

WASHINGTON TROUT ◆ R E P O R T ◆

Spring 1997

PRESERVE, PROTECT, RESTORE

Vol. 7 No. 1

Habitat Lost and Found:

Part Two

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Habitat, harvest and hatcheries are the three “H”s generally acknowledged as being at the heart of our current problem with fish stocks. Of these, habitat loss is probably the most serious long-term problem facing fish. Habitat loss occurs on a daily basis, sometimes just because we don’t think about the consequences of what might seem like innocuous actions. When something becomes commonplace, there is a tendency to overlook the problem or to assume that nothing can be done to correct the problem. In this article, we will explore a major contributing factor to habitat loss and degradation that has had little exposure and may be the most common limiting feature in the decline of fish populations in most of our streams. So common that we pass hundreds of these in-stream structures in our daily driving and they have become such an accustomed part of our environment that we may not even perceive that they are there. We are talking about culverts.

There has been much exposure in the media concerning the role of large barriers to fish passage in the decline of salmonid populations, such as the dams on the Columbia, Elwah and other streams. While these dams are major contributors to the decline of fish populations in



some of our larger waterways, the effect is limited to the watershed containing the dam. A more widespread and insidious problem is the role that culverts play in limiting fish populations because these structures are present in almost every stream from the mouth to the headwaters. Every road that crosses a stream needs a culvert (or bridge) to allow water to pass under the road, whether it be a major highway or a logging road high in the watershed; likewise for every railroad that crosses a stream, including those railroads used in the past for timber harvest operations. Every drainage ditch needs a culvert to pass water under the road, every irrigation system and water diversion system in agricultural lands also need culverts to pass water. There are hundreds of thousands of these structures in this State alone. On your next drive to work, try to count how many culverts you pass. I think the number will surprise you. And consider this: it is not unreasonable to state, based on surveys conducted by Washington Trout, that 70% of culverts in a given drainage are barriers or impediments to fish migration. We shall explore these data again a little later.

I deliberately stated that these culverts need to pass water, because in many cases that is all that they have been designed to pass. Many culverts have been installed on streams without consideration or engineering that will allow fish to pass through them.

In part 1 of this series we noted that many of our smaller streams are in fact fish bearing, and may constitute critical fish spawning and rearing habitat, particularly for coho and cutthroat trout; and that most of these streams were incorrectly typed as being non-fish bearing. As a direct result of this, the culverts installed on such streams are not required to allow fish passage, either upstream or downstream, and so this leads to the loss of that habitat by rendering it inaccessible to fish. Poor stream typing leads to further habitat loss by limiting or preventing fish access to habitat via improperly installed culverts.

Culverts: a major limiting



Salmon pooling below a culvert that is an impediment to upstream migration.

Conversely, poorly installed culverts can also lead to incorrect stream typing. Stream reaches upstream from poorly installed culverts can be devoid of fish solely because the culverts do not permit access to that habitat. Since the streams are no longer “fish-bearing” they could be water typed as such. Land use practices can then be conducted without regard for fish habitat. Although anthropogenic (man-made) barriers cannot, in law, be used to justify typing a stream as non-fish bearing, the practicality of life is that it happens. An

factor to all fish state-wide



insidious circle is thereby created that could easily migrate downstream, reach by reach, if culverts are not designed to pass fish.

How do culverts prevent or impede fish migration? There are in fact many aspects of culvert design that have to be considered in this regard. Here is a list of basic considerations that need to be addressed when designing, installing and maintaining the culvert:

- Fish need to have adequate access to the pipe, e.g. sufficient plunge pool depth for upstream migration, with suitable pool configuration to allow sufficient room to initiate a jump. If fish cannot approach the culvert because of debris accumulation at the outfall, they may not be able to orient their jump to successfully enter the pipe.

- The outlet of the culvert needs to be low enough to permit fish to enter the pipe, i.e. the perch height should not exceed the leaping capability of the fish. The leaping ability of fish varies with species, life history stage, size and condition. A culvert that is passable to coho in the lower reaches of a stream may not be passable further upstream as the condition of the fish deteriorates.

- There may be a cumulative effect of culverts upon the energy reserves of fish that can limit the extent of upstream migration. While each culvert may in itself be passable, but an impediment to migration, the net effect is to limit the range of usable habitat within the drainage.

- The water velocity within the pipe should not exceed the swimming capability of the fish. This is influenced by the type of structure, roughness characteristics and physical dimensions (length and diameter and slope) of the pipe and water discharge during the migration periods.

- The culvert should have sufficient water depth to permit the fish to swim through the pipe. Water depths that support cutthroat migration may not permit adult chinook or chum migration. Wide culverts with low water depth may also inhibit juvenile migration during seasonal low flow periods.

- The culvert should be free of blocking debris within the pipe, although in some cases debris may be beneficial by reducing water velocity within the pipe.

- There should be adequate egress conditions at the upstream end of the pipe. Debris accumulation, bedload accumulation, or an acute angle between stream and culvert at the upper end of the pipe may induce hydraulic conditions that prevent the fish from exiting the pipe. Therefore the pipe should be designed to pass bedload material without excess accumulation in or above the pipe.

- The culvert conditions listed above must be appropriate for the species and life history stage and physical condition of the fish in the stream. Juveniles need access to rearing habitat, and conditions that are passable to steelhead adults may not be passable to coho or cutthroat adults.

- The culvert should be designed to permit migration under the mean flows expected during the migration periods



Perched culvert

for all of the fish species and life history stages present in the stream.

- The culvert must be designed to be consistent with the stream channel.

Therefore when designing culverts with a view to permitting fish passage, one must take into consideration the hydrology of the basin, the physical characteristics of the pipe which influence the hydraulic conditions within the culvert and the biology of the fish, including species, life history class, physical condition and biomechanical capabilities of the fish.

There are many examples of culverts that are clear blockages to fish passage. There are many, many more that

are impediments to migration because the biomechanics of the fish have not been taken into account during the design and installation of these pipes. These impediments may not be immediately apparent upon simple visual inspection of a culvert. A full mathematical evaluation of the physical parameters of the culvert in conjunction with a knowledge of the biomechanical capabilities of the species in question is required.

In addition to preventing or hindering access to habitat, culverts also play a role in habitat degradation. Many culverts are installed in such a way as to limit downstream flow of bed material such as gravels. If the upstream azimuth of the culvert to the stream is acute, or the pipe is inadequate, gravels can be deposited on the upstream side of the culvert. In addition to creating a potential culvert blockage and



Road failure due to improperly installed culvert

subsequent road failure leading to a mass wasting event, these culverts can deprive downstream reaches of essential spawning gravels, thereby reducing the reproductive capacity of that reach. If a culvert does block and cause a mass wasting event, the road prism material may be carried a significant distance downstream, carrying with it streambed material and instream structures, resulting in scouring and stream bank damage. The material is transported to lower gradient reaches and deposited there, causing habitat degradation or even rendering the stream subterranean.

The recent road failure on the Cathcart-Snoqualmie River road near Monroe deposited an estimated 24,000 cubic yards of road fill into Elliot Creek, covering spawning gravels

and filling in deeper pools. It will lead to further habitat degradation by limiting insect populations and reducing the ability of instream structures to slow down higher flows. This failure was due to an inadequate culvert that was identified as such by Washington Trout in 1995. We were unable to obtain sufficient funding to fix the problem in time.

Culverts that cause mass wasting may also be high in the headwaters, upstream of fish-bearing waters, but if not properly designed or maintained then those culverts may have a significant effect upon downstream fish habitat. Culverts are also seldom capable of passing the large woody debris, such as logs and rootwads, that are essential for creating rearing habitat and preventing streambed scouring and bank erosion.



John Means surveying a culvert

What can be done to mitigate the effects of culverts on our fish populations? The first steps towards the restoration and protection of our fish stocks require asking a number of fundamental questions and establishing a sound, logical approach to their resolution. These questions are: Where are the fish now, what was their historical range, are their habitats accessible and contiguous, or are their historic habitats rendered inaccessible or fragmented by man-made barriers, and are those habitats protected?

Washington Trout has been conducting culvert assessment, at the basin-wide level using a systematic and consistent methodology to examine man-made barriers in a number of watersheds throughout the State. We have collected data on thousands of culverts and, while much of these data are still being analyzed, the results of our preliminary work

clearly indicates the magnitude of the problem. In Lynch and Crazy Creeks in the Tolt drainage, two culverts blocked anadromous access to more than fourteen miles of spawning and rearing habitat, of which seven miles historically were used by a currently depressed summer steelhead stock.

In the Skookumchuck, although all of the culverts in the anadromous zone appeared to be passable, 100% of the culverts in the stream reaches containing resident fish were blockages to fish migration. Overall, approximately 75% of the culverts surveyed by Washington Trout are blockages or impediments to fish passage. If this is representative of most of our drainages, we have lost significant amounts of fish habitat Statewide.



WT Crew: Dennis Brown, Frank Staller, Mary Lou White and David Crabb.

How many culverts are there in this State? Nobody knows for sure, but that number can be counted in the hundreds of thousands and perhaps more than a million. Washington State Department of Transportation estimates that there are 350 blocking culverts within its dominion. Washington Department of Fish and Wildlife estimated that there were approximately 2,400 blocking culverts that prevented anadromous access to more than 3,000 miles of habitat Statewide. King County Surface Water Management estimates that 45-50% of culverts in non-forested King County are an impediment to fish migration, demonstrating that the problem is not restricted to forest lands.

Culverts have been shown to compress and reduce the amount of habitat available to fish populations by preventing fish access to spawning and rearing habitat.

They have also been shown to contribute to the degradation of fish habitat. Concomitant with this is a decrease in the abundance and distribution of fish populations throughout their range. When fish distribution and numbers are limited, other species can suffer too. Many other species depend upon salmon carcasses for winter sustenance. Clearly, any obstacle that limits fish distribution has consequences that impact the entire ecosystem, not just the fish species in question.

It might also be argued that any culvert that limits fish migration contributes to a decline in water quality due to deprivation of that stream reach of marine-derived nutrients. That reach might then qualify for listing in the Department of Ecology's 303(d) water quality impaired list. Washington Trout is exploring this avenue to facilitate the recognition of fish passage issues in maintaining the health and water quality of our stream systems.

Culverts may also influence and contribute to a reduction in genetic diversity in our fish populations. Clearly, impassable culverts in areas of resident trout populations will restrict the breeding population to those fish that are present in a given stream reach. No further genetic input is possible within the reach from populations downstream. Since headwater cutthroat populations tend to be small and widely spaced, this can lead to inbreeding depression and render the population more likely to face extinction because of the limited diversity within the population and the reproductive isolation afforded that population by blocking culverts.

In the anadromous zone, culverts that create impediments to fish passage may select for fish that are larger in the case of velocity or perch barriers, or for fish that are smaller in the case of depth barriers. Flow regimens may only allow passage within a narrow time window and therefore select for return time. These factors all contribute to a decrease in genetic diversity within the populations in any given stream, thereby reducing overall fitness of the population and reducing the effective breeding population in that stream reach. Therefore culverts can affect not only total population numbers, but they can also influence the genetic makeup of populations through artificial selection processes that lead to an overall reduction in fitness and/or diversity within a population.

Man-made barriers are having a detrimental effect on the health of our fish stocks. However, it should also be stated that there are many beneficial, natural barriers that have contributed to the evolutionary diversity of fish populations, and many perceived barriers, such as beaver dams actually provide ideal rearing conditions for juvenile fish. These beaver dams may be temporary barriers, but salmonids and beaver have coevolved successfully for ten thousand years. Coho juveniles in particular thrive in environments created by beaver dams. The presence of natural seasonal migration barriers may have led to the evolution of summer run steelhead, since they were able to reach their spawning habitat above the barrier only during the flows and temperatures prevalent in the summer months.

Culverts have a wide range of influences, not only on the migration patterns of fish, but also on the physical, chemical and biological properties of the stream. Culverts can also have an impact upon entire ecosystems. These influences are summarized below.

Culverts can:

- Affect fish species distribution by restricting or preventing fish migration.

- Affect distribution of host and symbiotic species. For example, freshwater mussels, require the presence of fish for successful reproduction and dispersion of juvenile mussels. Culverts therefore can influence the distribution of mussel populations.

- Reduce nutrient distribution. It is now recognized that marine derived nutrients are essential for the productivity of our stream ecosystems. Marine-derived nutrients can only be delivered to our streams in the form of salmon and steelhead carcasses. These nutrients have been shown to have a direct effect upon the ability of a stream to produce healthy populations of juvenile fish and the insect populations upon which they depend. By depriving the upstream reaches of these nutrients, the stream is rendered less capable of supporting fish, and continued deprivation might result in ecological shifts that ultimately prevent or limit the ability of fish to recolonize those reaches in the future.

- Alter stream morphology by redirecting flows or causing mass wasting events.

- Influence water quality. Culvert failures lead to debris flows and deposition within the stream, causing sedimentation impacts and blocking culverts prevent marine-derived nutrients from fertilizing stream reaches.

- Influence water typing. Poorly installed culverts can lead to incorrect stream typing because stream reaches are no longer available for fish use and therefore may be typed as non-fishbearing despite having supported fish populations in the past.

- Have the potential to disrupt historic and current gene flow. Blocking culverts can limit or restrict the size of breeding populations and may prevent gene flow into or out of stream reaches, reducing the genetic diversity of fish populations by fragmenting their habitat. They may also artificially select for run timing or size of the fish because of the effect of the culvert(s) on stream hydraulics.

- Have a widespread ecological effect. Culverts that limit fish distribution affect entire ecosystems by impacting upon the many and varied animal, bird and aquatic insect species that depend upon fish and fish carcasses for forage. This list is long and diverse, but includes such species as eagle, bear, raccoon, wren, dipper, raven etc.

What is being done to address this problem? Washington Trout is conducting an extensive culvert survey program in conjunction with our water typing project in various drainages in the Western Washington Cascades Province and Southwest Washington. Under this program, streams are first water typed to determine the extent of fish habitat within the system; then culverts are mapped and assessed for their ability to permit fish passage within the known range of fish-bearing waters.

The assessment process is broken down into three broad categories. These are culverts that are 1) passable to fish, 2) impassable to fish, and 3) possible impediments to fish passage. The analysis is performed at the basin level to provide a comprehensive assessment of habitat availability within entire drainages.

In order to determine to which category a culvert belongs, Washington Trout has adopted a culvert assessment procedure developed for Washington Trout by Alan Johnson

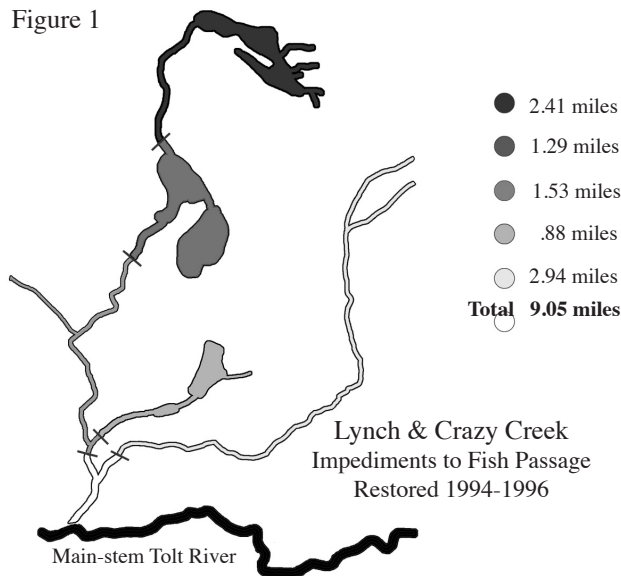
and John F. Orsborn Ph.D., P.E. This procedure is a surveying methodology for recording the physical features of any given culvert and the stream reaches immediately above and below the culvert. The methodology utilizes standard surveying techniques and is designed to record data in a manner independent of the time of survey or flow regimens and in a manner that can be used to predict fish passage capability under varying flow conditions. Currently, there is no uniform, or recognized, procedure for culvert assessment that is used throughout any State agency in assessing the ability of culverts to facilitate fish passage. Such a standardized tool is essential if culverts are to be surveyed in a consistent manner.

These protocols have been incorporated into a technical manual which complements Washington Trout's educational program called "Culvert College." This is a teaching program developed by Washington Trout which has been taught to a number of Federal, State, and County agencies as well as the timber industry, tribes and private citizens.

Concomitant with the development of the assessment protocols, we are assembling a database containing the physical measurements of all of the culverts surveyed by Washington Trout. This database is compatible with a culvert analysis program that is being developed for Washington Trout which permits rapid analysis of culverts for their ability to permit fish passage under various flow regimens. This will be the only known program which can assess culverts for fish passage in relation to the measured physical parameters of the culvert and the known or estimated flow regimens for any given stream. The program will permit analysis of culverts by species, life history class, flow regimens and will identify those culverts which fall into the gray area of "impediments" to passage. The first version of this program is now being tested with data collected by Washington Trout field teams and, when thoroughly tested and debugged, it will be made available to interested parties at no charge.

Can the culvert problem be rectified? Yes, but only if the blocking culverts are first identified. This is one of the principal aims of Washington Trout's Habitat Lost and Found field research program and the educational program offered through our Culvert College course.

Figure 1



Successes:

Washington Trout was contracted by the Weyerhaeuser Corporation to conduct culvert analysis on Griffin and Tokul Creeks (tributaries to the Snoqualmie River) as part of Watershed Analysis. The results of the data showed that 78% of the culverts were an impediment to fish passage. There were two precedent setting issues that occurred in these drainages; first, never before had there been a complete basin assessment for fish passage at culverts during Watershed Analysis, and second, and most commendable, was that Weyerhaeuser agreed to fix all of the identified culverts within the next five years.

Two blocking culverts at Lynch and Crazy creeks in the Tolt River system, were replaced by bridges at considerable expense, in a collaborative project funded by the City of Seattle and Weyerhaeuser. In this same system, three other culverts were repaired in a collaborative effort by Weyerhaeuser, the Jobs for the Environment Program, the Tolt Habitat Restoration Group and Washington Trout. The total amount of reclaimed fish habitat was over nine miles (see figure 1). 95% of the habitat of these two streams had been completely blocked to anadromous fish passage for the past thirty years. Summer steelhead were observed spawning above the Lynch Creek bridge shortly after the bridge was installed.

In Stossel Creek, Washington Trout played a key role in implementing fish passage restoration projects, conducted as a cooperative effort with the Jobs for the

Environment Program, the Tolt Habitat Restoration Group and the Washington Dept. of Fish and Wildlife, that permitted fish passage throughout their full historic range in the basin. Eight different impediments to fish passage were repaired. The identification and rectification of barriers to fish migration is one of, if not the most cost effective habitat restoration processes. A clear advantage of this type of repair is that it is easily monitored and the benefits can be easily measured through increased fish numbers and increased spawning and rearing of fish in previously unavailable habitat.

We have demonstrated that improperly designed, installed or maintained culverts can have a significant effect upon the availability of habitat to fish populations. We have also described various ways in which culverts can contribute to habitat degradation and the effects of limiting fish distribution upon other members of the ecosystem. These facts are becoming recognized and accepted as valid among biologists. What is disturbing is that no State agency has yet to design or adopt a defined protocol for assessing culverts for fish passage, yet it is deemed illegal in Washington State to install a culvert that prevents fish passage. What is more disturbing is that neither Habitat Conservation Plans nor State or Federal Watershed Analysis procedures require that culverts be assessed for fish passage, nor do they require that remedial action be taken in the event that a culvert is shown to be blocking fish passage. We are pursuing the insertion of water typing and culvert assessment into these plans since despite the implicit aim of these plans to protect fish habitat, the plans do not require that the habitat be both identified and accessible to fish! Nor do they require that fish habitat first be identified by water typing. These are problems that have to be addressed and Washington Trout is stepping up to the plate by obtaining field data pertinent to both of these problems via our stream typing and culvert assessment projects. The data collected in these projects will be instrumental in persuading the appropriate agencies that recognition, and rectification, of these problems is of paramount importance.

Footnote: Any parties interested in attending a "Culvert College" training course should contact our main office at (425) 788-1167. ☛