The Effects of Highways on Western Cold Water Fisheries

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Abstract

Impacts of highways to terrestrial wildlife are often obvious; the bodies are on the roadway. Impacts to fishes are often more difficult to identify, may be more complex, and usually are accumulative. Improved highway networks have followed human development of the West and have impacted cold water fishes through loss of habitat, changes in habitat quality, isolation of populations, reduced populations of both fish species and invertebrate food supplies, and changes in species makeup of aquatic systems. Major changes in habitat conditions can occur from highway improvements such as bank stability and channelization, placement of bridge supports, adding sediment and rocks to stream systems in cleanups from storm damage or widening projects, etc. The problem of improperly designed and installed culverts as barriers to fish migration in fairly well known. Less well known are other impacts from culverts such as head cutting in side canyons, genetic isolation of fishes, erosion, and habitat loss. Road maintenance can cause habitat degradation through sedimentation of spawning gravels and runoff from salt mixtures can decrease desirable types of aquatic invertebrates. Damage from natural disasters such as flooding often result in rapid and massive cleanup and improvement work; accumulative impacts adversely affecting aquatic systems rarely attracts notice and may have greater importance to the ecosystem health and possible survival of rare species of fish.

Scope of Problem

The impacts of highways to cold water fishes and other aquatic resources in western North America are often thought of as simply barriers to migration from poorly designed, installed, and maintained culverts. While culverts are important and they can cause adverse impacts in a number of ways besides blocking migration, I will discuss them as only one factor in a complex problem. Additional factors include loss of habitat, erosion, storm water runoff, and anesthetics. The problem of effects of roads on western fishes is historic in that the impacts of the past may be different from today's impacts and may change again in the future.

Impacts may be considered negative, benign, or positive depending upon the value that humans put upon the results. They often can be viewed as having more than one value depending on how humans look at them. Accumulative impacts are rarely recognized, monitored, or viewed with alarm as are spectacular disasters. Funding and dedication of labor to restore habitats are also much slower or non-existent with accumulative impacts.

I'd like to use an example from a study underway at the University of Montana by a graduate student named Sophie Osborn. She is studying landscape effects on the habitat selection, distribution, and productivity of the American Dipper, a six-inch bird found along fast-flowing streams. They swim in the water and even walk on the bottom in search of food and normally build nests in cliffs and large boulders. They have a pretty song and are neat birds to watch and photograph. Sophie's study is finding that the populations of dippers are reduced where stream portions have been developed. However, when highway bridges are present in disturbed area, the dippers build nests under them and population levels increase to about the same as in undisturbed locations. Sounds great, right? But what if the disturbances to the stream had resulted in decreased fish habitat, and what if an endangered species was in the stream where high survival is needed to keep it from becoming extinct. Guess what dippers eat? Fish eggs, fry, and aquatic insects in competition with fish. Highway bridges may indirectly adversely impact the endangered fish by providing nesting habitat for American Dippers. Feel like you can't win?

Background

The settling of the North American West and the beginning of impacts to fishes was characterized by the construction of railroads. When railroads met mountain streams and rivers, whether the main lines or spur lines being build for mining, logging, or other uses, they are constructed using the gentlest slopes possible up the valleys. These routes often extensively crossed streams, denuded slopes of trees to build bridges and ties, etc. As wagon roads developed up the same valleys, they usually developed on the opposite side of the streams, effectively disturbing slopes of both sides. Improvement in roads from dirt to gravel to paving usually resulted in further disturbances, with sideling, more cutting into the toes of slopes, and adverse impacts to the aquatic ecosystems. As vehicle numbers and speed increased on these roads, demands forced improvements in dangerous curves, better maintenance, and more widening and heavy duty movement of dirt and rocks. Where major traffic loads occurred, the roads became four-lane and even divided highways and interstates further impacting the stability of slopes and aquatic habitats.

Although construction of roads along the tops of ridges or well up on the hill sides generally produce less environmental impacts to aquatic systems, there are numerous factors mandating that most highways in the West be built in valleys and along streams. Improving existing road beds is usually less costly than starting from non-existing routs. Ridge tops rarely remain level and such fluctuations require extensive earth movements to construct the roadway. Expensive bridges with long spans may be required when side canyons, tributaries, and geological features interfere with straight road. Residences and businesses often have been established along the original stream-side route, and may still need access. Junctions with other highways may best occur where streams come together rather than one or bother roads needing to rise to the top of a hill.

Life History Requirements of Fishes

In most cases, the cold water fishes of concern are native trout and salmon species. In the areas impacted by highways, there are five species of anadromous salmon (chinook, sockeye, coho, chum, and pink), and two species of anadromous trout (steelhead trout and searun cutthroat trout). Anadromous species spawn in cold headwater streams with clean spawning gravel and high oxygen levels. Young fish migrate to the ocean where they grow from two to six years before returning to the original streams to spawn. The salmon spawn only once before dying while trout may return more than once to spawn. Population segments of nearly all anadromous fish have become extinct, are listed as threatened or endangered under the Endangered Species Act, or are being considered for listing due to habitat destruction and declining populations. Some of the anadromous fish have land-locked strains (such as the kokanee form of the sockeye salmon) that are in less trouble.

Native resident trout species at fish include bull trout int he Pacific Northwest presently being considered for listing as threatened or endangered and several subspecies of cutthroat trout in mountain streams throughout the West whose populations and habitats have declined. These fish need cold, clean streams with a variety of habitats (spawning gravel, pools, riffles, runs.).

An important concept in the survival of native trouts is that of metapopulations. For example, the bull trout may have three different life forms: those that spend their whole life in the headwater streams (small growth rate), those that spawn the headwater streams but migrate to larger streams and rivers for rearing (faster growth rate, larger fish), and those which migrate from the spawning areas to lake environments (fast growth, large fish). Barriers which restrict movements of the three life forms threaten the continued existence of the species. The form moving to lakes have nearly been eliminated in wild populations. Most remaining populations stay in the headwater streams and become isolated populations, sometimes even becoming different genetically. If a disaster such as a forest fire eliminates these isolated populations, they probably will never recover. If the migratory form still exists within these headwaters streams, destroyed populations my be restored. The goal of the metapopulation concept is to preserve numerous pockets of fish in headwater streams and include some of the migratory form within their genetic makeup. In this way, destroyed populations can be restored and the species not continue towards extinction.

In some cases, physical isolation is not bad. The rare native redband trout survives mainly because it is isolated by water temperatures and some physical barriers from stellhead trout and non-native rainbow trout, both of which out compete or phybridize with it. Bull trout are often out competed by and phybridized with exotic brook trout. Thus, there are instances when existing migration barriers should be preserved, and this is yet another concern for highway engineers.

Road Maintenance

Dirt, rocks, and mud routinely is deposited on highways in mountainous terrain. The usual cleanup by highway crews has been to push the materials over the side where it often is deposited in the stream. More "enlightened" crews attempt to remove and pile the materials, but this is often governed by factors such as amount of material, availability of equipment and sites to dump materials, safety for traffic and crews, etc.

Side drainage may flood across roads during heavy rains or snow melt, sometimes combined with blocked culverts and dn leave materials on the roadway. Often larger in volume is the material deposited from hill-side slumps where heavy moisture contacts unstable slopes whose "toe" was removed during road construction. Both situations can be more destructive with "rain-on-snow" conditions where heavy runoff can block the highway or even wash out sections of it. The worst examples of this problem occur when the vegetation and soil stability of the slopes have been removed or disturbed.

A well documented case of this last example recently occurred in Idaho. In the summer of 1994, an elderly couple from Pennsylvania drove a large motor home pulling a small car up Idaho State Highway No. 55 along the scenic Payette River. The car blew out a rear tire, which was not detected by the driver. The tire became overheated, caught on fire, and eventually caught the car on fire - all undetected by the couple in the motor home. Before being stopped by other motorists, the couple set forest fires up the steep slope for some 15 miles, and caused some $3 ½ million in damages to lost timber and expenses of the fire fighting. Even though grasses and some shrouds had established in the burned area by the end of 1996, heavy rains on snow in the area caused extensive flooding, blowouts, and land slumping. The community of Lower Banks was destroyed, the main north-south highway within Idaho was blocked for a couple of weeks, and complete highway restoration was not completed for about nine months.

Attempts were made to keep some of the sediment out of the river, but the sheer magnitude of the flooding and the priority of re-opening the highway to at least some traffic resulted in major amounts of sand, mud, and rocks entering the river and degrading fish habitat.

Winter conditions cause additional maintenance problems where ice and snow on the roads are plowed and sanded with salt mixtures. Salt and salt substitutes have been found to affect aquatic invertebrates which the fish depend upon for food (molles 1980). While all insects are rarely killed, their reproduction and total biomass is reduced, less desirable species of invertebrates from fishes standpoint result, and decreases in trout condition have been found. The sand often ends up in the streams as fine sediment and reduces spawning habitat. Plowing and sanding of highways is an important safety factor, but efforts should be made to try to keep the sand mixture from entering the stream similar to cleanup techniques for dirt, and highways should not be over-sanded.

Runoff of petroleum products from highway pavement after rains is a potential problem to the aquatic environment. However, it is probably less of a problem with highway systems and their traffic patterns than with city streets, where petroleum products from heavy traffic accumulate on the road surface during dry periods and are flushed into aquatic systems through drains when heavy rains occur. Death and deformities are known to have occurred after exposure to petroleum products.

Bank Stabilization and Stream Channelization

As mentioned earlier, highway construction through mountainous terrain often causes slope instability and related slumps and slides that deposit debris on the roadway and into the adjacent streams. The ability to stabilize the slopes depends upon factors such as (1) the steepness of the slopes, (2) the type and amount of underlaying and exposed rock base, (3) how much of the toe of the slope was removed or disturbed, (4) what kind and amount of vegetation is on the slope, and (5) how much time there is to stabilize the slope before a major storm event occurs. The rate of stabilization varies widely; some slopes heal quickly and others remain problem areas for many years. A recent example of the latter is the Interstate Highway just east of Grand Junction, Colorado where the slopes remain largely bare years after construction and a September rainstorm caused slides which closed the freeway and deposited some sediment into the Colorado River. Many western mountains are made up of decomposed granite and shale which are very difficult to stabilize once disturbed. Even timber harvest from National Forests in these types of slopes have been curtailed or alternate harvest techniques (helicopters, horse, etc.) used to prevent large amounts of sediment from entering important fish-bearing streams. Studies by Thurow and Burns (1992) document detrimental effects of sediment from granitic materials on fish populations and behavior. Research to control erosion in decomposed granite in California (Haynes 1992) utilized over a dozen types of erosion control devices (soil, fertilizers, bales, brush wattles, terraces, etc.), mostly with poor success after rains and frost actions. Attempts to stabilize slopes and keep sediment from streams must continue in these areas. However, it may be better to find ways to avoid disturbing the slopes than to try to stabilize them later.

Straight roads are cheaper to build than curving ones and are safer to drive. However, it is natural for streams and rivers to meander across valley floors. Any straight stretch of road close to a stream will be worked on by the water's force to produce curves. The stock engineering solution to this problem is rip-raping of the bank along that stretch to prevent bank erosion. This process transfers the energy of the water to other points of the banks, and soon the stream is channelized with large boulders on one side to protect the highway and on the other side to protect the railroad track. The stream changes from microhabitats of pools, riffles, and runs to a long section of rapids largely devoid of fish habitat. Kyakers would love to except that he aesthetic value of the experience is ruined by the presence of man-made structures.

Stream channelization can also (1) cause scouring of the stream channel and move sediment and rocks downstream, (2) cause migration velocity barriers to fish, effectively isolating populations, (3) reduce riparian vegetation along the banks which provide shade for cooling water temperature, cover for fish, and habitat for aquatic insects. Studies by Bottom, et al. (1985) produced examples of changes in composition and diversity of fish communities, reduced fish production, and reduces the water storage ability of the streams.

Mitigation attempts where streams were channelized for highway construction were evaluated by Lund (1976) who found that most structures (jetties, rock clusters) helped in the recovery of fish habitat and populations. Additional useful information may be found in Wootton et al. (1996) describing the effects of disturbance of streams on food web interactions, and the guidelines for removal of stream obstructions of McConnell (1983).

Culvert Problems

Problems with road culverts as fish migration barriers due to poor design, placement, and maintenance have been well documented in numerous reports, including Gebhards and Fisher (1972) and Carey and Wagner (1996). Typically, these problems involve too small of a plunge pool below a vulvert's downstream edge, too much distance between the pool and the lip of the culvert, and water velocities coming through the culvert at too high a speed to allow the fish to enter the culvert.

The plunge pool should be about 2 ½ times as long as the fish to allow it to jump towards the attraction water coming from the culvert. Water pressure usually can develop a plunge pool, but the size and amount of water contained depends upon factors such as (1) the amount and velocity of water coming through the culvert, (2) the substrata, slope, and amount of debris below the culvert, and (3) the distance from and influence from the main stream. It would be rare that a fish could jump vertically more than twice its length and successfully enter and swim through a culvert. Water velocities more than the fishes sustained swimming ability (about 2 cubic feet per second) are at the maximum to allow fish passage. Water velocity problems are intensified when culverts are angled too steeply, further adversely affecting fish passage, or when velocity is further speeded up when small diameter culverts are used.

Preferred design for culverts to allow fish passage is one of relatively large size and elliptical shaped. Even better would be an open bottomed or arch shape culvert or a bridge. Rarely are there fish passage problems when the natural tributary stream bottom remains in place under the road. Where is danger of culverts plugging, such as when the slope is either very steep and debris may accumulate at the upper lip, or are sluggish, wetland type underpasses where vegetation and debris may clog the culvert during heavy rainfalls or snow melt, it is desirable to (1) use more than one culvert or (2) use a larger than normal sized culvert, the open bottomed type, or a bridge. Bridges that do not have pillars within the tributary's flood plain are preferred.

Occasionally, culverts are installed that extend past the mouth of the tributary stream and empty directly into the main stream or river. These devises rarely are successful at allowing fish migration, may adversely effect the habitats in the main stream through debris deposits, and are subject to damage during high water conditions in the main stream.

Blocking of migration rates are only of the problems that can be found with culverts. Debris coming from the tributary streams and accelerated by water velocities through the culverts can cause fish and aquatic invertebrate habitat quality and quantity changes in the larger streams. Habitat types can change as in pools below a tributary stream filling in with debris and becoming a riffle. Sediment can decrease amounts of insects producing areas and spawning gravels in the main stream.

Even more important , are impacts that can occur in the tributary above the culvert if erosion occurs due to the culvert installation. Head cutting, beginning at the upper lip of the culvert, can rapidly move upstream and destroy aquatic habitat for miles. Not only is existing habitat removed or degraded, but fish populations can be isolated by the fragmented habitat. This isolation can further threaten species at risk of extinction. Removal of the material can also lower the watertable and reduce the storage capacity of the stream. A perennial stream may become intermediant and result in death of fish and aquatic insects. Where water remains in the tributary, the competition between remaining species and individuals is increased. Again, this scenario presents several advantages for the open-bottomed culvert or bridge.

Wetland And Riparian Vegetation

Wetland and riparian areas make up less and two percent of the landscape in the West. In spite of some major efforts to protect and enhance these valuable areas, probably less than 30 percent are in good to excellent ecological condition. Among the values of these areas are water storage and recharge, flood control, shade, stream and lake shore stability, and providing habitats for a wide variety of plant and animal life. There are also legal requirements tied to protection of these fragile areas and regulatory responsibilities by the Corps of Engineers and Environmental Protection Agency.

There have been numerous bad examples of wetlands being filled or drained during highway construction, especially when they have cut off from connectivity to the streams. Mitigation efforts in development of new wetland areas may replace much of the values lost, but the time factor in replacing functioning systems is extensive. While less common, there have been cases of wetlands been drained by culverts and bridges placed at lower elevations than the wetland. Reasons are usually so that the culverts will not plug and case highway damage. A possible solution would be to have ditches leading to the culvert for draining of flood waters, but with dikes on both sides of the ditch to maintain water levels in the wetlands during normal conditions. An excellent publication on protection and recovery of wetlands threatened by roads has been produced by Exodic (1996).

Riparian vegetation along stream and lake banks are known to be extremely important in reducing erosion and enhancing habitats for aquatic and other life forms. Such vegetation should be protected and often can be used to supplement or replace physical structures such as rip-rap to reduce debris entering the streams and stabilize stream banks.

Suggestions And Possible Solutions

It is more popular to just point out problems and "view with alarm", but I think it is more useful to at least try to seek solutions. The problems are mainly (1) debris entering streams from slope disturbances, (2) habitat degradations from bank channelization, (3) sediment and adverse effects from salt mixtures used in road maintenance, (4) migration barriers and habitat modification from culvert placement, and (5) loss of riparian vegetation and wetland losses tied to highway construction, culverts, and bank channelization.

Possible solutions to slope instability is more care during construction, avoidance of certain soil-and geologic-type slopes, and proactive and creative restoration programs. Use of in-stream devices such as rock clusters, large woody debris, and beams may reduce the impacts from bank channelization or even the need to use such protection. Problems with chemicals and sand placed on roads for winter ice conditions can be reduced by not over-salting and trying to keep the materials from entering streams by plowing and collecting excess materials into barrow areas or hauled away for recycling. Culvert problems are described earlier and use of correct sizes culverts, using proper placement, or use of bridges will solve most of them. Finally, retention of riparian vegetation along streams are key to stability, shade and cover for fish and their food base, and maintaining cooler water temperatures, and wetlands need to be protected and preserved wherever possible. Each highway is different as are the factors affecting fish populations and habitats. Pat answers will not solve all problems, but this list may help.

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