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NOTES

Comparison of Midsummer Survival and Growth of Age-0 Hatchery Coho Salmon Held in Pools and Riffles

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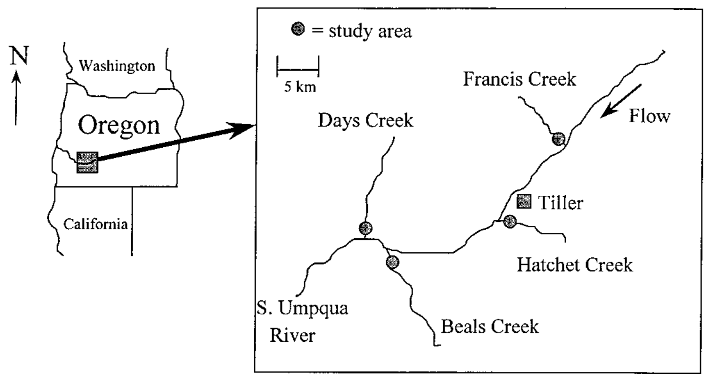

FIGURE 1.—The locations of the four study streams within the South Umpqua River basin, southwestern Oregon.

Study Sites

The study was conducted on the lower 1 km of four different tributaries to the South Umpqua River, Oregon (Figure 1). Elevations ranged from 247 m to more than 396 m. Historically, the dominant upland vegetation in these basins was Douglas fir *Pseudotsuga menziesii.* Riparian areas contained maple *Acer* spp., alder *Alnus* spp., and blackberry *Rubus*

TABLE 1.—Habitat characteristics of the pools and riffles of the four study streams. Values are means, with standard errors in parentheses.

Characteristic	Francis	Hatchet	Days	Beals
Pools				
Depth (m)	0.19 (0.018)	0.14 (0.010)	0.15 (0.011)	0.13 (0.011)
Substrate (m)	0.05 (0.004)	0.02 (0.005)	0.01 (0.002)	0.02 (0.003)
Velocity (m/s)	0.08 (0.014)	0.07 (0.013)	0.08 (0.009)	0.04 (0.007)
Riffles				
Depth (m)	0.07 (0.005)	0.06 (0.004)	0.09 (0.004)	0.05 (0.005)
Substrate (m)	0.06 (0.004)	0.04 (0.007)	0.03 (0.004)	0.03 (0.002)
Velocity (m/s)	0.16 (0.018)	0.17 (0.024)	0.18 (0.021)	0.14 (0.016)

havior, growth, and survival of the study fish could be altered by the presence of another species (Resetarits 1995; Harvey and Nakamoto 1996). Excluding all the electrofished animals reduced the potential confounding effects from other fish species and provided the most standardized baseline for evaluating the influence of habitat type on coho salmon survival and growth, especially in the South Umpqua River basin where fish densities differ significantly within and among habitat types and streams (Roper 1995; Kruzic 1998). Chicken wire (2.5-cm mesh) was placed above the uppermost block net of each stream to catch debris.

Age-0 coho salmon (mean length 82.3 mm, mean weight 7.2 g) were obtained from the Oregon Department of Fish and Wildlife's Butte Falls Hatchery (South Umpqua River basin parent stock) and stocked at 1.0 fish/m^2 (20 fish per pool or riffle) into the block-netted areas on July 17, 1996. We used hatchery coho salmon because sufficient numbers of wild coho salmon could not easily have been collected for the study. Using hatchery fish, which were raised under identical conditions, also reduced the potential biases associated with using wild coho salmon, which would have been collected predominately from pools. The density of the coho salmon was slightly higher than that typically found in streams of the upper South Umpqua River basin (Roper 1995), but it represented an intermediate value in the density range reported in Pacific Northwest streams (Chapman 1962; Bisson et al. 1988a; Nielsen 1992; Rodgers et al. 1992). We stocked both riffles and pools at the same density per unit of area in order to evaluate the effect of habitat type. Because juvenile coho salmon do not typically position themselves directly above conspecifics in the water column in the South Umpqua River basin (L. M. Kruzic, personal observation), stocking pools and riffles at the same density would provide the same amount of usable area (Sullivan 1986). All fish were anesthetized in 0.05 g/L tricaine methanesulfonate (MS-222; trade name Fintrol) and individually measured to the nearest millimeter of fork length (FL) and weighed to the nearest 0.1 g before being stocked. All of the 20 surplus fish that were put into a live well in one stream and retained for 2 d survived.

During the first week after the fish were stocked, the block nets were checked daily to remove debris and ascertain fish mortalities. After the first week, the block nets were checked every two to 4 d. Fish were held in the block-netted areas until August 19–21, 1996, or slightly more than one month, at which time the enclosed areas were again sampled with electrofishing (three passes) to recover the stocked coho salmon. Fish were enumerated and measured again for length and weight. Because of the different dates on which the fish were collected, all lengths and weights were standardized to 35 d.

The pools and riffles in between the block-netted units and upstream and downstream of the study area were also electrofished in an attempt to recover hatchery coho salmon that might have escaped from the block nets. Based on the movement patterns of age-0 coho salmon in the South Umpqua River basin (Kruzic 1998), the areas sampled should have been sufficient to recapture fish that escaped. Hatchery coho salmon could be distinguished from wild coho salmon because they were 10–30 mm longer, exhibited greater condition factor, and did not have well-defined parr marks. No hatchery coho salmon were recovered outside the block-netted areas, so it was assumed that all fish not recovered died within the block netted area or were lost to predation.

Twenty randomly selected measurements of depth, substrate size, and mean water velocity were obtained in each of the block-net areas to quantify the habitat conditions (Table 1). Depth was measured to the nearest 0.01 m, and substrate size was determined by averaging three measurements of the intermediate-length axis of the piece of substrate. Mean depth was calculated by averaging all depth measurements, and maximum depth was the maximum depth recorded at the random locations. Mean velocity was obtained with a Price-type ''mini'' flowmeter placed at 0.6 the

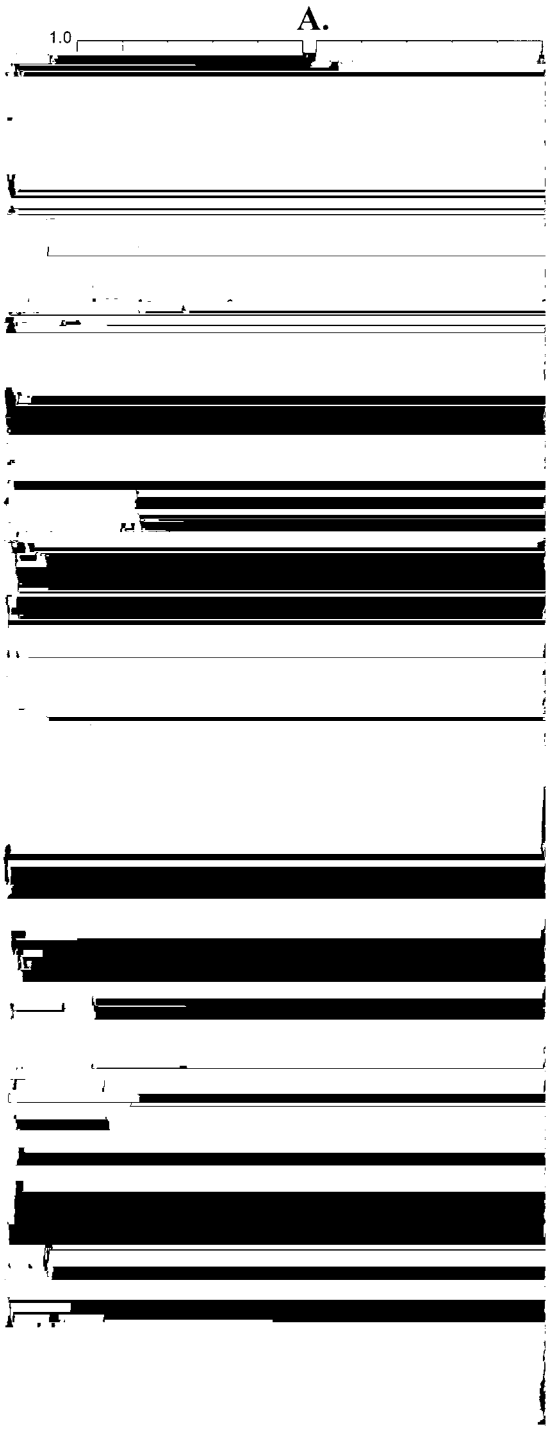

FIGURE 2.—Responses of coho salmon in terms of survival, change in mean length, change in weight, and change in condition factor by habitat type (pool or riffle) in Francis, Hatchet, Days, and Beals creeks. Means (6SE) are reported. Asterisks indicate a significantly

Growth

At the start of the experiment, the length and weight of the coho salmon stocked into pools were not significantly different from those of the fish stocked into riffles (ANOVA: *P* 5 0.39). Fish lengths did not change significantly over the course of the study (ANOVA: *P* 5 0.11): the mean length of coho salmon stocked into pools increased less than 1 mm, while that of fish stocked into riffles decreased 2 mm (Figure 2b). However, the difference between the changes in length experienced by the two groups of fish was significant (ANOVA: *P* 5 0.04). On average, the fish weighed less at the end of the experiment than when they were stocked, but the weight changes were not found to be related to habitat type or stream (ANOVA: *P* . 0.20; Figure 2c). Because the mean weight of fish decreased in both pools and riffles, production (g/m^2) was negative. The length-frequency distributions of the two groups of coho salmon were not statistically different at the beginning and end of the experiment (x^2 , 2.0; df 5 6; *P* . 0.05).

Condition Factor

The condition factor of fish stocked into pools was not significantly different from that of fish stocked into riffles at the start of the experiment (ANOVA: *P* 5 0.96). On average, the condition factor decreased throughout the study for all fish (ANOVA: *P* , 0.05), but no significant differences were found between the change experienced by fish occupying riffles and that experienced by fish occupying pools (ANOVA: *P* 5 0.08; Figure 2d). However, the condition factor did change depending on the stream where the fish were stocked (ANOVA: *P* , 0.01). The fish stocked into the riffles of Beals Creek constituted the only group for which condition factor increased throughout the study period (Figure 2d). The change in these fishes' condition factor was significantly greater (ANOVA: *P* , 0.02) than it was for all other groups, except for fish stocked into the pools of Beals Creek (Figure 2d).

Discussion

Previous studies have shown the distribution and density of fish to be influenced by the habitat

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(*P* , 0.05) higher response for a particular habitat type. Where interaction effects (habitat type 3 stream) occurred, means with different letters are significantly (*P* , 0.05) different.

characteristics of the stream (Bilby and Bisson 1987; Meehan 1991; Beechie et al. 1994). Sullivan (1986) showed that only a proportion of the available habitat is within a tolerable range for juvenile coho salmon, that range being defined by combinations of water depth, velocity, and substrate. Coho salmon were distributed in direct proportion areas where pool habitat has been degraded, causing greater emigration rates and lower production for juvenile coho salmon in natal streams (Bilby and Bisson 1987; Fausch and Northcote 1992). Restoring complex pool habitat in small streams is essential to conserving and recovering many imperiled coho salmon stocks throughout the Pacific Northwest and California.

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