Title
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Abstract

Road culverts located on federal, state, and private lands currently block upstream passage of juvenile salmon to thousands of miles of suitable juvenile rearing habitat. Washington State Department of Transportation (WSDOT), in cooperation with partner state and federal agencies, is currently leading a cooperative program to study juvenile salmonid passage through culverts by systematically conducting statistically designed experiments in full-scale culvert systems at the Culvert Test Bed (CTB).

The overall goal of the CTB program is to identify culvert configurations and the associated hydraulic conditions that facilitate successful upstream passage of juvenile salmonids. Previous studies have used juvenile coho salmon to examine the factors influencing passage success and leaping ability. This study begins research focused on retrofitted culverts. A retrofitted culvert is one in which the bed characteristics of an existing culvert are modified or engineered to improve fish passage. The main objectives of this study were to determine the passage success of juvenile salmon swimming through a series of configurations baffles under different culvert slopes and water flow conditions and to relate fish passage success to culvert slope, water flow, water velocity, turbulence intensity, water depth, and other hydraulic parameters for the installed retrofit design.

In 2005 and 2006, testing was conducted using a culvert-baffle configuration commonly used in Washington to enhance upstream adult salmonid passage. The primary question to be addressed is what passage success is achieved for juvenile salmon with this standard culvert-baffle configuration. The fish-passage tests evaluated passage success in a 40-ft corrugated culvert with three weir baffles at one culvert slope (1.14%) and over five flows conditions (1.5, 3, 6, 8, and 12 cfs). In addition, a full hydraulic analysis of flow conditions inside the CTB was conducted.

The relationships between natural logarithm of passage success of juvenile coho salmon (94 mm to 104 mm) and culvert discharge were statistically significant and curvilinear for all three configurations. For the configuration without baffles, passage success was about 40% at 1.5 cfs, increased to about 70% at 3 cfs, and then decreased to less than 10% at 12 cfs. The curves for configurations without baffles and with baffles and elevated backwatering condition did not differ significantly. Both these curves were significantly greater than the curve for the configuration with baffles and standard backwatering condition. Backwatering influences passage success through baffled culverts and will need to be considered as an experimental variable in future tests.

Differences between our results and other research results indicate that fish size has substantial influence on passage success and that these tests will need to be repeated for smaller juveniles. The lower passage success at 1.5 cfs relative to the higher flows both with and without baffles indicates that the lower passage success at 1.5 cfs is not a function of baffling conditions, i.e., baffles or no baffles, but rather is due to some aspect of culvert discharge. More exploratory behavior was observed at 1.5 cfs than at higher flows. The observations also suggest that consistent upstream movement may require a cue that is associated with higher flows. The nature of the cue is not known but could be related to higher velocities, greater depth, or more distinct low-velocity pathways.

Behaviors associated with successful upstream passage were more complex with baffles than without baffles. A significant quadratic relationship between the probability of passage success and the number of entries was found for all configurations at flows above 1.5 cfs. These relationships suggest that fish may be achieving the same level of passage success for less effort in the baffled configuration. The behavioral observations indicate that the fish use low-velocity pathways to accomplish passage and that these pathways differ between the baffled and unbaffled conditions and perhaps differ with flow for the baffled condition. The fish appear to be able to find and use low-velocity pathways to accomplish the passage in several different settings.

Overall, the results obtained thus far in the culvert test bed system demonstrate that the juvenile coho salmon have remarkable abilities to adapt their behavior to accomplish upstream passage in different system configurations and under different flows. The fish appear able to find and use low velocity pathways to accomplish the passage.