FISH PASSAGE CENTER

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Mr. Orri Vigfússon
North Atlantic Salmon Fund
Skipholti 35
105 Reykjavík, Iceland

Dear Mr. Vigfússon,

We have received your request to provide responses to questions based on our experience regarding juvenile and adult salmon passage through the Columbia River system of hydro power projects. We understand that three hydro power stations have been proposed for construction in the Thjorsa River, South Iceland and that you are concerned that the combined effects of the three proposed power projects will dramatically change the present river and have impacts on the future survival of North Atlantic Salmon (*Salmo salar*) in the Thjorsa River. The Fish Passage Center has compiled the following information to address your questions:

We have been provided with the following information: "Example of places where bypass channels have provided good results in coloured water are Bonneville Dam and Lower Granite Dam in the Columbia River in USA where the survival estimate of smolts that go through bypass channels is 98-99% according to measurements." Are there any studies that have been conducted that explain what percentage of juvenile salmon smolts passing these projects would be expected to enter these surface bypass channels?

Yes, many studies have been conducted on the Columbia River hydroelectric project system. Bonneville Dam is located in the lower Columbia River and is the last project encountered by all smolts migrating through the hydro system on the way to the estuary, while Lower Granite Dam is located in the lower Snake River and is the first project that smolts originating in the Snake and Clearwater rivers pass on their way downstream through the hydro system. Not all fish that pass a project will pass through surface bypass channels. The fate of fish passing a hydro project is dependent on installed structures and river flow operations. Dye tests (coloured water) are indicators of the hydraulic conditions encountered by fish approaching a project, but are not used to determine the proportions of fish that pass via different routes.

Passage studies are conducted on juvenile yearling Chinook and steelhead and other salmonid species when available. The data for yearling Chinook and steelhead are most comparable to Atlantic salmon and we will present those here.

Lower Granite Dam is equipped with a mechanical bypass system comprised of fish screens that divert fish away from turbine units. The Dam is also equipped with a removable spillway weir (RSW) in one spill bay that is designed to pass surface flow and would be analogous to a surface bypass channel. Conventional spill is also provided at the project. Beeman et al., 2008 conducted a series of experiments using radio tagged fish to determine their route of migration through the Lower Granite Project. Based on their data, at Lower Granite Dam approximately 39% of the yearling Chinook entering the project passed through the powerhouse (8% through the turbines and 31% through the bypass), while 33% of fish passed over the spillway, and 28% passed through the removable spillway weir (surface bypass channel). For steelhead, 48% passed through the powerhouse (6% through the turbines and 42% through the bypass), while 28% passed over the spillway and 25% through the removable spillway weir (surface bypass channel).

The Bonneville second powerhouse is equipped with a surface bypass channel that is known as the corner collector. The corner collector facility includes a 2,800-foot long transportation channel, a 500-foot long outfall channel, a plunge pool, and modification of the ice and trash chute. Data (Ploskey et al., 2011) at Bonneville Dam indicate that 46% of the yearling Chinook and 57% of the steelhead passing the Bonneville second powerhouse passed via the corner collector.

It is important to note that both Lower Granite Dam and Bonneville Dam do not rely solely on the operation of surface bypass routes during the juvenile migration. Passage routes over conventional spill bays, along with surface bypass channels, are provided to pass juvenile salmonids at the hydro project via routes other than entering the powerhouse. The use of surface bypass channels alone does not provide adequate bypass passage. In addition, concern has been expressed based on data collected through 2007 suggesting that survival to adulthood for fish passing through the corner collector was not as high as for those passing in spill. In March 2004, the U.S. Fish and Wildlife Service (FWS) released over 220,000 sub-yearling fall Chinook from Spring Creek National Fish Hatchery (NFH) with coded wire tags (CWT) to evaluate smolt-to-adult return rates (SAR) back to the hatchery under two operations at Bonneville Dam. Tagged fish were released in two groups: one group released during four days of spill operation at Bonneville Dam and one group released during four days of corner collector operation at Bonneville Dam. Results from this single year of study showed that the overall smolt–to-adult return (*SAR)* was 0.118% for the fish released during the spill operation and 0.100% for fish released during the corner collector operation. The overall *SAR* for fish released during the spill operation was 18% higher than the *SAR* for fish released during the corner collector operation; however this difference was not statistically significant. Using Bayesian statistical methods, FWS estimated an 80% probability that the *SAR* for the spill operation release was higher than the *SAR* for the corner collector operation release. Applying the results from the 2004 March release operations to the March releases from Spring Creek NFH over 2005-2007, FWS estimated that a foregone loss of 15,200 adults (range 2,400-38,900) may have occurred due to corner collector-only operations during 2005-2007.

Can we expect that the juvenile survival estimates calculated at the dam bypass structure of 98-99%, and through Kaplan Turbines of 85-90%, to be sufficient to describe the total

effects of these hydro power projects on salmon survival? Would there be additional effects of hydro power project passage on survival to the adult return stage?

No, the direct juvenile survival estimates you describe are not sufficient to describe the effects of dam bypass passage on salmonid survival. The dam bypass estimates of 98-99% are measured from the forebay of a dam to the tailrace of a dam. The Kaplan Turbine estimates of 85 – 90 % translate to 51 – 85% over all three projects. Again, these estimates only include the “direct” mortality from turbine passage. These “direct” estimates do not include any mortality that occurs outside these zones, nor do they take into account the <u>complete</u> impacts of mechanical injury, large pressure changes, stress related mortality and mortality caused by increased predation rates associated with dam passage.

Juvenile survival through river reaches includes the mortality due to dam passage, as well as the mortality due to the alteration of river flow from impoundments. This survival estimate captures some, but not all, of the mortality that is expressed subsequent to leaving the immediate area of the hydro project. Evidence for delayed mortality associated with powerhouse passage was found by Ferguson et al., (2006). Their analysis showed that fish passing through turbines have a lower survival rate when survival was measured over a longer reach than when measured over a short reach. Fish released into turbines had relatively high survival to the tailrace of McNary Dam (0.93 to 0.946) as measured by balloon tags. Survival to arrays located 45 km downstream was between 0.814 and 0.858 and was found to be significantly lower. Ferguson et al., (2006) concluded that direct mortality (mortality to the tailrace of the dam such as the estimates you quote) made up 30% to 54% of total mortality. In this case delayed juvenile mortality was up to 70% of total mortality estimated in this study.

In addition, several independent studies have indicated that delayed and latent mortality occurs in fish passing the powerhouse collection bypass systems (Budy et al., Buchanan et al., 2010; Schaller and Petrosky, 2007; Petrosky and Schaller, 2010; Tuomikoski et al., 2011; Scheurell and Zabel, 2006: Ham et al., 2009; Marsh et al., 2009; McMichael et al., 2010). These various analyses indicate that delayed or latent mortality is occurring due to powerhouse passage and that the impact of powerhouse passage is not fully manifested until later in the migration. This delayed mortality reduces adult return. This implies that the site specific project and powerhouse and short reach survival estimates that are generated to assess juvenile survival through hydro projects are likely to be underestimates of the actual impact of the dams on salmon and steelhead.

The effects of bypass systems on juvenile salmon and steelhead travel times and smolt-to-adult return were analyzed in the Comparative Survival Study Annual Status Report for 2010. Three sets of analyses were conducted:

a. The first set of analyses evaluated the effects of bypass systems on fish travel time from Lower Granite Dam to Bonneville Dam.
b. The second set of analyses evaluated the effects of bypass history on SARs from Bonneville outmigration as juveniles to return to Bonneville as adults.
c. The third set of analyses examined the effect of cumulative bypass passages during the juvenile outmigration, on smolt-to-adult return rate.

The methods for these analyses are described in Chapter 7 of the CSS Annual Status Report for 2010 available on the FPC website http://www.fpc.org/documents/CSS.html .

The analyses of bypass passage on fish travel time identified significant migration delays for juvenile Chinook salmon and steelhead that were bypassed, relative to non-bypassed fish. The average magnitude of the delay among the significant cases was 0.69 days (16.6 hours) for Chinook and 0.73 days (17.5 hours) for steelhead. Significant migration delays for bypassed fish were identified in the majority of the year-dam combinations for Chinook (67%) and a large proportion of the cases for steelhead (23-33%). The lower percentage of significant migration delay identified for steelhead was likely due to the smaller sample sizes available for steelhead.

The analyses of effects of bypass on post-Bonneville smolt-to-adult return (SAR) indicated that post-Bonneville SARs are lower for bypassed Chinook and steelhead smolts than non-detected smolts. These analyses indicate that subsequent downstream passage experience may further influence smolt-to-adult return rate, with the smolts that pass undetected through the dams expected to have higher smolt-to-adult return rates than those smolts that are bypassed one or more times. Model estimates for Chinook salmon showed a 10% reduction in post-Bonneville SAR per bypass experience at upstream dams. Steelhead showed a 6% reduction in SAR per bypass experience at Snake River dams and a 22% reduction in post-Bonneville SARs per bypass experience at Columbia River dams. For Chinook estimates of bypass effects were similar across Columbia and Snake River dams. For steelhead bypass effects were more severe at McNary and John Day dams.

The analyses of cumulative bypass effects showed that non-bypassed yearling Chinook LGR-LGR SARs averaged 52% higher, and non-bypassed steelhead SARs averaged 91% higher, than smolts that were bypassed at one or more of the collector facilities.

The results of the CSS analyses indicate that route specific estimates of juvenile survival rate underestimate project impacts because they do not account for the mortality associated with migration delay or the latent mortality associated with project passage. Additionally, in spite of the existence of mechanical bypass systems and surface bypass channels, goals for smolt to adult return rates in the Columbia River are not being met, and fish stocks remain on the endangered species list.

Downstream of the Urridafoss project there will be a reduced water flow, down to only 10 m^3/s, which is a dramatic decrease from the 360 m^3/s which is the natural average stream flow of the river. These lower flows will continue over natural barriers, such as the Uridafoss waterfall. Have you observed any similar situations on the Columbia River and do you have any information describing potential impacts to adult salmon migrants? Will this create low flow barriers to fish passage? Can you estimate the potential extent of these barriers?

When rivers are dammed and flows through a reach are significantly reduced, low flow barriers to the adult salmon migration can be created. There is literature to support the concept that barriers to adult migration are created when the water depth is significantly decreased due to hydro development. (Thompson, 1972; Reiser and Bjorrn, 1979). In many rivers of the Pacific Northwest of the United States, dams and water withdrawals reduce flows to a level where significant numbers of passage barriers are created to adult salmon migration (Figure 1).

It would be important to evaluate how many low-flow instream barriers would be created in Thjorsa River by the placement of the three hydro dams. To estimate the potential extent of these barriers a survey to measure the bathymetry of the river between and below the dams should be made. Then a physical model of the river could be built to determine how many and the location of all the low flow barriers to migration that are created. This evaluation would be a critical element in determining the overall impact of the dams to the salmon population productivity.

Figure 1. The following photos are examples of low-flow instream barriers that were encountered in dammed Pacific Northwest rivers.

Are the numbers of salmon caught (here by both net and rod) an appropriate way to monitor salmon abundance?

No, catch data, the numbers of salmon caught, are not usually used as estimates of salmon abundance, since fishing effort is not constant. Catch estimates can vary according to the amount of effort and, consequently, increases in catch attributed to increases in effort may be mis-interpreted as increases in abundance. The more accepted way of using catch data is to estimate the catch per unit of effort (CPUE). Effort can be expressed in terms of nets or rods used, and a time is associated with the effort.

There are several other methodologies available to estimate adult salmonid abundance. Annual counts of spawning adults returning to rivers and the redds constructed during spawning can be used to track annual changes in the salmonid breeding population size. Rivers may be monitored for overall adult abundance using equipment such as sonar to count targets of specific sizes. Side beam split-beam sonar technology has been used effectively to estimate salmon abundance in the Kenai River, Alaska (Miller et al., 2004). Other methodologies may include mark recapture studies, where a portion of adult salmonids entering a river may be marked and subsequently recaptured upstream. This type of methodology is also applied to juvenile salmonids in the Columbia River, primarily through the Comparative Survival Study (Tuomikoski, 2011).

Given the concern regarding the impact of hydro power project development of the Thjorsa River it would seem prudent to include a population viability analysis (PVA) as part of a biological assessment. Population viability analysis is a technique to estimate the probability of a stock attaining given sizes, usually zero or very low, sometime in the future (Gilpin and Soulé, 1986). PVA is a stochastic modeling technique predicting changes in population abundance given uncertain biological parameters (Beissinger 2002). PVA models use a detailed life history cycle incorporating uncertainty in juvenile and adult survival rates, and the inter-relation between the two due to delayed mortality associated with juvenile hydro project passage. A PVA model could be used to estimate the probability of causing extinction over a given number of life-cycles based on the range of uncertainty associated with the survivability of juvenile and adult salmonids under the proposed hydro project development in the Thjorsa River.

We hope that we have addressed your questions adequately. Please feel free to contact us if you need additional information.

Sincerely,

Margaret Filardo, Ph.D.
Fishery Biologist

Michele DeHart
Fish Passage Center Manager

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