HIGH, WIDE, AND HANDSOME: DESIGNING MORE EFFECTIVE WILDLIFE AND FISH CROSSINGS FOR ROADS AND HIGHWAYS

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Abstract: As wildlife and fish crossings in highways and roads increase, the emphasis will change from defending their legitimacy to increasing their effectiveness. In the recent past, when wildlife and fisheries crossings were provided, it was often on the basis of "least cost." Unfortunately, many of these structures did not meet the intended purposes – or did so marginally. Road and highway wildlife and fisheries crossings should be planned and designed for multiple species. By applying ecological and behavioral concepts the effectiveness of wildlife and fisheries crossing structures can be greatly improved. While more effective, these structures will also be more expensive. Factors such as the height, width, approach, bottom surface, lighting and spacing need careful consideration. Future structures should appear more natural to increase use and should be placed in areas that animals naturally use. Culverts in stream channels present potential problems to fish and wildlife passage. Their effectiveness in situations where wildlife and fish passage is important is limited, and other types of structures should likely be considered.

Introduction

Designing highways to be more wildlife and fish friendly will not be easy or inexpensive. There are many complexities. Have appropriate linkage habitats been identified for the species of concern? Have the non-public land ownerships within the linkage areas been secured by agreement, easement, or purchase? And last, are the crossing structures appropriate for the species of concern, and will they be used? This last question is a major concern among transportation agencies. Ensuring that wildlife and fish will use crossing structures is one of the last hurdles to increased confidence and implementation by transportation and resource agencies.

History of Wildlife and Fish Crossings

Our past has largely been a series of hit-and-miss attempts to cross a single species (or few) in very limited areas. Often, little or no consideration was given to fish or wildlife crossings. When provided, crossings were often designed at the absolute minimum standard to allow a fish or animal to cross a structure. The combination of minimal consideration for linkage areas, focusing on only one or two species, minimal number of crossing structures and minimal size or design specifications for crossing structures has provided us with minimal costs (an intended outcome) and minimal effectiveness (an unwanted outcome).

Designing wildlife and fish crossings that are more effective will cost more than less effective designs. However, providing minimal design crossings that do not sustain wildlife and fish populations is a poor investment strategy. Past experience with salmon, native trout, rare carnivores, and many others species suggests that by adopting the least cost path, at the expense of long-term ecosystem function, we eventually strap society with complex, expensive, and socially divisive solutions. Delaying important conservation measures also results in higher long-term costs. Many contentious experiences with threatened and endangered species have evolved from developing ineffective or unsound conservation programs that turned out to be shortsighted in their economic costs and benefits. A longer view of economic costs, one that includes the costs of maintaining our natural resources, must be considered in highway planning.

An example of a recent expensive lesson is fish passage for anadromous species – some listed under the Endangered Species Act, such as Chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*Oncorhynchus nerka*) and Coho salmon (*Oncorhynchus kisutch*), and steelhead trout (*Oncorhynchus mykiss*). For approximately 30 years natural resource agencies have been designing culverts and other stream crossings to facilitate passage by these species. We did this by a variety of means, including assessing the adult swimming speeds and applying water velocity criteria to culvert and bridge designs.

Why did this process prove to be inadequate in many situations? First, as the life history and ecology of anadromous salmonids evolved, it was determined that younger age classes of fish also need to move up and downstream to sustain runs. The younger age classes of salmon and trout are smaller in size and do not have the swimming ability of adults. Other situations also reduced passage effectiveness including migration requirements at either very high or very low water levels, changes in velocity caused by stream scouring and other factors. On the Olympic National Forest, stream morphology was changed by the high numbers of culvert road crossings and resulted in lower salmonid carrying capacities. The end result has been that inadequate designed stream crossings on highways and roads have been a significant factor in the decline of salmon and steelhead numbers in the lower 48 states. Recent surveys by the Forest Service in Washington, Oregon, and Alaska suggest 15,000 or more culverts may be full or partial barriers to anadromous species. Similar spot checks of culvert stream crossing on the Lolo National Forest indicate passage problems for young and/or adult bull trout (*Salvelinus confluentus*).

What is still not known is the affect these road and highway crossings are having on other species such as sculpins (*Cottus* sp) and other fish, amphibians, reptiles, and small mammals. It is likely that many of the same structures that have fragmented fish habitat are having similar effects on other small animals and their habitat.

Ecological and Behavioral Considerations of Crossing Structures

The primary objective of wildlife and fish crossings is to maintain habitat and population connectivity. For many species, this may require maintaining or simulating the natural functions of their habitat within or on top of traffic crossing structures. Many crossings are designed to facilitate movement of a single or small number of species. Structures would be more functional if connectivity of habitat across highways were given more consideration. More species would be provided for, especially plants, invertebrates, and small animals, if habitat connectivity were at least as important as providing crossings for a few target species. Connectivity of habitat and populations is an ecosystem approach.

Barriers to movement can be physical or behavioral. Both considerations must be incorporated into crossing designs for optimal use. Until more research is conducted, biologists, engineers, and highway planners will have to rely on the professional judgement of people with the best knowledge of wildlife behavior and habitat. Two considerations that may lead to better wildlife and fish crossings include: (1) How natural do the structures appear (behavioral acceptance or avoidance)? and (2) Have the natural processes been maintained or mimicked (biological integrity and connectivity)?

Some factors that should be considered when designing wildlife and fish crossings are:

Height and Width of Crossing Structure

The height and width of crossing structures provide the basis for how large the crossing structure will be. The physical proportions of the structure will limit the size of animals that can or will use it. For small and mid-sized animals that are not averse, or may prefer, small crossing structures, an opening size of approximately 36" may suffice. Species that can be expected to use such structures include raccoons (*Procyon lotor*), coyotes (*Canis latrans*), foxes (*Vulpes* sp), many rodents, fisher (*Martes pennanti*), American marten (*Martes Americana*), some turtles, and other reptiles. Many of these animals exist in situations where space is confined. Excluded will be larger animals and those with either behavioral avoidances or habitat limitations. These include some species like wolves (*Canis lupus*), grizzly bear (*Ursus arctos*) and ocelot that physically could use such structures, but will not because of behavioral issues – or some amphibians that need specific light, moisture or bottom structure. If such pipes can be buried and have a natural soil bottom, more species can be expected to use the structure. There is evidence from Europe that species prefer concrete pipes to steel pipes.

Structure height and width can also effect climatic conditions such as moisture, light and air movement. Small structures tend to be dark and without adequate moisture to sustain vegetation. Small structures also exhibit a "tunnel effect" which is avoided by many species. Larger structures may have enough light and moisture, particularly if they contain streams, to sustain some natural vegetation. Large spans often provide enough light and moisture to maintain grasses, shrubs and some trees. They also provide more light, better sight distances and appear more natural than other large structures like steel culverts (see figures 1 and 2). A crossing structure's "openness" may be a primary reason why wary animals use or avoid it.

Spanning structures may provide the best crossings for multiple species in mountainous, hilly or broken terrain. Multiple spans or bridging may also provide the best habitat connectivity for sensitive areas such as marshes, fens, bogs and talus slopes where disturbance of the natural habitat is a concern. Spanning or bridging of large rivers and streams provide perhaps the most effective wildlife and fish crossings for many species, especially large carnivores like grizzly bears and wolves.

Fig. 1. Span on I-70 in Colorado, east of Vail. Structure has grasses and other vegetation. Light transmission is excellent and avoidance by most mobile species would be low.

Fig. 2. Steel Arch on Trans-Canada Hwy in Banff National Park. Structure is large, but still has more "tunnel effect" than span in Figure 1. Some mobile species like deer and elk readily accept these structures. Other may be intimidated by the "tunnel effect."

For most species in most situations, the larger the crossing structure, the more effective it will be. In The author's opinion, inadequate size of wildlife crossings and insufficient number of wildlife crossings are two primary causes of poor use or non-use by wildlife and fish.

Bottom Surface of Structures

Not much research has been conducted on the bottom surface and structure of wildlife crossings. It is known that moisture levels can effect movement of some amphibians such as salamanders (Jackson 1999). The addition of hiding cover within or on crossing structures has been shown to enhance use and movement by small mammals and amphibians in the Netherlands (Bekker 2001). Europeans have noted that the surface of both wildlife underpasses and overpasses is important for many wildlife species. Most species appear to favor natural soil, rocks, vegetation and large woody debris and resist using cement, asphalt or gravel road surfaces (Wildlife Mortality SCAN Report 2001).

Observations by this author, an others, suggest some species like white-tailed deer (*Odocioleus virginianus*), mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*), prefer to use trails rather than road surfaces when using underpasses designed for rural roads (figures 3 and 4). Bottom surfaces should simulate that of the habitat of the surrounding area.

It is becoming increasingly clear that maintaining a natural bottom structure within bridges and culverts can enhance salmonid passage.

Fig. 3. Animals commonly use natural appearing habitat to cross under highway bridges, rather than use the road surface. In this case, white-tailed deer were using the trail in the center of the picture rather than the road surface.

Fig. 4. Indicates a deer trail in the foreground. Deer and other animals used this portion of the bridge rather than the road surface.

Light and Moisture Considerations

Light and moisture conditions are critical for some species – perhaps many. Already mentioned are the salamanders and likely frog species that require moisture to breathe through their skin. Species associated with moist conditions, such as voles, and other species associated with marshes, riparian areas and other wetlands may also favor crossings with high soil moisture. Also mentioned was the relationship between light and moisture and vegetation.

Innovative ways of getting both light and moisture into wildlife under crossings include installation of grates that would allow rain and sunlight to penetrate road surfaces, use of similar grates as “skylights” to reduce the “tunnel effect” of some crossings, and providing high bridges or spans. Highway segments in areas where wildlife crossings are planned can be divided to reduce the “tunnel effect” of underpasses crossing multiple traffic lanes (Cleavenger et al 1999). Underpasses with high “openness ratios” are preferred by mule deer and other wildlife species (Foster and Humprey 1995, Reed et al 1975). Light within crossing structures can be maximized by making the top of the structure wide to allow maximum light into the crossing.

Stream crossings, even intermittent streams, provide excellent opportunities to provide crossings with moist soil adjacent to the stream flow. To provide this, structures must be designed to allow for both a natural stream bottom and adequate room for animals to use the crossing at all water levels. Some species such as toads, salamanders and frogs move during specific rain and/or high water events. Other species may be forced to move during high water due to swamping or flooding of their habitat.

A decided advantage of wildlife overpasses is that moisture and light levels are the same as adjacent habitat. As a result, native vegetation can be planted and grown on top providing a contiguous habitat across highways.

Long, dark culverts or bridges may be barriers to salmonids and other fish.

Noise Levels and Human Activity

The relationship between noise levels, human use and wildlife use of crossing structures is an obvious one, but not well studied. Gloyne and Clevenger (2001) found more cougar (*Felis concolor*) use of Trans-Canada Highway crossing structures furthest from the town of Banff. The further structures had less human use. Cleavenger, et al (1999) and Clevenger (1998) also found decreasing carnivore use associated with increasing human use. Reducing human use at wildlife crossings is a constant concern. In many situations it will be necessary to provide separate crossings for mountain bikers, ATV's and hikers.

The author is not aware of where active attempts were made to reduce traffic noise, except on the Trans-Canada Highway wildlife overpasses. In these situations, dirt berms were placed on each side of the overpasses to reduce noise and light (Bruce Leeson, personal communication). Traffic noise is commonly abated in urban settings with the use of cement noise barriers. Similar structures could be used in situations where noise or headlights are a concern to wildlife use and movements. Commonly used "Jersey" or "Texas" rails, used to control vehicles, might be used to reduce noise and head lights on and adjacent to wildlife crossings.

Location

Regardless of other factors, locations of wildlife crossings have a profound effect on use. Wildlife crossings must be placed where animals want to cross. These are usually in natural habitats, dispersal areas, crossings and migration corridors. Information such as road kill data, radio telemetry data, observations of animal tracks, and observations of animals crossing or attempting to cross highways is important for the best placement of crossing structures.

On a larger geographic scale, it is important that linkage habitat be mapped and given full consideration in wildlife crossing decisions. Determining potential linkage habitat involves the mapping and analysis of vegetation data, terrain factors, drainage patterns, human uses and land ownership patterns to determine the best crossing locations. This is the information that allows agencies to make informed decisions as to what habitat is being linked and to ensure land uses and ownership patterns are and will be consistent with wildlife use of crossings. Unfortunately, in many cases neither animal use data nor the linkage habitat mapping is required as part of highway planning.

Natural Appearance

In human terms, aesthetics are often given great weight in highway decisions. Trees, shrubs and grasses are planted, hydra-mulch is placed on bare soil, vistas are planned and designs are adjusted to reflect human landscape values. For wildlife and fish, natural appearances may be required for animals to use crossing structures. Progress to date has been poor at getting antelope (*Antilocapra americana*) to use underpasses or cross busy highways (Castillo-Sanchez 1999). Antelope have other distinctive behaviors such as a reluctance to jump fences, even though they are capable of doing so (they prefer to cross under the lowest wire on the fence). The solutions to antelope movement across highways remain to be discovered. They almost certainly involve making the crossings look more "natural." The antelope's best defenses against predation are their keen eyesight and speed. Antelope crossing may have to be designed as overpasses where they have natural habitat extending across the highway and where they have comfort approaching the crossing, on the crossing and on the far side. Antelope can often be seen grazing near highways, so traffic noise and disturbance is not likely the primary reason antelope do not use underpasses.

Female grizzlies, wolves, ocelots (*Leopardus pardalis*), bighorn sheep (*Ovis Canadensis*) and other wildlife may require crossings that are very similar in appearance to their natural habitat if they are to be regularly used. In these situations, long span bridges across streams, rivers and gullies or overpasses may provide the best wildlife crossings. Other options may include tunneling through mountains or burying highway sections as is more common in Europe. In Germany, wildlife overpasses are combined with rural road crossings and "landscape connectivity" in land bridges that are several hundred meters wide. While on these structures, humans and animals are not aware that a highway is beneath them. While such costly measures as overpasses, tunneling and burying highways may be ridiculed by some, they may be the only designs used by certain wildlife species.

Multiple-Use Wildlife, Fish and Drainage Crossing Structures: How Do We Do It?

Inherent to all roads and highways are drainage structures. Most drainage structures are designed for a single purpose, water. An increasing number of stream crossings in the western United States and Canada are designed for water and fish. Almost none have been designed as multiple-use facilities that effectively provide for drainage, allow for variable species and size classes of fish passage, and facilitate wildlife movement. These drainage structures, often culverts in small or intermittent streams, provide a great opportunity to base a comprehensive program providing watershed integrity and wildlife and fish habitat connectivity.

Providing for fish passage, even in its present form, was more costly and complicated than merely getting water across roads and highways. In some places, neither fish nor wildlife is given much concern at stream crossings. Species as diverse as fresh water mussels and clams require madtoms and other fish to transport their larval stages upstream. It is not just fish or warm-fuzzy wildlife that requires well-designed drainage structures, it is critical to overall ecosystem integrity. The constriction of streams through culverts and bridges can result in many unintended consequences.

The most ecologically defendable stream crossings are those that are not restricting of flows regardless of stream discharge, maintain the ability of streams to function naturally, and allow for fish and wildlife passage. Many wildlife species prefer to move along riparian zones or stream courses. There are several options for providing multiple-use stream crossings.

The first involves replacing culverts with bridges or structures that span the stream banks at high flow, plus allow room for wildlife to cross on either side. Where traffic volume is low, larger, more mobile species could cross over the road surface (deer, coyotes, etc). At least two feet, or more, on each side of the stream should be provided for amphibians, small mammals and other species. On higher volume highways, enough room should be provided on both sides of streams and rivers so large and small animals can cross, including at high water events. The stream banks should be of natural material and not armored, if possible. Armoring is normally a requirement where stream flow is restricted and increased water velocities are expected. If streambeds were allowed to function more naturally within bridge or spans, fish passage would normally not be restricted. Streambed material within bridges and culverts should be as natural as possible to provide habitat and facilitate movement of all aquatic species.

A second option being tried in anadromous fish streams on the west coast involves removal of under-sized culverts and replacing them with arches or buried pipes that allow stream (including at high water) to flow over natural channels rather than on corrugated steel pipe beds. These structures also provide a foot or two of space between high water and the pipe or arch. This is primarily to allow a safety valve in cases where stream flows exceed those expected and to allow some natural functioning of streams, but also can provide space for small animals to cross.

In intermittent stream crossings, providing oversized pipes with natural bottoms would likely provide wildlife crossings for many species.

Providing consideration and designs that provide for appropriate drainage, fish passage and wildlife crossings would be a good start in restoring habitat and population connectivity for many species. It would also allow our streams and rivers to function naturally, resulting in more productive watersheds. Providing better crossing structures at all drainage’s does not take the place of doing adequate pre-project animal use and linkage habitat analysis. It would provide a wildlife and fish crossings network that would only require additional structures for special habitat or wildlife situations (antelope, grizzly bear, species inhabiting flat terrain).

Innovative biologists, engineers and highway planners will undoubtedly design new ways to accommodate drainage, wildlife and fish. More emphasis is needed to ensure wildlife and fish linkage analysis is done by highway, wildlife and land management agencies.

Criteria for Designing More Effective Wildlife and Fish Crossings

Fortunately, the solution to the design and implementation of better and more effective wildlife and fish crossings is relatively simple. Suggestions for developing ecologically sound highways are as follows:

1. Require that wildlife and fish habitat linkage analysis be used as a standard procedure for highway planning.
2. Design crossing structures for multiple species crossings or habitat connectivity, not single species.
3. Provide an adequate number of wildlife and fish crossing structures. Every culvert and bridge within wildlife or fish habitat should be viewed as an opportunity for multiple species crossings.
4. Design crossing structures so that most individuals within a population will utilize them.
5. Protect hydrologic and watershed integrity. Undersized stream and river crossings not only impede wildlife and fish movement – they create serious upstream and downstream impacts on stream channels, riparian habitat, stream stability, stream structure and biotic processes (Ruediger and Ruediger 1999).
6. Develop a structured, scientifically based, research and monitoring program. Learn from our mistakes and successes and share what we know works!

Serious consideration for wildlife habitat connectivity, fish habitat connectivity and ecosystem functions is needed when considering future roads and highways. Biologists, engineers, planners and resource managers should be working in synergistic ways to ensure both public transportation and public natural resources are managed at state-of-the-art levels. In the future, our publics will require roads and highways that minimize habitat fragmentation and wildlife mortality. Let's get going!

Biographical Sketch: Bill Ruediger is the national ecology program leader for highways and forest roads (U.S. Forest Service) throughout the United States. With over 31 years of experience in the U.S. Forest Service, Bill has dealt with issues related to wildlife, fisheries, forestry, roads and highways in various roles: as forester, wildlife biologist, and ecologist. Previously, Bill was forest wildlife biologist and staff officer on the Kootenai National Forest in Montana and Gifford Pinchot National Forest in Washington. He also spent 16 years as the endangered species program leader for the Northern Region, Missoula, Montana. Bill holds a B.S. degree in wildlife management from Utah State University, and an M.S. in forestry from the University of Idaho.

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