Above the Dam

Coho salmon colonize Washington's Cedar River

By Joseph H. Anderson

— *University of Washington* —

This article is based upon two recently published scientific articles, and resulted from the cumulative efforts of many dedicated researchers. In particular, I wish to acknowledge Paul Faulds, John McDowell, Peter Kiffney, George Pess, Thomas Quinn, Jeremy Cram, Andrew Kingham, Kris Kloehn, and Ryan Klett for their work in developing ideas, collecting data, and interpreting results. Many others, too many to list here, have aided the research program through logistical or funding support.

Author Joseph Anderson is a Ph.D. student at the School of Aquatic and Fishery Sciences, University of Washington. His primary research interests are the behavior and ecology of Pacific salmon, and his graduate work has focused on the population expansion of salmon in the Cedar River, Washington. He can be reached at joeander@u.washington.edu.

Declining Pacific salmon runs have been linked to many causes, but primary among them is lost access to spawning and rearing habitats. Graf (1988) reported over 2,000 dams greater than two meters in height in the Pacific Northwest, and many block migrating salmon from reaching suitable habitat. Eliminating migration barriers, either through dam removal or the construction of fish ladders, offers promise as a means of restoring declining salmon runs. This concept is gaining momentum, as salmon will soon regain access to areas of the Elwha, Green and White Salmon rivers in Washington, and the Rogue and Deschutes rivers in Oregon, among others. By restoring access above dams, we can offer salmon a refuge from the countless stressors they face throughout their range. However, research on the behavior and ecology of salmon populations as they expand into areas above dams is needed to understand the process of colonization, and give the greatest likelihood for long term sustainability and success in such projects.

Unfortunately, very few scientific studies have described the ecology of salmon colonization. We can make some inferences from geologic history of salmon streams, and several artificial introductions. As recently as 10,000 years ago, glaciers buried much of coastal Washington, British Columbia, and Alaska, and thus from an evolutionary perspective, salmon have rapidly expanded into these areas. Furthermore, salmon have shown a remarkable ability to exploit open habitat following introductions outside their native ranges. Documented examples include Chinook salmon in New Zealand and Argentina, as well as pink salmon in the Great Lakes. In each case, salmon rapidly dispersed into nearby unoccupied streams and established self-sustaining populations. Unfortunately, the initial stages of these colonization events are shrouded in the past, and processes occurring at the onset of colonization are not well understood.

Removing dams and building fish ladders provides a substantial opportunity to create refugia for expanding spawning and rearing habitat.

The construction of a fish ladder by Seattle Public Utilities at Landsburg Diversion Dam on the Cedar River, WA presented a rare opportunity to investigate the process of salmon colonization. The fish passage facility, completed in fall 2003, made 33 km of suitable spawning habitat accessible to Chinook salmon, coho salmon and steelhead trout that had been excluded since the dam was constructed in 1900. Salmon were allowed to enter the ladder and bypass the dam on their own volition, without any transplanting or direct hatchery supplementation. By opening the door to an area that had been denied to salmon for over 100 years, the fish ladder tested the rate of population expansion under a policy of natural recolonization.

General features of the Cedar River watershed are important to interpret research results and their significance to other fish migration barrier removal projects. The Cedar River drains a 487-square-km watershed in Washington State, flowing westward from the crest of the Cascade Mountains into the southern end of Lake Washington, and then to marine waters via a shipping canal through Seattle. Landsburg Diversion Dam, situated at river kilometer 35, supplies Seattle residents with drinking water. The fish passage facility made available over 33 km of habitat in the mainstem Cedar River (20 km) and tributaries (13 km, primarily in Rock Creek).

Two factors were critical considerations in the potential for salmon recolonization. First, the City of Seattle manages the area above the dam as a *de facto* reserve, without development, recreation, or commercial logging. Thus the new habitat offers salmon a protected refuge sustaining ecological processes characteristic of healthy rivers such as large woody debris recruitment and natural nutrient cycling. This contrasts with the watershed below the dam, where development of varied intensity covers the landscape. Secondly, coho and Chinook

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salmon spawn naturally in the Cedar River and tributaries below Landsburg Diversion Dam, providing a nearby potential source population.

The new Landsburg Fish Passage Facility provided a unique opportunity to investigate salmon colonization from the very beginning of population expansion. Seattle Public Utilities, the National Marine Fisheries Service and the University of Washington have developed a large collaborative research program to document the recolonization of habitat above the dam. The results presented here focus on coho salmon, and address three primary questions. First, will salmon find the fish ladder on their own, and recolonize the new habitat without supplementation? Second, where will the adult colonists spawn, and to what extent will they explore the new habitat before spawning? Third, will juvenile salmon only be found in the areas where their parents spawned, or will they search for new, unoccupied habitat as well?

To determine the rate of population expansion, and hence the ability of salmon to locate and ascend the fish ladder, all salmon were sampled as they entered the new habitat. Results showed a general pattern of increasing numbers of coho salmon. The exception was 2007, perhaps related to the depressed productivity of coho salmon stocks across the West coast. Unfortunately, the lack of comprehensive abundance data on coho salmon below the dam makes it impossible to determine whether the increase in abundance over time reflects higher rates of colonization or merely increases in coho salmon throughout the system.

The vast majority of coho salmon mature as three year old adults, and thus the increased abundance of salmon in 2006 and 2007 compared to 2003 and 2004 raises the possibility that a portion of the more recent runs were offspring of the original colonists. This would indicate a shift towards self-sustaining production, which is critical to the long term success of the expanding population. Ongoing genetic studies are focusing on this question, and determining the proportion of salmon in recent years that were produced by first generation colonists.

Eighty-six coho salmon bypassing the dam in 2003 and 2004 were given radio tags, and their movements were tracked to evaluate exploration of the new habitat and spawning site selection. A combination of permanent listening stations operating at all hours of the day and mobile tracking by inflatable raft, vehicle and foot determined the positions of the tagged salmon. Our tracking surveys paid particular attention to the use of Rock Creek based on the general observation that coho salmon often spawn in small tributaries. Although 38% of radio-tagged salmon entered Rock Creek at least once, the vast majority of these trips were short duration visits by male salmon.

The two sexes adopted dramatically different movement patterns. Many of the males moved extensively throughout the watershed, often reversing directions and repeatedly swimming upstream and downstream in the Cedar River, likely in search of mates. On the other hand, female salmon tended to move upriver more deliberately, and select a nest site without the back and forth movements characteristic of the males. Spawning sites were identified based on inference from the movements of radio-tagged salmon and visual observation of salmon nests, and virtually all were located in the mainstem Cedar River. While we cannot preclude the possibility that a small number of coho salmon spawned in the tributaries, the vast majority spawned in the Cedar River, primarily in the first six stream kilometers upstream from the dam.

This coho salmon is one of many that have returned to Washington's Cedar River to colonize new habitat made available by the construction of fish passage over a former barrier. Photo by Joseph Anderson.

The third component of our research program was snorkel surveys to evaluate the spatial distribution and abundance of juvenile coho salmon. Juvenile coho salmon in this portion of the species' geographic range spend one year rearing in freshwater streams, rivers and lakes prior to migrating to the ocean. Thus, the snorkel surveys for the first two broods of juvenile coho salmon (conducted in the summers of 2004 and 2005) were designed to compare the locations of offspring to the areas where their parents had spawned the previous fall. Results indicated that most juvenile coho salmon remained in spawning reaches, but some dispersed

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as much as several kilometers into previously unoccupied habitats, notably a tributary to the main river. Coho salmon were largely absent from Rock Creek in the spring, but as the season progressed through summer, they appeared in the creek at higher densities and further upstream. By the end of the summer, they were found as much as 2.6 kilometers upstream from the river mouth. These observations indicate that juveniles entered and moved upstream within Rock Creek, where few, if any, adults spawned. While the total number of juvenile salmon entering Rock Creek was small compared to the number rearing in the Cedar River, these exploratory juveniles clearly expanded the range of habitats used for rearing.

These results have added to our knowledge of the patterns and processes of salmon colonization. Coho salmon ascended the fish ladder under their own power and successfully spawned in the very first generation that they were given access to habitat above the dam. The number of salmon that entered the new habitat via the dam passage facility, as well as the widespread movements of some salmon above the dam, suggest that exploration is an innate component of salmon breeding behavior. Exploratory behavior was not limited to the adults, as juveniles moved from the Cedar River into Rock Creek in search of rearing habitat.

The immediate use of the fish ladder by salmon and the initial success of the expanding population suggest that barrier removal is an effective conservation strategy. Initially, all salmon entering the new habitat had strayed from some other source population, presumably the lower Cedar River below the dam. The long term success of the new population will be determined by the reproductive success of these original colonists, and their ability to produce offspring that return to spawn above the dam. Therefore, although the population is too young to clearly demonstrate the capacity to sustain itself over longer time scales, initial results offer an optimistic perspective on the ability of salmon to recolonize formerly lost habitat. This response was particularly impressive considering the population's urban migratory pathway through a man-made shipping canal bisecting Seattle, the heavily altered Lake Washington shoreline and a watershed below the dam characterized by suburban development. Thus salmon took advantage of a refuge in upriver areas for natural spawning and rearing despite widespread urbanization of the lower portions of the watershed.

The implications of Cedar River salmon re-colonization extend beyond the Lake Washington watershed, and imply that the removal of barriers to salmon migration should be prioritized as a conservation measure. Dam removal or fish ladder projects are expensive, and resource managers are justifiably uncomfortable with the uncertainty of biological responses to any proposed restoration projects. A local government agency considering a barrier removal project wants to know that the proposed action will provide a clear benefit to fish populations, and outweigh the financial cost. Anadromous fish passage on the Cedar River provides a concrete example of well spent restoration dollars, and a documented response of the local salmon population.

While natural colonization after barrier removal gives no guarantees, it offers the greatest chance for long-term salmon restoration.

Dams are ubiquitous throughout the Pacific Northwest, and thus dam removal or circumvention offers great potential to salmon restoration. Results from the Cedar River can help identify barriers whose removal are most likely to benefit salmon. On the Cedar River, two major factors promoting colonization were the nearby source population below the dam, and the relatively high quality of habitat above the dam. Identifying dams in watersheds that mirror this situation will give the greatest potential for success. Movement barriers are not just limited to dams, as road culverts impassable to fish plague countless small streams. Restoring access to these areas is likely to benefit juvenile salmon seeking rearing habitat, as demonstrated by the immigration of juvenile coho into Rock Creek in this study.

Lessons from the Cedar River will also provide management advice for salmon populations during recolonization of formerly inaccessible habitat. Pacific salmon will soon regain access to lost habitat on some of the more famous rivers in the region including Elwha, Deschutes, Green, and White Salmon rivers. There are a variety of options on how to manage expanding salmon populations in these and other rivers. Although jumpstarting the population with hatchery supplementation may be tempting for a quick boost in abundance, the risks of such actions may outweigh the costs. A focus on hatchery production at the onset of colonization might threaten the long term fitness of the population through genetic, behavioral, or ecological interactions between hatchery and wild fish. The proven ability of salmon to exploit open habitat, both in the Cedar River and other areas such as New Zealand and Argentina, implies that such risks can be avoided by allowing salmon to colonize under their own power.

Removing dams and constructing fish ladders provides a substantial opportunity to create refugia for natural spawning, rearing and population expansion. In my mind, salmon conservation does not simply reduce to a desire for more fish; it requires an appreciation for the innate behaviors of wild fish and their connection to the entire stream ecosystem. Although a policy of natural recolonization following barrier removal cannot promise an immediate increase in abundance, it offers the greatest likelihood for long term restoration of salmon as keystone species in our rivers. Management should therefore prioritize reconnecting isolated habitats so that the exploratory behavior instinctive to Pacific salmon, and not artificial production, will promote population expansion.