Research Preliminary Proposal

Evaluation of Foster Adult Fish Trap Performance, 2016

Study Code APH-15-05-FOS

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Project Summary

A. Goal

The primary goal of this study is to gather information related to adult Chinook Salmon and steelhead attraction and entry at the Foster Dam (FOS) adult fish facility (AFF). The information will be used to improve the effectiveness of AFF operations and to reduce holding by pre-spawn adult fish in the Foster Dam tailrace.

In 2016, we will address four general research questions:

1) ***What is the distribution and behavior of adult Chinook salmon and steelhead in the Foster tailrace?***
2) ***How do fish distribution and behavior relate to dam and fishway operations and to AFF trapping efficiency?***
3) ***How does water temperature and water chemistry (e.g., conductivity, pH, dissolved oxygen, dissolved free amino acids) vary across the Foster tailrace, fishway, and AFF?***
4) ***Are environmental parameters associated with adult fish distribution or AFF trap capture efficiency?***

B. Objectives: 2016

Objective 1) Review and assess data collected before and after Foster AFF trap construction

Objective 2) Develop and deploy temperature monitoring and water chemistry equipment at relevant locations below the dam and within the adult passage system

Objective 3) Evaluate adult Chinook salmon behavior and fishway passage metrics at FOS AFF during experimental fishway operations

Objective 4) Analyze data from Objectives 2 and 3 to test for experimental effects and environmental correlations

Objective 5) Identify causative factors and measures that could be tested to increase adult fish collection and passage rates

C. Methods

Objective 1: We will collect historical Foster trap records from years before the facility reconstruction and from the post-collection years (2014-2015) to assess the timing and rate of adult salmon and steelhead collection. We will also use existing radiotelemetry data from the 2011-2014 basin-wide Chinook Salmon and steelhead studies to assess timing and trap capture rates. Lastly, we will analyze data from a 2015 pilot study of weir gate operations experiment, the systematic tailrace count data from 2015, the water temperature monitoring data, and other relevant operations data (e.g., tailwater elevation, spill, etc.) in consultation with Corps and ODFW biologists.

Objective 2: As part of the evaluation of the 2015 temperature data, we will assess whether additional temperature monitoring sites are needed for 2016. We also propose to conduct routine water chemistry sampling with continuous monitoring equipment at a subset of the temperature monitoring sites used in 2015. Continuous parameters will include the temperature, pH, conductivity, and dissolved oxygen [DO], hereafter referred to as 'core water quality' parameters. Dissolved free amino acids (DFAA) play a strong role in homing olfaction in salmonids. Consequently, we propose to characterize DFAA composition in the AFF, tailrace (e.g., spillbay and turbine) and upstream water sources to test whether inadequate olfactory cues contribute to low collection rates of the AFF.

Objective 3: A key unknown is the collection efficiency of the Foster AFF, but generating accurate and precise estimates of the AFF capture efficiency and of fish behaviors in the tailrace and fishway will be challenging given uncertainly about the number of fish present in the tailrace. A randomized block experiment will alter fishway hydraulic conditions as in 2015. We propose estimating a series of complementary metrics using the following approaches during the experiment:

- *Component 1, Tagging:* Collect and tag adults at a location downstream from Foster Dam, such as at Lebanon Dam, using either passive (i.e., PIT) or active (i.e., radio) tags. Simultaneously, collect genetic tissue samples to assign adults as progeny of above- or below- Foster Dam parents. This alternative would provide accurate estimates of AFF collection efficiency (number collected/number entering tailrace), tailrace residence time, and eventual fate (e.g., remain in tailrace, move to downstream reaches or movement out of S. Santiam) for hatchery-origin and above-FOS-origin unclipped adult Chinook salmon not entering the trap (*in combination with Alternative 3*), but requires capture and tagging.

- *Component 2, Passive Visual and Acoustic Imagery:* Use underwater optical video and sonar (DIDSON) to monitor adult fish in the Foster tailrace and near fishway openings, coupled with visual counts of adult abundance in the tailrace. Alternative 2 will provide information on qualitative behavior at the entrances and in the lower ladder (e.g., entry rate/approach rate, AFF exit rate), identify turnaround location within the fishway, and collection rate in relation to alternative operations and water chemistry parameters. If *Component 1* is not implemented, *Component 2* will also provide a proxy estimate of daily AFF collection efficiency (daily collected/daily tailrace visual count). The proxy of collection efficiency will be unable to estimate total seasonal efficiency and will be unable to determine if the AFF collection efficiency differs for hatchery versus wild fish from either above or below FOS. In addition to providing qualitative information on behavior near entrances, optical video may be suitable for identifying individual fish from unique marks, and it may be possible to estimate approximate residence times for a subsample of the fish present.

● Component 3, Genetic Pedigree Assignment: Use genetic pedigree analysis results (OSU/ODFW ongoing) to identify the natal location of wild (unclipped) fish entering the FOS tailrace (*Component 1)* and/or collected in the Foster adult trap and at downstream spawning locations. A combined approach (Components 1 & 3) would allow separate estimation of the collection efficiency of the AFF for wild origin adults assigning to above- and below- FOS parents, representing successfully homing versus unclipped 'strays' to the FOS AFF, respectively.

Objective 4: We will use established methods to analyze the observational data (video / DIDSON) or tagged fish data in relation to monitored environmental and operational conditions in the Foster Dam tailrace, fishway and AFF.

Objective 5: We will use the information gathered in Objectives 1-4 in an adaptive management approach to make recommendations about potential experiments or operational changes that can be undertaken to improve trap effectiveness.

D. Relevance

The Willamette Valley Project (WVP) consists of 13 dams and associated reservoirs, five hatcheries and 42 miles of channel fortifications. The WVP is jointly managed by the U.S. Army Corps of Engineers (USACE), Bonneville Power Administration (BPA), and Bureau of Reclamation (BOR). The 2008 WVP Biological Opinion (NMFS 2008) outlined the impacts from WVP operation, including hatchery operations, on ESA-listed Pacific salmonids and the habitats on which they rely. The Biological Opinion also outlined specific actions, termed Reasonable and Prudent Alternatives (RPAs), believed to "…allow for survival of the species with an adequate potential for recovery, and avoid destruction or modification of critical habitat." The Objectives described here address RPAs 4.1, 4.2, 4.6, and 6.1.5, associated with measures to improve natural production of the Upper Willamette River Chinook Salmon and winter steelhead ESUs, which were listed as threatened under the ESA (NMFS 1999). These RPAs also address improvements and effectiveness evaluations of adult trapping facilities.

Project Description

A. Background

The Foster adult fish facility was reconfigured in the winter of 2013-2014 with significant structural modifications. The rebuild addressed several objectives, including more efficient collection and sorting of adult migrants, reduced handling, and improved ability to transport fish to outplant sites upstream from Foster Dam. In spring and summer of 2014, ODFW hatchery personnel observed that many adult Chinook salmon were congregating in the Foster tailrace, but that few were being collected in the trap facility. Similar holding behavior was observed in some years prior to the new construction (USACE 1995) and was a concern for managers because: 1) extended tailrace holding may delay broodstock collection; 2) delayed collection may compromise trap-and-haul of wild fish to upstream release sites; and 3) failure to collect hatchery fish may result in increased straying and inter-breeding with wild fish at downstream sites.

In addition to the observations of adult fish holding in the Foster tailrace, data from a basin-wide radiotelemetry study conducted in 2011-2014 indicated that many adults held downstream from Foster Dam for extended periods (Jepson et al. 2015). Adult Chinook salmon were radio-tagged at Willamette Falls and then their behavior was monitored downstream from Foster Dam, with increased monitoring effort in 2014 after the construction was completed. In each year, 15-29 salmon had sufficient radio detections in the Foster tailrace to estimate tailrace residence times. These fish spent 25-52 days, on median, near the dam (Figure 1) before being recaptured at the Foster AFF, being reported harvested, or permanently moving downstream from the dam. Behaviors were generally similar for wild (unclipped) and hatchery origin salmon. In 2014, a total of 49 tagged Chinook salmon were detected at one or more of the Foster radio antennas and 47 were detected at the dam or fishway. Sixteen radio-tagged salmon (34% of 47) were never collected at the adult trap, although all were detected at one or both fishway openings. These data corroborated concerns that some adult salmon were not collected.

Several hypotheses for the apparently low trap collection rates have been suggested. Possible hydraulic explanations include poor attraction to fishway openings or false attraction to non-collection sites such as the spillway or turbine outlets. Operational modifications that included modifying flow from the auxiliary water supply (AWS) and closing the downstream fish weir produced generally inconclusive results. In a third hydraulic test conducted in 2015 (analyses ongoing) provides preliminary evidence that operating the trap with the weir gate completely lowered (‘Open’ treatment) has collected adults more effectively than when the weir gate was run partially raised to increase hydraulic head (‘Auto’ treatment; Figure 2). Although the Open treatment may be an improvement over baseline, systematic observations of adult salmon in the Foster tailrace in 2015 indicate that ~100-500 fish were routinely present daily during the experiment (George Naughton, UI, *unpublished data*).

It is also possible that differences in water temperature or water chemistry contribute to the observed Chinook salmon behaviors in the Foster Dam tailrace. Because water for the adult fish facility and water entering the tailrace is sourced from several locations (i.e., spillway, turbines, reservoir hypolimnion, etc.), large water temperature gradients have been observed in the study area. In 2015, we conducted water temperature monitoring at ten locations (13 loggers), including along the north shore, at the base of the spillway, at the turbine outflow, and at several sites adjacent to and inside the fishway and trap (Figure 3). Preliminary data indicate that mean daily temperatures have varied by ~5-8 ^{o}C across sites, with generally warmer water along the north shore and in the spillway basin, and cooler water near the turbine outflow, the fishway opening near the turbines, and inside the fishway (Figure 4). Most of the holding salmon have been observed in the cooler water. Notably, temperatures in the ladder and pre-sort pool have been lower than many tailrace sites, suggesting temperature differences between the ladder and tailrace may impede fishway entry. Temperatures differences between the top and bottom of fishways has been shown to slow passage and affect body temperature in Chinook salmon at Lower Granite Dam where the fishway was warmer than the tailrace (Caudill et al. 2013), the converse to that observed at Foster Dam.

To date, temperature is the only water quality parameter that has been monitored in the Foster tailrace, but it has been hypothesized that other differences related to water source may be affecting salmon behavior. For example, chemical differences between reservoir surface water and hypolimnetic reservoir water may present confusing cues to adult salmon given their use of olfaction while homing to natal sites (Dittman and Quinn 1996; Keefer and Caudill 2014a). Disolved free amino acids (DFAAs) are relatively stable through time and have been shown to play a key role in olfactory homing responses in salmon (Yamamoto et al. 2013; Ueda et al. 2014). It is possible that the cold hypolimnetic water in Foster Reservoir is primarily sourced from Green Peter Dam while warmer South Santiam River water is predominant in the Foster Reservoir surface water and the combination of source, depth, and temperature produce quite different chemical signatures at the AFF, spillbay and turbine outflow. While it is unlikely that water chemistry and concomitant olfactory signature alone can account for the observed salmon behaviors given observed response to changes in fishway operation (Figure 2) and observed temperature gradients, it is possible that water chemistry is a contributing factor. Alternatively, biogeochemical processes within the reservoir may decrease differences or homonogenize DFAAs among water sources.

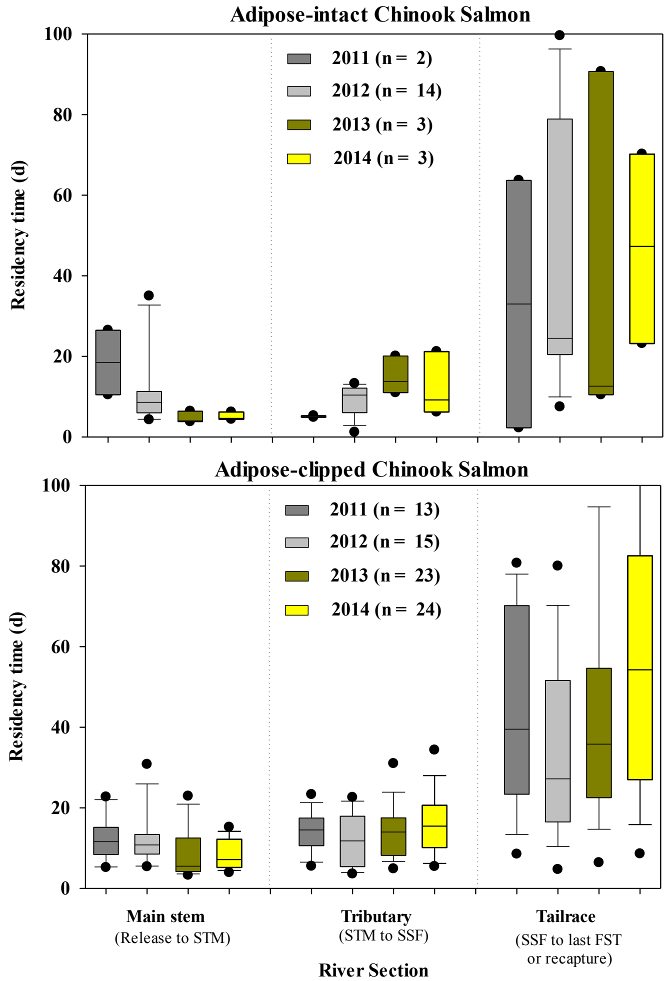

Figure 1. Box plots showing the distributions of radio-tagged adult Chinook salmon residence and transit times (days) in the main stem Willamette River (left panels), in the Santiam and South Santiam rivers (middle panels), and in the Foster Dam tailrace (right panels) in 2011-2014. Top graph is for wild (unclipped) salmon and bottom is for hatchery salmon. Release = Willamette Falls Dam; STM = Santiam River mouth; SSF = Foster Dam tailrace; FST = Foster Dam trap. Source: Jepson et al. (2015).

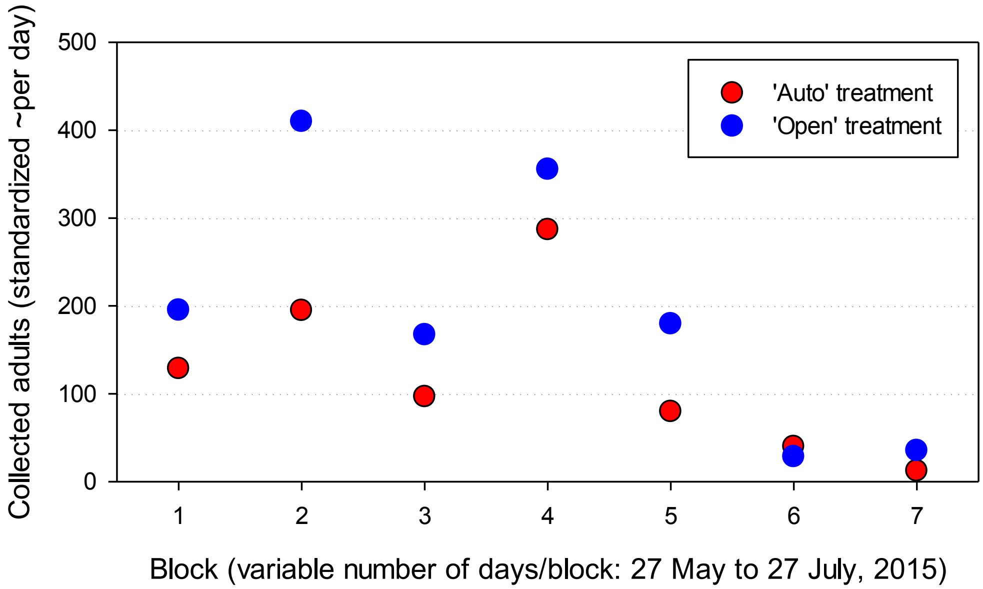

Figure 2. Numbers of adult Chinook salmon collected at the Foster trap during seven experimental treatment blocks in 2015 where the weir gate was either partially raised ('Auto') or lowered completely ('Open'). Results were standardized by dividing by number of days per treatment (2-6). In total 2,422 salmon were collected during the 'Auto' treatment and 3,275 were collected during the 'Open' treatment. All results are preliminary.

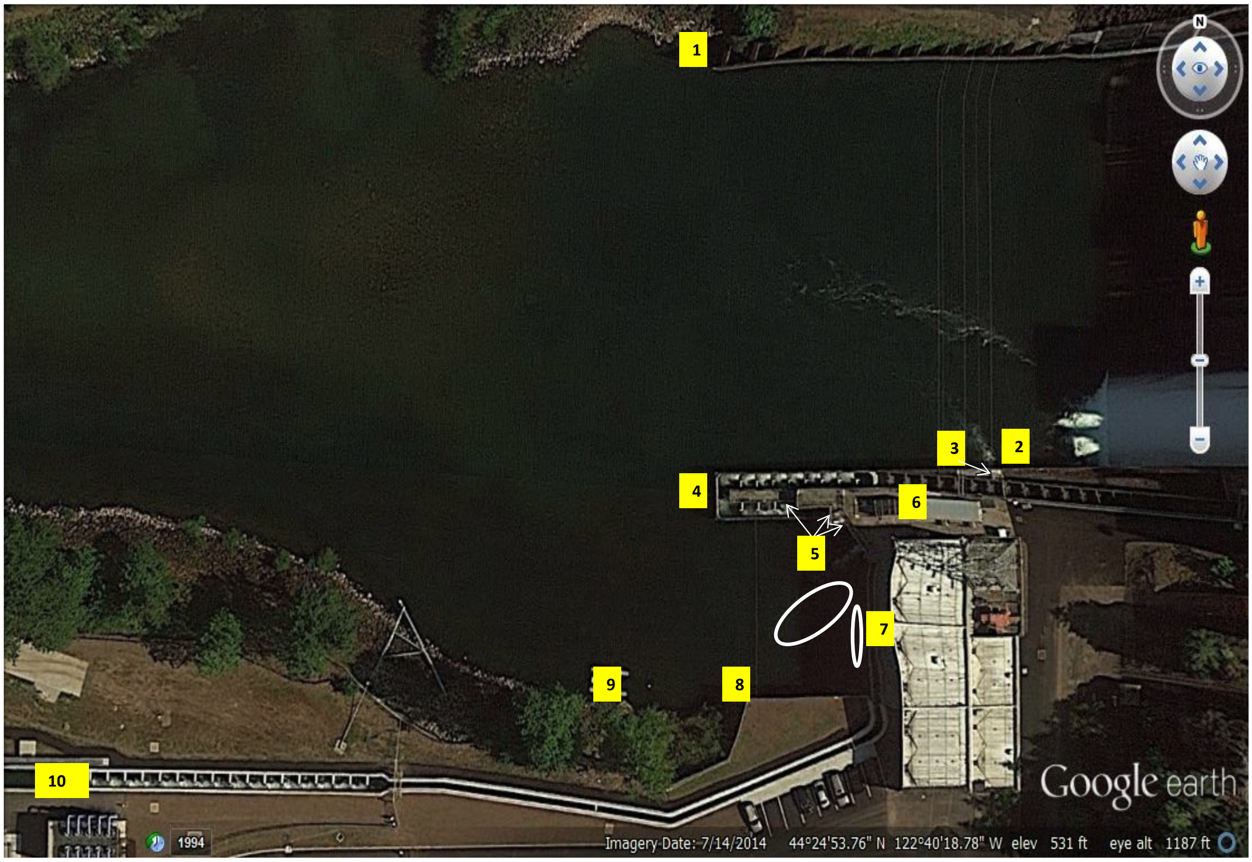

Figure 3. Map of the Foster tailrace study area with water temperature logger locations (numbered boxes) and sites where adult fish were most frequently observed (white ovals) in 2015. Logger sites: 1) North shore; 2) spillway weir; 3) spillway fishway entrance (two loggers: outside and inside); 4) outside ladder wall; 5) tailrace entrance (three loggers: outside, inside, and ~2nd weir); 6) auxiliary water supply; 7) powerhouse; 8) turbine wall; 9) screw trap; 10) adult pre-sort pool.

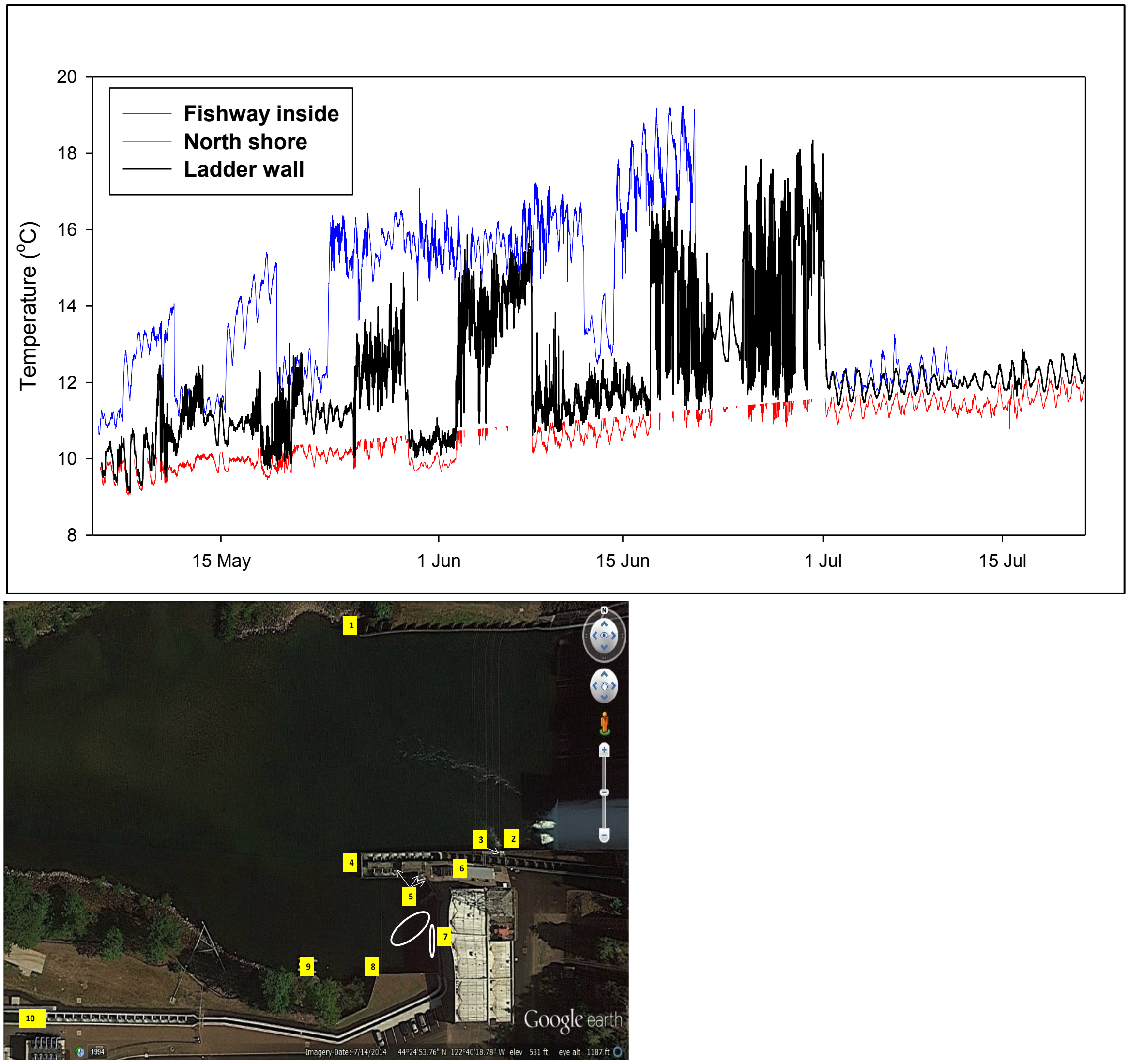

Figure 4. Time series of water temperature data collected using 15-min loggers at 3 key sites in the Foster Dam tailrace (North Shore, #1 lower panel), junction of spillbay and turbine outflow ('Ladder Wall'; #4), and inside of fishway (#5), 2015.

B. Objectives: 2015

Objective 1) Review and assess data collected before and after Foster trap construction

Objective 2) Develop and deploy temperature monitoring and water chemistry equipment at relevant locations below the dam and within the adult passage system

Objective 3) Evaluate adult Chinook salmon behavior and fishway passage metrics at FOS AFF during experimental fishway operations

-*Component 1, Tagging*
-*Component 2, Passive Visual and Acoustic Imagery*
-*Component 3, Genetic Pedigree Assignment*

Objective 4) Analyze data from objectives 2 and 3 to test for experimental effects and environmental correlations

Objective 5) Identify causative factors and measures that could be tested to increase adult fish collection and passage rates

C. Methods

Objective 1: We will collect historical Foster trap records from years before the facility reconstruction and from the post-collection years (2014-2015) to assess the timing and rate of adult salmon and steelhead collection. We will also use existing radiotelemetry data from the 2011-2014 basin-wide Chinook salmon and steelhead studies to assess timing and trap capture rates. Lastly, we will analyze the 2015 trap capture data in relation to the weir gate operations experiment, the systematic salmon observation data, the water temperature monitoring data, and other relevant operations data (e.g., tailwater elevation, spill, etc.) in consultation with Corps and ODFW biologists.

Objective 2:

The primary aims of water chemistry sampling will be to 1) reconstruct the water masses contributing to water in the AFF and fishway compared to turbine and spillway water sources, and 2) test for associations between water chemistry and behavior through time. The use of core water chemistry parameters may be largely sufficient to reconstruct water sources because temperature differences exist, conductivity should be conservative, and the system is well represented by a simple two-member mixing model for conservative chemistry (Middle and South Santiam River inputs).

Water temperature sites: As part of the evaluation of the 2015 temperature data we will assess whether additional temperature monitoring sites are needed for 2016 (Figure 3).

Water chemistry: We will use datasondes (e.g., Hydrolab, Hydromet, Loveland, CO) to sample core water chemistry parameters (temperature, pH, DO, conductivity) in paired fishway and tailrace sites at fifteen minute intervals. Sondes will be co-deployed on I-beams used for video monitoring. Continuous sampling of core parameters at fixed sites will be augmented by point sampling of core parameters in water originating from different sources (i.e., forebay surface water, AFF, reservoir hypolimnion, turbine outflow, etc.) to assess whether the chemical signatures at these locations may be affecting adult salmonid behavior.

We propose to evaluate the composition of dissolved free amino acids (DFAAs) as well because DFAAs are thought to be the primary olfactory cues used by homing salmon (Yamamoto et al. 2013; reviews in Ueda 2012, 2014; Keefer and Caudill 2014). We hypothesize that DFAA profiles in the AFF, spillbay and turbine outflow differ in association with inputs from the South and Middle Santiam Rivers water masses, if DFAA profiles remain stable in the reservoir. Profiles may also differ between reservoir surface waters and the hypoliminon. Benthic biofilms are thought to be the primary source of DFAAs in streams (Ishizawa et al. 2010) and DFAA concentrations are likely affected by bacterial processing in the reservoir. Thus, the DFAA profiles may be similar across the face of the dam if biological processing by biofilms and bacterial communities overwhelm any differences in DFAA composition between inputs to the reservoir, or DFAA profiles may be distinctive among epi-, meta-, and hypolimnetic waters depending on both movement of source water masses and any differences in biogeochemical processing among water layers. Characterization of profiles among locations and through the run season will test the plausibility that adults are attracted to or are rejecting the AFF based on DFAA profiles.

Table 1: Summary of proposed water temperature and water chemistry monitoring, Foster Dam, Tailrace, and Reservoir, 2016.

Parameter(s)	Locations	Frequency of Sampling	Method	Notes
Temperature	-Multiple (10+) AFF and tailrace sites (e.g., Figure 2)	15 minutes	Onset Hobo loggers	Similar to 2015
	-Forebay	15 minute	Loggers	USACE forebay string
Core Water Chemistry	-Inside fishway entrances (2) -Spillway pier nose	15 minute	Data Sonde (e.g., Hydrolab HL4)	Core parameters = temperature, pH, conductivity, DO
DOC + free amino acid profiles	-S. Santiam inlet -Mid. Santiam inlet -Forebay epi-,	-early, mid, and late run	Collect water samples, lab analysis	Yamamoto et al. (2013)

	meta-, and hypoliminon -AFF water supply -spillbay -turbine outlet -lower forebay			

Objective 3: A key unknown is the collection efficiency of the Foster AFF, but generating accurate and precise estimates of the AFF capture efficiency and of fish behaviors in the tailrace and fishway using passive monitoring methods will be challenging given uncertainly about the number of fish present in the tailrace. We propose estimating a series of complementary metrics to monitor behavior that include tagging and passive monitoring. Monitoring will occur during a randomized block experiment similar to the 2015 pilot to alter fishway hydraulic conditions (e.g., Figure 2; Appendix 1).

- *Component 1, Tagging:* Collect and tag adults at a location downstream from Foster Dam, such as at Lebanon Dam, using either passive (i.e., PIT) or active (i.e., radio) tags. This alternative would provide accurate estimates of AFF collection efficiency (number collected/number entering tailrace), tailrace residence time, and eventual fate (e.g., remain in tailrace, downstream reaches or movement out of S. Santiam) for hatchery-origin and above-FOS-origin unclipped adult Chinook salmon not entering the trap (*in combination with Alternative 3*), but requires capture and radio-/PIT-tagging. If this option is exercised, we recommend that a minimum of ~50 wild and ~50 hatchery adults be tagged with PIT-tags at Lebanon Dam and a subsample of at least 30 wild and 30 hatchery adult be double tagged with radio-tags. Adults would be collected at an Ice-harbor style trap (Keefer et al. 2014b) fitted to the exit of the northshore fishway (Figure 5) and sampled and radio- and/or PIT-tagged using similar methods to those developed in previous years in the WVP (Caudill et al. 2014; Jepson et al. 2015, Naughton et al. 2015).

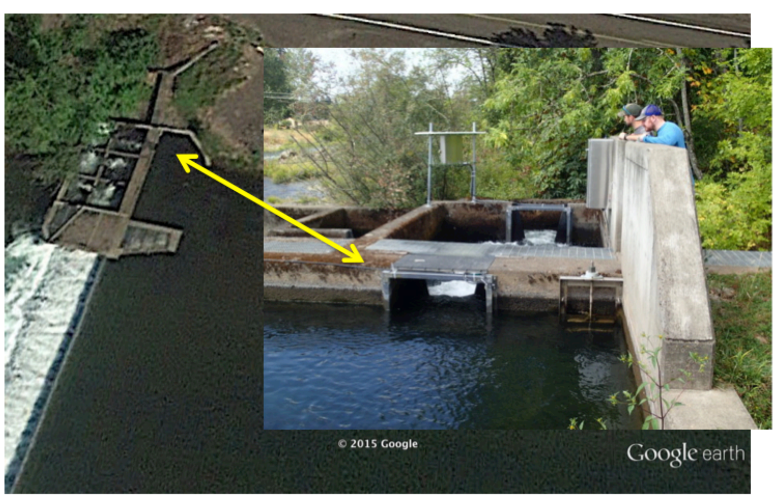

Figure 5: North shore Lebanon Dam fishway exit, potential site of collection for adult Chinook Salmon collection and tagging. Adults would be tagged at a stream-side tagging station and returned to the S. Santiam River upstream of the dam.

- *Component 2, Passive Visual and Acoustic Imagery:* Use underwater optical video and/or sonar (DIDSON) to monitor adult fish in the Foster tailrace and near fishway openings, coupled with visual counts of adult abundance in the tailrace. Alternative 2 will provide information on qualitative behavior at the entrances (video and DIDSON) and in the lower ladder and collection channels (e.g., entry rate/approach rate, AFF exit rate). Analyses will compare behavior and collection rate in relation to alternative operation treatments and water chemistry parameters and will be used to infer turn-around location using differences in event rates between sites within the fishway. If *Component 1* is not implemented, *Component 2* will also provide a coarse estimate of daily AFF collection efficiency (daily collected/daily tailrace visual count). This coarse estimate of collection efficiency will be unable to estimate total seasonal efficiency and will be unable to determine if the AFF collection efficiency differs for hatchery versus wild fish from either above or below FOS. In addition to providing qualitative information on behavior near entrances, optical video may be suitable for identifying individual fish from unique marks, and it may thus be possible to estimate approximate residence times and movement metrics for a subsample of the fish present using only video observations.

We propose to use optical video cameras deployed on I-beams located at strategic locations determine movement rates into and within the ladder. Imagery will be analyzed to evaluate qualitative behaviors and to enumerate event rates including approach, entry, exit, and up/down stream and holding movements (e.g., Thompson et al. 2012, 2013; Kirk et al. 2015). DIDSON observations (if employed) would qualitatively characterize adult salmonid behavior in the tailrace near entrances (i.e., what proportion of adults make directed movements toward the fishway vs. proportion of 'swim-bys'). The feasibility of identifying individual adult salmon and steelhead at locations within the ladder will be explored through the use of specialized video image analysis software in a pilot analysis coupling video and detections of previously PIT-tagged adults.

Proposed locations of cameras include inside and outside the spillway and turbine entrances, in the fishway channel, and at the entrance to the pre-sort pool (Table 2). We note that cameras will be co-located with new PIT-antennas to support the pilot ID study where feasible and locations of I-beams may be affected by physical constraints and availability of mounting surfaces and 110V power after consultation with USACE personnel. Cameras will be oriented in line with the lateral axis of the fish (i.e., we will capture 'side-views') to determine fish movement direction (upstream/downstream) and provide the best images possible for individual identification as detailed below.

Dual-frequency identification sonar (DIDSON) is well suited for monitoring fish behavior in and near fishways (Grote et al. 2014; Kirk et al. 2015). Standard units can sample to a range of ~15 m in high frequency (1.8 MHz) mode and to ~40 m in low frequency mode (1.1 MHz) (Burwen et al. 2010). A DIDSON deployed in the Foster tailrace could effectively image fish as they approach and enter the fishway openings. Imagery could also be collected of fish in the locations where they have been observed holding for extended periods. The data would be effective for enumeration and can be used to qualitatively assess adult fish behaviors in response to structures and operations (e.g., Kirk et al. 2015; Keefer et al. *in review*). We propose to deploy the DIDSON camera in an orientation that will image the entrance slot and nearby tailrace environment at one or both of the entrances. Imagery would be collected for three four-day periods at each location at the beginning, middle and end of the randomized block experiment. Each four-day period would span two treatments in the randomized block design.

Video equipment and deployment: Video cameras will be deployed at six locations within and in near proximity to the fish ladder using a deployment system consisting of 3-inch aluminum I-beams and custom camera trolleys which slide along the I-beam tracks (Thompson et al. 2012; Table 2; Figure 7). I-beams will be installed at USACE-approved locations during the dewater period in early 2016 and may require dive support in some locations (e.g., fishway entrances, tailrace locations). The number of cameras at each location will depend on water depth and multiple cameras may be required at some sites to cover the majority of the water column. I-beams in concrete areas will be fastened to the lateral aspect of the fish ladder using 3/8 inch Hilti bolts, or otherwise anchored using an appropriate clamping system.

Table 2. Locations of video camera deployments at Foster Dam fish ladder.

Location	No. I-beam	No. Cameras
FSE, tailrace	1	1-3
FSE, inside entrance	1	1-3
FSB, tailrace	1	1-3
FSB, inside entrance	1	1-3
Mid-channel	1	1*
FST Sort pool	1	1*

*These cameras will have laser array for fish measurement and ID. Number of cameras / site will depend on depth.

Camera trolleys will be raised and lowered into the water manually by means of cabling secured topside (Figure 6). Each camera trolley will consist of one infrared light for low-light conditions and one CCD black and white, high resolution, low light camera (Model SS408. Sidus, San Diego CA). For the two ID locations, the trolleys will have a laser array allowing total size of the fish to be estimated regardless of distance from the camera as an identification trait to supplement pigmentation and scar patterns.

Figure 6. Example of a weighted camera trolley designed for deployment along 3 inch I-beam. The optical video camera is visible in the lower part of the trolley, and two infrared accessory lights are located at the upper section. The black section is a steel weight.

Data collection/transmission: BNC cable ends and power cables from lights, cameras, and lasers will be routed to an air-conditioned, NEMA 4-rated electrical enclosure bolted to an approved location. Two enclosures will be used, one located near the ladder entrance, and one near the fish trap. Enclosures will house a customized personal computer-based digital video recorder (DVR; Intel dual-core processor, 2 GB RAM, PCI slot, 2 SATA hard drive ports, Windows 7 OS), using 8- or 16-channel Hikvision video capture cards (Model DS-4008HCI and DS-4016HCI; Hikvision USA, City of Industry, CA) and 2 TB of hard drive space dedicated to video recording. Additionally, for power protection an uninterrupted power supply (UPS-Tripplite OMNI900LCD, Chicago IL) will be added to each enclosure. All video cameras will be set to record 24 hours a day, 7 days a week (Mid-May to the end of August) with the following parameters: 704 x 480 resolution; high quality record (30 frames per second); grayscale color scheme, and no audio.

Remote connectivity to the two DVR units will be achieved using a local wireless internet service provider (Peak Internet). A small (less than 20 inch) diameter dish will be mounted to an approved location near the top of the powerhouse, and the wireless internet signal transmitted to routers housed with the enclosures. Remote connectivity allows for staff at UCD to monitor the live status of all cameras, adjust recording parameters, and receive automated notifications in the event of equipment malfunctions. Additionally, recorded video data will be backed up to UCD servers daily for analysis and redundant storage using the CBVision video acquisition module via a FTP connection. Video will be saved in native MPEG-4 format (.mp4), using standard H.264/MPEG-4 video compression codecs (Thompson et al. 2012). UI staff will be present to maintain cameras (e.g., cleaning lens) and address any issues with a 12-24 hour response time.

Image processing: Video data from all cameras will be uploaded from the two DVRs and processed using CBVision acquisition and image analysis modules (Negrea et al. 2014). Briefly, the software employs various background subtraction and image tracking algorithms to reduce the length of underwater video files by removing frames where objects are below a specified size, velocity, and duration.

Video annotation: Processed video clips will be viewed and annotated by experienced staff using the open-source VLC Media Player, version 1.1.11 (www.videolan.org). Files will be reviewed at a playback speed of 2–4x. Specific scored behaviors and metrics are described in Objective 4.

For all locations, a minimum of video will be reviewed corresponding to 5 days per week, 9 hours a day, and using 2 time blocks that alternate every seven days (Table 3) for the fish passage season spanning late May through the end of August. Slight adjustments to the schedule are possible in the month of August, when the length of day is several hours shorter and allocation of effort may be further concentrated to the experimental period.

Table 3. Alternating weekly schedule of video observations at Foster Dam fishway.

<u>Block 1</u>	<u>Block 2</u>
6-9am	7-10am
11-2pm	12-3pm
4-7pm	5-8pm

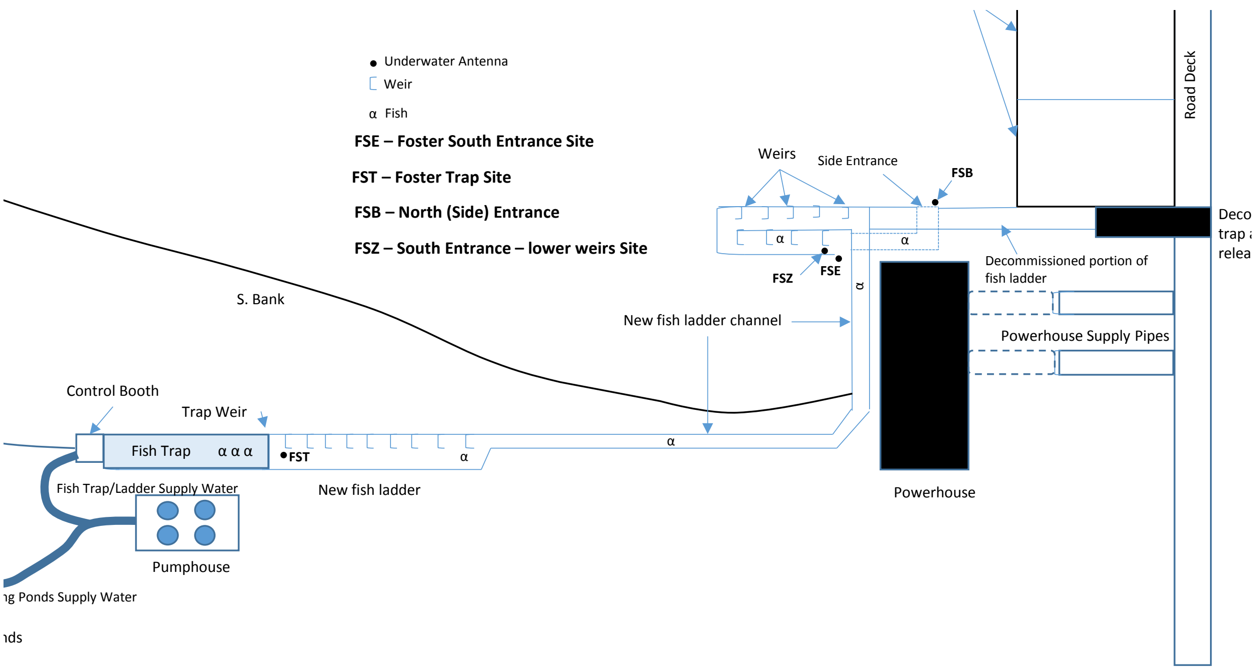

Figure 7. Diagram showing radiotelemetry receivers used to monitor adult Chinook salmon and steelhead at Foster Dam in 2014. An additional receiver was located downstream to monitor fish as they entered the tailrace.

<u>Automated fish identification:</u> To explore the possibility of re-identifying unique fish within the fish ladder without handling and tagging, we propose to develop a pilot software program employing similarity-based automated identification (Chen et al. 2009) and fish tracking through various video monitored areas. The fish identification program will consist of two main elements: fish measurement and automated body feature analysis. For measurement, we will

build and deploy an underwater laser measurement system to discriminate fish based on their length and place them into various size bins. As passing fish may not be within narrow spatial confines, the measurement system will use two parallel laser arrays, each projecting a vertical fan of precisely measured laser beams perpendicular to the water flow. The low power, low wattage lasers will be energized topside and mounted directly to the camera trolleys, on either side of the camera, and employ long wavelength (ca. 650nm) red emitting lasers used elsewhere to measure fish (Nelson, et al. 2005). As passing fish intersect the beams, two reference points will be created on the fish's lateral aspect and serve as the basis for computing their length.

For each size bin, a computer will run machine learning algorithms tuned to identify individual fish based on body features like fin shape and position, body pigmentation and any marks or scars (Merz et all, 2012). Some of the algorithms we plan to test to extract unique fish features out of images (frames of video) include Principal Component Analysis, Independent Component Analysis, Linear Discriminant Analysis and Latent Semantic Analysis. To classify extracted features, we will test multiclass versions of the following classification algorithms: Neural Networks, Decision Jungle, Logistic Regression, Decision Forest and a One-vs-All adaptation of the two-class Support Vector Machines (SVMs). Validation of these methods on random fish will be done by comparison with evaluations by staff annotators.

For this element of the proposal, it is anticipated that a minimum of 100 fish will be used as test subjects. Standard measures of precision and recall will be used to report the results of the comparison. We will use time stamps of any previously PIT-tagged adult Chinook salmon detected at up- and downstream arrays as an independent validation of the automated identifications. Development of such technology would provide opportunity for individual based studies in the future without capture or handling of individuals at locations with fishways below collection facilities (e.g., Lebanon Dam, Bennett Dam).

- *Component 3, Genetic Pedigree Assignment:* Use genetic pedigree analysis to identify the natal location of wild (unclipped) fish entering the FOS tailrace (*Component 1)* and collected in the Foster adult trap and at downstream spawning locations. A combined approach would allow estimation of the collection efficiency of the AFF for wild origin adults assigning to above- and below- FOS parents, representing successfully homing and unclipped 'strays' to the FOS AFF, respectively.

Genetic research conducted by ODFW (e.g., Sard et al. 2015) has used parentage / pedigree analysis to match Chinook salmon offspring to their parents in the McKenzie River and South Santiam River adult outplant programs. This ongoing research has provided a genetic baseline that could be used to indirectly estimate Foster AFF capture rates. Two groups of fish would need to be genetically sampled: 1) wild (unclipped) salmon collected in the Foster AFF, and 2) wild salmon collected in ODFW carcass surveys downstream from Foster Dam. Parent assignments as determine by ongoing OSU/ODFW studies for these groups will be used to estimate both the proportion of collected and uncollected wild fish that originated upstream from Foster Dam in relation to AFF collection. This component would be especially useful if coupled with genetic sampling at Lebanon Dam because the composition of adults entering the tailrace (hatchery/wild; above/below FOS) vs. the composition of adults collected in the trap can be directly evaluated.

<u>Objective 4:</u>

A random subset of DIDSON imagery will be analyzed to determine diel patterns of behavior in the tailrace, the movement rate and direction of adults in the tailrace near the entrance, rate of apparent entry attempts, rate of entries, and rate of exit for Chinook salmon-sized acoustic targets.

The following data will be collected for each optical video camera:

FSE/FSB: Rate of entry and exit of adult fish, approach rate, average time and location of fish holding.

Mid-Channel: Fish identification (manually and software), upstream and downstream counts and rates, time of holding.

Sort Pool: Fish identification (manually and software). Pool exit and entrance rates.

All entry/exit rates will be determined by hour, by day, season, or operational regime (auto vs. manual weir gate). Many of the metrics described above would be qualitative because individual fish cannot be conclusively identified, but through locating cameras at specific openings at ladder structures and in relatively close proximity to fish, a reasonable estimate of behavior and passage is possible. Fishway approach and entry metrics, for example, would necessarily be qualitative but even qualitative differences in behavior can be associated with environmental and operational conditions (e.g., Kirk et al. 2015). Similarly, estimates of adult abundance and distribution are likely to be sensitive to conditions in the Foster tailrace. We will use appropriate graphical and statistical techniques to assess the data.

Fish passage rates in the tailrace entrance and ladder and observed holding behaviors will be assessed in relation to changes in water quality parameters described in Objective 2.

<u>Objective 5:</u> We will use the information gathered in Objectives 1-4 in an adaptive management approach to make recommendations about potential experiments or operational changes that can be undertaken to improve trap effectiveness.

D. Facilities and Equipment

Work will be conducted at Foster Dam and a downstream collection location for an adult tagging study, if *Component 1* is implemented. USACE and ODFW will operate the Foster AFF trap facilities and provide transport (if needed) for transport and release of fish. UI and UCD (working as a subcontractor to UI) will provide equipment needed to sample fish (if needed) and water chemistry including vehicles, data sondes, computers, specialized software, etc., on a rental basis. Other equipment, including video cameras, infrared light sources, temperature loggers, water chemistry sampling tools, and other supplies will be provided on a rental basis or from project funds. USACE will purchase radio transmitters (if needed) and provide receivers from existing equipment stores, including funds to update receivers to legal frequencies if needed, with the exception of up to 36 receivers to be provided by UI on a rental basis. USACE will provide use of a DIDSON camera if used. ODFW will provide assistance during spawning ground surveys in the South Santiam downstream from Foster Dam, including surveyors, boat, otolith vials, genetic sampling, and scale envelopes.

Coordination between UI, USACE and ODFW will be necessary in the Foster tailrace and at the Foster trap to facilitate installation of optical video, datasondes and DIDSON cameras.

E. Impacts of study on Corps projects and other activities

Division or district Corps personnel will be needed to provide technical review of research proposed for 2016 and assistance from project personnel will be required as follows:

1. Provide access to Foster Dam AFF and tailrace to install equipment and sample fish. We anticipate a time frame for this from about April to October, 2016.
2. Provide access to the Foster Dam AFF and tailrace to install I-beams for video monitoring. Some sites may require dive support.

F. Biological Effects

Minimal biological effects are expected for proposed water chemistry and passive monitoring methods. Any anticipated effects of a tagging study would depend on the tag type and collection methods, though we anticipate minimal effects based on previous radio- and PIT-telemetry studies.

G. Key Personnel

The Principal Investigators for this project are Christopher Caudill, Cameron Sharpe, and Frank Loge. Caudill and Sharpe will be involved in all aspects of this project, including planning, administration, protocol development, permitting, equipment specifications and purchase, data analysis, and reporting. Caudill will be primarily responsible for fish collection, telemetry studies, and analyses of condition and fate. Loge and Don Thompson will be responsible for video collection and analyses. George Naughton will be the primary project field biologist for UI. Sharpe will provide logistical support and conceptual input and will coordinate ODFW spawning ground surveys. Both PIs will actively participate in data analyses and reporting.

H. Technology Transfer

Information and analyses from this study will be provided regularly to managers via reports and oral presentations, including the USACE WFSR. A draft final report will be submitted by 15 April 2017 and a final project report submitted by the end of the project period (30 September 2017). Information that is appropriate will be published in scientific journals. Special efforts will be made to provide information to managers during the field season as requested, including approximately monthly updates that include summaries of numbers and species of fish collected and tagged and available telemetry results.

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Appendix 1: Randomized block experimental design used in 2015 to test for effects of open vs. automatically controlled entrance gates at the Foster Dam AFF. A similar design is proposed for 2016 and final treatments will be determined pending full analysis of the 2015 data and consultation with the RME team.

Start Date	End Date	Block	Treatment	Treatment
27-May	29-May	1	High	Auto
29-May	2-Jun	1	Low	Open
2-Jun	5-Jun	2	Low	Open
5-Jun	9-Jun	2	High	Auto
9-Jun	12-Jun	3	High	Open
12-Jun	16-Jun	3	Low	Auto
16-Jun	19-Jun	4	Low	Open
19-Jun	23-Jun	4	High	Auto
23-Jun	26-Jun	5	Low	Open
26-Jun	30-Jun	5	High	Auto
30-Jun	10-Jul	6	Low	Open
10-Jul	14-Jul	6	High	Auto
14-Jul	21-Jul	7	High	Open
21-Jul	28-Jul	7	Low	Auto

Appendix 2: Response to comments by WATER RME Team:

Responses provided in italics below.

Response to comments by ODFW dated 1 October 2015:

APH-15-05-FOS – Evaluation of Foster Adult Fish Trap Performance, 2016
• ODFW does not support handling and tagging of fish at Lebanon Dam.

We have retained an active tagging study as a potential component because a key parameter (collection efficiency) requires information on individual movement rates into the tailrace and AFF

• Recommend that proposal include visual evaluation (or DIDSON) of fish in the tailrace, in combination with video installation at Lebanon Dam.

We have included a DIDSON video monitoring component at Foster Dam as potential component, pending availability of a DIDSON camera

• Include ODFW biologists when consulting on water chemistry and tagging methods (Methods – Objective 2 indicates only consultation with Corps biologists; Objective 3 indicates consultation with NMFS and Corps biologists and other members of WATER)

Edits incorporated as appropriate

• Modify the description of the potential for use of genetic pedigree information – this study is being implemented, so the data would just need to be analyzed or researcher should consult with that researcher.

Edits incorporated

• Clarify if the olfactory components (DOC and amino acids) will be included – the presentation indicated they would, but the proposal indicates only a possibility.

This section has been updated and expanded

• Please include the temperature graphs shown in the presentation with potential explanation of temperature patterns.

Changes made

• Coordinate tailrace sonde deployment with the TDG study that is also deploying sondes in the tailrace.

We will work with USACE biologists to coordinate

• High priority to evaluate ladder and trap; ODFW does not support radio tagging at Lebanon Dam.
Acknowledged. See note above

Response to comments from NMFS Dated 5 October, 2015:

APH-15-05-FOS, "Evaluation of Foster Adult Fish Trap Performance"
1. While NMFS recommends this proposal for funding in FY 16, we will not approve trapping and tagging adult fish in ladders at Willamette Falls or Lebanon Dam.

Acknowledged, see note above.

2. Objective 3 – NMFS recommends that the Corps install underwater optical video at Lebanon dam to count fish passing that location. Continuation of behavioral observation as well as visual counts in the tailrace and at the trap would provide data to identify the number of fish that do not arrive at the trapping facility. This should be employed over the season along with the various trap and weir operations, temperature and chemistry studies to identify if specific measures increase or decrease attraction at the ladder entrance and fish returns to the Foster Trap. These non-invasive measures should be carried out prior to consideration of capture and tagging methods.

Acknowledged. Proposal does not include video monitoring component based on guidance from USACE.

Response to comments from USFWS dated 16 October 2015:

APH-15-05-FOS
Objective 3 – Is radio telemetry the best way to monitor trap catch data and presence of adults in the tailrace? Recommend alternative approach

Unfortunately, individually marked adults with active tags are the best method we are aware of for definitively quantifying movement into the tailrace.