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WILLAMETTE VALLEY FISH PASSAGE MONITORING VIA ROTARY SCREW TRAPS, 2021

Final Report

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Applied Research in Fisheries, Restoration, and Ecology.

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Introduction

The U.S. Army Corps of Engineers' (USACE) management of the Willamette Valley Project (WVP) dams is a complex process and presents challenges in meeting competing demands such as instream flows, fish passage, and flood control. Dams as structures make upstream and downstream passage of fish difficult in any circumstance. Two anadromous fish in the WVP are listed under the Endangered Species Act (ESA), spring Chinook salmon, *Oncorhynchus tshawytscha* and steelhead, *Oncorhynchus mykiss* (NMFS, 2008). In 2008, the USACE, the U.S. Bureau of Reclamation, and the Bonneville Power Administration (BPA) (jointly known as the Action Agencies) consulted with the National Marine Fisheries Service (NMFS) to evaluate the impact of the WVP on the ESA-listed salmon and trout, which resulted in NMFS issuing the 2008 Willamette River Biological Opinion (BiOp; NMFS, 2008). In the BiOp, NMFS identified a Reasonable and Prudent Alternative (RPA) that set forth specific actions the Action Agencies could implement to satisfy their legal obligations under the ESA to "…avoid the likelihood of jeopardizing the continued existence of the ESA listed species or the destruction or adverse modification of their designated critical habitat (NMFS, 2008)."

Several RPA measures listed in the Willamette River BiOp relate to the downstream passage of UWR spring Chinook salmon and winter steelhead. They include RPA 4.8 (Interim Downstream Fish Passage through Reservoirs and Dams), 4.10 (Assess Downstream Juvenile Fish Passage through Reservoirs), 4.11 (Assess Downstream Juvenile Fish Passage through Dams), and 4.12 (Long-Term Fish Passage Solutions). Beginning in 2008 when the BiOp was drafted, the Action Agencies were required to start conducting downstream passage monitoring studies. Information about timing, size at migration, and production of spring Chinook salmon outmigrants from WVP reservoirs is essential to understanding whether passage at WVP dam sites is improving because of new infrastructure and operational changes. These fish monitoring efforts are designed to evaluate the effectiveness of the downstream passage measures in the RPA.

In 2018, the Action Agencies reinitiated ESA consultation with NMFS on the effects of the WVP to ESA-listed species and their critical habitat. In 2020, the USACE, BPA, and NMFS identified and agreed to implement a suite of interim measures, in addition to the measures in the RPA, to benefit ESA-listed salmonids in the Willamette until the reinitiated consultation is completed. Broadly, the interim measures were intended to improve water quality and downstream passage of juvenile salmonids. The following interim measures, as originally contemplated, are pertinent to this monitoring effort:

Interim measures 5-7 (Detroit and Big Cliff):

5) "The Corps will modify Detroit Dam operations during the drawdown when fish passage rates are high, as follows: Once the reservoir elevation is less than 100 feet over the turbine intakes (elevation 1500 feet to 1450 feet), typically around November 1 through February 1, turbines will not be operated at Detroit Dam between 6:00 AM - 10:00 AM and 6:00 PM - 10:00 PM except for station service power. The Corps will manage discharge from Detroit Dam to reduce TDG levels downstream of Big Cliff dam."
6) "The Corps will operate multiple spillway gates at Big Cliff Dam to spread total flow across the spillway and reduce TDG levels below Big Cliff Dam. The operation occurs when the Corps is operating the spillway (e.g., high flow events). The Corps will monitor TDG downstream and identify the extent that TDG criteria is met under this operation."
7) "When the Detroit Dam reservoir is above the spillway crest, the Corps will use a blend of spillway and turbine releases for summer water temperature management until the reservoir is

drawn down below spillway crest. Once the reservoir is below the spillway crest, the Corps will shift to turbine only releases until mid- to late October or until outflow water temperatures reach 50 degrees Fahrenheit. The Corps will utilize the upper RO in conjunction with turbine releases into November."

Interim measures 15-17 (Cougar):

15) "The Corps will employ a split gate operation at the temperature tower at Cougar Dam to minimize fish passage rates through the regulating outlet or penstocks when the pool is greater than 1570 feet and optimize fish passage efficiency when the pool is between 1570 feet and 1516 feet."
16) "The Corps will limit refill of Cougar Reservoir to 1600 feet beginning February 1 and operate to achieve a reservoir elevation of 1570 feet on or before September 1. Once the reservoir is below 1570 feet to January 1, regulating outlet and turbine operations would follow Special Operations Request (SOR) 2019 and 2020. The operation is subject to a determination on whether to implement Measure 16 or Measure 17."
17) "Delay refill of Cougar Reservoir to maintain a lower pool from February 1 to May 1 (depending on hydrology), where the lower pool levels would be determined in coordination with NMFS and informed by hydrologic modeling that balances fish passage performance, supplementing downstream flows, and water temperature operations. April 1 to June 15 regulating outlet and turbine operations would follow SOR 2019 and 2020. The Corps will model the operation to determine, in coordination with NMFS, whether the operation should replace Measure 16 for implementation (as the operations are not compatible)."

Interim measures 21 (Lookout Point):

21) "The Corps will refill Lookout Point Reservoir to 900 feet (if inflows allow) following the normal reservoir refill schedule in the water control diagram and then operate spillway gates to provide surface spill in the spring and summer as long as hydrologic conditions can support the operation, with a total discharge to meet downstream flow targets. During this same period, the Corps will conduct spill operations at Dexter Dam daily from 6:00 PM to 10:00 PM and limit turbine operations unless total discharge results in high TDG and there is a need to reduce spillway flows."

Interim measure 22 (Fall Creek):

22) "The Corps will operate trap(s) upstream of Fall Creek Reservoir to collect and transport juvenile spring Chinook salmon around the Reservoir and Fall Creek Dam during their migration season (approximately January to May), and the Corps will also consider installing fish guidance measures, such as resistance board weirs, to improve collection rates."

Additionally, in September 2021, the U.S. District Court for the District of Oregon issued an Interim Injunction Order directing the USACE to implement certain interim injunctive measures to improve fish passage and water quality at several WVP dam sites to benefit UWR spring Chinook salmon and winter steelhead. These interim injunctive measures replaced some of the prior interim measures and continued others. This study evaluated the biological effects of these measures that were implemented in fall 2021 on downstream passage of emigrating juvenile Chinook salmon (i.e., timing, size at migration, and natural production).

To understand the effects of these BiOp RPA, interim, and interim injunctive measures, rotary screw traps (RST) were used to monitor downstream outmigration of juvenile salmonids and other fishes. RST methods followed those from previous years (Keefer et al. 2012 and 2013; Romer et al. 2013-2017). The RSTs were operated in rivers downstream of Big Cliff, Lookout Point and Cougar dams and upstream of Fall Creek Reservoir. Specifically, RSTs were used to address six research objectives: 1) enumerate catch of out-migrating native juvenile Chinook salmon and other nontarget fish; 2) evaluate size and condition of juvenile spring Chinook salmon; 3) describe the out-migration timing patterns of naturally produced juvenile Chinook salmon leaving WVP reservoirs; 4) estimate out-migration abundance numbers at sites where trap efficiency estimates were sufficient; 5) collect juvenile Chinook salmon upstream of Fall Creek Reservoir and transport them below Fall Creek Dam; and 6) estimate out-migrating juvenile Chinook salmon mortality at our Cougar site utilizing a 24-hour post collection holding trial. These biological monitoring objectives were developed to evaluate the BiOp RPA measures, interim measures, and interim injunctive measures that relate to the evaluation of improvements for juvenile salmonid downstream passage and survival.

This report includes a summary and analysis of the field study completed by Cramer Fish Sciences (CFS) under contract with the U.S. Army Corps of Engineers through November 30, 2021, with a focus on addressing the impacts of the interim measures and interim injunctive measures on increasing downstream passage of juvenile salmonids.

Methods

Rotary Screw Traps

Rotary screw traps consist of a cone rotated by current from moving water, supported by two pontoons, with interior baffles to direct fish into a live box. The trap set up includes a cable tethered to a highline spanning across the river to two anchor points (e.g., trees), one on the left bank and one on the right bank. The tether allows for trap positional adjustments to account for changes in flow, and to move the trap to one side of the river if necessary. Traps were routinely accessed via wading or inflatable kayak. In some instances, it was necessary to pull the trap into shallow water on the side of the river to allow for safe access and sampling before being returned to the river thalweg for continued operation. To accomplish this, additional cable and pulley systems were installed for use at those sites (Big Cliff, Cougar Regulating Outlet). Rotary screw traps are manufactured by E.G. Solutions in Corvallis, Oregon. CFS acquired three new 2.4-meter traps from E.G. Solutions for this project. In addition to the new traps, CFS repaired and refurbished an additional five traps that the USACE had on hand. Trap repairs included debris doors, debris wheel assemblies, rivets, pontoons and cone screens, seals, and collar replacements.

Sampling Sites

A total of eight RSTs were deployed for juvenile Chinook salmon monitoring at four sites within the Willamette River drainage basin (**Figure 1**). Trapping location and duration were based on implementation periods associated with interim and interim injunctive measures and historical monitoring efforts (Romer et al. (2012-2017) and Keefer et al. (2012, 2013)).

- At Fall Creek, a single 2.4-meter RST was installed just downstream of Dolly Varden campground and operated continuously from March 10th to June 1st, 2021 (**Table 1**; Appendix A: **Figure A- 4**). *Note - A rotary screw trap was operated by the Corps Willamette Valley Project (WVP) staff in the Fall Creek Regulating Outlet (RO) channel during portions of the year with results reported separately.*
- Three 2.4-meter RSTs were operated below Lookout Point Dam, two in the powerhouse channel and one in the spill channel (Appendix A: **Figure A- 3**). The Lookout Point traps were monitored from March 15th to July 19th, 2021 when water temperatures increased and remained above permitted sampling levels.
- A total of three RSTs were operated below Cougar Dam, two 2.4-meter traps in the powerhouse channel and a single 1.5-meter trap in the regulating outlet channel (Appendix A: **Figure A- 2**). The traps installed at Cougar were monitored from March 24th to November 29th, 2021.
- A single 2.4-meter RST was installed below Big Cliff and was operated from May 23rd to November 29th, 2021 (Appendix A: **Figure A- 1**).

There were multiple days for each site where sampling stopped for various reasons including trap repairs, changes in dam operations, reaching temperature thresholds (>22°C), and presence of debris interfering with trap function (**Table 2**).

Table 1. Rotary screw trap installation dates and locations upstream or downstream of WVP reservoirs (2021).

Trap Location	Traps Deployed	Upstream/Downstream	Start of Sampling Period	End of Sampling Period
Fall Creek	1	Upstream	March 10	June 1
Lookout	3	Downstream	March 15	July 19
Cougar	3	Downstream	March 24	November 29
Big Cliff	1	Downstream	May 23	November 29

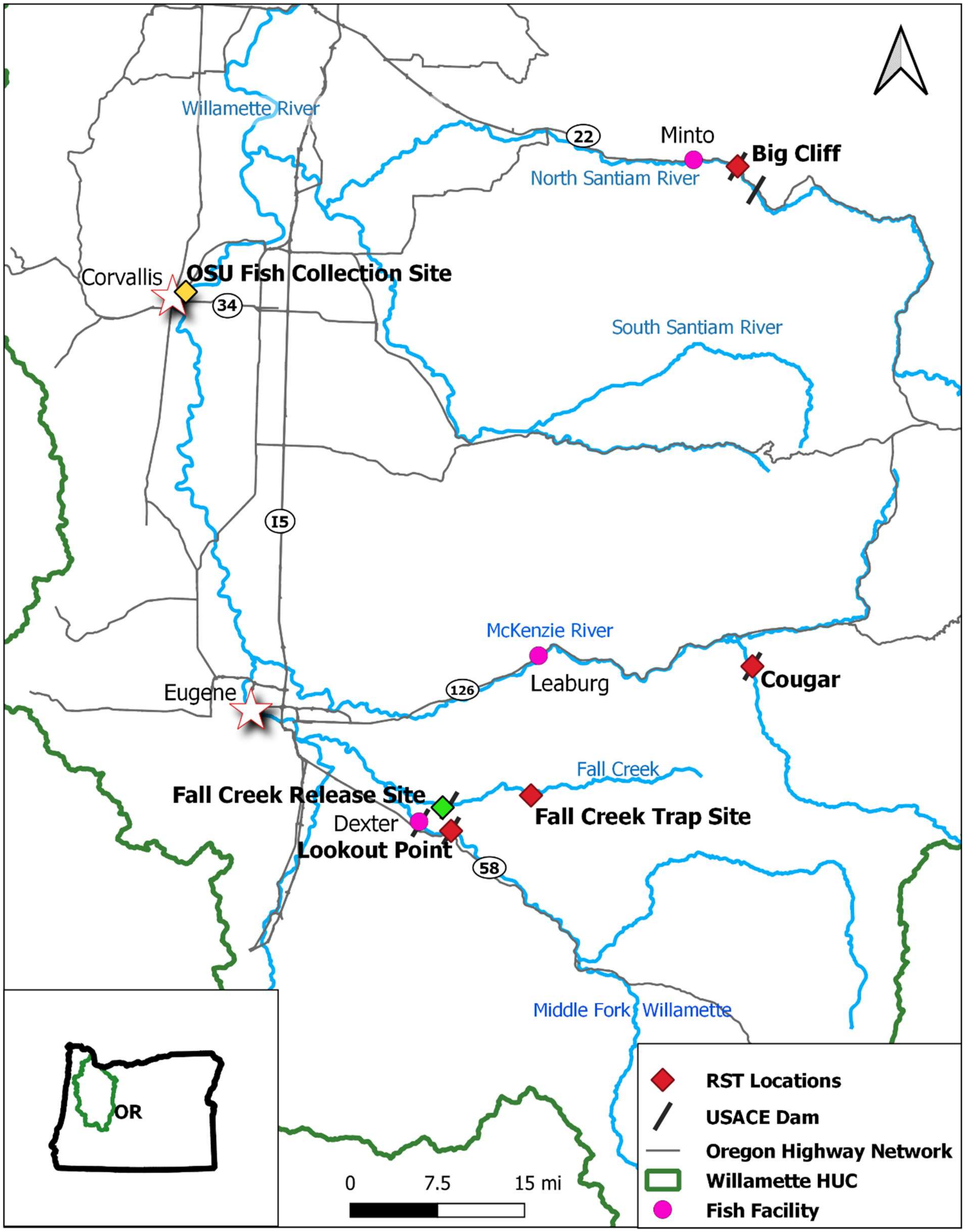

Figure 1. Locations of rotary screw traps, Willamette Valley Project Dams, and fish facilities used in 2021.

Table 2. Dates when rotary screw traps were not operating at all the sampling sites, 2021.

Site	Dates	Days	Reason
Fall Creek	March 23	0.5	Log stuck in cone upon arrival to trap
	April 21	0.25	Lifted cone for debris wheel repair
	April 30	0.5	Debris blocking cone upon arrival to trap
	May 1	0.5	Debris blocking cone upon arrival to trap
	May 2	0.5	Low flow, cone not spinning upon arrival to trap
	May 17	0.5	Log stuck in cone upon arrival to trap
	May 26	0.5	Log stuck in cone upon arrival to trap
	June 1	NA	End of sampling period, cone lifted
Cougar Trap 1/2 (PH)	March 29 - April 3	6	Traps stopped due to low water dam operations
	July 27 - July 28	2	Trap 1: A-frame repair
	Aug 11 - Aug 12	2	Trap 1: Debris door replacement/repair
	Sept 13 - Oct 20	38	No flow through PH channel due to dam operations
	Nov 7 - Nov 29	23	No flow through PH channel due to dam operations
	Nov 29	NA	End of sampling period by Cramer Fish Sciences, cone lifted
Cougar Trap 3 (RO)	March 24 - April 2	10	No flow through RO channel due to dam operations
	April 10 - May 30	51	No flow through RO channel due to dam operations
	June 4 - Sept 12	101	No flow through RO channel due to dam operations
	Nov 29	NA	End of sampling period by Cramer Fish Sciences, cone lifted
Lookout Point	June 9	0.5	Log stuck in cone upon arrival to trap
	June 11	0.5	Log stuck in cone upon arrival to trap
	July 11 - July 12	2	Log stuck in cone upon arrival to trap, required specific tools to cut log out of trap
	July 18	0.25	Trap 1: Anchor line snapped, lifted cone to repair/reposition trap
	July 19	NA	End of sampling period, cones lifted due to water temperature threshold
Big Cliff	June 28	0.25	Lifted cone for collar bolt repair
	Aug 24	0.25	Lifted cone for collar bolt repair
	Nov 22 - Nov 24	3	Lifted cone due to high flow, safety concerns
	Nov 29	NA	End of sampling period by Cramer Fish Sciences, cone lifted

Fish Collection

Traps were typically checked once per day, with more frequent checks when it was necessary to maintain efficient trap operation or to reduce the density of fish held in the trap. Frequency of daily checks depended on catch number, debris loads, and flow levels. We prepared a Tricaine methanesulfonate (Syndel USA Tricaine-S, MS-222) bath to anesthetize fish for proper handling procedure to limit stress and injury. Our procedure was to dissolve 5 grams of MS-222 into 0.47 liters with 10 grams of sodium bicarbonate as a buffer to create a diluted solution and reduce pH (Bowker et al. 2012; Allen and Harman 1970). In the field we measured out 50mL of this diluted solution and added it to approximately 12L of river water resulting in a final concentration of 44.3 mg/L MS-222. We anesthetized five to six fish at a time to decrease chance of overexposure and utilized air stones to maintain optimum oxygen levels within the anesthesia bath. Holding buckets (19L) were also set up with air stones to aid in quick recovery after fish handling. Water temperature was monitored in both the anesthesia bath and the recovery buckets. Water was replaced if temperatures in the bath or recovery buckets increased by more than 2 degree Celsius. Non-target species (everything besides Chinook salmon) were enumerated and released back into the river. For Chinook salmon, we collected fork length (FL) to the nearest mm, weight to the nearest 0.1 g, fish condition using various injury codes (**Table 3**). We enumerated the number of copepods that were attached to the gills and fins separately. In addition, we took a photo of the first, and every 5th Chinook salmon we caught. We also took photos of all mortalities.

Table 3. List of injury codes used to describe and evaluate the overall condition of migrating salmonids in the Willamette River basin, 2021. (See Appendix C – Injury Examples**).**

Injury Code	Description of Injury/Condition
NXI	Live fish with no external injuries
DS<20	Descaling <20% of body
DS>20	Descaling >20% of body
BLO	Bloated
EYB	Bloody eye (hemorrhage)
BVT	Bleeding from vent
FVB	Fin blood vessels broken
GBD	Gas Bubble Disease (fin ray/eye inclusions)
POP	Pop eye (eye popping out of head)
HIN	Head injury
OPD	Opercula damage
TEA	Body injury (tears, scrapes, mechanical damage)
BRU	Bruising (any part of the body)
HBP	Hole behind pectoral fin
HBV	Hole behind ventral fin
HBA	Hole behind anal fin
HO	Head only
BO	Body only
HBO	Head barely connected
FID	Fin damage
PRD	Predation marks (claw or teeth marks)
COP	Copepods (on gills or fins) one cop defined by adult w/two attached egg sacs
FUN	Fungus
MORT	Mortality

Trap Metrics

In addition to biological data, we collected environmental data and trapping metrics. Environmental data collected include stream temperatures (collected at the trap and monitored via nearby USGS gages), gage height/discharge (monitored via USGS gages and USACE dam operations data), and general weather conditions. We used electronic counters to count the number of revolutions of the cone for a given trapping period. Revolutions were recorded when a magnet attached to the back of the cone located in the live well passed the electronic counter. We also measured the number of seconds it took for three full cone rotations. This metric served as a backup to allow us to estimate total daily cone revolutions in the event that the electronic counters malfunctioned. Total trap revolutions were divided by the number of minutes that had elapsed since the trap was last checked to provide an estimate of mean cone revolutions per minute. Lastly, we carefully documented all trap stoppages (**Table 2**).

Trap Efficiency Trials

Trap capture efficiency was monitored at each site by releasing groups of marked juvenile Chinook salmon upstream of the RSTs. We used a caudal fin clip for the mark and alternated between upper and lower lobes on a weekly basis. Subsequent recaptures were pooled by week and used to calculate weekly RST capture efficiency estimates (see *Data Analysis* section below for RST capture efficiency and abundance estimate calculation methods).

- For the Cougar Dam tailrace and Big Cliff Dam tailrace sites, two methods were used - (1) mark-recapture trials of run-of-river juvenile Chinook salmon which were marked and released upstream on a daily basis and (2) large groups of hatchery-reared juvenile Chinook released periodically. Marked fish were released approximately 100-150m upstream at the base of the dam.
- At Lookout Point Dam tailrace, only hatchery fish trials were able to be conducted; daily trap efficiency trials with run-of-river fish was not conducted at Lookout Point due to low fish collection numbers and varying flow operations. Marked fish were released approximately 100-150m upstream at the base of the dam.
- For the Fall Creek site, because the primary goal during the 2021 season was to trap and transport juveniles from above Fall Creek reservoir to below the dam, we only used a small subset of the run-of-river fish captured to estimate trap efficiency. Specifically, juvenile Chinook salmon collected for two consecutive days were held overnight in a perforated bucket to form each release group. The goal was to create release groups with a greater likelihood of having sufficient numbers of recaptures to calculate capture efficiencies. Trap efficiency fish were released approximately 300 meters upstream of the Fall Creek trap (two pool/riffle sequences). For the 2021 season, no hatchery fish were to be released in Fall Creek above the dam.

For the large groups of ODFW hatchery-reared Chinook released at Lookout Point, Cougar, and Big Cliff fish were adipose fin clipped, 50 fish were measured (length/weight), and a percentage was humanely euthanized to simulate fish mortality catch patterns. We conducted two hatchery trap efficiency releases at Lookout Point on April 8 (1,114 fish) and July 13 (1,000 fish) with fish from Dexter Hatchery. For trap efficiency trials at Big Cliff and Cougar we collected fish from the Minto and Leaburg hatcheries, respectively. We switched to collecting fish from Oregon State University's Corvallis Research Hatchery when Minto and Leaburg hatcheries were facing disease challenges. At Cougar and Big Cliff, we conducted bi-weekly trap efficiency tests using approximately 500 hatchery Chinook starting early

October and running through the end of November. During transport the water temperature in the liberation trailer was monitored, and an oxygen tank was utilized to maintain optimum dissolved oxygen levels. Ice was used when necessary to ensure temperature would be within a few degrees of the final release site river temperature. For Fall Creek, in addition to the weekly trap efficiency test, we experimented with using radishes (50) and green peas (100), since they have near neutral buoyancy and our permit did not allow for the use of hatchery fish at this site (**Table 4**).

Table 4. Date of release, species, and total number of fish released for trap efficiency tests conducted at all the sampling sites over the fish passage monitoring season, 2021.

Location	Date of Release	Species	Life Stage	# Released
Lookout	8-Apr	HCHS	Smolt	1114
	13-Jul	HCHS	Parr	1000
Big Cliff	26-May	HCHS	Smolt	100
	9-Jul	HCHS	Fry	504
	5-Oct	HCHS	Parr	500
	12-Oct	HCHS	Parr	500
	25-Oct	HCHS	Parr	500
	9-Nov	HCHS	Parr	500
	25-Nov	HCHS	Parr	202
Cougar (PH)	5-May	HCHS	Parr	105
	5-Nov	HCHS	Parr	500
Cougar (RO)	23-Sep	HCHS	Parr	558
	4-Oct	HCHS	Parr	500
	18-Oct	HCHS	Parr	500
	1-Nov	HCHS	Parr	500
	24-Nov	HCHS	Smolt	500
Fall Creek	4-May	Vegetable	Radish	50
	4-May	Vegetable	Pea	100
	6-May	Vegetable	Radish	50
	6-May	Vegetable	Pea	100

24-Hour Post-Capture Holding Trial

Each week, defined as Sunday to Saturday, we held the first 50 juvenile Chinook salmon captured at our Cougar site for 24 hours and documented the occurrence of subsequent mortality. Fish were processed as normal except fish included in the study were not marked for use in trap efficiency testing. Two large holding tanks were utilized for this study with a constant flow of freshwater from the river. We used perforated 19 L buckets to sort our delayed mort groups labeling them RO-1 through RO-10 or PH-1 through PH-10 depending on which channel the fish originated from. Our priority was the RO fish, once they were measured and weighed, we placed them in a holding bucket with a maximum of six fish per bucket. We determined the average weight of fish per gallon of water to be 0.056 lbs per gallon which was in accordance with holding densities no greater than 0.5 lbs per gallon of water (i.e., consistent with the Corps' Snake River fish transport requirements (2021 Fish Passage Plan)). We recorded tank and bucket IDs, length (FL), weight (g), and conditions (**Table 3**) of each fish. Following the 24-hour holding period we counted the mortalities and recorded the length, weight and injury codes including the copepod infections and location. All the fish that survived the study were released back into the river downstream from the RSTs.

Data Analysis

To remain consistent with past studies, data analysis methods were taken from Keefer et al. 2013 and Romer et al. (2012 – 2017).

Outmigration Timing, Size, and Age

Age estimates determined in the field using relative size differences in fish are subject to some small, unknown level of error and so will be subsequently quality checked with length-frequency and length/weight analysis (DeVries and Frie 1996). We will plot individual fish size by date at each trap and determine juvenile age from what is typically a bimodal distribution (Romer et al. 2017).

Abundance Estimates of Out-migrating Chinook salmon

For comparison with previous studies weekly abundance estimates for out-migrants will be calculated by expanding trap catches using the equations used by Romer et al. (2012 - 2017):

$$N_m = c/e_m$$

And

$$e_m=r/m,$$

where

N_m = weekly estimated out-migrants

c = number of fish captured

e_m = measured weekly trap efficiency

r = number of recaptured marked fish

m = number of marked fish released.

We calculated estimates of the number of fish that passed each trap for sites where we had sufficient trap efficiency estimates during the period of peak migration. Following Romer et al. (2012-2017), we designated the period of peak migration as the interquartile range of cumulative catch data for the year (between 25^{th} and 75^{th} percentiles). Trap efficiency estimates were considered sufficient if more than five marked fish were captured per week for at least half of the weeks during the peak migration period. Weekly abundance estimates were summed for yearly totals. During weeks when recaptures are infrequent (< 5 recaptures/week), recapture totals for subsequent weeks were pooled to obtain at least five recaptures. If a trap was stopped for a period of one to several days due to high flows or debris, daily migrant catches were estimated as the mean number of fish captured the day before and after the stoppage period. If trap efficiency criteria were not met for a particular site, the actual number of fish captured was reported.

A bootstrap procedure was used to estimate the variance and construct 95% confidence intervals for each abundance estimate (Thedinga et al. 1994; 1,000 iterations used for each calculation). This procedure uses trap efficiency as one parameter in the calculation of variance. A weighted value for trap efficiency will be used to calculate confidence intervals. Each weekly estimate of trap efficiency will be weighted based on the proportion of the yearly migrant total estimated to have passed the trap that week, using the equation

$$e_w=e_m * (N_m/N_t)$$

where

e_w= weighted weekly trap efficiency

e_m= measured weekly trap efficiency

N_m= weekly estimated migrants

N_t= season total migrants.

The sum of the weighted trap efficiencies will be used in the confidence interval calculations. The assumptions of this calculation are that marking did not affect recapture, that all marked fish migrated past the trap, and that all recaptured marked fish were counted.

Results

Fall Creek

We operated a single 2.4-meter screw trap in Fall Creek above Fall Creek Reservoir from March 10, 2021 to June 1, 2021 (Appendix A; **Figure A- 4**). The trap was stopped on seven occasions, six days due to debris and once to perform repairs on the debris wheel. We estimate that a total of 3.25 days of effort were lost due to those stoppages. The trap fished for a total of 83 days and captured a total of 424 juvenile Chinook salmon. Of the total catch, 244 (58%) were transported and released downstream of Fall Creek Reservoir and 180 were released upstream of the trap (for trap efficiency) but were never recaptured. The total catch was predominately composed of sub-yearlings, 402 fry averaging 35 mm and 17 parr averaging 73 mm (**Table 5**). The size range for sub-yearlings was 28 – 86 mm for the season. We also captured a total of five yearling Chinook salmon that averaged 122 mm.

Table 5. Descriptive statistics of target species captured at the site above Fall Creek, 2021. Length and weight ranges, averages, and standard deviation for each age class.

			Fork Lengths (mm)				Weights (g)			
Site	Age Class	n	Min	Max	Mean	S.D.	Min	Max	Mean	S.D.
Fall Creek (Total)	Sub-Yearling (fry)	402	28	57	34.7	2.7	NA	NA	NA	NA
	Sub-Yearling	17	63	86	72.5	6.5	2.5	6.3	4.1	1.2
	Yearling	5	112	126	121.8	5.8	15.1	22	19.5	3.8

Catch of juvenile Chinook salmon peaked during the second week of March (152 fish) and then quickly tapered off after the first week of April (**Figure 2**). Sub-yearling fry dominated the catch during March and April while the remaining non-fry sub-yearlings were all captured during May (**Figure 3**). All five of the yearling Chinook salmon were captured during March.

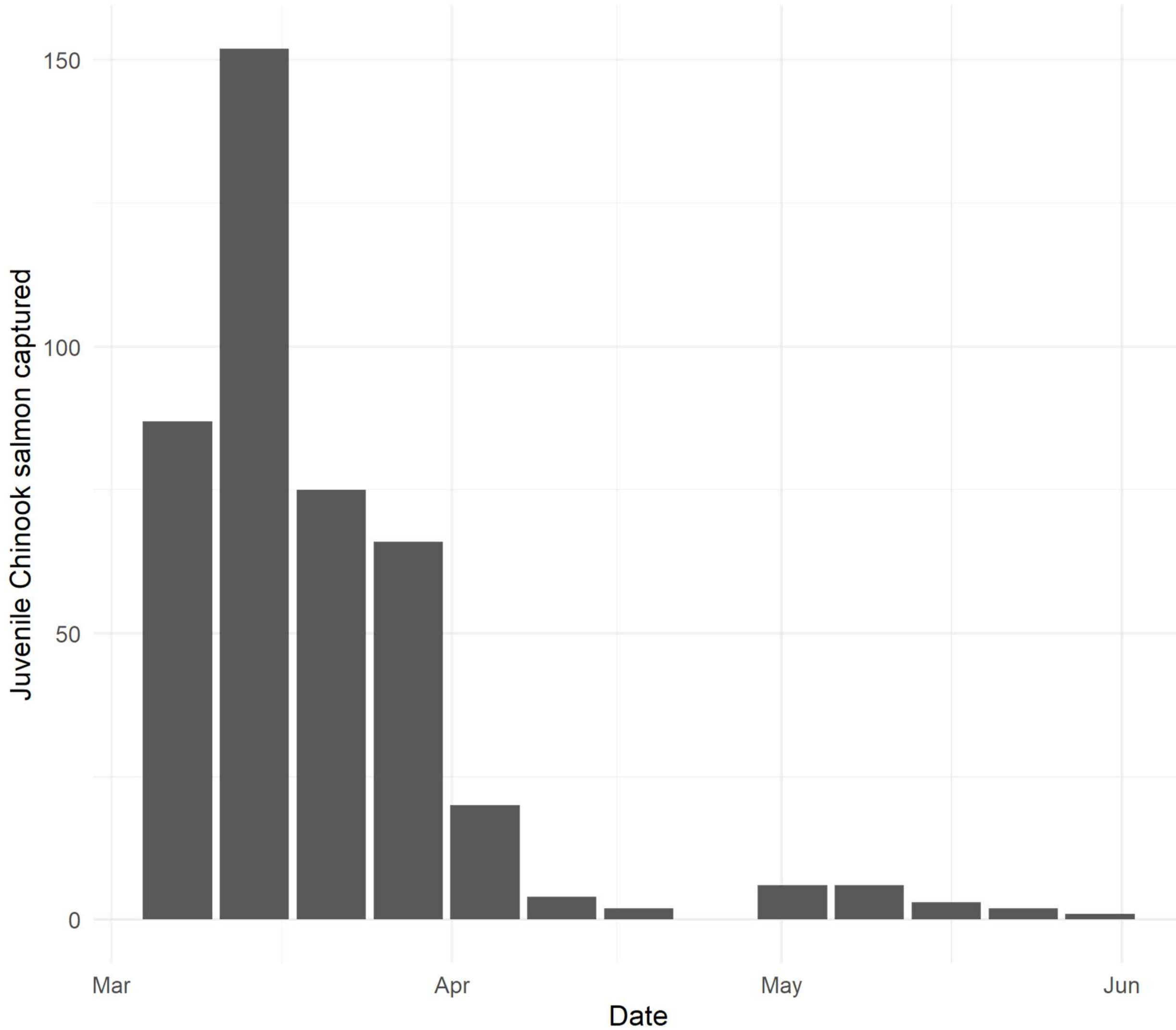

Figure 2. Weekly catch of juvenile Chinook salmon captured in the Fall Creek trap above Fall Creek Reservoir, 2021.

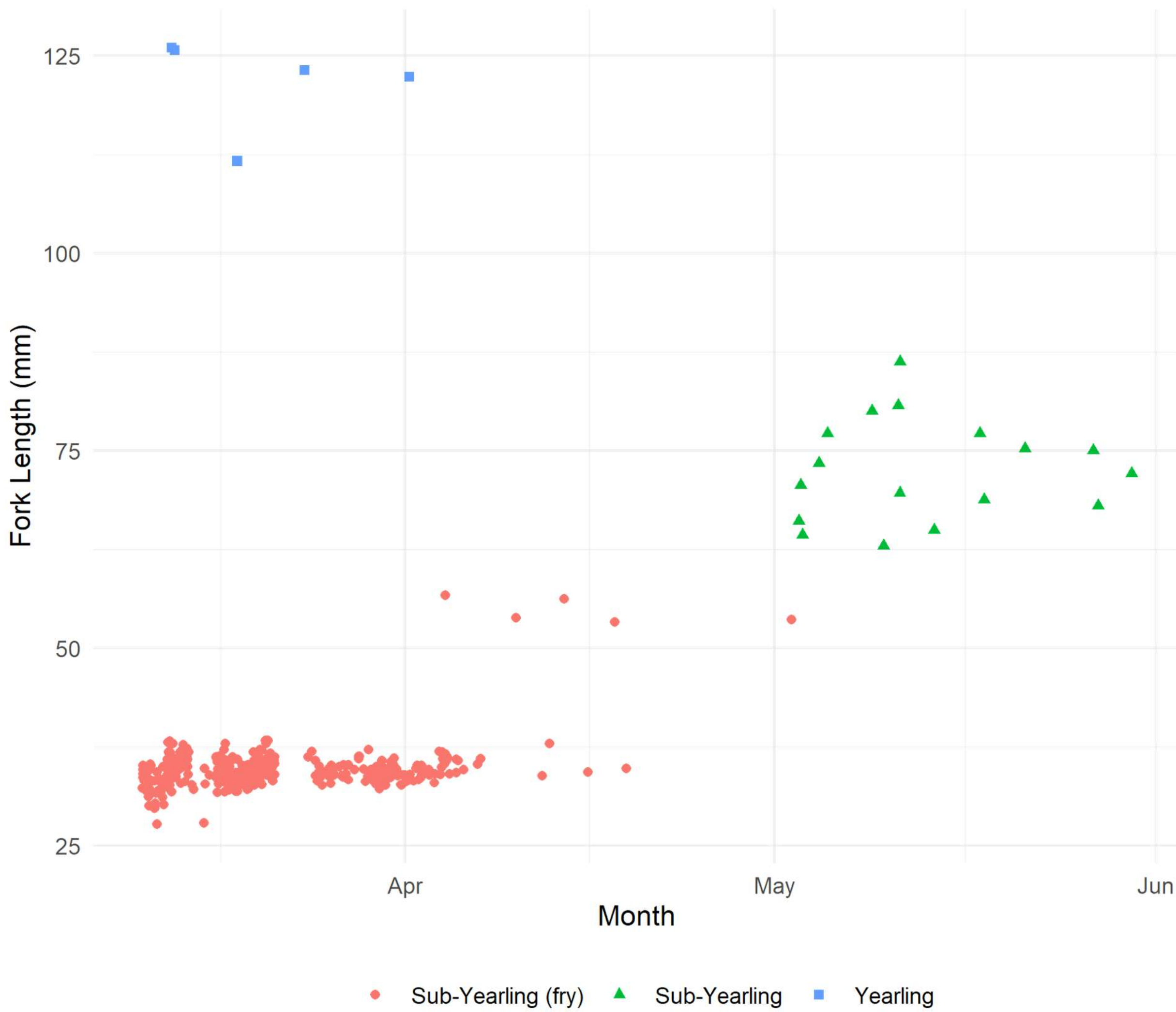

Figure 3. Fork lengths and capture dates of three age classes of juvenile Chinook salmon captured in the Fall Creek trap above Fall Creek Reservoir, 2021.

Gage height and water temperature were monitored via USGS gage number 14150290. Values for instantaneous gage height across the entire sampling period ranged from 0.91 m – 1.43 m (mean: 1.07 m) while temperature ranged from 4.4 C – 17.6 C (mean: 9.7 C). The trap was installed on the descending limb of a high water event (**Figure 4**), (red vertical line denotes install date). The largest number of fish caught coincided with a pulse of water from May 18th – May 23rd. The late may pulse was the last significant event of the season as gage height trended lower as the season progressed.

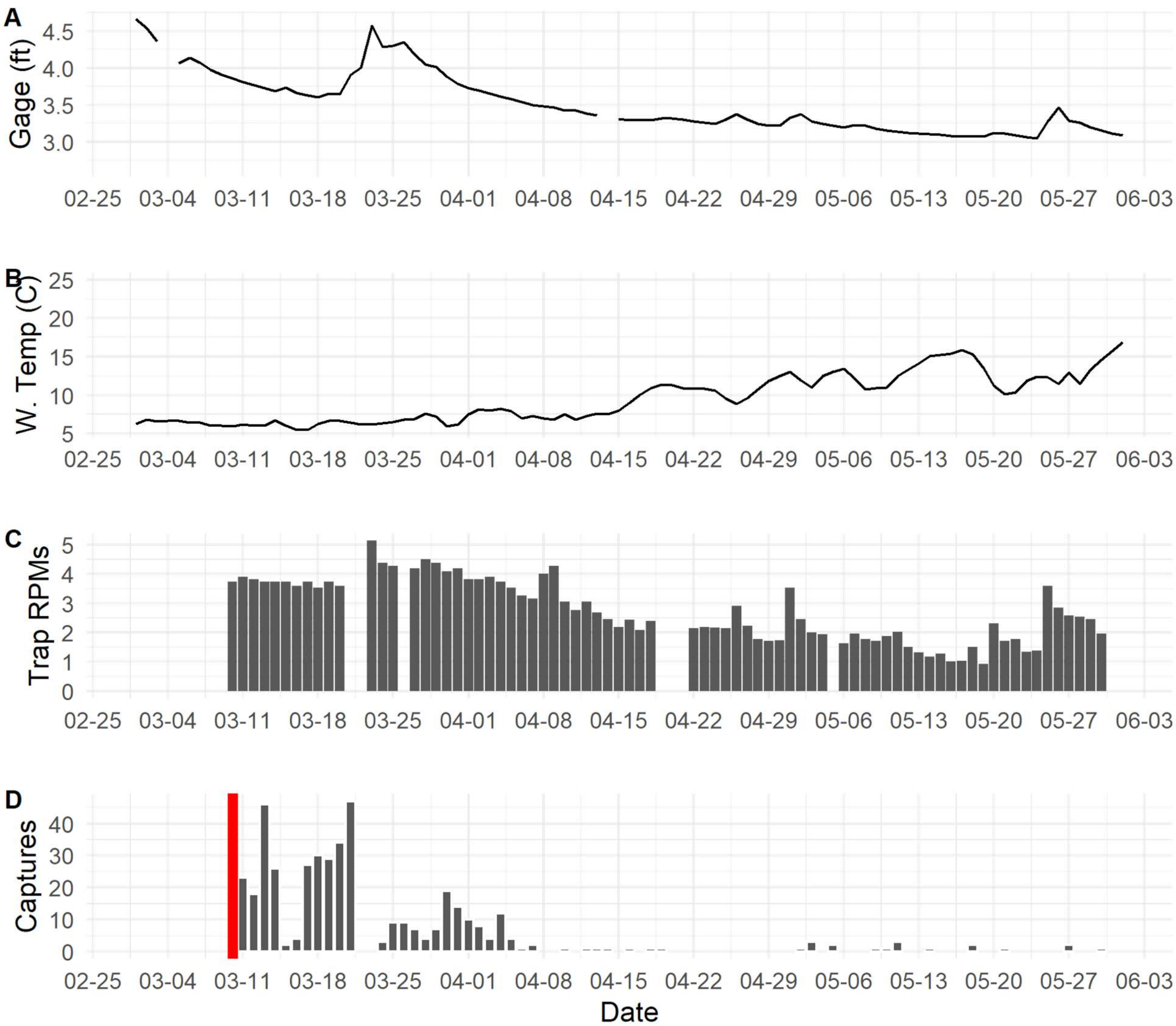

Figure 4. Gage Height (ft; panel A), water temperature (Celsius; panel B), trapping effort in mean revolutions per minute (panel C) and daily catch of target species (panel D) at the Fall Creek site, 2021. Trapping effort is calculated as trap revolutions divided by the number of minutes elapsed since the trap was last checked. The red bar represents the date that the trap was installed.

Trap Efficiency

Juvenile Chinook salmon catch was pooled each Friday and Saturday in order to create larger groups of fish to test trap efficiency while still transporting the majority of salmon caught downstream of Fall Creek Dam. We captured enough fish to form trap efficiency release groups during each week of March. However, we failed to meet the minimum weekly recapture number of five individuals during each of those weeks (**Table 6**). Furthermore, because we only recaptured a total of four individuals across the entire season, we were unable to pool recaptures across weeks to calculate a trap efficiency estimate.

Table 6. Results of trap efficiency trials conducted with unmarked naturally produced juvenile Chinook salmon fry at the Fall Creek above site, 2021.

Site	Week	# Released	Mean Length (mm)	# Recaptured	Recapture %
Fall Creek	3/7/2021	63	37	0	0
	3/14/2021	89	35	0	0
	3/21/2021	18	34	2	11.11
	3/28/2021	13	34	1	7.69
	4/4/2021	1	35	1	100

Condition

We observed a total of nine fish (2.1% of total catch) exhibiting at least one of seven unique adverse conditions. There were 6 mortalities (1.4% of total catch), all of which occurred during the first couple days of trap operation (**Table 7**). We believe these fish were accidentally crushed while our crew was gaining experience netting this fragile life stage during the first days of their field season.

Table 7. Injuries sustained by juvenile Chinook salmon from different age classes (sub-yearling fry, sub-yearling, and yearling) captured at the Fall Creek site, 2021. BRU = bruising, COP = copepods (gills and fins), HIN = head injury, MORT = mortalities, NXI = no existing injury, OPD = opercula damage, POP = pop eye – exopthalmia, TEA = body injury (tears, scrapes, etc.).

Site	Age Class	Condition Code	Observations
Fall Creek	Sub-Yearling (fry)	NXI	394
		MORT	6
		TEA	4
		HIN	2
		BRU	1
		OPD	1
		POP	1
	Sub-Yearling	NXI	17
		COP	1
	Yearling	NXI	5

Non-target species

In addition to Chinook salmon, we captured seven different non-target species at the Fall Creek site (**Table 8**). The most abundant non-target species were unclipped rainbow trout. In addition to fish that were clearly rainbow trout, our field crew identified 71 juvenile steelhead smolts. Rainbow trout were classified as steelhead smolts based on the following morphological characteristics (e.g., Appendix B; **B-1 Fall Creek Above-**):

- Silvery color, parr marks absent or very faded.
- Fusiform body shape.
- Deciduous scales.

- Spotting patterns.

The other notable non-target fish we encountered were 165 lamprey ammocoetes, which we were unable to identify to species.

Table 8. Non-target species captured at Fall Creek, 2021. COT = sculpin, CUT = cutthroat trout, HRBT = hatchery rainbow trout, LND = longnose dace, LPY = juvenile lamprey, LSS = large-scale sucker, RBT = rainbow trout, STH = steelhead smolt.

Site	Species	Total Catch
Fall Creek	RBT	824
	LND	251
	LPY	165
	CUT	117
	LSS	107
	STH	71
	HRBT	36
	COT	3

Lookout Point

We operated three 2.4-meter screw traps below Lookout Point Dam on the Middle Fork Willamette River from March 15, 2021 to July 19, 2021 (Appendix A; **Figure A- 3**). Two traps were fished in a "parallel-staggered" configuration (one trap behind and to the side of the other) in the powerhouse channel while the third trap was fished in the river left side-channel. Trap operations were interrupted on four separate occasions, three due to debris and once to perform repairs on an anchor line. We estimate that a total of 4.25 days of effort were lost due to those stoppages. The traps fished for 121.75 days and captured a total of 18 juvenile Chinook salmon. The total catch was composed of nine sub-yearlings averaging 106 mm, eight yearlings averaging 143 mm and a single 322 mm Chinook salmon that we suspect was a two-year old, having spent at least two winters in freshwater (**Table 9**).

Table 9. Descriptive statistics of target species captured at the Lookout Point dam site, 2021. Length and weight ranges, averages, and standard deviation for each age class.

			Lengths (mm)				Weights (g)			
Site	Age Class	n	Min	Max	Mean	S.D.	Min	Max	Mean	S.D.
Lookout Point	Sub-Yearling	9	95	122	105.6	8.1	5.6	20.5	11.2	4.4
	Yearling	8	108	176	143.2	26.6	14.1	60.9	36.6	18.4
	Age-2+	1	322	322	322	NA	NA	NA	NA	NA

The first juvenile Chinook salmon were captured on April 9th, nearly one month after sampling began below Lookout Point Dam (**Figure 5**). Over the next ten days a total of six yearling Chinook salmon were captured. The next noteworthy period of catch did not occur until nearly two months later when nine sub-yearling and 2 yearling Chinook salmon were captured between June 13, 2021 – June 21, 2021

(**Figure 6**). This period of relatively high catch coincided with spill operations at Lookout Point Dam (**Figure 7**).

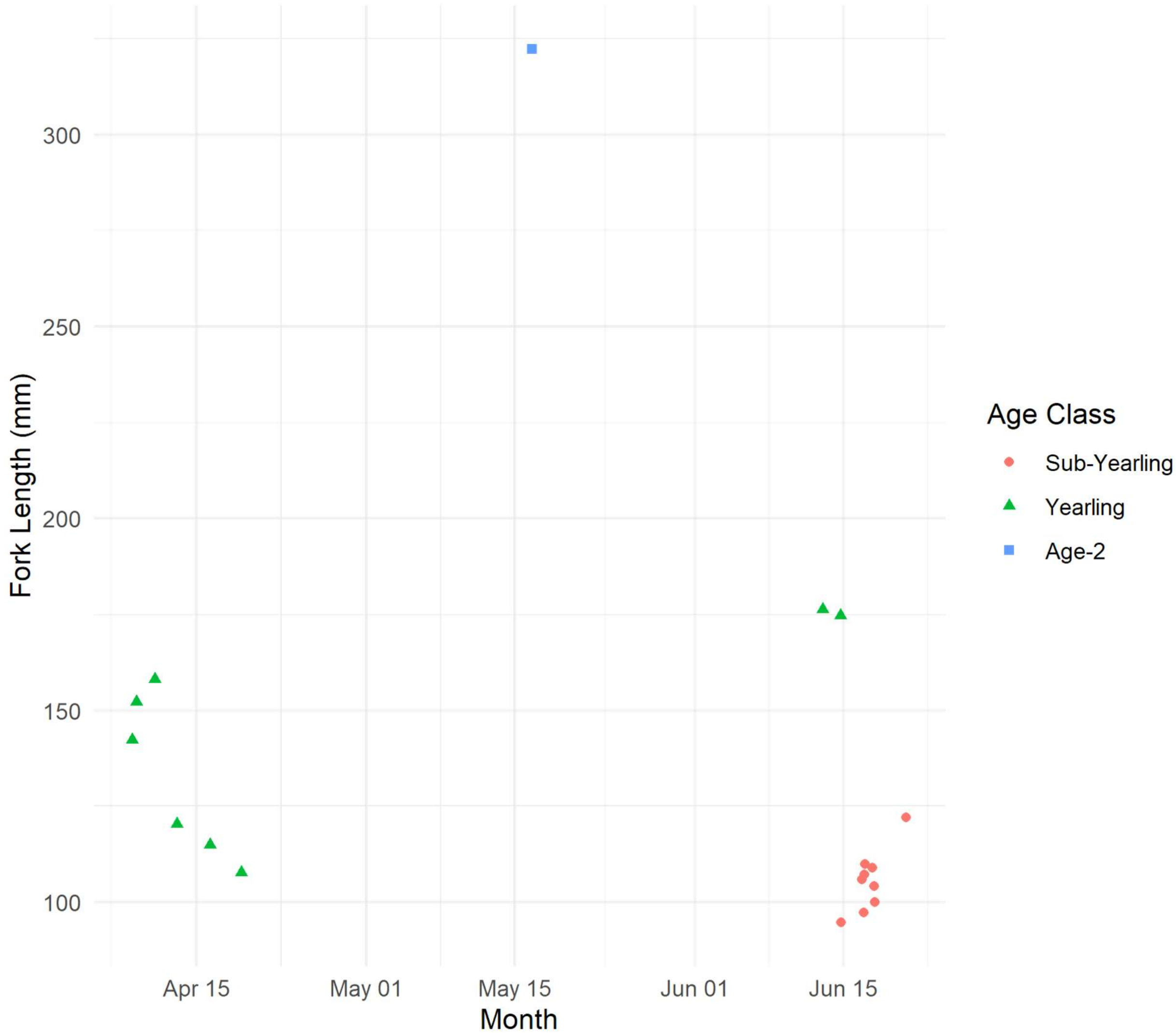

Figure 5. Fork lengths and capture dates of three age classes of juvenile Chinook salmon captured in the Lookout point traps below Lookout Point Reservoir, 2021.

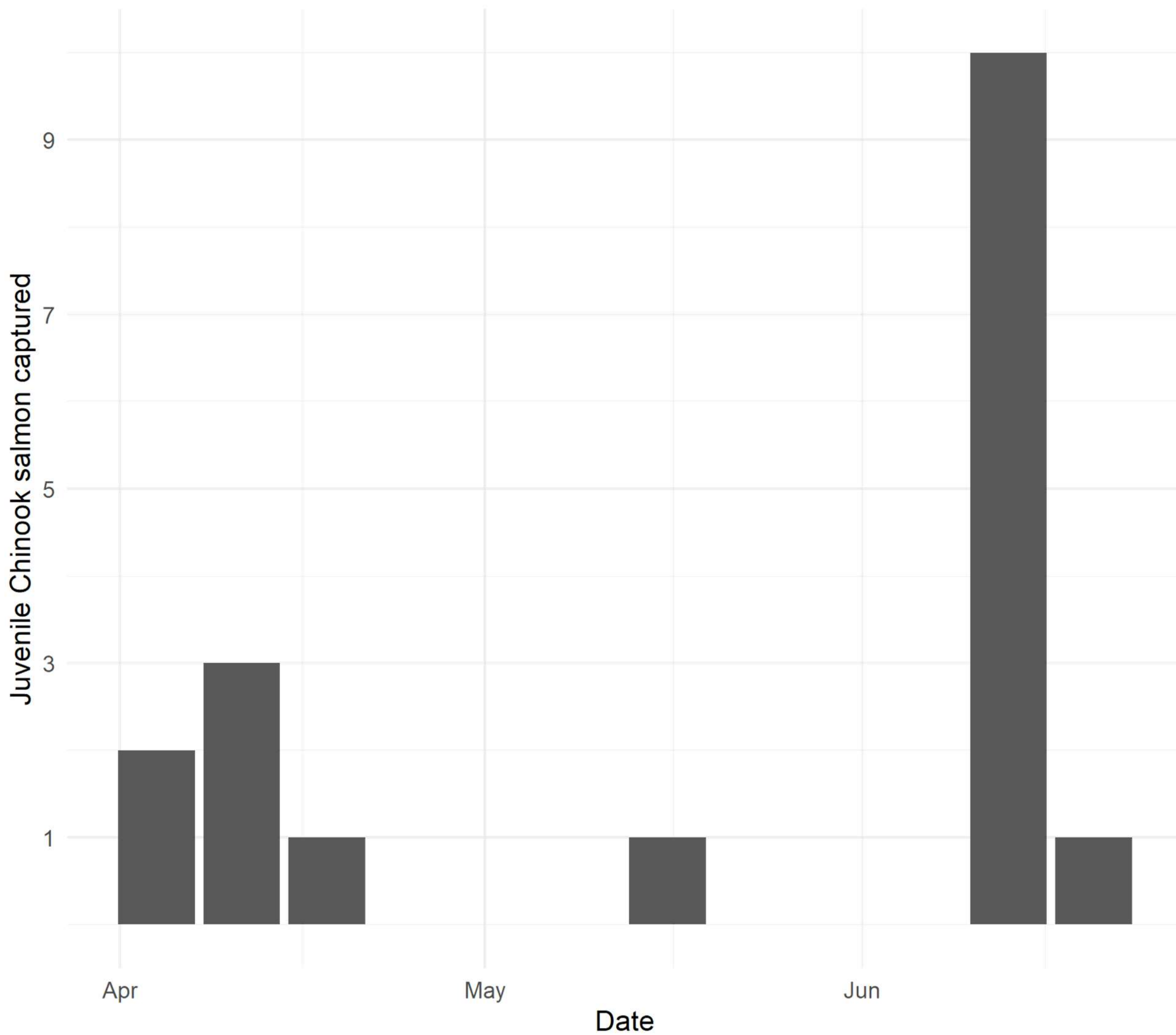

Figure 6. Weekly catch of juvenile Chinook salmon captured in the Lookout Point traps below Lookout Point Reservoir, 2021.

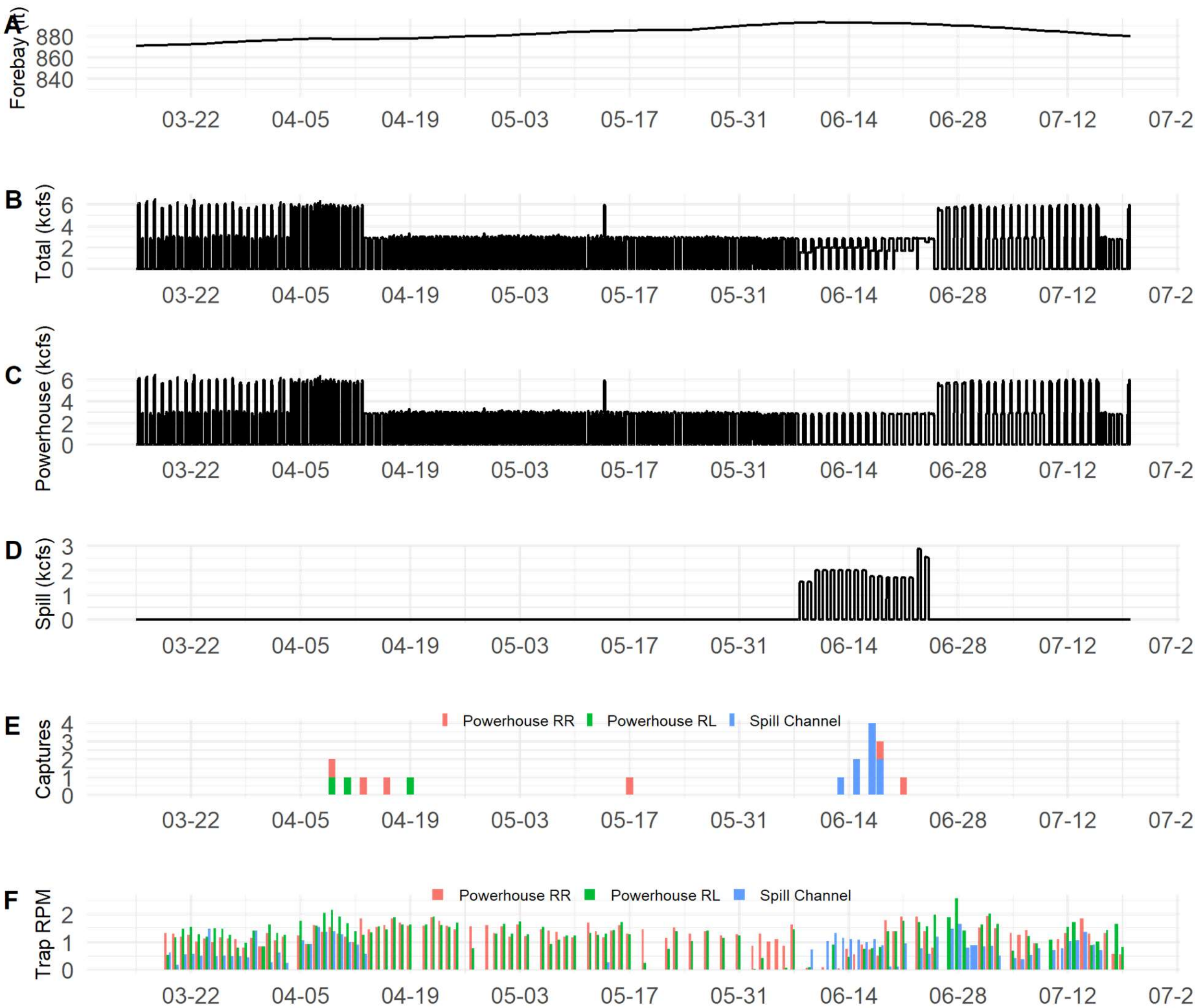

Figure 7. Forebay elevation (panel A), total outflow (panel B), powerhouse flow (panel C), spill (panel D), daily Chinook salmon catch (panel E), and trapping effort in mean revolutions per minute (panel F) below Lookout Point Dam. Trapping effort is calculated as trap revolutions divided by the number of minutes elapsed since the trap was last checked. RL and RR stand for river left and river right, respectively.

Trap Efficiency

Two trap efficiency trials were conducted with releases of hatchery reared Chinook. The first trial took place on April 8, 2021, with a group of 993 yearling Chinook salmon averaging 165 mm fork length. Three of those fish were subsequently recaptured for an estimated trap efficiency of 0.3% (**Table 10**). The second trial was conducted on July 13, 2021, with 950 sub-yearling Chinook salmon averaging 90 mm fork length. A single fish from that release group was recaptured resulting in an estimated trap efficiency of ~0.1%. Both trials failed to meet the minimum criteria of five recaptures.

Table 10. Results of trap efficiency trials conducted with ODFW hatchery reared Chinook salmon at the Lookout Point dam site, 2021.

Date	Site	Route	Species	Mean Length (mm)	Released	Recaptured	Efficiency (%)
4/8/2021	LOP	PH	HCHS	165	993	3	0.3
7/13/2021	LOP	PH	HCHS	90.4	950	1	0.1

Condition

We observed a total of six injured fish (33 % of total catch) exhibiting at least one of three unique adverse condition types (**Table 11**). Of the six injured Chinook salmon three were mortalities (17 % of total catch). In addition to the mortalities, two individuals presented with fin damage and one fish had a single copepod attached on a fin.

Table 11. Injuries sustained by juvenile Chinook salmon from different age classes (sub-yearling fry, sub-yearling, and yearling) captured at the Lookout Point site, 2021. COP = copepods (gills and fins), FID = fin damage, MORT = mortality, and NXI = no existing injury.

<table>
<tr><th>Site</th><th>Species</th><th>Age Class</th><th>Condition Code</th><th>Observations</th></tr>
<tr><td rowspan="6">Lookout Point</td><td rowspan="6">CHS</td><td rowspan="2">Sub-Yearling</td><td>NXI</td><td>4</td></tr>
<tr><td>FID</td><td>2</td></tr>
<tr><td rowspan="3">Yearling</td><td>NXI</td><td>6</td></tr>
<tr><td>MORT</td><td>2</td></tr>
<tr><td>COP</td><td>1</td></tr>
<tr><td>Age-2</td><td>MORT</td><td>1</td></tr>
</table>

Non-target species

In addition to Chinook salmon, we captured 10 different non-target species below Lookout Point Dam. The most abundant non-target species were bluegill, followed by crappie and sculpin (**Table 12**).

Table 12. Non-target species captured at the Lookout Point site, 2021. BBH = brown bullhead, BLG = bluegill, COT = sculpin, CRP = crappie spp., CUT = cutthroat trout, HCHS = hatchery Chinook salmon,

HRBT = hatchery rainbow trout, RBT = rainbow trout, RSS = redside shiner, SMB = smallmouth bass, WAL = walleye.

Site	Species	Total Catch
Lookout Point	BLG	71
	CRP	57
	COT	30
	SMB	6
	RSS	4
	HCHS	2
	BBH	1
	CUT	1
	HRBT	1
	WAL	1

Cougar

We operated three screw traps in the South Fork of the McKenzie River below Cougar Dam from March 24, 2021 to November 29, 2021. Two 2.4-meter traps were fished in parallel within the powerhouse channel and one 1.5-meter trap was fished in the regulating outlet channel (Appendix A; **Figure A- 2**). Each of the traps were stopped on several occasions due to inadequate flow as a result of dam operations. The powerhouse traps were not operational for a total of 71 days (28% of season), 69 days due to inadequate flow and depth as a result of dam operations and two days for trap repairs and maintenance. The regulating outlet trap was in operation every day that the regulating outlet was discharging water (88 days, 35% of season). Generally, the regulating outlet was operated when flows from the powerhouse were too low to operate the powerhouse channel traps and vice versa.

The traps below Cougar dam were monitored for a total of 250 days and captured a total of 3,223 juvenile Chinook salmon. The majority of the fish were captured in the regulating outlet channel (n = 2,880; 89.3 % of total catch). Sub-yearlings averaging 121 mm were the most abundant age-class captured, followed by yearlings averaging 190 mm, and fry averaging 42 mm (**Table 13**). Fork lengths ranged from 33 – 174 mm for sub-yearlings and from 91 – 239 mm for yearlings. We also captured a single 297 mm juvenile Chinook salmon that we suspect was a two-year old.

Table 13. Descriptive statistics of target species captured at the Cougar dam site, 2021. Length and weight ranges, averages, and standard deviation for each age class.

				Fork Length (mm)				Weight (g)			
Site	Route	age	n	Min	Max	Mean	S.D.	Min	Max	Mean	S.D.
Cougar	Powerhouse	Sub-Yearling (fry)	70	33	59	41.7	8.4	1.5	2.5	1.8	0.5
		Sub-Yearling	214	60	156	103.8	20.5	1.6	40.4	13.4	7.3
		Yearling	58	94	223	140.8	27.2	7.9	112.9	32	20
	Regulating Outlet	Sub-Yearling (fry)	3	36	45	42	5.2	NA	NA	NA	NA
		Sub-Yearling	2,545	69	174	122.8	14.0	4.7	263	20.7	9.1
		Yearling	331	91	239	198.8	21.8	8.9	169.5	82.7	23.3
		Age-2	1	297	297	297	NA	90.2	90.2	90.2	NA

Fry and yearling Chinook salmon captured in the powerhouse channel dominated the catch below Cougar Dam from April through early June (**Figure 8**). Catch rates were low throughout the summer months and consisted almost entirely of sub-yearlings. Weekly catch began to trend upwards once the regulating outlet began operating in mid-September (**Figure 9**). Weekly catch peaked during the third week of October when 591 sub-yearling and 102 yearling Chinook salmon were captured in the regulating outlet channel (**Figure 8**). Catch rates remained high through early November but then quickly trended downward as the month progressed. By the end of November, catch rates had returned to levels observed during the summer months.

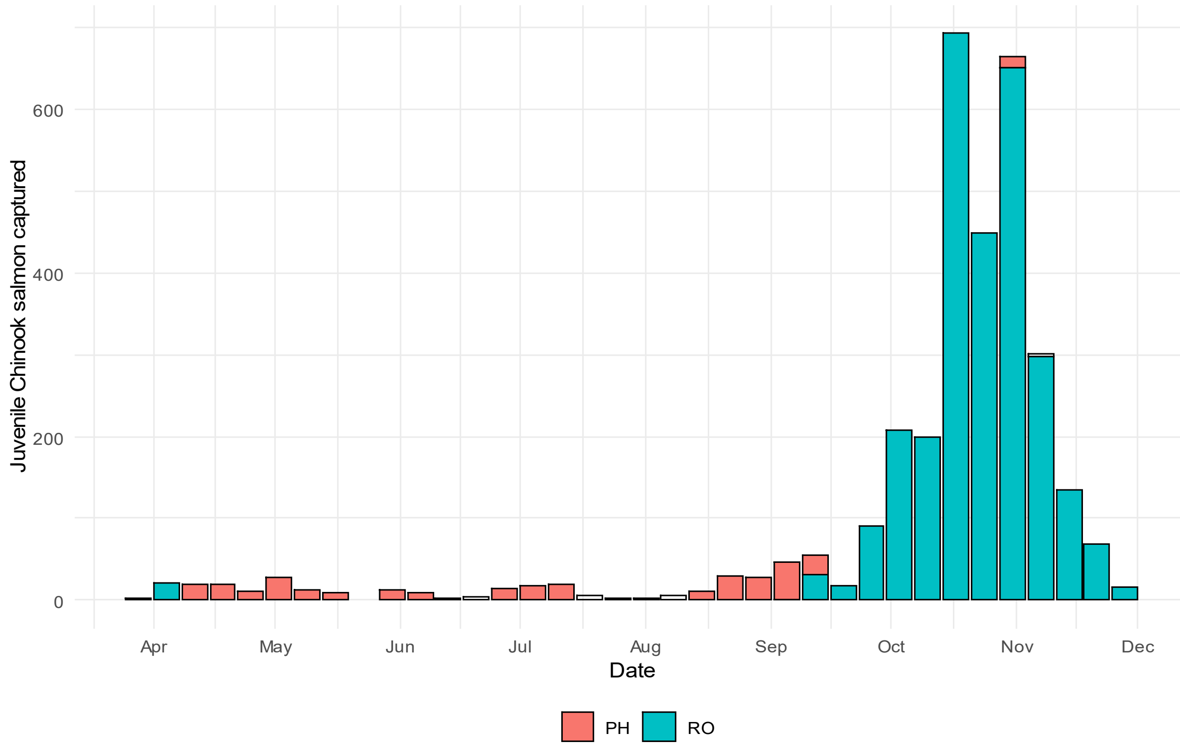

Figure 8. Weekly catch of juvenile Chinook salmon captured in the Cougar traps below Cougar Reservoir, 2021.

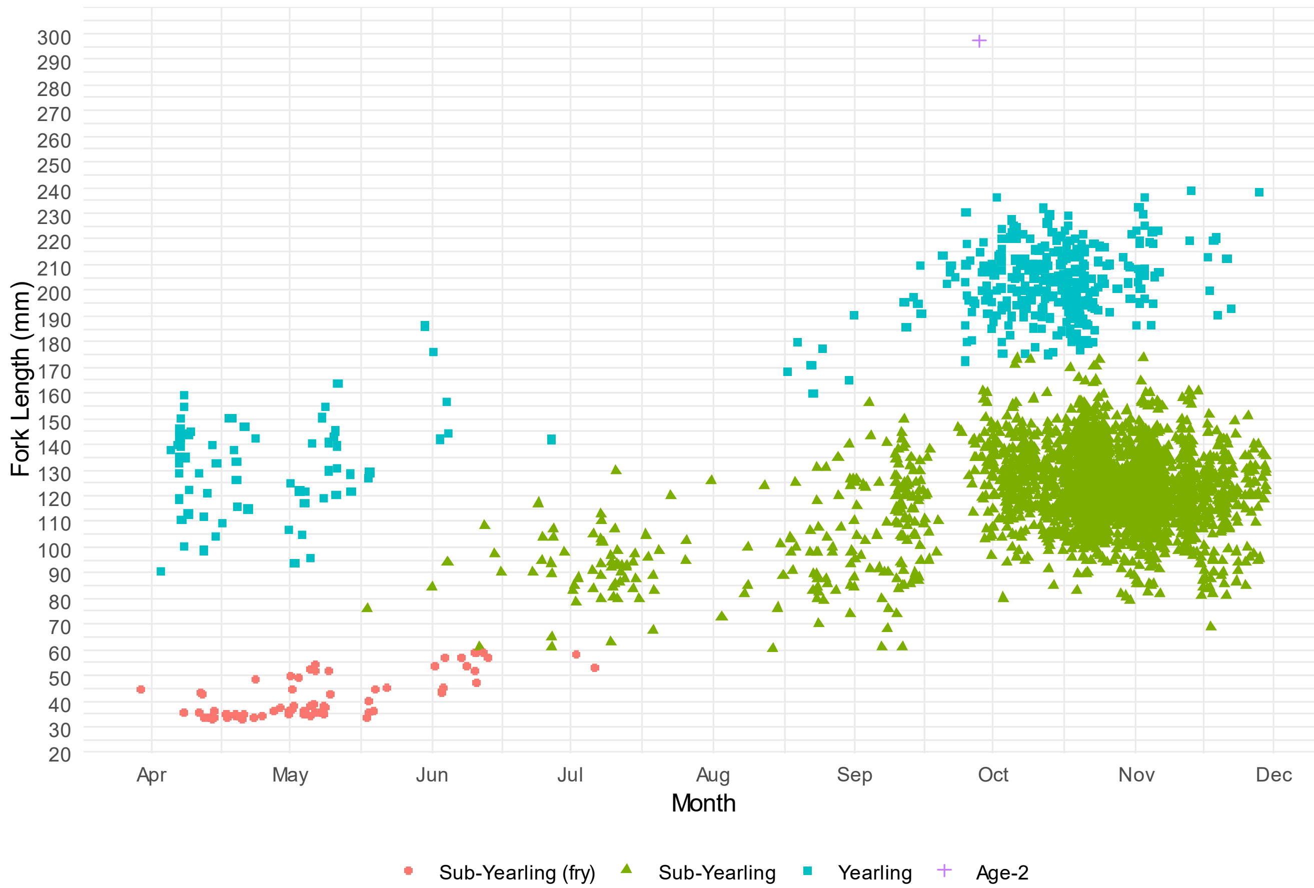

Figure 9. Fork lengths and capture dates of four age classes of juvenile Chinook salmon captured in the Cougar traps below Cougar Reservoir, 2021.

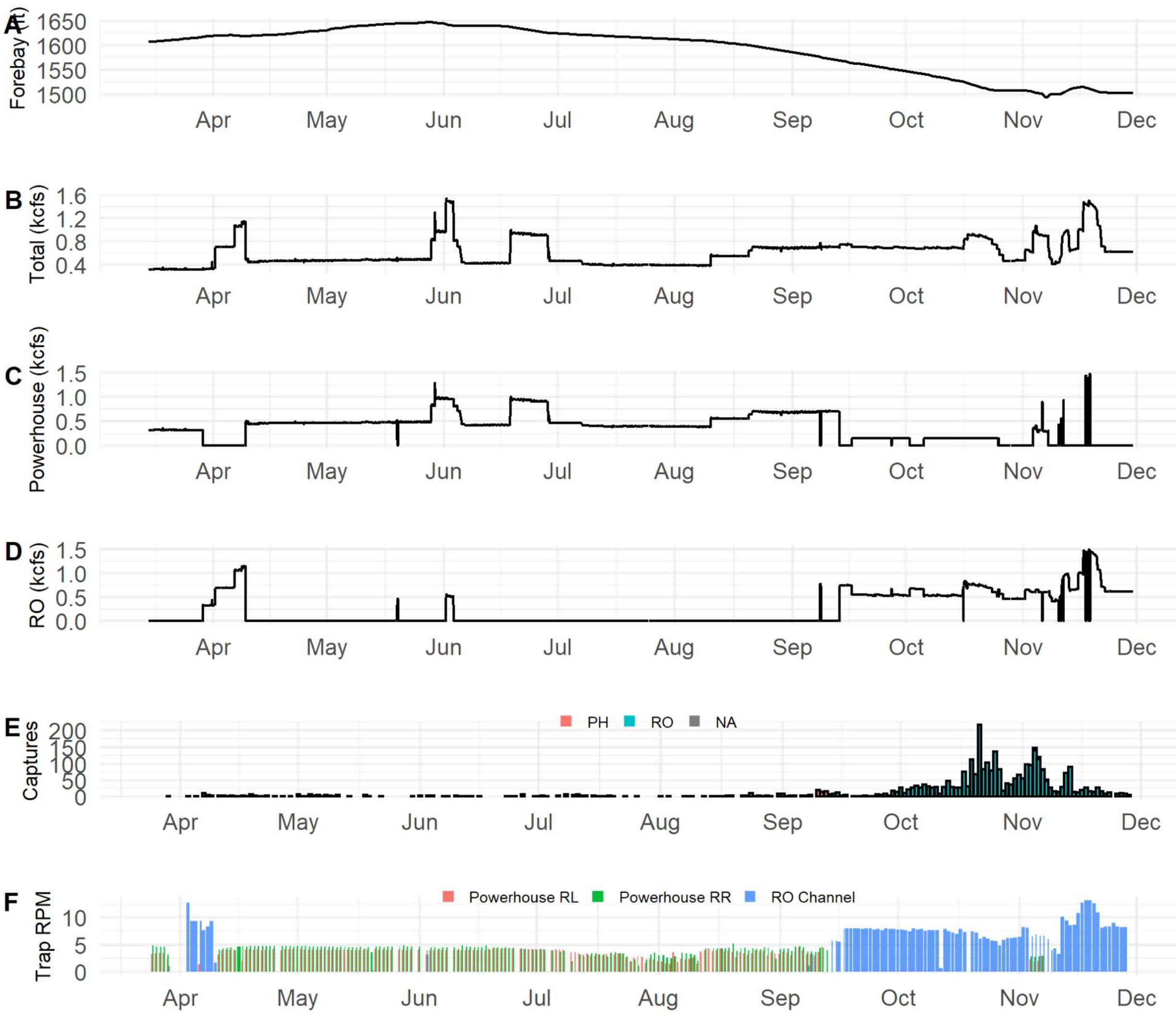

Figure 10. Forebay elevation (panel A), total outflow (panel B), powerhouse flow (panel C), spill (panel D), captured Chinook salmon (panel E), and trapping effort (panel F) below Cougar Dam, 2021. Trapping effort is calculated as trap revolutions divided by the number of minutes elapsed since the trap was last checked. RL and RR stand for river left and river right, respectively.

Trap Efficiency

Fires during 2020 and disease during 2021 limited the availability of hatchery reared fish until Fall of 2021. In total, we were able to conduct seven trap efficiency trials with releases of hatchery reared Chinook (**Table 14**). The first trial took place on May 5, 2021 when we released a group of 105 sub-yearling Chinook salmon averaging 62.5 mm into the powerhouse channel. Thirty-seven of those fish were subsequently recaptured for an estimated trap efficiency of 35.2%. The remaining trials all took place during the fall and were conducted on a bi-weekly basis between September 19, 2021 and November 28, 2021. We also conducted daily trap efficiency releases using run-of-river fish. Trap efficiency in the regulating outlet channel during the period of peak migration ranged from 2.1% - 7.6% (mean = 4.6%). We estimate that a total of 84,775 (95% CI: 61,000 – 137,962) juvenile Chinook salmon passed the regulating outlet trap between September 5, 2021 and November 29, 2021.

Table 14. Results of trap efficiency trials conducted with ODFW hatchery reared Chinook salmon at the Cougar Dam site, 2021.

Date	Site	Route	Species	Mean Length (mm)	Released	Recaptured	Efficiency (%)
5/5/2021	CGR	PH	HCHS	62.5	105	37	35.2
9/23/2021	CGR	RO	HCHS	86.4	508	22	4.3
10/4/2021	CGR	RO	HCHS	88.2	450	10	2.2
10/15/2021	CGR	RO	HCHS	95	450	24	5.3
11/5/2021	CGR	PH	HCHS	101.5	450	15	3.3
11/1/2021	CGR	RO	HCHS	98.1	451	25	5.5
11/24/2021	CGR	RO	HCHS	105.8	450	34	7.6

Condition

We observed a total of 2,126 fish (65.9% of total catch) exhibiting at least one of 21 unique adverse condition types (**Table 15**). Fish that passed via the regulating outlet were injured at a higher rate than fish that passed via the powerhouse (**Figure 11**). The most common adverse conditions were copepod infections (n = 2,016; 62.5% of catch), descaling over less than 20% of the body (n = 1,100; 34% of catch), descaling over more than 20 percent of the body (n = 388; 12% of catch), fin damage (n = 285: 9% of catch), and mortality (n = 256; 8% of catch). Nearly all mortalities occurred in fish that passed Cougar Dam via the regulating outlet (**Table 15** = 250; 97.6% of all mortalities; **Figure 12**). Relative mortality rate, calculated as the number of fish caught divided by the number of mortalities observed, was 5.9 times higher for fish passing via the regulating outlet (RO = 0.104, PH = 0.017). Mortality rate across age-classes was greater for yearlings than it was for sub-yearlings.

Table 15. Injuries sustained by juvenile Chinook salmon from different age classes (sub-yearling, yearling and Age-2) captured at the Cougar site, 2021. BRU = bruising, BVT = bleeding from vent, COP = copepods (gills and fins), DS<20 = descaling less than 20%, DS>20 = descaling more than 20%, EYB = bloody eye – (hemorrhage), FID = fin damage, FUN = fungus, FVB = fin blood vessels broken, GBD = gas bubble disease, HBA = hole behind anal fin, HBP = hole behind pectoral fin, HBV = hole behind ventral

fin, HIN = head injury, MORT = mortality, NXI = no existing injuries, OPD = opercula damage, POP = pop eye – exopthalmia, PRD = predation (claw or teeth marks), and TEA = body injury (tears, scrapes, etc.).

Site	Age Class	Condition Code	Observations
Cougar	Sub-Yearling (fry)	NXI	70
		TEA	2
		COP	1
	Sub-Yearling	COP	2,116
		DS<20	1,239
		DS>20	364
		OPD	317
		FID	286
		BRU	226
		MORT	171
		NXI	133
		TEA	113
		EYB	90
		HBP	55
		HBV	32
		FVB	30
		GBD	27
		POP	10
		BVT	5
		FUN	3
		HIN	3
		PRD	2
		HBA	1
		HPV	1
	Yearling	COP	338
		DS<20	155
		DS>20	105
		MORT	83
		FID	42
		OPD	19
		TEA	15
		EYB	14
		NXI	14
		BRU	10
		POP	4
		FVB	3
		BVT	2
		HBP	1
	Age-2	COP	1
		DS<20	1
		MORT	1

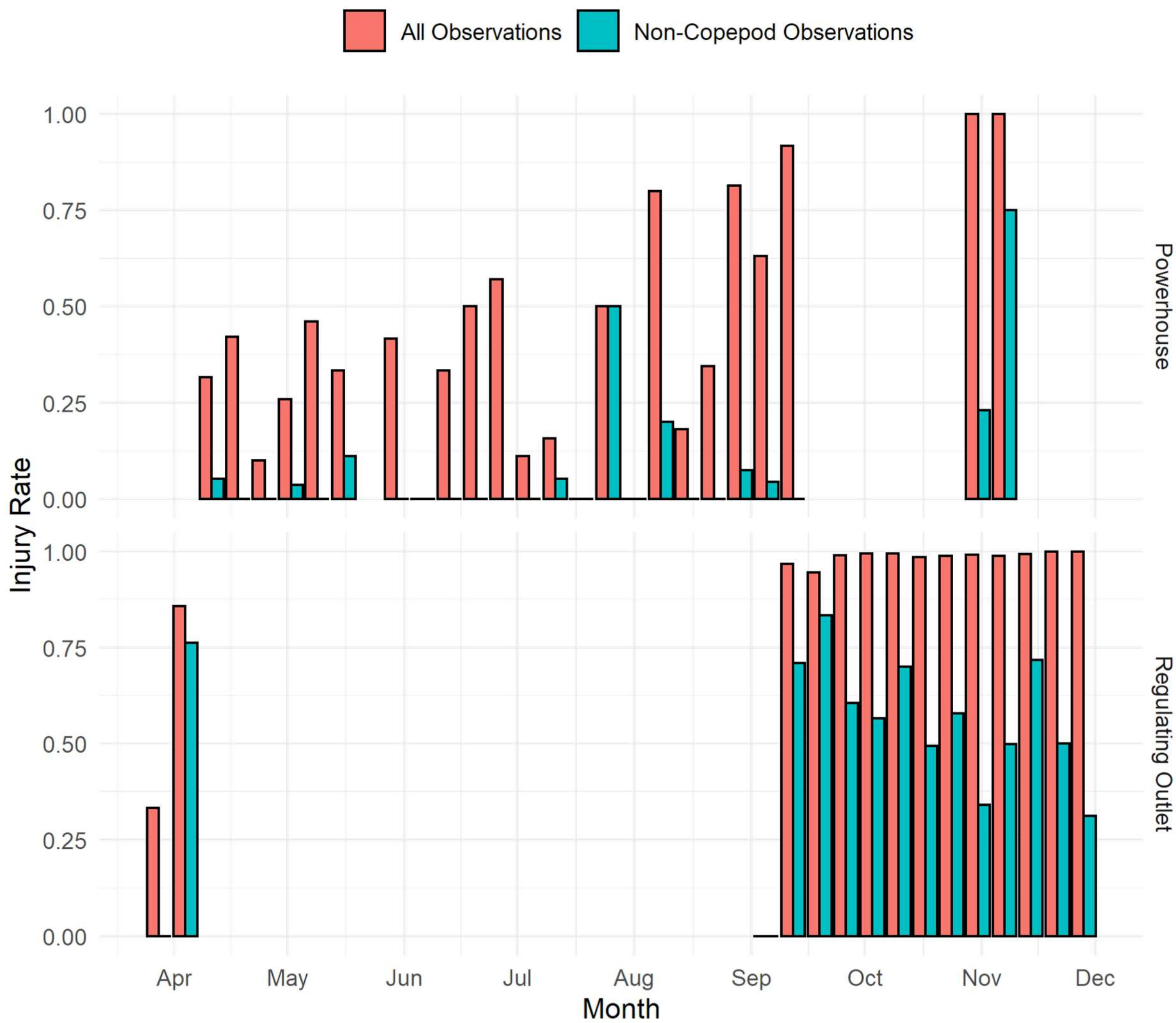

Figure 11. Weekly injury rate observed in juvenile Chinook captured below Cougar Dam in the powerhouse channel (top panel) and the regulating outlet (bottom panel). Red bars depict the injury rate with the presence of copepods counting as an injury. Blue bars depict the injury rate not including copepods.

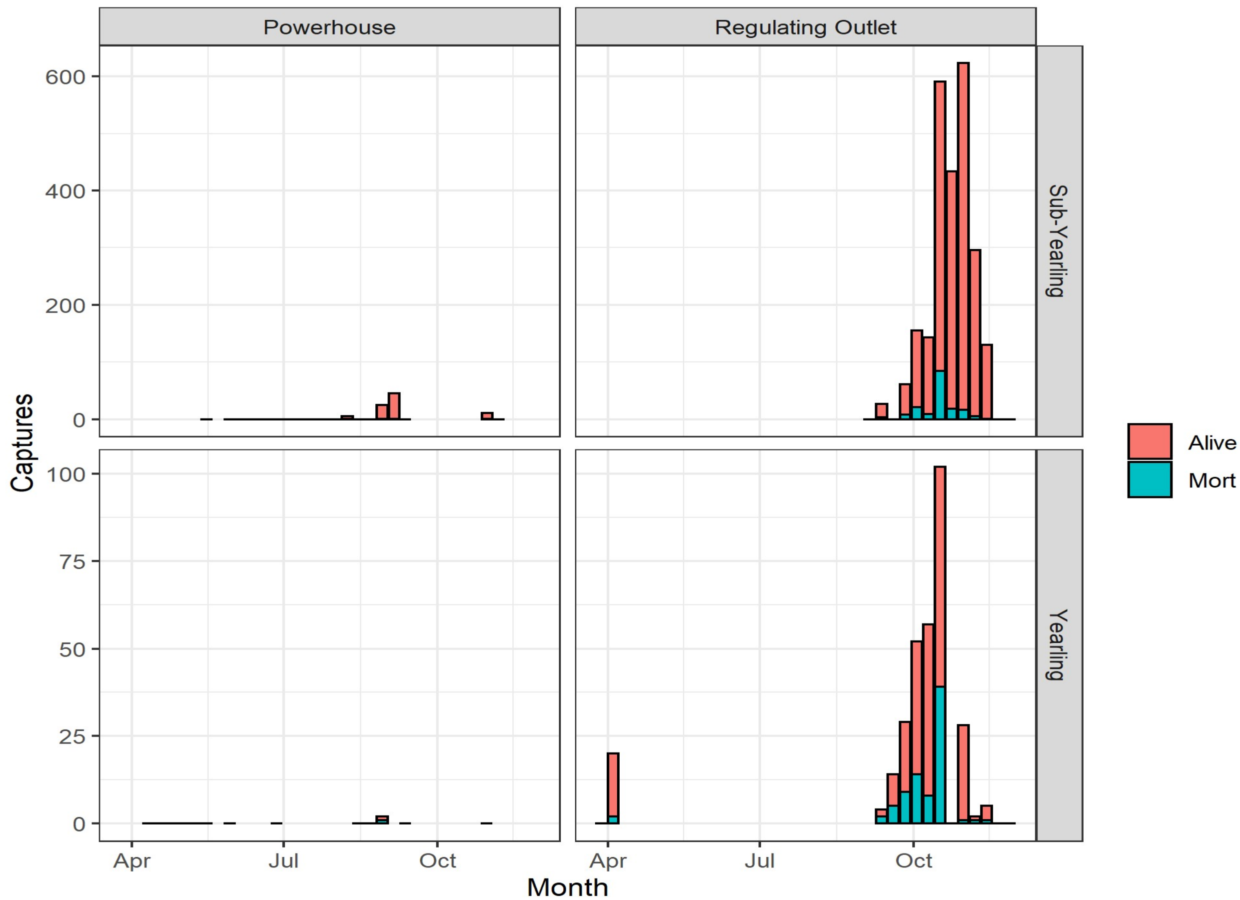

Figure 12. The number of juvenile Chinook salmon captured below Cougar Dam that were alive (red) or dead (blue) by route of passage (powerhouse vs. regulating outlet (bottom panel). Red bars depict the injury rate if we assume copepod infections are an injury. Blue bars depict the injury rate if copepod infection is not considered an injury.

Copepods

Copepod Infections were the most common adverse condition observed in juvenile Chinook salmon caught below Cougar Dam. The monthly infection rate was fairly steady between April and August, averaging 0.33 and ranging from 0.12 to 0.43 (**Table 16**). A large increase in the severity of gill infection occurred in August when an average of 7.4 copepods were observed in the brachial cavities of fish passing Cougar Dam. The August spike in gill copepods was followed by an overall increase in infection rate from September through November. Infections peaked in October with 97% of fish being infected with an average of six copepods in the brachial cavity and two copepods on the fins. Larger fish tended to be infected with a greater number of copepods (**Figure 13**).

Table 16. Copepod infections of target species captured at the Cougar site. Infections are the number of fish with copepods, Rate is calculated as the number of fish with copepods divided by total catch, Gill Rate is calculated as the number of fish with copepods in their gills divided by total catch and Gill Severity is calculated as the total number of copepods observed in the gills divided by the number of

fish with copepods observed in their gills (mean number of gill copepods). Fin metrics were calculated using the same method, but with copepods observed on the fins, 2021.

Month	Site	Fish Inspected	Infections	Infection Rate	Gill Rate	Fin Rate	Gill Severity	Fin Severity
Apr	Cougar	28	10	0.36	0.32	0.04	2.44	5.00
May	Cougar	57	20	0.35	0.26	0.21	3.53	2.83
Jun	Cougar	36	14	0.39	0.25	0.33	2.33	2.33
Jul	Cougar	52	6	0.12	0.06	0.08	3.00	2.50
Aug	Cougar	60	26	0.43	0.28	0.32	7.41	2.16
Sep	Cougar	196	150	0.77	0.63	0.53	6.20	3.09
Oct	Cougar	1,581	1,533	0.97	0.95	0.55	6.06	2.17
Nov	Cougar	885	811	0.92	0.88	0.53	3.84	1.68

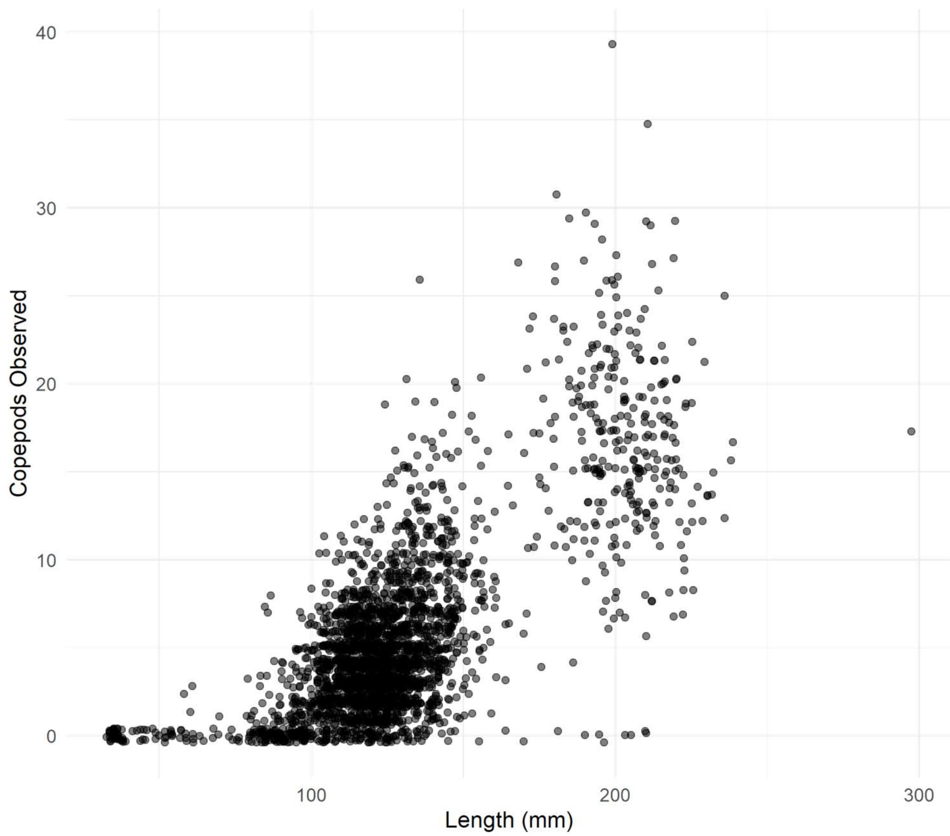

Figure 13. Fork length versus the number of individual copepods observed on the gills and fins of juvenile Chinook salmon caught below Cougar Dam.

Non-target species

In addition to Chinook salmon, we captured 10 different non-target species below Cougar Dam. The most abundant non-target species were large-scale sucker, hatchery Chinook salmon, and sculpin (**Table 17**). The hatchery Chinook salmon were a part of an Oregon Department of Fish and Wildlife (ODFW) PIT-tag study cohort that was released into the Cougar forebay. ODFW released 2,000 PIT-tagged fish into the Cougar Forebay Reservoir on October 21st, 2021 and an additional 2,000 on November 10th,

2021. We scanned all captured fish for PIT tags and provided ODFW with the recovery data. All PIT tag recoveries were then uploaded to PTAGIS by ODFW.

Table 17. Non-target species captured at the Cougar site, 2021. BLG = bluegill, HCHS = hatchery Chinook salmon, COT = sculpin, CUT = cutthroat trout, LMB = largemouth bass, LND = longnose dace, LPY = juvenile lamprey, LSS = largescale sucker, MWF = mountain whitefish, RBT = rainbow trout, SMB = smallmouth bass.

Site	Species	Total Catch
Cougar	LSS	452
	HCHS	330
	COT	140
	RBT	80
	LND	54
	CUT	36
	MWF	29
	BLG	4
	SMB	4
	LMB	2
	LPY	1

24-Hour Post-Capture Holding Trial

We conducted ten 24-hour post-capture holding trials this season utilizing 498 juvenile Chinook salmon captured below Cougar Dam (**Table 18**). We observed a total of 111 mortalities across all of the trials for a total mortality rate of 0.22. Weekly mortality rates ranged from 0.04 - 0.36 and averaged 0.21. On average, mortalities and survivors were of similar size (138 mm vs 135 mm) and presented with a similar number of adverse conditions per individual (1.5 vs 1.4). However, mortalities were more likely to have descaling over more than 20% of their body, more likely to be infested with copepods, and had more severe copepod infections when compared to fish that survived (**Table 19**).

Table 18. Results of the 24-hour post-capture holding trial at Cougar Dam, 2021. Mortality rate, mean lengths, injuries, and copepods were calculated each week.

Week	Subjects	Mortalities	Mort Rate	Mean Subject Length (mm)	Mean Mort Length (mm)	Mean Subject Injuries	Mean Mort Injuries	Mean Subject Copepods	Mean Mort Copepods
9/19/2021	13	2	0.15	180.2	141.0	1.4	2.0	12.1	13.0
9/26/2021	47	13	0.28	149.1	150.8	0.7	1.2	8.3	10.2
10/3/2021	88	32	0.36	146.9	142.6	0.9	1.1	8.5	8.9
10/10/2021	50	11	0.22	147.8	133.0	0.8	1.0	9.9	7.7
10/17/2021	50	14	0.28	139.6	153.6	0.9	1.1	8.9	12.3
10/24/2021	50	16	0.32	130.4	133.1	1.2	1.3	5.7	6.9
10/31/2021	50	12	0.24	124.2	116.0	1.8	2.4	4.0	4.5
11/7/2021	50	6	0.12	121.3	121.5	2.6	3.0	4.5	7.5
11/14/2021	50	2	0.04	113.3	134.0	2.2	2.5	3.4	6.0
11/21/2021	50	3	0.06	122.0	123.7	2.2	4.7	4.5	3.7

Table 19. Summary of the injury prevalence of the survivors and mortalities from the 24-hour post-capture holding trial at Cougar Dam, 2021. BRU = bruising, COP = copepods, DS<20 = descaling less than 20%, DS>20 = descaling more than 20%, EYB = bloody eye – (hemorrhage), FID = fin damage, FUN = fungus, FVB = fin blood vessels broken, GBD = gas bubble disease, HBP = hole behind pectoral fin, HBV = hole behind ventral fin, HIN = head injury, NXI = no existing injuries, OPD = opercula damage, and TEA = body injury (tears, scrapes, etc.).

Condition	Survived	Mortality	Survivor Prevalence	Mort. Prevalence
COP	343	106	0.69	0.95
DS<20	241	60	0.48	0.54
DS>20	50	47	0.10	0.42
OPD	88	15	0.18	0.14
BRU	59	13	0.12	0.12
FID	31	12	0.06	0.11
TEA	22	6	0.04	0.05
EYB	17	5	0.03	0.05
HBV	7	5	0.01	0.05
HBP	9	2	0.02	0.02
FVB	3	1	0.01	0.01
HIN	3	1	0.01	0.01
FUN	2	0	0.00	0.00
GBD	11	0	0.02	0.00
NXI	6	0	0.01	0.00

Big Cliff

We operated a single 2.4-meter rotary screw trap in the North Fork of the Santiam River below Big Cliff Dam from May 23, 2021 to November 29, 2021. The trap was stopped on three occasions, twice to replace a collar bolt and once due to safety concerns caused by high spill flows. We estimate that the trap was stopped for a total of 3.5 days during the season.

The Big Cliff trap was monitored for a total of 186.5 days and captured a total of 594 juvenile Chinook salmon. Sub-yearlings averaging 131 mm were the dominant age class (85% of total catch), followed by yearlings averaging 167 mm, and two fry averaging 50mm (**Table 20**). Fork lengths ranged from 43 – 195 mm for sub-yearlings and from 125 – 261 mm for yearlings.

Table 20. Descriptive statistics of target species captured at the Big Cliff dam site, 2021. Length and weight ranges, averages, and standard deviation for each age class.

			Lengths (mm)				Weights (g)			
Site	Age Class	n	Min	Max	Mean	S.D.	Min	Max	Mean	S.D.
Big Cliff (Total)	Sub-Yearling (fry)	2	43	56	49.5	9.2	NA	NA	NA	NA
	Sub-Yearling	501	65	195	130.9	21.4	3.2	105.6	27.4	15.2
	Yearling	87	125	261	167	26.9	11.8	180.5	50.2	30.5

Yearlings were the predominant age-class captured early in the season (**Figure 15**). Early season weekly catch rates suggest that the trap was installed either during, or after, the peak migration of yearlings in the spring (**Figure 14**). By July the predominant age-class had shifted to sub-yearlings, a pattern that would remain constant throughout the rest of the season. Peak catch occurred between July 4th, 2021 and August 7th, 2021 when 325 Chinook salmon were captured (64% of season total). The period of peak catch coincided with spill gates being opened at Big Cliff Dam (**Figure 16**). There was also a notable increase in catch during the first three weeks of November (**Figure 17**).

The USACE released approximately 1,000 fin-marked hatchery juvenile Chinook salmon into Detroit reservoir on November 10th, 2021. None of those fish were recovered in the trap below Big Cliff.

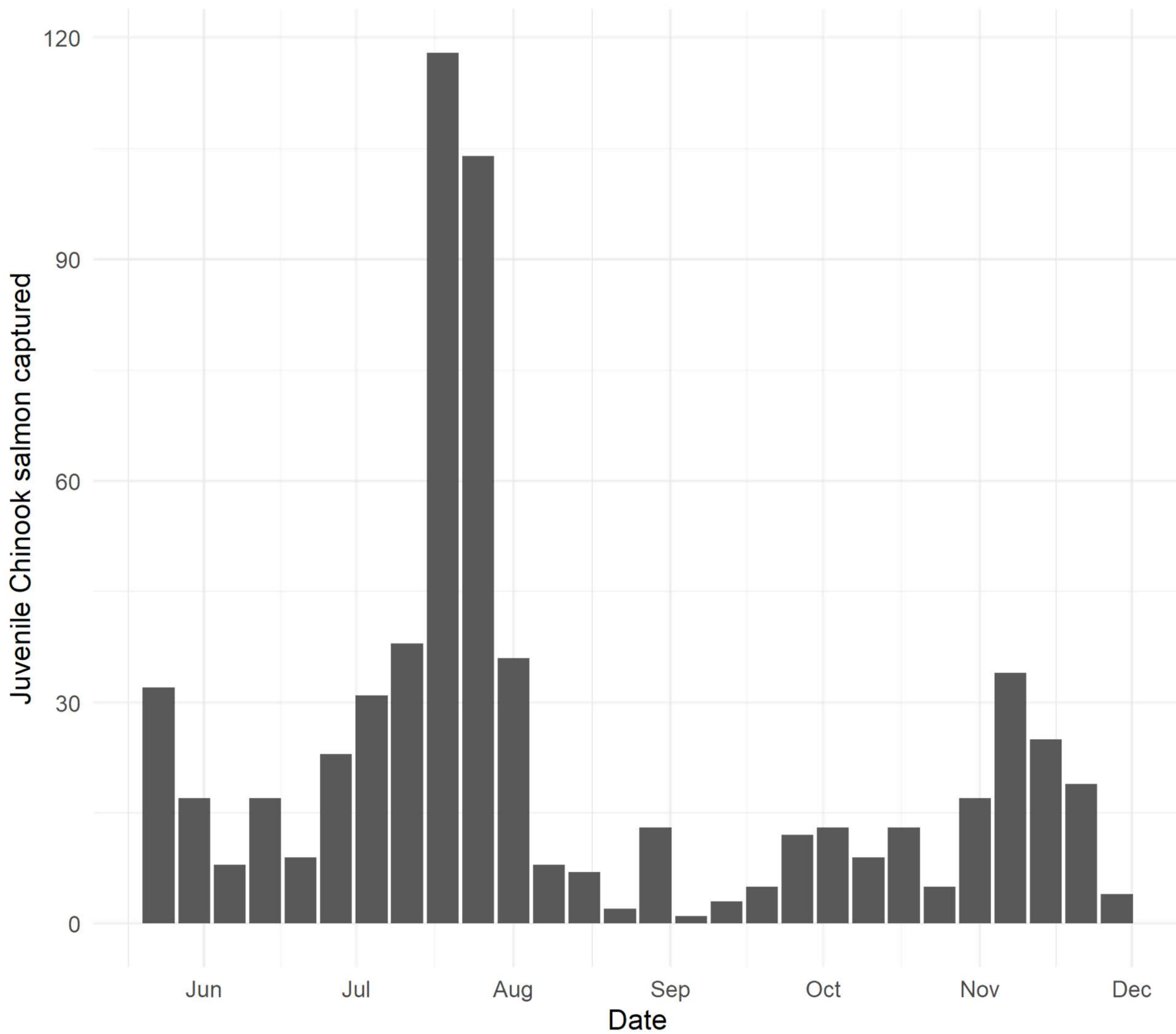

Figure 14. Weekly catch of juvenile Chinook salmon captured in the Big Cliff trap below Big Cliff Reservoir, 2021.

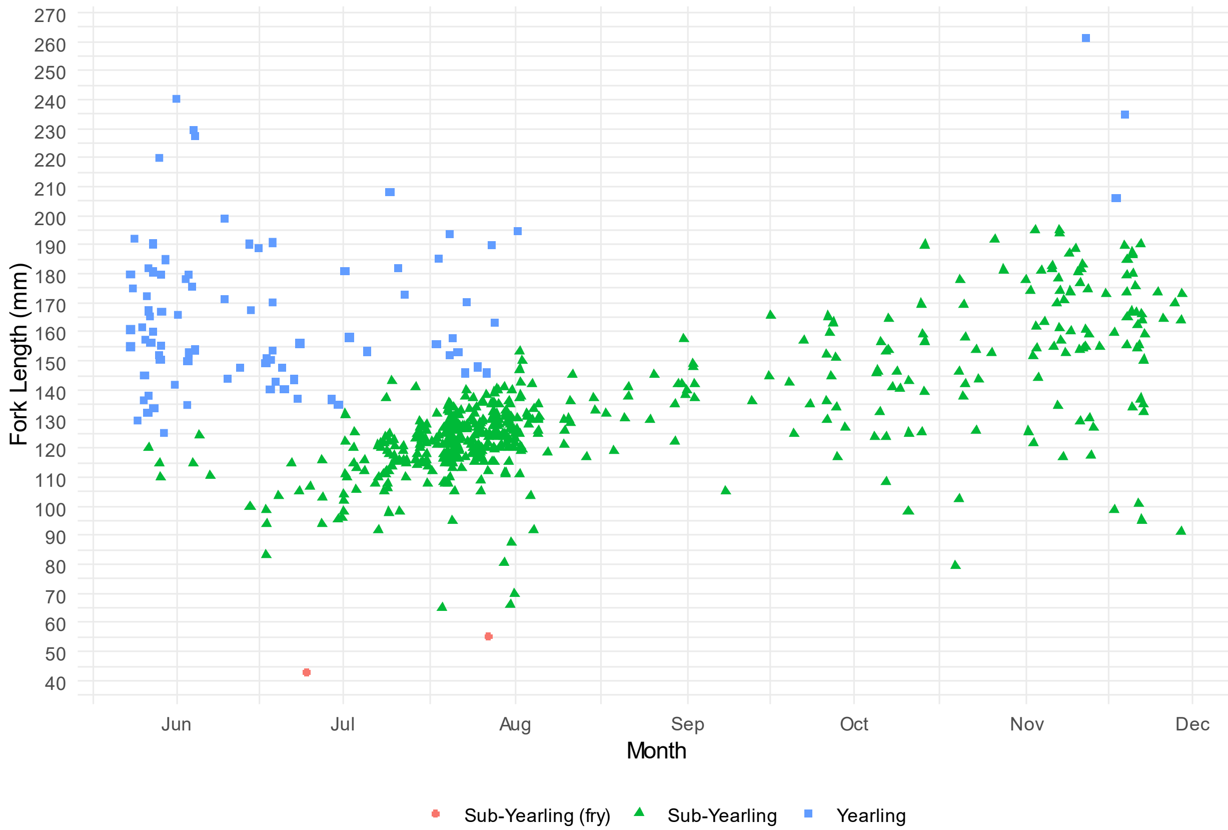

Figure 15. Fork lengths and capture dates of four age classes of juvenile Chinook salmon captured in the Big Cliff trap below Big Cliff Reservoir, 2021. Blue squares represent yearlings, green triangles represent sub-yearlings and red points represent fry.

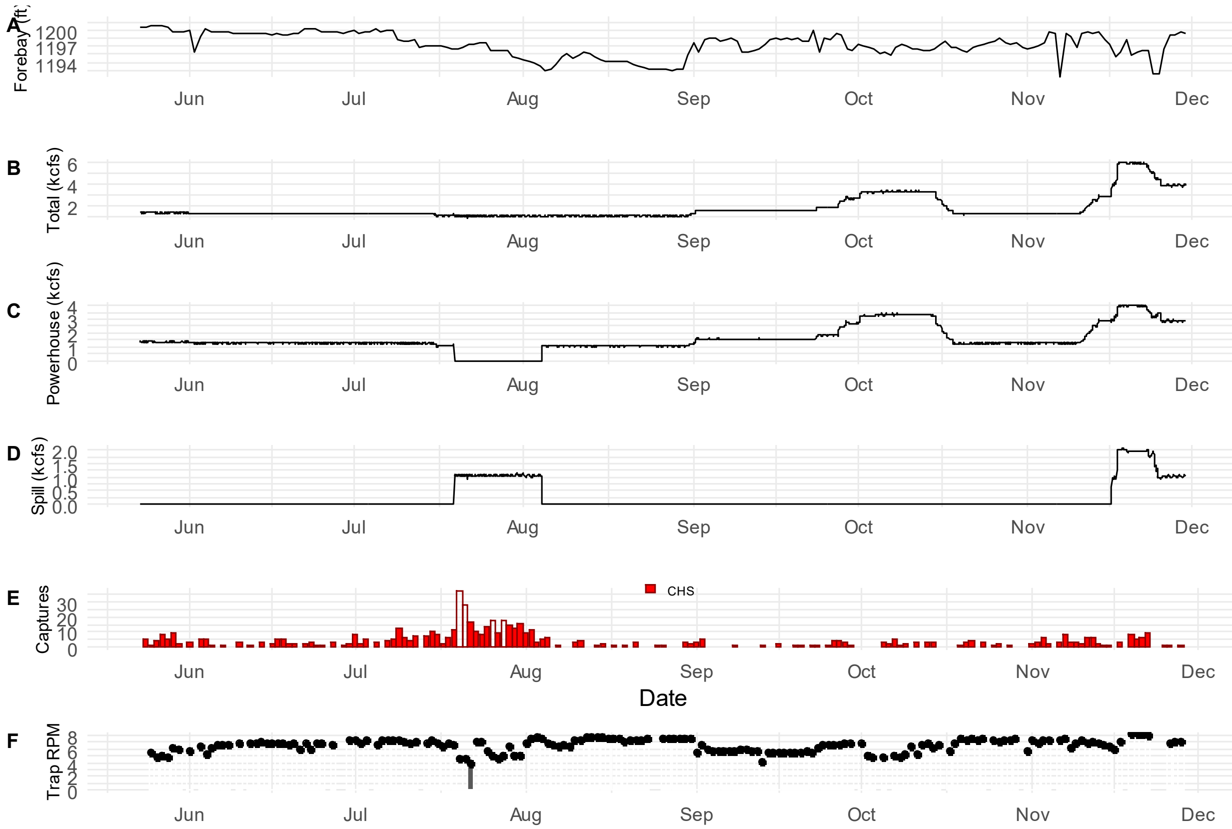

Figure 16. Forebay elevation (panel A), total outflow (panel B), powerhouse flow (panel C), spill (panel D), captured Chinook salmon (panel E), and trapping effort (panel F) below Big Cliff Dam, 2021. Trapping effort is calculated as trap revolutions divided by the number of minutes elapsed since the trap was last checked. RL and RR stand for river left and river right, respectively.

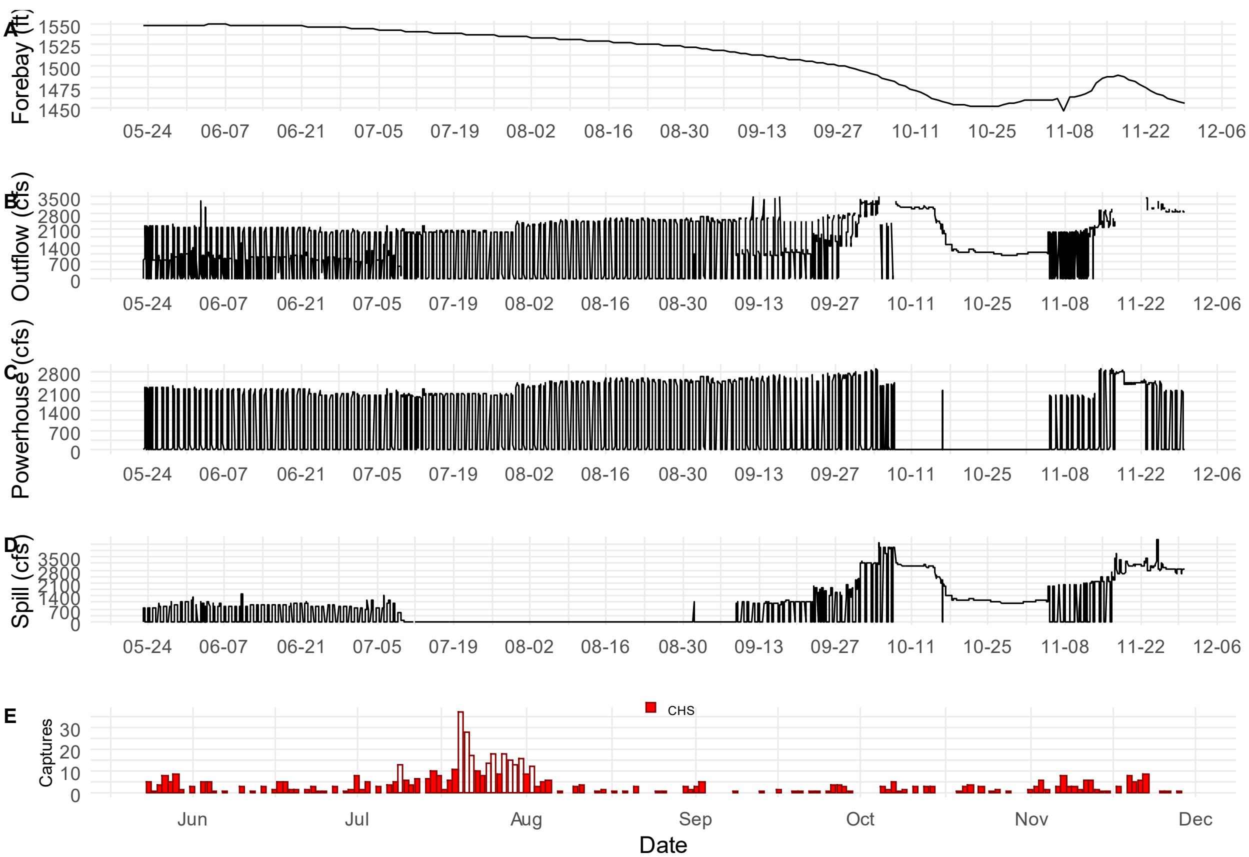

Figure 17. Forebay elevation (panel A), total outflow (panel B), powerhouse flow (panel C), and spill (panel D) at Detroit Dam, along with the number of Chinook salmon captured below Big Cliff Dam (panel E), 2021.

Trap Efficiency

We conducted a total of seven trap efficiency trials using hatchery reared Chinook salmon below Big Cliff Dam (**Table 21**). The first trial took place shortly after the trap was installed and consisted of the release of 543 yearlings averaging 159 mm. Hatchery fish were not available again until July when we released a group of 454 sub-yearlings averaging 66 mm. A disease outbreak during the summer eliminated the availability of hatchery reared fish until October. Beginning on October 5, 2021 we conducted bi-weekly trap efficiency trials until the end of the monitoring period. The low number of fish used for the final release group was due to there being no more fish at the hatchery. Trap efficiency estimates calculated from recaptures of hatchery reared salmon ranged from 0% - 13.3% (mean = 4.2%) for the season. We had adequate trap efficiency estimates from run-of-river fish during the period of peak migration (July 4th – August 8th) and estimate that a total of 4,066 juvenile Chinook salmon migrated past the trap during that period (95% CI: 2,489 – 8,507).

Table 21. Results of trap efficiency trials conducted with ODFW hatchery reared Chinook salmon at the Big Cliff dam site, 2021.

Date	Site	Route	Species	Mean Length (mm)	Released	Recaptured	Efficiency (%)
5/26/2021	BCL	PH	HCHS	159	543	8	1.5
7/9/2021	BCL	PH	HCHS	66	454	21	4.6
10/5/2021	BCL	PH	HCHS	93.3	446	23	5.2
10/12/2021	BCL	PH	HCHS	93	450	9	2
10/25/2021	BCL	PH	HCHS	97.5	450	60	13.3
11/9/2021	BCL	PH	HCHS	106	450	14	3.1
11/25/2021	BCL	PH	HCHS	115.3	182	0	0

Condition

We observed a total of 540 fish (91% of total catch) exhibiting at least one of 15 unique adverse conditions (**Table 22**, **Figure 18**). The most common adverse conditions were copepod infections (n = 479; 81% of total catch), descaling over less than 20% of the body (n = 104; 18% of total catch), and descaling over more than 20 percent of the body (n = 41; 7% of total catch). There were 196 individuals that exhibited an adverse condition but were not infected with copepods (32% of total catch). Adverse conditions were least common during the period spanning from July through August, particularly non-copepod conditions (**Figure 18**). There was a total of 37 mortalities for the season (6% of total catch). Mortality rate across age-classes was greater for yearlings than it was for sub-yearlings (**Figure 19**).

Table 22. Injuries sustained by juvenile Chinook salmon from different age classes (sub-yearling fry, sub-yearling, yearling, and Age-2) captured at the Big Cliff site, 2021. BLO = bloated, BO = body only, BRU = bruising, BVT = bleeding from vent, COP = copepods (gills and fins), DS<20 = descaling less than 20%, DS>20 = descaling more than 20%, EYB = bloody eye – (hemorrhage), FID = fin damage, FUN = fungus, FVB = fin blood vessels broken, GBD = gas bubble disease, HBA = hole behind anal fin, HBP = hole behind pectoral fin, HBV = hole behind ventral fin, HIN = head injury, MORT = mortality, NXI = no

existing injuries, OPD = opercula damage, POP = pop eye – exopthalmia, PRD = predation (claw or teeth marks), and TEA = body injury (tears, scrapes, etc.).

Site	Species	Age Class	Condition Code	Observations
Big Cliff	CHS	Sub-Yearling (fry)	DS>20	1
			NXI	1
		Sub-Yearling	COP	414
			DS<20	82
			NXI	54
			DS>20	36
			FID	31
			OPD	27
			BRU	23
			TEA	20
			MORT	19
			EYB	13
			FVB	6
			BVT	2
			POP	2
			BO	1
			FUN	1
			HIN	1
		Yearling	COP	65
			DS<20	22
			MORT	17
			FID	5
			DS>20	4
			TEA	4
			EYB	3
			NXI	3
			FUN	1
			OPD	1
			POP	1

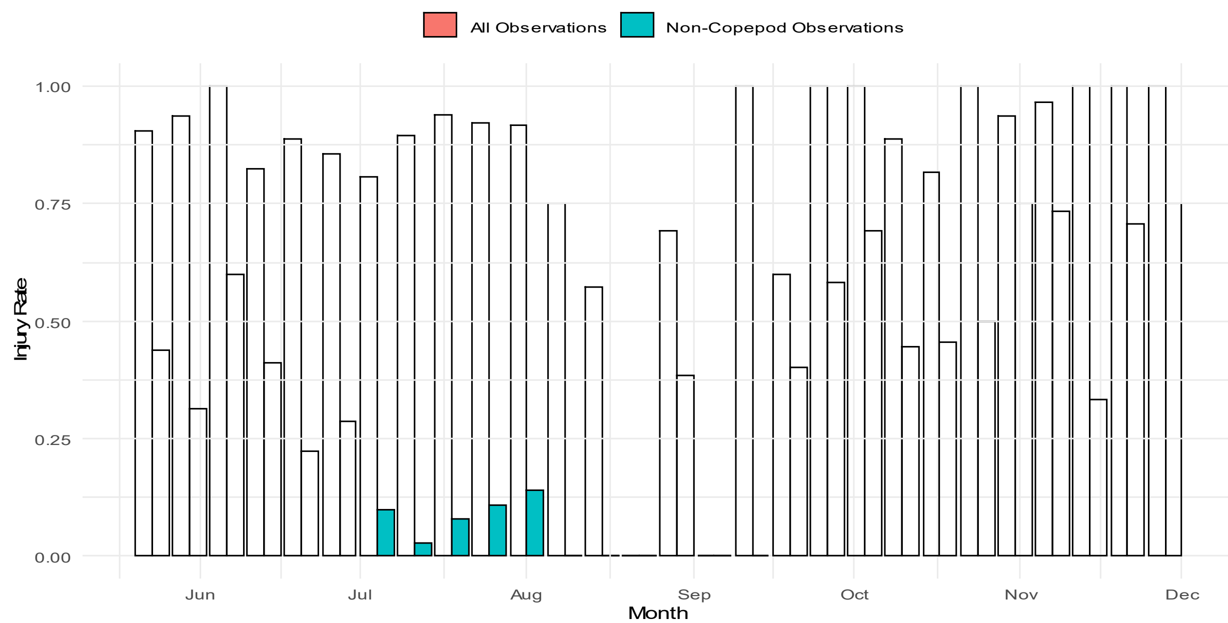

Figure 18. Weekly injury rate observed in juvenile Chinook salmon captured below Big Cliff Dam, 2021. Red bars depict the injury rate with the presence of copepods counting as an injury. Blue bars depict the injury rate not including copepods.

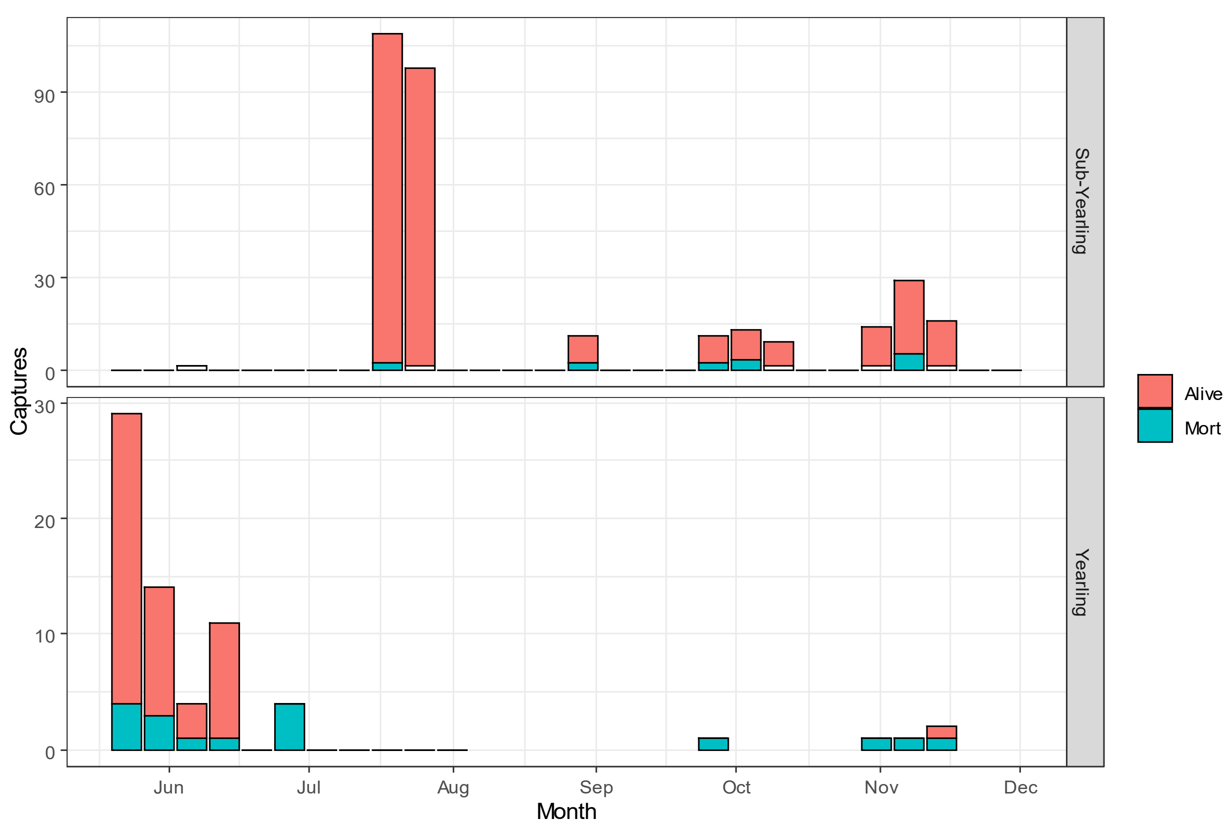

Figure 19. The number of juvenile Chinook salmon captured below Big Cliff Dam that were alive (red) or dead (blue) by age class (sub-yearling vs. yearling), 2021.

Copepods

Copepod infections were the most common adverse condition observed in juvenile Chinook salmon caught below Big Cliff Dam. The rate at which we observed infected individuals was fairly constant throughout the season with monthly infection rates averaging 0.79 and ranging from 0.70 to 0.85 (**Table 23**). The average number of copepods observed in the brachial cavity ranged from 3.4 – 6.4 while the average number of copepods on the fins ranged from 1.5 – 2.6. Plotting fork length versus total number of copepods suggests that larger fish tended to be infected with a greater number of copepods than smaller fish (**Figure 20**).

Table 23. Copepod infections of target species captured at the Big Cliff site, 2021. Infections are the number of fish with copepods, Rate is calculated as the number of fish with copepods divided by total catch, Gill Rate is calculated as the number of fish with copepods in their gills divided by total catch and Gill Severity is calculated as the total number of copepods observed in the gills divided by the number of fish with copepods observed in their gills (mean number of gill copepods). Fin metrics were calculated using the same method, but with copepods observed on the fins.

Month	Site	Fish Inspected	Infections	Infection Rate	Gill Rate	Fin Rate	Gill Severity	Fin Severity
May	BCL	34	27	0.79	0.71	0.35	5.2	2.2
Jun	BCL	51	36	0.71	0.51	0.51	6.4	2.6
Jul	BCL	329	279	0.85	0.77	0.57	3.4	1.9
Aug	BCL	66	54	0.82	0.76	0.56	4.1	1.9
Sep	BCL	30	21	0.70	0.63	0.47	5.9	1.5
Oct	BCL	38	31	0.82	0.82	0.24	4.5	2.2
Nov	BCL	86	72	0.84	0.83	0.30	6.0	1.8

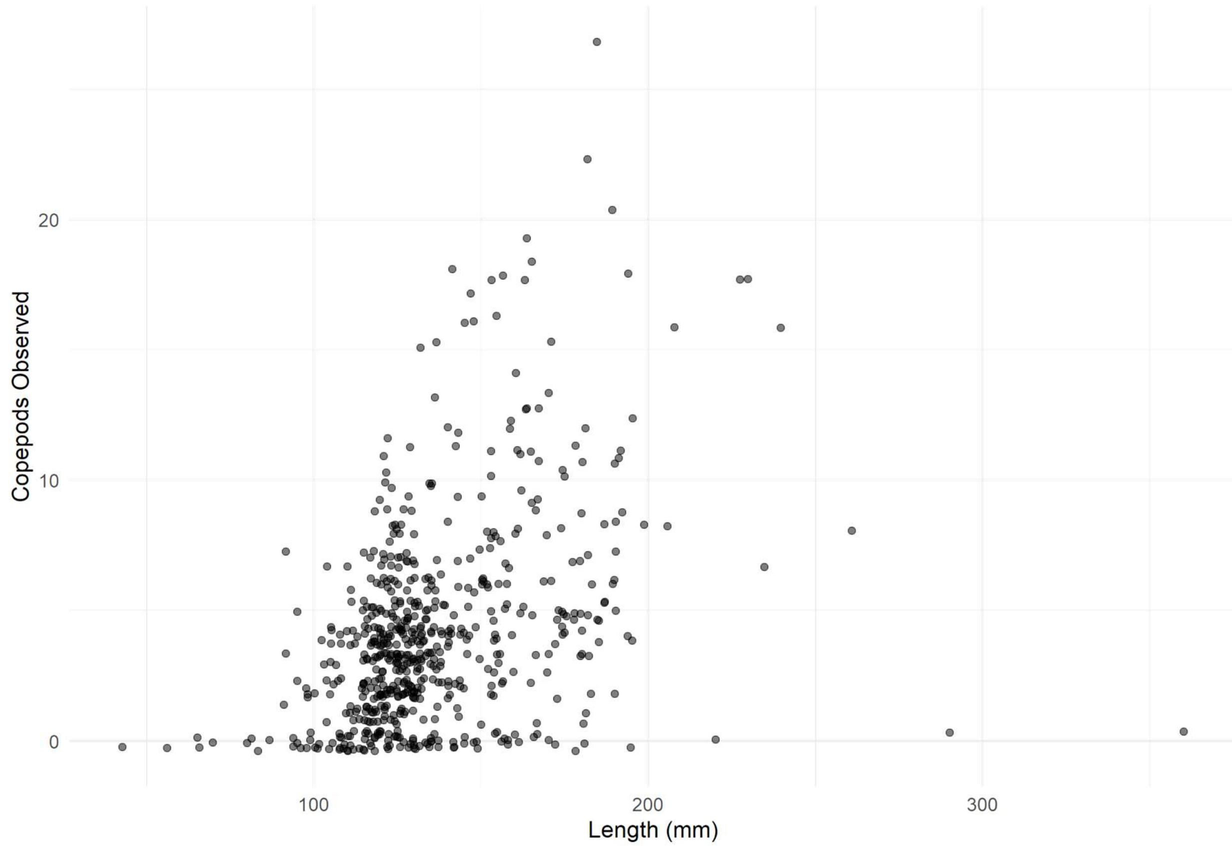

Figure 20. Fork length versus the number of individual copepods observed on the gills and fins of juvenile Chinook salmon caught below Big Cliff Dam.

Non-target species

In addition to Chinook salmon we captured an additional seven non-target species. Pumpkinseed were the most abundant non-target species encountered, followed by rainbow trout, and kokanee salmon (**Table 24**).

Table 24. Non-target species captured at the Big Cliff site, 2021. BLG = bluegill, COT = sculpin, HCHS = hatchery Chinook salmon, HRBT = hatchery rainbow trout, KOK = kokanee, MWF = mountain whitefish, PKS = pumpkin seed, RBT = rainbow trout.

Site	Species	Total Catch
Big Cliff	PKS	2,152
	RBT	95
	KOK	30
	HCHS	18
	COT	3
	HRBT	3
	MWF	1

Discussion

Fall Creek

There has been one previous study evaluating outmigration timing of juvenile Chinook salmon above Fall Creek Reservoir. Keefer et al. (2012, 2013) operated a single 2.4-meter trap above Fall Creek Reservoir from 2005 – 2008. During that period, they captured 9,273 juvenile Chinook salmon and reported trapping an average of 17.9 juvenile salmon per day. Catch was dominated by sub-yearling fry averaging 34 mm fork length and peak catch rates occurred from February through March. We began sampling at Fall Creek on March 10th, missing over a month of when peak passage occurred historically. We captured 424 juvenile Chinook during 83 days of monitoring (March 10 – June 1) for an average catch rate of 5.2 salmon per day. The sub-yearling fry that we captured averaged 35 mm, nearly identical to the findings of Keefer et al (2012). The late trap installation, combined with the relatively low catch and catch rate, suggests that peak emigration of juvenile Chinook from Fall Creek in 2021 likely occurred before we started monitoring. Future monitoring and trap-and-haul efforts (if conducted) should strive to have the trap installed and operational by late January to maximize the likelihood of capturing the peak migration.

Lookout Point

Keefer et al. 2012, reports on downstream rotary screw trap sampling from 2007 to 2010. In the span of these four years the traps operated for a total of 715 days during which they captured 528 juvenile Chinook salmon and calculated their trapping rate to be 0.7 salmon per day. More recently Romer et al. (2012 – 2016) reported the data from the rotary screw trap monitoring by the USACE below Lookout Point Dam from 2011 to 2015. Over the span of 5 years the traps operated for a total of 1,248 days, they captured a total of 343 unmarked native juvenile Chinook salmon with a trapping rate of 0.3 salmon per day. Our traps fished for 121 days, and we captured a total of 18 juvenile Chinook salmon our tapping rate was 0.1 salmon per day.

Prior to 2011, juvenile Chinook salmon exit Willamette Valley Project dams as sub-yearlings in late fall and winter ranging from October to February, related to reservoir drawdown and lowered pool elevation. Keefer et al. 2013 suggests that dam passage is restricted to late fall and winter when reservoirs are drawn down to the annual low flows allowing migrating salmon to find passage routes more easily through the dam. Keefer et al. 2012 found when reservoir elevation decreased, they observed an increase in the catch rates below the dam. Lookout Point at full pool elevation is 285 m, they observed the highest catch rate of 2.3 salmon per day at a pool elevation of ~255 m. They captured almost no salmon when the elevation was above 260 m, except during spill operations. Over the four-year period they found the highest percentage of migrants from November to February were in the 80 – 150 mm size class range (54%) followed by the 160 – 250 mm size class (38%), 260 – 380 mm (8%), and 30 – 50 mm (~1%). On average the sub-yearlings migrating in November were largest at LOP compared to other WVP sites (212mm FL) (Romer et al. 2012-2016). Our nine sub-yearlings captured in June had an average size of 106 mm.

Lookout Point is the exception to the typical migration period of October to February. In 2008, there was a change in dam operations which altered the peak capture timing, with a May regulating outlet spill event that contributed to 13% of the total Chinook capture that occurred over the four-year sampling period (Keefer et al. 2012). This demonstrates how migration through reservoirs and dams is constrained by dam operational conditions, like summer spill operations for downstream temperature control. The increased spill operations in summer months are atypical of the historical flow regimes and have altered the migration timing for Lookout Point juvenile salmonids, increasing the number of Chinook captured in May and June (Romer et al. 2012-2014). From 2012 to 2015, there has been a decrease in the number of Chinook captured below Lookout Point Dam. Romer et al. 2015 was unable to evaluate migration timing due to not operating the trap after February. The following year Romer et al. 2016 reported 10 yearling Chinook captured in January and February, the trap did not operate from June 23 - September 9 due to a malfunction and delayed repairs, after the repairs were finished the trap fished normally through December 1st, which typically was an increased migration period and unusual to not capture any fish. Our capture timing was similar to previous years with the highest capture rate taking place during spill operations. We captured six yearling Chinook in April and did not capture another Chinook until two months later during June when we captured nine sub-yearlings and two yearlings. The relatively high catch during June was coinciding with dam spill operations. We did not operate the trap after July 19th due to warm water conditions, so late fall and winter passage catch was not evaluated.

Keefer et al. 2012 observed an increase in mortality with an increase in salmon fork length, suggesting that larger salmon are more susceptible to injuries such as mechanical damage and barotrauma when passing through the dam when compared to smaller individuals. The common injuries for salmon mortalities caught below dams that they noticed were bruising, descaling, decapitation, and swim bladder issues and these varied with dam operational changes and passage routes. Over the sampling period 25.2% of the Chinook captured were mortalities, mortality was seen to increase with increases in reservoir elevation, total discharge, spill operations and size of fish. In our small sample size, we saw two fish with fin damage and three mortalities (17% of total catch). The mortalities we saw agree with what Keefer et al. 2012 observed, that larger fish have an increased mortality rate, the mortalities included two yearling (average 143 mm) and one Age-2 (average 322 mm) Chinook salmon.

Keefer et al. 2012 conducted trap efficiency tests over a seven-day period ranging from November to January in 2009-2010. They released 8,892 alive and 8,800 dead hatchery Chinook salmon of the 90 – 150 mm size class above the dam in turbine outwashes and turbine outlets. For the live salmon, capture efficiencies ranged from 0.00% - 1.87% and the dead salmon capture efficiencies ranged from 0.00% - 0.08%. They suggest the trap efficiency for the dead salmon was poor due to the way a dead salmon moved through the water column, potentially sliding along the substrate below the traps. Our trap efficiency was estimated from our two trials, one of which showed a slightly higher trap efficiency rate to what was seen by Keefer et al. 2012 with 0.3% and ~0.1% for our two release groups. The low trap efficiency could be due to multiple reasons including trap positioning, fish release locations and dam operations.

Cougar

The Oregon Department of Fish and Wildlife (ODFW) used rotary screw traps to monitor passage of juvenile Chinook salmon at Cougar dam from 2011 – 2016 (Romer et al. 2012 – 2017). During those years ODFW monitored fish passage year-round. In contrast, results presented in this report are based on only 250 days of monitoring from late-March through November. Therefore, it is not surprising that this season's catch of 2,732 juvenile Chinook salmon, while well within in the range of historical catch (1,317 – 4,566), fell 440 fish short of the 3,172 fish historical average. ODFW's results showed that catch was primarily composed of the sub-yearling age class. In fact, their results from 2012 – 2016 show that sub-yearlings represented 85 – 95% of the total catch. Results from this year reflect those historical findings as sub-yearlings represented 87% of the fish caught during 2021.

There have been several studies that have reported overall migration rates past Cougar Dam peaking in the fall as reservoir elevation decreases and discharge from the dam increases (Hansen et al. 2017). We observed the same pattern during 2021, with peak migration occurring during October as forebay elevation decreased and discharge increased. Romer et al. (2012-2017) report that the majority of yearlings pass Cougar dam in the spring while the majority of sub-yearlings emigrate in the fall. For example, Romer et al. (2015) reported that 83% of the sub-yearlings encountered below Cougar in 2014 were caught during November. Due to when monitoring began this year, it is not possible to fully evaluate if the peak emigration of yearlings and sub-yearlings were consistent with historical findings. However, if we assume that the catch patterns we observed in April – June (i.e., moderate – low catch of yearlings and sub-yearlings; **Figure 9**) are similar to what may have occurred from January through March 24th , then our results are somewhat surprising because the majority of yearlings we caught this year were caught in fall.

Several studies have reported observing a greater rate of injury and mortality for fish passing via the regulating outlet versus those passing the powerhouse (e.g., Taylor 2000; Romer et al. 2012, 2013). The same pattern existed during 2021; of the mortalities we observed at Cougar Dam, 97.6% were captured in the regulating outlet. Taylor (2000) reported that 7% of all fish that passed Cougar died passing the powerhouse while 32% died passing the regulating outlet. We observed much lower mortality percentages this year with 1.7% and 10.4% of total catch being mortalities in the powerhouse and regulating outlet, respectively. The most common injuries reported by ODFW were eye hemorrhaging, gas bubble disease, opercle damage, and severe descaling. Our findings were similar with copepod infection to be the most common adverse condition, followed by severe descaling, minor descaling, fin damage and opercle damage. Copepod infection rates of fish captured below Cougar Dam were not reported by ODFW. However, Monzyk et al. (2015) reported that 85 percent of sub-yearlings and 95% of yearlings caught in Cougar reservoir during 2012 and 2013 were infected by copepods. Therefore, it would not be surprising if copepod infection was one of the primary adverse conditions observed in fish caught below Cougar dam historically. Many of the historical ODFW reports note that mortality rate increased with fish size (e.g., Taylor 2000, Romer et al. 2012). While we did not explicitly compare fork length to mortality probability, we did observe a higher mortality rate in yearlings (mean fork length: 187 mm) compared to sub-yearlings (mean fork length: 127).

There have been at least two studies that evaluated delayed mortality rates at Cougar Dam (Hansen et al. 2017). Zymonas et al. (2011) reported that the mortality rates associated with fish held for 72 hours were 0.36 for those that passed via the regulating outlet and 0.19 for fish that passed via the powerhouse. Conversely, Normandeau and Associates (2010) held fish for 48 hours and reported mortality rates ranging from 0.12 – 0.15 for the regulating outlet and 0.58 – 0.64 for the powerhouse. Results of this year's post-capture holding study fell within the range of mortality observed historically for fish passing Cougar via the regulating outlet (mean: 0.21; range: 0.04 – 0.36). Discharge during the 24-hour post capture holding trials was almost entirely through the regulating outlet and we were therefore unable to make comparisons of delayed mortality for fish passing through the powerhouse.

Big Cliff

There have been a number of studies evaluating passage at the Detroit and Big Cliff projects (Hansen et al. 2017). ODFW used rotary screw traps to monitor passage of juvenile Chinook salmon at Detroit Dam from 2011 to 2014 (Romer et al. 2012 – 2015). They captured an average of 150 juvenile Chinook salmon across those years and noted that peak migration typically occurred during the fall. ODFW's trap below Detroit was badly damaged by high flows early in 2014 and was removed on March 6. Upon re-installation, ODFW opted to change monitoring locations and installed a 1.5-meter screw trap below Big Cliff on April 1, 2014. They would go on to operate a screw trap below Big Cliff from 2014 – 2016, monitoring fish passage at Big Cliff for an average of 310 days per year while capturing an average of 155 juvenile Chinook salmon per year. ODFW reported that peak migration past Big Cliff, like peak migration past Detroit, occurred during the fall in 2014 and 2015. Surprisingly, Romer et al. 2017 reported that peak migration shifted from the fall to the summer in 2016. In contrast with previous screw trap monitoring efforts, we operated a larger 2.4-meter screw trap below Big Cliff Dam for 186.5 days and captured 594 juvenile Chinook salmon. We captured 128 more juvenile Chinook salmon in 2021 than was captured in total by ODFW from 2014 - 2016. While we would expect to catch more fish using a larger trap, the magnitude by which catch increased came as a surprise. Another interesting finding this year was that peak catch occurred during the summer which is a pattern that was reported only once (2016) while ODFW was monitoring at Detroit and Big Cliff (Romer et al. 2017).

Our results provide some evidence of a pattern between dam operations at Detroit and the timing of juvenile Chinook salmon passage at Big Cliff. Beeman and Adams (2015) used acoustic telemetry to monitor downstream movements of tagged fish through the Detroit/Big Cliff project in 2014. They found that the highest proportion of tagged fish passed Detroit in the spring during spill operations (as opposed to the fall which was when ODFW reported experiencing the peak catch below Detroit). Beeman and Adams (2015) also reported a median migration rate of 0.12 – 0.24 miles/day for the 2.8 mile stretch between the Detroit tailrace and the Big Cliff forebay. If we extrapolate that rate, the median travel time through Big Cliff reservoir could be up to 23 days. In 2021, spill operations took place at Detroit from May 23 – July 9. If we assume that passage of juvenile Chinook salmon at Detroit was highest during spring spill, and we assume a median travel time through Big Cliff reservoir of 23 days, then we could also assume that the majority of juvenile salmon would have arrived at the Big Cliff forebay between June 15th and August 1st. As it happens, we observed an increase in catch rate that began on July 1st and peaked between July 20 and August 1. Peak catch below Big Cliff also coincided with the first spill operations of the season at Big Cliff. In fact, the highest daily catch for the season occurred on the very first day of spill operations (07-20-2021; n = 37) which suggests that fish were concentrated in the forebay prior to spill operations commencing. Results from this year lend some support to past findings of high springtime, spill-based, passage at Detroit followed by a relatively long navigation of Big Cliff reservoir.

The available historical reports provide very little information about the condition of juvenile Chinook salmon that pass through Big Cliff. In 2014, ODFW observed very high mortality during April and May (92%; Romer et al. 2015). This high mortality event coincided with spill operations which lead to elevated levels of total dissolved gas (mean: 124%, range: 117 – 130%) and evidence of gas bubble trauma in captured fish. In 2015 spill operations did not start until December 5th but ODFW reported that all the salmonids caught after that date showed signs of gas bubble trauma (Romer et al. 2016). While there were significant spill events during 2021, both in the spring as well as the fall, we did not observe a single fish with signs of gas bubble trauma. Analysis of total dissolved gas below Big Cliff dam suggest that levels never exceeded 120% during 2021. These results suggest that Interim Measure 6 has had a positive effect on water quality below Big Cliff Dam. Interim Measure 6 states that the Corps will operate multiple spillway gates at Big Cliff Dam to spread total flow across the spillway and reduce total dissolved gas levels below Big Cliff Dam. 2014 and 2015 were the only years ODFW reported on fish condition and there was no mention of injuries other than gas bubble disease.

Copepod infections

Pacific salmon and trout of the genus *Oncorhynchus* are particularly susceptible to infection from the freshwater ectoparasitic copepod *Salmincola californiensis* (Kabata, 1969). This copepod is an increasing concern for juvenile Chinook salmon in the Willamette River basin, as high prevalence has been seen in reservoirs above WVP dams (Beeman et al., 2015; Monzyk et al., 2015; Herron et al. 2018). *S. californiensis* has been reported to impact fish condition leading to gill damage and reduced swimming ability (Herron et al. 2018). Copepods attach to the gills, bone, or fin rays of their host (Kabata and Cousens 1973). Copepods attached in the brachial cavity have shown to more severely impact fish resulting in gill tissue damage, decreased fitness, and potentially leading to mortality (Kabata and Cousens 1977; Herron et al. 2018).

The lifecycle for *S. californiensis* consists of several stages affecting a single host fish. An adult female copepod has two egg sacs attached and these take about 1 month to hatch. Once hatched the free swimming infectious copepodids can survive for 2 days while they search for a host fish (Kabata and Cousens 1973). Copepod development has been reported to vary between cold and warm water environments where they develop more quickly in warmer waters (Neal et al. 2021). A laboratory study by Murphy et al. 2020 found that *S. californiensis* egg development was about 30% shorter at a warmer temperature of 16°C when compared to 13°C. Water temperature impacts both copepod infection rates and development timing which is seen to cause some serious implications for salmon residing in reservoirs (Vigil et al. 2015). The effects of high copepod densities combined with warm temperatures may explain why prevalence in reservoirs increases in the summer months (Hargis et al., 2014; Monzyk et al., 2015).

Monzyk et al. 2015 also showed evidence of a higher copepod prevalence and intensity in salmon reared in reservoirs compared to stream reared fish. The prevalence is defined by the percentage of fish infected with at least one adult female copepod, while the intensity is the number of copepods per infected fish. This study suggests there may be a difference in parasite prevalence between the rearing locations due to the larger size of reservoir reared fish (fork length). Multiple studies have also related a higher infection prevalence of various copepod species to larger juvenile salmonid size (Poulin et al. 1991; Nagasawa and Urawa 2002; Barndt and Stone 2003). In a laboratory study Poulin et al. 1991 showed a higher infection rate in larger host fish due to a larger surface area and greater exposure time. The brachial cavity is reported to be the preferred attachment site on juvenile host fish (Kabata and Cousens 1997; Monzyk et al. 2015). From our study our results also agreed with this, we saw higher gill infection intensity in the larger yearling Chinook salmon at our Cougar and Big Cliff monitoring sites. We recorded more copepods attached in the brachial cavity than on the fins.

During the sampling period we found the highest prevalence of infection in the summer months which corresponds with increased reservoir temperatures. Neal et al. 2021 found that the infection intensity increased with an increase in temperature and copepod density. They hypothesized that fish respiration rates and parasite development rates impact the prevalence of parasites in warmer water. Fish respiration increases with an increase in water temperature which leads to more water passing through the gills leading to an increase in the probability of the free-swimming infectious form of varying parasites encountering the gill surface (Neal et al. 2021). This is consistent with a previous study that showed increased ventilation in fish can lead to an increase in parasite prevalence (Mikheev et al. 2014).

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Appendices

Appendix A – Trap Locations

A-1 Big Cliff-

Figure A- 1. Rotary screw trap location below Big Cliff Dam, 2021. Red circle indicates trap fishing location (2.4 m trap positioned river left (top right photo).

A-2 Cougar-

Figure A- 2. Rotary screw trap locations below Cougar Dam, 2021. Red circles indicate trap fishing location (two 2.4 m traps in the powerhouse/tailrace channel (PH; river right) and a 1.5 m trap in the regulating outlet (RO; river left).

A-3 Lookout Point-

Figure A- 3. Rotary screw trap locations below Lookout Point Dam, 2021. Red circles indicate trap fishing location (two 2.4 m traps in the powerhouse channel (river right) and a 2.4 m trap in the surface and RO spillway channel (river left).

A-4 Fall Creek-

Figure A- 4. Rotary screw trap location upstream of Fall Creek Dam and Reservoir. Red oval indicates approximate trapping location in upper Fall Creek (2.4 m trap was positioned river right during monitoring period).

Appendix B – Field Photos

B-1 Fall Creek Above-

Figure B-1a. Spring passage – sub-yearling fry (March 13th – 33mm FL)

Figure B-1b. Spring passage – yearling smolt (March 24th – 123mm FL)

Figure B-1c. Spring passage - sub-yearling parr (May 9th - 80mm FL)

Figure B-1d. Rainbow Trout (RBT) (April/May - 175mm, 122mm, 187mm)

Figure B-1e. Steelhead (STH) (April – 219mm, 175mm, 188mm)

B-2 Lookout Point-

Figure B- 2a. Figure B-5a. Spring passage – yearling smolt (April 19th – 108mm FL)

Figure B-2b. Summer passage- yearling smolt (June 15th – 175mm FL)

B-3 Big Cliff-

Figure B-3a. Summer passage – yearling smolt (June 4th – 227mm FL)

Figure B-3b. Summer passage – sub-yearling smolt (July 10th – 116mm FL)

Figure B-3c. Fall passage – sub-yearling smolt (November 12th – 155mm FL)

Figure B-3d. Fall passage – sub-yearling smolt (October 26th – 192mm FL)

Figure B-3e. Kokanee (November 19th – 255mm FL)

Figure B-4c. Fall passage – *ye*arling smolt / RO (October 6th – 194mm FL)

B-4 Cougar-

Figure B-6a. Spring passage – yearling smolt (May 18th – 129mm FL)

Figure B-4b. Summer passage – sub-yearling parr (August 15th – 76mm FL)

Appendix C – Injury Examples

Figure C-1. Descaling greater than 20% (DS>20 – mechanical damage)

Figure C-4. Descaling less than 20% (DS<20 – mechanical damage)

Figure C-3. Bloody eye - hemorrhage (EYB – barotrauma)

Figure C-4. Bleeding from vent (BVT – barotrauma)

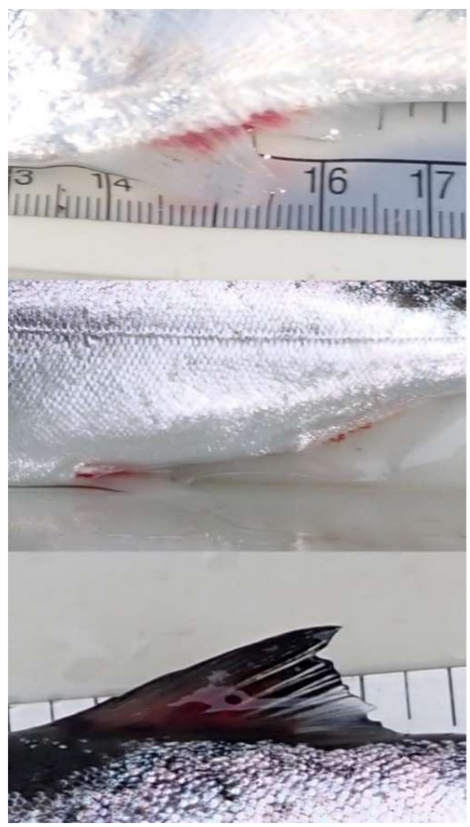

Figure C-5. Fin blood vessels broken (FVB – barotrauma)

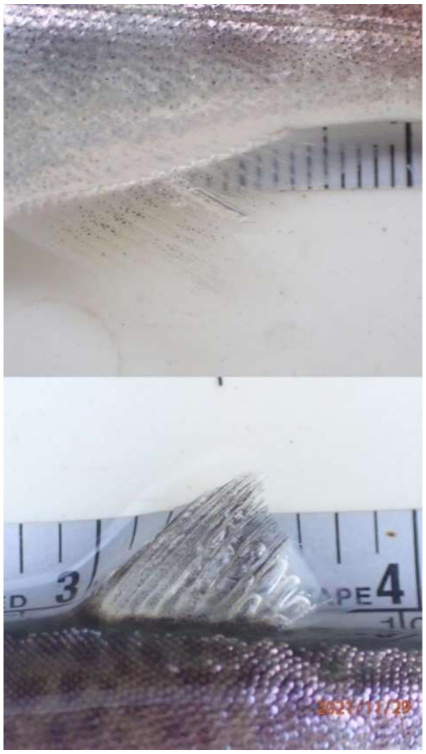

Figure C-6. Gas Bubble Disease – anal and dorsal fin rays (GBD - barotrauma)

Figure C-7 Pop eye – exopthalmia (POP – mech/baro)

Figure C-8. Opercula damage (OPD – mechanical damage)

Figure C-9. Body injury – tears and scrapes (TEA – mechanical damage)

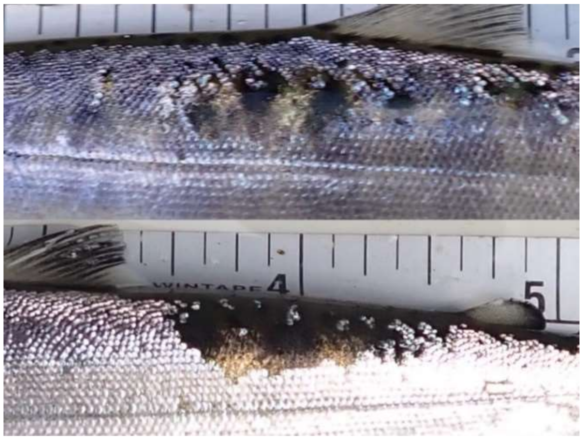

Figure C-10. Bruising (BRU – mechanical damage)

Figure C-11. Hole behind ventral / pectoral fins (HBV, HBP – mechanical damage)

Figure C-12. Body only (BO – mechanical damage)

Figure C-13. Head barely connected (HBO – mechanical damage)

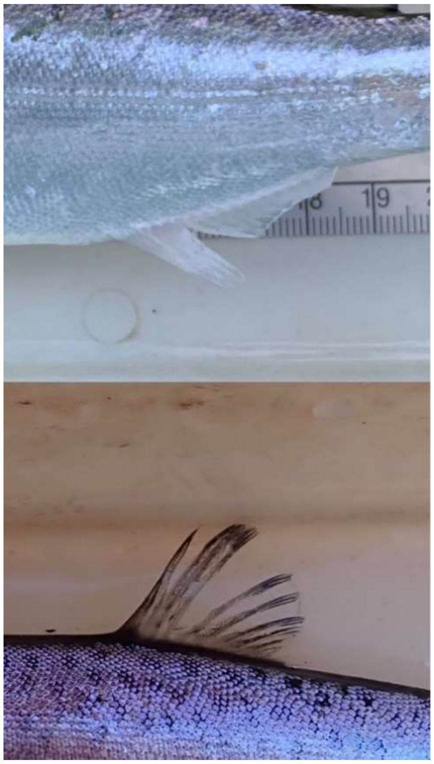

Figure C-14. Fin damage (FID)

Figure C-15. Predation marks – claw or teeth marks (PRD)

Figure C-16. Copepods – fins, one cop defined by adult w/two attached egg sacs (COP)

Figure C-17. Copepods – gills, one cop defined by adult w/two attached egg sacs (COP)