Spilling Water at Hydroelectric Projects in the Columbia and Snake Rivers – How Does It Benefit Salmon?

Hydropower development in the Columbia and Snake rivers has left its mark on salmonid populations, leaving many species on the Endangered Species List. The passing of juvenile fish over a spillway (spill) at a dam has long been used to mitigate the impact of hydropower development on salmon survival. Spill was initially implemented as an alternative route of passage at hydroelectric projects to improve juvenile fish survival by avoiding the mortality associated with passing through turbines. In its first formal application in the late 1970s and early 1980s, spill for fish passage was focused at projects that were not equipped with juvenile mechanical bypass systems. The mechanical bypass systems were designed to divert fish away from turbines, and then to pass fish downstream of the hydroproject. Spill at the time was generally opportunistic, meaning that, if additional water was available that could not be marketed for power, spill may be provided for fish passage. Since that time, the provision of a spill program has evolved from only providing spill mitigation when excess energy was present in the hydrosystem, to a planned spill program at each of the Federal Columbia River Power System (FCRPS) projects, under any river flow conditions.

The evolution of the spill program took place over several years. In February of 1987 the then Northwest Power Planning Council (now Northwest Power and Conservation Council, NPCC) amended their Fish and Wildlife Program to require the U.S. Army Corps of Engineers (COE) to develop a Fish Passage Plan to provide spill to achieve better than 90% survival at a dam for 80% of juvenile salmon and steelhead that migrate to sea during the spring and summer. This only applied to years in which flow was higher than occurred in a critical water year. A critical water year is defined as a year in which the annual runoff in the Columbia River Basin is equivalent to the amount recorded in 1937, a low flow year. This plan opened the door to the Ten Year Fish Spill Memorandum of Agreement (MOA) that was signed by the state, federal and tribal fishery agencies and the Bonneville Power Administration in December of 1988. Although the COE was not a signatory to the Agreement, they agreed to implement the Spill MOA. The Spill MOA provided more planned spill specifically for fish than had occurred in any previous year. It broadened the fish spill program to include more dams under its umbrella and was incorporated into the NPPC Fish and Wildlife Program in 1989. The Spill MOA focused on projects (it included spill at Lower Monumental, Ice Harbor, John Day and The Dalles dams) with no or with insufficient mechanical bypass systems.

With the listing of Snake River sockeye salmon in 1991, and Snake River spring/summer and fall Chinook in 1992, spill was included in the 1992 FCRPS Biological Opinion (BIOP). The BIOP included spill at the non-transportation collector projects and was intended to achieve a 70% fish passage efficiency (the percent of juvenile fish passing a dam via a non-turbine route) during the spring migration, and a 50% fish passage efficiency for the summer migration. Subsequent Biological Opinions broadened both the scope of projects included and the duration of time during the migration season when the planned spill program was implemented.

The latest modification to the spill for fish passage program occurred in a June 10, 2005 Court Opinion in the National Wildlife Federation v. National Marine Fisheries Service lawsuit, when Judge Redden granted the spill portion of the National Wildlife Federation's request for injunctive relief. The Court Opinion specified that the planned spill program include spill to the level allowable under the total dissolved gas cap, and greatly expanded the existing Biological Opinion spill program by including summer spill at all FCRPS projects, including the fish transportation collector projects. Spill to the gas cap means that spill at a project can occur in increasing volumes until the total dissolved gas at the tailrace gage below an individual hydroelectric project measures 120% saturation, or the total dissolved gas at the next downstream hydroproject forebay gage measures 115% saturation. This Opinion effectively created a planned spill program that included more planned spill for fish passage than had ever occurred in the present hydrosystem.

This raises the question as to whether we can describe and measure the benefits to salmon and steelhead from the increases in the spill volumes that have occurred over time. At the Fish Passage Center (FPC) we have reviewed and summarized the observations of juvenile fish passage characteristics developed through annual monitoring of downstream passage in the Smolt Monitoring Program (SMP) and smolt-to-adult return rates from life cycle monitoring conducted through the Comparative Survival Study (CSS). The SMP is an annually implemented state, tribal and federal fishery agency program that has monitored the migration characteristics of juvenile salmonids passing through the Columbia and Snake rivers hydrosystem since 1983. The CSS is a multi-fishery agency (with a CSS Oversight Board comprised of state, tribal and federal fish biologists) conducted study that began in 1996 with the objective of establishing a long term dataset of annual estimates of salmonid survival rates. The survival rates measure the full impact of the hydrosystem on salmon from their outmigration as smolts to their return to freshwater as adults to spawn (smolt-to-adult return rate; SAR). While the most extensive planned spill program has only been in effect since the Court Order in 2005, previously implemented spill programs and the annual variation in flow volumes that have occurred through the historic flow record have allowed us to evaluate spill under a wide range of scenarios.

The development and use of the Passive Integrated Transponder (PIT) tag for fish marking has provided us the opportunity to monitor juvenile migration characteristics on a much finer scale than previous generations of mark tags. Fish are uniquely tagged and tracked as they pass through the hydrosystem as juveniles, and detected again when they return to the river as adults. Knowledge of the specific timing and migration patterns of juvenile salmonids allows us to match them with the unique environmental and physical conditions during the time period when they were migrating. We can identify the specific flow, spill, temperature and other environmental variables that occurred when juveniles migrated, and to a certain extent the specific route of passage a fish took at a hydroelectric project. For a specific hydroproject we know whether a fish was placed into a fish transportation barge, passed undetected through spill or turbines, or whether it passed the dam via the bypass system.

Through the SMP the FPC has annually evaluated environmental variables associated with each of the juvenile cohorts and evaluated fish travel time and survival based on conditions at each dam and in the specific river reaches. When we look at the different variables associated with juvenile migration characteristics we have found through statistical analyses that the increasing proportion of spill provided for fish passage at hydroelectric projects has resulted in higher juvenile spring/summer Chinook, fall Chinook, sockeye and steelhead survival and faster juvenile fish migration rate through the Columbia River power system. The reduction in mortality from avoiding turbine or mechanical bypass passage is captured in the increases observed in juvenile survival rates. The faster juvenile fish migration rate is largely a result of fish passing a project through the spillway and the reduction in forebay delay that usually as occurs as fish approach a dam and hold in areas of low water velocity. We have also observed that the increasing spill proportion provides mitigation for low flows through the hydrosystem. In observations of years with similar flow and water velocity, juvenile fish survival and fish travel time are improved in years with higher average spill. This is an important finding since there are few mitigation measures available for fish during low flow years.

We have demonstrated that increased juvenile survival and faster migration speed through the hydrosystem is associated with increasing spill proportions at projects, but is there evidence linking migration experience through the hydrosystem to survival to adulthood? There are those who believe that the science shows that upon entering the ocean the conditions that affected the juvenile migrants are completely over-shadowed by ocean conditions and the effects on subsequent salmonid survival to adulthood, but what do the data show?

As said before, when the surviving adults from a cohort that migrated to the sea together return to their natal areas, the juvenile conditions under which they migrated can be defined. It is true that conditions in the ocean, under which fish mature before returning to natal rivers to spawn, are highly influential in determining salmonid survival to adulthood. However, there is mounting evidence to suggest that the juvenile fresh water passage conditions affect survival soon after ocean entry. This refers to delayed hydrosystem mortality, which is defined as mortality that occurs in the estuary and early ocean, but was originally caused by earlier experience in the hydrosystem. Delayed hydrosystem mortality is likely due to the cumulative effects from injuries or stress from migrating through juvenile bypass systems or turbines; the transmission of disease resulting from the concentration of fish in the forebays of dams and the bypass collection facilities, or when collected and put into fish transportation barges; changes to migration rates and timing affecting the exposure to negative survival factors and the timing of entry into salt water; depletion of energy reserves associated with prolonged migration; and altered hydrodynamic conditions in the estuary and plume as a result of the present hydrosystem configuration and operation. Budy et al. (2002) provided evidence that some estuary and early ocean mortality was related to hydrosystem passage experience during downstream migration. Schaller and Petrosky (2007) showed that the delayed mortality of Snake River stream-type Chinook salmon remained high, even as oceanic and climatic conditions improved indicating a link with hydrosystem development and operation. Several recent analyses have shown that early ocean survival and fresh water migration passage conditions are correlated. Petrosky & Schaller (2010) found that survival rates during the smolt to adult and first year ocean life stages for Chinook and steelhead were associated with both ocean and river conditions providing direct evidence for hydrosystem delayed mortality. Haeseker et al. (2012) concluded that freshwater and marine survival rates of Chinook and steelhead were correlated, indicating that a portion of the mortality expressed after leaving the hydrosystem is related to downstream migration conditions. Given all the recent studies, we continue to document the relation between juvenile passage conditions and survival during later life stages (delayed hydrosystem mortality), and show the importance of spill in affecting juvenile survival and consequently influencing the survival of returning adults.

Through information that has been collected over several years we recognize that the importance of a spill program has expanded beyond the original intent of providing a way for a fish to avoid turbine passage. We now know that spill improves the downstream passage survival of juvenile salmonid stocks by providing a hydroproject passage route associated with reduced project passage delay, and with less mortality relative to powerhouse bypass or turbine passage and that these benefits translate into improved survival to adulthood. The question is, "where do we go with the information that we now have?" We know that the present hydrosystem operation and configuration does not result in the recovery of ESA listed species. The CSS Oversight Committee convened a workshop in July of 2011, to evaluate the existing data and to develop potential paths for continued testing of the hypotheses. The workshop process addressed how we use recent analyses to evaluate and optimize FCRPS operations for ESA listed groups of anadromous fish to meet the regional goals for SARs established by the NPCC as 2% to 6%. Modeling studies using existing data have determined the range of improvement that might occur if juvenile passage conditions were altered. However, to verify the models real biological impact, studies will need to be conducted to determine whether manipulating the factors that most affect juvenile survival, such as spill, can be used to achieve adult survival goals. One question that needs to be answered is, "will spill in low flow years translate into large survival benefits to the adult return stage?" Improvement in survival in low flow years is a key conservation concern for recovering Snake River populations. There are restrictions on the conduct of these studies. Some restrictions are easier to address, such as the physical limit on the amount of spill that can occur due to current total dissolved gas standards, while others are more difficult to approach, such as the monetary impact to the power system operation that can be tolerated for the recovery of endangered species, since spill is considered to be foregone revenue for the power system. In summary, planned spill programs are proving to be one of the most important tools in the arsenal used in the recovery of endangered species. It is now up to the region to test how much more improvement can be gained from this mitigation measure to recover the salmon and steelhead population of the Snake and Columbia rivers.

References

Budy, P., G.P. Thiede, N. Bouwes, C.E. Petrosky, and H. Schaller. 2002. Evidence linking delayed mortality of Snake River salmon to their earlier hydrosystem experience. North American Journal of Fisheries Management 22:35-51.
Haeseker, S.L., McCann, J.A., Tuomikoski, J., Chockley, B. 2012. Assessing freshwater and marine environmental influences on life-stage specific survival rates of Snake River spring summer Chinook salmon and Steelhead. Transactions of the American Fisheries Society 141:121-138.

Petrosky, C. E., and H. A. Schaller. 2010. Influence of river conditions during seaward migration and ocean conditions on survival rates of Snake River Chinook salmon and steelhead. Ecology of Freshwater Fish 19, no. 4: 520–536.

Schaller, H.A., and C.E. Petrosky. 2007. Assessing hydrosystem influence on delayed mortality of Snake River stream-type Chinook salmon. North American Journal of Fisheries Management 27, no. 3: 810-824.