FISH PASSAGE CENTER

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MEMORANDUM

TO: Rob Lothrop, CRITFC

FROM: Michele DeHart

DATE: December 17, 2003

RE: Summary of Documented Benefits of Spill

In response to your request of December 11, 2003, the Fish Passage Center staff prepared the following summary of information addressing the benefits of spill for fish passage. The benefits of spill for fish passage are well established and accepted throughout the scientific community. There is substantial data and literature documenting the direct and indirect benefits of spill for fish passage. In some river reaches and some time periods, such as the lower Columbia River during the summer migration period, spill for fish passage is the only protection measure that has been provided consistently. For some stocks of salmonids such as Klickitat River, Umatilla River and other lower river tributaries spill is the only passage protection measure provided.

Juvenile Passage; Spill; and Total Dissolved Gas

Background

When fish approach a hydroelectric project they can either enter the powerhouse or continue migrating downstream by passing over the spillway. Upon entering the powerhouse fish either pass through a turbine unit or are mechanically collected and bypassed downstream without passing through the turbines. Employing the use of spill for juvenile migrants has long been used as an effective management tool for improving passage survival of migrating juvenile salmon at mainstem hydroelectric projects. Routing smolts through spillways at hydroelectric projects in the Columbia and Snake rivers is generally considered to be the safest passage strategy, when compared to the passage survival through bypass systems and turbine routes.

Prior to 1993 when the first Biological Opinion was issued, spill was used as mitigation at hydroelectric projects to enhance project survival for juvenile salmonids. Historically, spill occurred operationally, when project capacity or system generation needs were exceeded. As the hydrosystem was developed it became more efficient through such actions as the construction of the DC and AC Intertie transmission lines. As a consequence the occurrence of spill declined, accelerating the disagreements between operators and regulators and the fishery agencies regarding the provision of spill. In December of 1988 a 10-year spill program was developed for implementation of spill at projects that were not equipped with adequate bypass systems to achieve a fish passage efficiency goal. (Fish Spill Memorandum of Agreement).

As fish stocks continued to decline and were listed under the Endangered Species Act, it became clear that the negotiated contracts were not aggressive enough to recover endangered stocks. This lead to the modification of spill programs under the different versions of the Biological Opinion. At the same time that spill was identified as a key element in the recovery of listed stocks, the need to meet the objectives of the Clean Water Act was also identified. Spill causes increased levels of total dissolved gas that could increase mortality and eliminate the benefits associated with the implementation of an aggressive spill program. Therefore, subsequent implementation of a spill program has been within the confines of the "risk" associated with increased levels of total dissolved gas

Decreasing Migration Delays and Predation

Spill and Decreases in Delay associated with Project Passage

Spill is an effective tool in decreasing the amount of delay experienced by fish in forebays and tailraces of dams where predator populations and predation rates are highest. Beamesderfer and Rieman (1991) found that forebay populations of northern pikeminnow (*Ptychocheilus oregonensis*) and smallmouth bass (*Micropterus dolomieui*) were present in substantial numbers in the forebay of John Day Dam. Poe et al. (1991) reported that the diet of northern pikeminnow in the forebay of John Day Dam was 66% salmonid smolts. This suggests that delay of outmigrants in the forebay could reduce survival due to increased predation, and project operations such as daytime spill that decrease forebay residence time could increase survival. In addition, spill was also shown to be an important factor in reducing forebay delay in studies conducted by Snelling and Schreck (1994).

Hansel et al., (1999) showed that in general, yearling chinook salmon and steelhead that arrived in the forebay when no spill occurred tended to delay. Yearling chinook salmon and steelhead that arrived at night, concurrent with spill, passed the dam more readily. Residence times of yearling chinook salmon were markedly reduced with respect to daytime spill, whereas steelhead residence times decreased only slightly in the presence of daytime spill. When daytime spill went from 0 to 30% yearling chinook salmon residence time dropped from 8.5 h to 0.8 h in 1999 and 9.0 h to 2.4 h in 2000, while yearling steelhead residence time decreased from 11.4 to 11.3 h in 1999 and 11.4 to 9.4 h in 2000. Data collected in 1999 and 2000 suggest that hatchery steelhead (>200 mm) may delay in the John Day Dam forebay longer than wild steelhead (<200 mm). (NOAA, 2000)

Dispersal of Predators

Spill establishes a large flow net with increased velocity that disperses predators from the forebay and tailrace areas thus reducing the potential for predator/prey interactions (Faler et al., 1988). The concept of developing spill patterns at FCRPS dams specifically for fish passage was first addressed systematically in the 1960s to facilitate adult salmon passage into the adult fish collection systems. Junge (1967) observed improved adult salmonid passage under intermediate to large spill volumes if four or five gates at each end of the spillway were at low volume settings. At large dams this resulted in a tapered spill pattern near each end and a flat spill pattern across the central portion of the spillway. At smaller dams this produced a "crowned" pattern across the entire spillway tailrace, with the highest discharge in the middle bays. The success of adult salmon passage was evaluated by comparing ladder passage counts associated with various spill patterns. The spill patterns developed that appeared best for adult passage conflict with what is thought today to be best for juvenile passage (high shoreline velocities), since Junge kept near-shore velocities low to facilitate adult migration and passage into fishway entrances located along shorelines (NOAA 2000). Smolt residence time in spillway tailraces is likely influenced by spill volume and pattern. High spill volume and water velocity push water and presumably juvenile salmonids out of the immediate tailrace, and help redistribute piscivorous predators (northern pikeminnow) away from the immediate spillway tailrace, reducing potential predation opportunities (Faler et al. 1988).

Shively et al. (1996) found that ambient river flow velocities of at least 1 m/s were necessary to keep northern pikeminnow from holding in areas near bypass outfalls, and that the degree by which water velocity eliminated northern pikeminnow holding increased as outfall distance from shore and water depth increased. Hansel et al. (1993) found that hydraulic cover such as eddies and backwaters at velocities below this threshold were preferred northern pikeminnow feeding habitats, particularly when near primary smolt outmigration paths. Spill patterns that facilitate rapid juvenile egress from the spillway stilling basin through the tailrace likely increase juvenile survival. Current spill patterns are developed to increase the survival of juvenile fish through tailraces, by emphasizing minimizing hydraulic cover and maintaining high water velocities near spillway shorelines. To not interfere with daytime adult passage, these juvenile spill patterns are often employed during nighttime hours only (COE, 1999d; NOAA 2000).

Spillway Survival

Whitney et al. (1997) reviewed 13 estimates of spill mortality for salmonids (3 steelhead and 10 salmon) published through 1995 and concluded that 0 to 2% is the most likely mortality range for standard spillbays. They also pointed out that local conditions, such as back eddies or other situations that may favor the presence of predators, may lead to higher spill mortality.

Some point estimates for mortality in spillbays with spill deflectors are higher than estimates for spillbays without deflectors. For example, the highest estimates of survival for yearling chinook salmon and steelhead at Snake River dams were obtained from spillbays without flow deflectors, ranging from 98.4 to 100% (Muir et al. 1995b, 1996, 1998). Although lower survival estimates were obtained from spillbays with flow deflectors (ranging from 92.7 to 100%) (Iwamoto et al. 1994; Muir et al. 1995b, 1998), differences in survival between the two types of spillbays compared pairwise were not significant at Little Goose (steelhead), or Lower Monumental Dams (yearling chinook salmon) (NOAA, 2000).

A number of methodologies have been used to estimate spillway survival at lower Columbia River dams, including identification of test fish by fin clips (Holmes 1952), freeze brands (Johnsen and Dawley 1974, Raymond and Sims 1980), coded-wire tags and freeze brands (Ledgerwood et al. 1990), balloon tags (Normandeau Associates Inc. et al. 1996a, b).

At Bonneville Dam, Holmes (1952) estimated that subyearling chinook salmon survival through the spillway was 96 to 97%, depending on how the data were analyzed. Johnsen and Dawley (1974) compared the survival of subyearling chinook salmon passing through spillbays with and without flow deflectors, and found that relative survival was 87 and 96%, respectively, and that these differences were not statistically different. Ledgerwood et al. (1990) found that survival of subyearling chinook through spillbay 5 was not significantly different than for fish released downstream. Based on the balloon-tag methodology, the calculated survival probabilities for deflector and non-deflector spillways were both 1.0 at Bonneville Dam, however, fish passing through a spillbay without a spill deflector displayed a slightly higher injury rate (Normandeau et al. 1996a; NOAA 2000).

Spill and Total Dissolved Gas

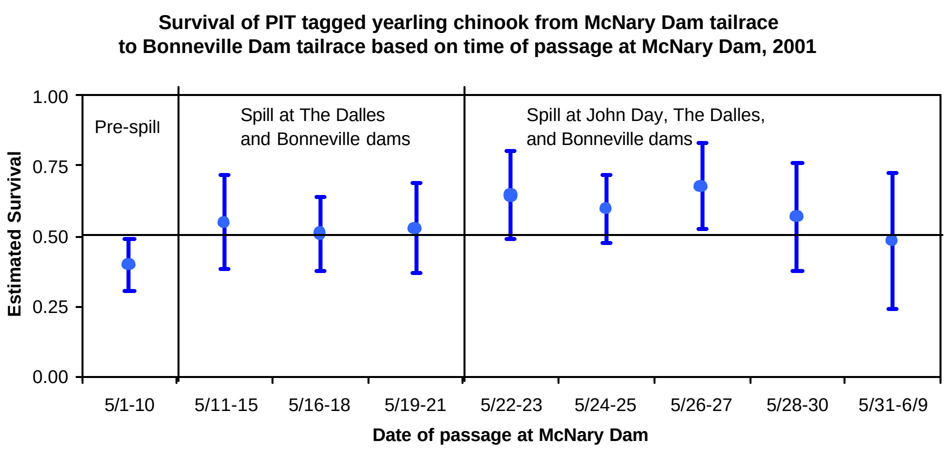
Spilling water can cause high dissolved gas to concentrate by entrainment of air in the form of bubbles as it passes over the spillway and plunges to the tailrace. The air is forced into solution, causing the water to become "supersaturated" at ambient atmospheric pressure with respect to dissolved gas. Water that is supersaturated with respect to dissolved gases may cause gas bubbles to form in the bodies of fish and other aquatic animals under certain conditions that impair their ability to function, or in extreme situations may lead to death. Consequently, spill management must recognize the tradeoff between survival benefits and the detrimental effects of high total dissolved gas levels.

The "Spill and 1995 Risk Management" report was developed by the region's fishery agencies and tribes document and provided part of the biological justification for the implementation of the 1995 Biological Opinion spill program. The document reviewed all available studies and quantified the trade-off between the increase in salmon survival associated with an increase in spill passage, against the potential fish mortality that might be incurred from increased levels of total dissolved gas (TDG). The assessment concluded that the benefits of spill passage outweighed the risk up to TDG levels between 120 to 125%. The annual voluntary spill program has been implemented within these constraints since that time.

In 2000 the NMFS included Appendix E in their Biological Opinion. This appendix was meant to serve as the justification and risk assessment for the spill program included in the 2000 Biological Opinion. The appendix addresses the 120% dissolved gas ceiling and builds on the findings of the 1995 document with information collected subsequently. The NMFS also uses the SIMPAS model as a means of quantifying an amount of system survival attributable to the 120% TDG spill program. The NMFS concludes, "the risk associated with a managed spill program to the 120% total dissolved gas (TDG) level is warranted by the projected 4% to 6% increase in system survival of juvenile salmonids. Recent research and biological monitoring results support the findings of the 1995 report, which predicted that the TDG in the 120% to 125% range, coupled with vertical distribution fish passage information indicating that most fish migrate at depths providing some gas compensation, would not cause juvenile or adult salmon mortalities exceeding the expected benefits of spillway passage. NMFS finds little evidence that this expected survival improvement would be reduced by the mortality related to gas bubble trauma (GBT). NMFS also concludes that physical and biological monitoring of GBT signs can continue to be used to indicate dissolved gas exposure in adult and juvenile salmon migrants."

System-wide Evidence for Spill Survival Benefits

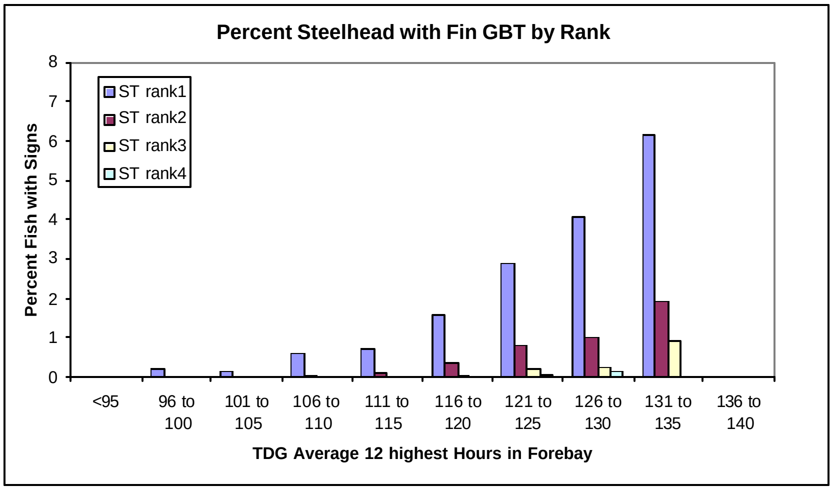
Analysis of smolt survival in the lower Columbia River index reach in 2001 was performed with the year split into periods of passage at McNary Dam (FPC, 2001). The McNary Dam passage distribution of PIT tagged yearling chinook was split into nine multi-day blocks with at least 10,000 PIT tagged smolts per block. A plot of the estimated survival from McNary Dam tailrace to Bonneville Dam tailrace shows evidence of shifts in estimated survival for yearling chinook smolts passing McNary Dam in the May 1-10, May 11-21, and May 22-June 9 periods (Figure 44). One likely explanation of this apparent grouping of the survival data was that spill in the lower Columbia River index reach did not begin at The Dalles and Bonneville dams until May 16 or at John Day Dam until May 25.

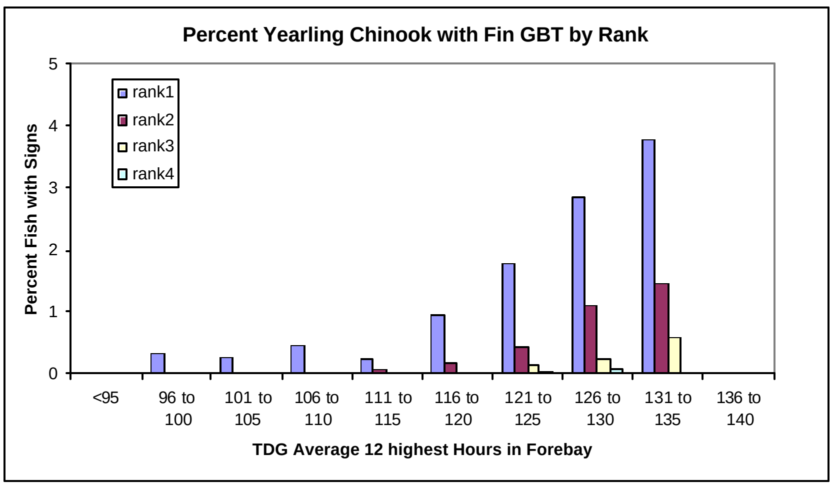


Analyses conducted by Muir et al. (2001) reconfirmed the findings of numerous earlier studies by demonstrating that spillway survival of smolts exceeds that incurred through both turbines and collector/bypass systems at dams on the Snake River.

Evidence for the Appropriateness of the Current Total Dissolved Gas Standards

The effects of elevated dissolved gas on migrating juvenile and adult salmon due to voluntary spill have been monitored each year of spill program implementation. Based on seven years of data from the biological monitoring program, the average incidence of gas bubble disease signs has been low, although the state-allowed maximum TDG due to spill was 120 percent in the tailrace and 115 percent in forebays during periods of voluntary spill. A high percentage of the spill that did occur in some years was involuntary, and often resulted in dissolved gas levels above the 120% waiver. The following graphs depict the incidence and severity of signs of GBT in fish collected for observation over the seven years, grouped in 5 percent TDG levels. Increases in the incidence of signs were observed with increases in the levels of TDG. The severity of signs also increased, but not until dissolved gas levels were above the 120 to 125% level.





These data suggest that total dissolved gas concentrations above 125% may have had a negative impact on survival. These high total dissolved gas measurements are a function of uncontrolled spill that occurred in the hydrosystem because of flow in excess of the hydraulic capacity of the project, or due to spill in excess of generation needs. They are not caused by the implementation of the Biological Opinion Spill Program.

Summary

All of the information collected to-date of survival and the benefits associated with spill indicate that spill provides a significant benefit to juvenile survival at levels up to 125% in the tailrace of the dam.

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