Differences in Swimming Performance Among Strains of Rainbow Trout *(Salmo gairdneri)*

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Swimming performance profiles, relating fish size to swimming time, were established for three strains of rainbow trout (*Salmo gairdneri*). No differences were found in slope of regressions; only in level at each size of fish. Swimming performances of New Zealand and Sand Creek strains did not differ, but were superior to the Manchester strain. In stamina results from

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189-day-old fish from individual matings of seven strains and various crosses, similar strains and crosses had closely matching profiles whereas profiles of unrelated groups were variable. Comparison of slowest, average, and fastest growing fish within the New Zealand strain showed that swimming ability was not related to growth rate.

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Nous avons determine les profils de performance de nage, faisant la relation entre la taille du poissonet le temps de nage, chez trois lignees de truite arc-en-ciel (*Salmo gairdneri*), Nous n'avons pas trouve de differences dans les pentes des regressions; seulement dans les niveaux a chaque taille de poisson. Les performances de nage des lignees de Nouvelle-Zelande et du ruisseau Sand ne different pas, mais sont superieures celles de la lignee de Manchester. Dans des tests d'endurance sur des poissons ages de 189 jours provenant d'accouplements individuels de sept lignées et de divers croisements, les lignees et croisements semblables ont des profils qui se correspondent etroitement, alors que les profils de groupes non apparentes sont variables. Une comparaison des poissons de la lignee de Nouvelle-Zelande a rythmes de croissance lent, moyen et rapide demontre que la performance de nage n'est pas lieeau rythme de croissance.

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Swimming performance of salmonids can be affected by factors such as disease, nutrition, stage of development, and rearing environment (Thomas et al. 1964; Fowler and Banks 1967; Thomas et al. 1969; Burrows 1964, 1969). Many authors have shown species differences in swimming performance between various salmon and trout, but differences between strains of the same species have rarely been considered. Usually only one strain is maintained at a location and comparisons would be confounded by stresses of transportation and differences in nutritional backgrounds and rearing environments. Apparent differences were noted by Thomas et al. (1964) between races of chinook salmon (*Oncorhynchus tshawytscha*) and by Green (1964) and Vincent (1960) between wild and domestic brook trout (*Salvelinus fontinalis*), but these groups had different environmental backgrounds. Differences between strains could be important in comparing results of different investigators, in understanding distribution among habitats within a species, and in designing fish passage and diversion equipment. Swimming performance of a number of strains of rainbow trout (*Salmo gairdneri*) has been investigated at the Fish Genetics Laboratory, Beulah, Wyoming, as one factor in the characterization of the strains. This report presents results of stamina determinations, (time that fish can maintain position in testing apparatus) on various strains under the same environmental and test conditions.

Materials and methods - Seven strains of rainbow trout and eight crosses between strains were evaluated in a stamina tunnel. A strain in this study is defined as a breeding population that has been geographically and reproductively isolated from other such populations long enough to be recognized as having distinct characteristics in growth pattern and life history. The strains tested were Manchester from the Manchester (Iowa) National Fish Hatchery, Wytheville from the Wytheville (Virginia) National Fish Hatchery, University of Washington and Donaldson strains from Seattle, Washington, DeSmet from Lake DeSmet in Wyoming, Sand Creek from spring ponds on the Fish Genetics Laboratory grounds (Wyoming), and New Zealand, which originated from eggs sent to New Zealand from California in the 1890s. In addition to large populations of different strains formed by multiple matings, individual matings were made of strains and crosses of various strains throughout the August–May spawning season, and small populations of fish from these matings were maintained for various growth evaluations. Of the three most abundant strains tested, the Manchester is a fast-growing, domesticated, fall-spawning strain, and the New Zealand and Sand Creek strains are more streamlined, grow slower, have had shorter periods of domestication, and spawn in the spring.

Fish of the Manchester, New Zealand, and Sand Creek strains were maintained in tanks 2 m diam and 0.3 m deep. Samples of 150 average-sized fish were taken from each strain population at 2-wk intervals throughout the rearing season and selected at random into three 50-fish groups for stamina testing. A number of 50-fish groups of the smallest and largest fish of the same age within the New Zealand population were compared with fish of average size. The groups were unfed and kept in trough compartments for at least 18 h before being tested (without change in water temperature) in the stamina tunnel. Groups varied from 8.7 to 28.5 g avg. wt. Larger fish were not used due to suspected effects of crowding in the rearing tanks.

Water temperature during rearing and testing was 12°C. The standard, open-formula trout diet (PR-6) used in Service hatcheries was fed to all groups with feeding frequencies and particle sizes determined by routine hatchery procedures.

Stamina of fish populations maintained from single matings — both pure strains and crosses — was tested under the same conditions except that tests were done only at 189 days of age and on two, rather than three, 50-fish groups.

A commercial model of the stamina tunnel, utilizing a recirculating, closed water system, described by Thomas et al. (1964) was used for all testing. Groups of fish placed in a Plexiglas® tube, 30 cm diam and 183 cm long, swam against a flow controlled by the differential in water level between the head and tail boxes. Flow rate was adjustable with a varidrive pulley and axial flow pump. Water temperature and oxygen content remained constant during testing. The testing procedure included 10-min orientation at 13.7 cm/s water velocity and stepwise increases of 3.7 cm/s each min until all fish were flushed from the tunnel. An electric field at the lower end of the tube induced the fish to continue swimming until exhausted. Exhausted fish were swept from the tube, tallied at 1-min intervals, and weighed at the completion of the test.

Average swimming time of each group was used to develop performance profiles (linear regressions). A stamina rating allowing direct comparisons between fish of different sizes has been developed using the formula $Pe = a + b\sqrt[3]{w}$, where Pe represents expected performance, a the value of the performance when the weight is 0, b the increase in performance for each cube weight gain, and $\sqrt[3]{w}$ the average cube root of the group. Performances were adjusted according to stamina ratings of the Manchester strain, which was assigned an expected performance rating (Pe) of 100. Ratings of individual fish groups were based on the formula 100 (Po)/Pe, where Po is the observed performance of that group.

Results and discussion - Performance of different strains — Performance profiles were expressed as linear regressions (Fig. 1A) and represent results from 1500 fish (30 groups) for the Manchester strain, 1250 fish (25 groups) for the Sand Creek strain, and 1650 fish (33 groups) for the New Zealand strain. In this manner, the expected performance (swimming time) of a specific-sized fish (cube root) could be determined for each strain.

All regressions in Fig. 1A were highly significant. Analysis of covariance revealed these relations: 1) slopes of the three profiles were not significantly different, 2) differences in levels of perfoimance of Manchester and New Zealand strains and of Manchester and Sand Creek strains of any given size were highly significant, and 3) performance of New Zealand and Sand Creek strains was not significantly different. The swimming ability of the Manchester strain was less than that of the other strains for all sizes of fish tested.

For approximately 210 groups stamina results were compared with performance profiles for the

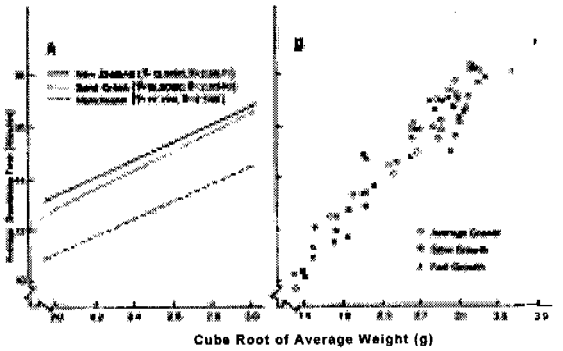
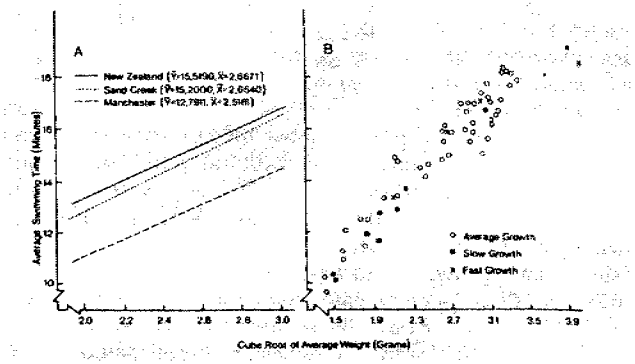


FIG. 1. A, Performance profiles for three strains of rainbow trout (*Salmo gairdneri*); B, Swimming performances of slow-, average-, and fast-growing fish from the New Zealand strain. All fish were the same age.

Manchester, New Zealand, and Sand Creek strains shown in Fig. 1A. Manchester, Wytheville, or Manchester–Wytheville crosses closely fitted the Machester performance profile, whereas New Zealand and Sand Creek strains, and crosses of the two, closely fitted the New Zealand and Sand Creek profiles. Groups which were Donaldson-DeSmet, DeSmet–Sand Creek, Donaldson-University of Washington, and Donaldson-DeSmet-University of Washington crosses also fitted the New Zealand and Sand Creek profiles. A few groups of University of Washington and DeSmet-Sand Creek–Donaldson strains had intermediate performance between the Manchester and New Zealand profiles. Fifteen tests of groups from Sand Creek–Donaldson crosses resulted in scattered performances; some were near each profile and some between them. Other types of crosses either did not survive to the 189-day evaluation period or could not be made due to differences in spawning time.

In addition to velocity profiles, we compared stamina ratings for 15.6-g fish of the Manchester, New Zealand, and Sand Creek strains, using the Manchester performance profile as a base (15.6 g was the average weight of the fish used to develop all three profiles). Stamina ratings were 100.0, 117.6, and 115.0 for the Manchester New Zealand and Sand Creek strains, respectively. Average swimming time values for the fish were 12.7, 15.0, and 14.6, respectively.

Effect of growth rate on performance — The rapidly growing Manchester strain had lower swimming ability than the slower growing New Zealand and Sand Creek strains. To determine whether swimming ability for these strains was due to growth rate rather than genetic differences, we compared the fastest and slowest growing fish


A
B
New Zealand (Ŷ=15,5090, X̄=2.6671)
Sand Creek (Ŷ=15,2000, X̄=2.6540)
Manchester (Ŷ=12,7911, X̄=2.5161)
Average Growth
Slow Growth
Fast Growth
Average Swimming Time (Minutes)
Cube Root of Average Weight (Grams)

within the New Zealand population (of identical age) with fish of average growth rate (Fig. 1B). No major variation from that of average-sized fish was apparent.

The performance profiles show that the streamlined, semiwild strains (New Zealand and Sand Creek) had better relative swimming ability than the deeper-bodied, domesticated Manchester strain. Such information should be useful in fishery management. The better-swimming strains could be stocked in stream environments where swimming ability would be important to survival and the faster-growing Manchester strain could be restricted to lakes and "put-and-take" fisheries where rapid growth is of major importance. The slope of the Sand Creek profile varied somewhat from the other two (not significantly), and was probably influenced by fewer small-sized fish being tested.

Results from the 189-day individual groups confirmed the reliability of the performance profiles. Since the fastest and slowest growing fish in the New Zealand strain had results that did not vary from their performance profile, we concluded that differences in swimming ability between strains were not related to growth rate.

The performance ratings presented for 15.6-g fish should be valid for any sized fish since there was no significant difference in the slope of the performance profiles. The mean fish weight of the three strains was used to compare the performance ratings with the average swimming time values. The actual swimming time values would vary depending upon fish size but the relationship between the three strains should remain constant.

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