Executive Summary of the Evaluation of Predictive Models for Upstream Fish

Passage Through Culverts

Master's Thesis by J. Seth Coffman

(For a complete description of methodology and analysis
refer to the full thesis document)

Fish diversity in the United States has been declining because of pollution, invasive species, and continual habitat degradation and fragmentation. Recent studies have shown that culverts at road crossings can fragment habitat by acting as barriers to the upstream movement of fishes. This prevents essential spawning migrations and inhibits recolonization of streams after natural or anthropogenic disturbances. With over 50,000 road crossings on eastern National Forest lands, these crossings can represent a serious threat to the viability of native fish fauna. Currently, there are few predictive models or software available that address fish passage through culverts, and those models have not been validated with field experiments. I developed 3 models for fishes common to the Mid-Atlantic Highlands region of the United States that predict whether a culvert is impassable or passable to upstream fish movement based on physical culvert characteristics. I validated these models using a mark-recapture movement study at 26 road-stream crossings on national forest lands in Virginia and West Virginia during the summer and fall of 2004. Culverts, regardless of model classification, appeared to impede upstream movement by stream fish. Fish movement through culverts classified as impassable was lower than movement through the natural stream for Salmonids during the summer and fall and for some Cyprinids during the fall. Movement by species from the families of Salmonidae, Cyprinidae, Percidae, and Cottidae through passable culverts (76 events) occurred 5 times as often as movement through impassable culverts (16 events). Fish movement through culverts was negatively correlated with the culvert characteristics of slope, slope x length, and velocity for cyprinids. Road crossings with outlet drops < 10 cm, slope < 2.0%, and slope x length values < 25 experienced the greatest movement illustrating the importance of those culvert characteristics in determining fish passage. The models were modified based on the results of the field experiment to increase their accuracy. The final predictive models from this study can be an effective tool for assessing fish passage through culverts and aid natural resource managers in prioritizing and implementing fish passage projects.

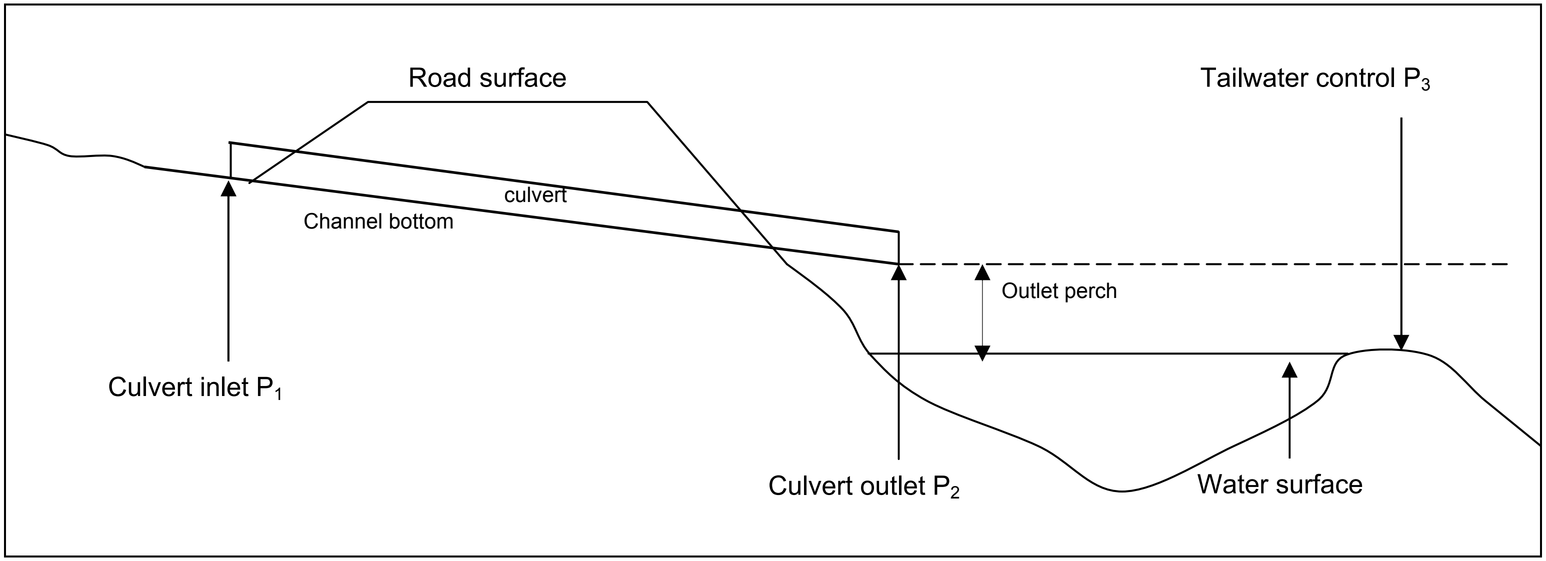

Figure 1. Profile of survey points used to calculate culvert characteristics associated with fish movement barriers and used in predictive models for upstream fish passage through culverts. Distance and elevation is measured for each location point designated by P_n and for the water surface. Adapted from Clarkin et al. 2003.

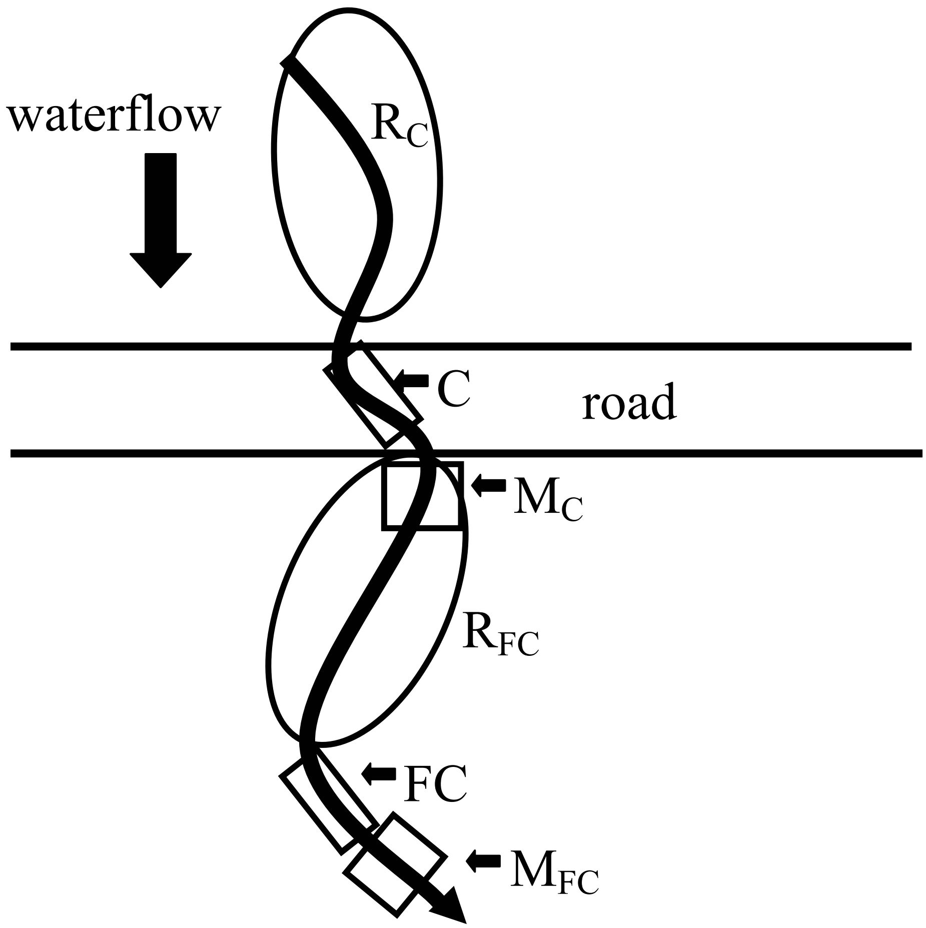

Figure 2.3. Study design for validating fish passage predictive models. M_{FC} and M_C are sections of stream where fish were initially marked. R_{FC} is the recapture section for fish from M_{FC} and R_C is the recapture section for fish from M_C. C is the culvert at the road crossing and FC is a section of undisturbed stream equal in length to C. Distances of each section are as follows: $M_{FC} = M_C =$ 5 times channel width or 50 m minimum, $R_{FC} = R_C = 4$ times M_{FC} or 200 m minimum, and FC = C = culvert length.

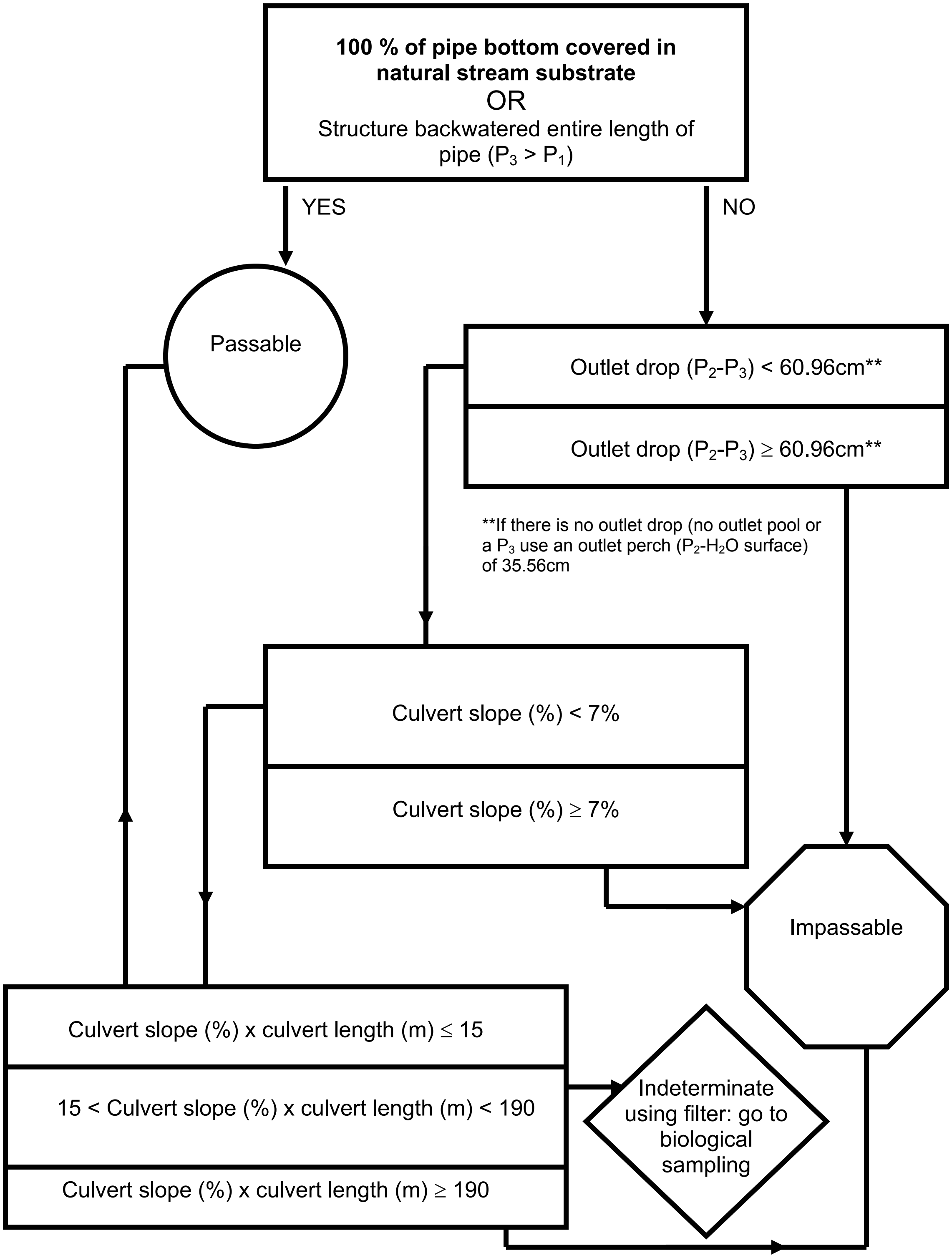

Figure 3. Modified upstream fish passage predictive model A for Salmonidae. See Figure 1.1 for a profile of survey points used in fish passage coarse filter. P_n = elevation measurements.

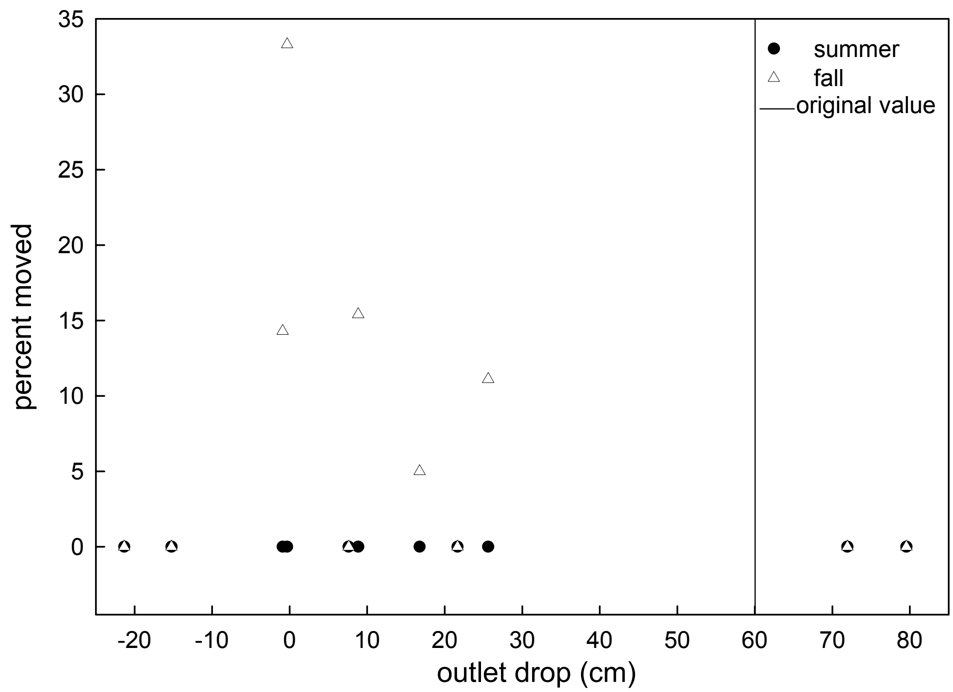

Figure 4. Scatterplot of outlet drop and proportional fish movement through culverts for Group A during the summer and fall of 2004 (n = 22). The vertical line (60.96 cm) is the threshold used in the original and modified models.

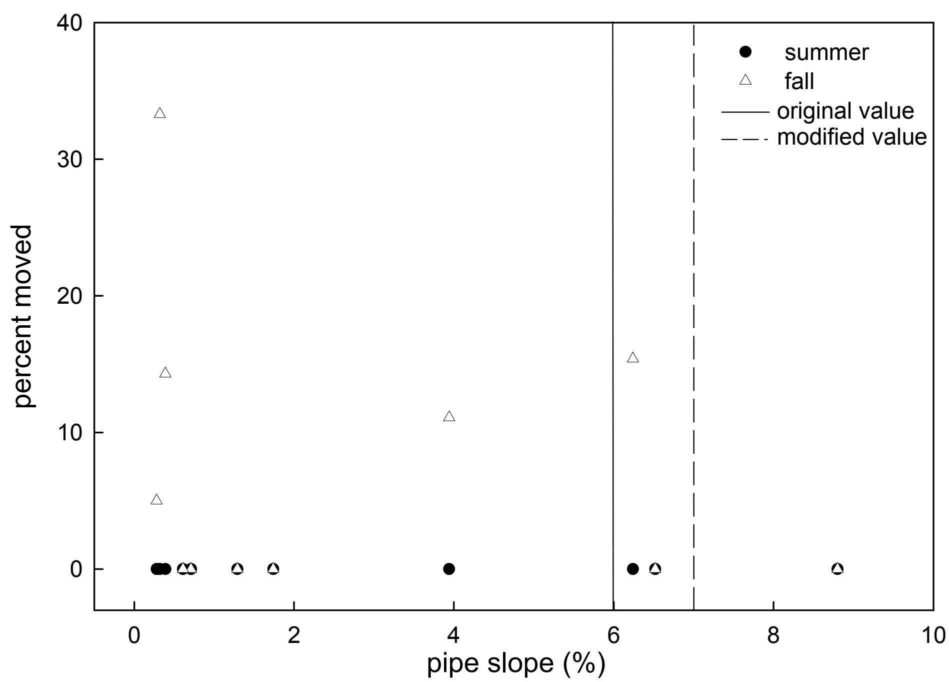

Figure 5. Scatterplot of pipe slope and proportional fish movement through culverts for Group A during the summer and fall of 2004 (n = 22). The vertical lines solid (6.0%) and dashed (7.0%) are the thresholds used in the original and modified models, respectively.

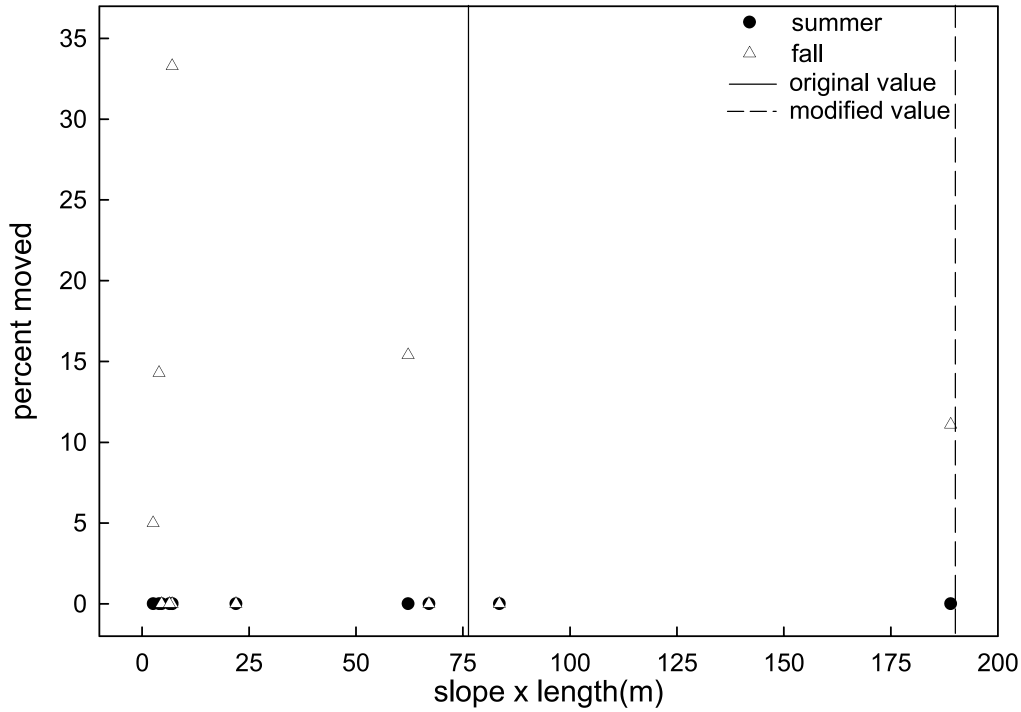

Figure 6. Scatterplot of pipe slope x length and proportional fish movement through culverts for Group A during the summer and fall of 2004 (n = 22). The vertical lines solid (76) and dashed (190) are the thresholds used in the original and modified models, respectively.

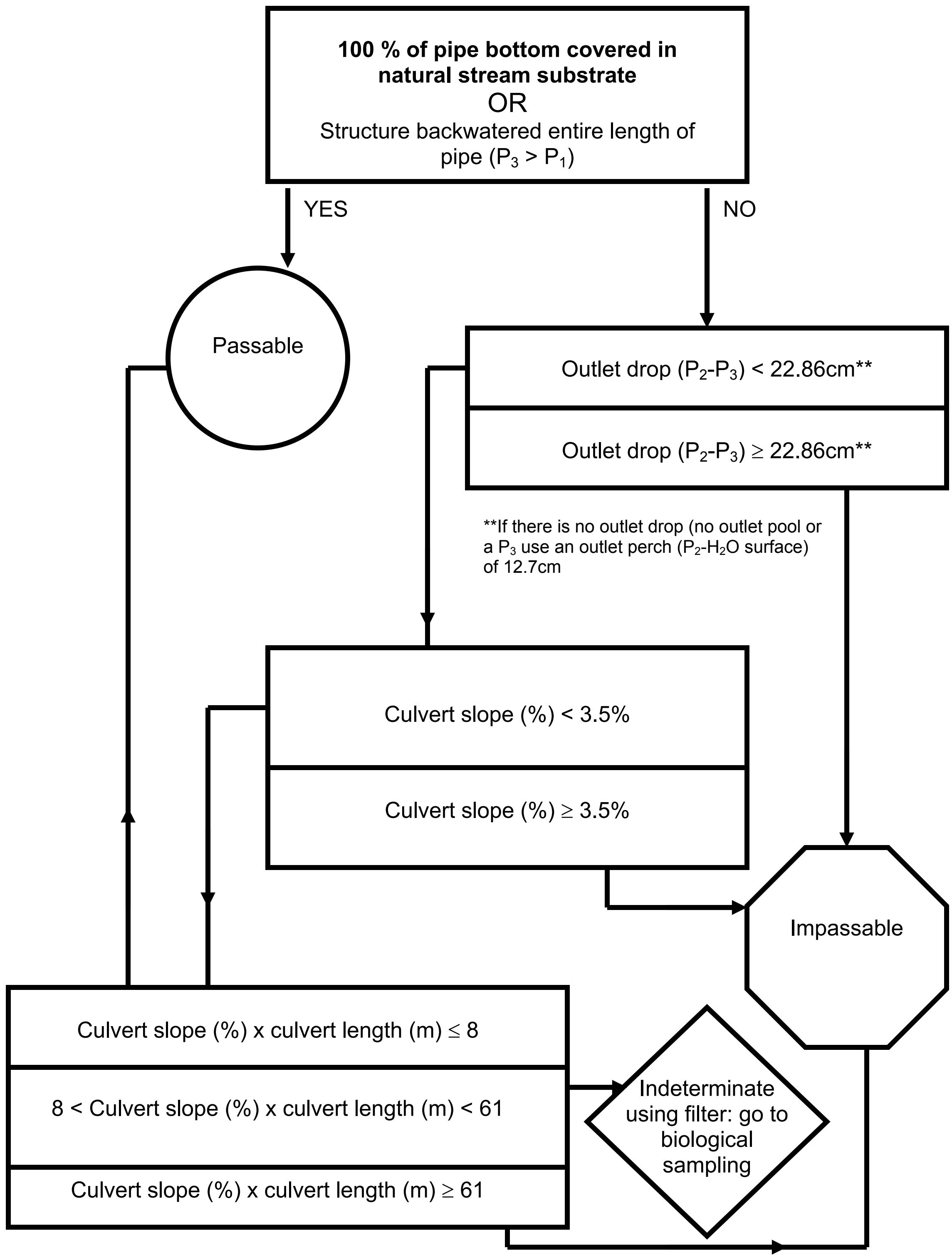

Figure 7. Modified upstream fish passage predictive model B for Cyprinidae and young of year salmonids. See Figure 1.1 for profile of survey points used in fish passage coarse filter. P_n = elevation measurements.

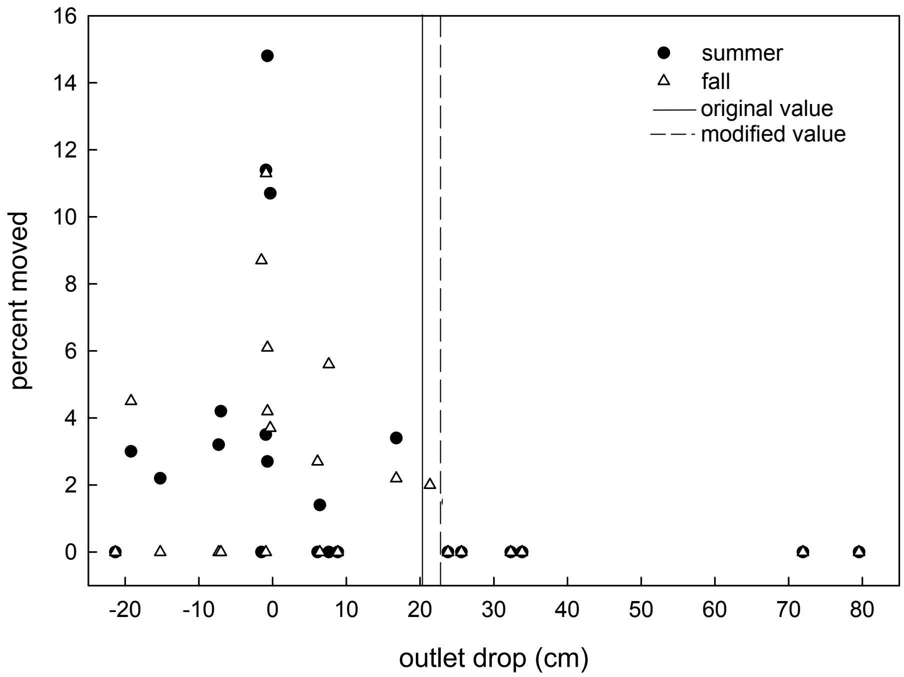

Figure 8. Scatterplot of outlet drop and proportional fish movement through culverts for Group B during the summer and fall of 2004 (n = 46). The vertical lines solid (20.32 cm) and dashed (22.86 cm) are the thresholds used in the original and modified models, respectively.

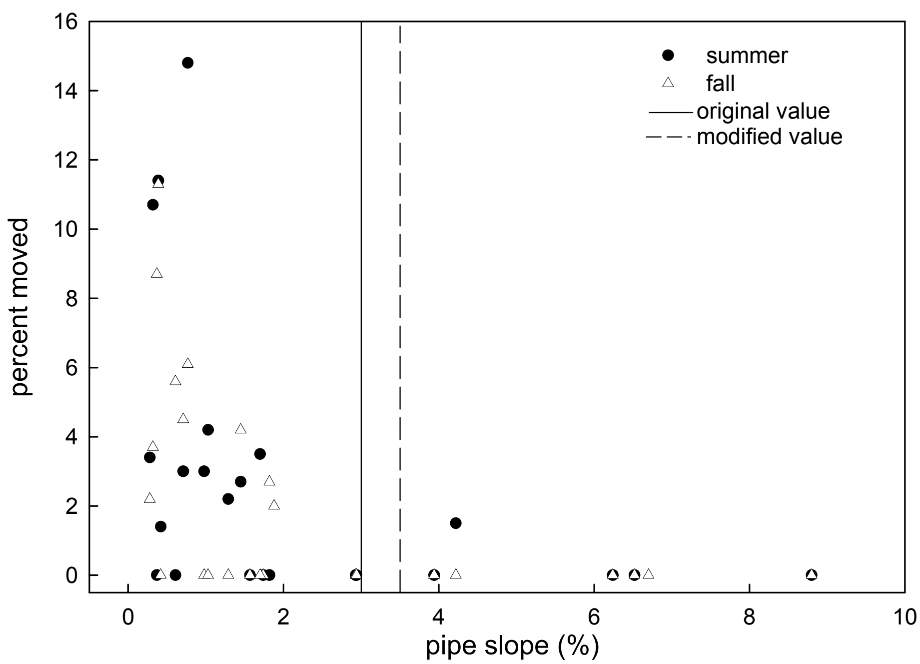

Figure 9. Scatterplot of culvert slope and proportional fish movement through culverts for Group B during the summer and fall of 2004 (n = 47). The vertical lines solid (3.0%) and dashed (3.5%) are the thresholds used in the original and modified models, respectively.

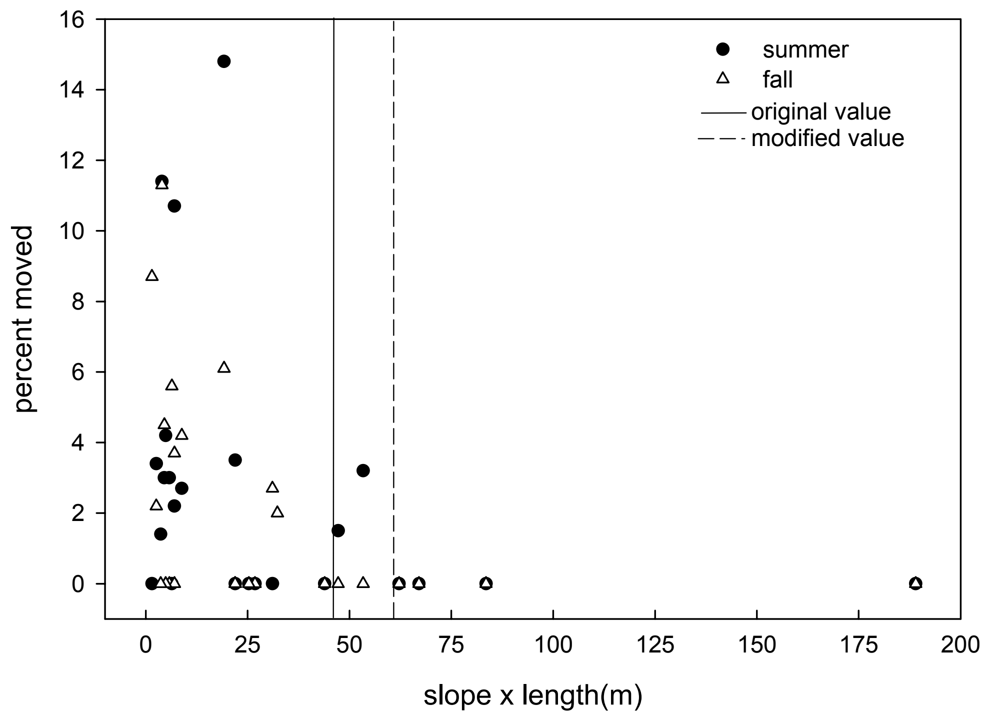

Figure 10. Scatterplot of culvert slope x length and proportional fish movement through culverts for Group B during the summer and fall of 2004 (n = 49). The vertical lines solid (46) and dashed (61) are the thresholds used in the original and modified models, respectively.

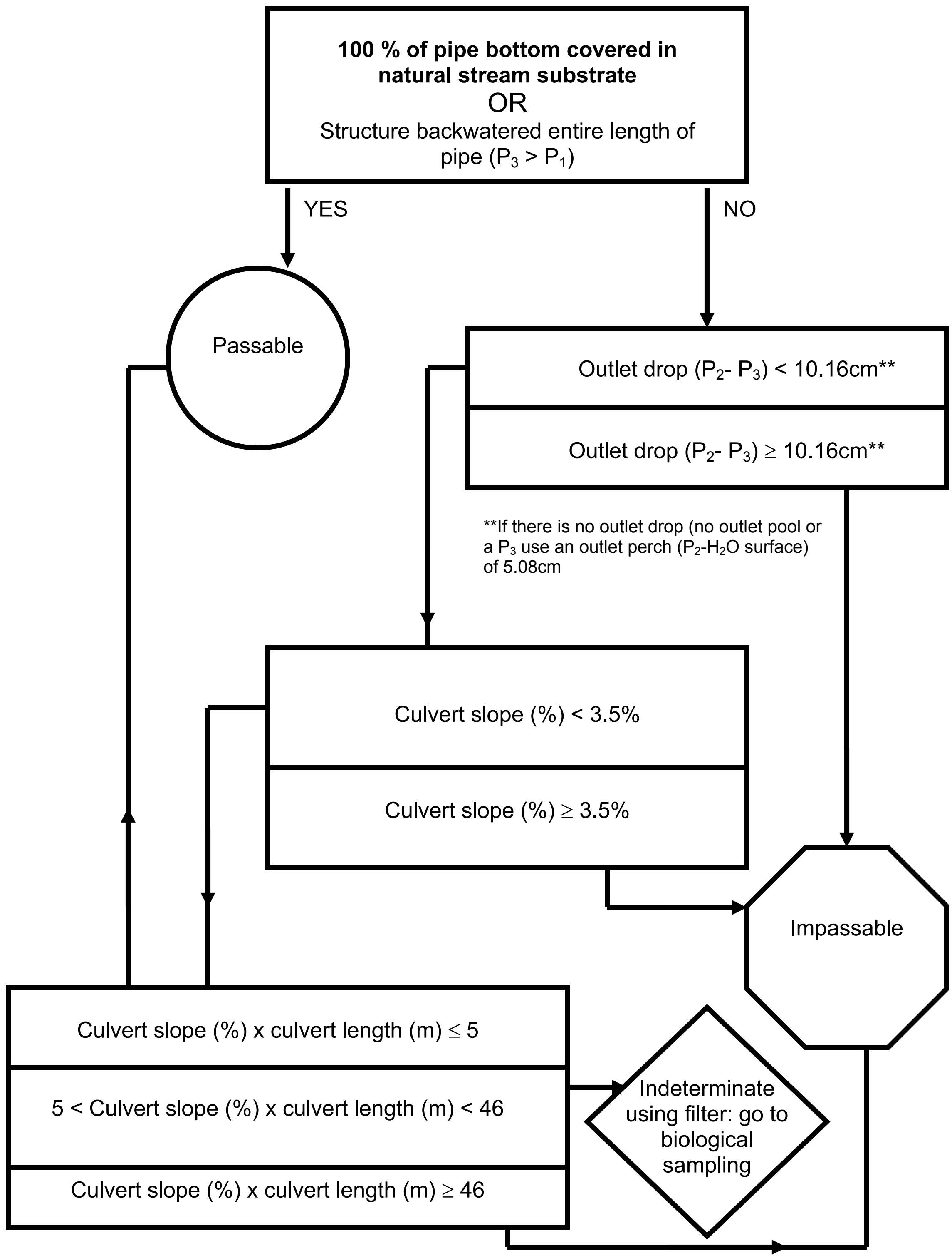

Figure 11. Modified upstream fish passage predictive model C for Percidae (except *Sander vitreus*, *Stizostedion canadense*, and *Perca flavescens*), and Cottidae families. See Figure 1.1 for profile of survey points used in fish passage coarse filter. P_n = elevation measurements.

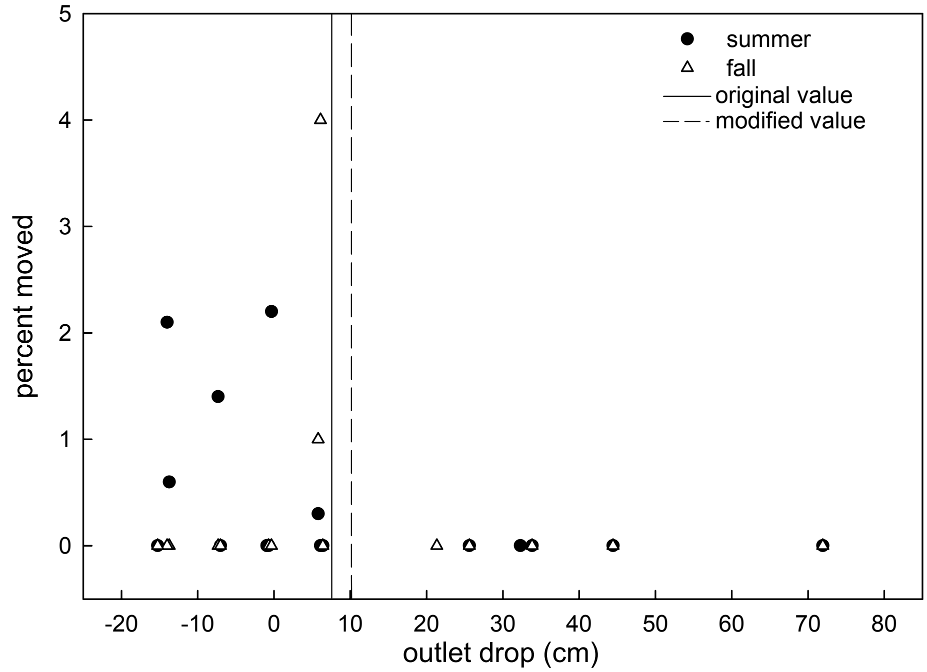

Figure 12. Scatterplot of outlet drop and proportional fish movement through culverts for Group C during the summer and fall of 2004 (n = 32). The vertical lines solid (7.62 cm) and dashed (10.16 cm) are the thresholds used in the original and modified models, respectively.

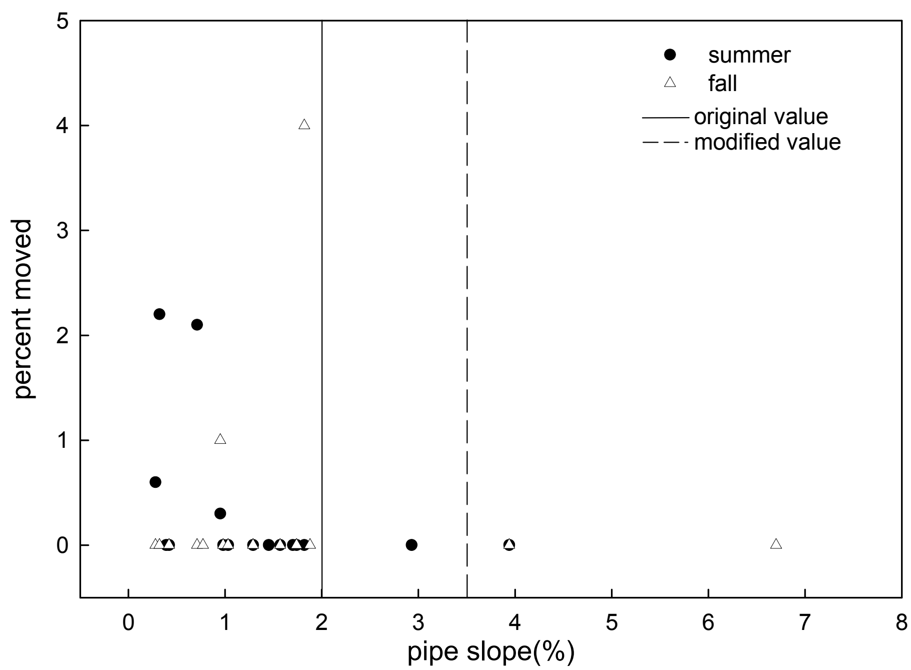

Figure 13. Scatterplot of culvert slope and proportional fish movement through culverts for Group C during the summer and fall of 2004 (n = 31). The vertical lines solid (2.0%) and dashed (3.5%) are the thresholds used in the original and modified models, respectively.

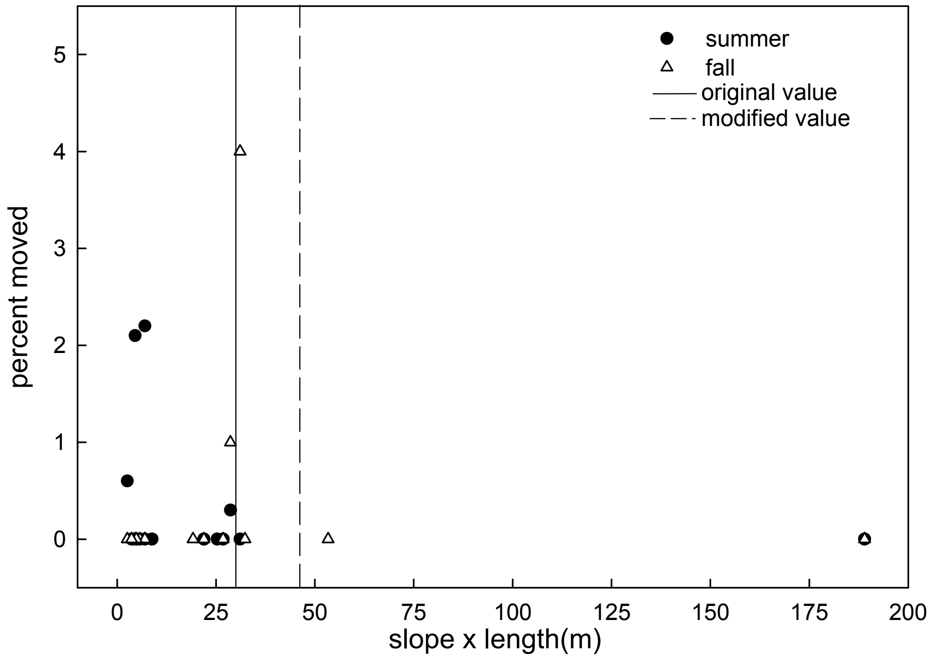

Figure 14. Scatterplot of culvert slope x length and proportional fish movement through culverts for Group C during the summer and fall of 2004 (n = 30). The vertical lines solid (30) and dashed (46) are the thresholds used in the original and modified models, respectively.

Synthesis and Management Implications

Culverts at road-stream crossings impeded fish movement in the study area for the species collected. The degree to which upstream movement is impaired depends on those physical characteristics of the culvert that create jump, velocity, exhaustion, depth and behavioral barriers. The incorporation of those characteristics into a model to predict fish movement produces classifications of passable or impassable. These preliminary classifications proved partially accurate in that (1) upstream fish movement through impassable culverts was either reduced compared to movement through the natural stream or did not occur and (2) upstream movement through passable culverts was comparable to natural stream movement.

Threshold values of the culvert characteristics used in the preliminary model for fish movement were identified and used to improve the model. These models could prove useful to natural resources managers assessing fish passage at road-stream crossings, because they can be an efficient method to screen thousands of road-stream crossings in forested watersheds of the eastern United States for a large assemblage of species. Providing passage to native fishes and preserving habitat connectivity should be a high priority for state and federal agencies. Conversely, impassable culverts may prevent the spread of nonnative invasive species, emphasizing the need for careful watershed prioritization for native species conservation.

Future culvert design and installation should take into consideration the thresholds of the culvert characteristics identified in this study to provide adequate passage for resident stream fish. The preservation of natural stream morphology and hydrology should be a goal of culvert design. This appears best achieved with bottomless arches or bridges.

Although they can be cost prohibitive, the benefit of increased habitat connectivity by bottomless arches and bridges for at risk species may outweigh the costs.