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Relative Growth and Survival of Three Strains of Rainbow Trout and Three Strains of Brown Trout Stocked into Small Michigan Inland Lakes

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Abstract.–The relative growth and survival was assessed over a 3-yr period for three strains of rainbow trout *Oncorhynchus mykiss* stocked as yearlings into two small oligotrophic lakes. Their relative tendency to emigrate was evaluated in one lake that had an outlet. The strains tested were Shasta (SH), Eagle Lake (EL), and Michigan steelhead (STT). Relative growth and survival was similarly evaluated for three stains of brown trout *Salmo trutta* stocked into four small, landlocked oligotrophic lakes. Brown trout strains examined were Wild Rose (WR), Seeforellen (SF), and Plymouth Rock (PR). No significant differences in survival of rainbow trout strains were found. However, point estimates of survival and standing crop in both lakes were highest for STT, intermediate for EL, and lowest for SH. EL-rainbow trout were significantly heavier than STT in four of the five samples collected over a 3-yr period from both lakes. EL trout were consistently heavier than SH in both lakes during the first 30 months after stocking. In West Lost Lake, EL were significantly larger than SH in all samples collected through 30 months after stocking, but at East Fish Lake weight differences were significant only for the sample collected ten months after trout were stocked. After 37 months residence, EL and SH in both lakes were of similar size. Overall results indicated few significant differences in growth of SH and STT. There was little evidence that any rainbow trout strain tested was more likely to emigrate from the experimental lake which had at outlet. Mean lengths and weights of WR and SF brown trout were similar during sampling periods from 6-37 months after stocking. WR and SF brown trout strains produced far more legal-sized fish (≥ 254 mm TL) than PR by six months after stocking because they were larger when stocked. There were no significant differences in survival or standing crops among brown trout strains after 30 months residence in the study lakes. When Ford Lake survival estimates were excluded from ANOVA analyses, survival of PR was significantly higher than for SF or WR, and survival of WR was higher than for SF after 30 months residence. After 30 months residence there were no significant differences in standing crops among brown trout strains.

The Michigan Department of Natural Resources (MDNR) has annually stocked approximately 2.7 million trout into inland lakes and streams in recent years (Anonymous 1993, 1994). Over 90% of these trout were yearlings that cost about 75 cents per fish to rear and stock. Fishery managers must choose between an array of species and strains of trout and attempt to stock those that will yield the best catch rates and benefit-cost ratios. Field evaluations of different strains of rainbow trout *Oncorhynchus mykiss* frequently demonstrate different rates of growth, survival, and catchability or yield to anglers (Brauhn and

Kincaid 1982, Hudy and Berry 1983, Dwyer and Piper 1984, Close et al. 1985, Hume and Tsumura 1992). Migration tendencies of various rainbow trout strains can likewise affect yield to anglers (Moring 1982, Fay and Pardue 1986). Although movement away from the stocking site is most likely to affect returns from fish stocked in streams, it could reduce catches from lakes with outlets if there was extensive emigration.

Relatively little information is available on the relative performance (survival, growth, and harvest) in the wild of different strains of hatchery brown trout *Salmo trutta*, although a variety of strains are maintained in federal and state hatcheries (Kincaid 1981). In Michigan, wild brown trout strains stocked into small inland lakes were found to survive twice as well as the domesticated Plymouth Rock (PR) strain (Alexander 1987). Johnson and Rakoczy (1995) reported that that Seeforellen (SF) strain brown trout produced better return to creel and higher yields than Wild Rose (WR) and PR when stocked into Thunder Bay, Lake Huron. They further reported that both SF and WR produced catch rates at least 5 times higher than those for PR in a large inland lake (Lake Charlevoix). It was not known if the differences in catch rates they observed among strains were due to differences in survival or angling vulnerability.

The primary objective of this study was to test the relative growth and survival in small inland lakes of the principal strains of yearling rainbow and brown trout reared in Michigan's hatchery system during 1991-92. A second objective was to determine if there were differences in emigration rates for the rainbow trout strains when stocked in a lake having an outlet.

Study Area

Six inland lakes located in the northern portion of Michigan's lower peninsula were used to assess growth and survival. These lakes had surface areas ranging from 1.2-6.5 ha. Five of the lakes are classified as limestone sinks and had limited littoral area. Maximum water depths in these lakes ranged from 8.8-18.0 m, and mean depths from 4.2-5.9 m. Lake substrates were primarily sand, marl, and organic detritus. These lakes were all landlocked and oligotrophic with sparse aquatic vegetation. The sixth lake (East Fish Lake) is a kettle lake with relatively more littoral area than the 5 other lakes. East Fish Lake has an outlet which discharges approximately 0.08 m^3/s through an inclined screen fish trap that passes water but retains fish. Maximum and mean water depths in East Fish Lake are 12.2 and 6.1 m, respectively. Temperatures and dissolved oxygen levels in these lakes are suitable for trout all year. All study lakes have been closed to fishing since 1965 and are patrolled regularly to detect evidence of poaching. MDNR personnel used gill nets to remove residual trout from North Twin, South Twin, Ford, and East Fish lakes during the fall before trout were stocked during April 1992. West Lost and Section 4 lakes were not netted by MDNR personnel. Subsequent sampling revealed that at least 88 of 94 brown trout that were not removed from West Lost Lake following a 1991 tagging study had survived. In Section 4 Lake some reproduction had occurred by brook trout remaining from a previous study. Gill netting was apparently very efficient in capturing residual trout in the other four lakes because only 5 trout from previous studies were captured during 1992-95 sampling.

Methods

During April 1992, a total of 1,953 rainbow trout and 2,184 brown trout were marked and stocked into study lakes at a rate of 246 per ha. Trout were anaesthetized with MS-222, then tagged with green Floy FD-68B fine-fabric anchor tags and given a single fin clip. Fin clips were administered to allow identification of trout strains if they lost their Floy tags. Total length, weight, and tag number of all individual trout were recorded. After tagging, trout were transferred to a fish carrier unit, transported, and stocked into the study lakes. All trout strains except steelhead were stocked the same day they were measured and tagged. Steelhead were held in a fish transport unit overnight and stocked the following day. All trout appeared vigorous at the time they were released and no mortalities were observed.

Rainbow trout were stocked into West Lost and East Fish lakes at a rate of 246 trout per ha using all three strains of rainbow trout combined. Equal numbers of each strain of rainbow trout were stocked in each lake. The strains stocked were Shasta (SH), Eagle Lake (EL), and Michigan steelhead (STT). SH-strain trout were cultured at the Harrietta State Fish Hatchery while the EL strain was reared at the Oden State Fish Hatchery. Michigan steelhead were reared at the Wolf Lake State Fish Hatchery from eggs obtained from fish which ascend the Little Manistee River from Lake Michigan.

Brown trout were stocked into North Twin, South Twin, Ford, and Section-4 lakes at a rate of 246 trout per hectare using all three strains combined. Equal numbers of Plymouth Rock (PR), Seeforellen (SF) and Wild Rose (WR) strain brown trout were stocked into each study lake. Both the SF and WR strains were cultured at the Oden State Fish Hatchery, whereas PR-strain fish were reared at the Harrietta State Fish Hatchery.

Relative growth rates of rainbow trout strains stocked in West Lost Lake were determined from electrofishing samples collected during November 1992, May 1993, and November 1993. Trout captured by electrofishing were held in a nylon-mesh net for 24-48 h depending upon whether sampling was conducted on 1 or 2 d. No mortality due to electrofishing was observed during these holding periods. After the holding period, trout were measured, weighed, given a fin clip to allow for subsequent mark-and-recapture population estimation, then released. Gill nets were used to sample and remove trout from the lake during October 1994 and May 1995. Rainbow trout in East Fish Lake were collected by angling during February 1993, and by electrofishing during May 1993. Fish captured by angling were held in a nylon-mesh net for a minimum of 48 h before being released. No hooking mortality was observed during these holding periods. During April and May 1994, rainbow trout used for growth analyses were collected from a fish trap located at the outlet of the lake. Gill nets were used to collect and remove rainbow trout from East Fish Lake during October 1994 and May 1995.

Relative growth of brown trout strains was determined from samples of brown trout collected by electrofishing during October 1992, May 1993, and November 1993. These fish were processed in the same manner as rainbow trout. Final samples of brown trout were collected with gill nets in October 1994 and May 1995.

Estimates of relative survival and standing crops for the rainbow and brown trout strains were derived by comparing the sums of the numbers and aggregate weights of each strain captured with gill nets and removed from the lakes during October 1994 and May 1995. The goal of this intensive netting effort (approximately 80 m of gill net fished per surface hectare/net set) was to capture and remove virtually all surviving trout during fall 1994. Because all fish were not captured during October 1994, additional gill netting was conducted in all lakes during May 1995 until no trout were caught for 2-5 consecutive 24-h netting periods. I assumed that any natural mortality occurring between October 1994 and May 1995 was similar between strains of trout. Data analysis revealed that sample sizes of trout collected by non-lethal methods were usually too small to yield precise, strain-specific population, survival and standing crop estimates from stocking to sampling dates prior to October 1994. Hence, meaningful survival estimates from planting to sampling dates prior to October 1994 could not be made.

Mean lengths and weights of trout strains at each sampling date were compared within lakes using one-way analysis of variance (Snedecor and Cochran 1989). Multiple comparisons among strains were made using Tukey's honestly significant difference test, and homogeneity of variance was examined using the Levene test. Survival and standing crop estimates were analyzed in a similar manner. ANOVA showed that survival and standing crops of brown trout in Ford Lake were significantly lower than in the other three lakes, so Ford Lake data were excluded from final comparisons of strain survival and standing crops. All statistical tests were judged significant if $\propto \leq 0.05$. All statistical analyses were made using SPSS for Windows (SPSS 1994).

Incremental growth in length and weight from stocking to each sampling date was determined for trout that could be individually identified by their Floy tag number. Trout that had lost their Floy tags were excluded from the incremental growth analysis.

Relative emigration of rainbow trout strains was assessed in East Fish Lake by comparing the numbers of each strain captured each year in an inclined screen trap located on the outlet of the lake. Spring population estimates were determined to be too imprecise to provide good estimates of the percentage of each strain that attempted to migrate each year. Relative strain emigration rates during 1994 were made by comparing the ratio of emigrants by strain to the sum of the number of each strain captured and removed from the lake during October 1994 and May 1995. Trout captured in the trap were weighed and measured, fin clipped to allow detection of multiple emigration attempts by the same fish, then transferred back into the lake.

Results

Growth of Rainbow Trout Strains

Both mean weights and lengths of EL rainbow trout were higher than those for STT in both study lakes during each of the five sampling periods (Figures 1 and 2). EL-rainbow trout were significantly heavier than STT in four of the five samples collected from each lake (Table 1). In East Fish Lake, EL-strain trout accrued significantly larger incremental increases in weight than STT between stocking and all five subsequent sampling periods (Table 2). Length increments for EL residing in East Fish Lake were significantly larger than those for STT during the first two years after stocking. However, at West Lost Lake, weight and length increments of EL and STT were not significantly different during any sampling period.

EL trout were consistently heavier than SH in both lakes during the first 30 months after stocking (Figure 1, Table 1). In West Lost Lake, EL were significantly larger than SH in all samples collected through 30 months after stocking (October 1994). However, weight differences in East Fish Lake were significant only for the sample of trout collected during February 1993, ten months after trout were stocked. After 37 months residence, EL and SH in both lakes were of similar size. Weight increments of EL fish in both lakes were larger than those for SH in all samples, but differences were significant only in February 1993 at East Fish Lake and November 1993 at West Lost Lake (Table 2). Differences in weight increments of SH and EL were unrelated to weight at stocking because their mean weights at stocking were virtually identical (Table 1).

In West Lost Lake, mean lengths and weights of SH and STT were not significantly different at any of the five sampling periods (Figures 1 and 2, Table 1). One year after stocking, SH in East Fish Lake were significantly longer and heavier than STT (Figures 1 and 2, Table 1). Mean lengths and weights of SH and STT sampled from East Fish Lake at 24 and 30 months post stocking were not significantly different. SH collected in May 1995 from East Fish Lake were significantly heavier than STT. Neither weight or length increments for SH and STT in East Fish Lake were significantly different at 4 of 5 sampling periods (Table 2). During the first year after stocking into East Fish Lake SH accrued significantly more growth in length and weight than STT. In West Lost Lake, weight and length increments of SH and STT were similar throughout the period of study.

All rainbow trout strains grew significantly larger and heavier in East Fish Lake than in West Lost Lake after equivalent periods of residence (ANOVA, $P < 0.05$). Growth in the two lakes appeared inversely related to survival and standing crop estimates determined after 30 months residence. In addition, brown trout were present in West Lost Lake. A minimum of 88 (maximum of 94) brown trout were present in this lake when rainbow trout were stocked. These brown trout were removed from the lake whenever they were captured during sampling periods. The numbers and aggregate weights of brown trout removed during the present study were as follows: November 1992, 13 fish weighing 4.53 kg; May 1993, 29 fish weighing 11.38 kg, October 1994, 30 fish weighing 14.96 kg, and May 1995, 16 fish weighing 8.84 kg.

Brown trout captured in gill nets during 1994-95 comprised 26% of the total salmonid biomass removed. By comparison, only 4 brook trout having an aggregate weight of 1.6 kg were captured from East Fish Lake during 1994-95. Thus, total standing crops of salmonids were higher in West Lost Lake than in East Fish Lake at both the beginning and end of the 1992-95 study period.

Survival and Standing Crops of Rainbow Trout

No significant differences in survival were detected among rainbow trout strains (ANOVA, $P > 0.05$). Thirty months after stocking, point estimates of survival were highest for STT and lowest for SH in both study lakes (Table 3). In East Fish Lake, STT survival estimates from stocking through 30 months residence were over 3 times higher than for SH and 1.5 times higher than for EL. In West Lost Lake over the same period, STT survival was over twice as high as for SH and 1.3 times higher for EL. Over the first 30 months after stocking, survival of EL fish was 2.1 and 1.7 times higher than for SH in East Fish and West Lost lakes, respectively.

No significant differences in biomass (standing crops) were detected among strains for trout captured and removed from the lakes at the end of the study (ANOVA, $P > 0.05$). However, rankings of strains based on biomass removed were consistent between lakes with STT yielding the highest standing crops, EL ranking second, and SH ranking lowest (Table 3). Standing crops for each rainbow trout strain were approximately 5 kg per hectare at stocking. At East Fish Lake, biomass of STT removed with gill nets was 3.1 times higher than at stocking, and biomass was 4.4 times higher than at stocking in West Lost Lake. Standing crops of EL fish removed were 2.4 and 3.4 times higher than at stocking in East Fish and West Lost lakes, respectively. SH standing crops in East Fish Lake were virtually the same at the beginning and end of the study while they increased 1.9 times in West Lost Lake.

Rainbow Trout Emigration

There was little evidence of differences in migration tendency among the three strains of rainbow trout during the first summer after stocking in East Fish Lake (Table 4). Over 90% of trout captured in the lake-outlet trap during 1992 attempted to emigrate within 10 days of stocking. During 1993, only 9 fish attempted to emigrate; STT (8 fish), SH (1 fish), EL (0 fish). During spring 1994, the ratio of EL emigrants to the sum of the number of EL captured and removed from the lake during October 1994 and May 1995 was higher than the analogous ratio for SH, which in turn, was higher than the ratio for STT. Gill nets were fished near the lake outlet and throughout the lake during May 1995 so relative differences in migration tendency could not be estimated after 1994.

Growth of Brown Trout Strains

Throughout the study, WR and SF strains were generally larger than PR. WR brown trout were significantly larger at stocking on April 1992 than SF or PR fish in all four study lakes (Figures 3 and 4, Table 5). However, mean total lengths and weights of WR and SF trout collected from 6-37 months after stocking were rarely significantly different (Table 5). The sole exception was found at Ford Lake during October 1994 when SF were significantly longer and heavier than WR.

WR remained significantly larger than PR through the 13 months residence in Ford Lake and 30 months in North Twin Lake (Figures 3 and 4, Table 5). In South Twin Lake, mean lengths and weights of WR and PR were not significantly different at 6, 30, and 37 months after stocking. In Section 4 Lake, WR were significantly longer, but not heavier, than PR throughout 30 months residency. No significant differences in the sizes of these two strains were evident 37 months after stocking in any of the study lakes.

SF were significantly longer than PR in all lakes at stocking and significantly heavier in 3 of 4 lakes (Table 5). SF in North Twin, South Twin, and Section 4 lakes were also larger than PR on all subsequent sampling dates, but the differences were significant in only about one third of the comparisons. By contrast, in Ford Lake, where initial growth of all strains was very slow, SF and PR were of similar size 6-19 months after stocking. Thirty months after stocking, SF were significantly larger than PR in Ford Lake.

Incremental increases in length and weight between stocking and subsequent sampling dates were rarely significantly different among strains (Table 6). Because of tag loss, sample sizes of fish available for comparisons of incremental growth were generally small. After 30 months residence in Ford Lake and 37 months residence in South Twin Lake, SF weight increments were significantly larger than those of either WR or PR. WR weight increments were significantly larger than PR after 6 months residence in North Twin Lake and 13 months in South Twin Lake. However, after 30 and 37 months residence in these two lakes growth increments for WR and PR were not different.

During the first 6 months after stocking, all brown trout strains grew significantly faster in North Twin and South Twin lakes than in Ford Lake (ANOVA, $P < 0.05$) (Figures 3 and 4, Table 6). All strains grew at least 6 times faster (based on weight increments) in North Twin Lake than in Ford Lake during the first six months (Table 6). However, after 30 months residence, when trout were collected by gill netting, all brown trout strains were significantly longer and heavier in Ford Lake than in the other three lakes (ANOVA, $P < 0.05$).

Survival and Standing Crops of Brown Trout

When data from all four study lakes were analyzed no significant differences were detected in survival among brown trout strains through 30 months after stocking (ANOVA, $P >$ 0.05), although point estimates of survival were higher for PR than for either WR or SF strains in all lakes (Table 7). The unweighted mean percentages of brown trout surviving for at least 30 months after stocking (averaged over 4 lakes) were 40% for PR, 32% for WR, and 26% for SF. Survival estimates for all trout strains through 30 months after stocking were lowest in Ford Lake. ANOVA analysis showed that mean survival in Ford Lake was significantly different than in each of the other three lakes. Thus, a second analysis of strain survival was performed with data from Ford Lake excluded. The Tukey multiple comparison test of data from North Twin, South Twin, and Section 4 lakes showed that PR survival was significantly higher than survival of either WR or SF. WR survival was significantly higher than for SF.

Estimates of standing crops produced by the end of the study did not differ significantly among strains (ANOVA, $P > 0.05$). No significant differences in standing crops were detected among strains when Ford Lake was either included or excluded from the ANOVA, although mean standing crops of brown trout for pooled strains were significantly lower in Ford Lake than in each of the other three lakes. Rankings of the strains based on point estimates of standing crops netted from the lakes paralleled survival rankings (Table 7). The unweighted mean standing crops of brown trout removed from the lakes at the end of the study were 13 kg/ha for PR, 11 for WR and 10 for SF. Because PR trout were the smallest individual size when they were stocked, final standing crop (based on unweighted means) was 3.5 times higher than standing crop stocked. Analogous increases in standing crop for SF and WR were 2.3 and 2.2, respectively.

Discussion

Judged on the basis of growth rates, EL rainbow trout were superior to STT. Almost all comparisons of EL and STT sizes and growth increments were significantly different in East Fish Lake. At West Lost Lake, EL were also significantly larger than STT during all sampling periods when strain-sample sizes were reasonably large. Based on growth EL also appeared superior to SH, because they were heavier in 9 of 10 comparisons, 5 of which were statistically significant. Overall results indicated few significant differences in growth of SH and STT. Detection of statistically significant differences in growth was probably hampered by small sample sizes during some sampling periods. Similarly, some apparent reversals in relative strain growth between sampling period may be attributable to small-sample bias.

There was no absolute proof that survival or standing crops produced by the three rainbow trout strains differed significantly during the study. However, I believe that estimates of relative survival and standing crops were precise. The accuracy of my precision assumption rests largely on netting efficiency. If netting efficiency was high then nearly all fish of all strains were caught and removed during gill netting and relative survival and production estimates were precise. The summer before rainbow trout were stocked into West Lost Lake, a graduate student recaptured and removed all but 94 of the total number of yearling brown trout stocked into the lake during spring 1991. We captured and removed 42 of these brown trout during November 1992 and May 1993 electrofishing samplings. Gill netting operations during October 1994 and May 1995 captured an additional 46 brown trout out of a maximum of 52 that could have been present. Thus, if there was no natural mortality of brown trout from spring 1991 to spring 1995, gill netting operations captured a minimum of 88.5% (46/52) of brown trout present. I suggest that the probability that no brown trout mortality occurred during 4 years is very low. Thus, actual netting efficiency for brown trout in West Lost Lake was almost certainly well over 90%. Similar levels of netting effort were expended on all lakes. Therefore I judge that few trout escaped capture in gill nets in any study lake. If this assumption is correct, STT survival and production was superior to that of either EL or SH. Similarly, EL survival and production was better than that of SH fish.

A second potential bias in survival and standing crop estimates could have occurred if mortality differed among strains between October 1994 and May 1995 gill netting operations. There were no obvious reasons to expect such differential mortality. Brown trout in West Lost Lake were not large enough to consume the rainbow trout present at that time. It is unlikely that any large piscivorous fish were present in East Fish Lake, and ice cover that was present on the lakes from approximately mid-November to late April should have precluded avian predation.

A third potential source of bias that could have influenced relative survival estimates was mortality caused by sampling methods. If a sampling method caused significant mortality and was more efficient at capturing different rainbow trout strains, then relative survival estimates could be biased. Significant bias introduced by sampling appears unlikely. Electrofishing was conducted with non-pulsed direct current electrofishing gear. Water temperatures during electrofishing ranged from 6-12° C. No mortality was observed during the 24-48 h trout were held in live cages after capture, and fish appeared vigorous when released. Because samples collected by electrofishing were generally quite small and differences in the numbers of fish of each strain captured on a sampling date even smaller, I judge that this sampling did not bias relative survival estimates. Some trout caught by angling through the ice of East Fish Lake may have died from delayed hooking mortality. Anglers used fishing techniques that minimized hook penetration into critical areas such as the throat or gill arches, and no mortality was observed during 48-72 h holding periods. Hooking mortality usually occurs with this time period (Hunsaker et al. 1970), and mortality of salmonids is very rare for individuals hooked in non-critical areas when water temperatures are low (Wydoski 1977, Nuhfer and Alexander 1992). The inclined fish trap at East Fish Lake could have influenced relative strain survival. The number of EL fish caught in the trap during spring 1994 was 24% of the number of EL later removed from the lake with gill nets. Analogous percentages for SH and STT were 16% and 7%, respectively. If loss of scales (usually minor) or other stress from trap capture resulted in delayed mortality, then it probably had relatively greater adverse impact on EL.

Higher survival of STT relative to the other strains could also have resulted from reduced predation mortality if they were more pelagic than the other strains. Some evidence from diet studies and creel census suggests that the EL strain inhabit littoral areas when conditions are suitable (King 1963, Schneidervin and Brayton 1992). Alexander and Shetter (1969) theorized that much higher natural mortality of brook trout compared to rainbow trout stocked into East

Fish Lake occurred because brook trout were less pelagic and hence more vulnerable to predation, particularly avian predators. Their mortality rates were similar when equal numbers were stocked into a shallow lake. During spring 1994, I observed bald eagles *Haliateeus leucocephalus* and osprey *Pandion haliaetus* preying upon rainbow trout that were spawning in shallow waters near the outlet fish trap at East Fish Lake. If relatively more EL and SH than STT were present near the trap, as suggested by trap capture records, avian predation may have contributed to lower survival of these strains.

No definitive conclusions about differences in emigration rates for the rainbow trout strains in a lake having an outlet could be made. Because population numbers of each strain were unknown during spawning periods, the proportion of each strain that emigrated into the fish trap could not be determined. Design of the fish trap appeared to inhibit movement. Emigrants had to swim 1 m toward the lake surface and pass over a sill to enter the trap. Observations that large numbers of rainbow trout spawned over sandy substrates within the lake near the outlet and trap suggested that these large fish were reluctant to swim over the sill. In addition, ripe adults were rarely caught more than once during one spawning season, which again suggested reluctance to enter the trap. I hypothesize that mature individuals of all the strains tested would emigrate at much higher rates in lakes without such a barrier. Such emigration could seriously deplete populations in lakes where such emigration opportunities exist.

The SF and WR brown trout strains appeared superior to PR based on mean size and growth rate, particularly during the first year after stocking. Because both WR and SF grew better than PR in Michigan's hatcheries, they were larger when stocked and hence more WR and SF grew to legal size (254 mm TL in most Michigan trout lakes) the same year they were stocked. None of the PR (stocked in April 1992) sampled during October 1992 had grown to 254 mm long in three of four study lakes, whereas all WR and SF collected from North Twin and Section-4 lakes exceeded this size. In South Twin Lake, 62% of WR and 71% of SF collected six months after planting were ≥ 254 mm TL. In Ford Lake, where initial growth of all strains was slow, only 25% of PR were ≥ 254 mm long more than a year after stocking, compared with 43% of SF and 61% of WR. Johnson and Rakoczy (1995) found that SF stocked in Thunder Bay, Lake Huron were significantly larger than WR at age 3, but not at age 2. Zielinski (1994) compared paired plants of SF with domestic brown trout in six New York lakes and found that although SF were about 25 mm shorter when planted, they were of similar size at age 2, and were more than 50 mm longer than domestic brown trout at age 3.

When survival data from all four test lakes were considered**,** there was no proof that survival or standing crop produced by the three brown trout strains differed significantly during the study. However, if the assumptions about netting efficiency and precision discussed above for rainbow trout also apply to brown trout, then on average, the PR strain was superior to either SF or WR based on their survival and standing crops 30 months after stocking. The second analysis of survival data, which excluded results from Ford Lake, did reveal significantly higher survival of PR versus WR or SF, and of WR compared with SF. If survival and catchability are directly correlated, the tendency of WR to exhibit higher survival and production than SF observed in small lakes contrasts with their performance in Thunder Bay of Lake Huron, where SF produced higher yields and angler catches than either WR or PR (Johnson and Rakoczy 1995). In tests of paired plants for three year classes of SF and domestic brown trout in New York lakes, only the 1989 SF year class (which was 25+ mm larger than other SF year classes at stocking) yielded better returns to anglers than domestic brown trout (Zielinski 1994). In the New York tests, all year classes of domestic brown trout were larger at stocking than SF. If reduced size-at-stocking had reduced survival in the present study, then PR, which were the smallest strain at stocking, should have had the poorest survival, yet they survived better than the other strains in all test lakes. The complete absence of piscivores in the Michigan test lakes may account for the contrast in findings.

Survival of PR could have been influenced more by effects of Floy tags than the other strains. PR lost significantly higher percentages of Floy tags than either WR or SF during the first 30 months after stocking (Nuhfer et al., in press). If Floy tags caused mortality, PR would have been the strain least affected. Brewin et al. (1995) reported attacks apparently directed at tags by mature brown trout. Such attacks have been reported to cause injury, and in some instances mortality, of rainbow trout tagged with brightly colored (red) tags (German and LaFaunce 1955). However, Nuhfer et al. (in press) found no significant differences between mortality rates of tagged and untagged groups of brown trout during 210 days residence in a spring pond.

Implications

Findings of this study indicate that both STT and EL strain rainbow trout ≥ 167 mm TL at stocking may survive better than SH when stocked in small inland lakes. Wild STT runs could be used as an alternative egg source for successful inland lake plants provided that yearlings are reared to a large enough size prior to planting. The good survival and acceptable growth rates demonstrated by the relatively large STT stocked for the present study supports the hypothesis of many Michigan fisheries managers that past failures of STT planted in inland lakes were related to their small size at planting. There was no clear basis for selecting the best brown trout strain for planting into small inland lakes. WR and SF produced approximately the same standing crops 30 months after stocking and because they were larger when stocked, they produced far more legal-sized fish (254 mm TL) than PR by six months after stocking. Conversely, PR produced slightly higher standing crops after 30 months than either WR or SF.

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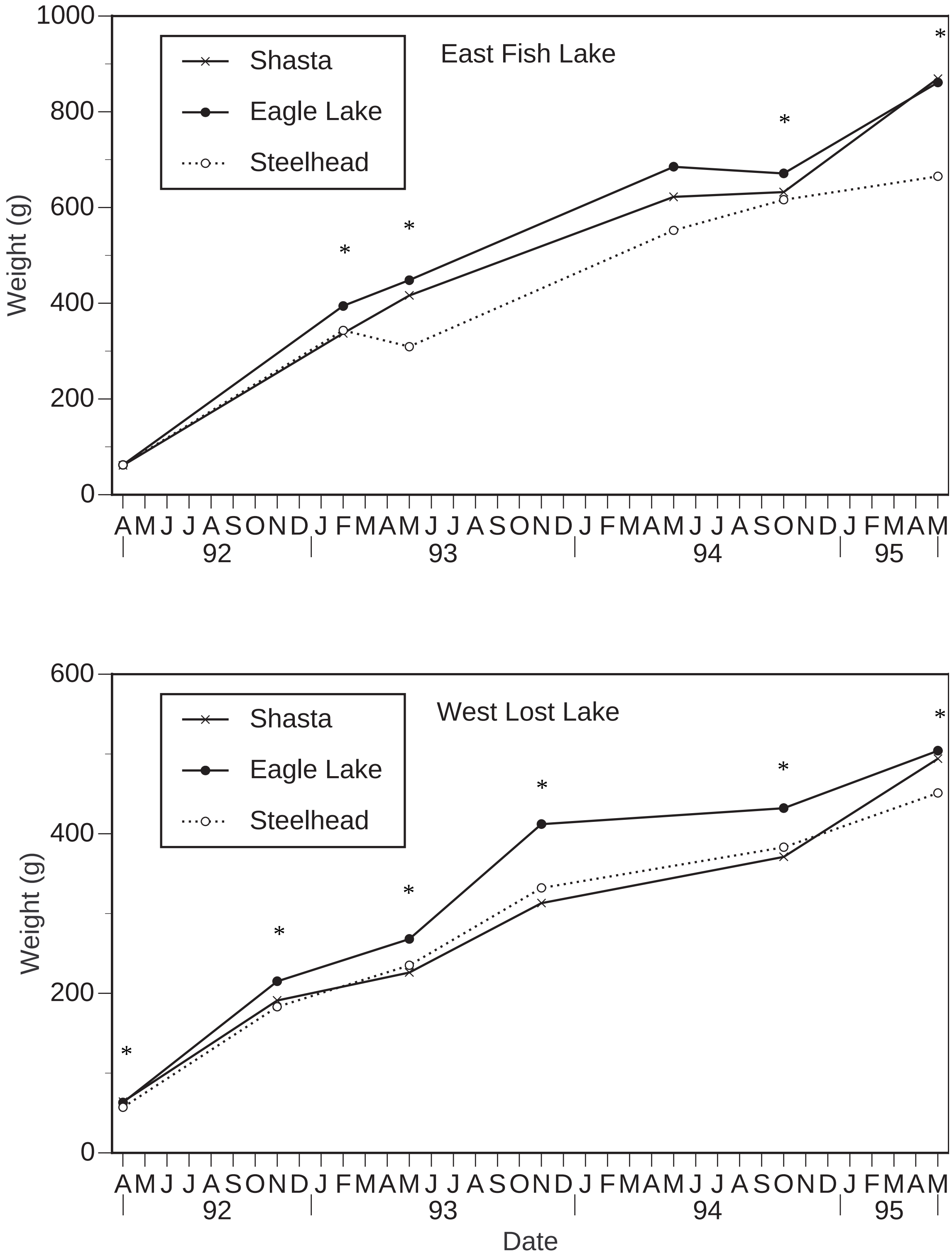


Figure 1.—Mean weight (g) for three strains of rainbow trout when they were stocked in April 1992 and at subsequent sampling periods in two study lakes. Asterisks indicate significant differences among strains during a sampling period.

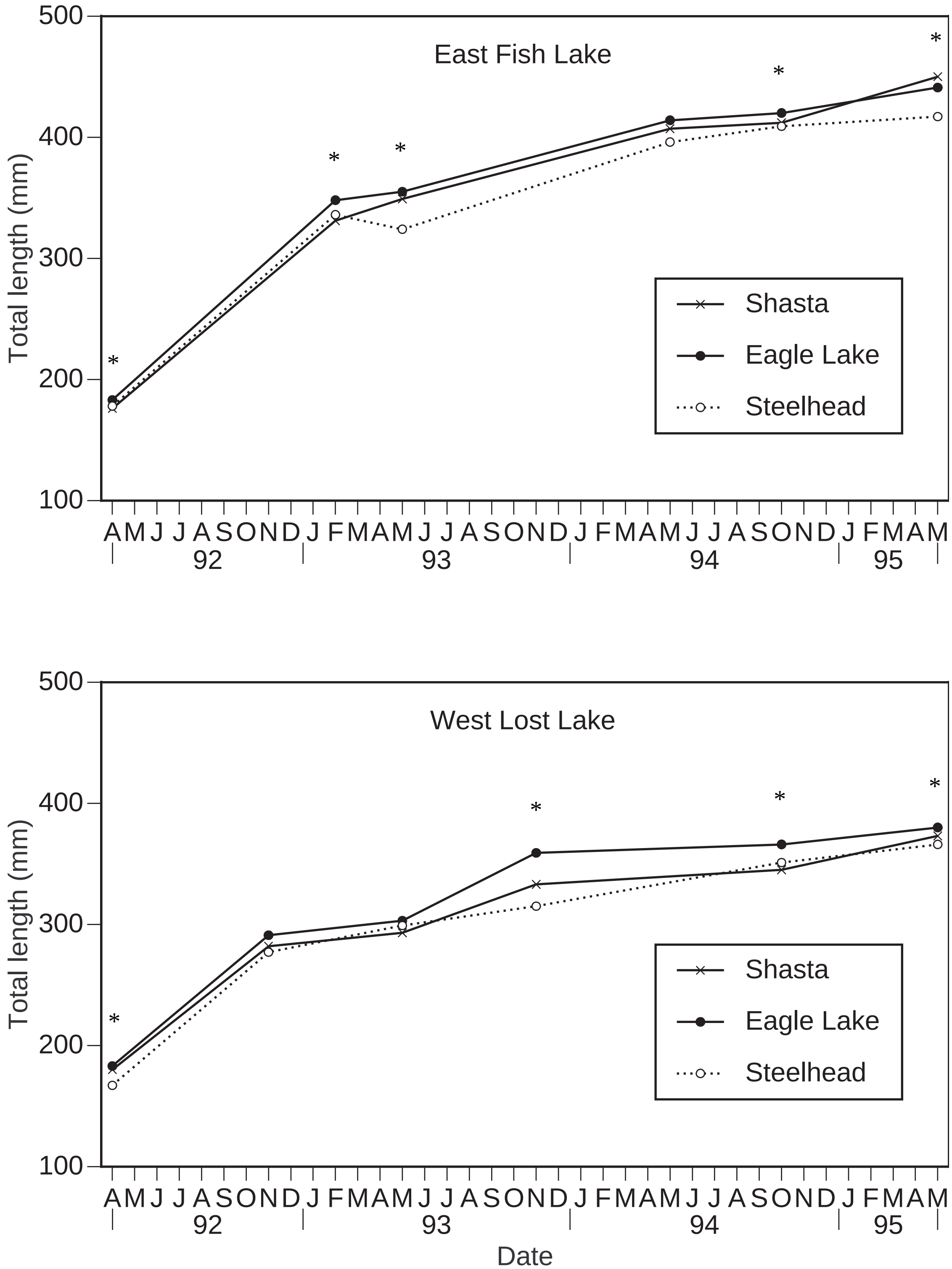
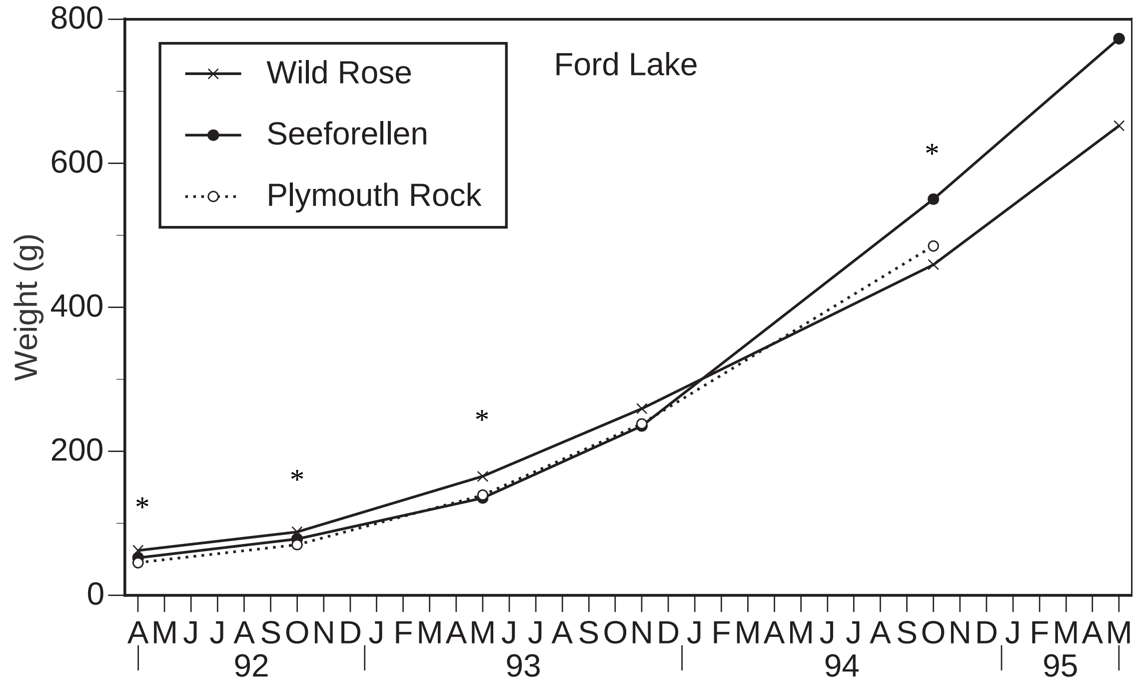


Figure 2.—Mean total length (mm) for three strains of rainbow trout when they were stocked in April 1992 and at subsequent sampling periods in two study lakes. Asterisks indicate significant differences among strains during a sampling period.



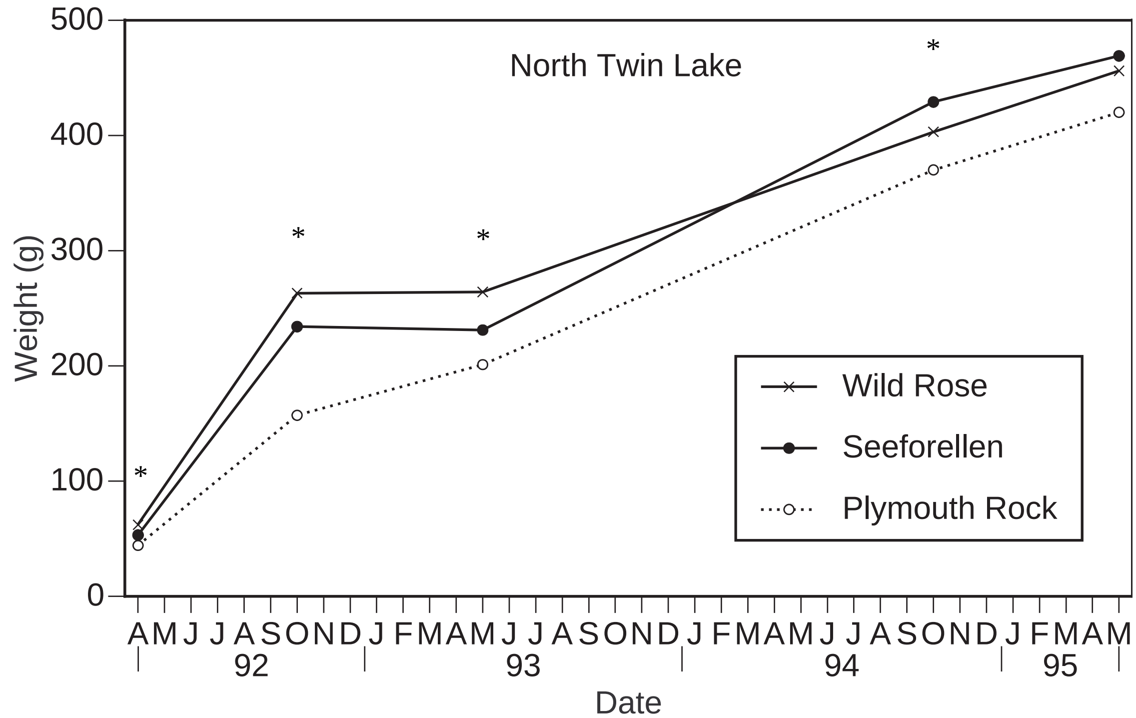
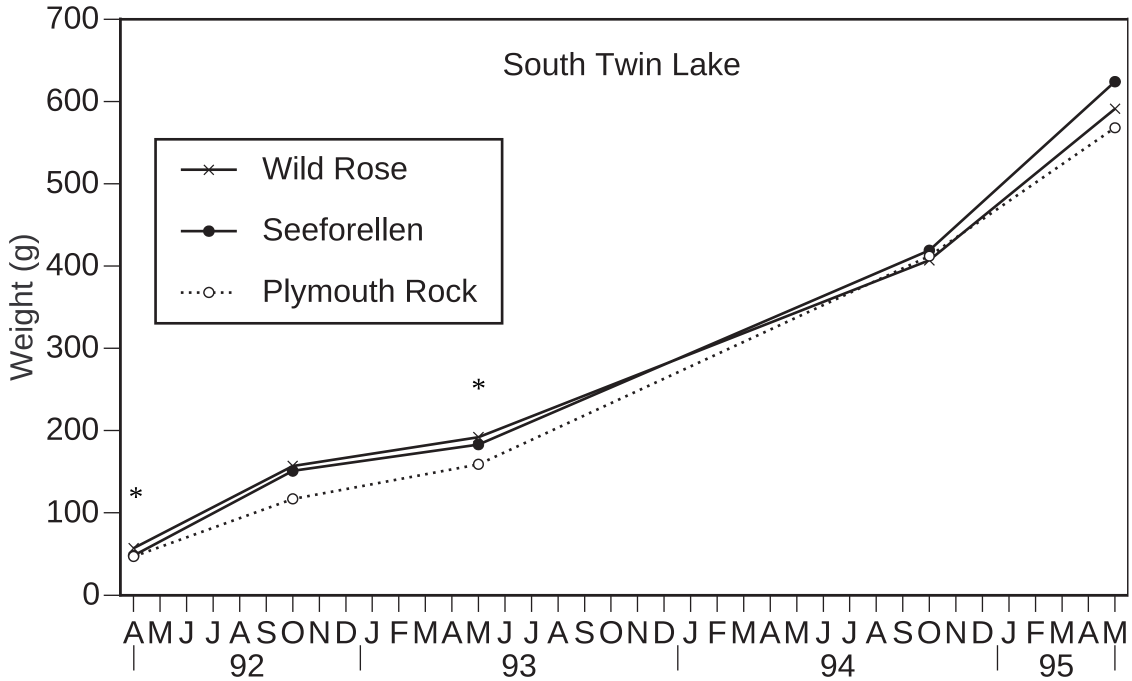


Figure 3.—Mean weight (g) for three strains of brown trout when they were stocked in April 1992 and at subsequent sampling periods in four study lakes. Asterisks indicate significant differences among strains during a sampling period.



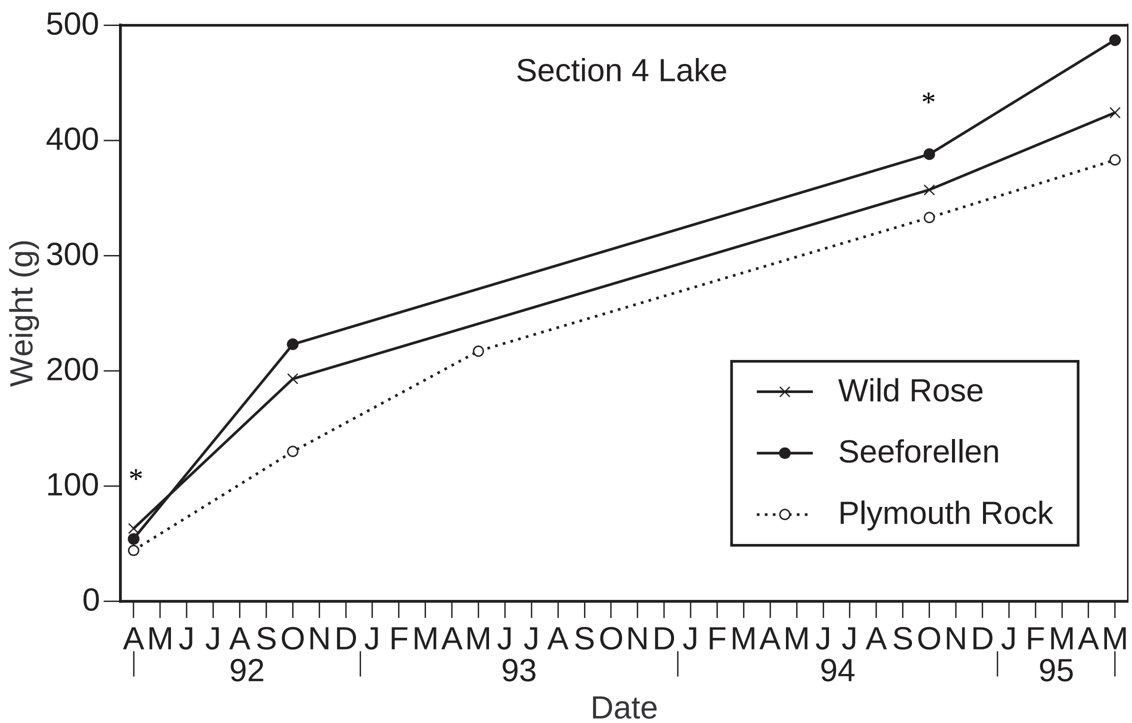


Figure 3.—Continued.

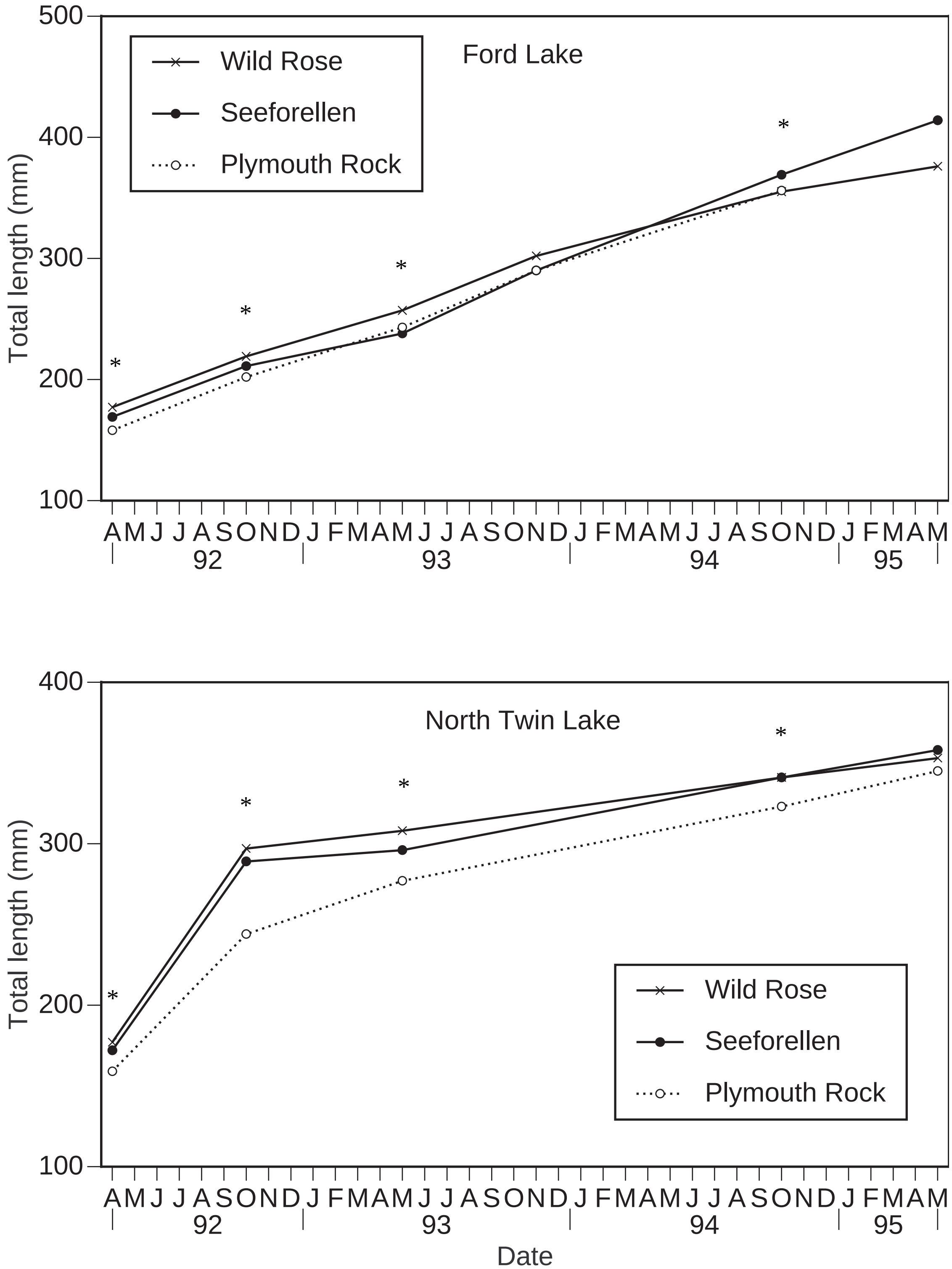
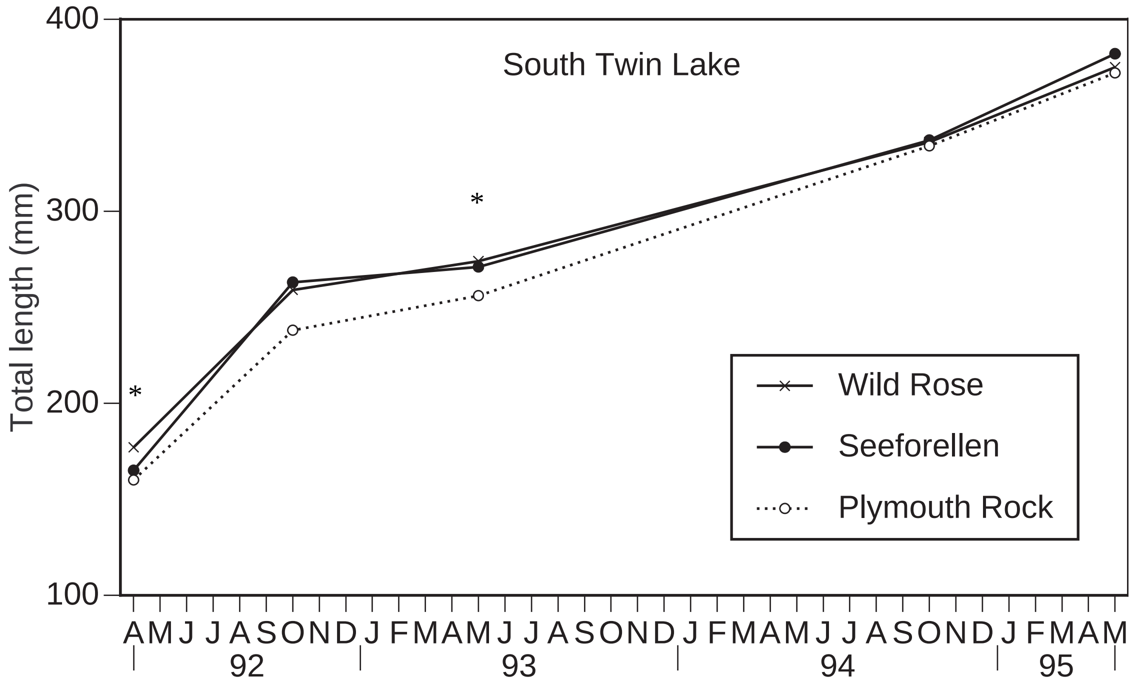


Figure 4.—Mean total length (mm) for three strains of brown trout when they were stocked in April 1992 and at subsequent sampling periods in four study lakes. Asterisks indicate significant differences among strains during a sampling period.



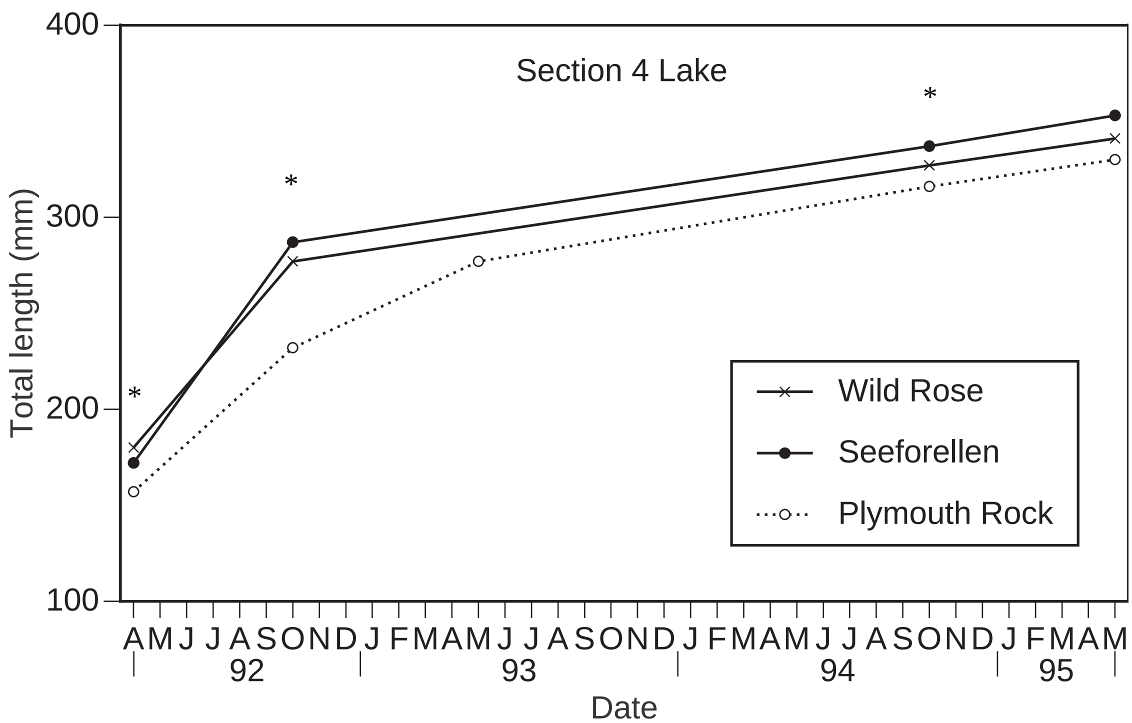


Figure 4.—Continued.

Table 1.–Mean total length (mm) and total weight (g) for three strains of rainbow trout at stocking and at subsequent sampling dates in two study lakes. One standard error is shown in parenthesis. Matching superscript letters in a row indicate which mean length estimates for strains were significantly different during a sampling period. Matching superscript numbers in a row indicate which mean weight estimates for strains were significantly different.

	Length of Each Strain			Weight of Each Strain		
Sampling period	SH	EL	STT	SH	EL	STT
				East Fish Lake		
April 1992	176 (1.1)[a] N=534	183 (1.1)[a,b] N=534	178 (1.5)[b] N=534	61(1.1) N=534	62 (1.1) N=534	62 (1.5) N=534
February 1993	331(3.1)[a] N=59	348 (3.5)[a,b] N=57	336 (2.9)[b] N=86	337(11)[1] N=59	394 (14)[1,2] N=57	343 (11)[2] N=86
April - May 1993	349 (4.2)[a] N=28	355 (6.7)[b] N=26	324 (4.6)[a,b] N=36	416 (17)[1] N=28	448 (21)[2] N=26	309 (10)[1,2] N=36
April - May 1994	407 (12.3) N=8	414 (6.2) N=26	396 (9.9) N=12	622 (73) N=8	685 (38) N=26	552 (33) N=12
October 1994	412 (3.2) N=44	420 (3.3)[a] N=72	409 (2.2)[a] N=138	632 (16) N=44	671 (15)[1] N=72	616 (10)[1] N=138
May 1995	450 (16.3) N=6	441(4.7)[a] N=35	417 (3.6)[a] N=25	869 (96)[2] N=6	861 (38)[1] N=35	665 (21)[1,2] N=25
				West Lost Lake		
April 1992	180 (2.4)[a] N=117	183 (2.6)[b] N=117	167 (4.0)[a,b] N=117	64 (2.5)[1,2] N=117	63 (2.5)[2] N=117	57 (3.8)[1,2] N=117
November 1992	282 (2.8) N=16	291 (5.9) N=14	277 (4.8) N=16	191 (5)[1] N=16	215 (8)[1,2] N=14	183 (7)[2] N=16
May 1993	293 (4.6) N=13	303 (4.1) N=20	299 (2.8) N=11	226 (12)[1] N=13	268 (11)[1,2] N=20	235 (6)[2] N=11
November 1993	333 (4.3)[a] N=11	359(10.8)[a,b] N=9	315 (6.3)[b] N=7	313 (10)[1] N=11	412 (41)[1] N=9	332 (21) N=7
October 1994	345 (3.3)[a] N=17	366 (3.4)[a,b] N=25	351 (3.5)[b] N=26	371 (9)[1] N=17	432 (9)[1,2] N=25	383 (10)[2] N=26
May 1995	373 (3.4) N=15	380 (5.3)[a] N=28	366 (2.9)[a] N=43	494 (22) N=15	504 (17)[1] N=28	451(13)[1] N=43

Table 2.–Growth increments of total length (mm) and total weight (g) for three strains of rainbow trout between stocking in April 1992 and subsequent sampling dates in two study lakes. Notation as in Table 1.

Sampling period	Length of Each Strain			Weight of Each Strain		
	SH	EL	STT	SH	EL	STT
			East Fish Lake			
February 1993	145 (2.3) N=57	151 (2.0)[a] N=57	138 (2.1)[a] N=72	267 (9.6)[1] N=57	317(11.3)[1,2] N=57	262 (8.9)[2] N=72
April - May 1993	160(4.7)[a] N=27	161 (4.9)[b] N=25	143 (4.8)[a,b] N=27	341(17.0)[1] N=27	373 (19.1)[2] N=25	246 (11.1)[1,2] N=27
April - May 1994	202 (17.2) N=7	215 (5.9)[a] N=23	179 (7.5)[a] N=8	517 (85.0) N=7	615 (41.8)[1] N=23	413 (18.6)[1] N=8
October 1994	225 (5.0) N=37	226 (3.7) N=54	217 (3.3) N=96	556 (18.5) N=37	600 (16.9)[1] N=54	546 (10.4)[1] N=96
May 1995	261 (29.1) N=3	251 (5.2)[a] N=26	213 (10.2)[a] N=12	727(174) N=3	811 (45.2)[1] N=26	569 (33.3)[1] N=12
			West Lost Lake			
November 1992	107 (5.8) N=13	94 (3.6) N=12	106 (8.1) N=13	131 (6.2) N=13	137 (4.9) N=12	129 (9.4) N=13
May 1993	127 (8.3) N=11	112 (3.0) N=16	125 (6.9) N=8	171 (15.9) N=11	203 (11.5) N=16	180 (8.2) N=8
November 1993	151 (8.4) N=8	160 (9.4) N=8	164 (26.7) N=2	236 (9.7)[1] N=8	310 (24.0)[1] N=8	256 (19.0) N=2
October 1994	180 (9.6) N=10	177 (7.4) N=17	181 (8.7) N=18	309 (13.1) N=10	369 (14.4) N=17	324 (17.4) N=18
May 1995	195 (10.2) N=9	183 (7.4) N=20	188 (6.5) N=28	413 (20.8) N=9	424 (19.6) N=20	387 (16.5) N=28

Table 3.–Population, standing crop (kg/ha) and percent survival for three strains of rainbow trout from stocking in April 1992 to gill net removal during October 1994 and May 1995.

	Rainbow trout strain								
	Shasta			Eagle Lake			Steelhead		
Date	Number per ha	Standing Crop	Percent Survival	Number per ha	Standing Crop	Percent Survival	Number per ha	Standing Crop	Percent Survival
East Fish Lake									
April 1992	82.0	5.0	N/A	82.0	5.1	N/A	82.0	5.1	N/A
October 1994[1]	7.7	5.1	9.4	16.5	12.1	20.1	25.2	15.7	30.7
West Lost Lake									
April 1992	82.0	5.2	N/A	82.0	5.2	N/A	82.0	4.7	N/A
October 1994[1]	22.6	9.7	27.6	37.4	17.6	45.6	48.7	20.7	59.4

[1] Data presented include trout collected with gill nets during May 1995. Thus, survival estimates are conservative estimates of survival through October 1994.

Table 4.–Number of rainbow trout of three strains that attempted to emigrate from East Fish Lake via the outlet stream from stocking in April 1992 through 1994.

	Rainbow Trout Strain			
Date	Shasta	Eagle Lake	Michigan Steelhead	Total
April 1992	22	27	17	66
May 1992	3	1	0	4
June 1992	2	0	0	2
July-December 1992	0	0	0	0
1992 Total	27	28	17	72
January-March 1993	0	0	0	0
April 1993	0	0	1	1
May 1993	1	0	7	8
June-December 1993	0	0	0	0
1993 Total	1	0	8	9
January-March 1994	0	0	0	0
April 1994	9	26	12	47
May 1994	1	1	2	4
June-December 1994	0	0	0	0
1994 Total	10	27	14	51

Table 5.–Mean total length (mm) and total weight (g) for three strains of brown trout at stocking and at subsequent sampling dates in four study lakes. Notation as in Table 1.

	Length of Each Strain			Weight of Each Strain		
Sampling period	WR	SF	PR	WR	SF	PR
Ford Lake						
April 1992	177 (1.1)[a,c] N=337	169 (1.3)[a,b] N=337	158 (1.4)[b,c] N=337	62 (1)[1,3] N=337	52 (1)[1,2] N=337	45 (1)[2,3] N=337
October 1992	219 (3.0)[a] N=25	211 (4.6) N=22	202 (3.8)[a] N=17	88 (4)[1] N=25	78 (4) N=22	70 (4)[1] N=17
May 1993	257 (3.4)[a] N=23	238 (10.3) N=7	243 (3.4)[a] N=29	165 (7)[1] N=23	135 (15) N=7	139 (6)[1] N=29
November 1993	302 (3.8) N=16	290 (10.7) N=5	290 (5.3) N=17	259 (10) N=16	235 (24) N=5	238 (12) N=17
October 1994	355 (2.6)[a] N=43	369 (3.5)[a,b] N=48	356 (2.5)[b] N=56	459 (9)[1,3] N=43	550 (16)[1,2] N=48	485 (10)[2,3] N=56
May 1995	376 (---) N=1	414 (---) N=1	No fish caught	652 (---) N=1	773 (---) N=1	No fish caught
North Twin Lake						
April 1992	177 (1.1)[b] N=157	172 (1.9)[a] N=157	159 (1.9)[a,b] N=157	62 (1)[1,3] N=157	53 (2)[1,2] N=157	44 (2)[2,3] N=157
October 1992	297 (6.4)[a] N=12	289 (4.7)[b] N=14	244 (7.4)[a,b] N=9	263 (16)[1] N=12	234 (10)[2] N=14	157 (12)[1,2] N=9
May 1993	308 (4.7)[a] N=16	296 (9.7) N=7	277 (3.4)[a] N=15	264 (14)[1] N=16	231 (23) N=7	201 (8)[1] N=15
October 1994	341 (2.5)[a] N=44	341 (3.5)[b] N=40	323 (2.5)[a,b] N=64	403 (9)[1] N=44	429 (14)[2] N=40	370 (8)[1,2] N=64
May 1995	353 (3.9) N=15	358 (5.0) N=9	345 (5.6) N=15	456 (17) N=15	469 (21) N=9	420 (21) N=15
South Twin Lake						
April 1992	177 (1.4)[a,c] N=134	165 (2.1)[a,b] N=134	160 (1.8)[b,c] N=134	57 (1)[1,2] N=134	48 (2)[2] N=134	47 (2)[1,3] N=134
October 1992	259 (6.0) N=13	263 (13.6) N=7	238 (5.8) N=5	157 (12) N=13	151 (19) N=7	117 (9) N=5
May 1993	274 (5.4)[a] N=21	271 (4.0) N=18	256 (3.8)[a] N=18	192 (10)[1] N=21	183 (6)[2] N=18	159 (6)[1,2] N=18
October 1994	336 (3.3) N=36	337 (4.0) N=25	334 (3.5) N=43	407 (12) N=36	419 (12) N=25	412 (13) N=43
May 1995	375 (4.7) N=18	382 (5.1) N=16	372 (4.9) N=16	591(21) N=18	624 (20) N=16	568 (21) N=16
Section 4 Lake						
April 1992	180 (1.3)[a,c] N=100	172 (2.3)[a,b] N=100	157 (2.2)[b,c] N=100	63 (1)[1,3] N=100	54 (2)[1,2] N=100	44 (2)[2,3] N=100
October 1992	277 (6.7)[a] N=6	287 (----) N=1	232 (1.3)[a] N=2	193 (18) N=6	223 (---) N=1	130 (7) N=2
November 1993	No fish caught	No fish caught	277 (1.5) N=2	No fish caught	No fish caught	217 (32) N=2
October 1994	327 (2.9)[a] N=26	337 (7.1)[b] N=15	316 (2.4)[a,b] N=42	357 (13) N=26	388 (31)[1] N=15	333 (8)[1] N=42
May 1995	341 (4.6) N=11	353 (8.4) N=10	330 (6.6) N=5	424 (22) N=11	487 (44) N=10	383 (27) N=5

Table 6.–Growth increments of total length (mm) and weight (g) for three strains of brown trout between stocking in April 1992 and subsequent sampling dates in four study lakes. Notation as in Table 1.

	Length of Each Strain			Weight of Each Strain		
Sampling period	WR	SF	PR	WR	SF	PR
			Ford Lake			
October 1992	38 (1.7) N=23	40 (2.8) N=20	40 (2.9) N=11	20 (2.8) N=23	26 (3.6) N=20	20 (3.4) N=11
May 1993	76 (3.4) N=20	82 (6.5) N=5	83 (3.6) N=17	102 (6.4) N=20	106 (9.7) N=5	95 (6.1) N=17
November 1993	125 (5.4) N=11	150 (21.7) N=3	126 (13.4) N=4	205 (10.9) N=11	229 (23.1) N=3	193 (34.0) N=4
October 1994	175 (4.8)[a] N=26	206 (7.7)[a,b] N=17	181 (5.2)[b] N=14	392 (12.6)[1] N=26	532 (34.1)[1,2] N=17	422 (23.9)[2] N=14
May 1995	---------No tagged trout caught---------					
			North Twin Lake			
October 1992	113 (5.6) N=10	114 (5.0) N=10	102 (6.5) N=7	189 (13.2)[1] N=10	183 (8.2)[2] N=10	129 (8.2)[1,2] N=7
May 1993	124 (3.9) N=13	126 (13.6) N=4	114 (4.0) N=9	190 (12.5) N=13	204 (22.5) N=4	156 (6.2) N=9
November 1993	---------Not sampled---------			---------Not sampled---------		
October 1994	160 (4.3) N=21	161 (8.1) N=18	161 (7.9) N=20	345 (13.1) N=21	365 (22.0) N=18	323 (17.3) N=20
May 1995	182 (3.5) N=8	183 (13.5) N=4	184 (11.4) N=6	406 (18.9) N=8	417 (37.8) N=4	404 (38.9) N=6
			South Twin Lake			
October 1992	78 (6.1) N=10	94 (8.2) N=6	86 (6.6) N=3	97 (13.7) N=10	99 (16.9) N=6	79 (4.5) N=3
May 1993	95 (4.6) N=17	102 (4.6) N=15	89 (2.8) N=15	133 (10.1)[1] N=17	130 (6.3) N=15	106 (3.5)[1] N=15
November 1993	---------Not sampled---------			---------Not sampled---------		
October 1994	161 (3.4) N=25	161 (6.6) N=17	174 (4.3) N=16	345 (11.6) N=25	351 (14.6) N=17	353 (12.8) N=16
May 1995	195 (5.7)[a] N=10	233 (7.3)[a,b] N=7	187 (11.8)[b] N=4	527 (25.7)[1] N=10	621 (24.7)[1,2] N=7	459 (37.8)[2] N=4
			Section 4 Lake			
October 1992	96 (9.4) N=4	114 N=1	66 N=1	135 (22.7) N=4	175 N=1	82 N=1
May 1993	---------Not sampled---------			---------Not sampled---------		
November 1993	---------No tagged trout caught---------					
October 1994	143 (5.5) N=13	164 (14.5) N=8	162 5.3) N=11	286 (15.9) N=13	327 (36.4) N=8	288 (8.2) N=11
May 1995	158 (5.8) N=5	168 (2.5) N=2	163 N=1	356 (28.8) N=5	401 (1.0) N=2	364 N=1

Table 7.–Population, standing crop (kg/ha), and percent survival for three strains of brown trout from stocking in April 1992 to gill net removal during October 1994 and May 1995.

	Brown trout strain								
	Wild Rose			Seeforellen			Plymouth Rock		
Date	Number per ha	Standing Crop	Percent survival	Number per ha	Standing Crop	Percent survival	Number per ha	Standing Crop	Percent survival
Ford Lake									
April 1992	82	5.1	N/A	82	4.3	N/A	82	3.7	N/A
October 1994[1]	11	5.0	13	12	6.6	15	14	6.6	17
North Twin Lake									
April 1992	82	5.1	N/A	82	4.4	N/A	82	3.6	N/A
October 1994[1]	31	12.9	38	26	11.2	32	41	15.7	50
South Twin Lake									
April 1992	82	4.7	N/A	82	3.9	N/A	82	3.9	N/A
October 1994[1]	33	15.5	40	25	12.6	30	36	16.4	44
Section 4 Lake									
April 1992	82	5.2	N/A	82	4.4	N/A	82	3.6	N/A
October 1994[1]	30	11.5	37	21	8.8	26	39	13.1	48

[1] Data presented include trout collected with gill nets during May 1995. Survival estimates are minimal estimates of survival through October 1994.

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