**Section 5**

# DEVELOPMENT OF A RACEWAY EXERCISE SYSTEM FOR FALL CHINOOK SALMON

by

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## Introduction

Fish culturists may be able to increase salmon postrelease survival by exercising them in high velocity currents prior to release. Salmonids are typically reared in raceways with velocities of 1 cm/s, or less, designed to settle out pathogen-containing feces and debris (Pennel and McLean 1996). Research has demonstrated that the exercise provided by higher velocity currents (> 5 cm/s) has several benefits for cultured fish. Exercised salmonids both grow faster and have better food conversion than conventionally-reared fish (Christiansen et al. 1989, Christiansen and Jobling 1990, Christiansen et al. 1992). Regular exercise also improves swimming performance (Besner and Smith 1983, Leon 1986, Schurov et al. 1986a) and should enhance the ability of fish to escape predators. Most importantly, the postrelease survival of exercised fish has generally (Burrows 1969, Wendt and Saunders 1972, Cresswell and Williams 1983, Leon 1986, and Schurov et al. 1986b), but not always (Lagasse et al. 1980, Evenson and Ewing 1993), been higher than that of unexercised fish. These benefits are usually generated by exercise programs which force salmonids to swim at velocities greater than one body length/second for 1 hour a day for at least a 2-week period.

The preferred approach would be to exercise salmonids in high velocity single-pass raceways which flush pathogens and debris out of the vessel. However, for smolt-size fall chinook salmon, the generation of one body length/second (about 8 cm/s) exercise velocities in single-pass raceways usually produces unacceptable fish culture and water use conditions. For example, lowering water depth in a standard raceway to produce exercise velocities of one body length/second will increase rearing density by a factor of five or more. Alternatively, increasing water flow to a standard raceway by the five or more times required to generate exercise velocities produces plumbing, pumping, and water consumption costs most existing facilities cannot support. Finally, even the combination of these approaches may fail to achieve the one body length/second exercise velocity required by yearling salmonids.

The 16-cm/s exercise velocity required by a 30-g (15-cm fork length) yearling salmonid can be achieved in multi-pass systems (e.g., circular tanks and Burrows ponds). However, the replacement of existing standard raceways with these types of vessels would be economically unacceptable. Therefore, a recirculating design, similar to the Burrows pond, was developed that can be retrofitted to existing raceways. This report describes both: 1) design and operational parameters of this exercise system retrofitted to a rectangular tank, and 2) some preliminary effects of the system on fall chinook salmon.

## Methods

The prototype recirculating design was installed and tested in six rectangular troughs at the Manchester Research Station freshwater salmon culture facility. The design uses the energy from inflowing water and low-energy pumps to circulate water around a central partition. Semi-elliptical screens are fitted to each end of the raceway to reduce the resistance of angled corners. Both the reduced cross-sectional area and the principle of inertia enable this design to produce

the swift water velocities needed to exercise yearling chinook salmon. Each trough (5.5 × 0.6 × 0.6 m deep) was operated with a 0.3-m water depth (Fig. 1). The center of each trough was divided by a long aluminum divider (4.9 m) which ran parallel to the trough sides. There was an open space of 29.2 cm between the divider and each end of the trough. Semi-elliptical drain screens fabricated from perforated plate were fitted to each end of the trough to smooth out water flow. A dual inlet system delivered water to the center of the trough parallel to each side of the divider, generating a clockwise flow pattern within the trough. Two powerhead pumps (75 W) were installed in the tank to boost the recirculating flow around the divider. Water drained from the trough via holes (5.1 cm in diameter) located in each of the four bottom corners.

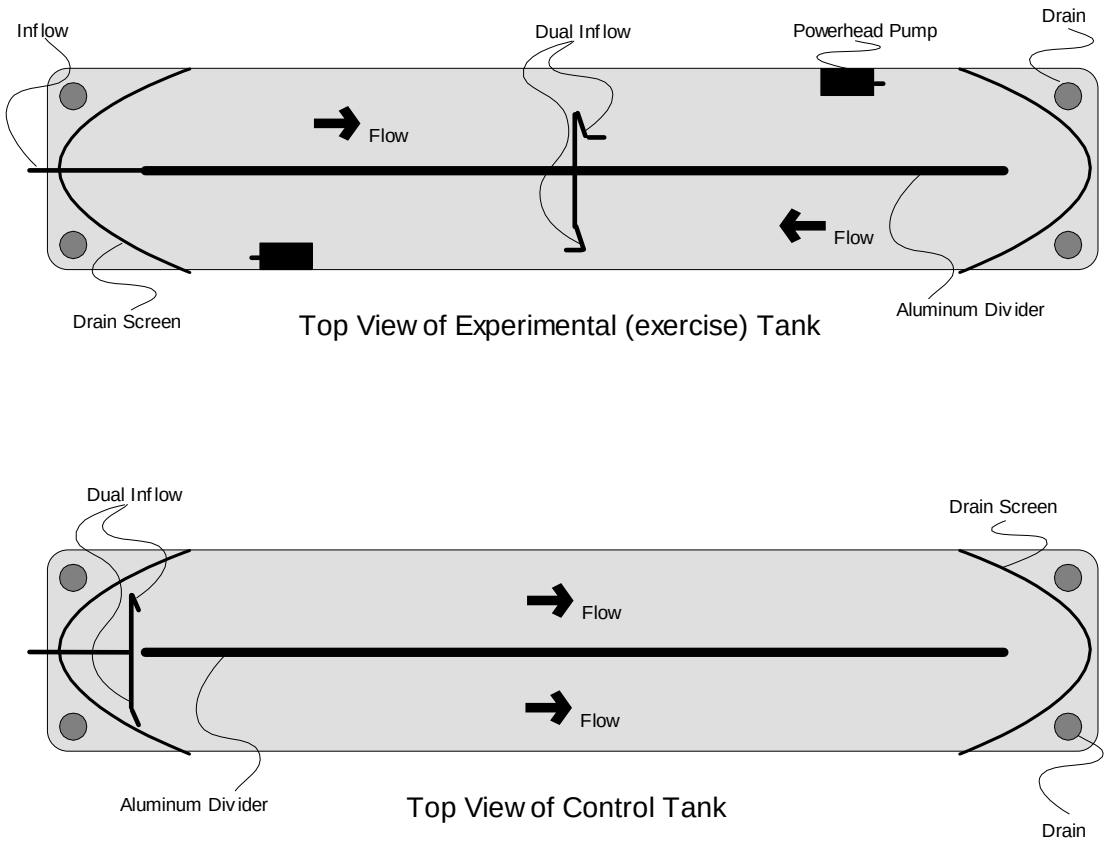


Figure 1. Top view of control and exercise troughs.

In summer 1998, a preliminary experiment on the effects of exercise on juvenile fall chinook salmon was initiated. The research was conducted in 12 rectangular troughs, half of which were designated as control troughs and the other half as exercise treatment troughs. The study was conducted with fall chinook salmon obtained from the WDFW Minter Creek Hatchery as swim-up fry that were reared in the NMFS Beaver Creek freshwater raceways until the fish were placed in the study. Seven hundred and fifty underyearling fall chinook salmon were

ponded into each of the 12 raceways on 1 July 1998. A single pump was installed and turned on in each raceway on 13 July 1998. On 23 July 1998 the second pump was turned on. On 5 August 1998 a current velocity meter was used to record current velocity three times at six locations in the raceways with both pumps on.

Each trough was supplied with raw Beaver Creek surface water (at least 40-L/min) which normally carries a variety of salmonid parasites and pathogens. The treatment group was exercised 24 hours a day for a 14-day period in water velocities of 18.0 to 38.3 cm/s. The controls were never exposed to water velocities greater than 1 cm/s, except during the occasional brief draw-downs which occurred when the troughs were cleaned. In mid July, a pathogen outbreak (pathologists did not diagnose cause) resulted in increased mortality in the exercise troughs. On 27 July 1998, the exercise regimen was cut back to only 2 h/d. This new protocol was continued for an additional 60 days, until postrelease survival could be evaluated. Except for the exercise regime, the handling and husbandry of fish in both treatments was identical and followed standard salmon culture protocols.

Although there was concern that the pathogen outbreak might confound the results, it was decided to go forward with the postrelease survival evaluation. The effect of the rearing treatments on postrelease survival was compared by releasing fish from both treatments into Olalla Creek (a local Kitsap County stream). Fish were recaptured at a temporary fish collection weir (47° 25' 35" N and 122° 34' 19" W). For these evaluations, a representative sample of 80 fish from each trough was anesthetized in tricaine methanesulfonate (MS-222) and marked with a visible green microsphere photonic tag injected with the aid of compressed $CO_2$ and a panjet inoculation gun into one of the pelvic fins. Control fish were tagged on the left fin, while exercised fish were tagged on the right fin. Prior to release, all fish were checked to ensure the tag was retained. After being allowed time to recover from the effects of tagging, an equal number of fish from both treatments were combined into a common hauling container and trucked to a release site at least 0.5 km above the weir. Two releases (9 and 11 September 1998) were made into Olalla Creek (47° 27' 4" N and 122° 34' 44" W) for a total of 413 tagged test and control fish released (826 total fish released). The weir was checked daily and the number of fish with left or right pelvic marks recorded. The recaptured fish were then released downstream from the weir. On 29 and 30 September 1998, several sections of Olalla Creek were electrofished. The weir was kept in operation through 30 September 1998. The postrelease survival of fish from the two treatments was compared with a 2 × 2 contingency table analysis.

## Results

The current velocities in the control troughs were less than 1 cm/s. Without fish present the current velocities in the experimental troughs ranged from 9.1 cm/s to 24.4 cm/s. The addition of fish to the experimental trough nearly doubled the current velocities, producing flows which ranged from 18.0 to 38.3 cm/s (Fig. 2).

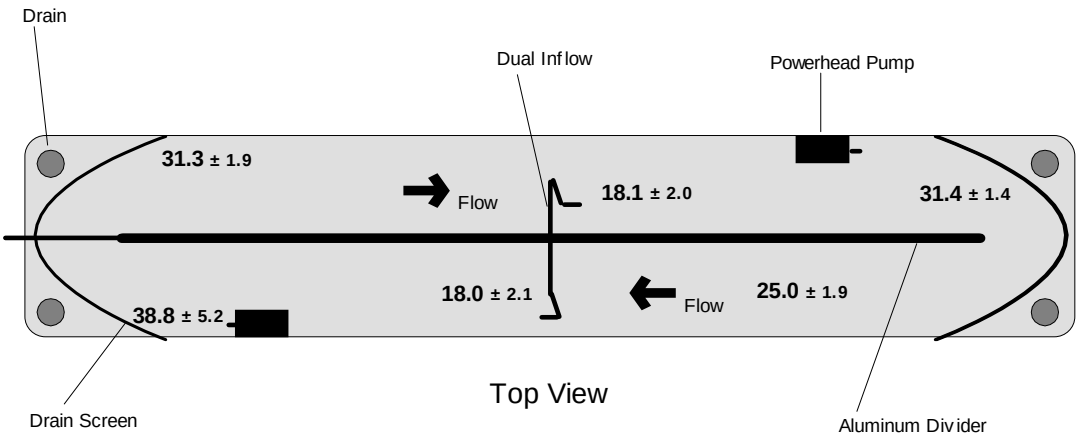


Figure 2. Mean current velocities (cm/s, n = 3) with standard deviations, as measured in exercise troughs with fish present.

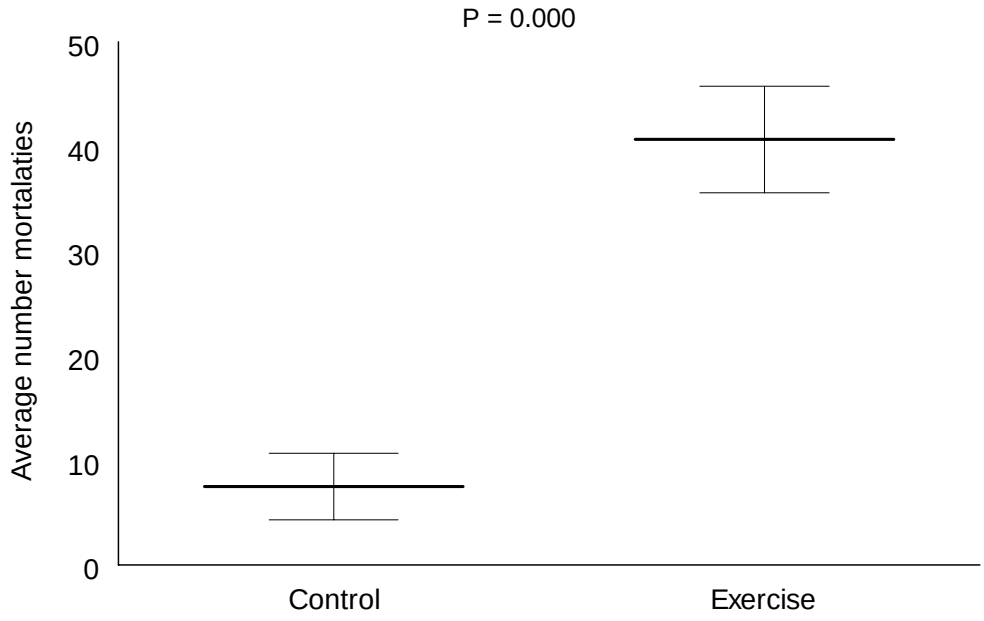


Figure 3. Average in-culture mortality (mean with standard error bars) in control (n = 6) and exercise (n = 6) troughs through 31 August 1998. Probability values (P) are based on *t*-tests.

The surface water supply to the rearing facility was warm (12.6 - 18.6° C) during the study period. The pathogen outbreak that occurred produced mortality that was statistically significant ($P < 0.001$) and four times higher in the exercise than non-exercise troughs (Fig. 3). This higher mortality rate within the exercise troughs continued during the late July and early August period when the exercise program was temporarily suspended and the fish were fed teramycin feed and given a formalin bath.

Control and exercised fish grew at similar rates. When the fish were tagged, exercised fish were slightly, but not statistically significantly ($P = 0.242$), shorter than control fish (Fig. 4).

The postrelease recovery of both exercised (15.3%) and non-exercised (16.2%) fish was similar and very low (Fig. 5). There was no significant ($P = 0.702$) survival difference detected between the two rearing treatments.

## Discussion

The exercise system successfully generated current velocities that could be used to exercise chinook salmon. Even the low-end velocity of 9.1 cm/s was sufficient to exercise a typical 5-g fall chinook salmon smolt at more than one body length per second. The 18.0 cm/s velocity was sufficient to exercise a 30-g spring chinook salmon smolt at more than one body length/s. In the study, two 75-W pumps were used to produce the exercise velocities in each 0.09 $m^2$ cross-sectional area raceway. This suggests that, to achieve similar velocities in a production raceway, it would require about 1,666 $W/m^2$ of cross-sectional area. Thus, a standard 8' × 80' (2.4 × 24.4-m) raceway with 0.6 m of water depth would require only 1,200 W of electrical energy to generate similar velocities (roughly equivalent to a small portable electric space heater). A standard 10' × 100' (3.1 × 30.5 m) raceway, with 0.9 m of water depth, would require only 2,250 W of electrical energy. The key to this energy efficiency is the use of inertia and the tendency of water to push-pull itself around the central barrier.

The increased mortality associated with fish reared in the exercise troughs is of major concern. It is not clear if the increased mortality was due to physical stress associated with exercise or the multi-pass nature of the flow in the experimental troughs. In either case, it was clear that, that under the study conditions, exercising salmonids in the system was detrimental to their health. If there was a beneficial effect of exercise it was masked by the pathological problems experienced by the exercised fish. The study is currently being repeated with a less extreme exercise regime which, hopefully, will produce different results.

In summary, it is possible to achieve exercise velocities in raceways which are economic in terms of energy costs. However, from these preliminary results, it is not possible to draw any conclusions regarding the benefits of exercise in multi-pass systems. Future research should identify which exercise protocols are most useful for improving postrelease survival without the risk of losing fish to outbreaks of pathogens.

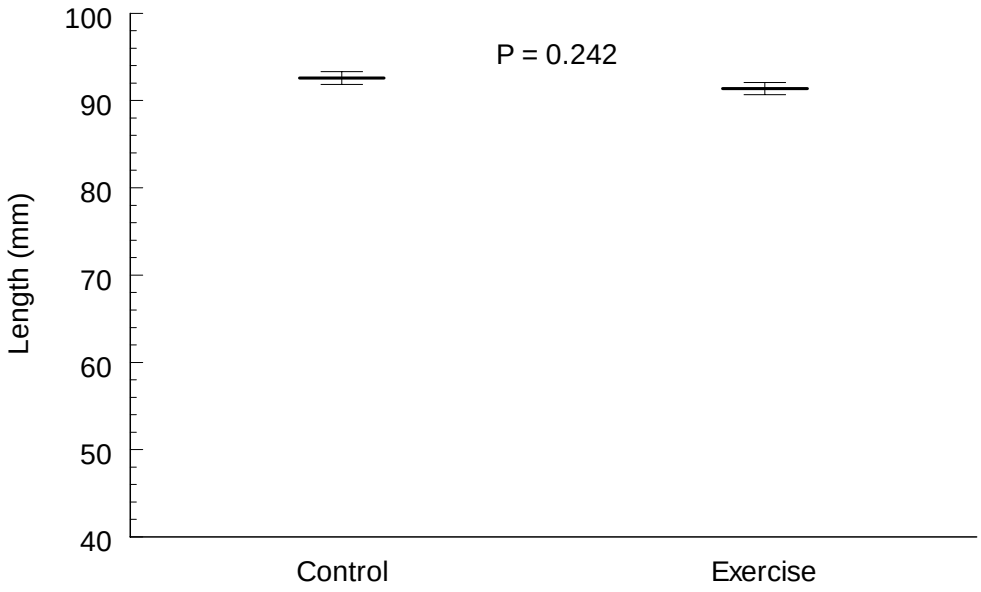


Figure 4. Mean fork length (with standard error bars) of control (n = 120) and exercised (n = 120) fall chinook salmon at tagging. Probability values (P) are based on *t*-tests.

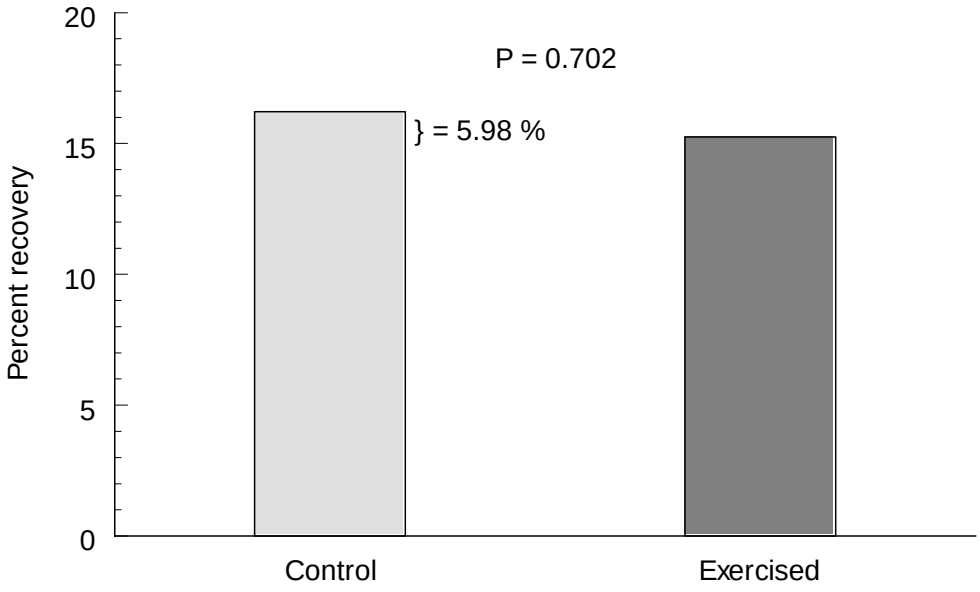


Figure 5. Percent recovery of control and exercised fish at Olalla Creek weir. Probability values (P) are based on chi-square analysis.

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