Comparison of Survival, Emigration, Habitat Use, Marking Mortality, and Growth between Two Strains of Brook Trout in Adirondack Ponds

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Abstract.—Performances of age-0 Assinica and Temiscamie strain brook trout Salvelinus fontinalis were compared in 1985 and 1986, 2–3 months after the fish had been stocked into two drainable ponds located in the Adirondack Mountains of New York. Overall recovery did not differ significantly between strains in three trials when both pond and inlet habitats were considered. Assinica fish emigrated at higher rates in all three trials than Temiscamie fish. In both 1986 trials, approximately 50% of the recovered Assinica brook trout were in the inlet stream, but less than 25% of the recovered Temiscamie brook trout had emigrated upstream. These differences in emigration may indicate habitat preferences of these strains or density-dependent displacement. The Temiscamie strain had higher marking mortality than the Assinica strain; thus, the Assinica strain appeared to be more resistant to the stress of handling. Temiscamie brook trout had significantly higher instantaneous growth rates after stocking than the Assinica strain. The Temiscamie strain, with faster growth and less emigration, may be best suited for population restoration, or "put-grow-and-take" fisheries. In contrast, the Assinica strain, being resistant to handling stress, may be better suited for catch-and-release fisheries, aquaculture, or put-and-take fisheries.

Differences in survival or angler harvest among salmonid strains after stocking have been demonstrated for several species. It has been suggested that such variable performance is due to differences in habitat use, the domestication of strains, and isozyme function (e.g., Vincent 1960; Trojnar and Behnke 1974; Reisenbichler and McIntyre 1977; Tsuyuki and Williscroft 1977). The recognition of intraspecific variation has led to the development of strain-specific management programs for salmonids (e.g., Keller 1979; Krueger et al. 1983).

Several studies of brook trout Salvelinus fontinalis have demonstrated the superiority of wild strains over domesticated strains (e.g., Greene 1952; Flick and Webster 1976; Gowing 1978; Webster and Flick 1981). Webster and Flick (1981) reported that oversummer survival of age-0 wild strain brook trout was superior to that of domesticated strains. Their study also indicated that hybrids between wild and domesticated strains had survival rates similar to or greater than the wild parents.

Differential survival among wild brook trout strains was reported by Webster and Flick (1981). They found that age-0 Temiscamie strain brook trout tended to have higher oversummer survival rates than the Assinica strain. Age-0 Temiscamie brook trout stocked in spring had oversummer survival rates of 56, 52, and 57% in various tests, whereas the Assinica strain had survival rates of 21, 21, 29, 50, and 36%. The last two estimates for the Assinica strain were obtained from trials with paired plants of both strains. The superior performance of the Temiscamie strain was attributed to probable differences in behavior, physiology, or responses to environmental factors (Webster and Flick 1981).

This paper compares the survival, emigration, habitat use, marking mortality, and growth between age-0 Assinica and Temiscamie brook trout stocked into small ponds in June. This report represents part of a larger study originally designed to identify critical periods of poststocking mortality for each strain through the use of multiple mark-recapture population estimation procedures (see Cone et al. 1988, this issue). An examination of the timing of mortality and of other factors discussed here was undertaken as a first step in determining the processes that cause the differential performance of these wild strains reported by Webster and Flick (1981).

Study Sites

This study was conducted in one pond in 1985 and two ponds in 1986. A small (0.25-hectare) reservoir (hereafter called the Reservoir) in Bay Pond Park, the northern Adirondack Mountains...
of New York State (South Branch of the St. Regis River drainage; 74°25'W, 44°25'N) was used both summers. This pond was bordered by alder Alnus sp. and maple Acer sp., had stands of Elodea canadensis in the shallow, inlet end (absent in 1986), and had an average depth of 1.0 m. The water flowing into the pond was thermally stable at 10°C and entered a shaded area (4 m x 2 m x 30 cm deep) where all fish processing took place. No flowing water was available below a barrier at the upper end of the Reservoir. The spring-fed stream was shaded between this inlet area and the headwaters. Other than the inlet area, the pond uniformly sloped to the deepest area by the dam. The upper half of the pond averaged 0.8 m in depth; the deeper end averaged 1.5 m, and its maximum depth was 2.1 m.

The second pond (used only in 1986) was Laramie, a small drainable pond (0.19 hectare) in the watershed adjacent to the Reservoir (Middle Branch of the St. Regis River; 74°25'W, 44°30'N). Laramie Pond was bordered by grasses and Sphagnum sp., had a bloom of Spirogyra in June, and had an average depth of 0.6 m. This pond had an inlet where water flowed for 30 m between an upstream barrier and the ponded waters. The inlet stream was shaded above the barrier by dense stands of alder, but flowed through an open meadow between the barrier and the pond. The inlet water remained cool and averaged 10°C. Processing of captured fish occurred in the flowing spring waters of this inlet. Laramie Pond was the same site as used by Webster and Flick (1981).

The Reservoir became thermally stratified in both summers, but the shallower Laramie Pond did not. Surface temperature averaged 15°C (range, 11--23°C) in the Reservoir and 12°C (9-15°C) in Laramie Pond. Dissolved oxygen averaged 8 mg/L in both ponds and was below 6 mg/L only in the deepest 0.5 m of the Reservoir. Temperatures exceeded 20°C only in the top 1.0 m of the Reservoir in 1985 and in the top 0.3 m in 1986.

Both ponds were poisoned with Rotenone prior to stocking. The ponds were drained and then the entire inlets were sprayed with Rotenone to achieve a concentration of 2 mg/L. All fish were removed from the Reservoir in 1985 and from Laramie Pond in 1986 by this procedure. Only the pond area of the Reservoir was poisoned in 1986, because we assumed that no fish were upstream. However, some of the 1985 study fish (which were returned to the Reservoir at the end of the study) emigrated upstream during the winter and returned to the Reservoir during the summer of 1986. Their large size precluded any confusion with the 1986 experimental fish, but their predation on stocked young-of-the-year fish undoubtedly contributed to the high mortality observed during the 1986 Reservoir study.

Methods

Brook trout strains. — Both strains of brook trout used in this study originated from the James Bay-Hudson Bay drainage of northern Quebec (Flick 1977). The Assinica strain was from Assinica Lake, on the Broadback River system, and originated from gametes collected from 6-10 individuals in 1962. The Temiscamie strain was from the Temiscamie River, a tributary of the Rupert River system, and originated from gametes collected from 20 to 30 individuals in 1967 (W. A. Flick, personal communication). Brood stocks of both strains have been maintained in Adirondack lakes since these original gamete collections.

Stocking. — The brook trout stocked into the Reservoir and Laramie Pond were progeny of brood stocks held in a nearby lake. Fertilized eggs and fry were reared at the Brandon Park Hatchery (Paul Smiths, New York). Paired lots of each strain were kept at equal densities in the hatchery and marked 2-3 d prior to stocking with left and right pelvic fin clips. Individual length and weight measurements were taken on samples of each strain 1 d prior to stocking. Due to an accident in the hatchery in 1986, the original lot of Assinica strain died and Assinica strain brook trout held at lower densities than the Temiscamie strain were substituted for the paired plants. The two strains were mixed in the transport tank and stocked by buckets into the study ponds in a single trip from the hatchery. Approximately 2,000 age-0 fish of each strain were stocked both years into the Reservoir. Laramie Pond was stocked with approximately 1,500 age-0 fish per strain in 1986 (Table 1).

Least-squares weight--length regressions (log_10 W = A + B log_10 L; W is individual fish weight in grams, L is total length in centimeters, A and B are constants) were calculated for each strain at stocking and for the pooled data of both strains. Regression slope (B) values were compared between strains by an F-statistic that tests the significance of the variance added by pooling the data (Snedecor and Cochran 1980).

Sampling. — Stocked brook trout were sampled on five occasions to calculate four population estimates within each trial. Sampling was done primarily with a 15.0-m x 1.5-m seine with 0.5-cm stretch mesh. In 1985, seining of the Reservoir
was limited to the shallow end in depths less than 1 m. In 1986, seining of the Reservoir was expanded to include portions of the deep end. Approximately 30 and 40% of the Reservoir area was sampled by seining in 1985 and 1986, respectively. Clear plastic, unbaited minnow traps with one end open were used in the deep portions of the Reservoir to obtain additional samples. Twenty traps were used in 1985 and 40 traps were used in 1986. Laramie Pond was seined on each occasion in a single haul that covered approximately 75% of the pond. The 30 m of Laramie Pond’s inlet below the barrier was sampled with a gas-powered DC backpack shocker.

Trout captured by seines or traps were held in 0.5-cm-stretch mesh holding bags (1 m × 0.5 m) in the spring-fed inlets of each pond. Approximately 20 individuals at a time were anesthetized with tricaine (MS-222), identified to strain by fin clip, examined for previous marks, measured for length and weight, and given marks specific to that sampling period and capture location. Marking was primarily by freeze-branding with liquid nitrogen. To avoid confusion with the oval parr marks, triangular freeze brands were placed on the ventral portion of the sides. For the final sampling period, however, caudal fin clips (applied to the outer edge of the upper or lower lobe) were used for marking. Fish sampled from the deep end of the Reservoir in 1986 were given marks distinct from those sampled in the shallow end. In Laramie Pond, fish sampled in the inlet stream below the barrier were given marks that were distinct from those applied to fish sampled in the pond. Trout were released in the same end of the pond in which they were captured. The last 20 fish of each strain to be processed during the first sampling period in the Reservoir in 1986 were held in a cage (1 m × 1.5 m in 0.5 m of water) for the duration of the 1986 study to evaluate handling mortality. Even though all fish were initially given a pelvic fin clip, fish that were caught and marked (by freeze brands or caudal clips) during the mark–recapture sampling are referred to as marked fish in this paper and all other fish are termed unmarked.

Emigration and immigration were controlled and measured during these studies. Immigration from upstream was prevented by poisoning of the ponds and inlet streams prior to stocking. Immigration from downstream was prevented by the dams that formed both ponds. Emigration was controlled by upstream barriers and downstream inclined screen traps (modified Wolf trap; Wolf 1951). Downstream emigrants were tabulated by strain and released downstream. We believe the outlet traps were completely effective at the Reservoir in 1985 and at Laramie Pond in 1986. In 1986, the outlet trap at the Reservoir was ineffective during two periods of high discharge, both of which lasted approximately 1 week. Upstream emigration was blocked by a beaver dam on the Reservoir inlet and by a screen box over a culvert pipe in Laramie inlet. Emigration above the inlet barriers was evaluated by electroshocking.

The ponds were drained immediately after the last sample to obtain a final census of the population size of each strain. Screen boxes were placed under the drains to capture fish, and electroshocking was used to catch fish that remained in residual pools. In 1986, electroshocking was used to obtain numerical estimates of the brook trout that had emigrated upstream above the inlet stream barriers of both ponds. Each inlet was electrofished on three separate days immediately before ponds were drained and all fish captured were removed.

**Statistical procedures.** —The three-sample Zipf removal method was used for estimation of the numbers of each strain in the inlets above the barriers of both ponds (Seber 1982). A goodness-of-fit test was applied to the data to test for equal capture probability among samples (Seber 1982).

Most statistical comparisons between strains involved contingency table comparison of proportions (Snedecor and Cochran 1980). We used t-tests to compare mean lengths and weights between and within strains (Snedecor and Cochran 1980). Null hypotheses were rejected if $P \leq 0.05$.

Instantaneous growth ($G$) was calculated from weight measurements of each strain at stocking and draining. Instantaneous growth was estimated by:

$$G = \log e \bar{w}_{t+1} - \log e \bar{w}_t;$$

(1)

$\bar{w}$ is the average weight of the group (strain) at time $t$ (Ricker 1975; Newman and Martin 1983). We chose to estimate the variance of $G$ by an approximation of the variance of the natural logarithm of a mean (the delta method; see Seber 1982). An approximation of such a variance from a Taylor series expansion is

$$\hat{V}(\log e \bar{w}_t) = \frac{V(w_t)}{\bar{w}_t^2}.$$  

(2)

The estimate of the variance of $G$ is

$$\hat{V}(G) = \hat{V}(\log e \bar{w}_t) + \hat{V}(\log e \bar{w}_{t+1}).$$

(3)

Comparisons between strains for values of $G$ can then be made with a Z or normal test, in the form of:
Results

Survival

No significant differences in the estimated total survival (recovery) between strains occurred in any of the three trials (Table 1). Total survival was estimated by the sum of the number recovered in the pond and the number estimated to have been in the inlet stream. The two-sample removal estimate was used instead of the three-sample estimate for both strains in Laramie inlet because the goodness-of-fit test rejected the assumption of equal capture probability for the Temiscamie strain. A heavy rain the night before the final sample increased discharge and the depth of Laramie Pond's inlet, and presumably decreased electrofishing efficiency during the third removal period.

Emigration and Habitat Use

Differential emigration consistently resulted in proportionally more Assinica than Temiscamie brook trout in the inlets and proportionally more Temiscamie than Assinica brook trout in the ponds in 1986 (Table 1; no upstream emigration occurred in 1985 due to low streamflow). The distributions of Assinica and Temiscamie brook trout between pond and inlet were different in both Laramie Pond ($\chi^2 = 102.3; P < 0.001$) and the Reservoir ($\chi^2 = 39.4; P < 0.001$). At the time of draining, Assinica brook trout were approximately evenly distributed between the Laramie Pond and inlet (25 and 21% of the number stocked, respectively), whereas the number of Temiscamie brook trout in Laramie Pond was 3.5 times the number estimated in the inlet (39 and 11%, respectively). The number of Assinica strain brook trout in the Reservoir in 1986 was 1.6 times the number estimated in the inlet (11 and 7% of the number stocked, respectively), whereas the number of Temiscamie strain brook trout in the Reservoir was over four times the estimated number in the inlet (13 and 3%, respectively).

The Assinica strain had more downstream emigrants than the Temiscamie strain during the 1985 study (Table 2), but not in the 1986 studies. The number of downstream emigrants in the Reservoir in 1985 was 46 Assinica strain and 22 Temiscamie strain brook trout (in a comparison with the numbers of each strain stocked, $\chi^2 = 8.6; P < 0.005$). In 1986, the outlet trap at the Reservoir dam failed twice due to high discharge, and thus a complete count of downstream emigration was impossible. The known emigration from the Reservoir in 1986 was 52 Assinica strain and 71 Temiscamie strain fish and was not significantly different between strains ($\chi^2 = 3.4; P < 0.07$). Three fish of each strain emigrated downstream from Laramie Pond.

Marking Mortality

Recovery of marked Temiscamie brook trout (29%) was less than of unmarked Temiscamie fish in 1985 (49%; $\chi^2 = 77.7; P < 0.001$; Table 2). In contrast, recoveries of marked (39%) and unmarked (44%) Assinica brook trout in the 1985 trial were not significantly different ($\chi^2 = 2.6; P < 0.1$; Table 2). The recovery of marked Temiscamie brook trout (29%) was also less than that of marked Assinica fish (39%; $\chi^2 = 9.8; P < 0.01$). A significant difference was not found in the recovery of unmarked Temiscamie and unmarked Assinica brook trout ($\chi^2 = 2.3; P > 0.1$). A similar tabulation and comparison was not made for the 1986 trials due to the unquantified emigration that occurred.

Temiscamie strain brook trout had significantly higher immediate and delayed postmarking mortality in the holding cage than Assinica strain fish ($\chi^2 = 7.0; P < 0.05$). Five of the twenty Temiscamie strain brook trout placed in the cage did not recover from the anesthetic and nine more died within the next two weeks (70% dead). One Assinica fish of twenty died immediately and five more died within the next 2 weeks (30% dead).

Growth

The instantaneous growth rate ($G$) of the Temiscamie strain after stocking was higher than the Assinica strain in all three trials (Table 3). The pooled comparison for the three trials indicated significant growth differences ($G_T - G_A; Z = 4.7; P < 0.001$). Tests of the individual trials were only statistically different between strains in Laramie Pond ($Z = 3.4; P < 0.001$), though the Temiscamie strain exhibited consistently higher growth rates than the Assinica strain brook trout in all trials. Growth rates of both strains were significantly higher in Laramie Pond than in Laramie inlet (Assinica: $Z = 3.42, P < 0.001$; Temiscamie: $Z = \ldots$)

\[
Z = \frac{G_T - G_A}{\sqrt{V(G_T) + V(G_A)}} ;
\]

$G_T$ is the instantaneous growth rate of the Temiscamie strain and $G_A$ is the growth rate of the Assinica strain.

Values of $G$ (and their standard errors) were divided by the number of days in the study to estimate daily instantaneous growth rate.
COMPARISON OF BROOK TROUT STRAINS

TABLE 1.—Stocking and recovery (after 2–3 months) of age-0 Temiscamie and Assinica strain brook trout in the Reservoir and Laramie Pond, New York. The estimated standard errors of the Zippin population estimates are in parentheses.

<table>
<thead>
<tr>
<th>Pond, date</th>
<th>Strain</th>
<th>Number stocked</th>
<th>Recovery in pond</th>
<th>Estimated recovery in stream</th>
<th>Total recovery (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reservoir, 1985</td>
<td>Temiscamie</td>
<td>1,989</td>
<td>711</td>
<td>0</td>
<td>36</td>
</tr>
<tr>
<td>(Jun 19-Sep 21)</td>
<td>Assinica</td>
<td>1,989</td>
<td>747</td>
<td>0</td>
<td>37</td>
</tr>
<tr>
<td>Reservoir, 1986</td>
<td>Temiscamie</td>
<td>1,998</td>
<td>265</td>
<td>57 (6.28)</td>
<td>16</td>
</tr>
<tr>
<td>(Jun 17-Aug 26)</td>
<td>Assinica</td>
<td>1,998</td>
<td>220</td>
<td>144 (5.71)</td>
<td>18</td>
</tr>
<tr>
<td>Laramie, 1986</td>
<td>Temiscamie</td>
<td>1,498</td>
<td>587</td>
<td>146 (27.96)</td>
<td>50</td>
</tr>
<tr>
<td>(Jun 16-Aug 25)</td>
<td>Assinica</td>
<td>1,500</td>
<td>378</td>
<td>309 (42.81)</td>
<td>46</td>
</tr>
</tbody>
</table>

3.60, \( P < 0.001 \))). Lengths and weights were not measured for brook trout captured in the inlet of the Reservoir.

Other Characteristics

The condition of Assinica brook trout in the hatchery prior to stocking was significantly greater than the Temiscamie strain in the 1985 trial. The slope of the Assinica strain weight–length regression (\( \beta = 3.41; \ SE = 0.19 \)) was different from that of the Temiscamie strain (\( \beta = 2.68; \ SE = 0.20; \ F = 9.25; \ P < 0.001 \)). Condition was not compared in 1986 because the strains were not reared at equal densities. Direct comparison of regression parameters was chosen as the method for evaluating the condition of the strains at stocking because the slopes of the weight–length regressions for both strains were significantly different from 3.0 (Ricker 1975; Snedecor and Cochran 1980).

The proportions of Assinica and Temiscamie brook trout subsampled from the holding net for subsequent marking were different from the proportions actually present in the net. All fish captured by sampling the ponds were held in a mesh net until processing. Small subsamples were then removed for marking until the entire sample was completed. Assinica brook trout were typically subsampled earlier in the processing period than Temiscamie fish. For example, the strain proportions of the last 30% of a 1985 Reservoir sample were different from the proportions in the first 70% (\( x^2 = 17.9; \ P < 0.001 \)). In this case, the first 70% of the sample contained equal proportions of the two strains (278 fish/strain), whereas the final 30% of the sample contained 67% Temiscamie (155 fish) and 33% Assinica strain brook trout (67 fish).

Discussion

There was no difference in survival between Assinica and Temiscamie strains in our study. However, if only the recovery of trout in the ponds was considered, we would have concluded that the Temiscamie strain had superior survival over the Assinica strain. Webster and Flick's (1981) conclusion that the Temiscamie strain had the higher survival rate may have resulted because they did not estimate upstream emigration from Laramie Pond. Although the confounding factors of differential emigration and differential handling mortality preclude precise estimates of survival in our

TABLE 2.—Stocking, losses, and recovery of marked and unmarked brook trout of two strains stocked into the Reservoir in 1985. The number marked versus unmarked was calculated by subtraction of the number marked at least once from the number stocked. The balance left was calculated by subtraction of the total known losses from the number of marked and unmarked possibly present.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Assinica</th>
<th>Temiscamie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number stocked</td>
<td>1,989</td>
<td>1,989</td>
</tr>
<tr>
<td>Marked or unmarked</td>
<td>869</td>
<td>930</td>
</tr>
<tr>
<td>Marked</td>
<td>1,120</td>
<td>1,059</td>
</tr>
<tr>
<td>Losses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emigration, outlet</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Emigration, inlet</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Sampling mortality</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Balance left</td>
<td>851</td>
<td></td>
</tr>
<tr>
<td>Recovered at draining</td>
<td>332</td>
<td></td>
</tr>
<tr>
<td>Recovery</td>
<td>39%</td>
<td>29%</td>
</tr>
<tr>
<td>Unmarked</td>
<td>1,100</td>
<td>1,059</td>
</tr>
<tr>
<td>Marked</td>
<td>910</td>
<td></td>
</tr>
<tr>
<td>Marked or unmarked</td>
<td>910</td>
<td></td>
</tr>
<tr>
<td>Marked</td>
<td>445</td>
<td></td>
</tr>
<tr>
<td>Marked or unmarked</td>
<td>445</td>
<td></td>
</tr>
</tbody>
</table>


Table 3.—Mean total lengths, weights, sample sizes, and daily instantaneous growth rates \((G)\) of the Temiscamie and Assinica strains of brook trout stocked into and recovered from the Reservoir in 1985 and 1986, from Laramie Pond in 1986, and above the barrier in Laramie inlet. The SE of each measurement is given in parentheses. Instantaneous growth rates and their SEs are given as daily averages.

<table>
<thead>
<tr>
<th>Strain</th>
<th>At stocking</th>
<th>End of study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SE) length (cm)</td>
<td>Mean (SE) weight (g)</td>
</tr>
<tr>
<td>Temiscamie</td>
<td>5.4 (0.16)</td>
<td>1.6 (0.13)</td>
</tr>
<tr>
<td>Assinica</td>
<td>5.5 (0.14)</td>
<td>1.8 (0.16)</td>
</tr>
<tr>
<td>Reservoir, 1985</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temiscamie</td>
<td>5.1 (0.06)</td>
<td>1.2 (0.05)</td>
</tr>
<tr>
<td>Assinica</td>
<td>6.5 (0.07)</td>
<td>2.7 (0.10)</td>
</tr>
<tr>
<td>Reservoir, 1986</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temiscamie</td>
<td>5.0 (0.05)</td>
<td>1.1 (0.04)</td>
</tr>
<tr>
<td>Assinica</td>
<td>6.3 (0.06)</td>
<td>2.6 (0.08)</td>
</tr>
<tr>
<td>Laramie Pond, 1986</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temiscamie</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Assinica</td>
<td>Same</td>
<td>Same</td>
</tr>
</tbody>
</table>

* Same as Laramie Pond fish.

study, differential emigration may have been the cause of Webster and Flick’s (1981) report of differential survival.

The recovery of both strains of brook trout from the Reservoir was significantly lower in 1986 than in 1985. Emigration and predation are likely reasons. Upstream emigration did not occur in 1985 but represented a significant portion of the 1986 recovery. More importantly, predation by age-1 brook trout (left from the 1985 trial) and by avian predators in 1986 probably lowered survival. No avian predators were seen during the 1985 trial, but belted kingfishers *Megaceryle alcyon* and common mergansers *Mergus merganser* were seen during the 1986 trial.

Upstream emigration of Assinica strain brook trout through the inlet barriers exceeded Temiscamie emigration in both 1986 trials. In addition, the Assinica strain emigrated downstream at a higher rate than the Temiscamie strain in the 1985 study. We believe that the ineffective inlet barriers in 1986 were not strain selective for three reasons. First, we found, at the end of the study, a hole at the water level in the culvert pipe at the Laramie Pond barrier that should have allowed easy passage of fish upstream. Second, the beaver dam on the Reservoir inlet had deteriorated considerably since the 1985 trial; although repairs were attempted, these were not effective due to the higher inlet discharge in 1986. Third, the passage of approximately the same ratio (2.5 Assinica per Temiscamie strain brook trout) through two different types of inlet barriers seems improbable if one or the other barrier was strain selective.

A significantly higher proportion of Assinica strain brook trout than of Temiscamie strain fish were located in stream habitats. The Assinica strain may prefer stream habitats to the open pond habitats more than the Temiscamie strain does, and the Temiscamie strain may prefer pond habitats. Alternatively, differences in density-dependent dispersal between strains may have caused the differential emigration. Some studies showed that upstream emigration into poor habitat was a function of fish size (e.g., Hulbert and Engstrom-Heg 1982), but we found that Assinica fish, which were larger (1986) or in better condition (1985) than Temiscamie fish, consistently emigrated out of the pond into areas where growth rates were lower.

Marking mortality was higher for the Temiscamie strain than for the Assinica strain. Recovery of marked Temiscamie brook trout was much lower than recovery of both marked Assinica and unmarked Temiscamie fish in the 1985 trial. This conclusion was also supported by Petersen population estimates (Cone et al. 1988). Petersen estimates (Seber 1982) calculated with the sample taken when the pond was drained should have provided unbiased estimates of the number of fish present at the various marking times during the summer. The assumptions required for these Petersen estimates were that the draining sample was complete and that marking mortality did not occur. In 1985, both strains had upwardly biased
Petersen estimates, which suggested that both strains suffered marking mortality. In 1986, only the Temiscamie strain had an upwardly biased estimate (Cone et al. 1988).

The stress of being held in a mesh bag and then marked was the most likely cause of delayed mortality. Some of the differential marking mortality may have resulted because Temiscamie fish moved to the bottom of the holding net, but there appears to be a difference in the ability of these two strains to withstand handling stress. When both strains were kept for the same amount of time in holding cages, the Temiscamie fish died at the higher rate. One possible cause of such differential mortality is a genetically based difference in the ability to process lactate or other compounds created during stress (Tsuyuki and Williscroft 1977). A similar phenomenon has been described for the Florida and northern subspecies of largemouth bass Micropterus salmoides (Williamson and Carmichael 1986) and for families of Atlantic salmon Salmo salar and rainbow trout Oncorhynchus mykiss (formerly Salmo gairdneri) (Refstie 1986).

Growth of the Temiscamie strain was significantly greater than that of the Assinica strain after stocking. In contrast, the Assinica strain grew faster in the hatchery, where they took feed better and were calmer than the Temiscamie strain (Fred Joost, Brandon Park Hatchery, personal communication). The differential ability to perform under hatchery conditions was probably the reason why Assinica fish were in better condition at stocking than the Temiscamie strain in the 1985 trial. Webster and Flick (1981 and personal communication), however, did not find significant growth differences between these two strains.

Management Implications

The consistent differences in emigration, response to handling stress, and growth in the wild between the Assinica and Temiscamie strains of brook trout suggest that each strain could have special uses in stocking programs. For example, the Temiscamie strain had superior growth in the wild and less emigration after stocking. Therefore, this strain might be better suited for management focused on population restoration or put-grow-and-take fisheries (Krueger et al. 1981). The Assinica strain seemed better suited to hatchery conditions and had a lower susceptibility to handling stress, both of which would be important for rearing fish to catchable size before they are stocked. Due to a possible resistance to handling stress, the Assinica strain may also be better suited for catch-and-release fisheries.

The differences in performance after stocking described here between two brook trout strains provide further evidence for a genetically based variation in traits that exist within species. This variation should be protected and conserved because it directly affects the species' ability to adapt to changing environments and because it is an important resource to fishery management and aquaculture.

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