Evaluation of Foster Dam Spillway and Green Peter Dam Spillway Operations for Juvenile Fish Passage Year 2

Stephanie Larson, Eric Fischer, Ben Vaage, Chris Vernon, Rahul Birmiwal, Ryan Harnish, Jenna Brogdon, Margaret Giggie, and James Hughes
Pacific Northwest National Laboratory, Richland, WA
stephanie.larson@pnnl.gov

Pacific Northwest National Laboratory (PNNL) conducted a fish passage and survival radio telemetry (RT) study for the U.S. Army Corps of Engineers – Portland District (USACE) during 2023. There were initially two efforts for this study, with results to help inform USACE biologists, engineers, resource managers, and regional decision makers. The purpose of both efforts was intended to help rebuild populations of Upper Willamette River Spring Chinook salmon (*Oncorhynchus tshawytscha*) and winter steelhead (*O. mykiss*) listed as threatened under the Endangered Species Act.

The first effort occurred at Foster Dam (Foster) and evaluated fish passage and survival and the efficiency and effectiveness of the interim nighttime spillway operations during spring (February 1–June 15) and fall (October 1–December 15) months as a benefit for passing juvenile Chinook salmon and winter steelhead. Results will inform the timing of operational adjustments for improved downstream fish passage at Foster. However, the surrogate Chinook salmon for the study became infected with diseases after the first February tagging effort. After multiple attempts to bring fish back to full health, the fish remained diseased, and tagging Chinook salmon at Foster for the remainder of the spring season was cancelled. Surrogate steelhead were unaffected and were able to be tagged and released during the spring spill evaluation. Fall study fish were from a different cohort and were not diseased, so fall tagging could occur as planned.

The second effort occurred at Green Peter Dam (Green Peter) during spring and fall to provide a continued evaluation of spring spillway operations and a baseline evaluation of the fall drawdown operations for juvenile Chinook salmon passage. Unfortunately, in the spring the Chinook salmon were from the same cohort as the diseased study fish described for the Foster effort. The onset of the diseased occurred prior to the start of the Green Peter effort. Because fish remained diseased after multiple attempts to bring them back to full health, the spring effort at Green Peter was cancelled. Similar to Foster, fall study fish were from a different cohort and were not diseased, so fall tagging could occur as planned.

As a result of the diseased fish, this presentation will focus on the spring 2023 study results of only steelhead passage at Foster. The Foster and Green Peter fall 2023 study results are currently being analyzed and will not be presented at the Willamette Fisheries Science Review. As such, the objectives that will be presented for the spring Foster effort evaluated if the nighttime spillway operations were a safer and more efficient passage route compared to the turbines for age-1 winter steelhead using the following metrics:

I. Seasonal and diel distribution, behavior, and movements of juvenile fish into and within the forebay of the dam.

II. Seasonal and diel downstream passage, including reservoir survival, forebay residency time, route distribution, dam passage efficiency, route specific survival, and reach survival.
    i. Reach survival will be measured to the confluence of the Santiam River with the mainstem Willamette River.
III. Efficiency and effectiveness of the nighttime spillway operation compared to the turbines.

Winter steelhead (age-1) surrogates for wild fish in the South Santiam River were provided by the Oregon State University Wild Fish Surrogate Program. Fish were double tagged with an RT tag and a Passive Integrated Transponder (PIT) tag (Table 1).

Table 1. Spring 2023 sample sizes at Foster Dam by pool elevation, release dates, and release location in the reservoir for age-1 winter steelhead.

Pool Elevation	Release Dates	Head-of-Reservoir (*n*)	Mid-of-Reservoir (*n*)	Foster Dam (dead fish) (*n*)	Total
613 ft (Low Pool)	Apr 18–20	195	193	50	438
	Apr 29–30	140	143	28	311
	Total	**335**	**336**	**78**	**749**
635 ft (High Pool)	May 21–24	275	259	50	584
	June 1–3	144	154	38	336
	Total	**419**	**413**	**88**	**920**
Total		**754**	**749**	**166**	**1,669**

Reach survival was estimated through Foster to the confluence of the Santiam and Willamette rivers (88.5 river kilometers [rkm] downstream of Foster) using the Cormack-Jolly-Seber model adjusted for tag life within the program ATLAS (Acoustic Tag Life-Adjusted Survival; Columbia Basin Research). Dam passage survival was estimated using the Virtual Release with Dead Fish Correction (ViRDCt) model to isolate dam and route-specific survival to a shorter river reach, because the reach survival estimates include mortality that occurs well downstream of the dams. ViRDCt estimated survival from passage through Foster to an RT detection array located ~2.5 rkm downstream of the dam.

Age-1 Steelhead

Reservoir Survival

A total of 671 RT-tagged age-1 steelhead were released alive during low pool between 18 April and 30 April 2023 at two locations in Foster Reservoir (*n* = 335 at the HOR and *n* = 336 at the

MOR; Table 1). Fish released at the HOR had an estimated survival probability of 0.027 (0.009) from release to Foster and those released at the MOR had an estimated survival of 0.057 (0.013). Estimates of reservoir survival should be considered joint probabilities of migration and survival due to the tendency of steelhead to remain in Foster Reservoir for an extended period.

A total of 832 RT-tagged age-1 steelhead were released during high pool between 21 May and 3 June 2023 at two locations in Foster Reservoir ($n = 419$ at the HOR and $n = 413$ at the MOR; Table 1). Only 3 RT-tagged age-1 steelhead released during spring high pool were detected passing Foster and no fish (0) were detected downstream of Foster, providing insufficient detections for survival estimation.

Reach Survival

A total of 28 RT-tagged age-1 steelhead were detected passing Foster during spring low pool and 3 RT-tagged steelhead were detected passing Foster during spring high pool. None of these fish were detected at or downstream of the I-5 Santiam Rest Stop Array. Therefore, reach survival to the I-5 Santiam Rest Stop Array could not be estimated.

Willamette Valley Downstream Fish Passage Monitoring Project – Bulk Marking Task

Ryan Flaherty, Nicole Eller, Griffith Bell, John Lyssenko, Brittney Norbury, and Hans Berge
Cramer Fish Sciences – Fish Ecology Lab, Portland Oregon

Ryan.flaherty@fishsciences.net

Cramer Fish Sciences was contracted by the U.S. Army Corps of Engineers to bulk mark juvenile Chinook salmon with Passive Integrate Transponder tags (PIT) in 2023. The purpose of the project was to contribute to the understanding of downstream passage of juvenile Chinook salmon in the Willamette Valley Project while meeting the objectives of the Interim Measures Research, Monitoring, and Evaluation plan. Juvenile Chinook salmon were marked and released within the South Fork McKenzie, Middle Fork Willamette, South Santiam, and North Santiam subbasins. Marking and releases began in May and continued through the end of December.

We PIT tagged and released a total of 178,858 PIT tagged juvenile Chinook salmon within the project area in 2023. Of those, 37,604 were released within the South Fork McKenzie subbasin, 66,096 within the Middle Fork Willamette subbasin, 36,267 within the South Santiam subbasin, and 38,891 within the North Santiam subbasin.

A total of 2,777 PIT tagged fish were recaptured or observed passing PIT tag arrays during 2023 resulting in a redetection rate of approximately 1.55 percent. The most significant number of detections, 1,629, occurred at CGR - Cougar Dam and were recaptured via rotary screw trap. Other notable detection counts include 434 at FAL - Fall Creek Dam, 227 at HCR - Hills Creek Dam, and 24 at NSANTR – North Santiam River via a screw trap operated in the Stayton Power Canal by the Oregon Department of Fish and Wildlife. The PIT tag antennas at Lebanon Dam, on the South Santiam River, collectively accounted for 203 observations.

The recapture of PIT-tagged juvenile Chinook salmon in the Upper Willamette River Basin provided insight into the post-release movement patterns of those fish. Unsurprisingly, across all basins we observed that the further downstream a fish was released the faster it travelled through the project. For example, travel time from release to the Cougar Dam Tailrace was shorter for fish released into the forebay compared to those released at the head of reservoir during the fall drawdown. Fish released in the Cougar forebay on November 14th, 2023 had a median travel time of 0.9 days to the Cougar Tailrace, whereas those released at the head of reservoir on November 13th, 2023 had a median travel time of 4.0 days.

There was also evidence that dam operations impacted travel times and rates. For example, mean travel time from head of Fall Creek reservoir to the Fall Creek tailrace went from 130.5 days for fish that were released on June 12th (full pool), to 24.4 days for fish released on September 28th (end of drawdown from 750ft to 738 feet), to 1.8 days for fish that were released on November 6th (middle of first low drawdown). Similarly, in the Cougar project area, the results illustrated that travel times were influenced by dam operations and reservoir elevation levels. Initial releases at Cougar in the late summer, under conditions of slow reservoir drafting and exclusive powerhouse flow, resulted in longer travel times for the juveniles to reach the tailrace. This contrasted sharply with releases during the fall drawdown period, where substantially shorter travel times were recorded, suggesting enhanced migratory passage efficiency as a result of lower forebay elevation and regulating outlet operations. The Hills Creek releases further emphasized the significance of dam operations on migration efficiency. Early releases at the head of the reservoir experienced prolonged travel times, aligning with periods of higher forebay elevations and consistent powerhouse flows. However, releases made in anticipation of or during fall drawdown operations saw markedly faster travel times, highlighting the role of dam operations in facilitating fish passage.

Unfortunately, we did not have enough recoveries to make meaningful insights about the impact of the deep drawdowns at Lookout Point and Green Peter reservoirs. The addition of the Lebanon Dam PIT antennas on the South Santiam River will help future iterations of this project evaluate the deep drawdown at Green Peter Reservoir. Currently there are no operational PIT detection arrays downstream of Lookout Point Reservoir. Adding detection arrays downstream of Lookout Point Reservoir may benefit the evaluation of the efficacy of the Lookout Point Reservoir deep drawdown on fish passage at Lookout Point Dam. However, it is important to note that PIT detection in the Willamette basin has many current challenges such as the limited numbers of PIT tagged salmonids present, challenges associated with installing and maintaining PIT detection systems in the basin, and unknown detection efficiencies. With additional PIT detection, there may still be an inability to collect enough data to draw meaningful conclusions, especially is the short timeframes associated with the injunction period (through 2024).

WILLAMETTE VALLEY FISH PASSAGE MONITORING VIA ROTARY SCREW TRAPS

Dillon Alegre, Ed Call, Rachel Ellison, Rand Romas, and Jason Phillips
Environmental Assessment Services, Richland, WA
dillon.alegre@easbio.com

Environmental Assessment Services (EAS) has conducted fish passage monitoring, utilizing rotary screw traps (RSTs), for the U.S. Army Corps of Engineers – Portland District (USACE) starting in October 2021, and which is ongoing at present. The data presented herein is for monitoring efforts conducted in 2023. The purpose of this study is to evaluate the biological effects of certain measures being implemented to improve fish passage and water quality at several WVP dam sites to benefit UWR spring Chinook salmon (*Oncorhynchus tshawytscha*) and winter steelhead (*Oncorhynchus mykiss*) as required under the Interim Injunction Order issued by the U.S. District Court for the District of Oregon. RST sampling, as part of this project, has occurred at 15 sites including the Breitenbush River, North Santiam River above Detroit Reservoir, Big Cliff Dam tailrace, Green Peter Dam tailrace, Green Peter Head of Reservoir- Middle Santiam River, Foster Dam Head of Reservoir- South Santiam River, Cougar Dam tailrace, Cougar Dam Head of Reservoir, Fall Creek Dam RO tailrace, Fall Creek Dam Head of Reservoir, Dexter Dam tailrace, Lookout Dam tailrace, Lookout Point Head of Reservoir, Hills Creek Dam tailrace, and Hills Creek Head of Reservoir- Middle Fork Willamette River.

The goals of this study are to provide juvenile salmonid data (e.g. emigration timing, and injuries) in relation to dam passage and Army Corps operations including passage by route (e.g. powerhouse vs spillway, where feasible), and characterize injuries including mortality after 24 hour holds following capture in RSTs. Target species include wild Chinook salmon at all sites, steelhead (*O. mykiss*) on the Santiam River (Breitenbush River, North Santiam above Detroit Reservoir, Big Cliff Dam, Green Peter Dam, Green Peter Head of Reservoir- Middle Santiam River, and Foster Dam Head of Reservoir), and marked hatchery Chinook salmon (see Cramer Fish Sciences reporting for additional details). Additionally, trap efficiency (TE) trials were conducted with hatchery Chinook, and natural origin run of river (RoR) Chinook and Steelhead where possible.

During monitoring in 2023, the primary objectives were to operate RSTs to determine species composition and collect biological information including passage timing and injuries of fish passing the respective sample sites. RSTs were checked once per day unless conditions necessitated additional checks for fish and/or trap safety. Upon arrival at a trap site, crews collected data on cone rotation speed, cone rotation count from last check to current check, water temperature at trap, and time of fish collection. Additional environmental data was collected from U.S. Geological Survey gauges and USACE dam operations data and included inflow, outflow by route, water temperature, and dissolved oxygen concentration where available. Biological data was collected for each target fish we captured. Data collected included species, fork length (FL), weight, fish condition, injuries, and assessment of presence of tags or other marks. Scales were collected from fish >50 mm fork length (FL), and fin clips for future DNA analysis were collected from fish >45 mm FL. All fish with a FL 65 mm or larger, not being placed into a 24-hour hold to investigate delayed mortality from passage and capture, were PIT tagged and released. At the Breitenbush River, North Santiam River above Detroit Reservoir, Green Peter Head of Reservoir-

Middle Santiam River, Cougar Dam Head of Reservoir, Fall Creek Head of Reservoir, Lookout Dam, Lookout Point Head of Reservoir, Hills Creek Dam, and Hills Creek Head of Reservoir-Middle Fork Willamette River sites, fish smaller than 65 mm and larger than 35 mm were marked with visible implant elastomer (VIE). A summary of data for 2023 sampling collected by site is provided in Table 1.

Table 1. Summary of data collected at each RST site in 2023.

Rotary Screw Trap Sampling Site	Trap Efficiency Trials	Target Species	Biological and Injury Data	Scale and DNA Samples	24-hour Holds (post collection)	PIT Tagging (>65 mm)	Elastomer Tagging (<65 mm)
Breitenbush River	Yes, Run of River Fish, Hatchery Fish	Spring Chinook and *O. mykiss*	Yes, weight (nearest 0.1 g), F.L. (mm), Injuries	Yes	No	Yes	Yes
Big Cliff Dam	Yes, Hatchery Fish	Spring Chinook and *O. mykiss*	Yes, weight (nearest 0.1 g), F.L. (mm), Injuries	Yes	Yes	Yes, on fish not included in 24-hour holds	No
Detroit Head of Reservoir – North Santiam River	Yes, Run of River Fish, Hatchery Fish	Spring Chinook and *O. mykiss*	Yes, weight (nearest 0.1 g), F.L. (mm), Injuries	Yes	No	Yes	Yes
Green Peter Dam Tailrace – Middle Santiam	Yes, Hatchery Fish	Spring Chinook and *O. mykiss*	Yes, weight (nearest 0.1 g), F.L. (mm), Injuries	Yes	Yes	Yes, on fish not included in 24-hr holds	No
Green Peter Head of Reservoir – Middle Santiam River	Yes, Hatchery Fish	Spring Chinook and *O. mykiss*	Yes, weight (nearest 0.1 g), F.L. (mm), Injuries	Yes	No	Yes	Yes
Cougar Dam Tailrace	Yes, Run of River Fish, Hatchery Fish	Spring Chinook	Yes, weight (nearest 0.1 g), F.L. (mm), Injuries	Yes	Yes	Yes, on fish not included in 24-hr holds	No
Fall Creek Dam	Yes, Hatchery Fish	Spring Chinook	Yes, weight (nearest 0.1 g), F.L. (mm), Injuries	Yes	Yes	Yes	No
Dexter Dam Tailrace	Yes, Hatchery Fish	Spring Chinook	Yes, weight (nearest 0.1 g), F.L. (mm), Injuries	Yes	Yes	Yes, on fish not included in 24-hr holds	No
Lookout Dam Tailrace	Yes, Hatchery Fish	Spring Chinook	Yes, weight (nearest 0.1 g), F.L. (mm), Injuries	Yes	Yes	Yes, on fish not included in 24-hr holds	Yes, on fish not included in 24-hr holds
Lookout Point Head of Reservoir	Yes, Hatchery Fish	Spring Chinook	Yes, weight (nearest 0.1 g), F.L. (mm), Injuries	Yes	No	Yes	Yes
Hills Creek Dam	Yes, Run of River Fish, Hatchery Fish	Spring Chinook	Yes, weight (nearest 0.1 g), F.L. (mm), Injuries	Yes	Yes	Yes, on fish not included in 24-hr holds	Yes, on fish not included in 24-hr holds
Hills Creek Head of Reservoir – Middle Fork Willamette River	Yes, Hatchery Fish	Spring Chinook	Yes, weight (nearest 0.1 g), F.L. (mm), Injuries	Yes	No	Yes	Yes

*Run of River trials are performed at all sites when sufficient numbers of natural origin fish of a markable size are captured. Sites denoted with Run of River trials are those that received enough fish meeting our criteria to perform trials in 2023.

Trap Efficiency Trials. A total of 168 trapping efficiency trials occurred using marked hatchery Chinook in 2023. In addition to the hatchery fish trials, efficiency trials utilizing run of river occurred at the Breitenbush River, Detroit Head of Reservoir- North Santiam, Foster Head of Reservoir- South Santiam, Cougar Dam, Cougar Head of Reservoir, Fall Creek Head of Reservoir, and Hills Creek Dam sites. Recapture data was evaluated by site across variables such as flow, cone revolutions, and brood year. Additional trials will be conducted in 2024 to further evaluate these and other variables impacting the capture efficiency of RSTs at each site.

Target catch and passage. Total target raw catch consisted of 24,958 juvenile Chinook and 1,345 O. mykiss captured at all sites during sampling in 2023. Where dam operations allowed, daily catch rates were standardized and weekly catch was calculated from the standardized daily catch rates. Building on the work of previous studies in the area, we calculated weekly passage estimates based on trap efficiency (TE) trials (see above). Passage estimates by site are presented in Table 2.

Table 2. Raw catch, Passage Estimates with 95% confidence intervals of target species by site and route captured in 2023, where possible.

Site	Route	Species	n	Passage est.	95% C.I.
Breitenbush River		Chinook	377	15,687	9,138 to 55,368
Breitenbush River		*O. mykiss*	361		
Detroit HOR- North Santiam		Chinook	10,141	216,134	153,414 to 528,666
Detroit HOR- North Santiam		*O. mykiss*	590		
Big Cliff Dam	Tailrace	Chinook	704	11,647	9,257 to 16,196
Big Cliff Dam	Tailrace	*O. mykiss*	251		
Green Peter HOR- Middle Santiam		Chinook	25		
Green Peter HOR- Middle Santiam		*O. mykiss*	1		
Green Peter Dam	Tailrace	Chinook	107	9,533	7,083 to 14,751
Green Peter Dam	Tailrace	*O. mykiss*	12		
Foster Dam HOR		Chinook	609	13,650	9,295 to 25,685
Foster Dam HOR		*O. mykiss*	124		
Cougar Dam	Powerhouse	Chinook	427	4,415	3,349 to 6,478
Cougar Dam	RO	Chinook	5,273	86,419	68,406 to 117,310
Cougar Dam HOR		Chinook	5,913	132,566	86,443 to 174,027
Fall Creek Dam HOR		Chinook	148	7,100	4,883 to 13,010
Fall Creek Dam	Tailrace	Chinook	150		
Dexter Dam	Tailrace	Chinook	57	7,782	5,648 to 23,612
Lookout Dam	Powerhouse	Chinook	68		
Lookout Dam	Spill	Chinook	71		
Lookout Point HOR		Chinook	142	5,967	3,992 to 11,805
Hills Creek HOR- MF Willamette		Chinook	93		
Hills Creek Dam	Powerhouse	Chinook	397	7,881	5,519 to 13,782
Hills Creek Dam	RO	Chinook	247		

Injuries. A total of 9,181 (37.8%) Chinook salmon displayed at least one of the injury codes listed in Table 4. The most common injuries observed, excluding the presence of copepods, were descaling less than 20% and fin damage, some of which likely incurred upon capture in the RST. Table 4 provides a list of injuries assessed on captured fish by type.

Table 4. Injury codes for Willamette Valley Downstream Fish Passage Monitoring Injury Assessments.

Description of Injury/Condition	Injury Code	Injury Category
Live fish with no external injuries	NXI	N/A
Mortality with no external injuries	MUNK	N/A
Descaling <20%	DS<2	N/A
Bloated	BLO	Barotrauma
Bloody Eye (hemorrhage)	EYB	Barotrauma
Bleeding from Vent	BVT	Barotrauma
Fin Blood Vessels Broken	FVB	Barotrauma
Gas Bubble Disease (fin ray/eye inclusions)	GBD	Barotrauma
Pop Eye (eye popping out of head)	POP	Baro/Mech
Head Injury	HIN	Mechanical
Operculum Damage	OPD	Mechanical
Body Injury (tears, scrapes, mechanical damage)	TEA	Mechanical
Bruising (any part of the body)	BRU	Mechanical
Hole Behind Pectoral Fin	HBP	Mechanical
Descaling >20%	DS>2	Mechanical
Head Only	HO	Mechanical
Body Only	BO	Mechanical
Head Barely Connected	HBO	Mechanical
Fin Damage	FID	N/A
Predation Marks (vert. claw or teeth marks)	PRD	N/A
Copepods (on gills or fins)	COP	N/A
BKD (distended abdomen)	BKD	N/A
Fungus	FUN	N/A

Willamette Valley Downstream Fish Passage Monitoring Project Reservoir Distribution Studies Task

Hans Berge, Kristin Connelly, Stephan Fogarasi, Jesus Vargas, and Anna Redside

Cramer Fish Sciences – Fish Ecology Lab, Portland Oregon

hans.berge@fishsciences.net

Cramer Fish Sciences was contracted by the U.S. Army Corps of Engineers to sample juvenile salmonids in Lookout Point and Green Peter Reservoirs during 2023. The purpose of the project was to assess juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) reservoir habitat use, longitudinal distribution, and growth in relation to water management strategies implemented as part of the interim injunction measures. Sampling in 2023 was conducted between June and December. This project will continue in 2024 with sampling planned to occur from February through November.

Nearshore sampling was conducted biweekly in both reservoirs beginning in mid-June and continued through mid-July using small Oneida Lake traps and box minnow traps. A stratified random sampling design was used to select daily trap placement locations within each reservoir zone (Lower, Middle and Upper). Captured Chinook salmon were enumerated, examined for marks (adipose fin clips, PIT or VIE tags), measured for length and weight, given a body condition examination (including for presence of parasitic copepods), and if untagged, were given a PIT tag. Offshore reservoir sampling was conducted using small mesh suspended gill nets set at six fixed sites spread along the longitudinal axis of each reservoir. Gill net sampling occurred from late July through September in Green Peter Reservoir and from August through early December in Lookout Point Reservoir. Limnological sampling (vertical profiles of temperature, dissolved oxygen and turbidity) were taken coincident with fish sampling events.

Across the 2023 nearshore sampling period (mid-June through mid-July), only 17 subyearling Chinook salmon were captured in box minnow and Oneida lake traps in Lookout Point Reservoir, of which 16 where natural origin and 1 was a hatchery origin Chinook salmon. All but one Chinook salmon were captured in Oneida lake traps. Based on fork length, all fish captured were subyearlings. The majority of trap sets had zero Chinook salmon catch, however, those that did were in the Upper and Middle reservoir zones, with 13 caught in the Upper zone nearest the head of the reservoir, 4 in the Middle zone, and zero captured in the Lower zone. These results suggest that subyearling Chinook salmon in June and July in the nearshore environment were predominantly located in the upper and middle zones of the reservoir, however catch rates were very low. Because only two weeks were sampled in the nearshore environment, changes in nearshore longitudinal distribution were not evaluated over time. Weekly mean surface water temperatures of nearshore trap sets ranged from 21.0 - 23.6ºC.

During offshore gill netting in Lookout Point Reservoir, a total of 13 Chinook salmon were caught over the course of the sampling season, of which 9 were hatchery origin (six pit-tagged as part of the bulk marking effort and 3 ad-clipped hatchery Chinook), and 4 were natural origin. Based on evaluation of fork lengths, all were subyearlings. Due to dropping reservoir elevations and shallow depths in the upper zone of the reservoir, offshore gill netting was restricted to stations in the Middle and Lower reservoir zones, and by the end of the season, only the Lower zone was accessible. Because of low catch rates, our ability to draw inferences on the offshore longitudinal distribution of Chinook salmon is limited.

No subyearling Chinook salmon were captured in nearshore traps set in Green Peter reservoir. Weekly mean surface water temperatures of trap locations ranged from 20.0 – 24.2ºC. Only one subyearling Chinook salmon was caught during offshore sampling in Green Peter Reservoir. The lone specimen was a 119 mm fork length natural origin subyearling, caught in the upper zone of the reservoir at the end of September. Sampling in Green Peter Reservoir was suspended after September because we were unable to safely access the reservoir on a regular basis.

Nearshore catches in both reservoirs were low. Low nearshore catch rates were likely related to the timing of sampling and elevated nearshore water temperatures above the ideal range for salmonids. Due to supply chain issues and other delays, sampling didn't commence until mid-June, after the peak migratory period of April-May seen in rotary screw traps above and below the reservoirs. Our nearshore sampling may have missed the peak migratory period and sampling was conducted after the reservoir surface waters had warmed to unsuitable levels. In 2024, sampling commenced in February to try to better capture the outmigration period.

Offshore catches were extremely low in comparison to previous assessments in Lookout Point Reservoir (e.g. Monzyk et al. 2015). There are several possible explanations for the reduced catch rates observed. The gill nets we used in 2023 were of much smaller surface area and contained smaller mesh sizes than those used previously by ODFW. While efforts were taken to duplicate ODFW's custom net specifications, supply chain issues and the timeline of the project necessitated using nets of different specifications. We are in the process of procuring gill nets of identical specification to ODFW for 2024 sampling. Other factors that may have come into play to reduce Chinook salmon catch rates include the drawdown, high turbidity, high temperatures throughout the water column during August and September, or potentially lower numbers of Chinook salmon upstream of Lookout Point Reservoir.

Our limnology results indicate clear temperature concerns for salmonids in Lookout Point Reservoir during August and September in 2023. From mid-August through late September, the water column down to 30 m was 19-21ºC. At that time, the maximum depth in the forebay was approximately 35 m, and depths greater than 30 m had low dissolved oxygen that would have presented stressful conditions for salmonids (less than 5 mg/L). Thus, during peak temperatures there was essentially no suitable habitat in Lookout Point reservoir for salmonids. Our limnology vertical profiles in Lookout Point reservoir and USGS Green Peter tailrace monitoring also identified turbidity levels in both reservoirs during the drawdown exceeding 200 NTU in November and December.

ASSOCIATIONS OF INJURY AND MORTALITY RATES OF CHINOOK SALMON WITH TOTAL DISSOLVED GAS BELOW DAMS IN THE UPPER WILLAMETTE RIVER

Tom Porteus, Hanbyeol Jang, Eric Parkinson, Mairin Deith, Aaron Greenberg, Roberto Licandeo, Murdoch McAllister
Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, BC, Canada
taporteus@outlook.com

Spring Chinook salmon (*Onchorhynchus tsawytscha*) populations in the Upper Willamette River (UWR), Oregon, are listed as threatened under the Endangered Species Act. Many factors have affected their populations, including multi-purpose high head dams constructed primarily for flood control. In addition to dams restricting access to spawning habitats, reservoir operations that spill water over the dam can result in supersaturated levels of total dissolved gas (TDG) in the river below the dam. Juvenile salmonids exposed to supersaturated TDG can develop gas bubble disease (GBD) and other injuries related to barotrauma (e.g., bloating, eye haemorrhage, bleeding from vent, fin blood vessels broken, pop eye), some of which can result in mortality. The objectives of this study were to evaluate how spill operations and TDG downstream of dams in the UWR affect 1) the incidence of GBD, 2) the wider incidence of barotrauma injuries, and 3) the mortality rate from all risk factors.

Rotary screw traps were used to capture juvenile salmon within 1 km downstream of Big Cliff dam spillway and the Cougar dam regulating outlet (RO). Trapping took place in two periods: before (2011-2016, operated by ODFW) and after (2021-2023, operated by Cramer and EAS) modifications to dam spill operations to reduce TDG downstream. Traps were checked every 1-2 days, and the number of captured Chinook salmon, the proportion with GBD, the proportion with barotrauma, and the proportion that were dead were calculated for each trap check. Using data from USGS monitoring gages <1 km downstream of each trap, observed % TDG was calculated for the interval prior to each trap check. Spill discharge via spillways and ROs over the dams was calculated for the same intervals at Detroit and Big Cliff combined and at Cougar. Binomial Generalized Linear Models were then used to model the proportions of captured fish that were observed with GBD, barotrauma, or dead in relation to TDG, spill, temperature, fish length, and trap event duration.

TDG and spill were positively correlated at both sites, but the relationship was weaker below Cougar, highlighting site specific differences in how spill generates TDG. Mean TDG in each trap event at each site were similar for each period (108.4% pre- vs. 108.9% post-implementation of TDG abatement measures below Big Cliff, and 106.1 vs. 106.8% below Cougar). Maximum TDG was reduced below Big Cliff from 133.8% to 127.0% but increased from 117.4% to 119.7% below Cougar. The incidence of GBD, barotrauma and mortality were all greater prior to the implementation of TDG abatement measures in 2021 (Table 1).

Modelling showed that the maximum TDG experienced by juvenile salmon when trapped in screw traps had a significant positive effect on GBD incidence in each site and period (Figure 1), but that mean TDG level below Big Cliff had no significant effect in the period before modifications to dam operations. Maximum TDG levels >130% resulted in 100% incidence of GBD. The optimal model for GBD incidence included interactions between maximum TDG and temperature, as the incidence of GBD was greater when TDG was high and temperature was low, and between maximum spill discharge and fish length, as the incidence of GBD was greater when spill was high and fish were longer. There was a significant positive effect of trap hours, as GBD incidence increased the longer that fish were held in traps. GBD incidence was significantly higher below Cougar, despite lower levels of TDG compared to below Big Cliff. The modifications to dam spill operations significantly reduced the incidence of GBD at both sites. Barotrauma incidence showed relationships with variables similar to those found with GBD incidence.

Overall, mortality was negatively related to TDG and positively related to spill, but due to interactions, the effects varied by site and period. Mortality rates were higher below Cougar compared to Big Cliff and were lower in the period following modifications to dam spill operations. Captured fish were significantly more likely to be found dead in traps both the longer they were and the longer they were held in traps.

This study found that maximum TDG levels of >130% can result in all Chinook salmon developing GBD, with high mortality rates of >50% during these trap events. Oregon water quality standards state that TDG should not exceed 110%. However, mitigation measures that kept TDG below 130%, e.g., through dam spill operations, were successful in reducing both incidence of GBD and barotrauma injuries, and in reducing mortality. Although use of RST data may represent a worst-case scenario for the effects of TDG as fish are held in traps near the surface and are thus unable to depth compensate, such measures could therefore reduce risks to threatened salmonid populations.

Table 1. Rotary screw trap records summarized from sites below Big Cliff dam and Cougar dam RO and hydrological variables observed during each discrete trap event.

Site	**Big Cliff**		**Cougar RO**	
Period	2014-2016	2021-2023	2012-2016	2021-2023
Trap events	190	587	259	418
Mean trap hours	48	24	36	24
Maximum spill (cfs)	10,580	7,370	6,780	3,580
Maximum TDG (%)	133.8	127.0	117.4	119.7
Total captures	743	4,054	5,147	12,654
Mean proportion with GBD	0.13	0.03	0.29	0.18
Mean proportion with barotrauma	0.29	0.14	0.45	0.32
Mean mortality rate	0.34	0.09	0.21	0.11

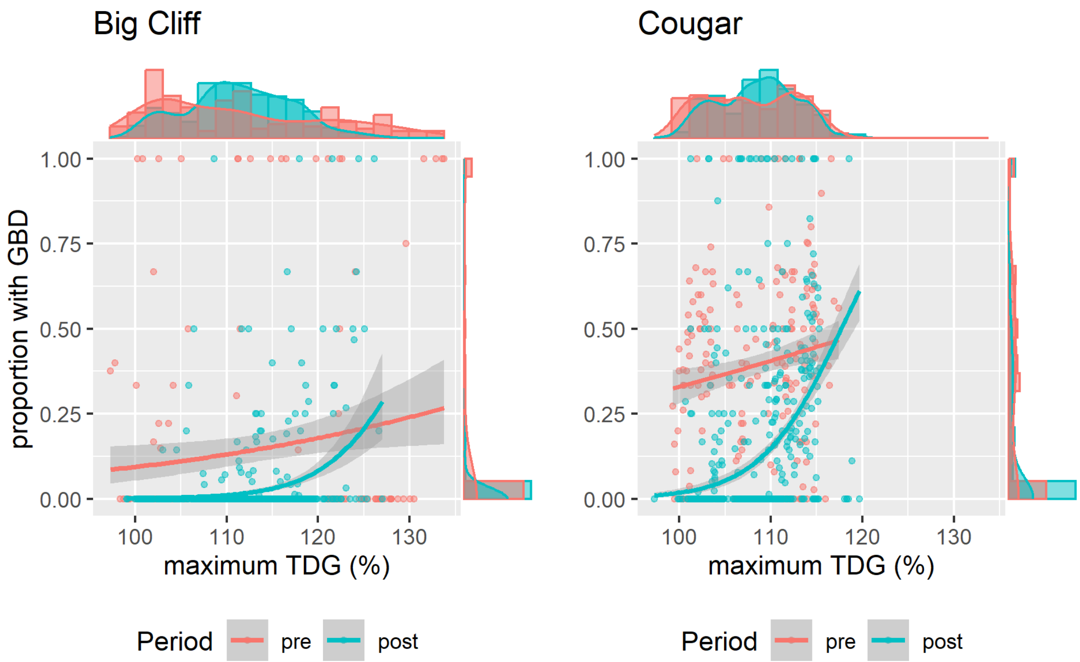


Figure 1. Estimated relationships of gas bubble disease (GBD) incidence in juvenile Chinook salmon captured in rotary screw traps located below Big Cliff and Cougar dams with the maximum TDG observed during each trap event. Shaded regions in the panels represent 95% confidence intervals for the mean predicted proportion with GBD. Trapping occurred pre- (2012-2016) and post-implementation (2021-2023) of abatement measures to reduce TDG downstream of the dams.

Comparing Potential Total Dissolved Gas (TDG) Mortality in Chinook Salmon Juveniles Below Big Cliff and Foster Dams

Eric Parkinson, Tom Porteus, Mairin Deith, Aaron Greenberg, Roberto Licandeo, Murdoch McAllister,
University of British Columbia, Vancouver, B.C. Canada
eparkx@gmail.com

The progeny of Chinook salmon (*Oncorhynchus tshawytscha*) outplants above Detroit and Foster dams migrate through downstream areas where Total Dissolved Gas (TDG) concentrations often exceed lethal levels. Mortality during smolt migration translates directly into proportional losses of returning spawners because most density-dependent survival compensation in Chinook salmon occurs during the pre-smolt stage. However, operations that generate high TDG, such as spill, are sometimes necessary to promote fish and non-fish values such as downstream passage and flood control. Quantifying mortality from Gas Bubble Disease (GBD) will provide information that is needed to compare policy alternatives that affect multi-attribute utility functions.

The estimates of mortality are generated by quantifying four processes: (1) TDG generation, (2) TDG dissipation, (3) laboratory estimates of mortality, (4) mortality mitigation in natural environments.

(1) TDG generation will be modeled for each US Army Corps of Engineers (USACE) facility for operational scenarios such as those included in the recent EIS (Eqn.1 and Table 22 *in* USACE 2022).

(2) Laboratory mortality estimates have recently been reviewed by Pleisier et al. (2020) and summarized in terms of 3 equations that describe the time to 3 events (T_{eGBT} = Onset of GBD, T_{LT10}=10% mortality, T_{LT50}=50% mortality) as functions of TDG concentration (C):

$$T_{eGBT} = 387e^{-0.174C} \qquad T_{LT10} = 1636e^{-0.174C} \qquad T_{LT50\_M} = 3361e^{-0.174C}$$

Using these relationships, mortality can be expressed as a sigmoid function of C:

Equation 1 $$M = 1/\left(1 + e^{-k(T-LT50)}\right) = 1/\left(1 + e^{-0.00127e^{0.174C}\left(T-3361e^{-0.174C}\right)}\right)$$

where k is a steepness parameter that is determined by the difference between T_{LT50} and T_{LT10}.

(3) TDG Dissipation modeling starts with a theoretical model (Kamal et al 2019), which indicates that C is an exponential function of the initial concentration, C_0 ($C=C_0\, e^{-kT}$). This model was validated using an empirical data set from large rivers and reservoirs that indicates that $log(k)$ v. $log(H/U)$ is linear. A depth-velocity data set for streams below Big Cliff and Foster dams has been developed using Lidar coverage of the bottom morphology to model depths and velocities as functions of discharge for stream segments that average about 125 m in length (Figure 2). We extrapolated the Kamal model to smaller rivers and then validated the model using TDG data sets from the North and South Santiam rivers. The result is two equations that model the dissipation as functions of discharge (q in m^3/s) and distance (L in km) for the South and North Santiam rivers, respectively.

Equation 2 $$C = C_0 e^{-3.4307L(q+5.6)^{-0.6300}} \quad \text{and} \quad C = C_0 e^{-6.3747L(q-11.0)^{-0.6506}}$$

Model results from these two equations suggest that dissipation in the North Santiam takes place over shorter distances and times, about half the time and distance compared with the S. Santiam over a range of discharges (Figure 5) mainly because of higher water velocities, and therefore turbulence, in the N. Santiam.

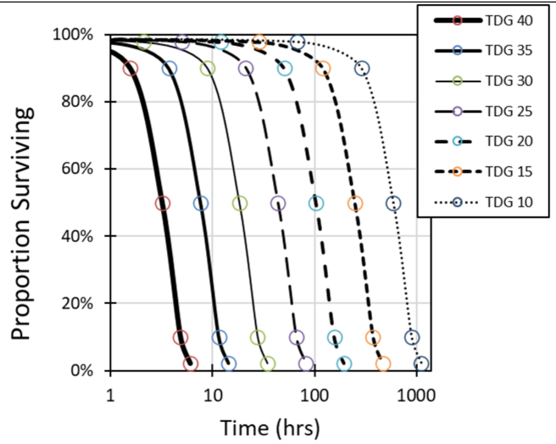


Figure 1. Sigmoid curves for seven values of xTDG[1] parameterized using laboratory relationships between time to mortality thresholds v. TDG concentration. Note the log scale on Time.

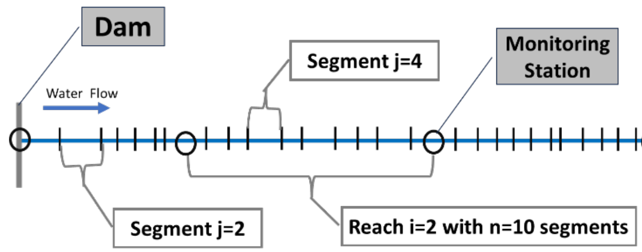


Figure 2. The layout of the depth-velocity X segment data set used in the dissipation analysis. The stream below a dam is organized of into Segments (index j) nested within Reaches (index i). There are n_i segments within a stream reach i. Reach end points are defined by the locations of the TDG monitoring stations.

[1] Expressing TDG concentration as xTDG = %*TDG-100%* simplifies these equations

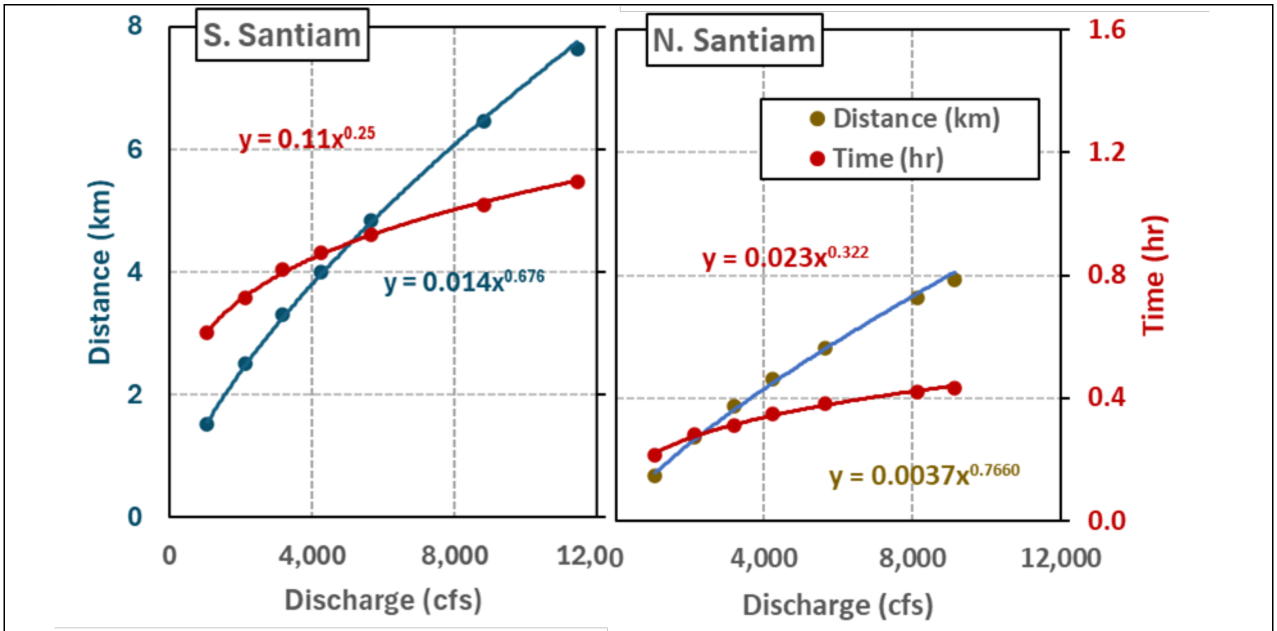


Figure 3. Distance and Time to 50% TDG dissipation for the South and North Santiam rivers below Foster and Big Cliff dams. Time is the sum of products of segment length (km) and water travel times (hr/km) using data from the segment model. The maximum discharge in each river correspond to the maximum discharge used in generating the depth-velocity X segment data sets.

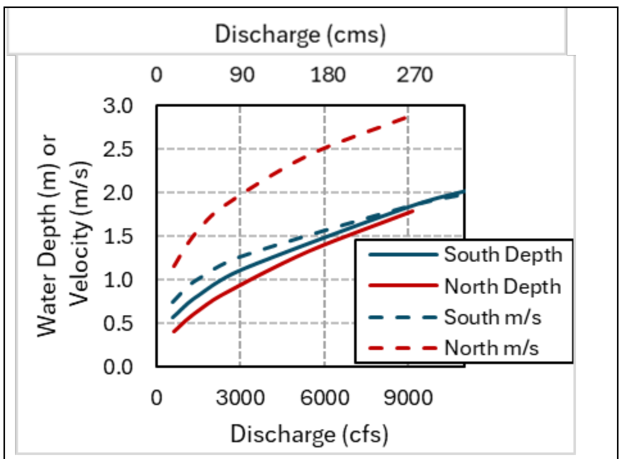


Figure 4. Modeled depth and velocity versus discharge for the first 5 km of the S. and N. Santiam rivers below Foster and Big Cliff dams.

(4) Mortality Mitigation in Natural Environments. In salmon and steelhead (*O. mykiss*) smolts, TDG risk may be mitigated by migration timing, migration speed, and migration depth, which, in various combinations, may lower T and/or C and the corresponding gas bubble trauma (GBT) mortality as quantified in Equation 1. Details of the relevant behavior in stream reaches directly below dams are poorly documented. We use a "Best Available Science" estimate of mortality that uses information from a variety of sources including: Migration rates and timing of juvenile Chinook salmon captured or released into reaches below dams in the Willamette Basin, movement and timing data on Chinook salmon in the mainstem Columbia River and other tributaries, and depth compensation behavior in laboratory experiments.

Migration Timing: Movement patterns of Chinook juveniles in the upper Willamette Basin involves movements of sub yearlings from spawning to rearing areas as well as smolt migrations (Schroeder et al 2016). We assume that fish move though dam tailwaters relatively quickly as part of a directed smolt migration and therefore the timing of smolt migration (Figure 3) is the most appropriate measure of the risk of GBT mortality.

Migration Speed: In the Columbia River, age-0 and age-1 chinook smolts move about 10 and 20 km/day (Giorgi et al. 1997), which is similar to the migration rates measured by Kock et al. (2015) for Chinook originating from the Detroit Reservoir on the N Santiam River.

Depth as a Refuge: In deeper water, hydrostatic pressure prevents bubble formation despite higher-than-normal concentrations of gas in fish tissues. The depth compensation rate is 9.7%/m. In natural environments, fish do not experience significant levels of GBD at TDG<120% (Backman 2002, Kusnierz 2024). Although smolts are surface oriented they travel at depths of 2-3 m in Columbia R reservoirs (Beeman and Maule 2006) and 75% are >1.5 m deep in the free flowing Hanford Reach (Dauble et al. 1989). Mean depths in the Santiam River tributaries range from 0.5m at low discharge to 1.5 m at high discharge.

Prior Exposure: In Equation 1 GBD mortality depends on exposure time (*T*). In lab experiments, such as those reviewed in Pleizier et al. (2020a), treatment prior to exposure is generally standardized by maintaining pre-exposure xTDG C_0 at values close to 0. In a natural environment, fish entering the tailwater of a dam may have been exposed to high TDG for long periods of time before dam passage. In an extreme case, fish traveling through a reregulation reservoir such as Big Cliff may absorb high levels of xTDG generated by an upstream dam (Detroit) for several days prior to dam passage[2]. If they remain below 3-4 m while in the reservoir, they will not exhibit any sign of GBD as they pass the downstream dam even though they have absorbed high levels of dissolved gas. If they remain on the surface in the tailwater, the time to the onset of GBD symptoms may be much lower than those implied by Figure 1.

[2] Dissipation rates are generally low in reservoirs because of their high depth to velocity ratios. This situation is common in the mainstem Columbia and Snake Rivers where tailwaters of upstream dams typically have deep water refuges (>5 m) that can mitigate GBT for xTDG $C<50$

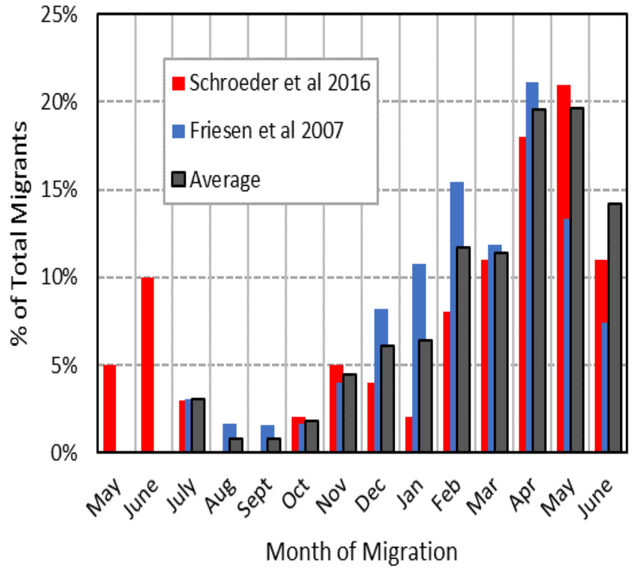


Figure 5. Monthly distribution of migrating juvenile Chinook inferred from Schroeder et al. (2016, Fig. 4, 5) and Friesen et al. (2007, Fig. 3). The Schroeder numbers represent juvenile Chinook passing Willamette Falls and are inferred from were from the detection of tagged juvenile Chinook salmon from the McKenzie River population. The proportion of Sub-yearling Smolts, (18%), Autumn Smolts (13%) and Yearling Smolts (69%) were spread across the months when they passed Willamette Falls. The Friesen numbers are from density indices derived from electrofishing and beach seine catches in the lower Willamette River. The two indices were standardized and then averaged to generate a single density index X month.

A more complex form of this process can be expected to occur in fish migrating downstream through a gradient of declining (i.e. dissipating) TDG below dams. During high TDG events, gas accumulation in fish tissue starts immediately after entry to the high TDG environment and then approaches an equilibrium where TDG in fish (TDG_f) is the same as TDG in the water (TDG_w). With continued movement downstream, the TDG dissipation process produces lower TDG_w in downstream reaches. The net result of these processes is that TDG accumulation in fish tissues slows as $TDG_f \rightarrow TDG_w$ and then reverses if $TDG_f > TDG_w$. Gill lamellae are efficient gas transfer structures (Park et al 2014) the equilibrium process can occur on time scales of minutes rather than hours (Elston et al. 1997). Hans et al. (1999) concluded that fish with GBD can recover quickly when transferred to low TDG water, but it is difficult to apply their results to fish moving through a declining TDG gradient.

Most of the data associated with this process are built into the mortality-time-TDG data set (Figure 8, Figure 9) which cannot be linked directly to TDG levels in the fish. As a result, the end of the accumulation phase and the start of the dissipation phase are poorly defined. Our approach is to define 2 alternative assumptions about fish behavior that bracket the upper and lower limits of TDG mortality.

1. The upper limit of TDG mortality assumes that the TDG level in the blood is established by the highest TDG that the fish encounters. This is equivalent to the experience of a fish permanently residing in the water immediately downstream of the TDG source.
2. The lower limit of TDG mortality assumes that:
   a. Fish continue to move downstream and encounter lower TDG values that are determined by the dissipation process. As the rate of travel $\rightarrow 0$, this option is equivalent to option 1
   b. The time scale of the mortality process is much slower than the time scale of dissolved gas movement across the gill membranes (e.g. hours vs. minutes). As the TDG dissipation rate $\rightarrow 0$, this option is equivalent to option 1

The pattern of mortality TDG in space and time are illustrated in Figure 6 for the Foster to Waterloo Reach of the S. Santiam R. TDG drops exponentially (Equation 2) with time and distance. Survival drops rapidly to just >1% as fish move downstream. Survival in each segment first drops because of increasing exposure time, even though TDG is declining. Segment survival then starts to rise and approaches 100% (over a 230 m segment) as TDG dissipates and falls below 15% xTDG (i.e. 115% TDG supersaturation).

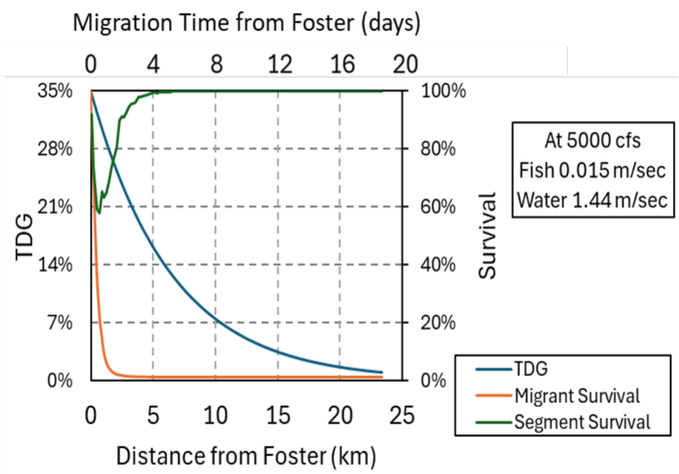


Figure 6. An example of the modeled survival of juvenile Chinook migrants exposed to TDG. The channel is the S. Santiam between Foster Dam and Waterloo. The discharge is moderately high, so the water is moving quickly (5.2 km/hr, 1.44 m/sec). The initial TDG (135%) and juvenile Chinook migration rate (0.054 km/hr, 0.015 m/s) have been chosen to produce low survival (1.0%) by the time the fish have covered the 23 km long reach. Note that the segment survival is approaching 100% by km 10. The segment structure is described in Figure 2. Average Segment length is 230 m. Survival does not include depth or season of travel as mitigating factors.

Low survivals are predicted to occur only when fish are assumed to be moving very slowly (<0.014m/s), water is moving rapidly (high discharge) and initial TDG is >120% (Figure 5). The pattern from top to bottom in each panel is the result of increasing water velocity with discharge, which carries high TDG water further downstream before it dissipates, combined with a constant fish migration velocity.

Our model suggests that migrating fish are only at risk of GBD if they pause in their migration in high TDG sections below dams. Risk of GBD is high for resident fish during high TDG events in the first 5-10 km below the dam but drops to much lower levels if fish move to deeper water (>1.5 m) during these events. Under the Figure 4 conditions, mortality is 100% at migration rates of <0.14 m/s.

The differences between the morphology of the two channels (Figure 4) produces differences in dissipation rates (Figure 3) that carry through to differences in survival (Figure 8). TDG levels in the Big Cliff tailwater appear to be about 10-15% higher than the Foster tailwater, but these higher levels are partially mitigated by the higher dissipation rates in the North Santiam River channel.

References

Backman, T.W., Evans, A.F., Robertson, M.S. and Hawbecker, M.A., 2002. Gas bubble trauma incidence in juvenile salmonids in the lower Columbia and Snake Rivers. *N.Am. J. Fish. Mgmt. 22:*.965-972.

Beeman, J.W. and Maule, A.G., 2006. Migration depths of juvenile Chinook salmon and steelhead relative to total dissolved gas supersaturation in a Columbia River reservoir. *Trans. Amer. Fish. Soc.*135:584-594.

Dauble, D.D., Page, T.L. and Hanf Jr, R.W., 1989. Spatial distribution of juvenile salmonids in the Hanford Reach, Columbia River. *Fish. Bull. 87*:775-790.

Friesen, T.A., Vile, J.S. and Pribyl, A.L., 2007. Outmigration of juvenile Chinook salmon in the lower Willamette River, Oregon. *NW Sci.81:*173-190.

Hans, K.M., Mesa, M.G. and Maule, A.G., 1999. Rate of disappearance of gas bubble trauma signs in juvenile salmonids. J.Aq. An. Health, 11:83-390.

Kamal, R., Zhu, D.Z., Leake, A., Crossman, J.A., 2019. Dissipation of supersaturated total dissolved gases in the intermediate mixing zone of a regulated river. DOI: 10.1061/(ASCE)EE.1943-7870.0001477

Kock, T.J., Beeman, J.W., Hansen, A.C., Hansel, H.C., Hansen, G.S., Hatton, T.W., Kofoot, E.E., Sholtis, M.D., and Sprando, J.M., 2015, Behavior, passage, and downstream migration of juvenile Chinook salmon from Detroit Reservoir to Portland, Oregon, 2014–15 http://dx.doi.org/10.3133/ofr20151220

Kusnierz, P.C., Bouwens, K.A. and Ransom, A.L., 2024. Predicting the likelihood of gas bubble trauma in fishes exposed to elevated total dissolved gas in the lower Clark Fork River, Idaho. *Trans. Amer. Fish. Soc.153*:39-54.

Schroeder, R.K., Whitman, L.D., Cannon, B. and Olmsted, P., 2016. Juvenile life-history diversity and population stability of spring Chinook salmon in the Willamette River basin, Oregon. *C. J. Fish. Aq. Sci.:73;*.921-934.

USACE. 2022. Willamette Valley System Operations And Maintenance, Draft Programmatic Environmental Impact Statement.

Appendix D: Water Temperature and Total Dissolved Gas Methodology, September 23, 2022.

Survival (Foster to Waterloo, 23 km)

Water Velocity (m/s)	Discharge (cfs)	Excess TDG (%)		Fish Velocity	0.007 m/s	Excess TDG (%)		Fish Velocity	0.014 m/s	Excess TDG (%)		Fish Velocity	0.028 m/s
		20	25	30	35	20	25	30	35	20	25	30	35
0.53	400	96%	95%	90%	63%	98%	98%	97%	91%	99%	99%	99%	97%
0.61	600	95%	93%	85%	40%	98%	97%	95%	85%	99%	99%	98%	95%
0.75	900	95%	91%	76%	13%	98%	97%	93%	75%	99%	99%	97%	93%
0.89	1,400	93%	87%	58%	1%	97%	95%	89%	57%	99%	98%	96%	89%
1.06	2,200	91%	79%	30%	0%	97%	93%	82%	29%	99%	97%	94%	82%
1.25	3,500	87%	64%	5%	0%	95%	90%	68%	5%	98%	96%	91%	68%
1.50	5,500	79%	39%	0%	0%	94%	84%	44%	0%	98%	95%	86%	44%
1.81	8,700	65%	10%	0%	0%	91%	73%	14%	0%	97%	92%	76%	14%
2.14	13,700	41%	0%	0%	0%	85%	53%	1%	0%	95%	88%	57%	1%

Figure 7. Pattern in survival between Foster and Waterloo (23 km) over a range of discharge (vertical axis), initial excess TDG (horizonal axes) and assumed migration velocities of fish (3 panels). For comparison, fish velocities in all 3 panels (max 0.028 m/s) are much lower than typical cruising speeds of fish (1 body length/s or 0.1 m/s for 10 cm fish) and the migration speed of Chinook Salmon smolts (10 km/day or 0.12 m/s).

Survival (Foster to Waterloo, 23 km)

Water Velocity (m/s)	Discharge (cfs)	Excess TDG (%) 20	25	30	35
				Fish Velocity	**0.015 m/s**
0.53	**500**	98%	98%	96%	88%
0.61	**800**	98%	97%	94%	82%
0.75	**1,100**	98%	96%	92%	72%
0.89	**1,700**	97%	95%	88%	55%
1.06	**2,400**	97%	94%	82%	32%
1.25	**3,600**	96%	91%	72%	9%
1.50	**5,300**	95%	87%	55%	1%
1.81	**7,700**	93%	80%	31%	0%
2.14	**11,300**	90%	69%	8%	0%

Survival (Big Cliff to 23 km)

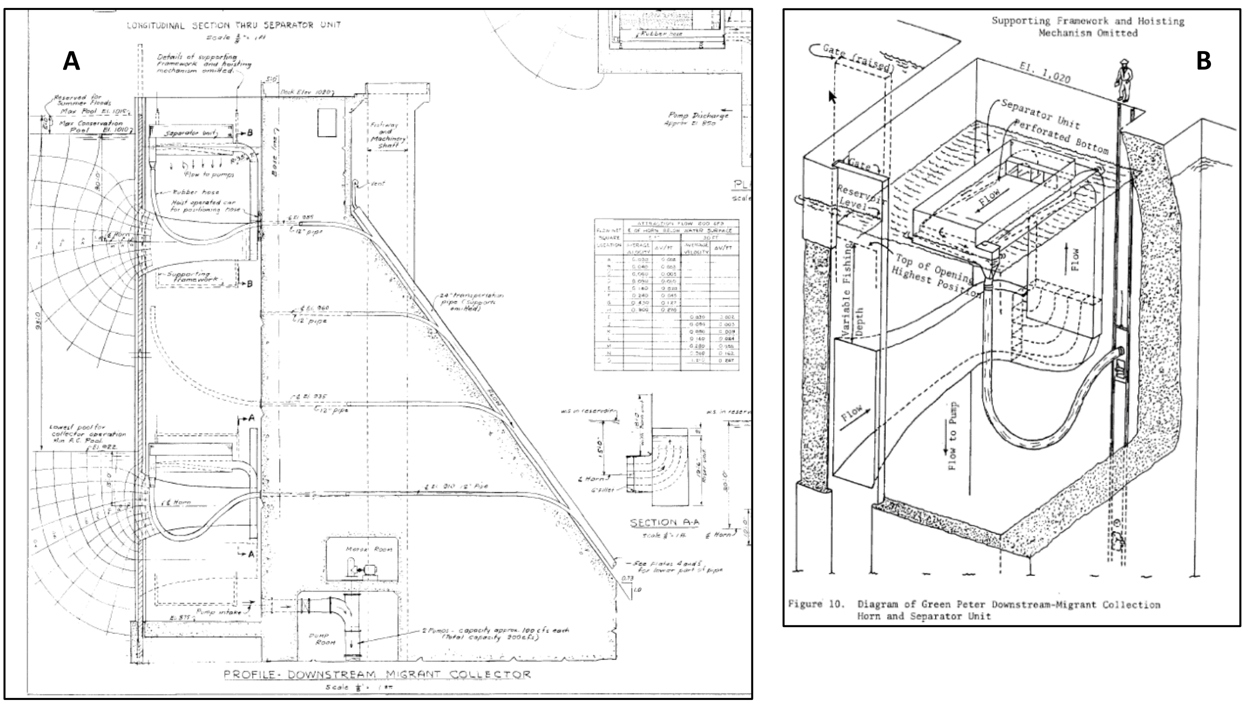
water velocity	Discharge (cfs)	Excess TDG (%) 20	25	30	35
1.86				**Fish Velocity**	**0.015 m/s**
0.86	**500**	99%	98%	98%	98%
0.97	**800**	98%	98%	98%	96%
1.14	**1,100**	98%	98%	97%	94%
1.31	**1,500**	98%	97%	96%	91%
1.47	**2,200**	98%	97%	94%	85%
1.69	**3,200**	97%	96%	92%	75%
1.94	**4,500**	97%	95%	88%	58%
2.22	**6,500**	96%	93%	82%	33%
2.56	**9,300**	95%	90%	71%	9%

Figure 8 Modeled survival profiles for the South (left) and North (right) Santiam rivers across a range of discharge and initial xTDG (i.e. C_0) values. The fish are moving at the same slow migration speed (~ 0.15 body length/sec) in both channels but excess TDG dissipates more quickly in the North Santiam (see Figure 3).

BACK TO THE FUTURE?
REVISTING AN INOVATIVE DOWNSTREAM FISH PASSAGE SYSTEM FROM THE 'SIXTIES'

Rich Piaskowski, Portland District, USACE
richard.m.piaskowski@usace.army.mil

Surface collection at high-head dams in the Pacific Northwest has been a focus for improving downstream passage of salmon and steelhead. For Chinook and steelhead, collection rates in surface collectors at high-head dams with large forebay areas built within the last 25 years have been relatively low. A floating surface collection system for downstream passage of anadromous salmonids was included at Green Peter Dam in the South Santiam River Sub-basin when constructed, operating from about 1967 to 1988. Evaluation of the system resulted in relatively high forebay collection efficiency for spring Chinook salmon. Attributes of the system will be reviewed and compared to other surface collectors operating at high head dams in the Pacific Northwest.



A. Longitudinal section through Green Peter Dam showing the "downstream migrant collector" entrance, separator, and bypass system. **B**. Diagrammatic perspective of the "downstream migrant collector" collection entrance and separator. (Source: USACE 1962; Plate 9).

DRAWDOWN OPERATIONS AT THE WILLAMETTE PROJECT: WHAT HAVE WE LEARNED?

Greg Taylor
U.S. Army Corps of Engineers, Willamette Project
gregory.a.taylor@usace.army.mil

The U.S. Army Corps of Engineers (USACE) operates and maintains a system of 13 dams and reservoirs within the Willamette River Basin, Oregon. This system operates for multiple authorized purposes including: Flood Damage Reduction, Hydropower, Navigation, Water Quality, Irrigation, M&I, Recreation, and Fish and Wildlife. Re-establishing Spring Chinook above dams with historic populations is an important tool to improve the status of fish listed under the Endangered Species Act. Historically, downstream passage of juveniles has been accomplished by a combination of structural or operational passage operations. One of the tools used to accomplish operational downstream passage is reservoir drawdowns. Reservoir drawdowns have been used at the Willamette Project since the 1960's to pass juvenile fish downstream. In 2023, USACE completed four reservoir drawdowns at the Willamette Project. In 2023, drawdowns at Green Peter and Lookout Point Dams occurred for the first time since those dams were completed. This presentation summarizes what we have learned about drawdown operations at the Willamette Project with an emphasis on the 2023 drawdowns of Green Peter and Lookout Point Dams.

EVALUATION OF RESERVOIR DRAWDOWN EFFECTS ON OUTMIGRATION BEHAVIOR AND SURVIVAL AT THE LOOKOUT POINT PROJECT DURING FALL 2023

Dalton Hance, Jake Kelley, Toby Kock, Amy Hansen, and Russell Perry
U.S. Geological Survey, Western Fisheries Research Center, Cook, WA
dhance@usgs.gov

A court-imposed interim injunction required the U.S. Army Corps of Engineers to undertake a suite of actions aimed at improving fish passage and water quality at several Willamette Valley Project dams since 2021. In 2023, one injunction measure required initiation of novel operations at Lookout Point Dam during summer/fall to "drawdown" Lookout Point Reservoir from an elevation of 888 feet to an elevation of 750 feet by November 15, 2023, approximately 100 feet lower than during normal operations. The biological goal of the drawdown was "to provide improved volitional downstream passage and survival for juvenile spring Chinook salmon through Lookout Point Reservoir and past Lookout Point Dam in the fall." (https://usace.contentdm.oclc.org/utils/getfile/collection/p16021coll7/id/24342). The target life histories for the drawdown were "salmon fry and subyearlings that entered the reservoir in the previous winter–spring and reared through summer in the reservoir, and subyearlings that enter the reservoir in summer and fall" (Document 278-1). The drawdown was intended to allow fish to access and volitionally pass through the regulating outlets (RO) of Lookout Point Dam with "high passage efficiency and survival anticipated" (Document 278-1). U.S. Geological Survey (USGS) was contracted to evaluate downstream migration behavior and to estimate reservoir and dam passage survival for this target population using acoustic telemetry.

Previous studies have shown that juvenile Chinook salmon primarily exhibit three life history patterns upstream of Lookout Point Dam, two of which were the target of the drawdown operations. Many juvenile Chinook salmon move downstream and enter Lookout Point Reservoir from March through May as fry and spend several months rearing in the reservoir, which thermally stratifies under normal conditions. Spring migrants experience high growth rates in the reservoir but are exposed to increased predation risk (by non-native fish species including smallmouth bass *Micropterus dolomieu* and walleye *Sander vitreus*) and experience high rates of infection by parasitic copepods *Salmincola californiensis*. Fall migrants rear in streams upstream of Lookout Point Reservoir during their first spring and summer, then move downstream into the reservoir during September - November. These fish don't experience the same growth rates as their spring migrant counterparts. Under pre-injunction operations, fish that survived until fall passed Lookout Point Dam as reservoir elevations decreased to levels where passage routes, both turbine and ROs, were relatively accessible. However, results from previous studies also suggested that fish passing Lookout Point Dam in fall experienced substantial injury or mortality. These factors are important to understand because of the potential for management actions (such as reservoir drawdown) to differentially affect spring and fall migrants in terms of reservoir survival, passage timing, and passage survival. The third life history, spring yearling migrants, are targeted by another injunction operation strategy (spring spill) that is not addressed by our study.

We conducted an acoustic telemetry study during August 2023–February 2024 to evaluate outmigration behavior and survival of juvenile Chinook salmon in the Middle Fork Willamette and mainstem Willamette rivers. We designed the study to be partly representative of both target life histories. Juvenile spring Chinook salmon were reared under Oregon State University's Wild Fish Surrogate Program to a size consistent with reservoir rearing spring migrant life history. Tagged fish were released at the head of Lookout Point Reservoir from late August through late October 2023 with earlier releases intended to represent of reservoir rearing spring migrants that survived to fall, and later releases intended to represent fall migrants entering from upstream tributaries. A total of 2,026 juvenile Chinook salmon were released over 9 weeks.

In this presentation, we will provide preliminary findings on reservoir survival, passage timing, and passage and downstream survival.

UPPER WILLAMETTE BULL TROUT SPAWNING ABUNDANCE AND PASSAGE AT COUGAR AND HILLS CREEK DAMS IN 2023

Nik Zymonas, Vince Tranquilli, and Alex Harrison
Oregon Department of Fish and Wildlife – Corvallis Research Lab
nik.zymonas@oregonstate.edu

Bull Trout *Salvelinus confluentus* declined in the Willamette Basin over the last century and remained only in the McKenzie River drainage by the early 1990s. The Upper Willamette Bull Trout Working Group formed in 1989 to coordinate activities to improve the status of bull trout populations and the group continues to guide recovery and mitigation efforts in the upper McKenzie, South Fork McKenzie, and Middle Fork Willamette drainages. Measures taken to improve the species' status have aimed to reduce angling-related mortality, improve habitat conditions and connectivity, restore the historical prey base, and reintroduce Bull Trout into formerly occupied tributaries. Comprehensive population monitoring and research on potential limiting factors are essential components of this program. We conducted monitoring efforts focused on Bull Trout in the Upper Willamette in 2023, and we will highlight selected results from these efforts in this presentation.

We assessed Bull Trout spawning abundance by conducting bi-weekly redd surveys at all local spawning reaches, installing PIT tag interrogation stations at the downstream end of spawning tributaries, and operating traps to capture post-spawn adult bull trout at three sites. The total redd count for the basin remained relatively high in 2023, amounting to the fourth highest total count on record (235 redds). Redd counts in the upper McKenzie and M. Fk. Willamette local populations increased slightly from the previous year while the count for the S. Fk. McKenzie decreased. Trapping operations provided the opportunity to collect biometric and demographic data and implant PIT-tags to facilitate monitoring efforts.

We operated PIT tag interrogation stations below Cougar and Hills Creek dams to detect tagged Bull Trout, we conducted angling efforts at Hills Creek Dam, and we assisted with processing and transporting bull trout collected at the Cougar Dam upstream passage facility. We detected one PIT-tagged adult Bull Trout below Hills Creek Dam in January of 2023, but subsequent capture efforts yielded no bull trout there. Multiple PIT-tagged bull trout have been detected at Hills Creek Dam since late autumn of 2023, and we will continue to conduct capture efforts to provide upstream passage. The Cougar Dam upstream fish passage facility collected eight Bull Trout during the 2023 operating season, including five of the nine PIT-tagged fish detected by our PIT tag antennas during the autumn 2022 – spring 2023 passage season. Three of these fish had also been captured and passed upstream in 2022. We obtained post-transport detections for five of the eight Bull Trout passed upstream, including four fish subsequently detected in upstream spawning reaches in autumn and one fish detected only after passing back downstream through the dam. The PIT tag detection systems in the Cougar Dam tailrace has detected several PIT-tagged Bull Trout since October 2023, and operation of the upstream fish passage facility for 2023 is scheduled to begin in mid-March.

LIFE HISTORY, STATUS, AND RESEARCH OF THE NORTHWESTERN POND TURTLE IN THE WILLAMETTE VALLEY, OREGON

Kathleen N. Smith
Environmental Stewardship Section
U.S. Army Corps of Engineers, Junction City, OR
Kathleen.N.Smith@usace.army.mil

The northwestern pond turtle, *Actinemys marmorata*, has been studied throughout its range for over 50 years. Yet certain aspects of its ecology and life history remain understudied, particularly within novel lentic reservoir environments. With its conservation status in Oregon listed as sensitive-critical and a candidate for Federal listing as threatened under the Endangered Species Act, it is a critical time to understand northwestern pond turtle life history, habitat use, and movement patterns in Willamette Valley System (WVS) reservoirs. These data will help agencies, managers, and biologists make informed decisions in the face of competing operational and biological priorities.

This presentation will help introduce the northwestern pond turtle to the greater Willamette Valley biological community by describing its life history, phenology, and recently re-defined conservation status. I will briefly discuss the U.S. Army Corps of Engineers' (USACE) historic and current conservation and management actions in the Willamette Valley and introduce our cooperative research project with U.S. Geological Survey, studying northwestern pond turtle movements as they relate to water level management in USACE reservoirs.

MOVEMENT AND HABITAT USE OF NORTHWESTERN POND TURTLES IN WILLAMETTE VALLEY PROJECT RESERVOIRS

Jennifer Fredrickson[1], Michael Adams[1], Christopher Pearl[1], and Kathleen Smith[2]
[1]U.S. Geological Survey Forest and Rangeland Ecosystem Science Center, Corvallis, OR
[2]U.S. Army Corps of Engineers Environmental Stewardship Section, Junction City, OR
jfredrickson@usgs.gov

Northwestern pond turtles (*Actinemys marmorata*; NWPT) are a semi-aquatic freshwater species native to the Pacific Coast. Due to population losses in parts of their range, the U.S. Fish and Wildlife Service proposed NWPT for federal listing under the Endangered Species Act in 2023. Several reservoirs within the U.S. Army Corps of Engineers' (USACE) Willamette Valley Project (WVP) support populations of NWPT. To complete their annual lifecycle, turtles move between aquatic and terrestrial environments for nesting and a period of winter dormancy. Because the timing of these seasonal movements may coincide with reservoir draw-down and refilling, altered water management stemming from the 2021 court injunction in the WVP may have implications for NWPT. To investigate how turtle movement and habitat use relate to changing water management, the U.S. Geological Survey Forest and Rangeland Ecosystem Science Center and USACE entered a partnership to capture and track NWPT in three WVP reservoirs between 2023 and 2026. The objectives of this study are to provide information regarding NWPT distribution, habitat use, and seasonal movement patterns in WVP reservoirs. Additionally, we are evaluating the feasibility of using GPS and satellite tracking technology to collect fine-scale geospatial information on terrestrial movement. We began trapping NWPT at Fall Creek and Hills Creek reservoirs in Spring 2023. In total, 62 NWPT were captured including 24 adult males, 15 adult females, 4 unknown adults, and 19 juveniles. A subset of adult turtles received VHF transmitters (n=30) or GPS transmitters (n=2). Transmittered individuals were relocated weekly and at each location we recorded microhabitat characteristics (e.g., number of basking structures, water temperature). In Fall of 2023, we closely monitored timing of turtle movement into uplands for overwintering, and rechecked individuals periodically during dormancy. This spring, we will monitor turtles as they emerge and move back to aquatic habitats and continue to track individuals until transmitter loss or battery failure. In Spring 2024, we will also expand the study to include trapping turtles at Lookout Point reservoir with the goal of adding 15-20 individuals to our telemetry study.

Investigating the Relation Between Streamflow and Habitat for Rearing and Spawning Spring Chinook in the McKenzie and Santiam Rivers, Oregon

James White[1], Karen Bartelt[1], Gabriel Hansen[2], Jacob Kelley[2], Brandon Overstreet[1], Rose Wallick[1], Tobias Kock[2]
[1]US Geological Survey, Oregon Water Science Center
[2]US Geological Survey, Western Fisheries Research Center
jameswhite@usgs.gov

The Willamette Basin, Oregon is home to at least 69 species of fish, including spring-run Chinook Salmon (*Oncorhynchus tshawytscha*) which is listed as "threatened" under the U.S. Endangered Species Act. Chinook Salmon and other aquatic organisms rely on the availability of suitable physical habitat, such as water depth, velocity, sediment size, and temperature to fulfill various aspects of their life cycle. These habitat variables are related, to varying degrees, to streamflow and channel hydraulics. In the Willamette River Basin (WRB), streamflow is managed, in part, by 13 US Army Corps of Engineers (USACE) dams located in tributaries upstream of the mainstem Willamette River.

To support federally protected salmonids, the 2008 Biological Opinion for the USACE's Willamette Valley Project established streamflow objectives which specified seasonal streamflow targets at several locations along the Willamette River and select tributaries. Several studies have investigated how juvenile Chinook Salmon use habitats in the WRB (Hansen et al., 2023) and how habitat availability varies with streamflow in the mainstem Willamette River (White et al., 2022). However, there are few robust studies that focus on these habitat dynamics in the large Willamette Basin tributaries draining the Cascade Mountains. This work investigates physical habitat/streamflow dynamics in the Santiam and McKenzie and Santiam Rivers, downstream of USACE dams, which are important spawning and rearing reaches for spring Chinook salmon. We use high-resolution hydraulic models to evaluate depth and velocity at a range of streamflows across these rivers and develop a novel approach to modeling the distribution of riverbed grain size at high resolutions throughout known spawning reaches. Together, these datasets facilitate quantitative evaluation of how Chinook salmon spawning and rearing habitat responds to streamflow.

Preliminary results suggest that modeled area of rearing habitat for juvenile Chinook is less sensitive to changes in streamflow compared with habitat previously evaluated on the mainstem Willamette River. Differences in modeled relations between streamflow and rearing habitat area for the McKenzie and Willamette Rivers likely relate to factors such as channel morphology and river gradient. However, preliminary results suggest spawning habitat is sensitive to the spatial distribution of bed-material sediment and the size thresholds selected for useability.

The USGS Willamette Integrated Water Science (IWS) Program: updates on hydrology and fisheries-focused research and data collection for 2024-2026

Rose Wallick[1], Krista Jones[1], Karen Bartelt[1], Mike Dodrill[2], Jason Dunham[3], Ian Jesorek[2], Jacob Kelley [2], Tobias Kock[2], Francine Mejia [3], Elena Nilsen[1], Brandon Overstreet[1], Jim Peterson[4], Caelan Simeone[1], Marc Stewart[1], Adam Stonewall[1], Christian Torgersen[3], James White[1]

[1]US Geological Survey, Oregon Water Science Center
[2]US Geological Survey, Western Fisheries Research Center
[3]US Geological Survey, Forest Rangeland Ecosystems Sciences Center
[4] US Geological Survey Cooperative Fisheries and Wildlife Research Unit
rosewall@usgs.gov

The Willamette River Basin was selected as the fourth of 10 planned U.S. Geological Survey (USGS) Integrated Water Science (IWS) basins, bringing major investments in water monitoring, hydrology and fisheries-focused research to inform local water management decisions while building transferable tools and knowledge for other basins nationwide. The Willamette IWS effort extends through 2031 and encompasses three complementary programs: USGS's Next Generation Observing System (NGWOS) focuses on improving and modernizing the water monitoring network; the USGS Integrated Water Availability Assessments (IWAAs) program will characterize patterns of water availability for humans and ecosystems, and the EcoFlows program will predict consequences of hydrologic variability on stream ecosystems. Between 2023-2026, IWAAs, NGWOS, and EcoFlows will conduct targeted studies and data collection to characterize surface water availability for people, spring Chinook salmon *(Oncorynchus tshawytscha),* and other focal native fishes in the first of two phases of the IWS program. A more comprehensive assessment of surface water, groundwater and water quality will be scoped and completed in the second phase of the IWS program spanning 2027-2031. To maximize the utility of this work to local water and fisheries managers, USGS is actively engaging in outreach with numerous stakeholder groups with more outreach planned for 2024. We provide the following key updates on phase 1 IWS hydrology and fisheries-focused research and data collection:

- New water level and stream temperature gages were installed in unregulated, above-dam river corridors of the Molalla, Santiam and McKenzie River basins in 2023. Additional gages will be installed along Fall Creek, Middle Fork Willamette River, North Fork Middle Fork Willamette River, Collawash River, and Clackamas River in 2024. These NGWOS-funded gages are installed near the upstream extent of reaches historically used for spawning by spring Chinook salmon.

- An Integrated River Mapping Program was developed to characterize salmon-bearing rivers and improve affordable monitoring capabilities of fluvial habitat conditions. In the near-term, the program is focused on above and below-dam corridors of the Santiam River Basin, with collection of new topo-bathymetric lidar, thermal-infrared (TIR) imagery, bathymetric surveys, and installation of a dense network of stream temperature loggers in select above-dam streams.

- A stream temperature data compilation, analysis and visualization effort is underway to summarize data from across the Willamette River basin and make these data available to managers and practitioners. This multi-scale "thermalscape" mapping effort includes compilation of historical thermal-infrared (TIR) mapping as well as in-situ data from many state, federal and local organizations. These remote sensing and in-situ measurements will later be integrated with modeling results to characterize and predict thermal heterogeneity in Willamette Basin salmon-bearing streams.

- Streamflow and stream temperature modeling and analyses are underway to characterize spatial and historical trends, evaluate natural and human controls, and predict future conditions. Efforts include trend analyses of long-term USGS streamflow and stream temperature data and development of a Willamette-specific statistical model of stream temperature. In the Santiam River basin, a detailed modeling study will develop and couple hydraulic and stream temperature models above and below dams to evaluate current and future patterns of habitat availability and water availablility for public supply and irrigation under a wide range of hydroclimatic and water management scenarios.

- Multiple efforts are underway to better characterize historical, current, and potential future habitat conditions for spring Chinook salmon across the Willamette Basin. A historical synthesis is providing detailed maps of Chinook salmon distributions at different points in time. Likewise, habitat criteria for different life stages are being developed and will be compared with hydrologic analyses and modeling to quantify historical and current patterns of habitat availability across the Willamette Basin and compare conditions across different river corridors. To support these habitat characterizations, fish sampling in 2024-2025 will focus on above-dam river corridors of the Santiam River Basin to describe fish distributions and to ground-truth habitat parameter metrics that were originally developed via literature review.

- A variety of new research and development efforts are being evaluated as part of NGWOS, including evaluation of Passive Integrated Transponder (PIT) tagging technologies at USGS gaging stations. A PIT-tag array on the South Fork McKenzie River above Cougar Dam was identified as the first location where PIT antennas will be evaluated for the dual purpose of detecting PIT-tagged fish and evaluating flow-based gravel transport. If successful, this approach could eventually be adapted at USGS streamflow gages throughout the United States, further enhancing the usefulness of these sites for providing river-based data collection throughout the nation.

- The EcoFlows program is supporting two new fisheries-focused studies that will leverage current and forthcoming hydrologic analyses and hydraulic models from the IWAAs study. The first EcoFlows study will develop drift-foraging-bioenergetics models to link existing 2D hydraulic models with foraging ecology to understand juvenile spring Chinook salmon growth dynamics. This bioenergetics modeling will be supported by substantial field collection of invertebrate drift samples and otoliths from juvenile Chinook salmon in 2024-2025.

- The second EcoFlows study will develop species distribution models for Pacific lamprey (*Entosphenus tridentatus)* and two species of freshwater mussels (western pearlshell mussel [*Margaritifera falcata]* and western ridged mussel [*Gonidea angulata*]) for the Willamette Basin. This project has been planned and implemented as a fully co-produced effort, in cooperation with partners working in the Willamette Basin. Currently, USGS is meeting with partners across the basin to gather existing data on mussel and lamprey observations and assist in identifying key factors to include in models of species distributions. Partners are also asked about their level of interest in participation (communications and project updates, data sharing, full participation as a co-author on study products). USGS will utilize partner-supplied distribution data to build distribution models that also incorporate hydrologic and geomorphic data.

Reviewing the Wild Fishes Surrogate Project's Impact on Juvenile Salmonid Studies in the Willamette River Basin in 2023-2024

Crystal L. Herron[1], Claire Couch[1,2], Michelle M. Scanlan[1], Olivia Hakanson[1], Seth White[1,3], Ryan Couture[4], Carl B. Schreck[1], James T. Peterson[1,5]

[1] Department of Fisheries, Wildlife, and Conservation Sciences, Oregon State University, Corvallis, OR. 97331
[2] Department of Biomedical Sciences, Oregon State University, Corvallis, OR. 97331
[3] Oregon Hatchery Research Center, Oregon State University, Corvallis, OR. 97331
[4] Oregon Department of Fish and Wildlife, Salem, OR. 97324
[5] US Geological Survey, Oregon Cooperative Fish and Wildlife Research Unit
Oregon State University, Corvallis, OR. 97331

The Wild Fishes Surrogate Project rears juvenile Chinook salmon and steelhead trout for other USACE funded projects to investigate fish passage through infrastructure built in the Willamette River Basin and its tributaries. These surrogate fish are reared in such a way that their resulting phenotype is more akin to naturally reared salmonids as opposed to their hatchery reared counterparts. To date these surrogate fish have been used in a wide variety of projects including evaluations of juvenile fish passage, distribution, and survival at several hydropower dams, high head bypass, reservoir and dam passage fry survival, weir injury/survival, reservoir distribution and survival, and the effects of copepod infection on stress and survival in juvenile Chinook salmon. Previous and ongoing research of the surrogate project have focused on the development and refinement of methods for producing high quality fish for researchers. Most recently, the project has been investigating intermittent fasting as a tool to rear fish that are more prepared to enter the river system upon release. Fish size was recorded, and samples were collected to assess the fish's innate immune ability and energy resource allocation throughout the experiment. We found that fish who experienced cyclic fasting appear to have a more natural growth curve. Additional research is being conducted to evaluate the effect of diet on the gut microbiome and immune function of Chinook salmon reared on the surrogate diet. Preliminary findings indicate that the surrogate diet results in a gut microbiome that is more similar to that of naturally reared fish than hatchery fish, and that diet alters the expression of stress- and immune-related genes. Our research is refining rearing methods as well as providing further evidence for the resulting phenotype of our fish to be more comparable to naturally occurring phenotypes.

2023 SPRING CHINOOK SALMON SPAWNING SURVEYS IN QUARTZVILLE CREEK, ABOVE GREEN PETER DAM

Rand Romas, Dillon Alegre, Rachel Ellison, Mark Morasch, Kelsey Scott, Bailey Morgan, Ellie Rondon, Sky O'Rourke
Environmental Assessment Services, Richland, WA
rromas@easbio.com

Environmental Assessment Services (EAS) conducted spring Chinook salmon (*Oncorhynchus tshawytscha*) spawning ground surveys above Green Peter Dam in Quartzville Creek and major tributaries to determine both the abundance and distribution of spring Chinook salmon adults, in addition to redd distribution, composition, and longevity throughout the duration of the study for the U.S. Army Corps of Engineers – Portland District (USACE) during September, October, and November of 2023.

This presentation summarizes results from data gathered by EAS field staff regarding a multitude of environmental variables, live fish observations, recovered carcasses, redd abundance, distribution, timing, and subsequent longevity of redds. Chinook salmon carcasses were retrieved and identified to species, recognized as hatchery-reared (adipose fin absent) or native origin (adipose fin present), thoroughly assessed for sex, prespawn mortality (egg retention), scavenging, morphometric characteristics, and analyzed for research tags or markers that were present and/or absent (floy tags and Coded Wire Tags (CWT)). Furthermore, all carcasses determined to contain a CWT had the tag area retained and will be sent to ODFW personnel.

In total, 31 independent surveys were conducted from September 28, 2023, to November 15, 2023, along five main reaches (Quartzville 1, Canal Creek, Quartzville 2, Quartzville 3, and Quartzville 4) and additional exploratory tributaries that potentially could be classified as productive spawning habitat (Figure 1). Surveys began approximately two days after 100 female and 100 male Chinook salmon were outplanted at Miner's Camp along Quartzville Creek above Green Peter Dam.

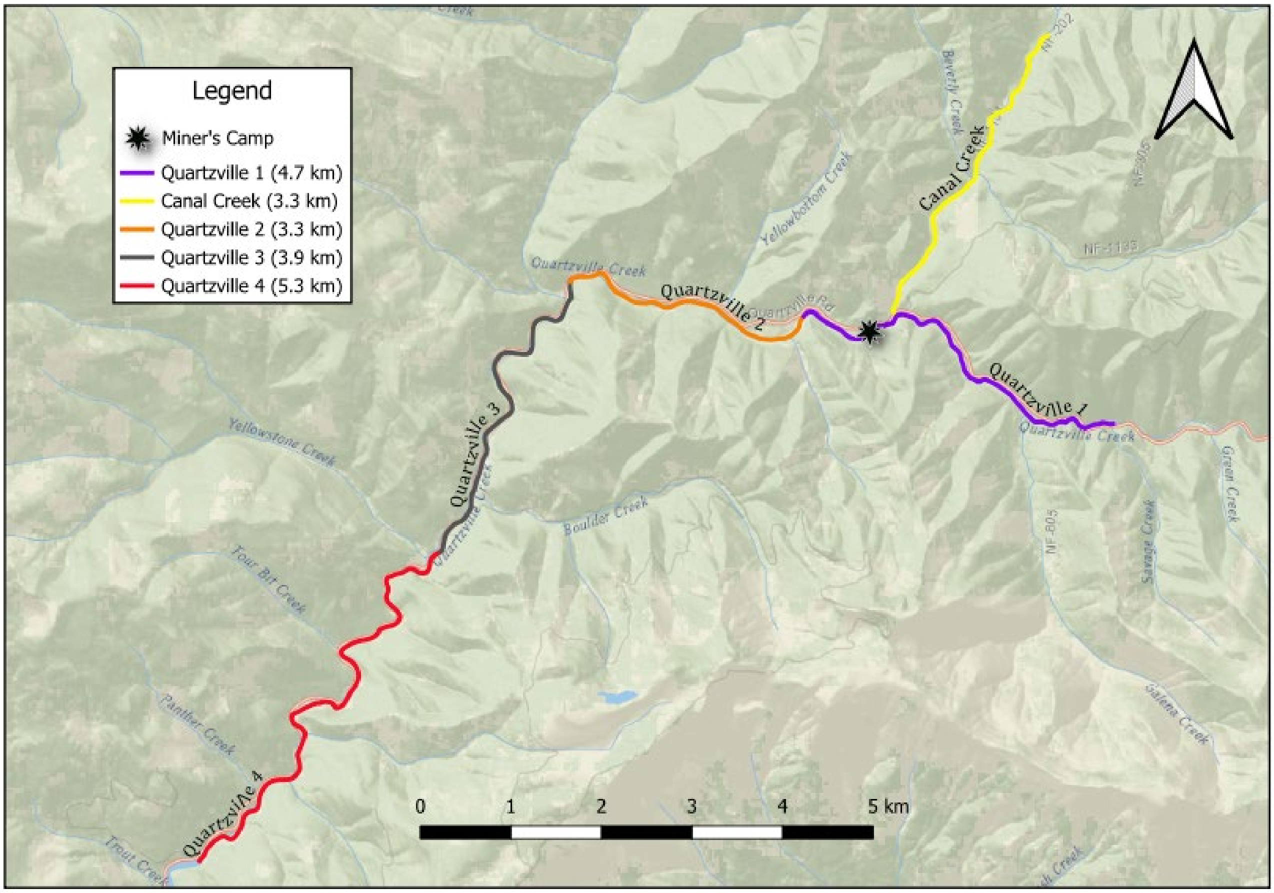


Figure 1. Illustrates five survey reaches within Quartzville Creek and the Miner's Camp outplanting site.

Collectively, 127 live Chinook salmon were observed throughout the duration of the surveys, 95 (74.8% of total observations) were encountered within the Quartzville 1 reach (Table 1 and Figure 2). The peak observation of live fish sightings occurred during week 1 of the surveys (September 28, 2023, to September 30, 2023). Live fish observations decreased throughout the season and where applicable, habitat location, behavior and sex were recorded for each sighting.

Table 1. Illustrates observations of live adult Chinook salmon by survey week and reach. Cells with 'N/A' represent survey reaches not completed during that specific survey week.

Week	Quartzville 1	Canal Creek	Quartzville 2	Quartzville 3	Quartzville 4	Total
1	55	16	N/A	N/A	N/A	71
2	40	3	10	1	0	54
3	0	0	1	0	1	2
4	0	0	0	0	0	0
5	0	0	0	N/A	N/A	0
6	N/A	N/A	N/A	0	0	0
7	N/A	N/A	N/A	N/A	N/A	N/A
8	0	0	0	0	0	0
Totals	**95**	**19**	**11**	**1**	**1**	**127**

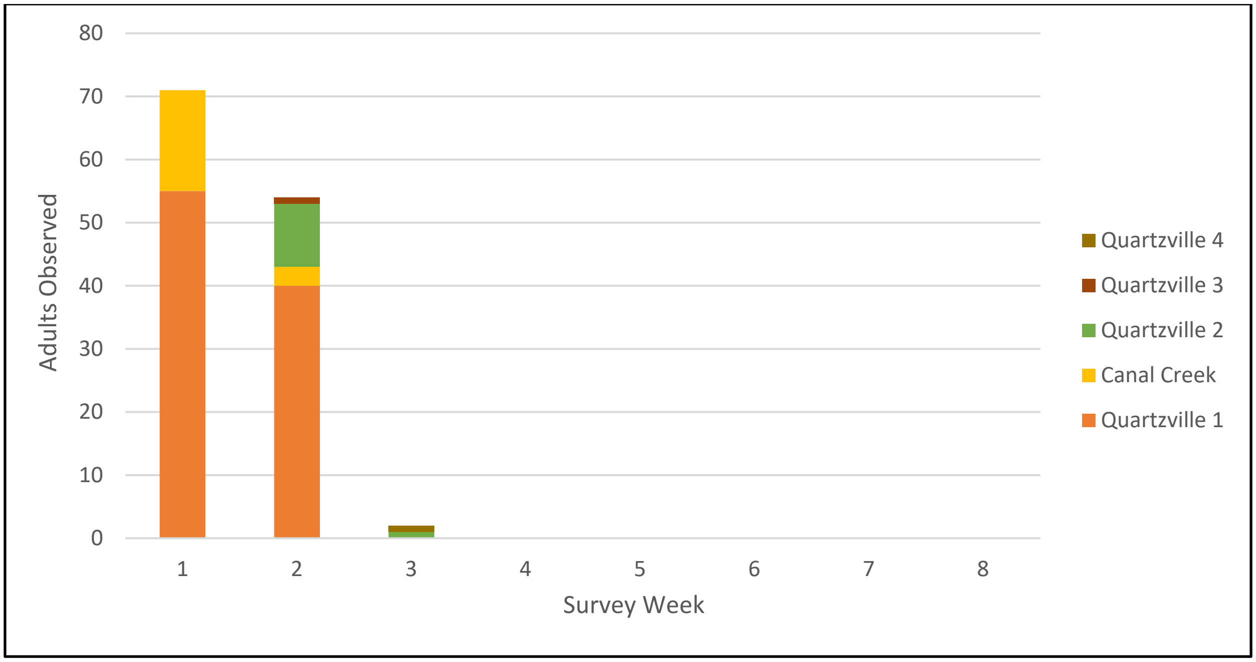


Figure 2. Illustrates live adult Chinook salmon observations each survey week and within each distinct reach.

Of the 200 outplanted hatchery-reared Chinook salmon, 85 carcasses (42.5% of all Chinook salmon outplanted) were collected throughout EAS' survey efforts. Of these 85 collected carcasses, 52 (61.2% of total collected carcasses) were recorded as female, 26 (30.6% of total collected carcasses) were recorded as male, and seven (8.2% of total collected carcasses) were recorded as unknown (Figure 3).

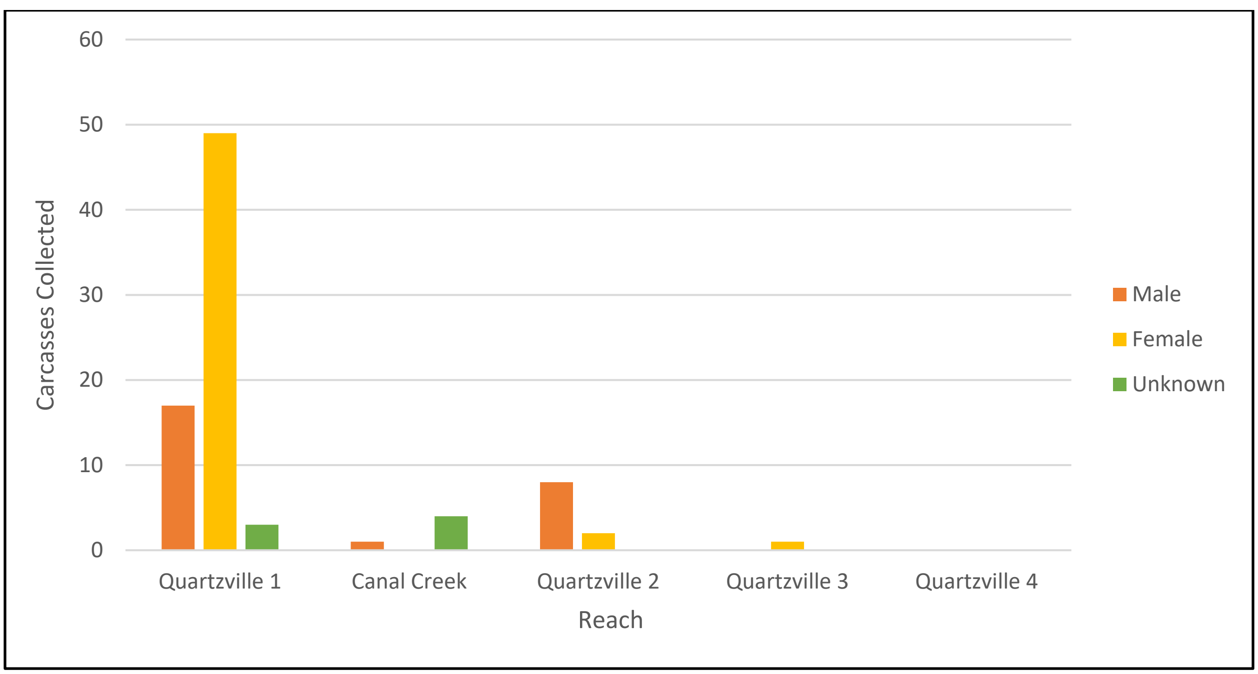


Figure 3. Illustrates Chinook salmon carcasses by sex and reach.

Furthermore, survey crews identified CWT and floy tag presence or absence on all recovered carcasses. A total of five CWTs (5.8% of total collected carcasses) were identified and collected.

Of the collective 85 carcasses sampled, 23 (27.1% of total collected carcasses) had lost their floy tag prior to the carcass being discovered. Floy tags were known to be present when these fish were released at Miner's Camp on September 26, 2023. Based on EAS' findings, there was no pattern of tag retention observed throughout the duration of the surveys. Additionally, six female carcasses were recorded having a red tag present on their dorsal sinus, denoting female fish not treated with Erymicin antibiotic.

Throughout the duration of the spawning surveys, 52 female carcasses were collected and assessed. Across all reaches, survey crews determined egg retention rates for 50 female carcasses (96.2% of total collected female carcasses).

Survey crews collected the first female Chinook salmon carcass on October 3, 2023, within the Quartzville 3 reach. This was the initial fish encountered and was classified as a prespawn mortality due to having an observed egg retention of 100%. The first female Chinook salmon that was collected and defined as having less than 50% egg retention was encountered on October 5, 2023.

Female carcasses were enumerated by egg retention status. Of the collective 52 female Chinook salmon observed, 33 (63.4% of total collected female carcasses) were denoted as having 0% egg retention, meaning that they were fully spawned at the time of collection. Additionally, four (7.7% of total collected female carcasses) were found to have 5–10% egg retention, seven (13.5% of total collected female carcasses) were found to have 10–25% egg retention, two (3.8% of total collected female carcasses) were found to have 25–50% egg retention, and four (7.7% of total collected female carcasses) were found to have greater than 50% egg retention (Figure 4). Additionally, two (3.8% of total collected female carcasses) were observed with unknown egg retention. These two Chinook salmon were excluded from prespawn mortality calculations as they were both marked "unknown" due to their level of decay upon observance.

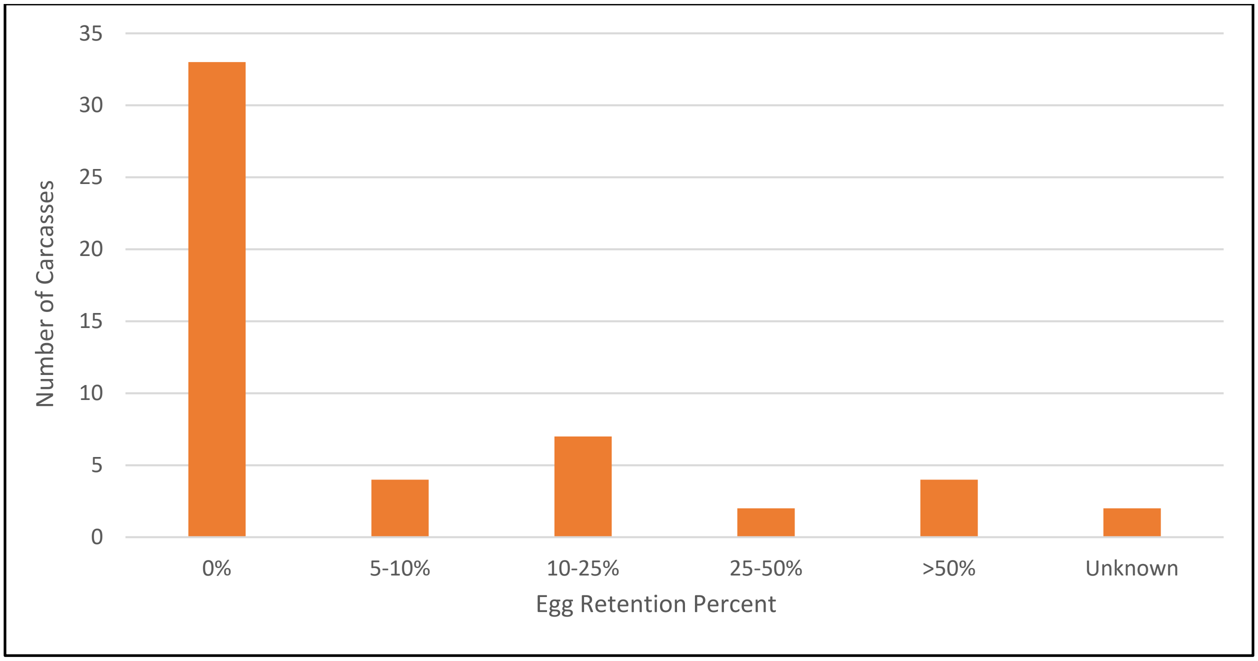


Figure 4. Illustrates the number of carcasses collected and their corresponding egg retention as determined during spawning surveys.

Female Chinook salmon that were observed to have an egg retention percent greater than 50 were recorded as prespawn mortalities. Excluding the two unknown Chinook salmon, the 2023 spawning surveys along Quartzville Creek found that there was a 7.7% prespawn mortality. Therefore, it was calculated that 46 of the 50 (92% of total collected female carcasses with an egg retention percent) female Chinook salmon were found to have spawned during the survey period.

EAS survey crews first observed Chinook salmon constructing redds on September 28, 2023, the first day in which the surveys took place and two days after their initial release at Miner's Camp. The first spawned carcass observed by EAS staff was found on October 5, 2023, approximately 10 days after initial release at Miner's Camp.

A total of 89 unique redds were observed throughout the duration of the spawning surveys (Figure 5). Cumulatively, 73 redds (82.0% of total observed redds) were seen along the Quartzville 1 reach. Additionally, 12 unique redds (13.5% of total observed redds) were observed in Canal Creek, and four unique redds (4.5% of total observed redds) were found within the Quartzville 2 reach. Throughout the duration of the spawning surveys, there were no redds observed within the Quartzville 3 and Quartzville 4 reaches (Figure 5).

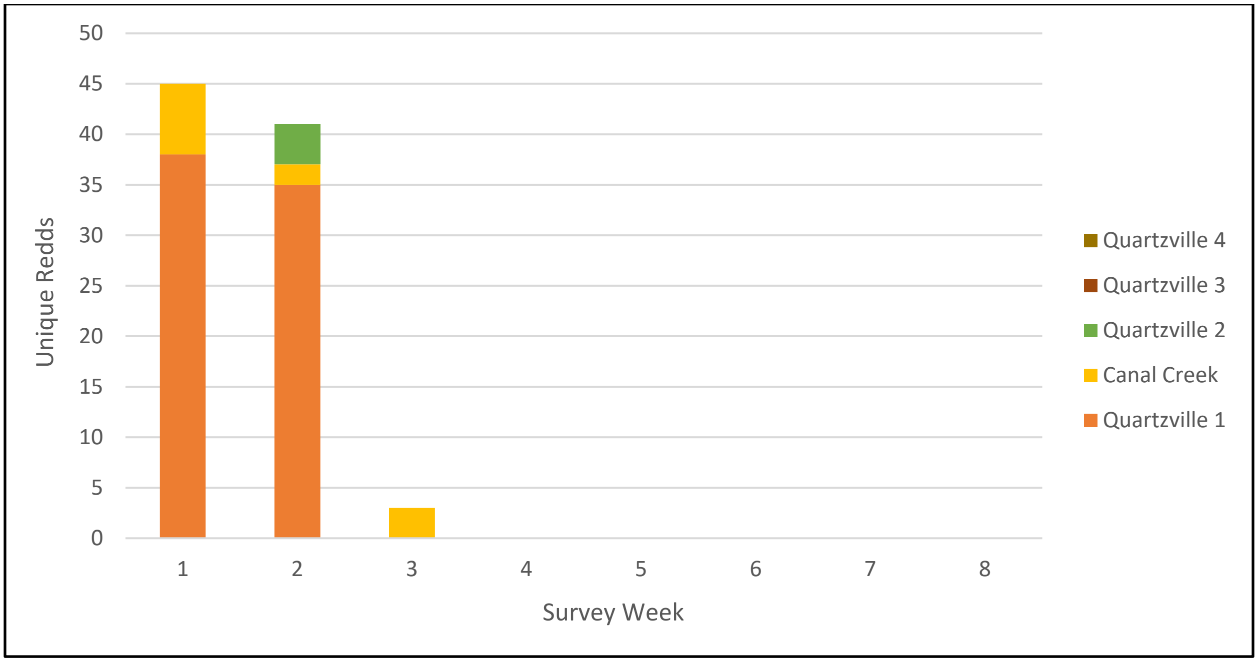


Figure 5. Illustrates unique redds observed by survey week over the duration of the spawning surveys.

Peak redd counts for all reaches were observed during survey week 2 (October 1, 2023–October 7, 2023), approximately four to ten days after the 200 outplanted adults were released at the Miner's Camp site (Figure 6). Redd construction began in survey week 1 (September 24, 2023–September 30, 2023) peaked during survey week 2, as stated above, and were completed by survey week 3 (October 8, 2023–October 14, 2023) (Figure 6).

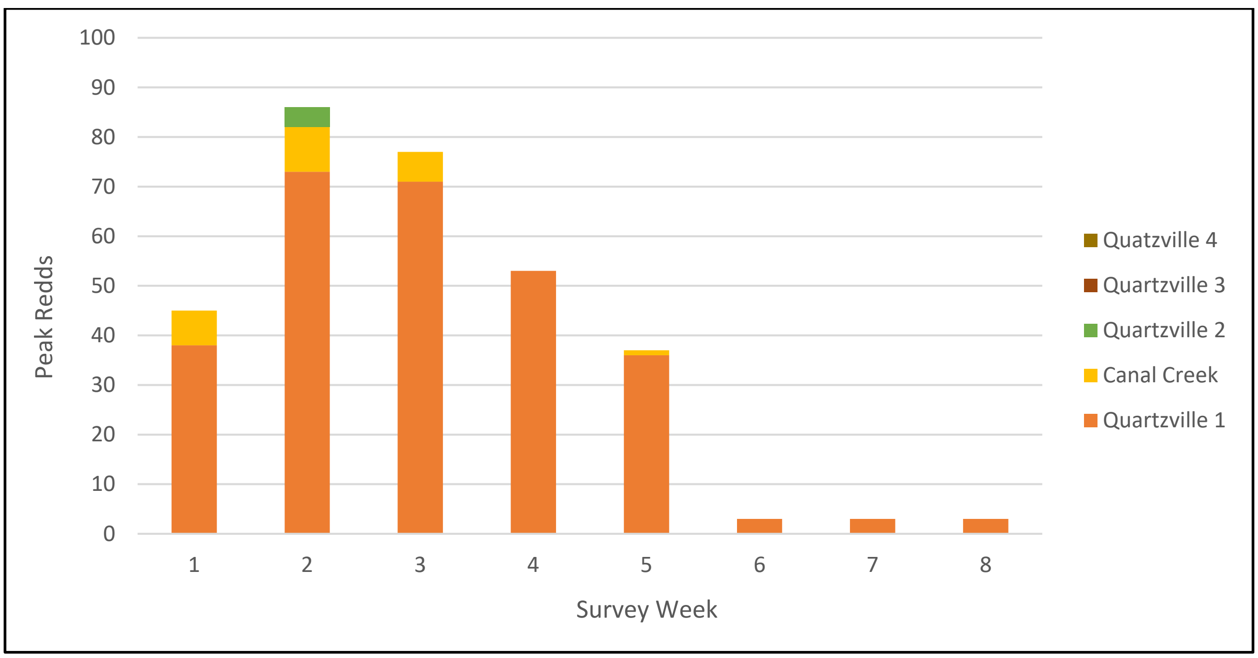


Figure 6. Illustrates peak redds observed during each survey week over the duration of the project. Peak redds occurred during survey week 2.

Test redds were observed while surveying exploratory reaches of Quartzville Creek, in addition to the predefined survey areas. These coordinates were recorded for use in future studies. Throughout the spawning surveys, EAS survey crews noticed that a portion of the discovered redds were washed out or were no longer visible. By survey week three (October 8, 2023–October 14, 2023), two redds in the Quartzville 1 reach and three redds in Canal Creek were no longer visible. Additionally, by survey week 4 (October 15, 2023–October 21, 2023), there were 18 further redds no longer visible within the Quartzville 1 reach. At the completion of survey week 6 (October 29, 2023–November 4, 2023), 86 unique redds (96.6% of total observed unique redds) had been washed out or were no longer visible to EAS survey crews.

Spawning quality, the timeline of outplanting adult fish, and relative river conditions all impact the success of redds in the system. Additional factors that could influence EAS redd counts include redd duration, survey timing, frequency of redd counts, spawning timing and river conditions affecting flow and visibility.

In 2022, 200 hatchery Chinook salmon adults were released on September 8, approximately 18 days earlier than the release in 2023 (September 26, 2023). Whereas 2022 surveys did not observe any redd formation until survey week 2, and only 3 redds were recorded in Canal Creek, EAS personnel had observed 45 redds in survey week 1, 38 in Quartzville 1 reach and seven within Canal Creek. This could indicate that the hatchery-reared Chinook females were ripe upon release in September 2023 when compared to 2022 outplanting. Additionally, observing 82.0% of total redds in the Quartzville 1 reach could indicate that female Chinook salmon were ready upon outplanting, or even past their peak spawning window and did not have the energy to explore areas further away from Miner's Camp or to find additional, potentially more suitable habitat.

In addition to different release dates between 2022 and 2023, the stark difference in water quality between the two surveys is worth noting. In 2022, peak flow discharge was recorded as 70 cfs midway through the CFS survey and remained between 25-40 cfs for the majority of other survey weeks. In 2023, adult Chinook salmon experienced a peak flow discharge of 3,150 cfs during survey week 7 (resulting in unsafe conditions for surveys to be undertaken), and additional smaller peaks of 2,500 cfs (November 6, 2023), 1,480 cfs (November 11, 2023), and 764 cfs (November 2, 2023).

Availability of suitable spawning habitat plays a large role in redd distribution. However, Chinook salmon released in Quartzville Creek were ready to spawn and began searching for suitable habitat immediately upon their outplanting. Figure 7 illustrates that the majority of redds was dispersed upstream of Miner's Camp in the Quartzville 1 reach. Quartzville 1 has adequate spawning habitat, but it was also the habitat that would have been discovered immediately upstream of the drop site. Several redds were discovered in Canal Creek but were located only at the very beginning and very end of that reach, respectively. The middle section of Canal Creek predominantly consists of deep pools and bedrock, with very little spawning gravel and minor suitable flow.

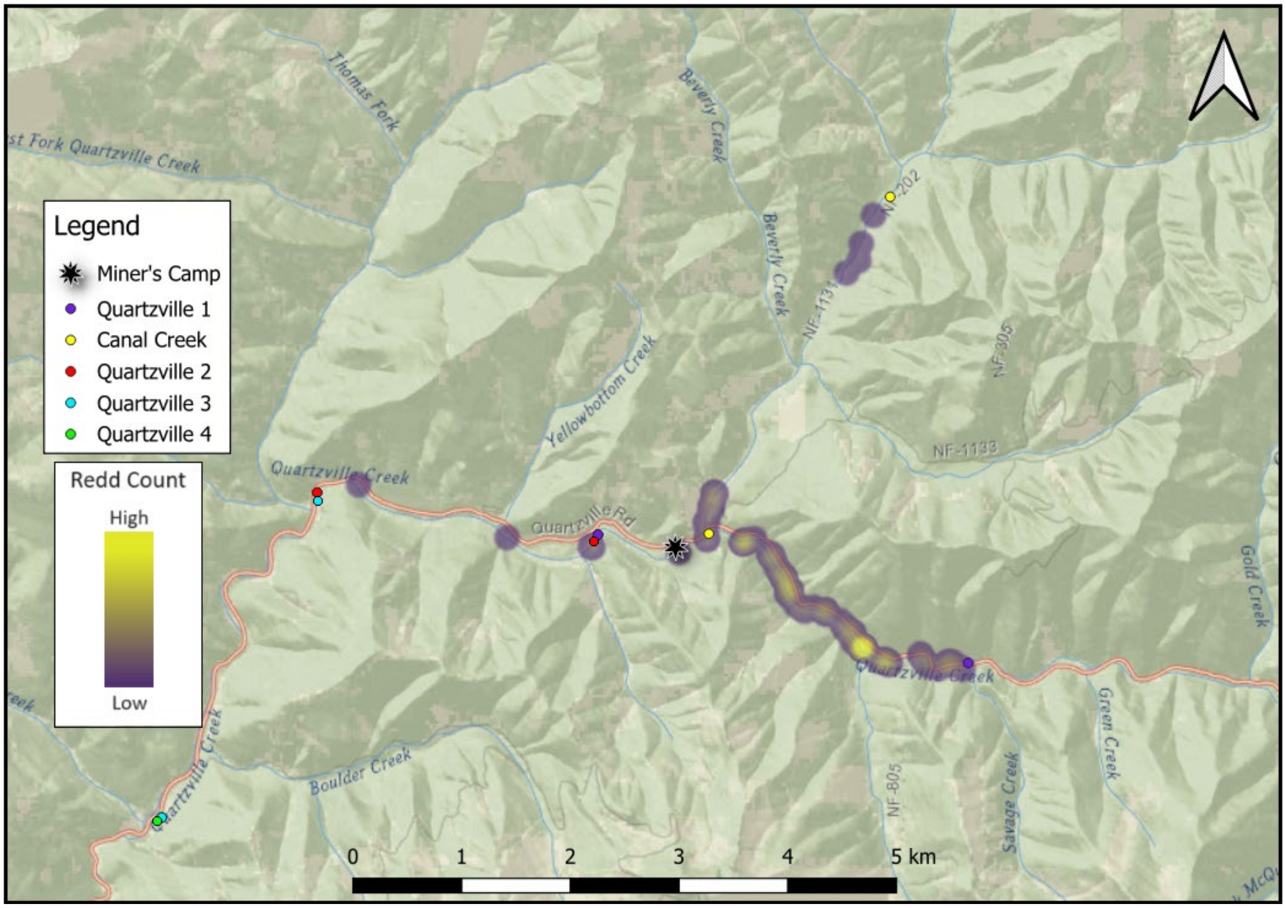


Figure 7. Illustrates a heat density map detailing the distribution of redds within the Quartzville 1, Canal Creek, and Quartzville 2 reaches. Miner's Camp is denoted with an asterisk.

Monitoring Coarse Bed Sediment Transport and Aquatic Macroinvertebrate Communities to Inform the Sustainable Rivers Program

James White[1], Christina Murphy[2], Max Schwid[1], Mackenzie Keith[1], Rose Wallick[1]
[1]U.S. Geological Survey, Oregon Water Science Center
[2]U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit
jameswhite@usgs.gov

The Sustainable Rivers Program (SRP) is a partnership between the U.S. Army Corps of Engineers (USACE) and The Nature Conservancy to adaptively modify operations at USACE dams with the goal of enhancing habitat conditions for the plants and animals that depend on river flows downstream of USACE dams. The Willamette SRP began in 2007 through a series of stakeholder-driven environmental flow workshops, which culminated in a series of environmental flow recommendations for Willamette tributaries downstream of USACE projects. To inform the adaptive management cycle, USGS has developed and implemented a monitoring program to examine (a) flows required to mobilize and transport coarse bed sediment and (b) how sediment mobilization affects ecological indicators, specifically aquatic macroinvertebrate populations.

In gravel-bed rivers, such as those downstream of USACE Willamette Valley Project dams, coarse bed sediment is the architect of channel form and plays an important role in riverine thermal, ecological, and biogeochemical processes. Of the 63 Willamette River Basin SRP flow recommendations that were identified by stakeholders, 33 relate to bed sediment mobilization to achieve various ecological outcomes. However, due to a dearth of data in the Willamette Basin, these flow targets were developed primarily based on expert judgement and theoretical relations between relative flows and bedload transport. Subsequently, the SRP monitoring framework report recommended additional monitoring and modeling to refine flow targets. To address this data gap, USGS has developed and deployed four passive acoustic monitors (hydrophones) to identify flow thresholds for coarse bed sediment mobilization on two Willamette River tributaries—the North Santiam and McKenzie Rivers—and conducted bedload sampling to determine transport magnitudes associated with a range of flows.

Bedload distribution and transport is thought to key driver of aquatic macroinvertebrate assemblages. To explore this relation, USGS also developed a macroinvertebrate monitoring program that was implemented across seven locations in 2022 and two additional locations in 2023. Data collected during this effort are being used to examine patterns of invertebrate communities and biomass relating to flow and sediment characteristics, to parameterize flow response models, and to provide baseline data to assess future change. Preliminary results from macroinvertebrate monitoring highlight (a) the importance of bed sediment in structuring invertebrate communities, (b) the potential mismatch in current SRP flow targets related to bedload transport, (c) the importance of continued monitoring to refine SRP flow targets on the Santiam, McKenzie and Middle Fork Willamette Rivers, and (d) broader benefits of macroinvertebrate monitoring, such as detection of potential assemblage changes resulting from identified aquatic invasive species.

EVALUATING SPRING CHINOOK SALMON RELEASES ABOVE FOSTER DAM ON THE SOUTH SANTIAM RIVER, USING GENETIC PARENTAGE ANALYSIS

Kathleen G. O'Malley[1], Cristín K. Fitzpatrick[1], Kevin C. Olsen[1], Ryan Couture[2]
[1]State Fisheries Genomics Lab, Coastal Oregon Marine Experiment Station, Department of Fisheries, Wildlife and Conservation Sciences, Oregon State University, Newport, Oregon
[2]Oregon Department of Fish and Wildlife, Corvallis, Oregon
kathleen.omalley@oregonstate.edu

On the South Santiam River in Oregon, access to ~85% of historical spawning habitat for spring Chinook salmon (*Oncorhynchus tshawytscha*) is impeded by two dams; Foster and Green Peter. Outplanting of hatchery-origin (HOR; adipose fin removed) salmon and trap-and-transport operations for natural-origin (NOR; adipose fin intact) salmon have been implemented to facilitate dispersal above Foster Dam. Previous research has used genetic parentage analysis to evaluate the contribution of spring Chinook salmon released above Foster Dam to subsequent adult salmon recruitment to the river (O'Malley *et al.* 2014; O'Malley *et al.* 2015, O'Malley *et al.* 2017). Here, we extend the genetic parentage analysis by assigning the 2016 – 2020 adult salmon returns to salmon sampled above or below Foster Dam in 2011 – 2017.

We found that assignment rates of returning adult Chinook salmon in 2016 – 2020 ranged from 43% (2018) to 73% (2017). When samples from the 2015 and 2016 South Santiam Hatchery Chinook salmon broodstock were excluded from the analysis, assignment rates for the 2019 adult returns decreased from 64% to 44% while assignment rates for the 2020 adult returns decreased from 68% to 47%. Overall, our assignment results indicate that up to 31% of the adult salmon sampled within a year may be unmarked (adipose fin intact) HOR salmon. The inferred age structure based on our genetic parentage analysis results indicates that most adult offspring are age-4 with interannual fluctuations in the proportions of age-3 and age-5 salmon.

Above Foster Dam in 2011 – 2015, about 9% of Chinook salmon, on average, produced at least one adult offspring each year that was identified through genetic parentage analysis. Notably, in 2014, only 4% of salmon produced adult offspring that were detected through genetic parentage analysis. Mean female TLF was greater than mean male TLF in all years except 2014 when they were nearly equal. We found that *sex* and *release day* had a significant interactive effect on TLF. In both sexes, TLF increased with later release days, but this association was markedly stronger for females.

CRR_{total} was less than one in all years from 2011 – 2015, indicating that the population above Foster Dam is not replacing itself. The maximum CRR_{total} (0.16) was observed in 2013, and minimum CRR_{total} (0.04) was observed in 2014. Furthermore, the effective number of breeders (N_b) has continued to decline since genetic monitoring of the reintroduction program began in 2007. Notably, in 2014, N_b dropped to 7.0, revealing low genetic diversity in the reintroduced population and potentially decreased ability to adapt to future environmental changes. Continued declines in genetic diversity threaten the stability and potential for adaptation to environmental change in the reintroduced population above Foster Dam.

It has been noted that the Foster Trap experienced poor adult collection rates, possibly attributed to the water temperatures in the ladder. As a result, more NOR adult offspring could have returned to the South Santiam River but were not sampled at the Foster Trap, and subsequently spawned downstream of Foster Dam. However, information and data on spawning activity below Foster Dam is limited. Given that modifications to the Foster Trap were tested in September 2019 and initiated in June 2020, it will be important to extend this genetic parentage analysis to determine if, in fact, estimates of TLF and CRR increase in subsequent years because of improved adult collection at the trap.

Reference

O'Malley, K.G., Fitzpatrick, C.K., Olsen, K.C., Couture, R. (2024) Evaluating spring Chinook salmon releases above Foster Dam on the South Santiam River, using genetic parentage analysis. U.S. Army Corps of Engineers.

LINKING MODELS AND THEIR USERS: ENHANCING ACCESSIBILITY OF THE fbwR DAM PASSAGE MODEL THROUGH AN R SHINY APP

Mairin Deith, Tom Porteus, Aaron Greenberg, Roberto Licandeo, Murdoch McAllister
Institute for the Oceans and Fisheries,
University of British Columbia, Vancouver, BC, Canada
m.deith@oceans.ubc.ca

Scientific simulation models often play a role in informing decision-making processes in natural sciences, but the adoption of models may be hindered by their technical complexity. For example, the Fish Benefits Workbook (FBW) is a simulation model that assesses the dam passage survival and passage effectiveness of spring Chinook steelhead (*Oncorhynchus tshawytscha*) and winter steelhead (*O. mykiss*) juvenile migrants under different dam management alternatives in the Upper Willamette Basin. Despite its potential usefulness to the many scientists, managers, and others working to improve dam passage in the region, FBW's usability is limited by its accessibility—the model can only be parameterized and run using large, technically demanding Excel workbooks or, more recently, by using the R language and fbwR library. To improve the ease of access and use of the fbwR simulation model, we are developing new tools and extensions to the software, including a new interface to FBW: an interactive web-based Shiny application.

Currently in its final stages of development, the fbwR Shiny app is designed to link scientific simulation models and potential model users. We seek to improve the accessibility of FBW's methods by providing an interactive, intuitive, informative, and user-friendly way to interface with the fbwR modelling software, allowing for more seamless interaction between model users and the dam passage simulation model. By incorporating information boxes, interactive elements, dynamic visualizations, and real-time feedback to the app user, the Shiny app not only facilitates more accessible understanding of the FBW model but also offers to facilitate dam passage analyses in real time. Interactive app elements and reactive visuals highlight potential errors before running the model, improving user experience, and limiting the amount of time needed to debug and understand model errors. For example, the app warns users when entered parameters fall outside of expected ranges (e.g., if survival rates are entered to be greater than 100%, or if minimum values are greater than maximum ones). The app also automatically creates plots when they are filled out (particularly useful for visualizing complex parameter inputs like dam passage efficiency which interact with other input parameters; see Figure 1 for an example).

In this talk, we will highlight the key features of the fbwR Shiny app, including:

1. **A user-friendly interface:** A simple, informative, and intuitive interface that enables practitioners to input parameters, run simulations, and visualize results in rapid time. When the app is in full production, it will be available to anyone via an internet browser-based webpage for online use, or the app can be downloaded and used offline on a personal computer.
2. **Immediate data validation to reduce debugging time:** The app guides users through the process of uploading or manually filling in the many parameters required for the model, improving clarity of inputs and how they interact. It then automatically checks

those parameters, validating values and ensuring that no required values are missing and that no values are outside of expected ranges.

3. **Interactivity and real-time feedback:** The app allows practitioners to explore the impact of various inputs and scenarios dynamically, which can be useful in workshop settings. The app allows users to save parameters, upload previously saved files, and tweak parameters between sessions for rapid evaluation of alternative management options. It also allows users to create and customize fbwR graphical results on-the-fly.
4. **Customization and scalability:** The flexibility of the R Shiny framework makes further development of the app easy, opening future potential to update the software according to new dam passage evaluation scenarios. It also improves our ability to visualize and adapt the FBW modelling framework as development of the fbwR library continues.

By presenting this Shiny app, we aim to demonstrate how more informed and efficient on-the-ground evaluations of management options can be achieved by making simulation software more accessible and user-friendly. We also seek to gather feedback from potential users, Shiny experts, technical experts, and other interested attendees on how we can improve the application in the future. The user-friendly interface and interactive features of the app are poised to enhance accessibility and usability, better leveraging the full potential of scientific simulation models, and improving our ability to continue developing the FBW model.

What fish passage structure should be used to calculate DPE?

Fish surface collector (FSC)

Minimum pool elevation (feet) where fish passage structure is accessible	**Maximum pool elevation (feet) where fish passage structure is accessible**
1450	

Fish can only access the FPS when the reservoir pool is between the minimum and maximum elevation.

Pool elevation (feet)	Elevation description	Baseline DPE	FSS DPE	FSC DPE	Weir DPE
1340	Upper RO	0.77	0.69	0.77	0.80
1375	25' over top of RO	0.77	0.69	0.27	0.80
1415	40' over top of RO	0.30	0.69	0.04	0.80
1425	Min power	0.77	0.69	0.77	0.80
1450	Min cons.	0.27	0.69	0.85	0.80
1500		0.04	0.69	0.85	0.80
1540		0.03	0.69	0.85	0.80
1541	Spillway crest	0.77	0.69	0.85	0.80
1574	Max pool	0.77	0.69	0.85	0.80

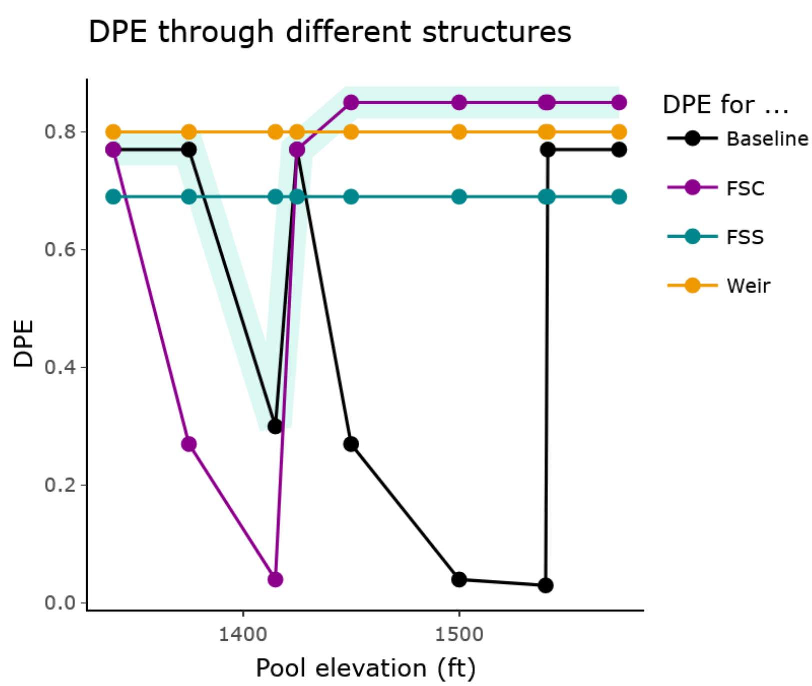


Figure 1. Example of reactive graphics in the fbwR Shiny app, showing the link between user inputs and informative graphics. The top panel shows how model users can input information that influences how dam passage efficiency (DPE) is calculated. To calculate DPE, fbwR requires information about dam passage rates through several types of fish passage structures at different pool elevations. In the Shiny

app, users select what type of fish passage structure to use in DPE calculations (one of baseline, where there is no structure; floating screen structures (FSSs); floating surface collectors (FSCs); or weirs), provide the minimum and maximum pool elevations where the passage structure is accessible, and fill in a table of DPE-by-elevation under different structural options (baseline, and each fish passage structure). The bottom panel shows a plot of the DPE-elevation relationship for each structural option that is automatically updated as the user fills in the DPE table. Blue highlighting in both the table and linked plot indicates the realized DPE-elevation relationship that will be applied in the fbwR model runs. Baseline DPE is used where no structure is present or when the structure is inaccessible to fish (e.g., when pool elevation is less than 1450 feet); otherwise, DPE through the selected fish passage structure is used.

DETECTING SALMON POPULATION RESPONSES TO CHANGES IN DAM PASSAGE IN THE UPPER WILLAMETTE RIVER: HOW MIGHT CANDIDATE MONITORING METRICS AT DIFFERENT LIFE STAGES PERFORM?

Murdoch McAllister, Mairin Deith, Tom Porteus, Roberto Licandeo, Aaron Greenberg, Eric Parkinson
University of British Columbia, Vancouver, B.C. Canada
m.mcallister@oceans.ubc.ca

The ESA listing of winter steelhead (*Onchorhynchus mykiss*) and spring chinook salmon (*O. tshawytscha*) in the Upper Willamette River (UWR) has led to requirements to improve dam passage for downstream migrating juvenile salmonids at US Army Corps projects in the basin. With the implementation of new dam passage measures (DPMs), the Corps has been preparing to monitor salmon population responses for evaluation of their effectiveness within an adaptive management framework. Performance metrics that have previously been identified include passage rates, injury rates and survival rates. The metrics adopted for monitoring should give accurate and precise feedback on implemented measures. It is common to select metrics that will meet a desired level of precision considering the sampling error variance of the monitoring methods (e.g., Skalski 2016). Given that responses could vary between years due to changes in flow and other conditions, interannual variability is also an important design consideration for identifying realistic timelines for assessing population responses. I am going to focus on the following: Firstly, I will contrast two categories of population responses (1) survival rates at particular life stages, and (2) composite population response that may span more than one life stage such as the cohort replacement rate. Secondly, how might candidate monitoring metrics perform in assessing these population responses?

Performance of metrics that monitor dam passage survival rates

Dam passage measures, e.g., increased spring surface spill and structural passage devices, are designed to improve both passage efficiency (DPE) and dam passage survival (DPS) rates of downstream migrating juvenile salmonids. The Fish Benefits Workbook (FBW) makes predictions about the DPE and DPS accounting for fish species, life history type, pool level, passage routes, etc. under alternative DPMs. While improvements to DPE and DPS could be quite substantial under the new measures, it is expected that both will be quite variable between years based on interannual variation in conditions for passage, e.g., cumulative precipitation and flow conditions (Figures 1 and 2). Monitoring DPE and DPS offers to provide critical information and merits prioritization, since it provides an initial proof of concept for the dam passage measure. If DPS were found not to improve, this may require a change to some alternative dam passage measure. On the other hand, should dam passage survival be found to have improved there could yet be other components that have not improved and have worsened, e.g., pre-spawn mortality, (PSM).

Figure 1. Density histograms of DPE and DPS for spring Chinook salmon of different migrant types passing through the Detroit Dam under spring spill at Detroit and Big Cliff and fall drawdown at Detroit with the variability resulting from different flow conditions and reservoir pool levels between years.

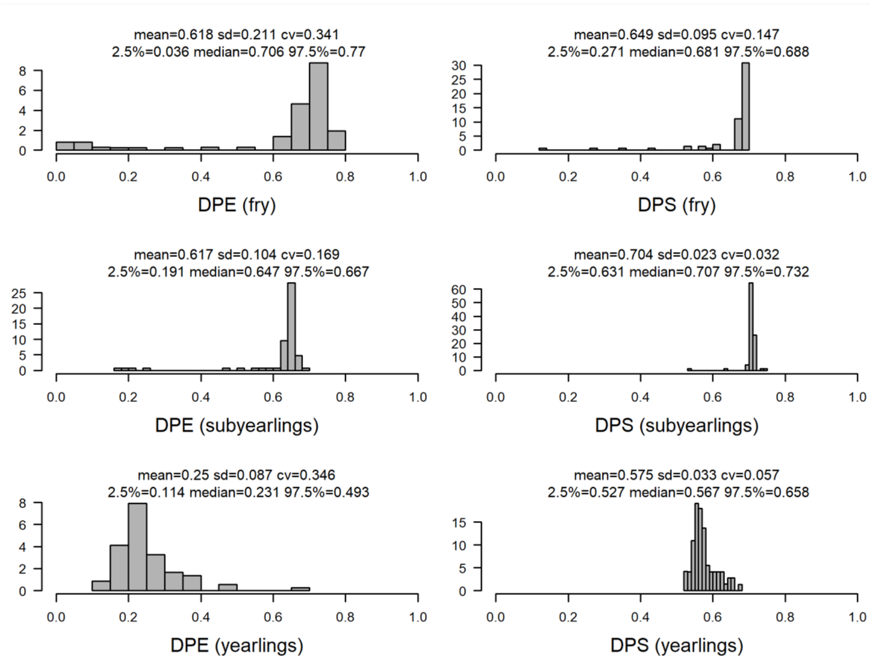
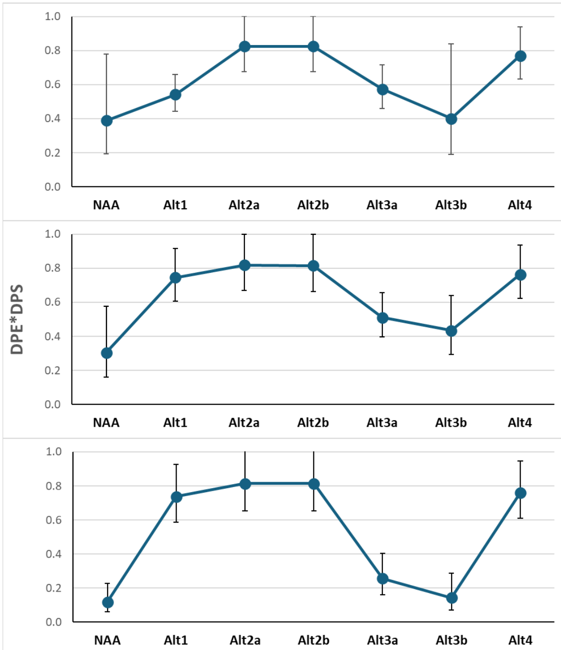


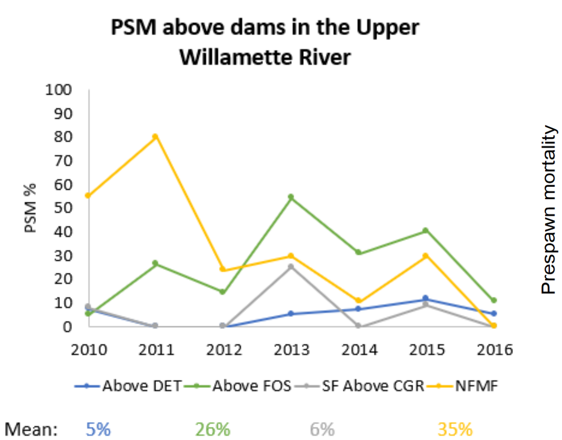
Figure 2. Average and 95% bounds with one year of monitoring of DPE*DPS for spring Chinook salmon fry, subyearling, and yearling migrants at Detroit Dam based on FBW runs in the draft EIS and assuming a coefficient of variation of 10% in estimation error from field sampling data.

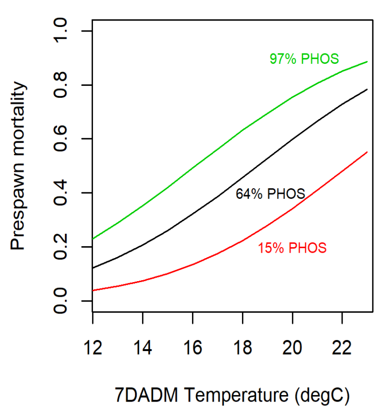


Monitoring metrics for population responses at other life history stages

Due to net changes to pool levels in the reservoirs and spill associated with new dam passage measures it is widely understood that there could be associated changes in (1) juvenile salmonid mortality rates from changes in predation and parasitism rates in reservoirs and changes in TDG below dams, (2) marine survival rates associated with changes to growth rates of salmon parr in reservoirs and thus mean body size of smolts, and (3) pre-spawn mortality (PSM) rates of upstream migrating adults associated with changing river temperatures (Figure 3).

Figure 3. Left panel: Estimates of PSM for adult Chinook salmon above the Detroit (DET), Foster (FOS), Cougar (CGR) and Lookout Point Reservoirs (NFMF) 2010-2016. Middle panel: Bowerman et al. (2018) predictions of PSM in the UWR based on seven-day average maximum daily river temperature (7DADM) and the proportion of hatchery origin spawners (PHOS). Right panel: 7DADM temperature under different flow year conditions and different passage measures.





		Maximum 7DADM temperature (°C): 1 May - 2 Aug	
Measure	Flow year	North Santiam (below Big Cliff)	South Santiam (below Foster)
No Action	High	18.7	19.5
	Normal	19.3	20.8
	Low	23.5	23.5
Structural	High	19.9	21.3
	Normal	22.1	23.5
	Low	22.5	24
Spring Spill + Fall Drawdown	High	19.2	19.7
	Normal	21.4	22.9
	Low	21	22.3
Spring Drawdown + Fall Drawdown	High	18.6	17.8
	Normal	24.5	24
	Low	25.8	25.3

Source: Cannon et al. 2011; Sharpe et al. 2013, 2014, 2015, 2016, 2017

These responses could trade-off against each other, and thereby create challenges for assessing the life cycle-wide responses to alternative DPMs, especially when focus has been put on monitoring metrics focused on relatively few life stages.

The life cycle models (LCMs) that have been developed to evaluate dam passage measures for the EIS can provide a useful framework for evaluating the monitoring requirements to test for improvements in dam passage survival in the face of uncontrolled noise. For example, the cumulative effects of passage operations on juveniles and temperature exposure effects on PSM are accounted for in the LCMs. We have considered a number of performance metrics to evaluate population responses to alternative DPMs, including fry-to-smolt survival rate, smolt-to-adult survival rate (SAR), Number of Recruits per Spawner (R/S), and long-term average abundance of natural origin spawners. LCM modeling has shown that the responses to a new DPM at different life stages in combination may determine both the short-term and long-term population responses (Figures 4 and 5).

Figure 4. Natural origin spawner abundance of wild spring Chinook salmon returning to the Minto Dam simulated using life cycle modeling under (1) no change to dam passage with only outplanting of hatchery-origin Chinook salmon above Detroit, (2) spring and autumn draw downs, and (3) a floating screen structure.

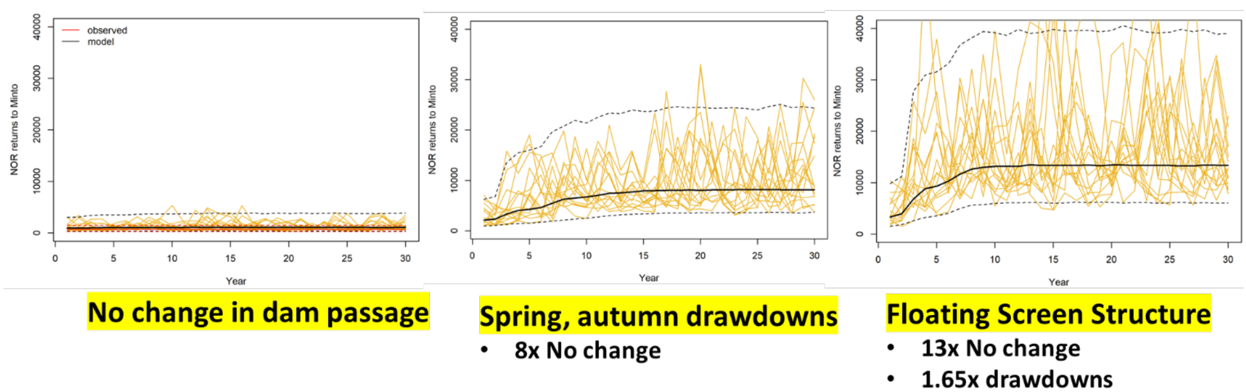
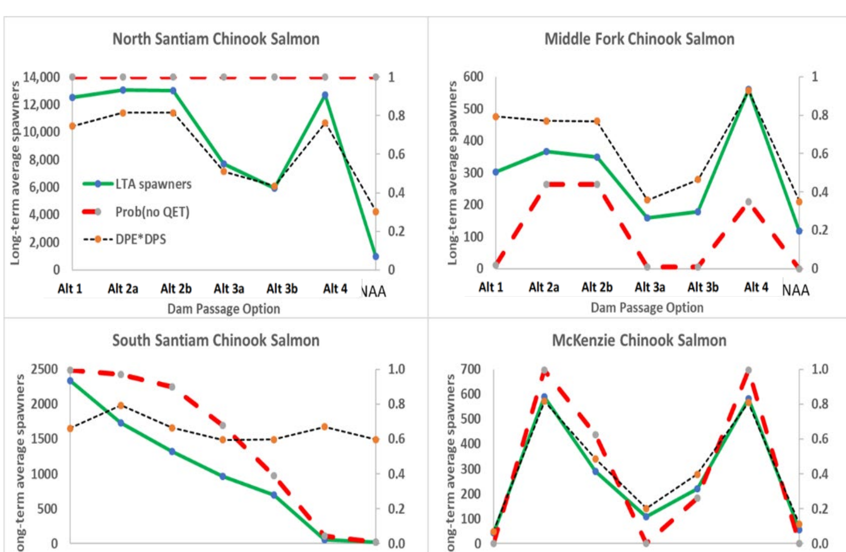


Figure 5. The product of DPE and DPS and long-term average natural origin spawner abundance and probability of no quasi extinction of spring Chinook salmon returning to the Minto Dam simulated using life cycle modeling under seven alternative dam passage measures from the EIS.



A question arising is which population metrics could be considered to be appropriate measures of a life cycle response? Different candidate metrics are available each with their own trade-offs, e.g., in terms of information content versus uncontrolled for noise. The pedigree cohort replacement rate (CRRpg) uses genetic samples taken from populations of spawners in each year and based on pedigree analysis of the resulting offspring that spawn in future years. It can only be accurately measured when all adults from a brood year have returned (Figure 6). An alternative measure of CRR could be to use annual measures of the number of recruits per spawner associated with each brood year, which would require an accurate count of the number of natural origin spawners in each year (Figure 7). The age composition of spawners associated with each historical brood year would need to be measured. Annual recruits per spawner data such as these are commonly compiled for stock-recruit analysis. Life cycle modeling can be applied to simulate how these measures of CRRpg and CRR using R/S and could be expected to vary over years before and after implementing a new dam passage measure.

Figure 6. The pedigree cohort replacement rate (CRRpg) for the above Cougar dam population of spring Chinook salmon both simulated over years going from the no action alternative (NAA) to a long-term measure (i.e., EIS Alternative 5). This accounts for six juvenile life history types and the two dominant spawner ages, i.e., ages 4 and 5. Five stochastic simulated runs are shown by different colored trajectories; the black line shows the median outcome over 1000 model runs.

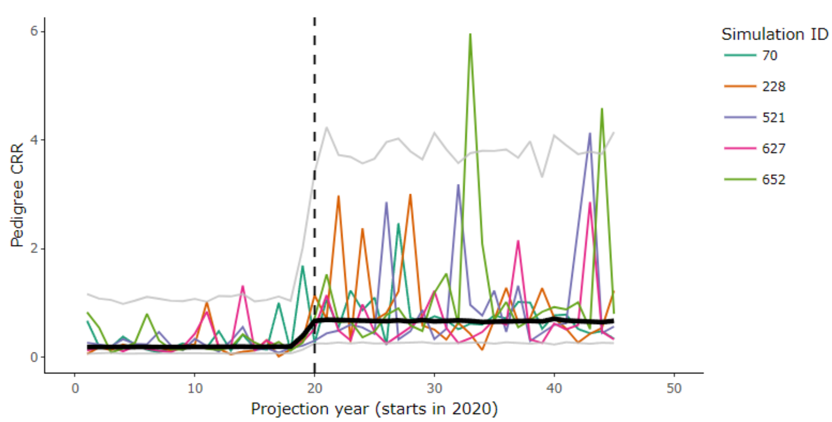
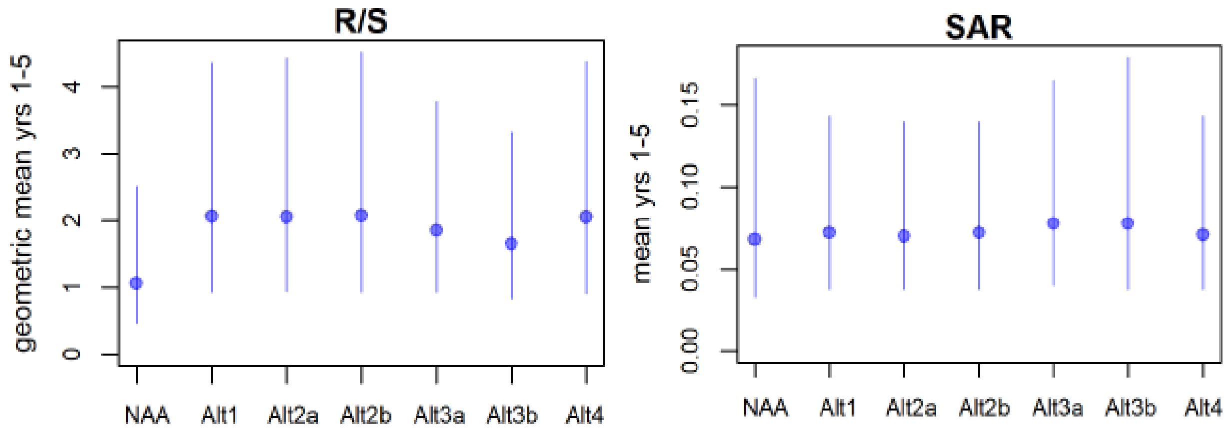


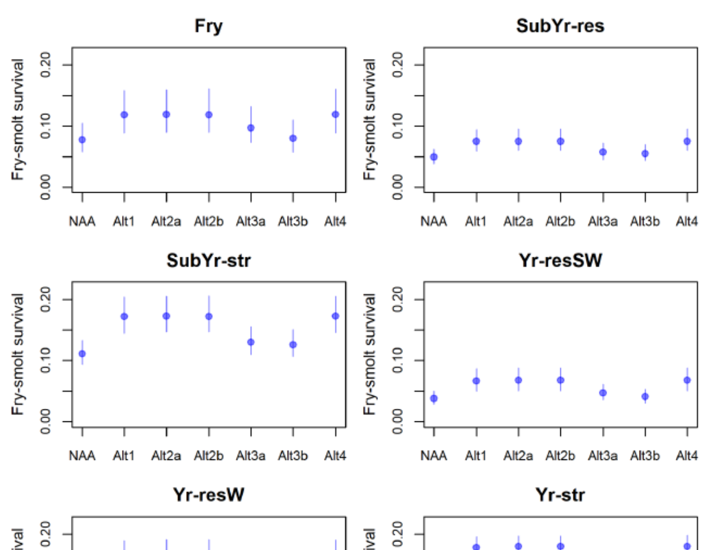
Figure 7. Average and 95% bounds over the first five-years following changes to dam passage of a measure of CRR from numbers of spawning recruits per spawner (R/S) left panel and smolt to adult survival rate (SAR) from life cycle modeling under seven dam passage options evaluated in the recent EIS (right panel) for spring Chinook salmon in the North Santiam sub-basin.



Conventional metrics for CRR might not perform well for assessing responses to DPMs for the following reasons. They would take a minimum of five years to compile before they could provide information. Interannual variability in both metrics for CRR is very high. A major source of variance is interannual variation in marine survival rates (Figure 7). The variability in conventional metrics for CRR is so high that it may be impossible to detect long-term average responses in these variables even after many years of monitoring. It is thus clear that traditional CRR metrics though containing full life cycle responses would have too much error variability to allow reliable assessment of responses to DPMs.

An example of an alternative performance metric that could potentially inform about the potential effectiveness of dam passage measures for improving the status of spring Chinook salmon and winter steelhead in the UWR could include a fry-smolt survival rate metric. Figure 8 shows the statistical behaviour of fry-smolt survival rates for spring Chinook salmon from LCM modeling on how mean and 95% probability intervals in fry-smolt survival can vary with DPM. Fry-smolt survival rate provides composite measure of full juvenile freshwater stage response. Mean values from 5 years appear to be moderately informative. Estimation error variance from, e.g., radio telemetry studies, needs to be considered also. For Chinook salmon, however, this would exclude the potential response in PSM in adults.

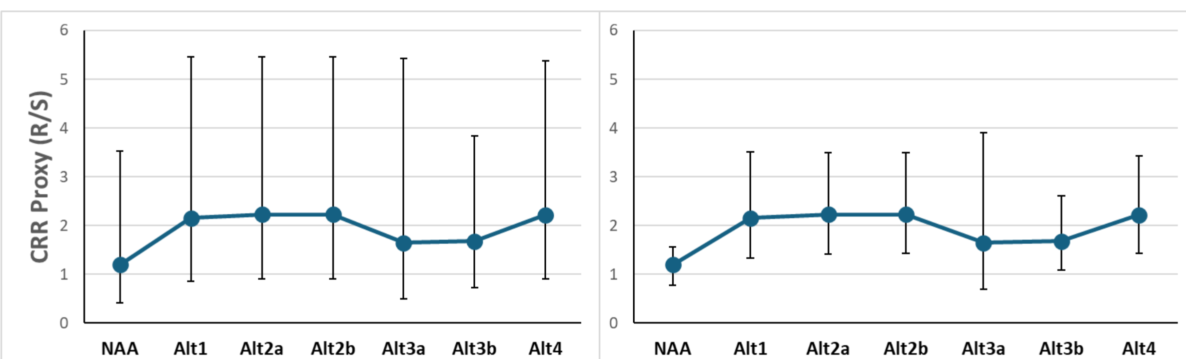
Figure 8. Average and 95% probability bounds over the first five-years for fry to smolt survival rates for wild spring Chinook salmon in the UWR for six juvenile migrant types under six alternative dam passage measures from life cycle modeling, ignoring measurement error.



A second example of a composite monitoring metric could be a CRR proxy (CRRp) that excluded the variable marine survival rate component. To eliminate the noise coming from variation in marine survival rates, we suggest here:

CRR Proxy: = LTA Fry Production * Fry-smolt survival * LTA marine survival * (1-PSM). This metric uses (i) a long – term -average (LTA) fry production estimate, (ii) annual measures of fry-to-smolt survival rate, e.g., from radio telemetry, (iii) annual measures of PSM from, e.g., carcass surveys, and (iv) a long-term average (LTA) marine survival rate (instead of annually varying ones). This LTA marine survival used would assume a fixed and constant value for this parameter. It thereby eliminates the variability in estimated annual marine survival rates but may still need to account for smolt size effects on marine survival rates. This CRR proxy could be assembled from within – year data, to give an immediate CRRp by year and could be assembled for either all types or, to reduce monitoring costs, only the dominant juvenile life history type for the population. Figure 9 from LCM modeling shows how the mean and 95% bounds in CRRp could vary with DPM.

Figure 9. Median and 95% bounds for a CRR proxy using R/S when the SAR component is held constant. Level panel: Five-year average CRR based on R/S for spring Chinook salmon under seven dam passage options in the North Santiam, including variance from SAR. Right panel: Five-year average CRR proxy for spring Chinook salmon under seven dam passage options in the North Santiam, removing variance from SAR



The CRR Proxy using R/S excluding variability from marine survival provides a composite measure of fry-smolt freshwater stage + PSM response. A Proxy CRR of this could be taken from monitoring metrics taken within a single year, avoiding the need to wait 4-5 years to obtain a full response. Mean values taken from 5 years could be moderately informative. Estimation error variance from e.g. radio telemetry studies needs to be considered also.

Conclusions

Life cycle modeling can show how salmon population metrics could perform in providing feedback during adaptive management processes (i.e., informing how salmon populations may respond to dam passage measures). We have shown that interannual variability in monitoring metrics may be important to consider in the adoption and interpretation of monitoring metrics since there can be significant interannual changes in conditions that cause large interannual variation in the metrics. FBW modeling shows that moderate amounts of interannual variability in DPE and DPS can be expected especially under operational measures. Time frames of a few years may be required to establish effectiveness at anticipated levels of variability. More work is needed to characterize and quantify the sources of variability in estimation of dam passage survival rates and identify effective sampling schemes for measuring dam passage survival. Due to different directions and magnitudes of response at different life history stages, it may be appropriate to monitor and assess composite population responses to dam passage measures. A commonly available full life cycle composite measure is cohort replacement rate (CRR) which measures the ratio of spawning adult abundance to the abundance of their parents. Results from LCMs show that conventional measures of cohort replacement rate for spring Chinook salmon in the UWR will include too much interannual variability to make them useful to detect population responses to new dam passage measures. Large interannual variation in marine survival rates would make it difficult to use full life cycle measures such as CRRpg or CRR(R/S) to evaluate effectiveness of new DPMs. We have identified some composite performance metrics that could potentially inform about the overall effectiveness of dam passage measures for improving the status of spring Chinook salmon and winter steelhead in the UWR. These include measures of fry-to-smolt survival rates and CRR proxies that use a long-term average value for marine survival rate and offer to provide informative and timely measures of population responses.

References

Bowerman, T., Roumasset, A., Keefer, M.L., Sharpe, C.S., and Caudill, C.C. 2018. Prespawn Mortality of Female Chinook Salmon Increases with Water Temperature and Percent Hatchery Origin. Trans. Am. Fish. Soc. 147(1): 31–42. doi:https://doi.org/10.1002/tafs.10022.

Sharpe, C.S., Cannon, B., DeBow, B., Friesen, T.A., Hewlett, D., Olmsted, P., and Sinnott, M. 2015. Work Completed for Compliance with the 2008 Willamette Project Biological Opinion, USACE funding: 2013 hatchery baseline monitoring. Oregon Department of Fish and Wildlife, Corvallis, Oregon.

Sharpe, C.S., Cannon, B., DeBow, B., Friesen, T.A., Hewlett, D., Olmsted, P., and Sinnott, M. 2016. Work Completed for Compliance with the 2008 Willamette Project Biological Opinion,

USACE funding: 2014 hatchery baseline monitoring. Oregon Department of Fish and Wildlife, Corvallis, Oregon.
Sharpe, C.S., Cannon, B., DeBow, B., Friesen, T.A., Johnson, M., Olmsted, P., Schroeder, R.K., Tinus, C.A., and Whitman, L. 2013. Work Completed for Compliance with the 2008 Willamette Project Biological Opinion, USACE funding: 2011 hatchery baseline monitoring. Oregon Department of Fish and Wildlife, Corvallis, Oregon.
Sharpe, C.S., Cannon, B., Friesen, T.A., Hewlett, D., and Olmsted, P. 2014. Work Completed for Compliance with the 2008 Willamette Project Biological Opinion, USACE funding: 2012 hatchery baseline monitoring. Oregon Department of Fish and Wildlife, Corvallis, Oregon.
Sharpe, C.S., Mapes, R.L., Cannon, B., Olmsted, P., Sinnott, M., DeBow, B., Bailey, E., Hoblit, T., and Friesen, T.A. 2017. Abundance, Distribution, Diversity and Survival of Adult Spring Chinook Salmon in the Upper Willamette River: 2015 and 2016. Oregon Department of Fish and Wildlife.
Skalski, J.R. 2016. Review of Tagging Study Designs to Estimate Reservoir Passage Survival in the Willamette Valley Project. Report prepared by John R. Skalski, Columbia Basin Research, School of Aquatic and Fishery Sciences, University of Washington, Seattle WA for the U.S. Army Corps of Engineers Portland District, Portland, Oregon.

RECONSTRUCTION OF MARINE SURVIVAL IN WINTER STEELHEAD IN THE ABOVE DAM SOUTH SANTIAM SUB-BASIN

Aaron Greenberg, Mairin Deith, Tom Porteus, Roberto Licandeo, Murdoch McAllister
Institute for the Oceans and Fisheries,
University of British Columbia, Vancouver, BC, Canada
a.greenberg@oceans.ubc.ca

A life cycle model (LCM) for winter steelhead (*Oncorhynchus mykiss*) which included both virgin and repeat spawners was recently applied to evaluate the performance of alternative dam passage measures in the Foster Dam that were intended to improve dam passage survival for juvenile salmonids. Assumptions about the magnitude and variation in marine survival rates for winter steelhead in the above dam South Santiam sub-basin were found to impact assessed steelhead population responses to alternative dam passage options. We recently updated the Steelhead LCM to estimate the marine survival rates for winter steelhead from the South Santiam River tributary much earlier than previously, i.e., going back into the mid-1960s when the Foster Dam was built. The much longer time series of estimated time series is in itself interesting but also creates further questions about how to represent future marine survival rates based on the much longer historical time series of marine survival rate estimates. Using the updated LCM we re-evaluate the sensitivity of results on dam passage options to different sets of assumptions about fecundity and marine survival rates.

The talk will start by summarizing what is known about how marine survival has changed since the 1960s in nearby streams. It will show that over time the marine survival rate has declined from above .3 to well below .1 in nearby streams. This talk will review some previous analyses showing how dam passage survival and marine survival jointly determine some quantities of interest, such as recruits per spawner and spawner abundance.

A brief overview of two different variations of the LCM will be presented comparing a simple version to a version with some added realism. Then the model fits will be shown and the estimated marine survival series for both a short and long time series will be presented.

The importance of autocorrelation in marine survival will be discussed and best estimates of it will be presented. (See Figure below.)

Finally, a forward-looking simulation analysis will be presented to compare the two different variations of the LCM with respect to recruits per spawner and spawner abundance.

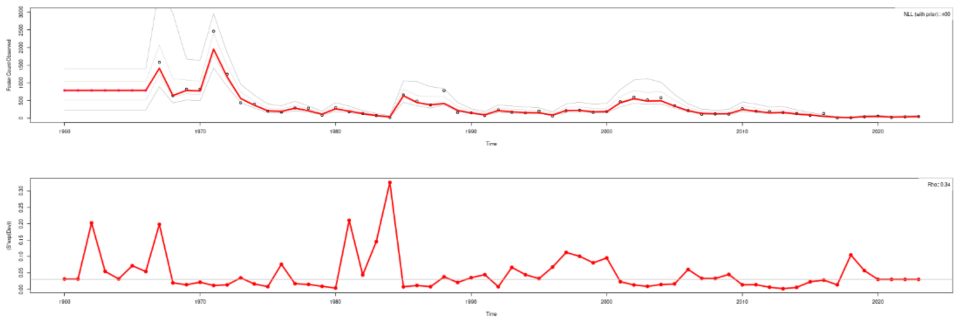


Figure The top panel shows the fit of the steelhead life cycle model to female wild spawner counts for the South Santiam subbasin extending from 1967-2023. The bottom panel shows the estimates of marine survival rates in red (left axis).