Wildlife Habitat Connectivity Considerations in Fish Barrier Removal Projects
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The concepts of fish passage and terrestrial wildlife habitat connectivity are inextricably linked. Riparian corridors, where aquatic and terrestrial environments meet, comprise small portions of the landscape but provide disproportionately important ecosystem functions (Wissmar 2004). These areas are commonly utilized by wildlife to travel between patches of suitable habitat (Bellis and Graves 1971; Feldhammer et al. 1986; Finder et al. 1999; Malo et al. 2004; Seiler 2005; Dussault et al. 2006; Gunson et al. 2009; 2010), and in highly fragmented urban landscapes, represent some of the last remaining travel routes available.

Salmon have been linked to over 137 species of wildlife, providing them life-affirming food resources and habitat (Cederholm et al. 2000). Salmon, like most species, rely on intact riparian corridors to navigate their life needs. Undersized or incorrectly constructed culverts can create barriers to the necessary movements required to meet these life needs – the same applies for terrestrial wildlife species, only the entire road system acts as a potential barrier, while crossing structures serve to reduce the barrier. Terrestrial wildlife species that encounter highways while traveling in riparian corridors will use appropriately sized underpasses to safely cross beneath the road. When not available or appropriately sized, these animals will either turn back, potentially failing to establish a territory of their own, or cross the highway at-grade, potentially leading to dangerous wildlife-vehicle collisions.

Addressing terrestrial wildlife habitat connectivity at the same time as fish barrier removal work leads to engineering efficiencies, and ultimately cost-savings, associated with performing planning and construction tasks at a single point in time. Enhancing fish barrier removal projects for terrestrial wildlife species typically results in only a minor cost increase above the fish-only plans, while constructing standalone wildlife crossing structures would be significantly more expensive in the long-term. Proactively addressing terrestrial wildlife and fish connectivity needs simultaneously will protect valued wildlife resources for future generations and enable a holistic wildlife corridor planning process that incorporates the efforts of partners and co-managers.

WSDOT's Fish Barrier Removal work aimed at providing access to upstream fish habitat presents an opportunity to simultaneously provide habitat connectivity for other species which also suffer from highway-imposed habitat fragmentation (Figure 1). Improving conditions for wildlife movements past our highway system is an important goal articulated in WSDOT's Executive Order 1031.02, Protections and Connections for High Quality Natural Habitats. A key section of the Executive Order refers to WSDOT's intention to develop criteria and guidance for the construction of wildlife passage structures. WSDOT's Fish and Wildlife Program developed Habitat Connectivity Investment Priorities to identify and communicate the highway segments that warrant serious consideration for improvements to benefit wildlife passage.

Figure 1. Fish and Wildlife Crossing Structure on U.S. 97 - a Fish Barrier Removal project that received terrestrial habitat connectivity enhancements.

The following excerpt from WSDOT Executive Order E 1031.02, Protections and Connections for High Quality Natural Habitats, applies:

III. Assuring Protection and Preservation

The Washington State Department of Transportation (WSDOT), in partnership with other agencies, organizations, and the public, will assure that road and highway programs recognize, together with other needs, the importance of protecting ecosystem health, the viability of aquatic and terrestrial wildlife species, and the preservation of biodiversity.

To meet these aims, WSDOT intends:

• To promote and support Practical Solutions and Planning and Environmental Linkages (PEL) as processes that identify potentially affected fish and wildlife habitats as early as possible during the planning process for projects and programs and in preparation of regional and statewide long-range transportation plans. PEL seeks to integrate habitat connectivity and biodiversity plans and other available natural resource information. Transportation planning should recognize and respond to particular concerns and opportunities for habitat preservation and the need for habitat connections. The earlier that habitat concerns are taken up in project planning, the likelier that good habitat approaches to state investment in habitat protection and habitat connectivity can be incorporated into projects.

• To make use of the highway prioritization map known as Habitat Connectivity Investment Priorities as a means to locate specific opportunities to restore habitat connectivity already damaged by human transportation corridors. The identified priority highway segments should be the focus of efforts to reduce wildlife-vehicle collisions and improve connectivity. Long-range planning, highway improvement projects, and highway maintenance all have a role in maintaining and improving connectivity in priority areas. Building and maintaining wildlife crossing structures and barrier fencing are effective actions.

• To cooperate and coordinate with other agencies involved in wildlife habitat protection. This aim will provide for compatibility of natural resource and habitat management in adjacent areas so that wildlife connections provided at roadways will link to functional and permanently protected wildlife corridors. WSDOT further intends to continue its involvement with the Washington Habitat Connectivity Working Group to ensure that this coordination endures.

• To support the use of site appropriate native plant species in roadside landscaping and vegetation management and to protect adjacent natural plant communities.

• To develop and follow design criteria for transportation structures that help promote fish and wildlife movement and minimize habitat degradation. WSDOT recognizes the Washington Department of Fish and Wildlife's manual, Water Crossing Design Guidelines, as a primary source for information on fish passage designs. The Environmental Services Office has expertise and written materials to support wildlife infrastructure design and should be consulted when projects are being developed.

• To protect and enhance important wildlife habitat areas near highways on highway rights of way in ways compatible with highway operations, and to support efforts to promote the

traveling public's awareness and enjoyment of wildlife in the state.

IV. Secretary's Executive Order

WSDOT's Environmental Services Office shall coordinate the implementation of this policy by working with the support and cooperation of planning, design, engineering, construction, and maintenance offices throughout WSDOT, including all of its departments, divisions, and offices.

Habitat Connectivity Investment Priorities

In response to the Executive Order and WSDOT's long range plan, the Fish and Wildlife Program initiated the identification of Habitat Connectivity Investment Priorities (HCIP). Site specific priorities for investing in highway improvements to benefit habitat connectivity were developed using GIS data related to habitat networks, collision histories, traffic volumes, and adjacency of protected land blocks. The entire state highway system was divided into one-mile-long segments, and two separate ranks, one for Wildlife-related Safety and the other for Ecological Stewardship, were assigned to segments. Assigned ranks were high, medium, low, or no rank. Less than 2% of highway segments received high ranks for both Ecological Stewardship and Wildlife-related Safety. A high Ecological Stewardship rank was assigned to 12% of highway segments and 8% received a high Wildlife-related Safety rank. A medium rank for Ecological Stewardship was assigned to 16% of the highway system and a medium rank for Wildlife-related Safety was assigned to 24% of the system. Both categories of the Habitat Connectivity Investment Priorities for the state highway system are available on WSDOT's Environmental Workbench.

How a Terrestrial Habitat Connectivity Evaluation can be Triggered for a Fish Barrier Removal Project

1. The fish passage project falls in or adjacent to a one-mile highway segment ranked high for Wildlife-Related Safety in WSDOT's Habitat Connectivity Investment Priorities model.
      or
2. The fish passage project falls in or adjacent to a one-mile highway segment ranked high for Ecological Stewardship in WSDOT's Habitat Connectivity Investment Priorities model.
      or
3. A project team member requests a habitat connectivity evaluation for a fish barrier removal project. This ensures that local knowledge unbeknownst to a computer model is not overlooked during the prioritization process. People working in the area often know more than a computer model can predict.

Discussion

Recent research has demonstrated that a number of factors influence wildlife use of structures for crossing roads. Factors include the species (deer, elk, moose, bear, cougar, small mammals, etc.), presence of wildlife fencing, size and shape of the structure, volume of noise and light emitted from passing vehicles, substrate in the structure, terrain leading to the structure, characteristics of vegetation around the openings of the structure and the amount of human use (Allen 2011; Clevenger and Waltho 2000, 2005; Schwender 2013). The size and shape of a structure are the most permanent of these features that affect structure use and should be considered early. Structure dimensions should be based on site-specific species presence, and the openness index (O.I.), which is calculated by multiplying the width (span) by the height (vertical clearance) of the structure and dividing the product by the length (Figure 2). The O.I. and minimum structure dimensions help predict potential wildlife use (Table 1). The O.I. has been reported in several studies and a minimum O.I. of 2.0 is reported to pass deer (Reed and Ward 1985).

WSDOT has monitored over 43 structures for at least one year and has determined the O.I. for all of them. Bridges tend to have the highest O.I., ranging from 2.2 to 687.8, while culverts (including box, arch, and round) ranged from 0.07 to 2.9. Sixteen of the monitored structures, or 39%, were regularly used by elk. Elk only used bridges or overpasses with an O.I. ranging from 17.1 to 687.8. Deer have been documented using 36 of the 42 monitored structures (86%). The four structures with the highest deer passage rates had moderate to very high openness values (2.9, 19.6, 168.8 and 12.8). Two of these are in the Snoqualmie Pass East project area, and two are fish barrier removal projects that included terrestrial habitat connectivity enhancements (Figure 3). The smallest structure with documented deer use was a long box culvert located in a well-vegetated ravine with an O.I. of 1.1; while deer use was recorded, it was at a far lower rate (0.34 deer crossings per day) than at the top four performing structures (average ~2 deer crossings per day).
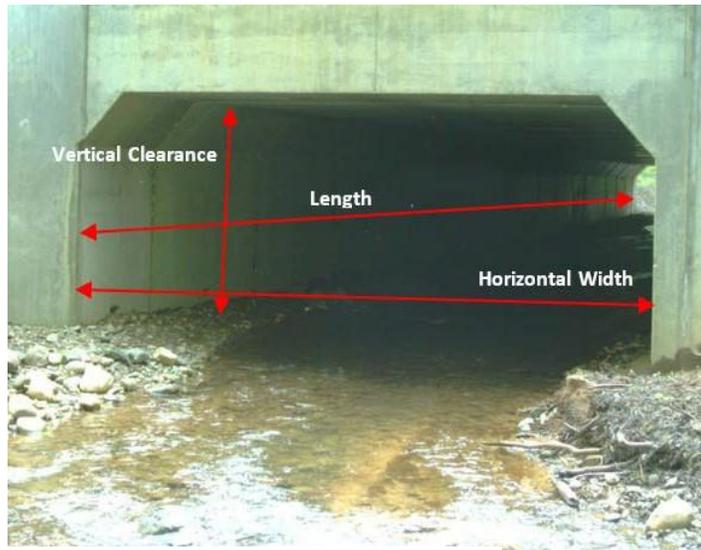

Figure 2. Dimension definitions

While there are many factors that contribute to the acceptance of structures by wildlife, the O.I. and minimum width (span) and vertical clearance measurements will be used as an indicator of the structure's potential to pass different species. Based on the O.I. and monitored structures with documented use by deer and other wildlife, we recommend a minimum 10 ft vertical clearance, minimum 20 ft width (span), and O.I. of 2.0 or greater for most wildlife crossing structures. A structure meeting these minimums for width, vertical clearance and O.I. will be used by the vast majority of species in the state. However, increases in one or both dimensions are necessary for exceptionally long structures, generally anything over 100 ft. Furthermore, structures intended to be attractive to elk will need to be much larger, we recommend a minimum 15 ft vertical clearance, 60 ft width, and an O.I. of 18.0 or greater (Table 1).

Figure 3. Deer and fawns using combined Fish and Wildlife Crossing Structure in Washington State

The openness values that follow are based on measurements in feet.

Table 1. Examples of the Openness Index (O.I.) and its suitability for different wildlife

Width (span)	Height	Length	Openness	Wildlife Suitability
4ft	4ft	50ft	0.3	Bobcat and smaller
6ft	6ft	50ft	0.7	Bobcat and smaller
10ft	10ft	100ft	1.0	Bobcat and smaller
20ft	10ft	100ft	2.0	Deer and smaller
30ft	20ft	100ft	6.0	Deer and smaller
50ft	12ft	50ft	12.0	Deer and smaller
60ft	15ft	50ft	18.0	Elk and smaller
120ft	35ft	180ft	23.3	Ex. Snoqualmie Pass East Undercrossing

Additional Links
Example project photos and plans can be found here:
http://sharedot/eng/dev/envs/fishwl/Photos/Forms/AllItems.aspx

A variety of other resources related to reducing the risk of wildlife collisions can be found here:
https://wsdot.wa.gov/construction-planning/protecting-environment/reducing-risk-wildlife-collisions

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