, including both stocked and naturally reproduced fish, ranged from 1,009/mile to 1,331/mile in the Waupaca River during the study period (Table 2). Total biomass ranged from 21 lb/acre to 31 lb/acre. Legal-size brown trout (i.e. $\geq$12 inches) comprised 5% to 8% of the populations present with densities ranging from 60/mile to 78/mile.

Survival of Stocked Cohorts. Survival of the initial cohort of W trout stocked in the Waupaca River was 2.5-3.5 times greater than that of OD and D trout during their first year and was 4-8 times greater by the end of their second year (Fig. 3). After 1 year, survival of W, OD, and D trout was 34%, 13%, and 10%, respectively. Densities ranged from 60/mile to 195/mile, and the W trout population was significantly greater than either population of domestic trout (Table 3). After nearly 2 years in the river, survival of W, OD, and D trout was 8%, 2%, and 1%, respectively. Densities ranged from 6/mile to 45/mile, and the W trout population remained significantly greater than either cohort of domestic trout (Table 4). Substantial differences in survival between OD and D trout were not evident during the 2 years even though numbers of OD trout were higher than and significantly different from the population of D trout during the final population survey. Adjusting survival percentages to include estimated angler harvest of W, OD, and D trout during the 1995 fishing season (Table 6) yielded 2-year survival estimates of 8%, 3%, and 4%, respectively. Even so, these inflated

Table 2. *Brown trout populations in the Waupaca River during spring and fall, 1993-1995 (P.E.=population estimate).*

Inch	September 1993		May 1994		October 1994		April 1995		September 1995	
Group	P.E.	Wt. (lb)	P.E.	Wt. (lb)	P.E.	Wt. (lb)	P.E.	Wt. (lb)	P.E.	Wt. (lb)
2			2	<1	2	<1			19	<1
3	171	3	434	8	174	3	280	4	398	6
4	1,050	30	491	20	657	20	420	11	525	14
5	409	22	474	27	448	25	266	13	133	7
6	56	5	232	17	298	27	237	22	182	15
7	107	15	200	29	457	63	284	42	265	35
8	186	39	226	52	475	98	241	51	288	59
9	160	44	144	44	308	88	256	76	325	89
10	137	52	103	44	210	81	211	83	259	97
11	82	42	93	53	126	64	117	61	174	89
12	58	39	70	52	67	46	91	62	73	50
13	26	22	31	30	27	22	46	42	30	24
14	19	21	27	31	12	14	29	31	20	21
15	13	18	12	16	15	20	9	12	16	23
16	12	20	9	14	11	19	8	12	8	11
17	13	25	5	11	8	16	5	8	3	5
18+	9	21	8	20	4	12	4	10	6	14
Total	2,506	418	2,561	469	3,299	618	2,503	540	2,724	559
95% C.I.	±269		±324		±243		±261		±304	
No./mile	1,010		1,033		1,331		1,009		1,098	
Lb/acre		21		24		31		21		28

Figure 3. *Survival of wild, optimum domestic, and domestic brown trout stocked in the Waupaca River in October, 1993 and 1994.*

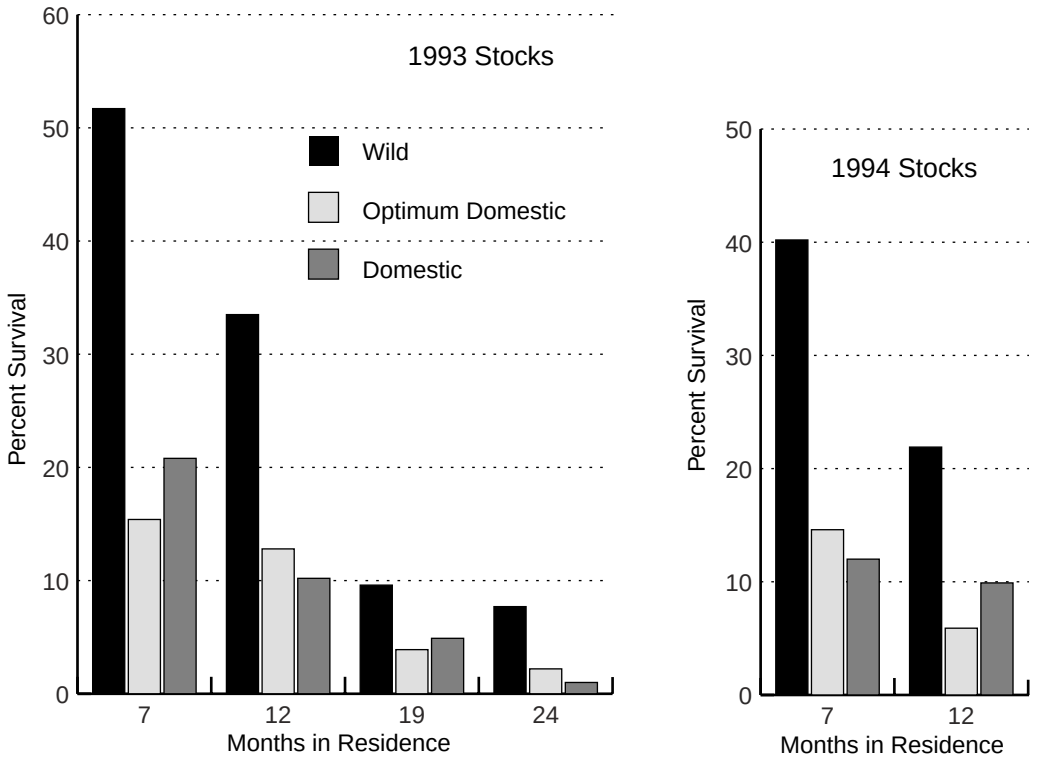


Table 3. *Brown trout populations stocked in fall 1993 and remaining in the Waupaca River during spring and fall 1994 (W = wild, OD = optimum domestic, D = domestic).*

Inch Group	May			October		
	W	OD	D	W	OD	D
2	2					
3	422	3				
4	276	32		2		
5	37	105		34		
6	7	70	3	198	10	
7	2	14	105	183	49	
8			159	60	77	3
9			35	6	43	27
10					6	66
11						36
12						15
13						1
14						
15						
16						
17						
18+						
Total	746	224	302	483	185	148
95% C.I.	±185	±68	±178	±80	±53	±33
No./mile	301	90	122	195	75	60

Table 4. *Brown trout populations stocked in fall 1993 and remaining in the Waupaca River during spring and fall 1995 (W = wild, OD = optimum domestic, D = domestic).*

Inch Group	April			September		
	W	OD	D	W	OD	D
2						
3						
4						
5	4					
6	7	2				
7	37	2		5		
8	53	10		14	3	
9	28	26	2	29	7	
10	11	11	6	37	11	
11		7	22	21	9	
12			28	5	3	5
13			9			4
14			4			5
15						
16						1
17						
18+						
Total	140	58	71	111	33	15
95% C.I.	±54	±30	±19	±22	±11	±3
No./mile	56	23	29	45	13	6

estimates[2] do not substantially alter survival comparisons between the 3 cohorts of trout.

Survival of the second cohort of W trout released in the Waupaca River was 2.2-3.7 times greater than the survival of the corresponding cohorts of OD and D trout during their first year in residence (Fig. 3). Initial overwinter survival of W, OD, and D trout was 40%, 15%, and 12%, and survival after 1 year was 22%, 6%, and 10%, respectively. Densities ranged from 35/mile to 129/mile and the W trout population was significantly greater than either population of domestic trout (Table 5). No significant difference in survival between OD and D trout was evident.

Growth of Stocked Cohorts. Earlier spawning of OD and D trout resulted in fish that were 1.3 months and 3 months older, respectively, than W trout when the initial cohorts of age 0 trout were stocked (Table 1). Average sizes of the W, OD, and D trout when stocked were 3.1 inches, 4.7 inches, and 6.8 inches, respectively. One-year later, average growth of individual cohorts of trout was not substantially different and ranged from 3.7 inches for OD trout to 3.9 inches for W trout (Fig. 4). In April 1995, after 19 months, average growth

[2] Estimates are inflated because all trout harvested would not have survived the summer had they not been harvested.

Table 5. *Brown trout populations stocked in fall 1994 and remaining in the Waupaca River during spring and fall 1995 (W = wild, OD = optimum domestic, D = domestic).*

Inch Group	April			September		
	W	OD	D	W	OD	D
3	266					
4	295	2				
5	24	31	3	57		
6	2	79	32	143		3
7		97	99	95	5	5
8		6	41	24	23	28
9				2	46	64
10					9	38
11					3	8
12						
13						
14						
15						
16						
17						
18+						
Total	587	215	175	321	86	146
95% C.I.	±178	±85	±50	±70	±26	±34
No./mile	237	87	71	129	35	59

of W and D trout remained similar at 5.2 inches and 5.3 inches, respectively. Growth of both cohorts was noticeably better than a corresponding growth of 4.9 inches for OD trout. Average size of the W, OD, and D trout was 8.3 inches, 9.6 inches, and 12.1 inches, respectively. Only the D trout averaged larger than the minimum legal size of 12 inches and presented a substantial opportunity for angler harvest when the 1995 trout fishing season opened in early May. By late September 1995, after 2 years in the river, average growth of W and D trout was 7 inches and 6.8 inches, respectively. The somewhat slower growth of D trout may, however, be an anomaly caused by the angler harvest of larger, faster growing individuals during the 1995 fishing season. Nevertheless, growth of W and D cohorts remained substantially better than an average growth of 5.8 inches for OD trout. Average lengths of the 2-year-old W, OD, and D trout were 10.1 inches, 10.5 inches, and 13.6 inches, respectively.

Average lengths of W, OD, and D trout stocked in October 1994 were 3.5 inches, 5.9 inches, and 6.6 inches, respectively (Table 1). Earlier spawning of OD trout and D trout again resulted in fish that were 1.2 months and 3 months older, respectively, than W trout. Approximately 1 year later, in September 1995, average growth for both W and OD trout was 3.3 inches, substantially better than a corresponding growth of 2.9 inches for D trout (Fig. 4). Average lengths of the yearling W, OD, and D trout were 6.8 inches, 9.2 inches, and 9.5 inches, respectively.

The Sport Fishery. Anglers fished 11,032 hours (120 hours/acre) and harvested 728 trout (63/mile) from the 11.5-mile study reach of the Waupaca River in 1995 (Table 6). Average length of creeled trout was 13.3 inches. Trout stocked in the fall of 1993 and 1994 comprised 31% of the harvest; trout of unknown origins (unmarked) comprised the remaining 69%. Of the W, OD, and D trout stocked in the fall of 1993, anglers creeled 1/mile, 2/mile, and 15/mile, respectively. Anglers also creeled 1/mile of the OD trout stocked in the fall 1994.

Of 68 creeled trout measured, 12% were sublegal, averaging only 11.6 inches (range 11.5-11.7 inches). Average size of 15 D trout measured was 13 inches and 80% of the sample was creeled on opening weekend. Average size of 4 OD trout measured was 11.6 inches, and 3 of the fish were sublegal. Other sublegal trout included one D trout stocked in 1993 and 4 fish of unknown origin.

Figure 4. *Accumulative growth of wild, optimum domestic, and domestic brown trout stocked in the Waupaca River in October, 1993 and 1994.*

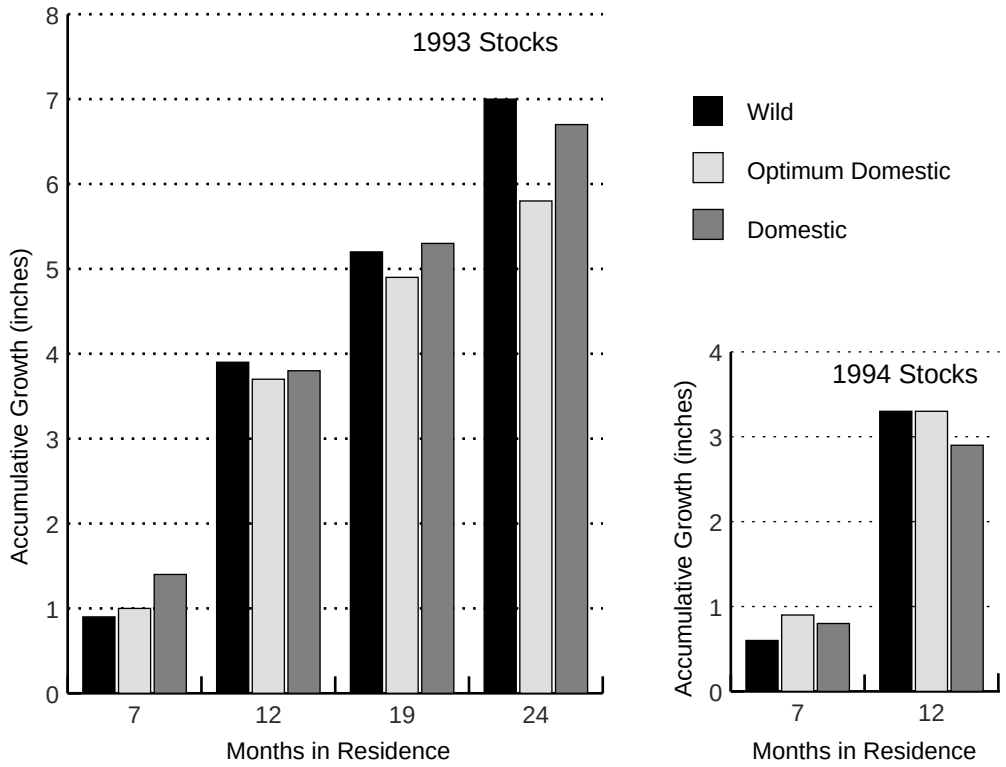


Table 6. *Estimated fishing pressure and brown trout harvest in the Waupaca River, 1995.*

Creel Survey Periods	Hours Fished	No. Mks.	Harvest[1] D	OD	W	od	Total
May							
Opening Weekend	2,848	206	99	8	0	0	313
Weekend/holidays	1,439	67	28	0	6	0	101
Weekdays	1,687	76	17	17	8	0	118
Subtotal	5,974	349	144	25	14	0	532
June							
Weekend/holidays	991	40	0	0	0	0	40
Weekdays	686	14	0	0	0	0	14
Subtotal	1,677	54	0	0	0	0	54
July							
Weekend/holidays	718	22	0	0	0	0	22
Weekdays	720	0	29	0	0	0	29
Subtotal	1,438	22	29	0	0	0	51
August							
Weekend/holidays	274	8	0	0	0	0	8
Weekdays	570	6	0	0	0	0	6
Subtotal	844	14	0	0	0	0	14
September							
Weekend/holidays	559	28	0	0	0	0	28
Weekdays	540	33	0	0	0	16	49
Subtotal	1,099	61	0	0	0	16	77
Total	11,032	500	173	25	14	16	728
No./mile		44	15	2	1	1	63
Hrs./acre	120						

[1] D = domestic trout, OD = optimum domestic trout, W = wild trout. Upper case stocked in October 1993; lower case stocked in October 1994.

West Fork Kickapoo River

Stocked and naturally reproduced trout populations in the West Fork Kickapoo River ranged from 1,229/mile to 2,189/mile during the study period (Table 7). Total biomass ranged from 157 lb/acre to 292 lb/acre. Quality size trout (i.e. ≥15 inches) comprised from 1% to 5% of the populations. Even though only catch-and-release angling was allowed, density of quality-size trout declined progressively from 108/mile in October 1994 to 14/mile in April 1996. The reason for the decline was not clear.

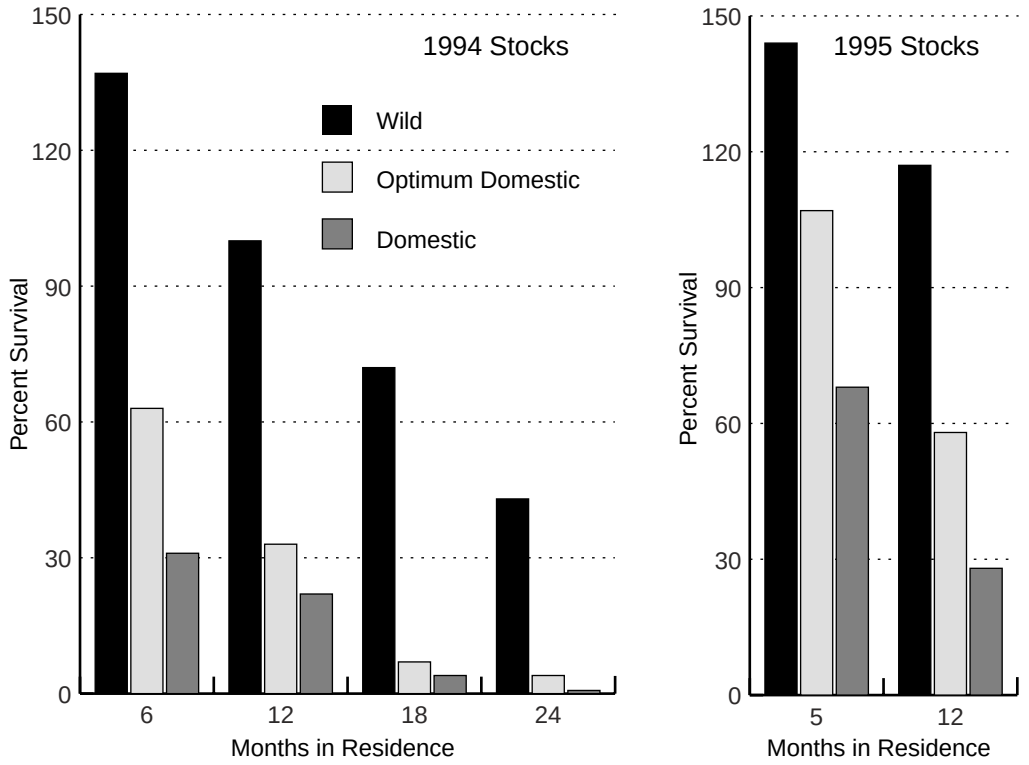
Survival of Stocked Cohorts. Survival of the initial cohort of W trout stocked in the West Fork Kickapoo River was 2.2-4.5 times greater than that of OD and D trout during their first year and was 10.8-42 times greater by the end of their second year (Fig. 5)[3].

[3] Within cohorts, equal numbers of trout were released at 6 stream sites and were expected to distribute themselves throughout the entire 7.5-mile study area. Initial stocking density for each cohort was, therefore, equivalent to the number of trout stocked divided by 7.5 miles. Better than average habitat in 6 stream segments selected to monitor trout populations (a total of 1.7 miles) resulted in proportionately greater numbers of trout taking up residence in these stream segments. Subsequent densities of some cohorts of stocked trout in the 1.7-mile stream reach sampled therefore equaled or exceeded initial stocking densities computed on the 7.5-mile study area as a whole. As a consequence, density (vis-à-vis survival) of some cohorts equaled or exceeded 100% as much as 1 year following their initial release. Since all three cohorts of trout had equal opportunity to use the available habitat in the river, comparisons of survival rates between cohorts remain valid.

Table 7. *Brown trout populations in the West Fork Kickapoo River during fall and spring, 1994-1996 (P.E. = population estimate).*

Inch Group	October 1994		April 1995		October 1995		April 1996	
	P.E.	Wt. (lb)	P.E.	Wt. (lb)	P.E.	Wt. (lb)	P.E.	Wt. (lb)
3	4	<1	4	<1	14	<1		
4	125	5	31	1	58	2	30	1
5	282	18	127	7	66	4	66	4
6	102	10	99	10	53	5	42	4
7	302	47	168	26	197	28	76	11
8	663	138	337	75	462	94	205	46
9	425	122	516	155	776	220	414	127
10	359	141	388	154	809	308	566	230
11	496	262	287	154	348	174	367	194
12	388	254	262	179	215	139	168	111
13	268	226	147	122	167	137	97	80
14	124	124	71	71	84	84	36	37
15	105	130	36	44	24	27	12	14
16	31	49	14	20	13	18	6	8
17	10	18	9	16	9	15	2	4
18+	34	91	12	32	12	32	3	9
Total	3,721	1,635	2,508	1,066	3,307	1,287	2,090	880
95% C.I.	±318		±222		±120		±108	
No./mile	2,189		1,475		1,945		1,229	
Lb/acre		292		190		230		157

Figure 5. *Survival of wild, optimum domestic, and domestic brown trout stocked in the West Fork Kickapoo River in April 1994 and May 1995.*



Survival of W, OD, and D trout after 1 year was 100%, 33%, and 22%, respectively. Individual populations ranged from 76/mile to 302/mile and the W trout population was significantly greater than either population of domestic trout (Table 8). In April 1996, after 2 years in the river, survival of W trout was 43% compared to 4% for OD trout and <1% for D trout. Population densities of individual cohorts ranged from 1/mile to 129/mile and the W trout population remained significantly greater than either cohort of domestic trout (Table 9). Survival of OD trout was 1.5-4 times better than the survival of D trout during their 2 years in the river, even though survival of both cohorts was far below that of the W trout. Populations of OD trout exceeded populations of D trout during all sampling periods and were significantly greater in two sampling periods even though a greater number of D trout were initially stocked.

Survival of the second cohort of W trout released in the West Fork Kickapoo River was 1.3-4.2 times greater than that of OD trout and D trout during their first year (Fig. 5). After 1 year, survival of W, OD, and D trout was 117%, 58%, and 28%, respectively. Population densities ranged from 97/mile to 289/mile, and the W trout population was significantly greater than either population of domestic trout (Table 10). Survival of OD trout was 1.6-2.1 times greater than that of D trout. Although almost twice the number of D trout as OD trout were initially stocked, OD trout outnumbered D trout at the end of 1 year.

Growth of Stocked Cohorts. Earlier spawning of hatchery trout resulted in both D trout and OD trout being one month older than W trout when the 3 cohorts were stocked in April 1994 (Table 1). Average lengths of W, OD, and D trout when stocked were 6 inches, 10.3 inches, and 9.9 inches, respectively. One year later, in April 1995, an average growth of 3.2 inches for W trout was substantially greater than the corresponding growth of 1.6 inches and 1.7 inches for OD trout and D trout, respectively (Fig. 6). By October 1995, growth of both W trout and D trout was markedly greater than the corresponding growth of OD trout. An average growth of 4 inches for W trout, however, was much greater than the corresponding growth of 2.9 inches for D trout and 1.9 inches for OD trout. Average size of W, OD, and D trout was 10 inches, 12.2 inches, and 12.8 inches, respectively. In April 1996, 2 years after their initial release, W trout maintained their growth advantage over OD trout. Average growth of W and OD trout was 4.5 inches and 2.4 inches, respectively. Only 2 D trout were captured thus negating corollary growth comparisons. Average size of W, OD, and D trout was 10.5 inches, 12.7 inches, and 14.9 inches (n=2), respectively.

Average lengths of W, OD, and D trout stocked in May 1995 were 6.8 inches, 8.6 inches, and 9.3 inches, respectively (Table 1). Roughly one year later, in April 1996, an average growth 2.1 inches for W trout was substantially better than a corresponding growth of 1.5 inches for D trout and moderately better than 1.8 inches of growth for OD trout (Figure 6). More rapid growth of the smaller W and OD trout noticeably reduced the size difference between the 3 cohorts of trout. Average length of W, OD, and D trout in April 1996 were 9 inches, 10.4 inches, and 10.8 inches, respectively.

Table 8. *Brown trout populations stocked in spring 1994 and remaining in the West Fork Kickapoo River in fall 1994 and spring 1995 (W = wild, OD = optimum domestic, D = domestic).*

Inch Group	October 1994			April 1995		
	W	OD	D	W	OD	D
3						
4						
5	1					
6	31					
7	151			39		
8	303	2		144	1	
9	174	14	5	236	5	1
10	38	39	72	85	12	24
11	5	158	84	9	58	58
12	2	85	20	1	67	41
13		10	3		18	5
14			1			1
15			1			
16						
17						
18+						
Total	705	308	186	514	161	130
95% C.I.	±65	±45	±35	±69	±35	±30
No./mile	415	181	109	302	95	76

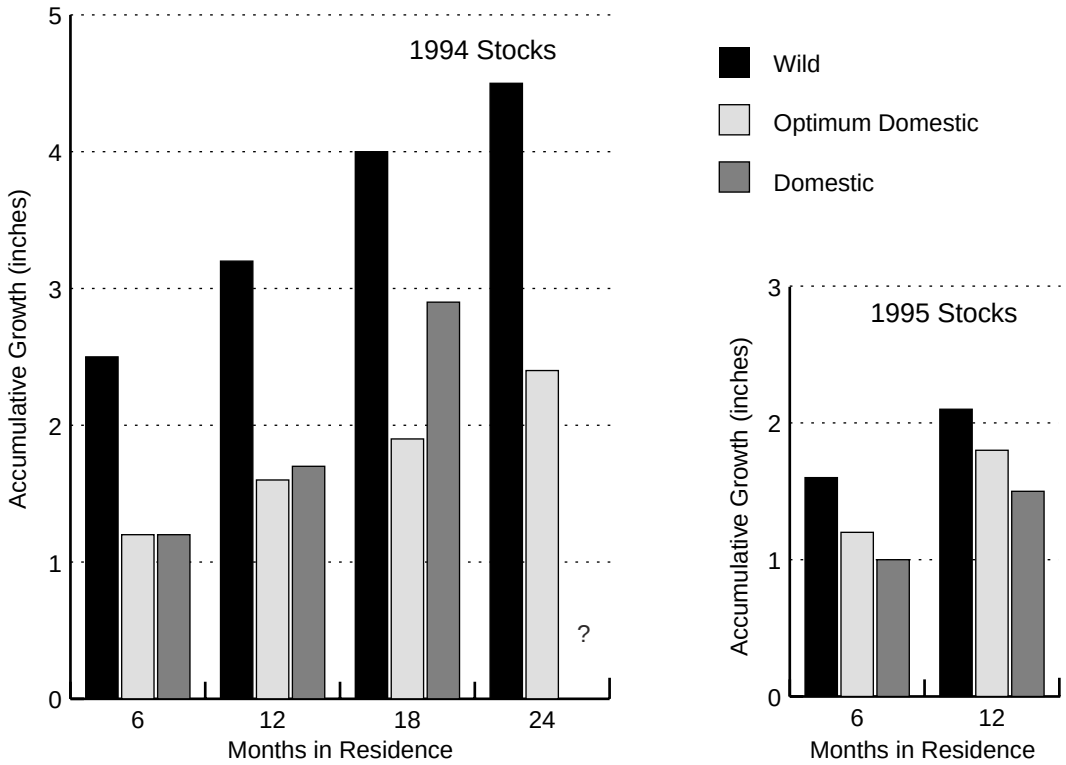
Table 9. *Brown trout populations stocked in spring 1994 and remaining in the West Fork Kickapoo River in fall 1995 and spring 1996 (W = wild, OD = optimum domestic, D = domestic).*

Inch Group	October 1995			April 1996		
	W	OD	D	W	OD	D
7	7					
8	33			9		
9	133			56		
10	138	2		95	1	
11	44	10		43	2	
12	14	14	16	16	8	
13	1	7	2	1	6	
14			3		2	1
15						1
16						
17						
18+						
Total	370	33	21	220	19	2
95% C.I.	±27	±7	±6	±24	±7	±0
No./mile	218	19	12	129	11	1

Table 10. *Brown trout populations stocked in spring 1995 and remaining in the West Fork Kickapoo River in fall 1995 and spring 1996 (W = wild, OD = optimum domestic, D = domestic).*

Inch Group	October 1995			April 1996		
	W	OD	D	W	OD	D
5	2					
6	33			8		
7	145	2	3	49		1
8	247	26	9	159	6	1
9	148	167	92	194	37	14
10	21	124	223	66	102	71
11	7	15	74	15	34	64
12		2			5	14
13						
14						
15						
16						
17						
18+						
Total	603	336	402	491	184	165
95% C.I.	±44	±39	±37	±54	±21	±18
No./mile	355	198	236	289	108	97

Figure 6. *Accumulative growth of wild, optimum domestic, and domestic brown trout stocked in the West Fork Kickapoo River in April 1994 and May 1995.*



Discussion

Despite having a much smaller average body size when stocked, wild-strain brown trout dramatically outperformed domestic-strain brown trout stocked concurrently in the Waupaca River and West Fork Kickapoo River during the ensuing 2 years. Survival of wild strains was consistently and substantially higher than domestic strains whether stocked as fall fingerlings or spring yearlings. Growth of wild fall fingerlings was similar to that of domestic fall fingerlings in the moderately fertile Waupaca River and the size advantage of the domestic strain at planting was maintained over the 2 years. Growth of wild spring yearlings in the fertile West Fork Kickapoo River exceeded the growth of domestic spring yearlings and noticeably reduced the initial size advantage of the domestic strain over 2 years.

Our results generally complement previous published studies. Alexander (1985) captured wild fingerling brown trout from 4 different Michigan streams and stocked 3 of these wild strains along with a domestic strain into 4 Michigan lakes. Two-year survival rates for wild trout strains were approximately twice those of the domestic trout strain and growth of 3 of the 4 wild strains was significantly better than the domestic strain. Avery (1974) took wild fingerling brown trout from one Wisconsin stream and stocked them in another stream along with fingerling domestic trout. Survival of wild trout was almost 3 times that of the domestic trout after 11 months and 26 times that of the domestic trout at the end of 2 years. Growth of the domestic trout exceeded that of the wild trout, however. Field performance of half-wild brown trout and domestic brown trout, hatched and reared in the hatchery, were compared by Bugas and Mohn (1992) and Borowa (1988). Survival and growth of half-wild trout was significantly better than domestic trout in both studies. In contrast to the above studies, Berg and Jorgensen (1991) found no significant difference in survival of a wild and a domestic strain of brown trout hatched and reared in the hatchery and planted together in a small Danish stream.

A unique aspect of our study, when compared to previous stocking evaluations, was the season-long creel survey on the Waupaca River during 1995. The resulting harvest information quantifies a "mortality" factor missing in other studies and provides insights into the comparative recreational fishing opportunities and/or returns to the angler provided by wild and domestic trout strains. Although domestic trout provided a greater return to the angler during their second summer in the Waupaca River (because few wild trout had reached the 12-inch minimum size), the significantly higher survival of wild trout provided an opportunity for similar if not greater overall return to the angler in succeeding fishing seasons. In addition, the higher survival of wild trout to reproductive maturity (third fall) provided greater potential for natural reproduction and the establishment of a self-sustaining population than that presented by the few surviving domestic trout.

An important contribution of our study and the second "reason" why the study was carried out was to determine if improving the rearing environment in the hatchery would significantly enhance field performance of domestic brown trout strains. Significant differences in the field performance of domestic trout reared under "optimum" and "standard" hatchery protocols did not occur in the Waupaca River but did occur in the West Fork Kickapoo River. Accordingly, reducing rearing densities and minimizing human contact for domestic brown trout in cooperative trout rearing facilities such as those used for fish stocked in the West Fork Kickapoo River could result in better long-term trout survival and similar trout growth following stocking. Even so, significantly greater improvement in field performance would result from rearing wild trout strains at such cooperative trout rearing facilities. We therefore conclude that improving the rearing environment for domestic trout strains in Wisconsin hatcheries and cooperative trout rearing facilities does not warrant the extra effort.

We believe this study, in conjunction with numerous other corroborating studies, addresses and removes the final obstacles to rearing wild trout strains as part of Wisconsin's trout propagation program. Wild trout strains will clearly outperform domestic trout strains when the objectives of stocking are to provide sustained recreational fisheries with significant carryover of adult fish and/or to develop self-sustaining trout populations. Many "put-grow-and-take" fisheries could also benefit from the better field performance of wild trout strains.

Management Applications

Results of this study have been presented at numerous meetings with FH staff, fisheries managers, and hatchery supervisors. As a result, Wisconsin now has a growing wild trout rearing and stocking program that in 2000 produced approximately 414,000 wild-strain brown trout and 86,000 wild-strain brook trout (pers. comm. Al Kaas, DNR Fish Propagation Specialist)

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