High Head Bypass Fish Passage Investigations Year Two: Truck Transport vs. Bypass

Stephanie Liss, Eric Fischer, Ryan Harnish, Ben Vaage, James Hughes, and Jarrod Ver Steeg
Pacific Northwest National Laboratory, Richland, WA
stephanie.liss@pnnl.gov

Pacific Northwest National Laboratory conducted a Year Two fish physiology study during fall 2020 at Green Peter Dam (Green Peter), Oregon, for the U.S. Army Corps of Engineers – Portland District (USACE), to investigate the effects of downstream passage at a high head dam on fish health. We compared two conveyance methods: (1) downstream fish passage through a bypass system (bypass pipe), and (2) downstream fish passage at a collection facility with vehicle conveyance (truck transport) using juvenile Chinook salmon that were infected with copepods, and separately fish that were healthy. The goal of this study was to understand if there was a downstream passage conveyance that minimized stress in juvenile fish. Full-scale studies using copepod-infected and healthy fish were separately evaluated for fish stress (utilizing concentrations of cortisol [a primary stress response hormone], glucose, and lactate [secondary stress response metabolites]), injury (e.g., hemorrhages, eye damage, torn operculum, etc.), and short-term (24 h) survival after exposure to one of two downstream passage conveyances, representative of transport conveyance (truck transport) or bypass pipe passage.

Infected and healthy Chinook salmon surrogates were provided by the Oregon State University Wild Fish Surrogate Program and were reared to the approximate size (mean: 140–160 mm in fork length) of migrating juveniles. The infected fish study occurred first, followed by the healthy fish study. Fish were transported to Green Peter and randomly and equally sorted into holding tanks. Fish in the bypass pipe simulation were held in tanks on top of Green Peter on the forebay side of the bypass, whereas fish for the truck transport simulations were held in tanks at the base of the dam. Simulations (bypass pipe or truck transport) began after a two-week acclimation period at Green Peter. Fish either underwent a simulation or were controls (i.e., did not undergo any simulation). There was one bypass pipe treatment and three truck transport treatments, representative of different holding times at a collection facility prior to downstream transport (i.e., 1 h, 12 h, and 24 h). Subsamples of control fish were taken for blood plasma analyses at one time prior to the start of each treatment. Subsamples of treatment fish were taken at six times post-treatment (0, 0.5, 1, 3, 6, and 24 h). Injury assessments and survival occurred at the same post-treatment sampling times. Cortisol analyses were performed in the laboratory and glucose and lactate were evaluated using handheld devices in the field.

Copepod-Infected Fish

We sampled 557 copepod-infected fish (n = 479 simulation fish and n = 78 controls). The cortisol stress response results indicated all fish were stressed as a result of the bypass pipe and truck transport simulations. Differences in environmental conditions (water temperature and dissolved oxygen) and cortisol concentrations for control fish among holding tank locations from the infected fish objective indicated a potential tank location effect; therefore, treatment:control

cortisol concentration ratios (T:C) were used for analyses. However, true concentrations were also utilized for ease of comparability. True concentrations were used for infected fish glucose and lactate analyses because no differences in those variables were identified among holding tank locations for control fish.

Cortisol concentrations peaked between 0.5–1 h post-treatment and returning to near baseline levels by 24 h post-treatment. Glucose concentrations varied across treatments, typically peaking at 3 h post-treatment, except for fish in the 1 h transport treatment, whose glucose peaked at 6 h post-treatment. Lactate concentrations followed the same trends as cortisol, with increased concentrations 0.5–1 h post-treatment and nearing or going below baseline levels by 24 h post-treatment.

Infected fish for the bypass pipe treatment had a greater number of injuries compared to infected fish in the 1 h and 12 h transport treatments (Fisher's exact test; $P < 0.001$), although there were no treatment differences in survival (Fisher's exact test; $P = 0.54$), nor in the proportion of infected fish with visible copepods or gill damage (Fisher's exact; $P = 0.62$).

Healthy Fish

We sampled 558 healthy fish ($n = 478$ simulation fish and $n = 80$ controls). Again, all fish were stressed as a result of the bypass pipe and truck transport simulations. Although there were differences in environmental conditions for the healthy fish among tank locations, there was no tank location effect because bypass pipe control fish had similar cortisol, glucose, and lactate concentrations as the transport control fish, and true concentrations were compared for all three variables. However, T:C analysis was also performed for cortisol for comparison to the Year One study.

Cortisol concentrations were consistently higher for fish in the bypass pipe treatment compared to the three truck transport treatments at all but one post-treatment sampling time (6 h). Interestingly, bypass pipe fish cortisol concentrations did not decrease from 6 h to 24 h post-treatment like they did for fish from the three transport treatments. Taken together, results from the Year Two study potentially indicate bypass pipe fish experienced a more severe stressor than the transport fish.

Glucose concentrations varied across treatments, typically peaking at 3 h post-treatment, except for bypass pipe treatment fish, whose glucose peaked at 6 h post-treatment. Lactate concentrations followed the same trends as cortisol, with peak concentrations occurring between 0.5–1 h post-treatment. There were no differences in injuries (Fisher's exact test; $P = 0.42$), nor in rate of survival (Fisher's exact test; $P = 0.76$) among treatments.

Overall, results from the Year Two study showed that when cortisol, glucose, and lactate concentrations were examined in combination, all fish (infected and healthy) were stressed from all of the truck transport and bypass pipe treatments. Fish stress also trended towards returning to baseline levels by 24 h post-treatment, indicating the fish were recovering and the effects of the initial (fight-or-flight) stress response were temporary. However, a clear trend in the Year Two study identified the bypass pipe treatment as a more stressful treatment, regardless of health

status (infected or healthy) and regardless of metric used to compare results (T:C or true cortisol concentrations).