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Evaluation of Adult Fish Weirs Used to Control the Proportion of Hatchery-Origin Fall Chinook Salmon in Six Washington Lower Columbia River Tributaries, 2013-2017




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Washington Department of FISH and WILDLIFE

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Executive Summary

Chinook salmon (*Oncorhynchus tshawytcha*) in the Lower Columbia River (LCR) Evolutionarily Significant Unit (ESU) were listed under the Endangered Species Act in 1999. The Hatchery Scientific Review Group, which completed a review of hatcheries throughout the Columbia Basin, found that interactions between natural- and hatchery-origin fish on the spawning grounds was one of the key factors limiting recovery of naturally spawning populations of LCR Chinook salmon (HSRG 2009b). In 2009, the Washington Fish and Wildlife Commission adopted the Fishery and Hatchery Reform Policy, which mandated that Washington Department of Fish and Wildlife reform its hatchery operations to comply with HSRG recommendations. As a result, Washington Department of Fish and Wildlife began a series of hatchery reform and monitoring actions oriented around LCR fall Chinook salmon, including the installation and operation of river-spanning weirs. The first weir was installed on the Grays River in 2008, followed by four weirs that were operational by the fall of 2011, and an additional weir that was installed in 2015. These projects have three objectives: (1) to complement existing adult salmonid monitoring efforts, (2) to promote recovery of fall Chinook salmon by controlling the proportion of hatchery-origin spawners (pHOS) on the spawning grounds, and (3) to assist collection of hatchery broodstock. This report focuses on the effectiveness at meeting objective two for weirs operated on the Grays River for the fall of 2008-2016, the Elochoman River for the fall of 2009-2017, the Green River for the fall of 2010-2017, the Coweeman and Washougal rivers in the fall of 2011-2017, and the lower Kalama for 2015-2017. In order to measure effectiveness, we quantified weir efficiency (the proportion of the upstream population captured at a weir) and pHOS, and began to document effects of weirs on natural spawning populations. Weir efficiencies were highly variable depending on the site and year. The three sites with permanent infrastructure (Green, Kalama, and Elochoman) had weir efficiency in excess of 90% for adult fall Chinook salmon in 16 out of 20 year by location combinations. For the three sites without permanent infrastructure (Grays, Coweeman, and Washougal), weir efficiencies were in excess of 90% for only 3 of 23 year by location combinations. In terms of managing pHOS, the Kalama River Weir had the greatest success, reducing pHOS by 35-48% during its three-year evaluation period. All other locations had significantly less impact on pHOS, with Grays River Weir showing the least impact at 1-12% reduction in pHOS over its nine-year period of evaluation. Overall, pHOS levels have been trending down for many of the populations since weir operations began. However, for most populations, pHOS targets are still not being met for several reasons, including spawning below the weir sites, contributions of hatchery-origin spawners to pHOS from subpopulations without weirs, and the inability to remove unclipped hatchery-origin spawners at weirs. Additionally, we have documented several unintended consequences of weir operations, including a downstream shift in the spatial distribution of fall Chinook salmon spawners, lower apparent residence time of spawners above weirs, and clustering of spawning in areas below weirs, all of which likely result from weirs impeding migration. We have not yet quantified the effects of these impacts on the dynamics of naturally spawning populations, but these results may be harmful, potentially offsetting benefits resulting from reduced pHOS. As a result of their high efficiency, we recommend continuing status quo weir operations on Kalama, Green, and Elochoman rivers. In order to have a greater impact at reducing pHOS, we recommend investing in permanent infrastructure and acquisition of land in order to improve weir effectiveness for the Grays, Coweeman, and Washougal weirs. Finally,

we believe it is imperative to better measure and understand the population dynamic effects of weir-induced migration delays in order to determine whether weirs are able to act as a net benefit to naturally spawning populations through pHOS reduction, or instead act as a net harm to wild populations through reduced population productivity due to migration delay and redistribution of spawners.

Introduction

Chinook salmon (*Oncorhynchus tshawytcha*) in the Lower Columbia River (LCR) Evolutionarily Significant Unit (ESU) were listed for protection under the Endangered Species Act in 1999. In a recent five-year review, the National Oceanic and Atmospheric Administration (NOAA) Fisheries concluded that these fish should remain listed as threatened (NOAA 2016a). The LCR Chinook Salmon ESU is composed of spring and fall populations split between the states of Washington and Oregon (Myers et al. 2006).

The Lower Columbia Fish Recovery Board's Recovery Plan (2010) describes a recovery scenario for LCR Chinook salmon. The plan identifies each population's role in recovery as a primary, contributing, or stabilizing population generally based on its baseline viability level and the desired recovery viability level. In 2007, the Hatchery Scientific Review Group's (HSRG) memo to the Columbia River Hatchery reform Steering Committee stated that one of the key factors limiting recovery of naturally spawning populations is interaction with hatchery-origin fish on the spawning grounds. The HSRG recommended management targets of less than 5% hatchery-origin spawners for primary populations, less than 10% hatchery-origin spawners for contributing populations without integrated hatchery programs, and less than 30% hatchery-origin spawners for both primary and contributing populations with integrated hatchery programs (HSRG 2009a).

In an effort to reduce the proportion of hatchery-origin spawners (pHOS) to meet HSRG guidelines and improve abundance estimates to meet NOAA's accuracy and precision guidelines, Washington Department of Fish and Wildlife (WDFW) began installing and operating river-spanning weirs for fall Chinook salmon management in LCR tributaries in 2008. This coincided with the phased implementation of LCR fall Chinook salmon mass marking (adipose clipping of all hatchery production) which began in 2005 and was fully realized in 2012 with all age-2-6 year old returns being marked. The Grays River Weir, installed in the fall of 2008, was the first LCR weir focused on fall Chinook salmon management. In the fall of 2009, the Elochoman River Weir was added, followed by the Green River Weir in the fall of 2010 and then the Coweeman River and Washougal River weirs in the fall of the 2011, and the Kalama River Weir in the fall of 2015.

This report focuses on the effectiveness of weirs operated on the Grays River for the fall of 2008-2016, the Elochoman River for the fall of 2009-2017, the Green River for the fall of 2010-2017, the Coweeman and Washougal rivers in the fall of 2011-2017, and the Kalama River for 2015-2017. For all six weir locations, operations are primarily focused on fall Chinook salmon abundance monitoring, management, and broodstock collection (Green, Kalama, and Washougal rivers only). However, information is gathered from other returning salmonids to improve monitoring and management when possible.

At all six locations removal of known hatchery-origin fish (identified by an adipose and/or left ventral fin mark) is utilized as a tool to promote recovery of natural-origin stocks and meet management guidelines and objectives. The proportion of hatchery-origin fish removed at each weir varies to meet management goals and objectives in the basin and, in some cases, is used to evaluate hatchery reform actions. WDFW annually conducts fall Chinook salmon spawning ground surveys on the Grays, Elochoman, Green, Coweeman, Kalama, and Washougal rivers. Staff funded by these weir projects assist in these surveys to collect data necessary to estimate total abundance of fall Chinook salmon populations, estimate proportions of hatchery- and natural-origin Chinook salmon, and evaluate weir effectiveness.

These projects have three objectives: (1) to complement existing adult salmonid monitoring efforts by developing accurate and precise estimates of spawner abundance, particularly for fall Chinook salmon, (2) to promote recovery of fall Chinook salmon populations by meeting management guidelines/objectives for control of hatchery-origin Chinook salmon allowed to spawn naturally, and (3) for collection of hatchery broodstock in the Green, Kalama, and Washougal rivers for WDFWs North Toutle, Kalama Falls, and Washougal Hatcheries, respectively. In this report, we: (1) estimate weir efficiency for adult fall Chinook salmon (the proportion of the upstream population that were captured at a weir, (2) estimate how effective weirs were at reducing pHOS for adult fall Chinook salmon, (3) examine where the hatchery-origin fall Chinook salmon spawners are coming from based on coded-wire-tag recoveries, and 4) begin to document unintended weir effects of naturally spawning populations.

Methods

Study area

The LCR Chinook salmon ESU extends from the mouth of the Columbia River up to and including the Big White Salmon River in Washington and Hood River in Oregon, and includes the Willamette River to Willamette Falls, Oregon. Within this ESU, there are a total of 13 Washington populations, 8 Oregon populations, and 2 populations (Lower Gorge and Upper Gorge) that are split between the states. As of 2017, WDFW has installed temporary weirs in six of these populations in Washington for the purpose of fall Chinook salmon management: the Grays/Chinook fall Chinook population, the Elochoman/Skamokawa fall Chinook population, the Toutle fall Chinook population (Green River), the Coweeman fall Chinook population, the Kalama fall Chinook population, and the Washougal fall Chinook population (Figure 1). The Grays/Chinook fall Chinook population is comprised of two subpopulations: the Grays and Chinook, and is identified as a contributing population with pHOS target of less than 10%. Only one weir is operated within this population, located on the lower Grays River at rkm 16.50, and therefore only controlling pHOS within the Grays subpopulation. The Elochoman/Skamokawa fall Chinook population is also comprised of two subpopulations: the Elochoman and Skamokawa, and is identified as a primary population with a pHOS target of less than 5%. Only one weir is operated within this population, located on the lower Elochoman River at rkm 4.39, and is therefore only controlling pHOS within the Elochoman subpopulation. The Toutle fall Chinook population is made up of three subpopulations within the Toutle River basin: the Green River, South Fork Toutle River, and North Fork Toutle River. The Toutle population is classified as a primary population that includes an integrated hatchery program and therefore has a pHOS target of less than 30%. Only one weir is operated within this population, located on the lower Green River at rkm 0.64, and is therefore only controlling pHOS for the Green River subpopulation. The Coweeman fall Chinook population is made up of a single population and is classified as a primary population with a pHOS target of less than 5%. The weir is located on the lower Coweeman River at rkm 10.94. The Kalama fall Chinook population is made up of a single population and is classified as a contributing population with a segregated hatchery program therefore has pHOS target of less than 10%. The weir is located on the lower Kalama River at rkm 4.38. The Washougal fall Chinook population is made up of a single primary population with an integrated hatchery program and has a pHOS target of less than 30%. The weir is located on the lower Washougal River at rkm 19.15.

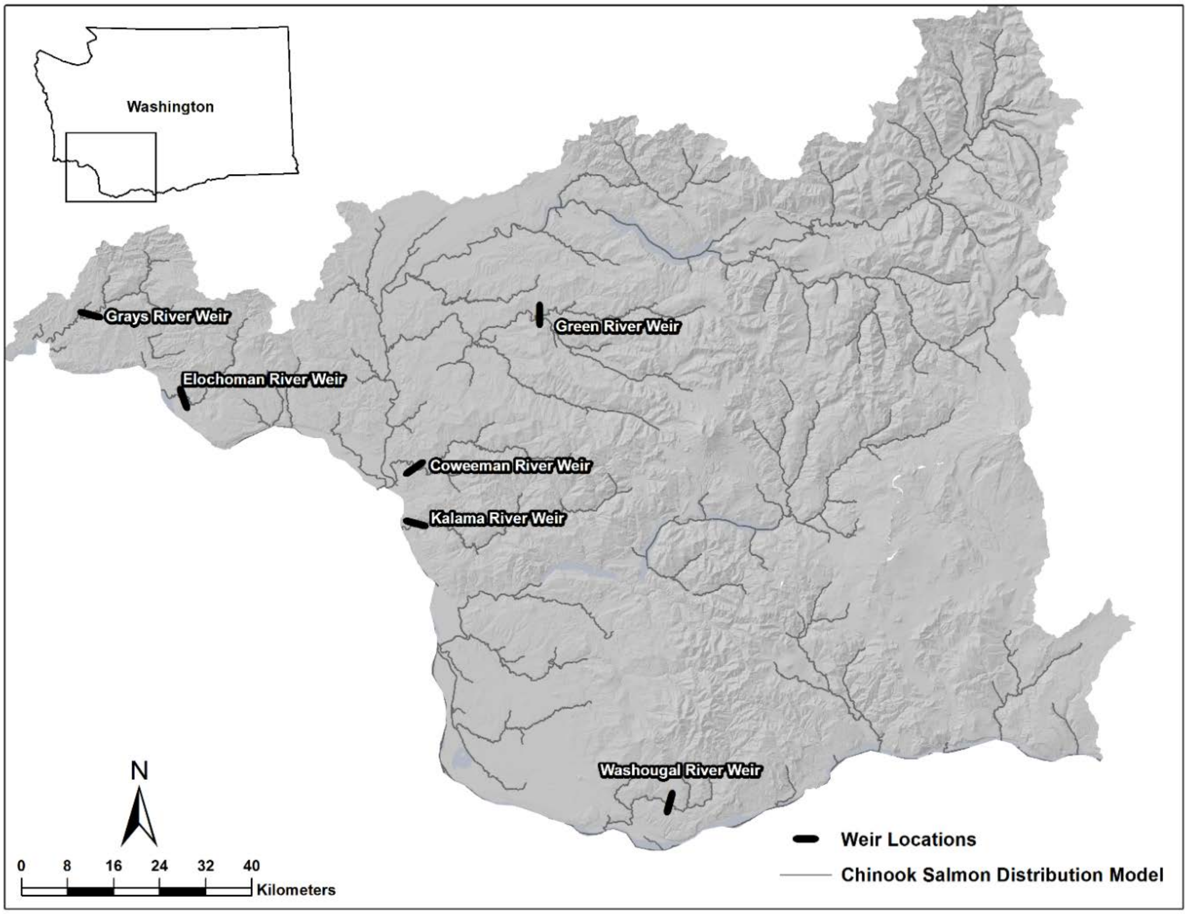

Figure 1. Location of weirs used for fall Chinook salmon management in the lower Columbia River.

Fish Capture

Weir designs varied based on the available infrastructure and goals. In general, two weir designs were used: a resistance board design and a hybrid fixed panel/resistance design. A resistance board design utilizes a floating resistance board section made of PVC pipe river-wide. It is typically anchored using duckbill anchors and cables (Figure 2). This design was used in the Grays, Elochoman, Coweeman, Kalama, and Washougal. A hybrid resistance board/fixed panel design utilizes fixed wooden panels on the perimeter and a floating resistance board section constructed primarily of PVC pipe in the center. This design was used in the Green River, which diverted fish into the North Toutle Hatchery adult holding pond. All weirs had 3.8 cm spacing to limit any size/species selectivity in weir catch.

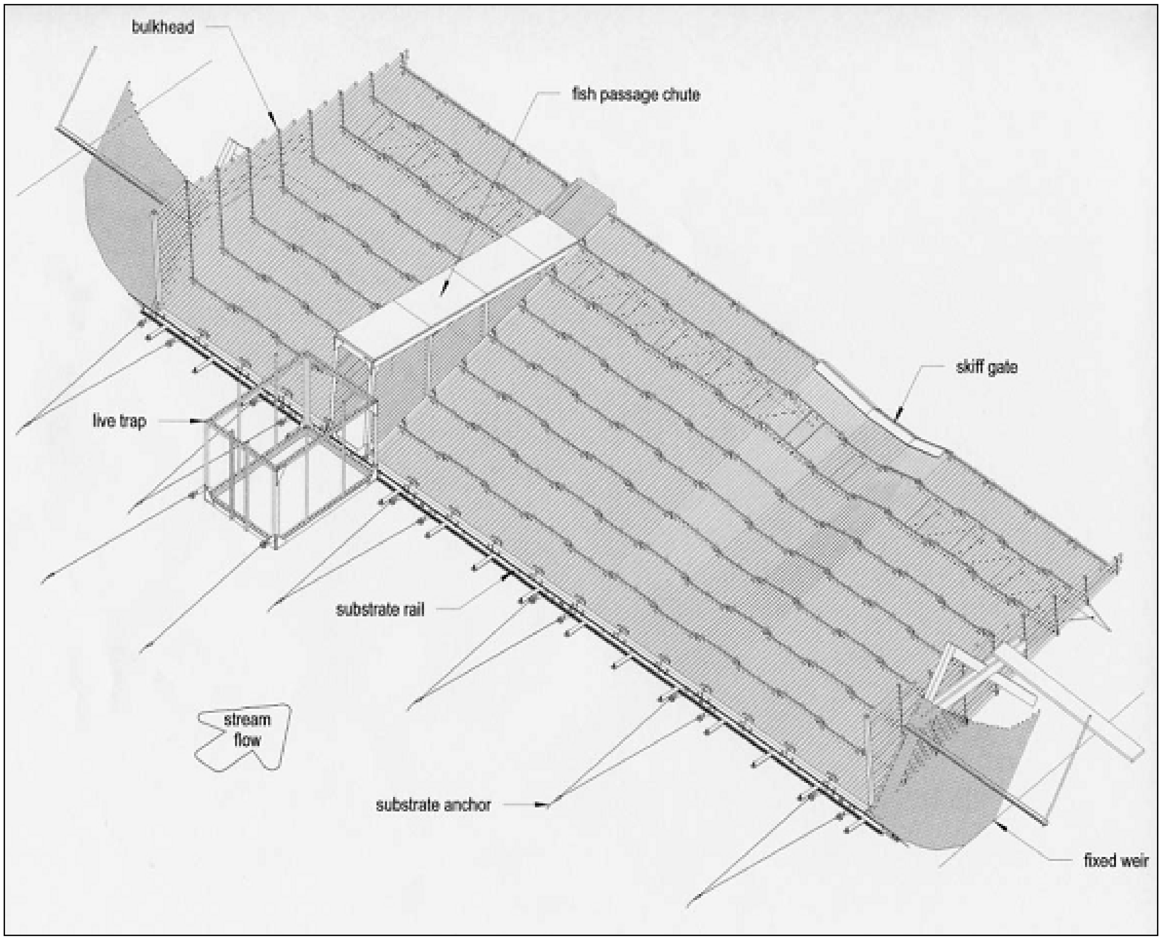

Figure 2. Schematic of a Resistance Board Weir (Stewart 2003).

Weir Operation and Sampling Protocols

Weirs and traps were staffed continuously while installed and the trap box was checked daily (multiple times per day when necessary). Close attention was paid to the recruitment of fish into trap boxes and the accumulation of fish below the trap. When the abundance of salmonids exceeded the ability of staff to efficiently work through fish, modifications were made to trapping protocols to facilitate passage without handling. This was accomplished by opening the upstream gate on the trap box and allowing fish to pass through without handling or submerging a panel section of the resistance weir to allow fish passage.

Streamflow and weather forecasts were monitored closely to ensure the well-being of captured fish in the live box. The Washington Department of Ecology (WDOE) operates telemetry streamflow gauges that provide near real-time information. Streamflow and weather forecast information, and ultimately direct observation, determined when flows began to limit accessibility to the trap box. When these conditions were encountered, the trap box was opened on both the upstream and downstream end to allow direct passage through the trap. Tagging of fish combined with stream surveys provided a means for estimating abundance and weir efficiency when fish were allowed through the trap unsampled and/or high flows compromised the ability to trap fish at the weir.

Adult fall Chinook salmon captured at each weir were sampled and tagged prior to release above the weir to evaluate weir efficiency and generate population estimates. Tagging was coordinated with spawning ground surveys to re-sight/recover these marks. Independent estimates of spawner abundance were made for fall Chinook salmon (Wilson et al. 2020) for comparison to weir counts. All adult salmonids that were bio-sampled, except those eligible for retention in sport fisheries upstream of weir sites, were anaesthetized with tricaine methanesulfonate (MS-222) or electroanesthesia prior to handling/tagging at the weir. All anaesthetized fish were allowed to fully recover before being released upstream of the weir. Table 1 outlines the planned disposition by species and origin for each of the weirs for 2013-2017.

Table 1. Planned disposition of salmonids by species and origin for the Grays, Elochoman, Coweeman, Green, Kalama, and Washougal weirs, 2013-2017.

Species	Origin	Grays	Elochoman	Coweeman	Green	Kalama	Washougal
Fall Chinook salmon	Unmarked	U	U	U	U[A]	U	U[A]
	Marked	R	R	R	R[B]	R[D]	R[C]
Coho salmon	Unmarked	U	U	U	U[A]	U	U
	Marked	U	R	R	R[B]	U	U
Chum salmon	Unmarked	U	U	U	U	U	U
	Marked	U	U	U	U	U	U
Steelhead	Unmarked	U	U	U	U	U	U
	Marked	U	U	U	R	U	U

U=Upstream, R=Removed
Unmarked fish are assumed to be of natural-origin (NOR) but a small subset may be unclipped hatchery-origin
Marked fish are assumed to be of hatchery-origin (HOR)
All LV-clipped fall Chinook salmon were removed at the weirs
[A] Denotes in excess of weekly broodstock needs. North Toutle (Green) and Washougal have integrated fall Chinook salmon programs and the North Toutle has an integrated coho salmon program. For these programs, 1 in 3 unmarked salmon were taken for brood and the remaining salmon were released upstream.
[B] Denotes in excess of weekly broodstock needs. If insufficient unmarked salmon were available to meet weekly broodstock collection goals, marked salmon were used as backfill. In 2013, for every unmarked fall Chinook salmon passed upstream, a marked fall Chinook salmon was passed upstream with the goal of seeding available habitat while reducing pHOS to near 50% and the remaining marked fall Chinook salmon were removed. In 2014-2017, all marked fall Chinook salmon were removed.
[C] Denotes in excess of weekly broodstock needs. If insufficient unmarked salmon were available to meet weekly broodstock collection goals, marked salmon were used as backfill. In 2013, 1 in 10 marked fall Chinook salmon were passed upstream with the goal of seeding available habitat while reducing pHOS and the remaining marked fall Chinook salmon were removed. In 2014-2017, all marked fall Chinook salmon were removed.
[D] The weir on the lower Kalama River has only been operated for fish management needs since 2015. In 2015, for every two unmarked fall Chinook salmon released upstream, one marked fall Chinook salmon was released upstream with the goal of achieving 30% pHOS. In 2016 and 2017, all marked fall Chinook salmon were removed in excess of broodstock needs.

Data Analysis

We estimated weir capture efficiency, pHOS at the population- and subpopulation-level (detailed in Wilson et al. 2020), what population and subpopulation-level pHOS would have been without the management action of removing hatchery-origin fish at the weirs, and the change in pHOS at the population and subpopulation-level for adult fall Chinook salmon by adding additional equations, summary statistics, and parameters to the models already developed to estimate abundance for each population (Wilson et al. 2020). All of the estimates were calculated for adult fall Chinook salmon, which are classified as 60 cm and larger for the purpose of this report. These analyses were conducted under a Bayesian framework utilizing WinBUGS (Spiegelhalter et al. 2003) called from within R using the R2WinBUGS package (Sturtz et al. 2005). Estimates are reported for the first time for 2013-2017. We also update previously reported estimates for these same metrics for year prior to 2013 as the models used to develop abundance estimates were updated and were applied to the entire time series. Therefore, these weir performance metrics have changed from earlier reports (Wilson et al. 2018; Wilson and Glaser 2015, Wilson and Glaser 2019a; Wilson and Glaser 2019b).

The model used to estimate these parameters is described below:

Weir efficiency, $Weff_{i,j}$, was estimated by adding the count of the fall Chinook salmon passed upstream at a weir site, $Wup_{i,j}$, and marked fall Chinook salmon removed, $Whrem_{i,j}$, and unmarked fall Chinook salmon removed, $Wwrem_{i,j}$, divided by the estimated escapement above the weir site (spawners + prespawn mortalities + recruits to hatchery facilities + sport harvest), $aw\_Esc_{i,j}$, plus weir removals with the subscript *i* denoting year-specific and *j* denoting basin specific parameters (eq. 1).

$$Weff_{i,j} = \frac{Wup_{i,j}+Whrem_{i,j}+ Wwrem_{i,j}}{aw\_Esc_{i,j}+Whrem_{i,j}+ Wwrem_{i,j}} \tag{1}$$

We estimated what pHOS would have been without the removal of hatchery fall Chinook salmon at the weir sites, $nwpHOS_{i,j}$, by adding the estimated number of hatchery-origin spawners, $Pop\_HOS_{i,j}$, to the number of hatchery fall Chinook salmon removed at the weir sites, $Whrem_{i,j}$, divided by the overall spawner abundance, $Pop\_Esc_{i,j}$, plus weir removals (eq. 2)

$$nwpHOS_{i,j} = \frac{Pop\_HOS_{i,j} + Whrem_{i,j}}{Pop\_Esc_{i,j}+ Wwrem_{i,j}+ Wwrem_{i,j}} \tag{2}$$

We estimated the change in pHOS due to removal of hatchery fall Chinook salmon at the weir sites, $cpHOS_{i,j}$, by subtracting the estimated number of hatchery-origin spawners, $Pop\_HOS_{i,j}$, from what pHOS would have been without the removal of hatchery fall Chinook salmon at the weir sites, $nwpHOS_{i,j}$ (eq. 3).

$$cpHOS_{i,j} = nwpHOS_{i,j} - Pop\_pHOS_{i,j} \tag{3}$$

Additionally, we examined handling mortality, spawn timing, spawning distribution, and apparent residence time to begin to evaluate unintended effects of operating river-spanning weirs on naturally spawning populations. We used a generalized linear mixed model to determine whether the probability of pre-spawn mortality (PSM) was related to prior handling at weirs. We used a binomial likelihood (whether or not fish exhibited PSM) with a logit link, continuous fixed effects for day of year and fork length, and a categorical fixed effect for whether fish were handled. To account for the hierarchical data structure, we included a random effect for weir, a random effect for year nested within weir, and a random effect of whether or not a fish was handled nested within weir and year (to account for year- and weir-specific deviations from the average handling effect). The model was estimated in a Bayesian framework using rstanarm (Goodrich et al. 2018). Vague normal priors were given to regression coefficients and half-Cauchy priors were used for random effect standard deviations. The model was run in four separate chains for 2000 iterations, discarding the first 1000 for burn-in. Convergence was assessed via Rhat and effective draws. All parameters had Rhat value less than 1.003 and a minimum of 1100 effective draws with most key parameters having greater than 4000 effective draws. We qualitatively examined spawn timing and spawning distribution on the Coweeman River by plotting cumulative spawn timing based on the number of live Chinook salmon identified as spawners and mapping georeferenced new Chinook salmon redds, respectively. We examined apparent residence time on the Coweeman River in years when we had successful mark-recapture estimates paired with live counts with complete temporal and spatial coverage (Parken et al. 2003).

An unbiased run timing estimate requires trapping over the entire run without any leakage. In practice, this is an unattainable goal with most of our temporary weirs. We set the following criteria in order to evaluate and report on a specific weir and year's run timing: (1) the mean weir efficiency must be greater than 85% and (2) the weir was operated for 85% of the days available for the fall Chinook salmon trapping season. We believe following these criteria will yield reasonable estimates of run timing where available. When these criteria were met, we used the daily total fall Chinook salmon catch (arrivals to the weir) by mark type to develop estimates of 50% passage and cumulative run timing plots.

Results

Weir Performance

Grays River Weir

A total of 532, 228, 607, and 248 adult fall Chinook salmon were trapped at the Grays River Weir in 2013, 2014, 2015, and 2016, respectively. The weir was not operated in 2017 due to riverbank erosion in the fall of 2016. Over these four years, over 88% of the adult fall Chinook salmon caught were marked while Select Area Brights (SABs) made up almost 59% of the total fall Chinook salmon catch (Appendix D: Table D1). SABs are hatchery fall Chinook salmon that are released into Youngs Bay as part of the Select Area Fisheries Enhancement (SAFE) program; they are a non-local stock that originated from Cole Rivers Hatchery on the Rogue River

Efficiencies for the Grays River Weir improved over time as the location of the weir moved downstream (Appendix E) (Figure 3; Table 3). The initial location at rkm 17.22 (2008-2010) had efficiencies of 23.8-32.0%. The second location at rkm 16.5 (2011-2012) had efficiencies of 23.1-42.3%. The final location at rkm 13.65 (2013-2016) had the highest efficiencies at 40.1-70.1%. A major flow event occurred in late September of 2013 that ended weir operations well before the targeted end date. Weir operations were nearly continuous through the third week in October for years 2014 and 2015. In 2016 weir operation again ended prematurely due to a high flows in the first week of October (Appendix A: Figure A1-A4) (Table 2).

Overall, pHOS has been high in the Grays River over the last decade with eight out of ten years exceeding 60% (Figure 4). The weir has reduced pHOS levels by as little as 1.1% in 2013 to as much as 11.9% in 2015, which was also the year with the highest weir efficiency during the nine-year period of evaluation (Figure 3; Table 4).

We did not examine run timing due to the low weir capture efficiency.

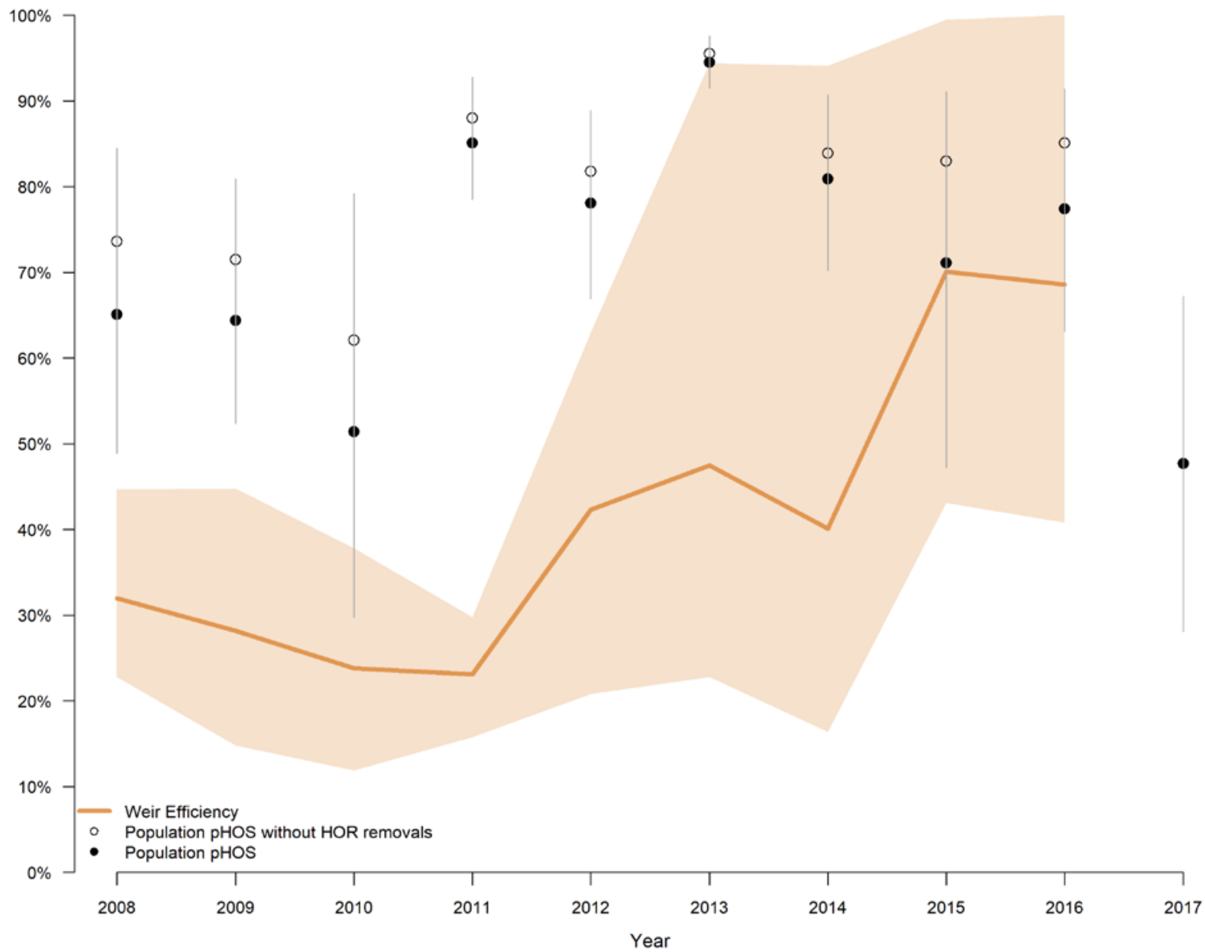

Figure 3. Estimates of weir effectiveness measured by weir capture efficiency and population-level proportion hatchery-origin spawners (pHOS) reduction for adult fall Chinook salmon for the Grays River Weir, 2008-2017. The colored line represents the mean weir efficiency with the shading indicating the 95% credible intervals. The black circle represents the mean pHOS with the grey error bars indicating the 95% credible intervals. The open circle represents mean pHOS without removal of marked fish at the weir with the grey error bars indicating the 95% credible intervals. Note that the weir was not operated in 2017.

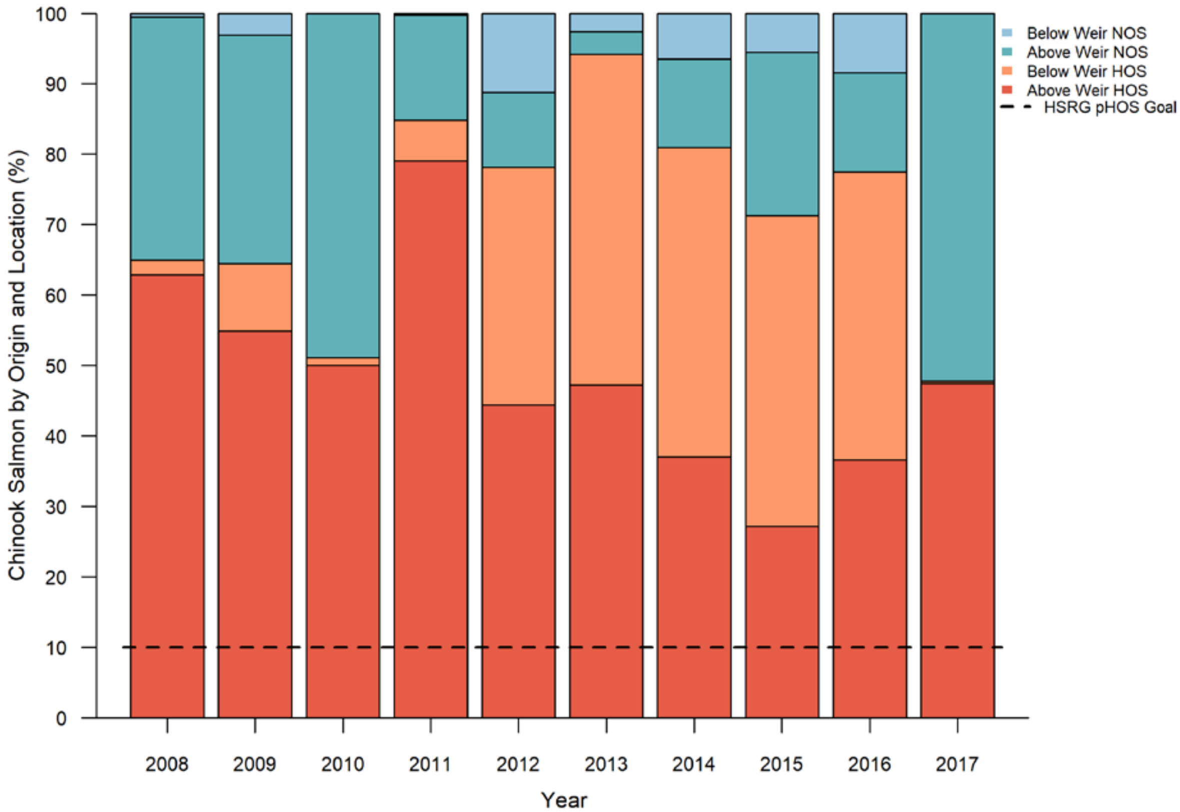

Figure 4. Estimates of contributions to proportion of hatchery-origin spawners (pHOS) by location for the Grays/Chinook fall Chinook population, 2008-2017. The warm colors represent hatchery-origin spawners (HOS) and the cold colors represent natural-origin spawners (NOS). The different shades of warm and colors represent contributions by location (e.g. below weir, above weir) and the black dashed line horizontal line represents the pHOS upper limit per HSRG.

Table 2. Target and actual weir operational dates, number of days in operation, number of days weir operations were known to be compromised while the weir was installed, and percentage of the target days the weir was in operation for the Grays River Weir, 2008-2016.

	Operational Dates				Operational Days			
	Target		Actual					
Year	Install	Removal	First Day	Last Day	Days Compromised While Installed	Target	Actual	% of Target
2008	8/5	10/31	9/18	10/29	5	87	36	41%
2009	8/5	10/31	8/14	10/26	6	87	67	77%
2010	8/5	10/31	8/24	10/9	0	87	46	53%
2011	8/5	10/31	8/17	10/20	4	87	60	69%
2012	8/5	10/31	8/3	10/22	5	87	75	86%
2013	8/5	10/31	8/7	9/27	2	87	49	56%
2014	8/5	10/31	7/30	10/15	3	87	74	85%
2015	8/5	10/31	8/5	10/23	0	87	79	91%
2016	8/5	10/31	8/1	10/6	1	87	65	75%

Table 3. Estimates of adult fall Chinook salmon weir capture efficiency for the Grays River Weir (mean, SD, and 95% credible intervals of the posterior distribution), 2008-2016.

Year	Mean	SD	L 95% CI	U 95% CI
2008	32.0%	5.8%	22.8%	44.7%
2009	28.2%	7.8%	14.8%	44.8%
2010	23.8%	6.8%	11.9%	37.8%
2011	23.1%	3.6%	15.8%	29.8%
2012	42.3%	11.1%	20.8%	63.0%
2013	47.5%	19.8%	22.8%	94.4%
2014	40.1%	21.6%	16.4%	94.1%
2015	70.1%	16.9%	43.1%	99.5%
2016	68.6%	17.4%	40.8%	100.0%

Table 4. Estimates of adult fall Chinook salmon proportion hatchery-origin spawners (pHOS), proportion hatchery-origin spawners with no hatchery-origin removals at weir (nwpHOS), and change in proportion of hatchery-origin spawners (cpHOS) for the Grays/Chinook fall Chinook population (mean, SD, and 95% credible intervals of the posterior distribution), 2008-2017.

Year	Parameter	Mean	SD	L 95% CI	U 95% CI
2008	nwpHOS	73.6%	6.2%	60.7%	84.5%
2008	pHOS	65.1%	7.9%	48.9%	79.4%
2008	cpHOS	8.5%	2.5%	4.5%	14.1%
2009	nwpHOS	71.5%	5.1%	61.0%	80.9%
2009	pHOS	64.4%	5.8%	52.4%	75.3%
2009	cpHOS	7.2%	2.4%	3.4%	12.5%
2010	nwpHOS	62.1%	9.2%	43.7%	79.2%
2010	pHOS	51.4%	11.1%	29.8%	72.6%
2010	cpHOS	10.7%	4.0%	4.5%	20.0%
2011	nwpHOS	88.0%	2.7%	82.4%	92.8%
2011	pHOS	85.1%	3.2%	78.5%	90.9%
2011	cpHOS	2.9%	0.7%	1.6%	4.5%
2012	nwpHOS	81.8%	4.2%	72.6%	88.9%
2012	pHOS	78.1%	5.2%	66.9%	87.1%
2012	cpHOS	3.8%	1.7%	1.2%	7.6%
2013	nwpHOS	95.5%	1.1%	93.2%	97.6%
2013	pHOS	94.5%	1.4%	91.5%	97.1%
2013	cpHOS	1.1%	0.4%	0.4%	1.9%
2014	nwpHOS	83.9%	4.2%	74.9%	90.7%
2014	pHOS	80.9%	4.9%	70.2%	88.9%
2014	cpHOS	3.0%	0.9%	1.5%	5.2%
2015	nwpHOS	83.0%	6.4%	68.2%	91.1%
2015	pHOS	71.1%	10.8%	47.2%	85.4%
2015	cpHOS	11.9%	4.8%	5.2%	22.9%
2016	nwpHOS	85.1%	3.8%	75.7%	91.4%
2016	pHOS	77.4%	6.0%	63.1%	87.3%
2016	cpHOS	7.7%	2.5%	3.7%	13.5%
2017[a]	nwpHOS	---	---	---	---
2017	pHOS	47.7%	10.2%	28.1%	67.2%
2017[a]	cpHOS	---	---	---	---

[a] Weir was not operated in 2017.

Elochoman River Weir

A total of 231, 1158, 1719, 407, and 247 adult fall Chinook salmon were trapped at the Elochoman River Weir in 2013, 2014, 2015, 2016, and 2017, respectively. During this five-year period, over 84% of the adult fall Chinook salmon caught were marked (Appendix D: Table D2).

Mean weir efficiency has been in excess of 90% in seven of out nine years (Figure 5; Table 6). The weir design changed in 2013 to a resistance board style (Appendix E) but weir effectiveness has been relatively steady. In 2013, high flows in late September topped the weir for nearly a week resulting in low weir efficiency. In 2014, flows began to increase by the second week of October but did not top the weir until October 22. In 2015, weir operations continued until the last week of October with no known flow events that would compromise weir efficiency. In 2016, while the weir was operational through October 26, some substantial time was missed in early-to-mid October due to moderate flows. In 2017, weir operations continued through October 18 (Appendix A: Figure A5-A9) (Table 5).

Overall, pHOS has been trending down in the Elochoman River since 2012 (Figure 6). From 2009-2011, some hatchery fall Chinook salmon were removed, but not all, with the goal of seeding the available habitat while still reducing hatchery-influence. In 2012, we transitioned to removing all hatchery fall Chinook salmon with the goal of reducing pHOS to HSRG guidelines. From 2012 to 2017, removal of hatchery fall Chinook salmon at the weir has reduced pHOS levels from as little as 14.1% in 2013 to as much as 65.9%. The highest reduction in pHOS (65.9%) occurred in 2014 when mean weir efficiency was 98.8% (Figure 5; Table 7).

Run timing was relatively consistent between 2014-2017 with 50% passage occurring the third week of September. There was little difference between unmarked and ad-clipped fall Chinook salmon timing. The 50% passage date of unmarked fall Chinook salmon ranged from September 17 to 22 while ad-clipped fall Chinook salmon ranged from September 17 to 25 (Appendix F: Figure F1).

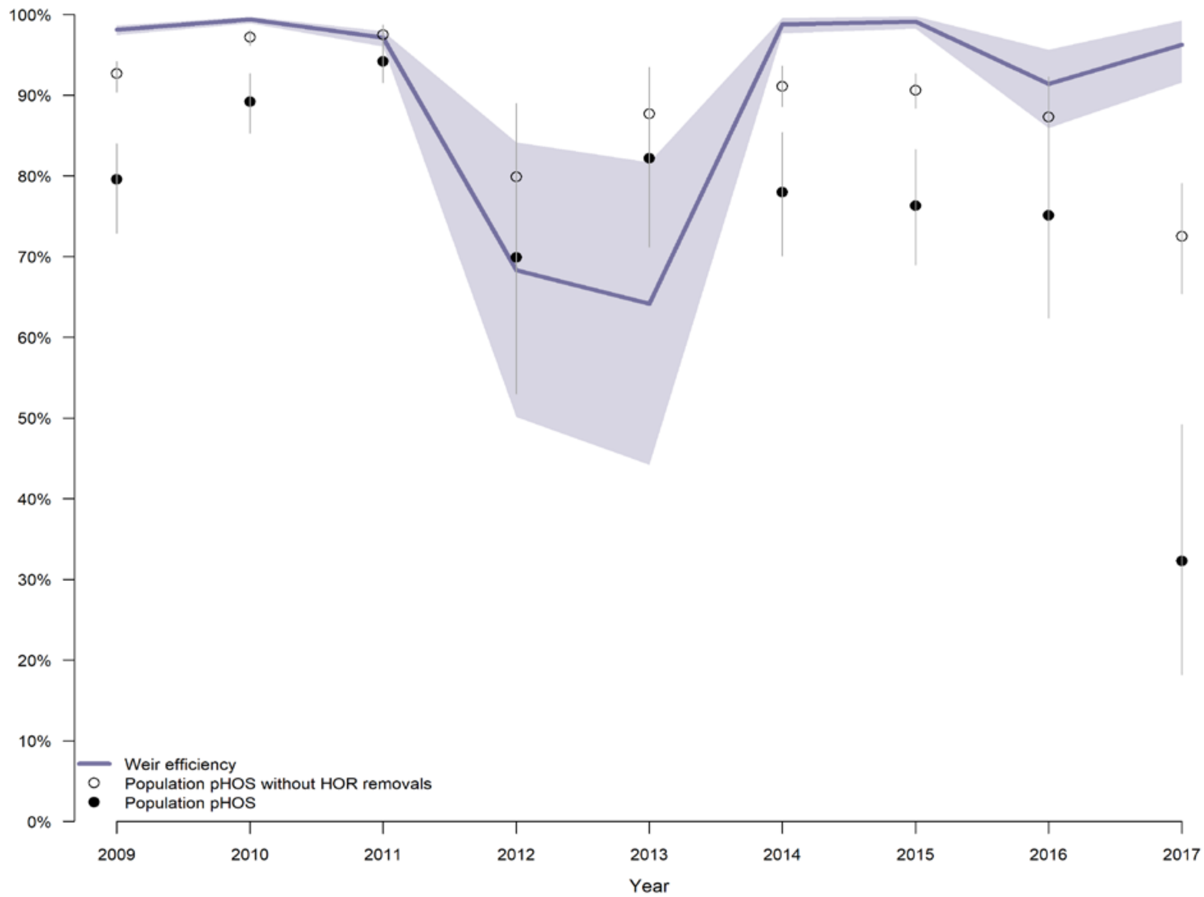

Figure 5. Estimates of weir effectiveness measured by weir capture efficiency and population-level proportion hatchery-origin spawners (pHOS) reduction for adult fall Chinook salmon for the Elochoman River Weir, 2009-2017. The colored line represents the mean weir efficiency with the shading indicating the 95% credible intervals. The black circle represents the mean pHOS with the grey error bars indicating the 95% credible intervals. The open circle represents mean pHOS without removal of marked fish at the weir with the grey error bars indicating the 95% credible intervals. No estimates of population-level pHOS were available for 2009; shown are subpopulation-level estimates.

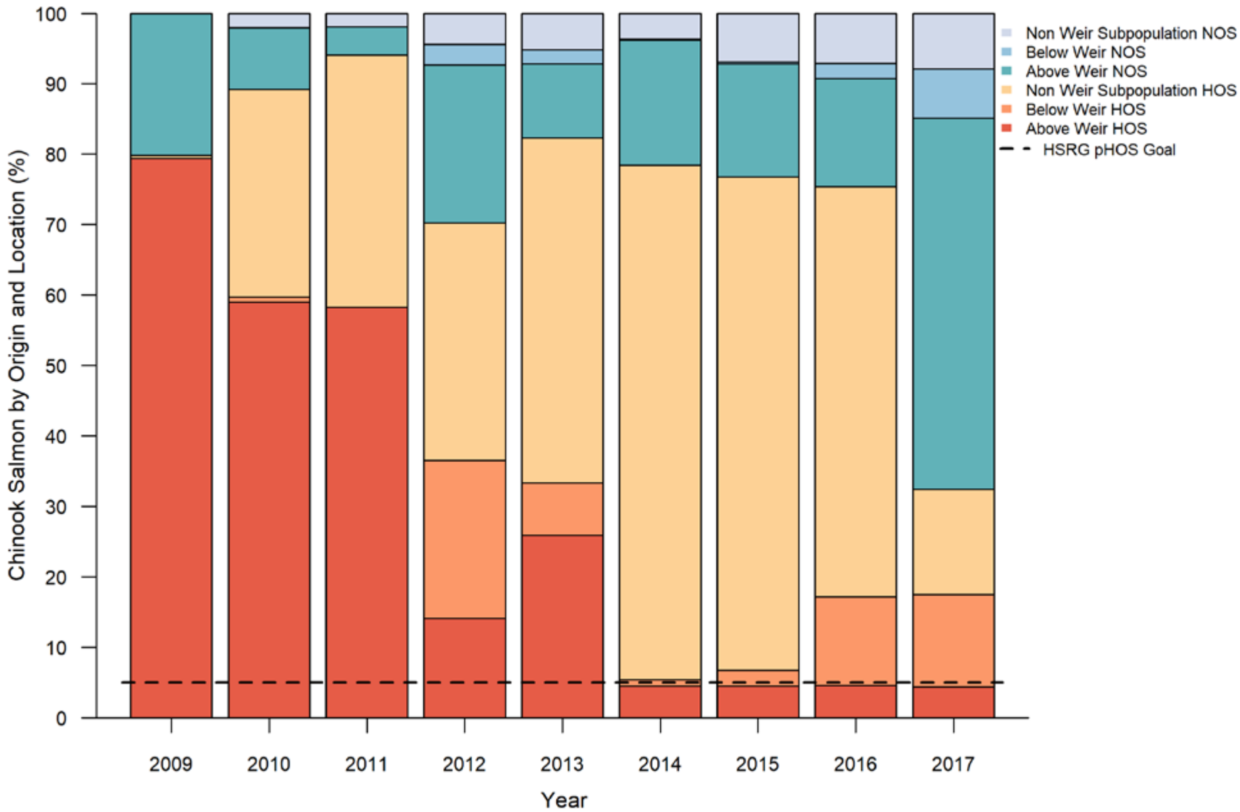

Figure 6. Estimates of contributions to proportion of hatchery-origin spawners (pHOS) by location for the Elochoman/Skamokawa fall Chinook population, 2009-2017. The warm colors represent hatchery-origin spawners (HOS) and the cold colors represent natural-origin spawners (NOS). The different shades of warm and colors represent contributions by location (e.g. non-weir subpopulation, below weir, above weir) and the black dashed line horizontal line represents the pHOS upper limit per HSRG.

Table 5. Target and actual weir operational dates, number of days in operation, number of days weir operations were known to be compromised while the weir was installed, and percentage of the target days the weir was in operation for the Elochoman River Weir, 2009-2016.

	Operational Dates				Operational Days			
	Target		Actual					
Year	Install	Removal	First Day	Last Day	Days Compromised While Installed	Target	Actual	% of Target
2009	8/15	10/31	8/24	10/20	0	77	57	74%
2010	8/15	10/31	8/8	10/10	3	77	60	78%
2011	8/15	10/31	8/9	10/22	3	77	71	92%
2012	8/15	10/31	8/17	10/26	0	77	70	91%
2013	8/15	10/31	8/15	11/29	14	77	92	119%
2014	8/15	10/31	8/6	10/22	0	77	77	100%
2015	8/15	10/31	8/7	10/27	0	77	81	105%
2016	8/15	10/31	8/8	10/26	11	77	68	88%
2017	8/15	10/31	8/7	10/18	0	77	72	94%

Table 6. Estimates of adult fall Chinook salmon weir capture efficiency for the Elochoman River Weir (mean, SD, and 95% credible intervals of the posterior distribution), 2009-2017.

Year	Mean	SD	L 95% CI	U 95% CI
2009	98.1%	0.3%	97.5%	98.7%
2010	99.4%	0.2%	98.9%	99.8%
2011	97.1%	0.5%	96.0%	98.0%
2012	68.3%	8.7%	50.1%	84.2%
2013	64.2%	9.8%	44.2%	81.7%
2014	98.8%	0.5%	97.7%	99.6%
2015	99.1%	0.4%	98.3%	99.8%
2016	91.4%	2.5%	85.9%	95.7%
2017	96.3%	2.0%	91.6%	99.3%

Table 7. Estimates of adult fall Chinook salmon proportion hatchery-origin spawners (pHOS), proportion hatchery-origin spawners with no hatchery-origin removals at weir (nwpHOS), and change in proportion of hatchery-origin spawners (cpHOS) for the Elochoman/Skamokawa fall Chinook population and Elochoman fall Chinook subpopulation (mean, SD, and 95% credible intervals of the posterior distribution), 2009-2017.

		Population-Level				Subpopulation-Level			
Year	Parameter	Mean	SD	L 95% CI	U 95% CI	Mean	SD	L 95% CI	U 95% CI
2009	nwpHOS	---	---	---	---	92.7%	0.9%	90.4%	94.2%
2009	pHOS	---	---	---	---	79.6%	2.7%	72.9%	84.0%
2009	cpHOS	---	---	---	---	13.0%	1.8%	10.2%	17.5%
2010	nwpHOS	97.2%	0.5%	96.2%	98.1%	97.5%	0.5%	96.6%	98.4%
2010	pHOS	89.2%	1.9%	85.3%	92.7%	87.2%	2.4%	82.5%	91.5%
2010	cpHOS	8.0%	1.5%	5.3%	11.0%	10.3%	2.0%	6.9%	14.3%
2011	nwpHOS	97.5%	0.6%	96.3%	98.7%	98.0%	0.5%	97.1%	99.2%
2011	pHOS	94.2%	1.3%	91.6%	96.9%	93.8%	1.7%	91.1%	97.5%
2011	cpHOS	3.3%	0.8%	1.7%	4.7%	4.2%	1.1%	1.7%	6.0%
2012	nwpHOS	79.9%	5.6%	67.6%	89.0%	77.2%	6.9%	62.0%	88.5%
2012	pHOS	69.9%	8.1%	53.0%	83.5%	58.2%	11.8%	33.7%	79.0%
2012	cpHOS	10.0%	2.9%	5.1%	16.1%	18.9%	6.0%	8.4%	31.5%
2013	nwpHOS	87.7%	3.7%	79.3%	93.5%	86.5%	4.6%	75.5%	93.5%
2013	pHOS	82.2%	5.1%	71.2%	90.5%	72.3%	8.1%	54.8%	86.1%
2013	cpHOS	5.5%	1.7%	2.7%	9.4%	14.1%	5.0%	6.0%	25.3%
2014	nwpHOS	91.1%	1.3%	88.6%	93.6%	89.2%	1.5%	86.4%	92.3%
2014	pHOS	78.0%	4.0%	70.1%	85.4%	23.3%	8.2%	10.5%	41.6%
2014	cpHOS	13.1%	3.0%	7.5%	19.1%	65.9%	7.2%	49.8%	77.5%
2015	nwpHOS	90.6%	1.1%	88.4%	92.7%	90.4%	1.2%	88.2%	92.8%
2015	pHOS	76.3%	3.6%	69.0%	83.3%	29.3%	7.6%	15.6%	45.1%
2015	cpHOS	14.3%	2.9%	9.0%	20.2%	61.1%	6.9%	47.0%	73.3%
2016	nwpHOS	87.3%	2.8%	81.1%	92.3%	86.5%	2.8%	80.5%	91.6%
2016	pHOS	75.1%	5.7%	62.4%	85.0%	47.8%	11.8%	25.3%	69.8%
2016	cpHOS	12.2%	3.3%	6.5%	19.2%	38.8%	10.3%	19.4%	58.4%
2017	nwpHOS	72.5%	3.7%	65.4%	79.1%	73.1%	3.5%	66.5%	79.2%
2017	pHOS	32.3%	8.1%	18.2%	49.2%	22.2%	7.6%	9.9%	39.5%
2017	cpHOS	40.2%	6.6%	25.4%	51.6%	50.9%	7.2%	34.4%	62.9%

Green River Weir

A total of 96, 85, 2,319, 1,407, and 55 adult fall Chinook salmon were trapped at the Green River Weir in 2013, 2014, 2015, 2016, and 2017, respectively. Over these five years, over 76% of the adult fall Chinook salmon caught were marked (Appendix D: Table D3).

Weir efficiencies have been high at the Green River Weir. The weir design has been very similar year-to-year (Appendix E). Mean weir efficiencies have exceeded 85% in all of the eight years it has been used for fall Chinook salmon management. The lowest mean weir efficiency was in 2013 at 85.7% and the highest in 2015 at 100% (Figure 7; Table 9). In most years, weir integrity was not compromised until late October with the exception of 2012 when high flows topped the weir in late September (Appendix A: Figure A10-A14) (Table 8).

Overall, pHOS has been trending down since 2012 (Figure 8). Similar to the Elochoman, from 2010-2012 some hatchery fall Chinook salmon were removed but pHOS was not reduced to the lowest possible level. Rather our objective was to fully seed the available habitat while still reducing pHOS. For 2010, pHOS actually increased as some hatchery-origin fish were released upstream and some unmarked fall Chinook salmon were collected for broodstock. From 2013-2017, we were trying to actively reduce pHOS to meet HSRG guidelines but still integrate unmarked fall Chinook salmon to brood. From 2010-2017, the weir reduced pHOS levels from as little as 25.9% in 2016 to as much as 53.4% in 2015 when weir efficiency was the highest (Figure 7; Table 10).

We assessed run timing for 2013-2015 and 2017 and found that run timing was very similar between these years. Unmarked fall Chinook salmon had a consistently later run timing than their ad-clipped counterparts. The 50% passage date of unmarked fall Chinook salmon ranged from September 19 to October 2 while ad-clipped fall Chinook salmon ranged from September 12 to 29 (Appendix F: Figure F2).

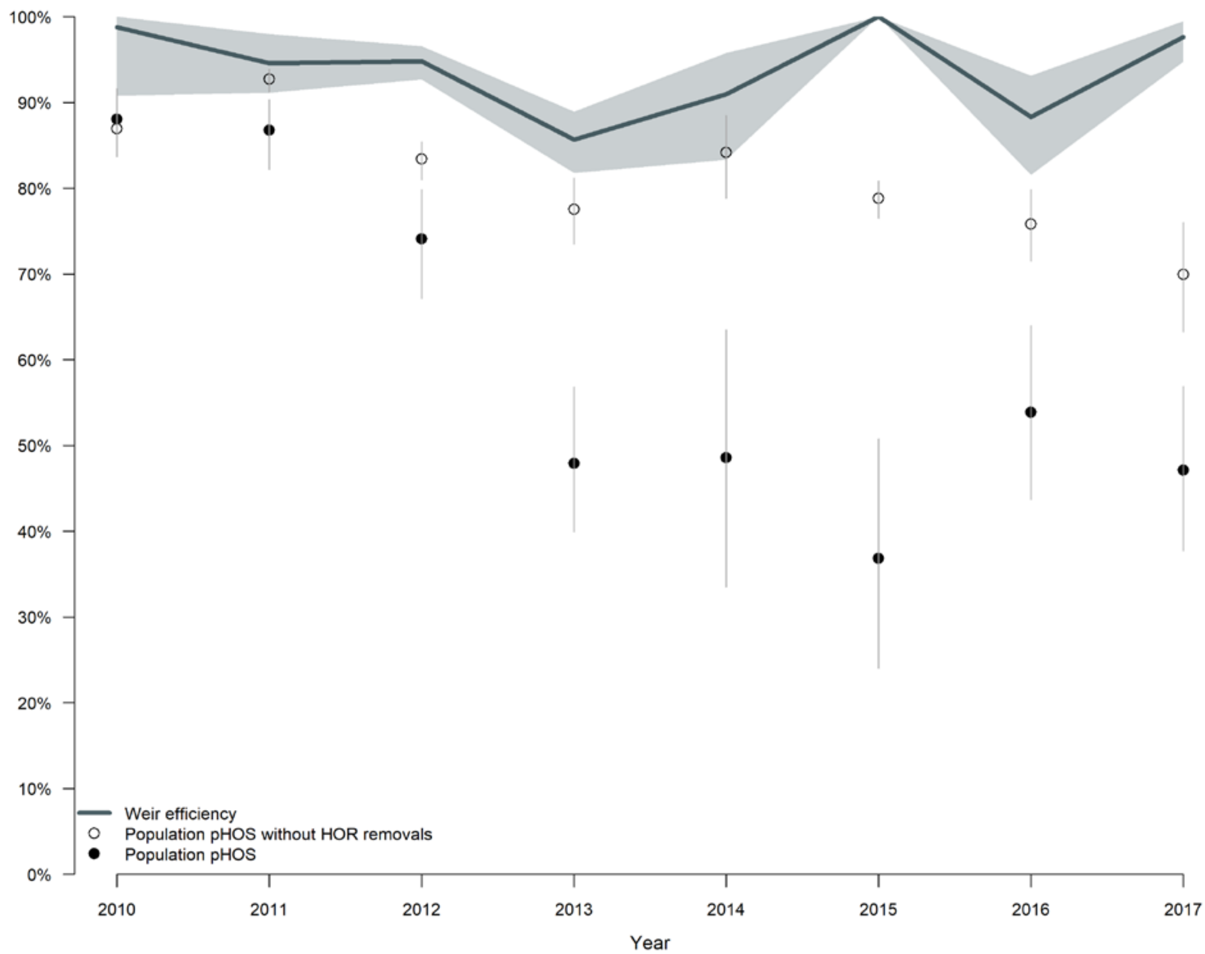

Figure 7. Estimates of weir effectiveness measured by weir capture efficiency and population-level proportion hatchery-origin spawners (pHOS) reduction for adult fall Chinook salmon for the Green River Weir, 2010-2017. The colored line represents the mean weir efficiency with the shading indicating the 95% credible intervals. The black circle represents the mean pHOS with the grey error bars indicating the 95% credible intervals. The open circle represents mean pHOS without removal of marked fish at the weir with the grey error bars indicating the 95% credible intervals.

Figure 8. Estimates of contributions to proportion of hatchery-origin spawners (pHOS) by location for the Toutle fall Chinook population by location, 2010-2017. The warm colors represent hatchery-origin spawners (HOS) and the cold colors represent natural-origin spawners (NOS). The different shades of warm and colors represent contributions by location (e.g. non-weir subpopulation, below weir, above weir) and the black dashed line horizontal line represents the pHOS upper limit per HSRG.

Table 8. Target and actual weir operational dates, number of days in operation, number of days weir operations were known to be compromised while the weir was installed, and percentage of the target days the weir was in operation for the Green River Weir, 2010-2017.

	Operational Dates				Operational Days			
	Target		Actual					
Year	Install	Removal	First Day	Last Day	Days Compromised While Installed	Target	Actual	% of Target
2010	8/15	11/5	9/21	11/10	2	82	48	59%
2011	8/15	11/5	8/23	12/20	0	82	119	145%
2012	8/15	11/5	8/27	10/24	1	82	57	70%
2013	8/15	11/5	8/9	11/26	18	82	91	111%
2014	8/15	11/5	8/15	11/19	12	82	84	102%
2015	8/15	11/5	8/12	11/9	8	82	81	99%
2016	8/15	11/5	8/12	11/4	24	82	60	73%
2017	8/15	11/5	8/11	11/13	24	82	70	85%

Table 9. Estimates of adult fall Chinook salmon weir capture efficiency for the Green River Weir (mean, SD, and 95% credible intervals of the posterior distribution), 2010-2017.

Year	Mean	SD	L 95% CI	U 95% CI
2010	98.8%	3.7%	90.8%	100.0%
2011	94.6%	1.8%	91.1%	98.0%
2012	94.8%	1.0%	92.7%	96.6%
2013	85.7%	1.9%	81.8%	88.9%
2014	91.0%	3.2%	83.3%	95.8%
2015	100.0%	NA	NA	NA
2016	88.3%	3.0%	81.6%	93.1%
2017	97.7%	1.2%	94.7%	99.5%

Table 10. Estimates of adult fall Chinook salmon proportion hatchery-origin spawners (pHOS), proportion hatchery-origin spawners with no hatchery-origin removals at weir (nwpHOS), and change in proportion of hatchery-origin spawners (cpHOS) for the Toutle fall Chinook population and Green fall Chinook subpopulation (mean, SD, and 95% credible intervals of the posterior distribution), 2010-2017.

		Population-Level				Subpopulation-Level			
Year	Parameter	Mean	SD	L 95% CI	U 95% CI	Mean	SD	L 95% CI	U 95% CI
2010	nwpHOS	86.9%	1.2%	84.4%	89.1%	87.3%	1.2%	84.8%	89.4%
2010	pHOS	88.1%	2.1%	83.7%	91.6%	88.8%	2.1%	84.3%	92.3%
2010	cpHOS[a]	-1.2%	0.9%	-2.5%	0.7%	-1.5%	0.9%	-3.0%	0.5%
2011	nwpHOS	92.7%	0.7%	91.2%	93.9%	93.2%	0.7%	91.7%	94.3%
2011	pHOS	86.8%	2.1%	82.2%	90.4%	87.9%	2.1%	83.2%	91.5%
2011	cpHOS	5.9%	1.4%	3.5%	9.0%	5.2%	1.5%	2.7%	8.4%
2012	nwpHOS	83.4%	1.2%	81.0%	85.4%	84.0%	1.2%	81.7%	86.0%
2012	pHOS	74.1%	3.3%	67.1%	79.9%	73.2%	3.9%	65.1%	80.3%
2012	cpHOS	9.3%	2.2%	5.5%	13.9%	10.8%	2.8%	5.8%	16.5%
2013	nwpHOS	77.5%	2.0%	73.5%	81.2%	81.9%	1.7%	78.6%	85.1%
2013	pHOS	47.9%	4.5%	39.9%	56.8%	52.7%	5.7%	41.9%	64.0%
2013	cpHOS	29.6%	3.1%	23.4%	35.5%	29.2%	4.3%	20.9%	38.0%
2014	nwpHOS	84.2%	2.5%	78.8%	88.5%	85.8%	2.5%	80.5%	90.1%
2014	pHOS	48.6%	7.9%	33.5%	63.5%	39.7%	10.1%	21.2%	59.9%
2014	cpHOS	35.6%	6.2%	24.0%	47.7%	46.1%	8.4%	29.5%	62.1%
2015	nwpHOS	78.8%	1.1%	76.5%	80.8%	79.9%	0.8%	78.3%	81.4%
2015	pHOS	36.8%	6.7%	24.0%	50.8%	26.5%	9.0%	11.1%	45.2%
2015	cpHOS	42.0%	6.2%	29.3%	53.9%	53.4%	8.8%	34.9%	68.8%
2016	nwpHOS	75.8%	2.1%	71.5%	79.8%	76.1%	2.1%	71.8%	79.9%
2016	pHOS	53.9%	5.3%	43.7%	64.0%	50.2%	6.1%	37.2%	61.0%
2016	cpHOS	21.9%	4.3%	14.3%	31.1%	25.9%	5.3%	16.9%	37.8%
2017	nwpHOS	69.9%	3.3%	63.2%	76.0%	72.5%	3.6%	64.8%	78.9%
2017	pHOS	47.1%	5.0%	37.7%	56.9%	40.6%	6.2%	28.4%	52.6%
2017	cpHOS	22.8%	4.2%	15.5%	31.8%	31.9%	7.1%	20.2%	47.8%

[a]cHOS was negative due to natural-origin fall Chinook salmon being retained for broodstock.

Coweeman River Weir

A total of 170, 657, 1461, 83, and 702 adult fall Chinook salmon were trapped at the Coweeman River Weir in 2013, 2014, 2015, 2016, and 2017, respectively. Over these five years, just under 22% of the adult fall Chinook salmon caught were marked (Appendix D: Table D4).

The weir was operated in two locations on the Coweeman River (Appendix E). At the upper site, mean weir efficiencies were in excess of 60% for five of the six years at this location. At the lower site, mean weir efficiency was 19.6% in its single year of operation (2016) (Figure 9; Table 12). This low weir efficiency was in large part due to intentionally sinking the weir to allow fish to pass unimpeded as fish were not recruiting well into the trap box. In 2013, a substantial amount of time was missed in late September and early October due to an extreme flow event. In 2014 and 2015, the weir fished nearly continuously until late October. Weir operations ended prematurely in 2016 and 2017 due to flow events in mid-October (Appendix A: Figure A15-A19) (Table 11).

During the last seven years, pHOS has been relatively low in the Coweeman River. Mean pHOS ranged from as low as 2.3% in 2015 to as high as 32.5% in 2013 (Figure 10). The reduction of pHOS levels due to removal of hatchery fall Chinook salmon ranged from 2.5% (2013) to 15.6% (2014) (Figure 9; Table 13). The small reduction in pHOS occurred in 2013 due to a large flow event that comprised weir efficiency in late September.

We assessed run timing for 2015 and found that the 50% passage date for unmarked fall Chinook salmon was about one week later than ad-clipped fall Chinook salmon. The 50% passage date of unmarked fall Chinook salmon was October 5-6 while ad-clipped fall Chinook salmon ranged was September 27-28 (Appendix F: Figure F3).

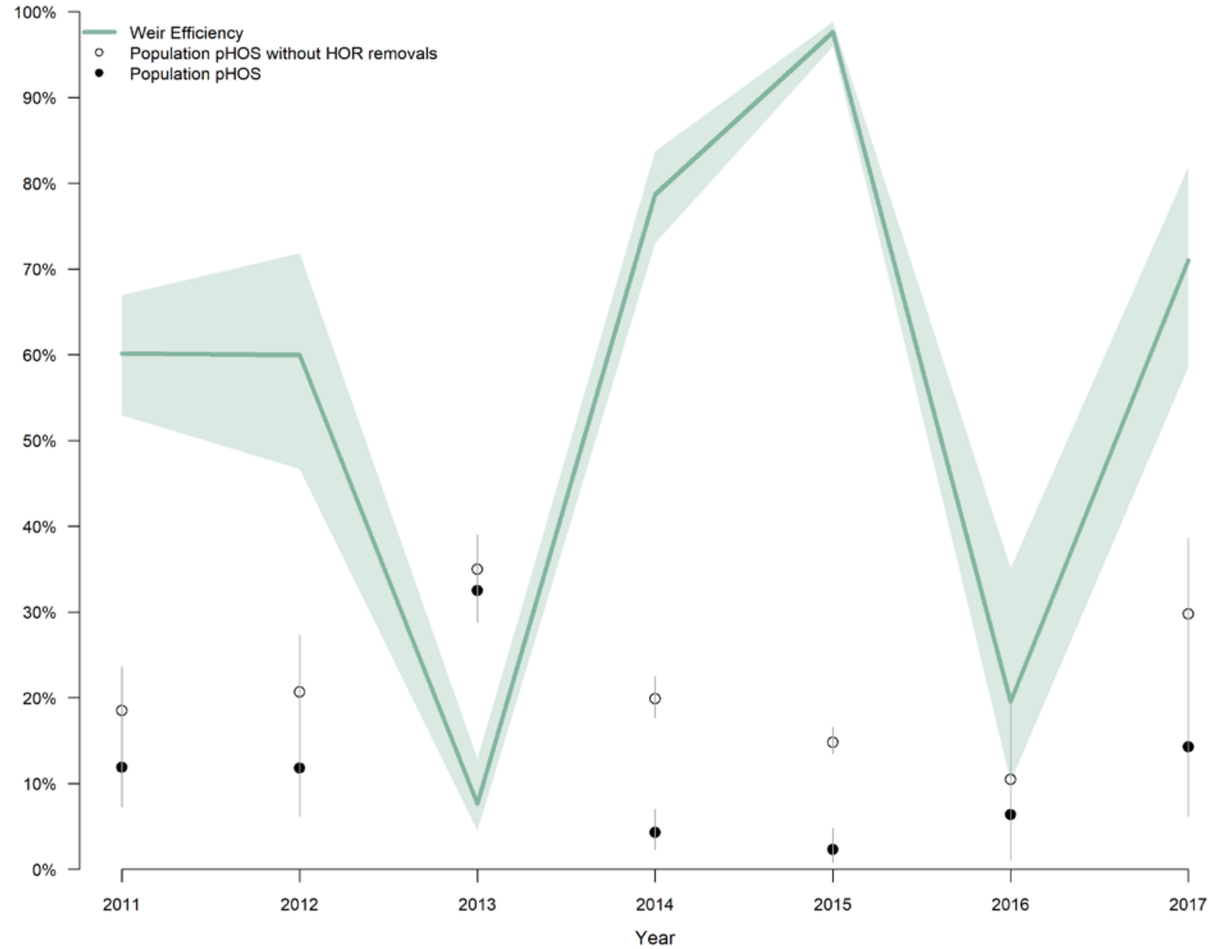

Figure 9. Estimates of weir effectiveness measured by weir capture efficiency and population-level proportion hatchery-origin spawners (pHOS) reduction for adult fall Chinook salmon for the Coweeman River Weir, 2011-2017. The colored line represents the mean weir efficiency with the shading indicating the 95% credible intervals. The black circle represents the mean pHOS with the grey error bars indicating the 95% credible intervals. The open circle represents mean pHOS without removal of marked fish at the weir with the grey error bars indicating the 95% credible intervals.

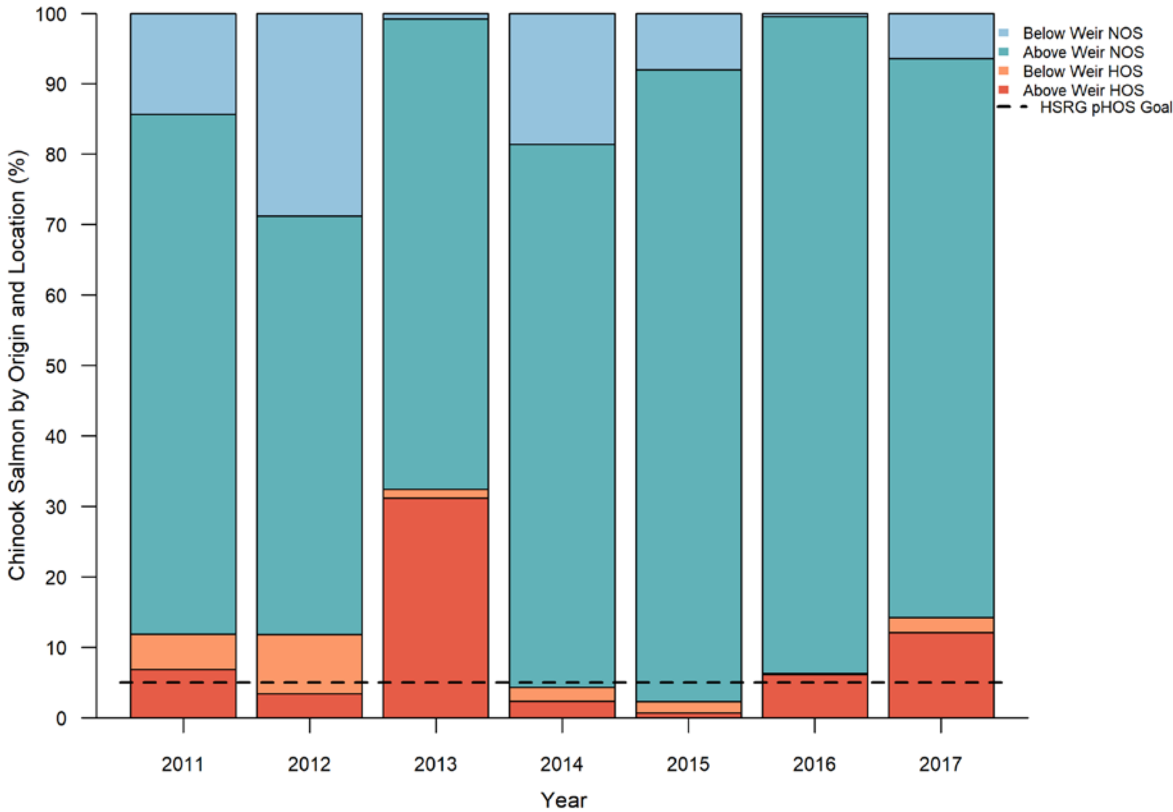

Figure 10. Estimates of contributions to proportion of hatchery-origin spawners (pHOS) by location for the Coweeman fall Chinook population, 2011-2017. The warm colors represent hatchery-origin spawners (HOS) and the cold colors represent natural-origin spawners (NOS). The different shades of warm and colors represent contributions by location (e.g. below weir, above weir) and the black dashed line horizontal line represents the pHOS upper limit per HSRG.

Table 11. Target and actual weir operational dates, number of days in operation, number of days weir operations were known to be compromised while the weir was installed, and percentage of the target days the weir was in operation for the Coweeman River Weir, 2011-2017.

	Operational Dates				Operational Days			
	Target		Actual					
Year	Install	Removal	First Day	Last Day	Days Compromised While Installed	Target	Actual	% of Target
2011	8/15	10/31	9/10	11/2	1	77	52	68%
2012	8/15	10/31	8/28	10/25	3	77	55	71%
2013	8/15	10/31	8/29	10/31	33	77	30	39%
2014	8/15	10/31	8/21	10/21	0	77	61	79%
2015	8/15	10/31	8/15	10/27	0	77	73	95%
2016	8/15	10/31	8/23	10/10	4	77	44	57%
2017	8/15	10/31	8/15	10/17	0	77	63	82%

Table 12. Estimates of adult fall Chinook salmon weir capture efficiency for the Coweeman River Weir (mean, SD, and 95% credible intervals of the posterior distribution), 2011-2017.

Year	Mean	SD	L 95% CI	U 95% CI
2011	60.1%	3.6%	53.0%	66.9%
2012	60.0%	6.4%	46.7%	71.9%
2013	7.7%	2.1%	4.5%	12.9%
2014	78.7%	2.7%	73.0%	83.8%
2015	97.6%	0.7%	96.0%	98.9%
2016	19.6%	6.4%	10.2%	35.1%
2017	71.0%	6.0%	58.6%	81.9%

Table 13. Estimates of adult fall Chinook salmon proportion hatchery-origin spawners (pHOS), proportion hatchery-origin spawners with no hatchery-origin removals at weir (nwpHOS), and change in proportion of hatchery-origin spawners (cpHOS) for the Coweeman fall Chinook population (mean, SD, and 95% credible intervals of the posterior distribution), 2011-2017.

Year	Parameter	Mean	SD	L 95% CI	U 95% CI
2011	nwpHOS	18.5%	2.4%	14.3%	23.6%
2011	pHOS	11.9%	2.6%	7.3%	17.5%
2011	cpHOS	6.6%	0.5%	5.6%	7.6%
2012	nwpHOS	20.7%	3.0%	15.6%	27.3%
2012	pHOS	11.8%	3.4%	6.2%	19.2%
2012	cpHOS	8.9%	1.2%	6.6%	11.4%
2013	nwpHOS	35.0%	2.0%	31.2%	39.0%
2013	pHOS	32.5%	1.9%	28.8%	36.3%
2013	cpHOS	2.5%	0.7%	1.5%	4.2%
2014	nwpHOS	19.9%	1.2%	17.7%	22.5%
2014	pHOS	4.3%	1.2%	2.3%	7.0%
2014	cpHOS	15.6%	0.9%	13.7%	17.3%
2015	nwpHOS	14.8%	0.8%	13.5%	16.6%
2015	pHOS	2.3%	1.0%	0.8%	4.8%
2015	cpHOS	12.5%	0.4%	11.6%	13.2%
2016	nwpHOS	10.5%	4.1%	4.7%	20.2%
2016	pHOS	6.4%	4.1%	1.1%	16.3%
2016	cpHOS	4.2%	1.3%	2.2%	7.4%
2017	nwpHOS	29.8%	4.1%	22.8%	38.6%
2017	pHOS	14.3%	4.8%	6.2%	24.7%
2017	cpHOS	15.5%	1.5%	12.6%	18.3%

Kalama River Weir

A total of 28,733, 19,416, and 16,561 adult fall Chinook salmon were trapped at the Kalama River Weir in 2015, 2016, and 2017, respectively. Over these three years, over 88% of the adult fall Chinook salmon caught were marked (Appendix D: Table D5).

Few modifications have occurred at the Kalama River Weir since 2015 (Appendix E). Weir efficiency has been high with mean weir efficiencies in excess of 89% all three years (Figure 11; Table 15). Flow events have not impacted weir operations while the weir has been installed (Appendix A: Figure A 20-22). However, weir operations were cut short in 2016 and 2017 prior to major rain events as a precautionary measure to ensure the weir could be removed (Table 14).

Since the Kalama River Weir began being used for pHOS control in 2015, pHOS levels have nearly been cut in half (Figure 12). From 2010-2014, mean pHOS estimates have ranged from 88.8-96.1% (Wilson et al. 2020). From 2015-2017, pHOS levels have ranged from 39.8-54.9% (Table 16). The Kalama River Weir has reduced pHOS levels from as little as 34.7% in 2015 to as much as 48.1% in 2016 (Figure 11; Table 16).

We assessed run timing for 2015 and 2017 and found run timing was variable between the years. Unmarked fall Chinook salmon were consistently later than their ad-clipped counterparts. The 50% passage date of unmarked fall Chinook salmon ranged from September 14 to 20 while ad-clipped fall Chinook salmon ranged from September 9 to 12 (Appendix F: Figure F4).

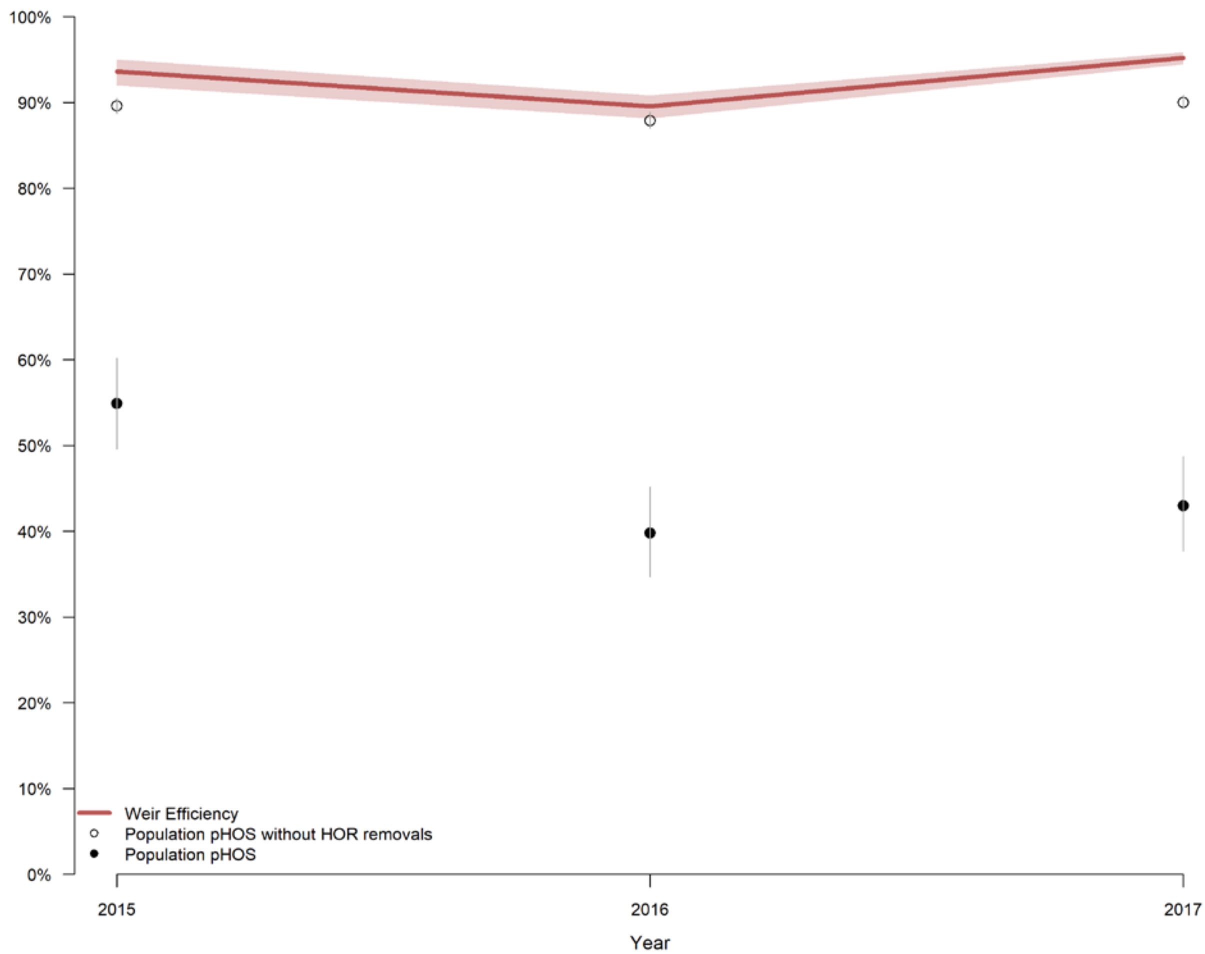

Figure 11. Estimates of weir effectiveness measured by weir capture efficiency and population-level proportion hatchery-origin spawners (pHOS) reduction for adult fall Chinook salmon for the Kalama River Weir, 2015-2017. The colored line represents the mean weir efficiency with the shading indicating the 95% credible intervals. The black circle represents the mean pHOS with the grey error bars indicating the 95% credible intervals. The open circle represents mean pHOS without removal of marked fish at the weir with the grey error bars indicating the 95% credible intervals.

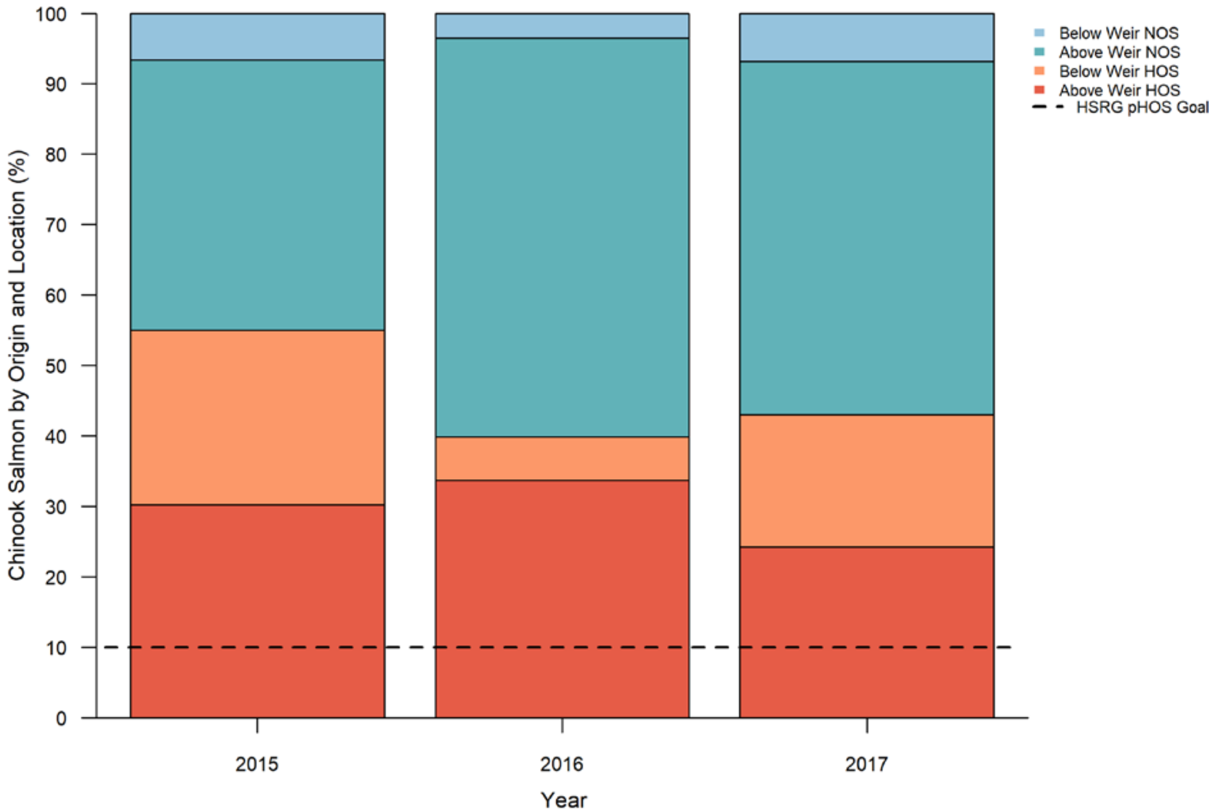

Figure 12. Estimates of contributions to proportion of hatchery-origin spawners (pHOS) by location for the Kalama fall Chinook population, 2015-2017. The warm colors represent hatchery-origin spawners (HOS) and the cold colors represent natural-origin spawners (NOS). The different shades of warm and colors represent contributions by location (e.g. below weir, above weir) and the black dashed line horizontal line represents the pHOS upper limit per HSRG.

Table 14. Target and actual weir operational dates, number of days in operation, number of days weir operations were known to be compromised while the weir was installed, and percentage of the target days the weir was in operation for the Kalama River Weir, 2015-2017.

	Operational Dates				Operational Days			
	Target		Actual					
Year	Install	Removal	First Day	Last Day	Days Compromised While Installed	Target	Actual	% of Target
2015	8/1	10/31	8/10	10/26	0	91	77	85%
2016	8/1	10/31	8/5	10/10	4	91	62	68%
2017	7/20	10/31	7/21	10/17	0	103	88	85%

Table 15. Estimates of adult fall Chinook salmon weir capture efficiency for the Kalama River Weir (mean, SD, and 95% credible intervals of the posterior distribution), 2015-2017.

Year	Mean	SD	L 95% CI	U 95% CI
2015	93.6%	0.8%	92.0%	95.1%
2016	89.6%	0.7%	88.2%	90.8%
2017	95.2%	0.4%	94.5%	95.9%

Table 16. Estimates of adult fall Chinook salmon proportion hatchery-origin spawners (pHOS), proportion hatchery-origin spawners with no hatchery-origin removals at weir (nwpHOS), and change in proportion of hatchery-origin spawners (cpHOS) for the Kalama fall Chinook population (mean, SD, and 95% credible intervals of the posterior distribution), 2015-2017.

Year	Parameter	Mean	SD	L 95% CI	U 95% CI
2015	nwpHOS	89.6%	0.5%	88.7%	90.5%
2015	pHOS	54.9%	2.7%	49.6%	60.2%
2015	cpHOS	34.7%	2.5%	29.8%	39.6%
2016	nwpHOS	87.9%	0.5%	87.0%	88.9%
2016	pHOS	39.8%	2.7%	34.7%	45.2%
2016	cpHOS	48.1%	2.5%	43.3%	52.8%
2017	nwpHOS	90.0%	0.4%	89.3%	90.9%
2017	pHOS	43.0%	2.8%	37.7%	48.7%
2017	cpHOS	47.1%	2.6%	41.9%	52.0%

Washougal River Weir

A total of 3,759, 10,116, 16,395, 6,674, and 3,002 adult fall Chinook salmon were trapped at the Washougal River Weir in 2013, 2014, 2015, 2016, and 2017, respectively. Over these five years, over 92% of the adult fall Chinook salmon trapped were marked (Appendix D: Table D6).

Weir efficiencies have been highly variable at this site despite a consistent weir location and design (Appendix E). Mean weir efficiencies have ranged from as low as 34.0% in 2013 to as high as 96.3% in 2014 (Figure 13; Table 18). In 2013, high flows topped the weir in late September and caused damage to the weir structure that did not allow for fish tight weir operations to resume for the year. In 2014 and 2015, flow events did not affect weir operations until late October. In 2016 high flows in the first week of October compromised weir efficiency. In 2017, flow events did not affect weir operations until the middle of October (Appendix A: Figure A23-A27) (Table 17).

The weir had varying degrees of success at reducing pHOS in the Washougal River depending on the year (Figure 14). The greatest impact was in 2014 when removal of marked fall Chinook salmon at the weir reduced pHOS levels by 53.9% (Figure 13; Table 19).

We assessed run timing for 2014 and 2015 and run timing varied between these two years. A consistent trend was unmarked fall Chinook salmon having run timing approximately one week later than ad-clipped fall Chinook salmon. The 50% passage date of unmarked fall Chinook salmon ranged from September 30 to October 6 while ad-clipped fall Chinook salmon ranged from September 23 to 27 (Appendix F: Figure F5).

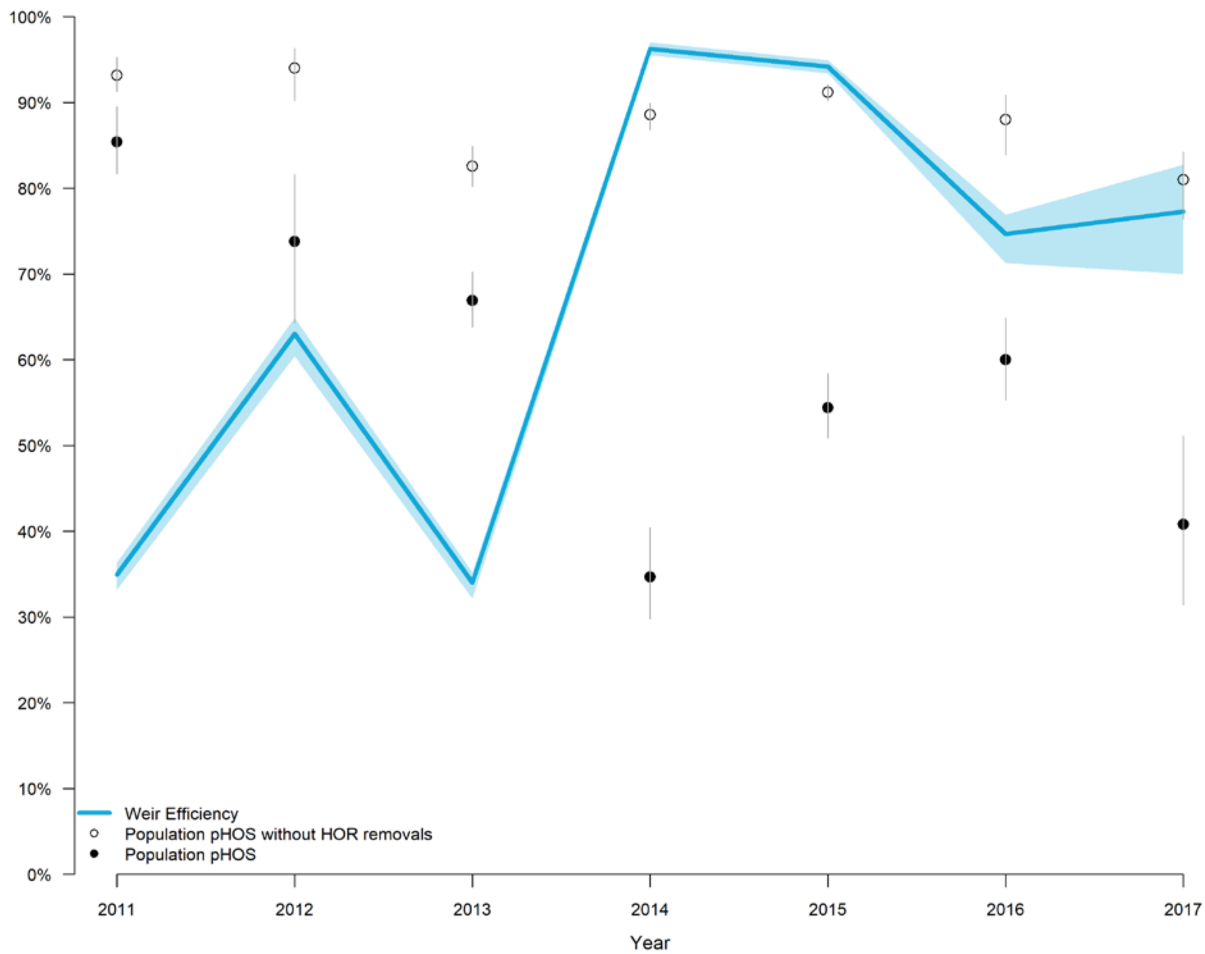

Figure 13. Estimates of weir effectiveness measured by weir capture efficiency and population-level proportion hatchery-origin spawners (pHOS) reduction for adult fall Chinook salmon for the Washougal River Weir, 2011-2017. The colored line represents the mean weir efficiency with the shading indicating the 95% credible intervals. The black circle represents the mean pHOS with the grey error bars indicating the 95% credible intervals. The open circle represents mean pHOS without removal of marked fish at the weir with the grey error bars indicating the 95% credible intervals.

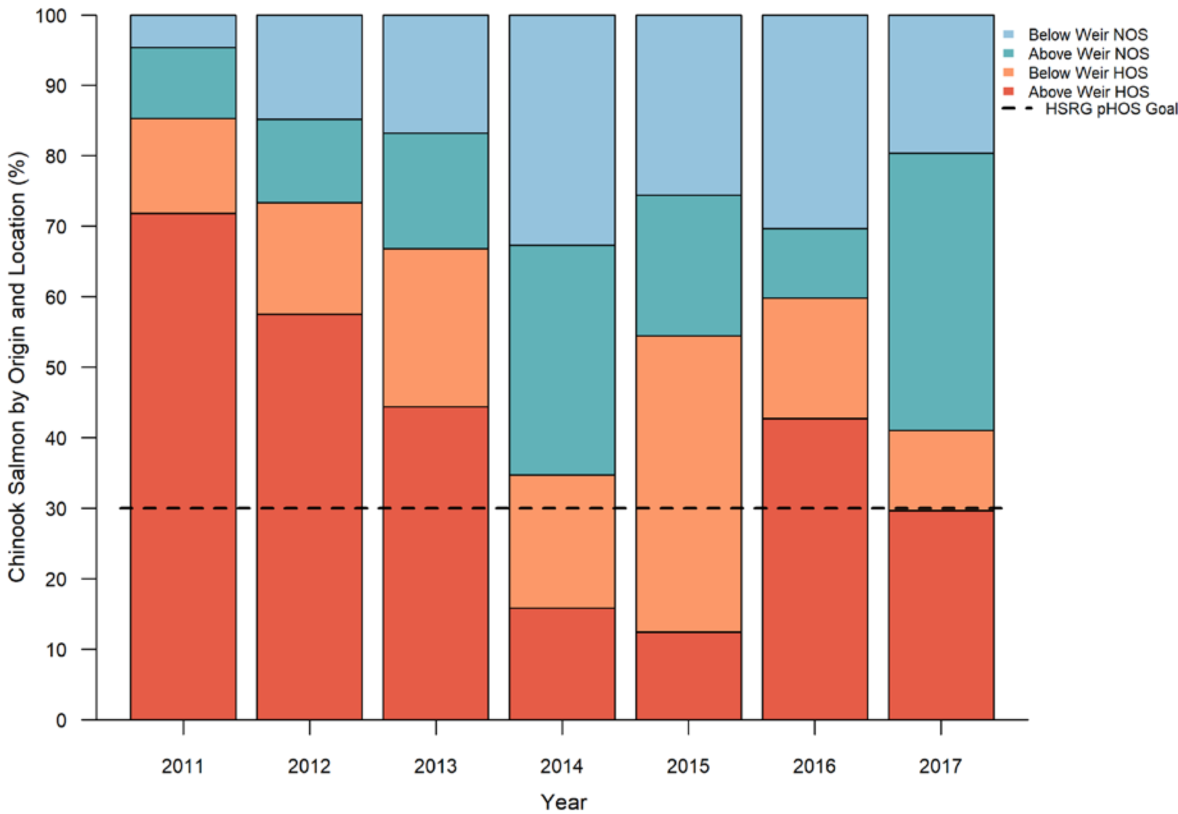

Figure 14. Estimates of contributions to proportion of hatchery-origin spawners (pHOS) by location for the Washougal fall Chinook population, 2011-2017. The warm colors represent hatchery-origin spawners (HOS) and the cold colors represent natural-origin spawners (NOS). The different shades of warm and colors represent contributions by location (e.g. below weir, above weir) and the black dashed line horizontal line represents the pHOS upper limit per HSRG.

Table 17. Target and actual weir operational dates, number of days in operation, number of days weir operations were known to be compromised while the weir was installed, and percentage of the target days the weir was in operation for the Washougal River Weir, 2011-2017.

	Operational Dates				Operational Days			
	Target		Actual					
Year	Install	Removal	First Day	Last Day	Days Compromised While Installed	Target	Actual	% of Target
2011	8/1	10/31	8/20	10/10	3	91	48	53%
2012	8/1	10/31	9/5	10/22	3	91	44	48%
2013	8/1	10/31	8/2	9/27	3	91	53	58%
2014	8/1	10/31	7/31	10/22	5	91	78	86%
2015	8/1	10/31	8/4	10/25	0	91	82	90%
2016	8/1	10/31	8/1	10/5	0	91	65	71%
2017	8/1	10/31	8/1	10/16	0	91	76	84%

Table 18. Estimates of adult fall Chinook salmon weir capture efficiency for the Washougal River Weir (mean, SD, and 95% credible intervals of the posterior distribution), 2011-2017.

Year	Mean	SD	L 95% CI	U 95% CI
2011	35.0%	0.8%	33.2%	36.4%
2012	63.0%	1.2%	60.4%	64.9%
2013	34.0%	0.8%	32.2%	35.2%
2014	96.3%	0.4%	95.5%	97.0%
2015	94.2%	0.4%	93.4%	95.0%
2016	74.7%	1.4%	71.3%	76.9%
2017	77.3%	3.2%	70.0%	82.8%

Table 19. Estimates of adult fall Chinook salmon proportion hatchery-origin spawners (pHOS), proportion hatchery-origin spawners with no hatchery-origin removals at weir (nwpHOS), and change in proportion of hatchery-origin spawners (cpHOS) for the Washougal fall Chinook population (mean, SD, and 95% credible intervals of the posterior distribution), 2011-2017.

Year	Parameter	Mean	SD	L 95% CI	U 95% CI
2011	nwpHOS	93.2%	1.0%	91.3%	95.3%
2011	pHOS	85.4%	2.0%	81.7%	89.5%
2011	cpHOS	7.9%	1.1%	5.7%	9.8%
2012	nwpHOS	94.0%	1.5%	90.2%	96.3%
2012	pHOS	73.8%	4.4%	64.3%	81.6%
2012	cpHOS	20.2%	3.0%	14.5%	26.5%
2013	nwpHOS	82.6%	1.2%	80.2%	84.9%
2013	pHOS	66.9%	1.6%	63.8%	70.2%
2013	cpHOS	15.8%	1.0%	13.8%	17.6%
2014	nwpHOS	88.6%	0.8%	86.8%	89.9%
2014	pHOS	34.7%	2.7%	29.8%	40.4%
2014	cpHOS	53.9%	2.5%	48.7%	58.5%
2015	nwpHOS	91.2%	0.5%	90.2%	92.1%
2015	pHOS	54.4%	1.9%	50.9%	58.4%
2015	cpHOS	36.8%	1.8%	33.1%	40.2%
2016	nwpHOS	88.0%	1.8%	83.9%	90.9%
2016	pHOS	60.0%	2.5%	55.3%	64.9%
2016	cpHOS	28.0%	2.1%	23.7%	32.1%
2017	nwpHOS	81.0%	2.0%	76.4%	84.2%
2017	pHOS	40.8%	5.0%	31.4%	51.1%
2017	cpHOS	40.2%	4.6%	30.9%	48.9%

Where are the Hatchery-Origin Spawners Coming From

The Washougal, Kalama, and Green rivers all have fall Chinook salmon hatchery releases within the basin. The coded-wire-tag (CWT) recoveries at these weirs operated in these basins show 99.7%, 92.3%, and 98.9% of CWT recoveries coming from these in-basin releases, respectively. The Grays, Elochoman, and Coweeman rivers do not have any fall Chinook salmon hatchery releases from within the basin. All marked fall Chinook salmon returning to these weirs/basins are strays from out-of-basin hatchery programs. Recovered CWTs from marked fall Chinook salmon surplused at the Coweeman Weir show that strays are primarily coming from Kalama River hatchery releases. Unexpanded CWTs recovered from surplused fall Chinook salmon at the Elochoman Weir shows almost half are from Big Creek Hatchery (an ODFW facility) and the other half are strays from Deep River net pen releases. Fall Chinook salmon strays to the Grays River continue to be dominated by SABs from South Fork Klaskanine (Oregon) with a handful of CWTs showing up from other locations (Table 20).

Table 20. Unexpanded coded-wire-tag (CWT) recoveries of fall Chinook salmon removed at the six lower Columbia River weirs, 2013-2017. Percentages represent the proportion of unexpanded coded-wire-tag from a given hatchery program at a given weir for five years combined (2013-2017). The numbers in parenthesis represent the raw number of coded-wire-tag recoveries.

	Recovery Location					
Release Basin	Grays Weir	Elochoman Weir	Coweeman Weir	Green Weir	Kalama Weir	Washougal Weir
Washougal	0% (0)	0% (0)	0% (0)	0% (0)	4% (35)	>99% (790)
Kalama	0% (0)	0% (0)	93% (13)	1% (1)	92% (910)	0% (0)
NF Lewis (Wild)	0% (0)	0% (0)	0% (0)	0% (0)	<1% (3)	0% (0)
Green River	0% (0)	0% (0)	0% (0)	99% (91)	0% (0)	0% (0)
Cowlitz	0% (0)	0% (0)	0% (0)	0% (0)	2% (21)	<1% 1)
Deep River	10% (3)	48% (46)	7% (1)	0% (0)	<1% (8)	0% (0)
Big Creek	3% (1)	50% (48)	0% (0)	0% (0)	<1% (9)	0% (0)
Youngs River & Bay	3% (1)	2% (2)	0% (0)	0% (0)	0% (0)	0% (0)
NF Klaskanine	17% (5)	0% (0)	0% (0)	0% (0)	0% (0)	<1% (1)
SF Klaskanine	67% (20)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)
Total CWT Recoveries	30	96	14	92	986	792

Weir Effects

We assessed the impact of handling live fish at weir sites by examining tagged and untagged female natural-origin carcasses recovered on spawning ground surveys upstream of weir locations to determine whether the probability of prespawn mortality was associated with fish having been previously handled and tagged at a weir. Sample sizes were too small in 9 out of the potential 27 year by weir combinations to assess the impact due to handling and tagging (Table 21). In the other 18 datasets, we were able to estimate the change in prespawn mortality due to handling and tagging. Results suggest the impact of handing and tagging was not significant for any of the datasets (all of the distributions span zero). However, most datasets showed a slight increase in prespawn mortality due to handling with the 2015 Washougal having the largest effect (Table 22). We will continue to examine this in future years as sample sizes allow, and we will work toward developing alternative methods of assessing handling mortality.

Table 21. Number of natural-origin female adult fall Chinook salmon carcasses evaluated for spawn success upstream of weir locations for spawn years 2013-2017. T represents tagged (e.g. handled at weir) and NT represents not tagged (e.g. not handled at weir).

		Basin											
		Grays		Elochoman		Coweeman		Green		Kalama		Washougal	
Year	Spawn Success	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT
2013	Yes	3	6	0	1	6	203	5	6	NA	NA	19	155
	No[a]	0	0	0	0	0	0	0	0	NA	NA	3	8
2014	Yes	3	8	5	0	62	71	6	0	NA	NA	51	2
	No[a]	0	0	1	0	3	5	0	0	NA	NA	14	1
2015	Yes	2	8	7	1	157	7	11	0	41	19	42	7
	No[a]	0	0	2	0	3	0	0	0	7	2	27	3
2016	Yes	0	3	0	1	0	15	10	1	113	10	6	21
	No[a]	0	0	0	0	0	0	1	0	16	2	2	0
2017	Yes	NA	NA	0	0	14	8	0	0	148	19	9	2
	No[a]	NA	NA	1	0	0	0	0	0	10	1	0	2

[a] No = >75% eggs retained.

Table 22. Estimates of change in adult fall Chinook salmon prespawn mortality (median and 95% credible intervals) due to handling and tagging at weir locations for spawn years 2013-2017.

Year	Weir Location	L 95% CI	Median	U 95% CI
2013	Coweeman	-0.7%	0.4%	5.2%
2014	Coweeman	-6.4%	0.2%	4.7%
2015	Coweeman	-3.4%	0.3%	2.5%
2017	Coweeman	-3.3%	0.3%	4.8%
2015	Elochoman	-18.1%	2.5%	18.7%
2013	Grays	-5.2%	0.4%	10.4%
2014	Grays	-5.9%	0.4%	9.5%
2015	Grays	-4.9%	0.4%	10.4%
2013	Green	-5.0%	0.4%	8.5%
2016	Green	-6.9%	0.7%	8.4%
2015	Kalama	-7.4%	3.0%	13.3%
2016	Kalama	-4.5%	2.1%	8.2%
2017	Kalama	-4.6%	1.5%	6.1%
2013	Washougal	-6.7%	2.7%	15.1%
2014	Washougal	-24.5%	2.6%	15.0%
2015	Washougal	-8.8%	12.4%	35.6%
2016	Washougal	-7.7%	3.8%	23.6%
2017	Washougal	-48.1%	-1.7%	11.9%

The Mitchell Act Biological Opinion (NOAA 2016b) suggests using change in peak spawning date as a measure of migration delay due to weir effect. Our data suggests peak spawn timing has some variation year to year but was relatively constant within a population if the pHOS composition remained constant (Wilson et al. 2020). Our monitoring program was not set-up to robustly analyze spawn timing for most of our LCR fall Chinook salmon populations until 2010 when a comprehensive VSP monitoring program was implemented. This happened to coincide with the implementation of many of these weirs. As a result, we do not have baseline spawn timing data for most populations prior to the implementation of weirs. The one fall Chinook population with intensive monitoring for several years prior to a weir being installed was the Coweeman River. We examined spawn timing based on counts of live Chinook salmon identified as spawners from spawning ground surveys in 2003, 2004, and 2007-2017. Fall Chinook in this population show similar spawn timing dates before and after implementation of the weir (2011), however 2004 and 2010 did show a slightly earlier spawn time (50% spawn date of October 1) (Figure 15). For the years prior to weir implementation, the 50% spawn date ranged from October 1 to October 8. For the years after weir implementation, the 50% spawn date ranged from October 4 to October 7. This could be due to a weir effect, natural variation, or higher proportions of hatchery-origin spawners these years. Another confounding factor is all of these weirs are intentionally removing hatchery-origin spawners from the system. It is possible that spawn timing will naturally shift later in many of these populations due to less early-timed hatchery-origin influence or due to continued evolutionary adaptation to changing environmental and habitat conditions (e.g. climate change).

An alternative metric that may be useful in quantifying migration delay is apparent residence time. Preliminary analyses suggest that apparent residence time for fall Chinook salmon in the LCR is typically shorter in places that have weirs compared to places that do not have weirs installed (*Jeremy Wilson, unpublished data, WDFW*). Again, having enough baseline data to compare across years in a single basin prior to weir implementation is problematic. We examined apparent residence time on the Coweeman River from 2002-2017 (Figure 16). The median value for years when the weir was not installed was 6.23 days while years with the weir installed was 3.14 days.

Displaced spawning below the weirs has been a problem at most sites throughout the evaluation period. This issue was exacerbated in years where we had extremely dry weather conditions in the early fall (e.g. 2014 and 2015). We used methods outlined in Wilson et al. 2020 to stratify abundance estimates above and below each of the weir sites (Table B1-Table B6). Similar to the other weir effect metrics, we have limited baseline data for most of the populations that now have weirs installed. The populations and years we do have data for are the Coweeman River from 2003-2004 and 2007-2010 and the Washougal River for 2009-2010. We examined redd distribution of fall Chinook salmon on the Coweeman River for years before a weir was installed (2003-2003, 2007-2010) compared to years after a weir was installed (2011-2017). Our results show a shift in spawner distribution to lower in the basin in years with the weir installed (Figure 17). More specifically, redd densities decreased in the upper Coweeman between Washboard Falls (rkm 50.13) and Baird Creek (rkm 43.13), and became more concentrated lower in the system, especially around the upper weir location.

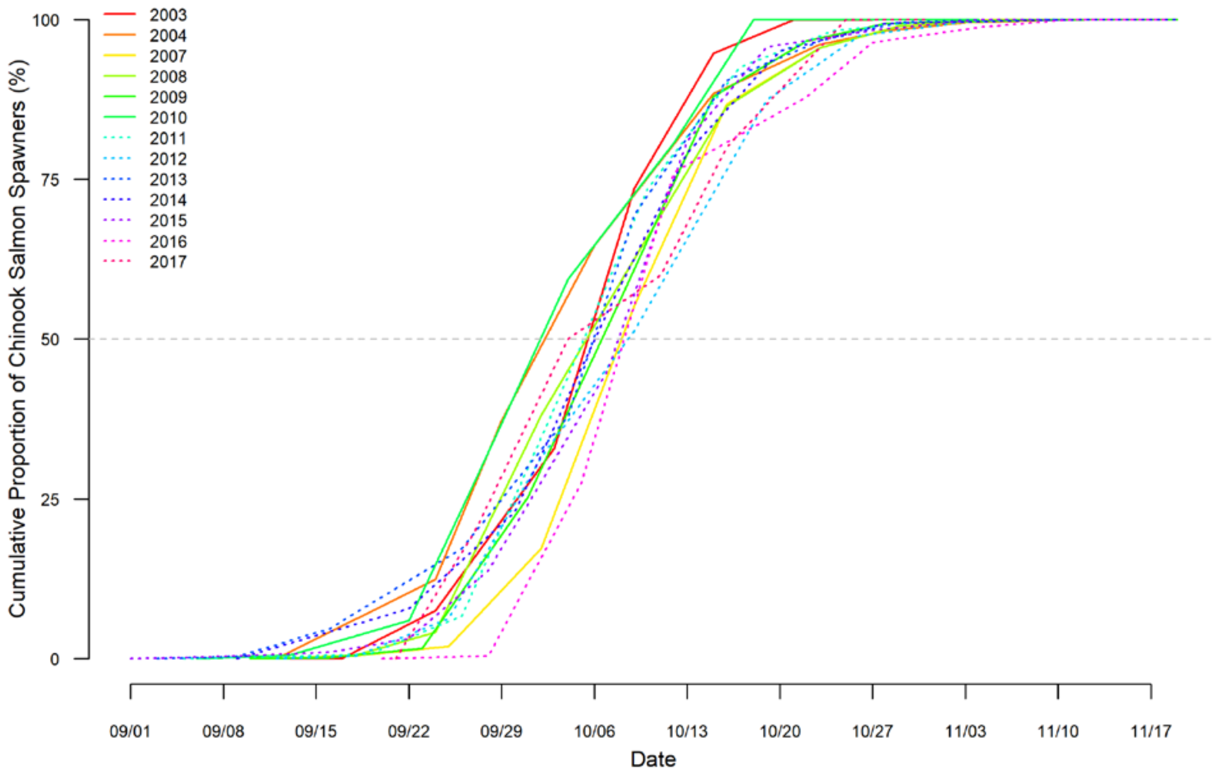

Figure 15. Spawn timing of adult fall Chinook salmon in the Coweeman River, 2003-2004, 2007-2017). Dotted lines represent years with the weir installed (2011-2017) and solid lines represent years prior to the weir being operated (2003-2004, 2007-2010).

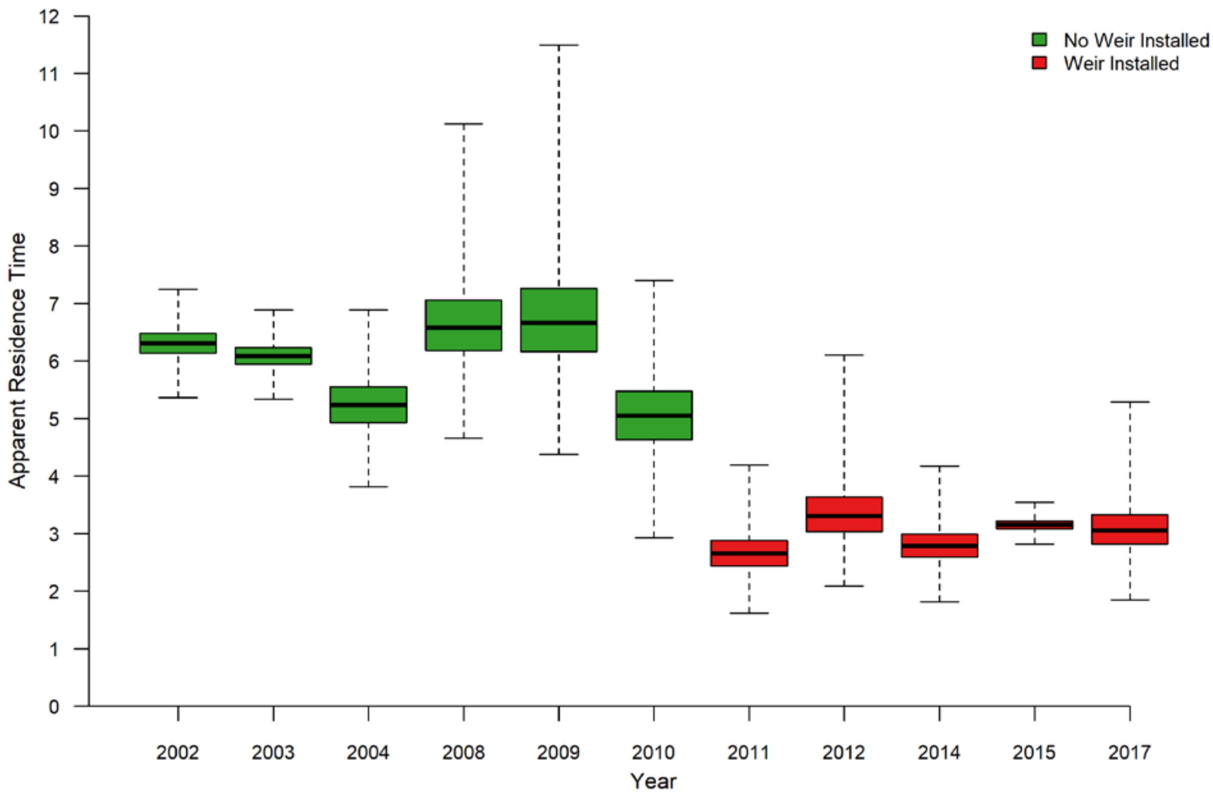

Figure 16. Estimates of apparent residence time of adult fall Chinook salmon on the Coweeman River (median, 25% and 75% quantiles, and 95% credible intervals of the posterior distribution), 2002-2017. Green indicates no weir installed and red indicates weir installed. Apparent residence time estimates were not available for 2005-2007, 2013, and 2016 due to unsuccessful mark-recapture estimates.

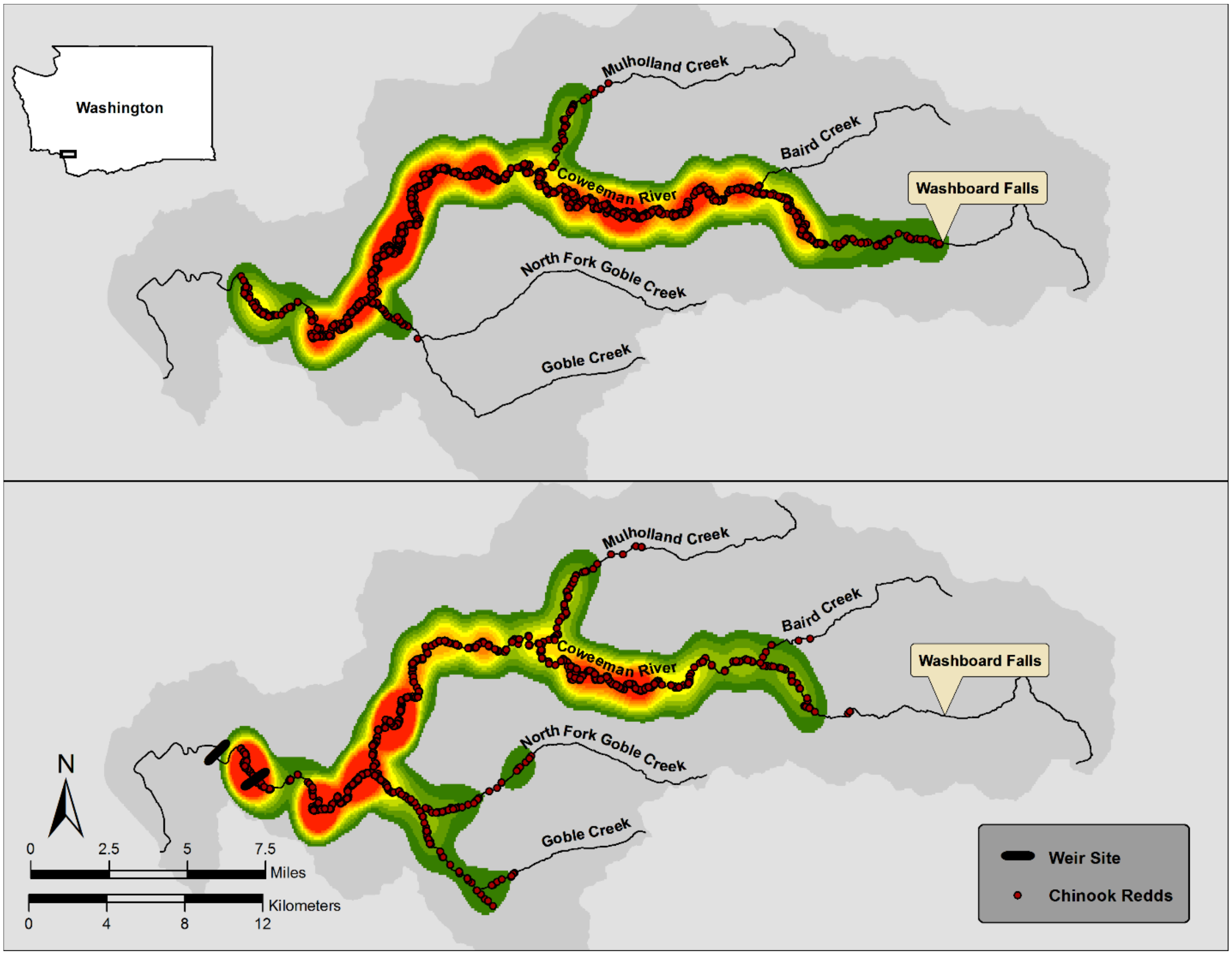

Figure 17. Fall Chinook salmon redd distribution in the Coweeman River in years without a temporary resistance board weir installed (2003-2004, 2007-2010) (top) compared to years with a temporary resistance board weir installed (2011-2017) (bottom). Densities of redds are represented using the kernel density function were red backgrounds represents the highest densities and green backgrounds represents lowest densities.

Discussion

Weir Performance

Weir efficiency was highly variable depending on the year and location. However, locations with permanent infrastructure (Kalama River Weir, Green River Weir, and Elochoman River Weir) had consistently higher weir efficiencies across years in comparison to locations without permanent infrastructure (Washougal River Weir, Coweeman River Weir, and Grays River Weir).

Weir efficiency is a measure of how well a weir can capture fish passing the weir site but this may or may not be directly related to how well a weir meets the primary objective of reducing pHOS. There are a several things that can confound a weir’s ability to reduce pHOS: (1) spawning below the weir site, (2) unclipped hatchery-origin fish, (3) low natural-origin abundance, and (4) subpopulations that contribute to population-level pHOS but do not have weirs to remove hatchery-origin fish.

The impact of fish spawning below a weir site on the ability to meet pHOS targets is best illustrated by the examining Washougal River data. In 2014 and 2015, weir efficiency was greater than 94% (See results section: Figure 13, Table 18). These high efficiencies indicate that few fish were able to bypass the weir. This can happen a variety of ways, such as jumping the weir structure, swimming through a small hole in the weir structure, or passing the weir site before the weir was installed or after the weir was removed. However, even with this exceptional weir efficiency and removal of over 26,000 HOR fall Chinook salmon during those years, we still did not meet our pHOS target of 30%. In 2014, the estimated pHOS was 51.2%, and for 2015, it was 67.4% (Appendix B: Table B6). Although the weir was largely stopping fish, all of the fish the weir stopped did not recruit to the live box. As a result, some spawned below the weir and the resulting contribution of these spawners drove the pHOS over the acceptable 30% limit.

The use of adipose fin excision as a mass mark for hatchery salmonids is highly successful. However, there are a small proportion of juvenile hatchery releases that do not display acceptable marks; this is typically less than 5% (RMIS, https://www.rmpc.org). The small proportion of hatchery-origin fish that remain unmarked may lead to bias in pHOS estimates. If fisheries, weirs, or hatcheries are not selectively removing adipose-clipped fish from the system at different rates than unclipped fish, the impact of unclipped hatchery-origin fish on pHOS estimates are minimal. However, this bias becomes amplified when large numbers of hatchery-origin fish are returning to populations with low natural-origin salmon abundance, even when the marked hatchery-origin fish are being removed (Appendix C). We adjusted our estimates of pHOS taking into account unclipped hatchery-origin fish using methods described in Wilson et al. 2020. In the most stringent scenarios (e.g. primary populations), current HSRG pHOS targets are unattainable even with high weir efficiency due to the inability to remove unclipped hatchery-origin fish.

Low natural-origin abundance, especially in the Coast strata, confounded with the flashy nature of many of the streams has made meeting pHOS objectives difficult. The Grays/Chinook and Elochoman/Skamokawa fall Chinook populations have annual NOR abundance estimates that averaged less than 150 fall Chinook salmon each over the last eight years. In most years, we have been successful at meeting pHOS objectives at the subpopulation-level on the Elochoman River. This is due to the Elochoman Weir having solid, stable, and permanent infrastructure (concrete sill and large trap box) that was constructed decades ago as part of an old hatchery program. However, if just a few hatchery-origin fish escape past the weir during a freshet, pHOS can quickly exceed management objectives. The Grays River Weir has the additional challenge of large numbers of SAB fall Chinook salmon straying into the system. These fish are hatchery-origin and have a prolonged time of entry into LCR tributaries; they first appear in Youngs Bay fisheries in June/July but do not spawn until mid-to-late October. Given the prolonged migration of these strays, the weir needs to be installed early enough to control SABs and weir efficiencies need to be high through at least mid-October to meet pHOS targets.

The upper threshold limits set by the HSRG for pHOS are population-level limits. Four of the six fall Chinook salmon management weir sites do not have contributing sub-populations (Grays, Coweeman, Kalama, and Washougal). The Toutle and the Elochoman/Skamokawa populations both have subpopulations, uncontrolled by weirs, that contribute to population-level pHOS. The Toutle population is comprised of the Green River, South Fork Toutle River, and to a much lesser degree the North Fork Toutle River. While the Elochoman/Skamokawa population is comprised of the Elochoman River and Skamokawa Creek. Although neither the South Fork Toutle River nor Skamokawa Creek have any direct releases of hatchery fall Chinook salmon, both have high pHOS levels that contribute to the population level pHOS estimates resulting in overall estimates over the acceptable limits.

Weir Effects

Weirs offer the potential to aid in monitoring wild populations, collecting broodstock, and/or reducing interactions between natural- and hatchery-origin fish on the spawning grounds. However, weirs may also have negative effects such as increasing mortality due to handling, delaying migration, and displacing spawning below the weir site due to weir rejection (NOAA 2016b). When weirs are not used specifically for controlling pHOS (e.g. broodstock collection and/or a mark-capture platform), these effects can be minimized by altering the trapping schedule and allowing some fish to pass unimpeded. With the exception of the Coweeman, the populations evaluated in this report experience disproportionately high numbers of hatchery-origin fall Chinook salmon, and therefore, require 24/7 operation of weirs to reduce pHOS to acceptable levels (Appendix C). The condition of continuous operation results in greater impacts, as described above. We have initiated some proactive measures in an effort to reduce these impacts. Such measures include seining below weir sites, modifications to weir and trap box designs, and multiple processing events per day to clear trap boxes of fish. However, further work should be done to develop prudent, quantifiable, and acceptable measures of weir effects.

Migration delay due to weirs may affect a fall Chinook's ability to reach the mid-to-upper watershed to spawn. The combined effect of impending maturity and limited energy reserves may force delayed fish to spawn lower in the system than that fish would without weir delay. Therefore, changes in spawning distribution above the weir site may also be a good measure of a weir effect. However, as with other measures of weir delay, having adequate baseline data, teasing out natural variability from true weir effects, and being able to quantify it may prove difficult.

Another promising measure of a weir effect is quantifying how spawner-recruit residuals are affected by spawner distributions, and the proportion of hatchery spawners. This would allow management to determine conditions where hatchery spawner removal can benefit a population.

We will continue to evaluate ways to improve recruitment to in the future. However, recruitment to trap live boxes during periods of low streamflow (early fall) will always be challenging. Decisions will need to be made in-season, and on a case-by-case basis, to allow for the greatest benefit to the specific population. For example, if fish begin schooling below a weir in a system with a large return of natural-origin fish and a relatively low hatchery-origin return, it may be acceptable to allow unimpeded passage for a short period knowing that pHOS levels are being compromised to a certain extent with the benefit of reducing delay. However, if fish begin schooling below a weir in a system with a large return of hatchery-origin fish and a relatively low natural-origin return, it becomes a tougher question: Is it better to confine hatchery-origin fish to spawn below the weir site (in presumptively lower quality habitat) but in doing so, also delay the migration of natural-origin fish and shift their spawning distribution downstream (including a portion forced to spawn below the weir)? Alternatively, is it worth intentionally comprising pHOS levels above the weir site (higher quality habitat) by sinking the weir to reduce the impact of displaced spawning below the weir sites?

This report evaluated the effectiveness and impact of several weirs used in Southwest Washington for management of fall Chinook salmon pHOS. We hope managers will use the results and lessons learned presented as a tool to inform the adaptive management feedback loop moving forward.

Recommendations

(1) Invest in permanent infrastructure and look for land acquisition opportunities for Coweeman, Grays, and Washougal weirs.

(2) Work towards 100% mass marking using automated fin clipping trailers.

(3) Ensure mass marking QA/QC sample sizes are adequate (a minimum sample size of 5000 fish per release site and year), are done consistently from hatchery to hatchery, and the raw data are available to adjust natural-origin spawner abundance estimates.

(4) Develop a new design for Elochoman Weir and secure funding to run the weir during higher flows in November and December to control coho salmon pHOS.

(5) Consider installing weirs on South Fork Toutle and Skamokawa to reduce population-level pHOS in the Toutle and Elochoman/Skamokawa populations.

(6) Evaluate and pursue potential weir sites further downstream on the Washougal River to reduce spawning below the weir site and increase trap box capacity to improve recruitment.

(7) Consider modifications to hatchery program sizes and/or changes in rearing strategies for populations where pHOS targets currently appear to been unattainable using the weir planning tool (Appendix C: Figure C1-C3).

(8) Continue to improve monitoring of weir impacts on wild population to better understand the population dynamic effects of weir-induced migration delays in order to determine whether weirs are able to act as a net benefit to naturally spawning populations through pHOS reduction, or instead act as a net harm to wild populations through reduced population productivity due to migration delay and redistribution of spawners.

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Appendix A - Total fall Chinook salmon catch, unmarked fall Chinook salmon catch, streamflow, and trapping events by date plots

Plots of total fall Chinook salmon catch, unmarked fall Chinook salmon catch, and streamflow were generated for each of the six fall Chinook salmon weir sites. We also included the following trapping events on each of the plots: weir installation date, weir removal date, when weir efficiency was known to be compromised, and when the weir was installed but not fishing. Streamflow data for the Grays River Weir was taken from the Washington Department of Ecology (WDOE) monitoring station on the Grays River (Station ID: 25B060). For the Elochoman River Weir, streamflow data were not available specific to the Elochoman River for 2013 and 2014. Therefore, we used the streamflow data described above from the Grays River. For 2015-2017, streamflow data were available specific to the Elochoman River from the WDOE monitoring station at Monroe Drive (Station ID: 25C060). No streamflow data were available for the Green River. Therefore, USGS data from the streamflow station on the NF Toutle River near Kid Valley, WA (Station ID: 14240525) was used as a surrogate. For the Coweeman River Weir, streamflow data was taken from the WDOE monitoring station on the Coweeman River near Kelso (Station ID: 26C075). For the Kalama River Weir, no streamflow data were available specific to the Kalama River. Therefore, we used the Coweeman streamflow data described above for the Kalama (Modrow) Weir site as a surrogate. For the Washougal River Weir, streamflow data was taken from the WDOE monitoring site at Hathaway Park (Station ID: 25B080).

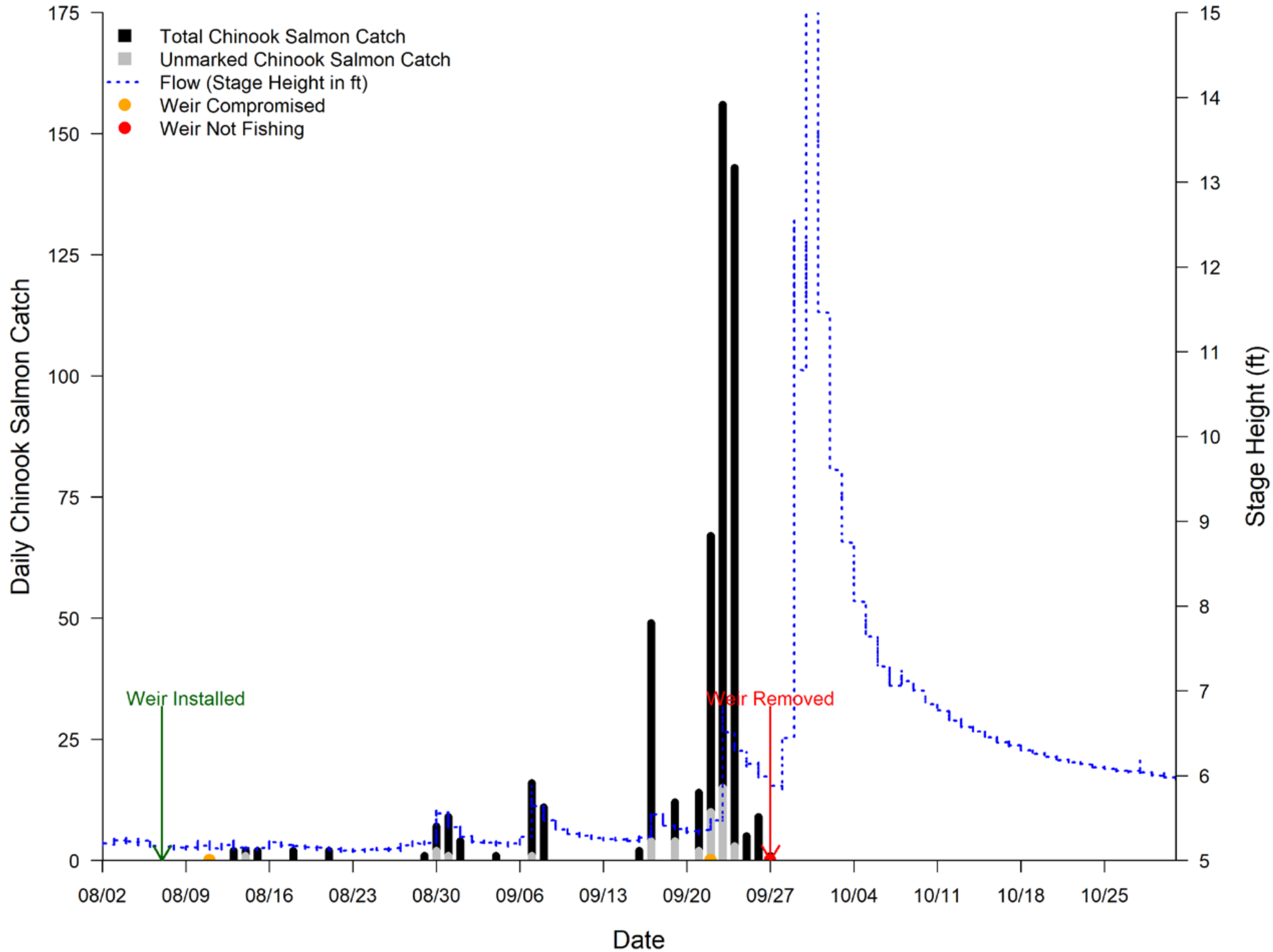

Figure A1. Total catch, unmarked catch, and stage height by date for fall Chinook salmon captured at Grays River Weir, 2013 (WDOE 2018). Maximum stage height is 15.37 feet.

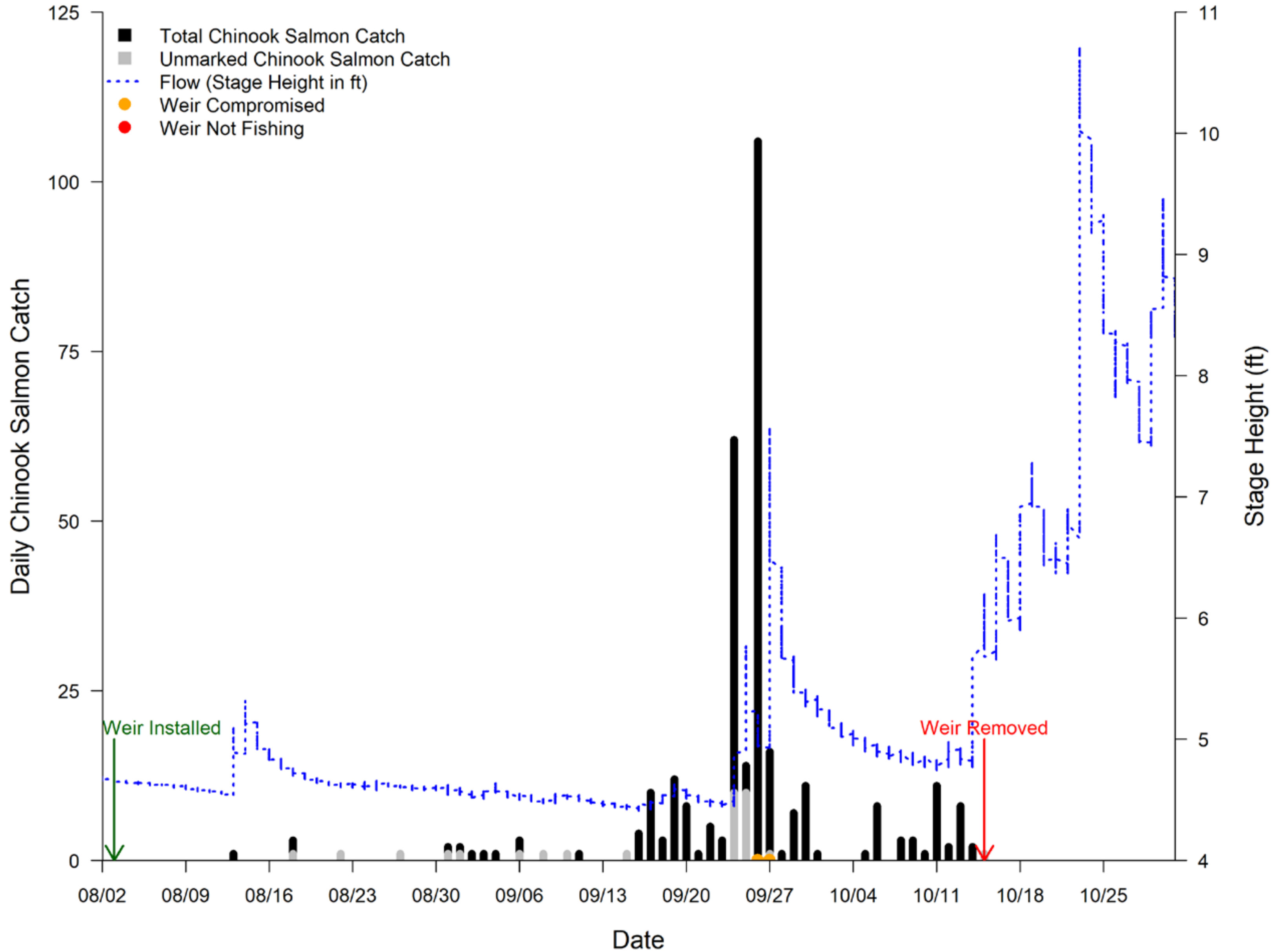

Figure A2. Total catch, unmarked catch, and stage height by date for fall Chinook salmon captured at Grays River Weir, 2014 (WDOE 2018).

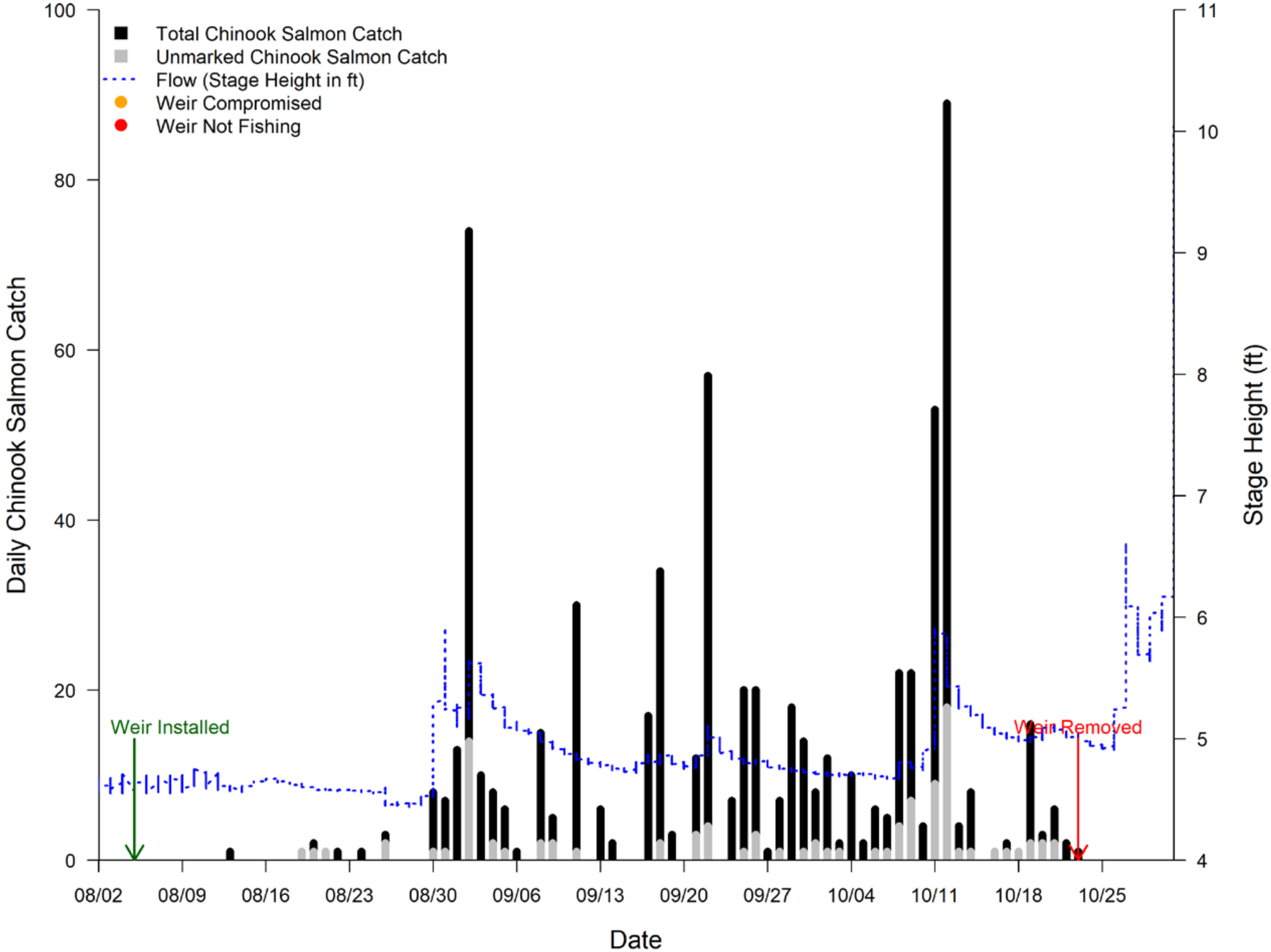

Figure A3. Total catch, unmarked catch, and stage height by date for fall Chinook salmon captured at Grays River Weir, 2015 (WDOE 2018).

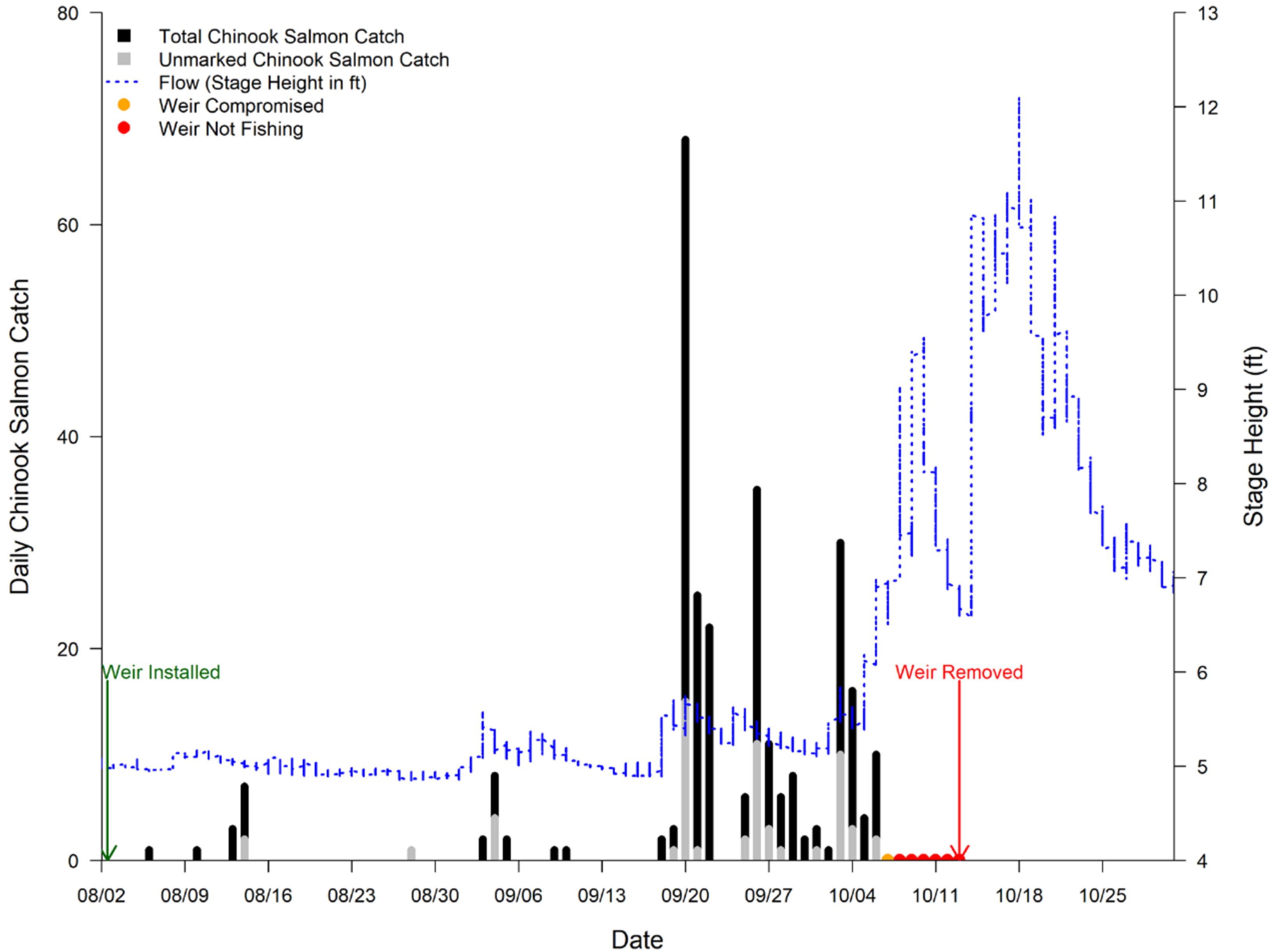

Figure A4. Total catch, unmarked catch, and stage height by date for fall Chinook salmon captured at Grays River Weir, 2016 (WDOE 2018).

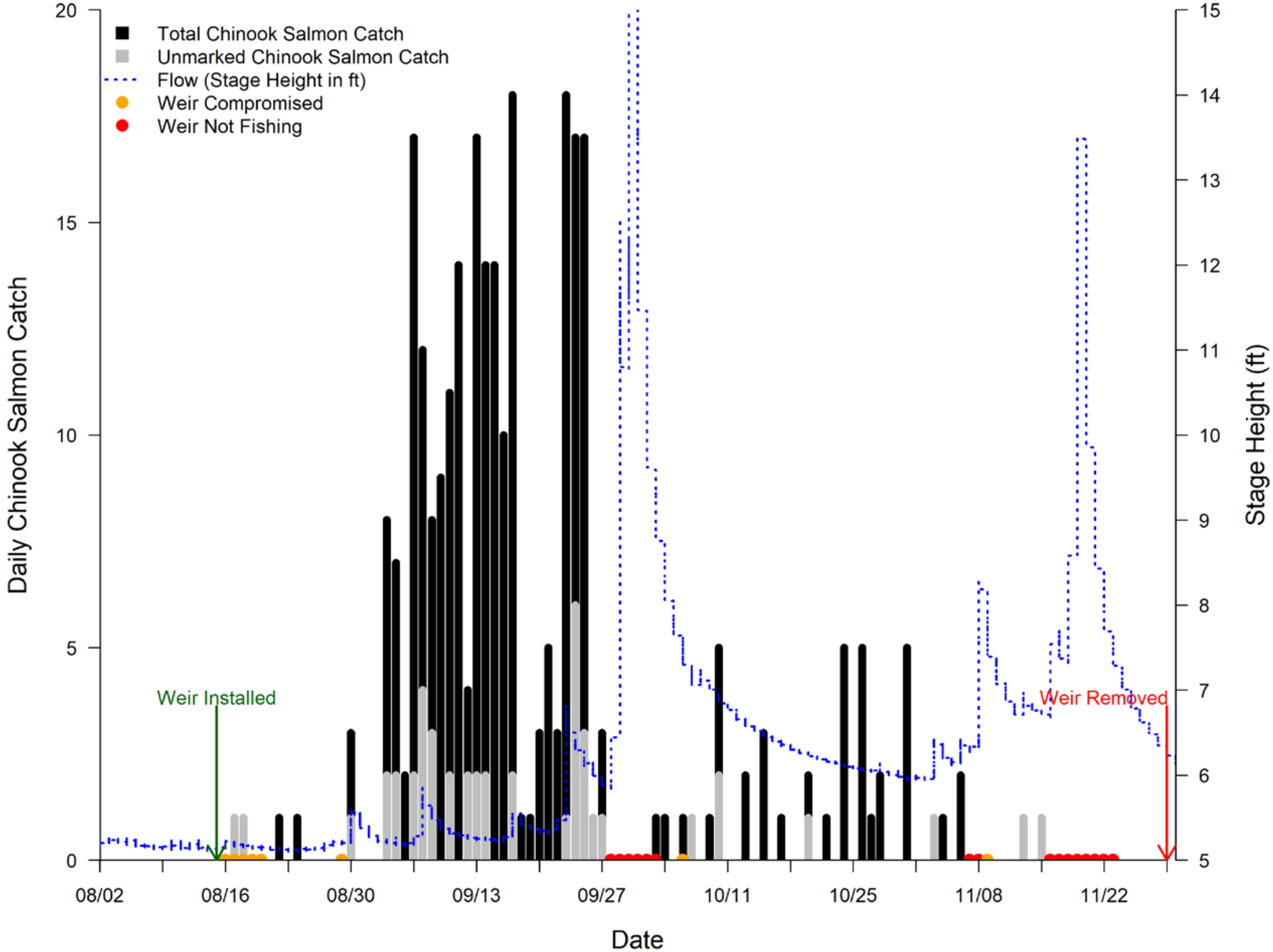

Figure A5. Total catch, unmarked catch, and stage height by date for fall Chinook salmon captured at Elochoman River Weir, 2013 (WDOE 2018). Maximum stage height is 15.37.

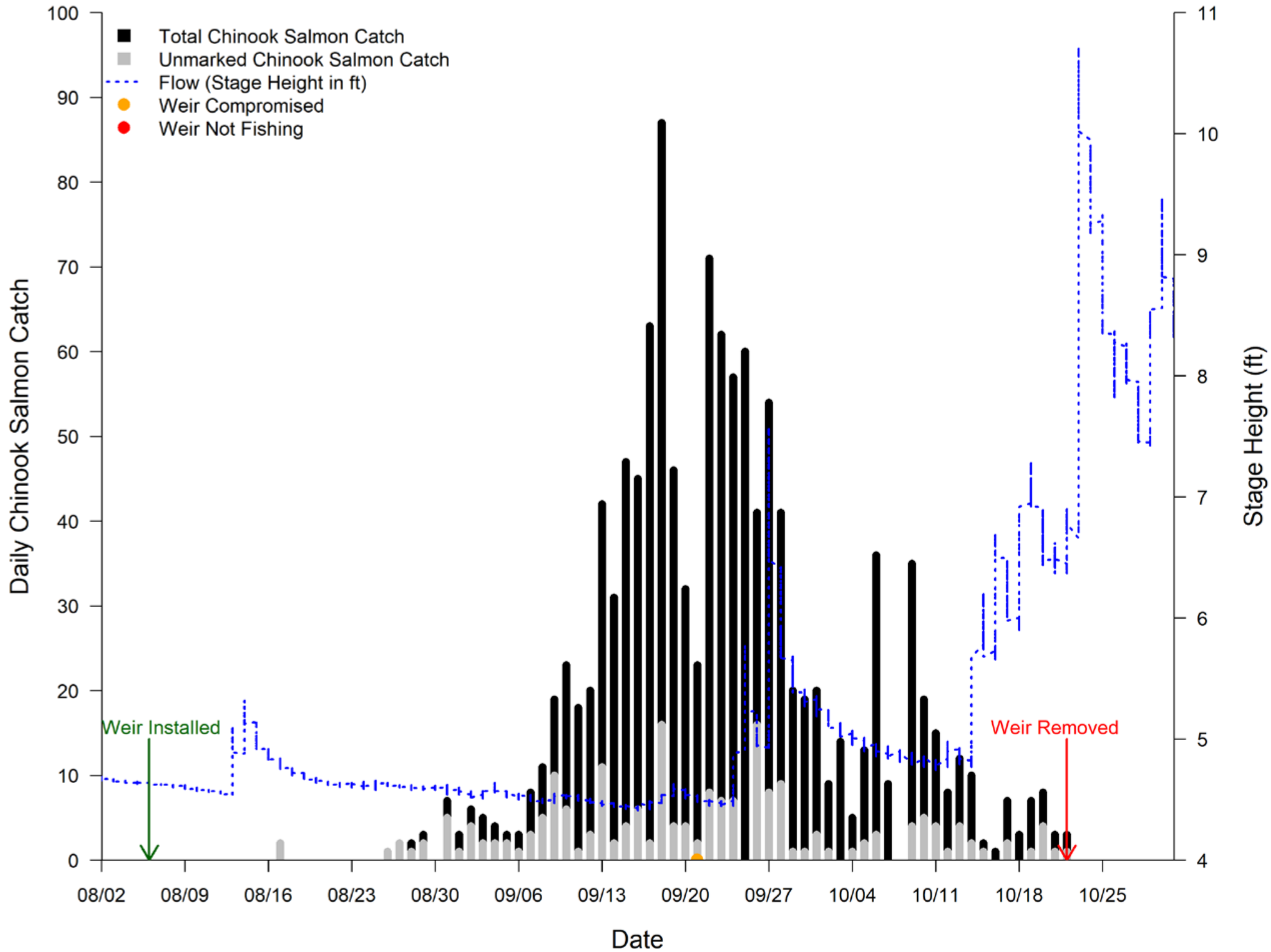

Figure A6. Total catch, unmarked catch, and stage height by date for fall Chinook salmon captured at Elochoman River Weir, 2014 (WDOE 2018).

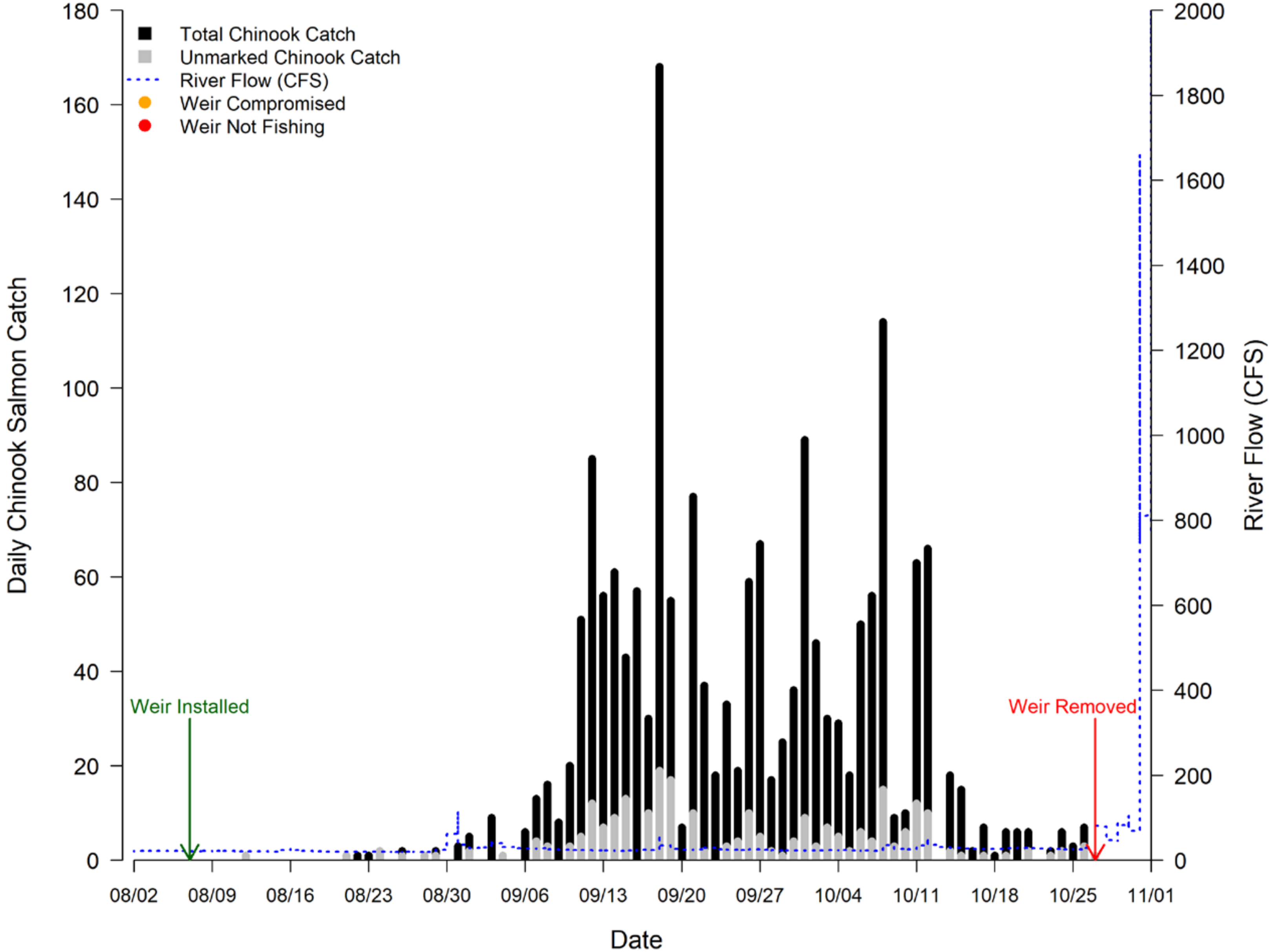

Figure A7. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Elochoman River Weir, 2015 (WDOE 2018).

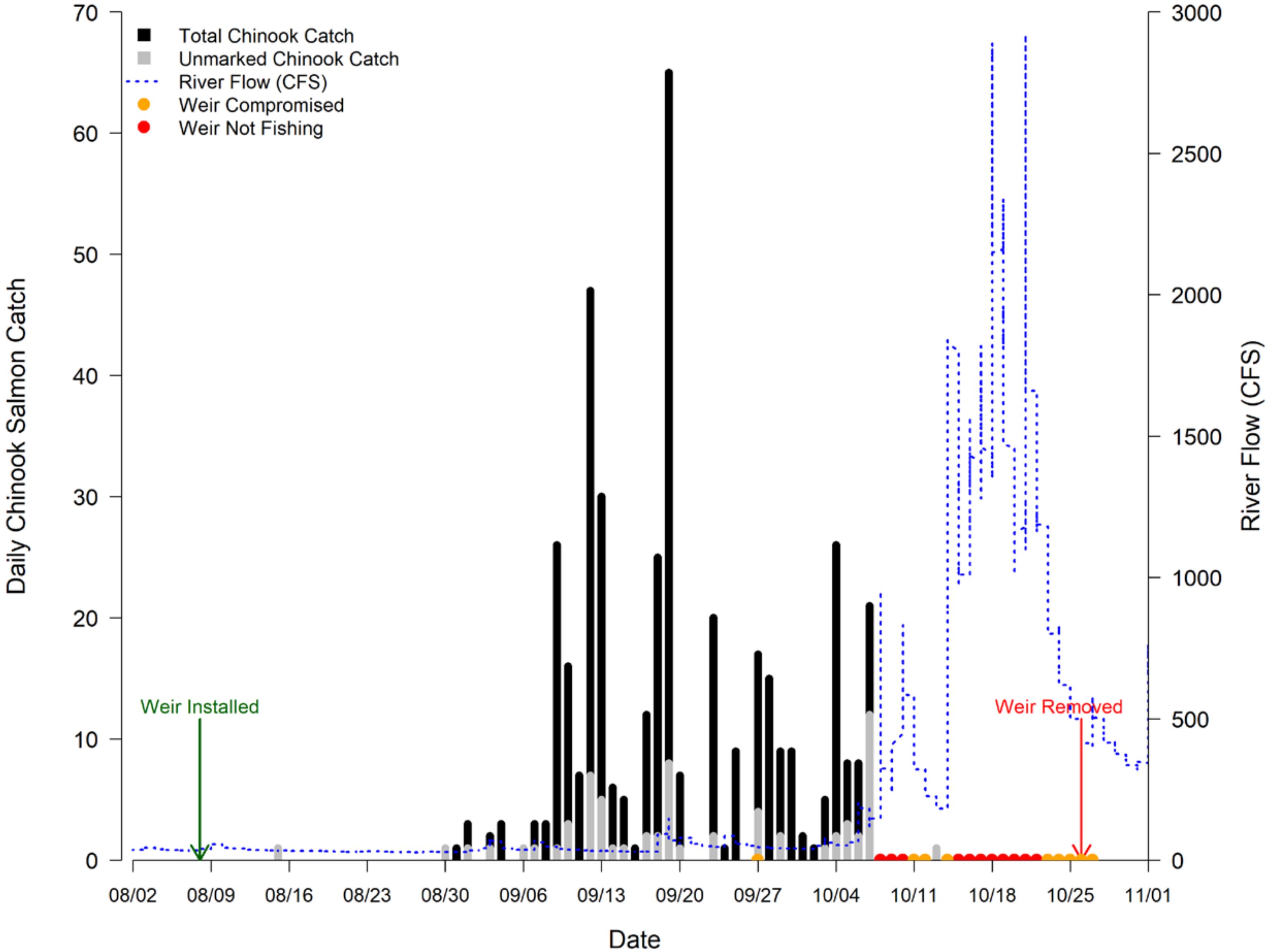

Figure A8. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Elochoman River Weir, 2016 (WDOE 2018).

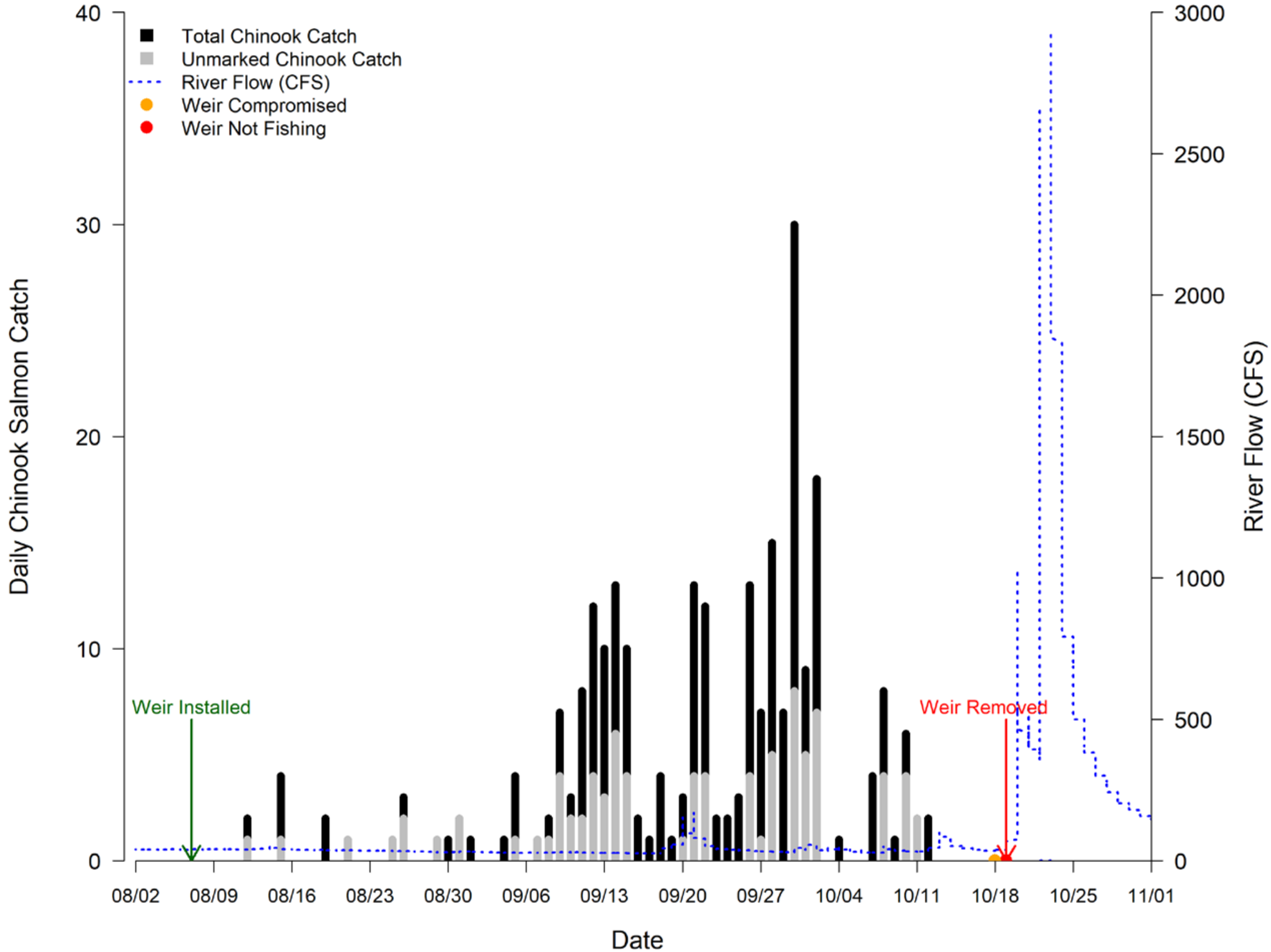

Figure A9. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Elochoman River Weir, 2017 (WDOE 2018).

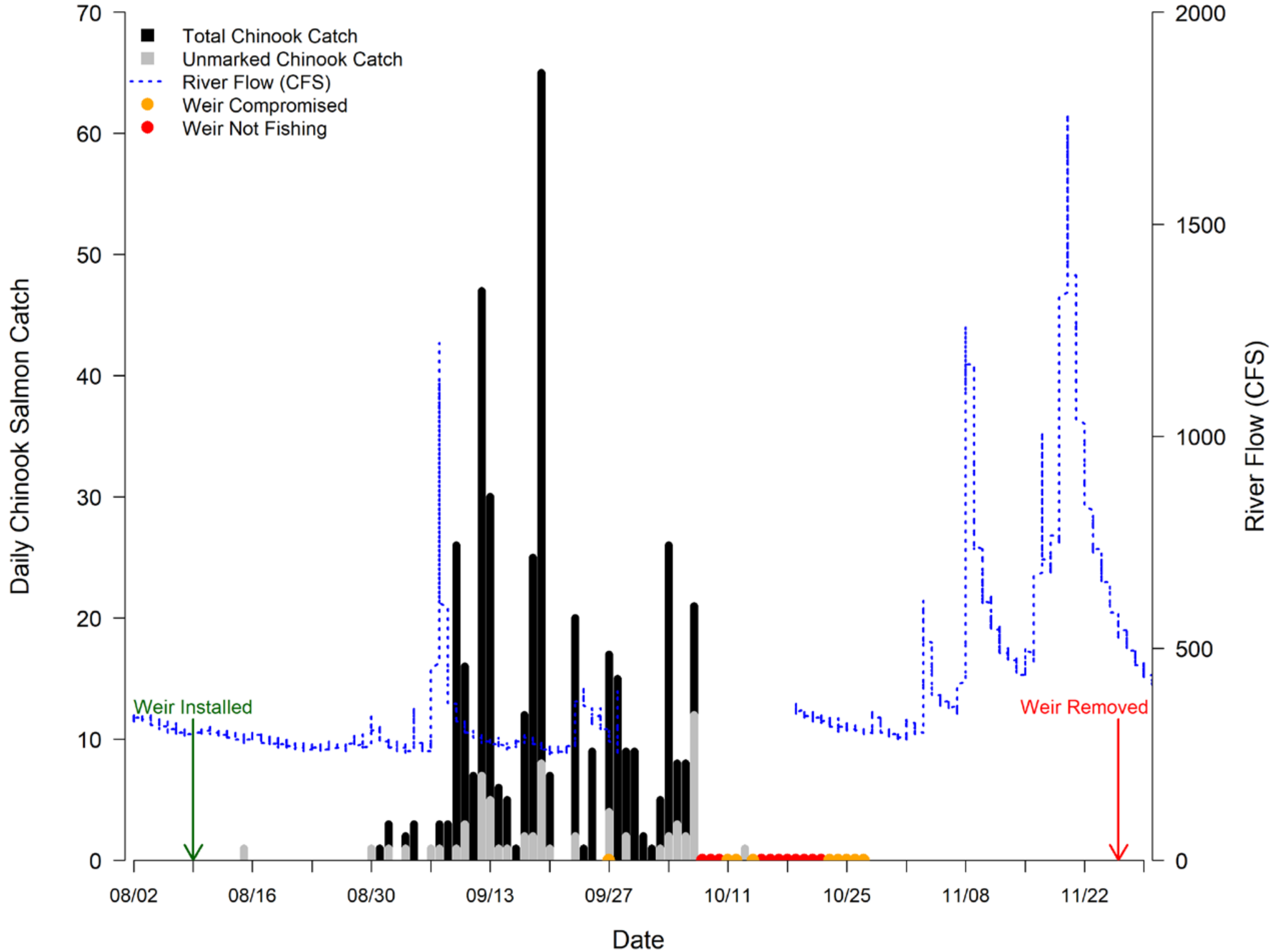

Figure A10. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Green River Weir, 2013 (USGS 2018). No streamflow data available from September 28 to October 17.

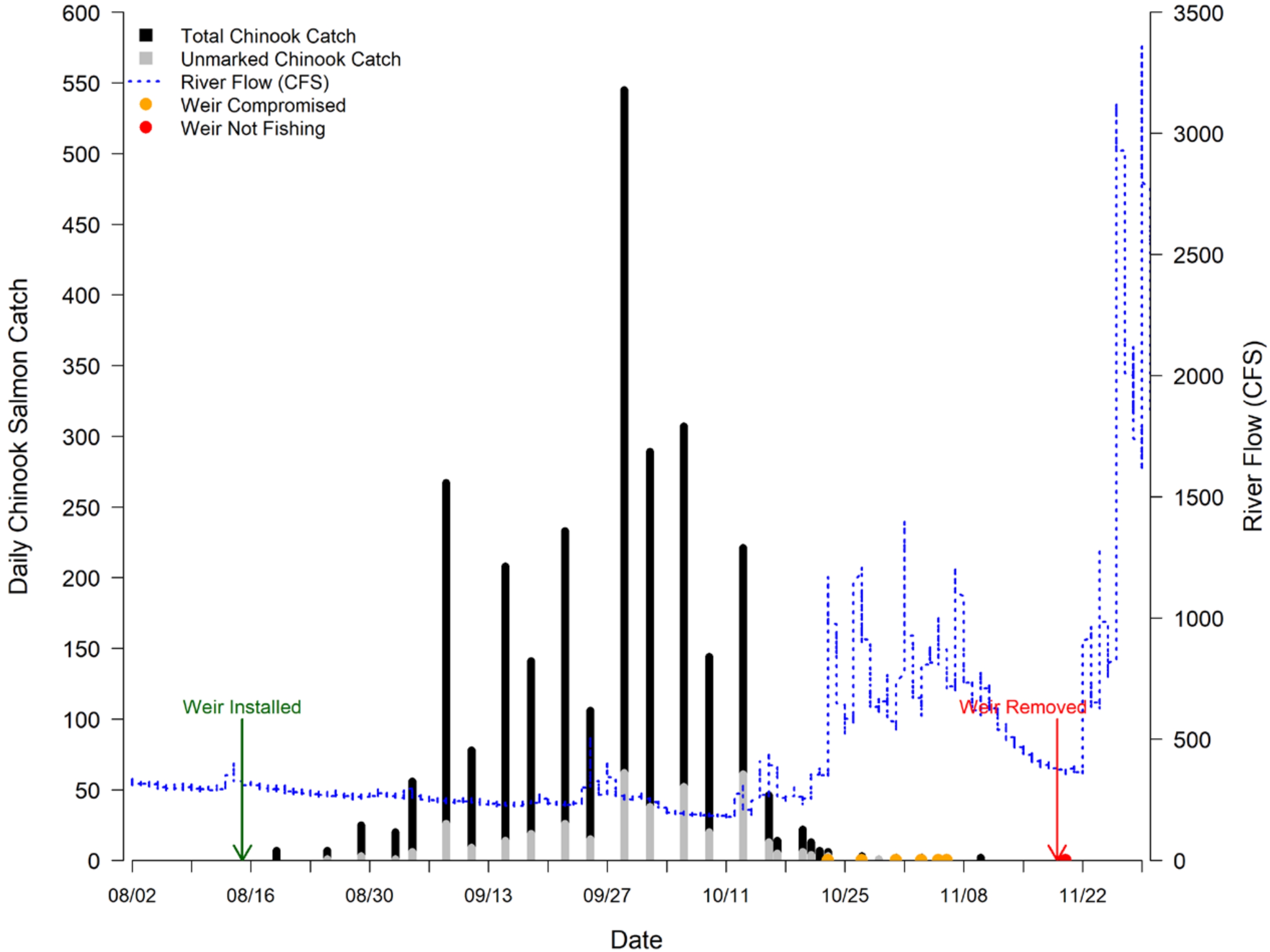

Figure A11. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Green River Weir, 2014 (USGS 2018).

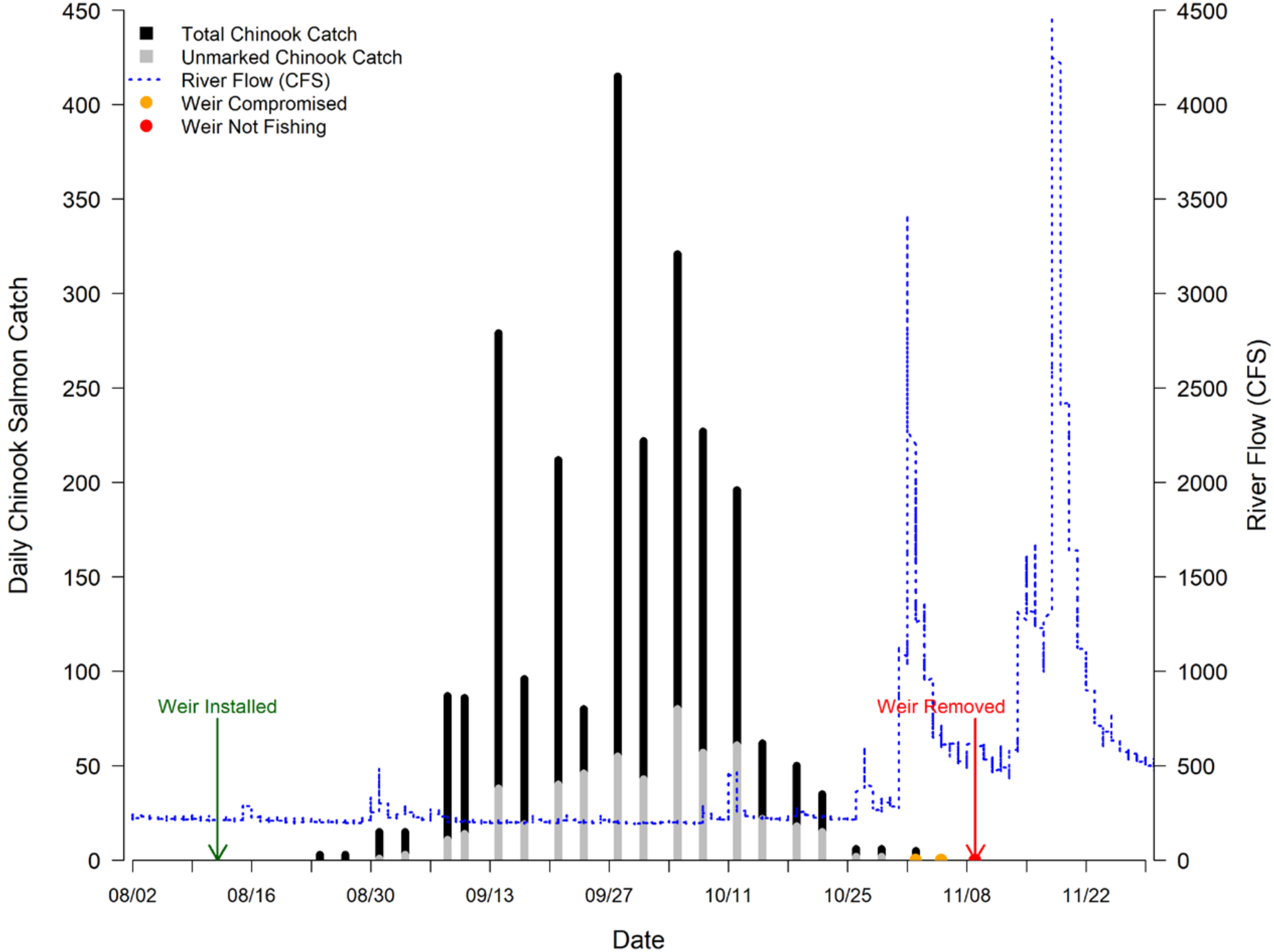

Figure A12. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Green River Weir, 2015 (USGS 2018).

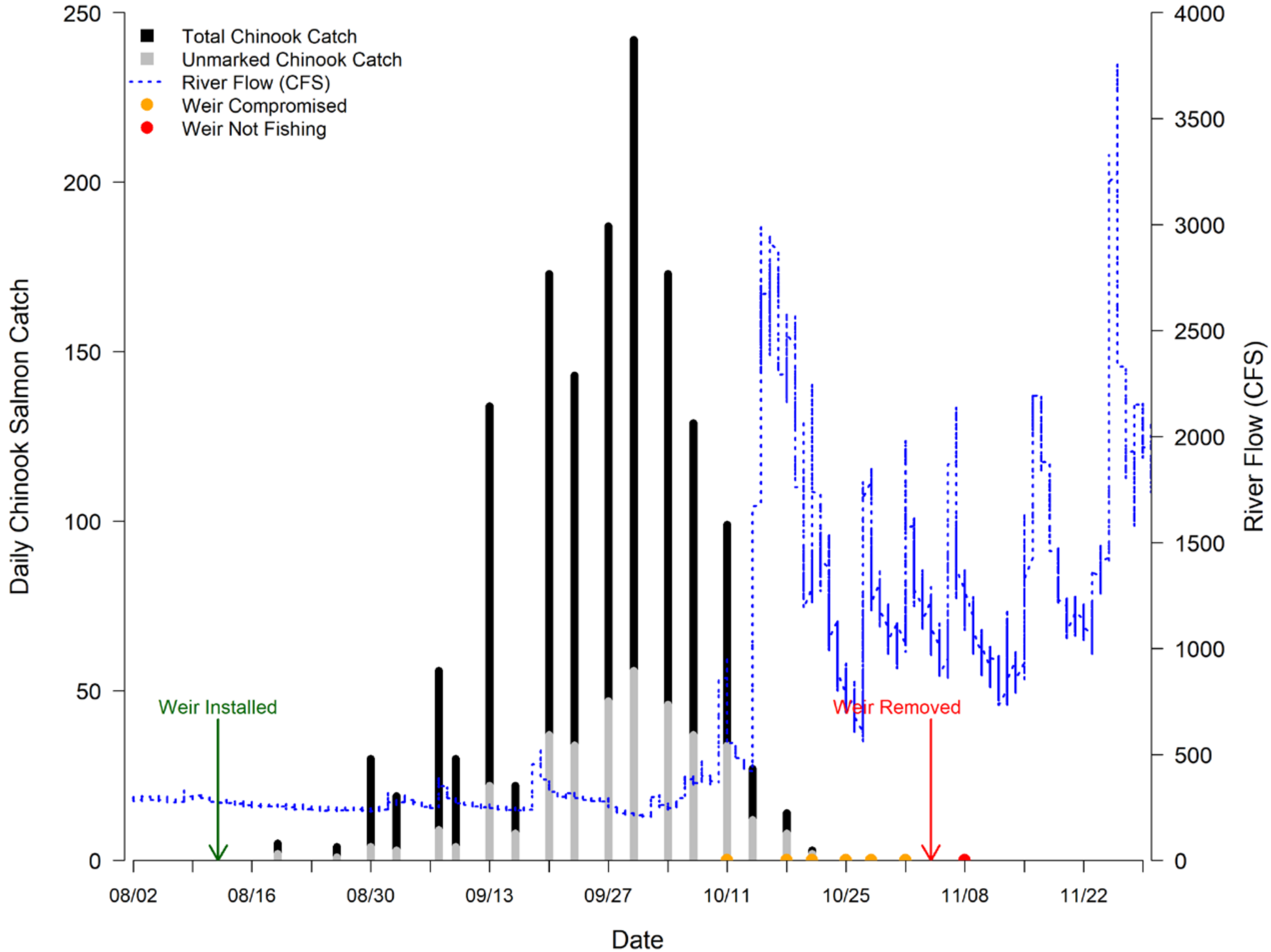

Figure A13. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Green River Weir, 2016 (USGS 2018).

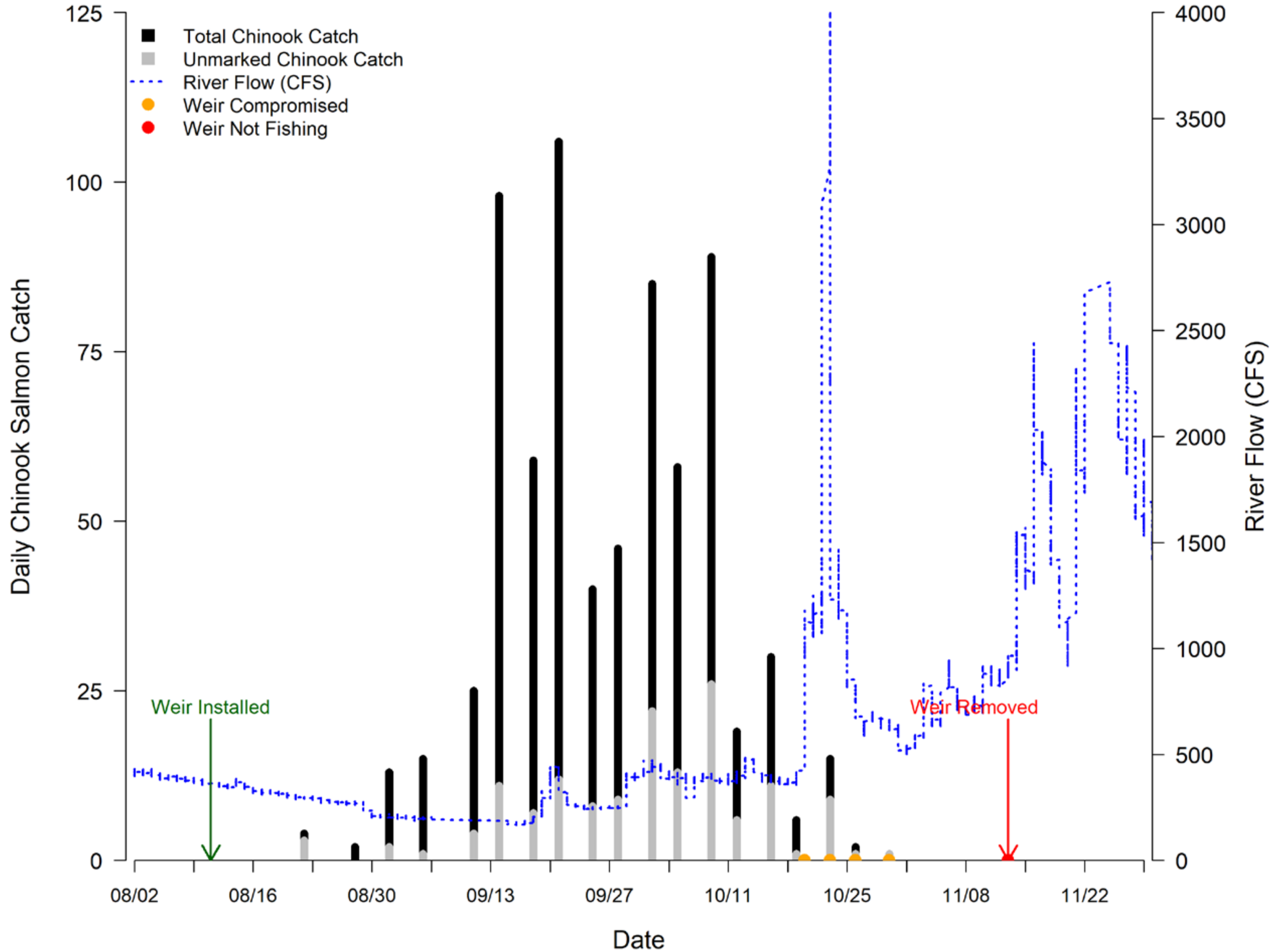

Figure A14. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Green River Weir, 2017 (USGS 2018).

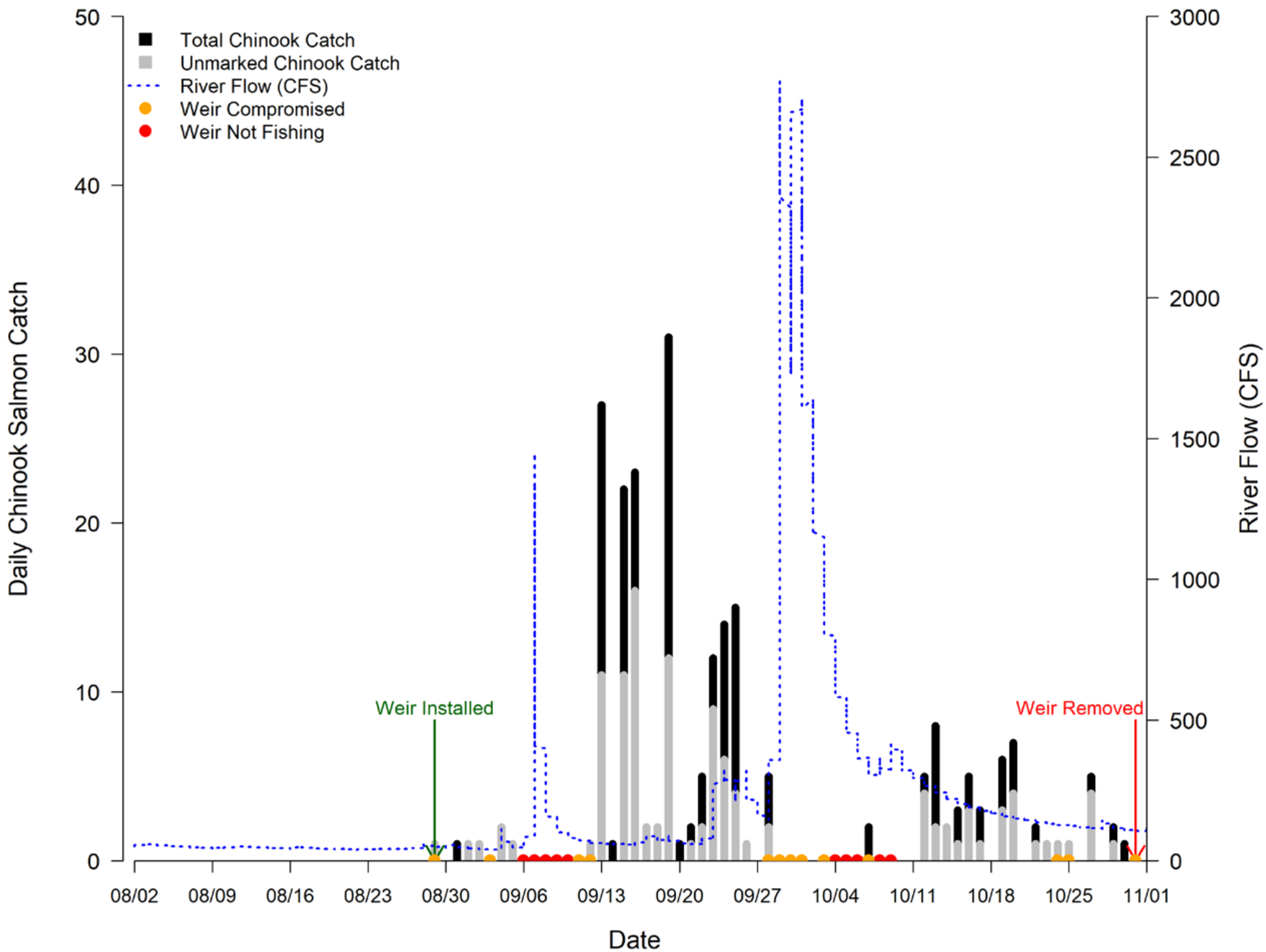

Figure A15. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Coweeman River Weir, 2013 (WDOE 2018).

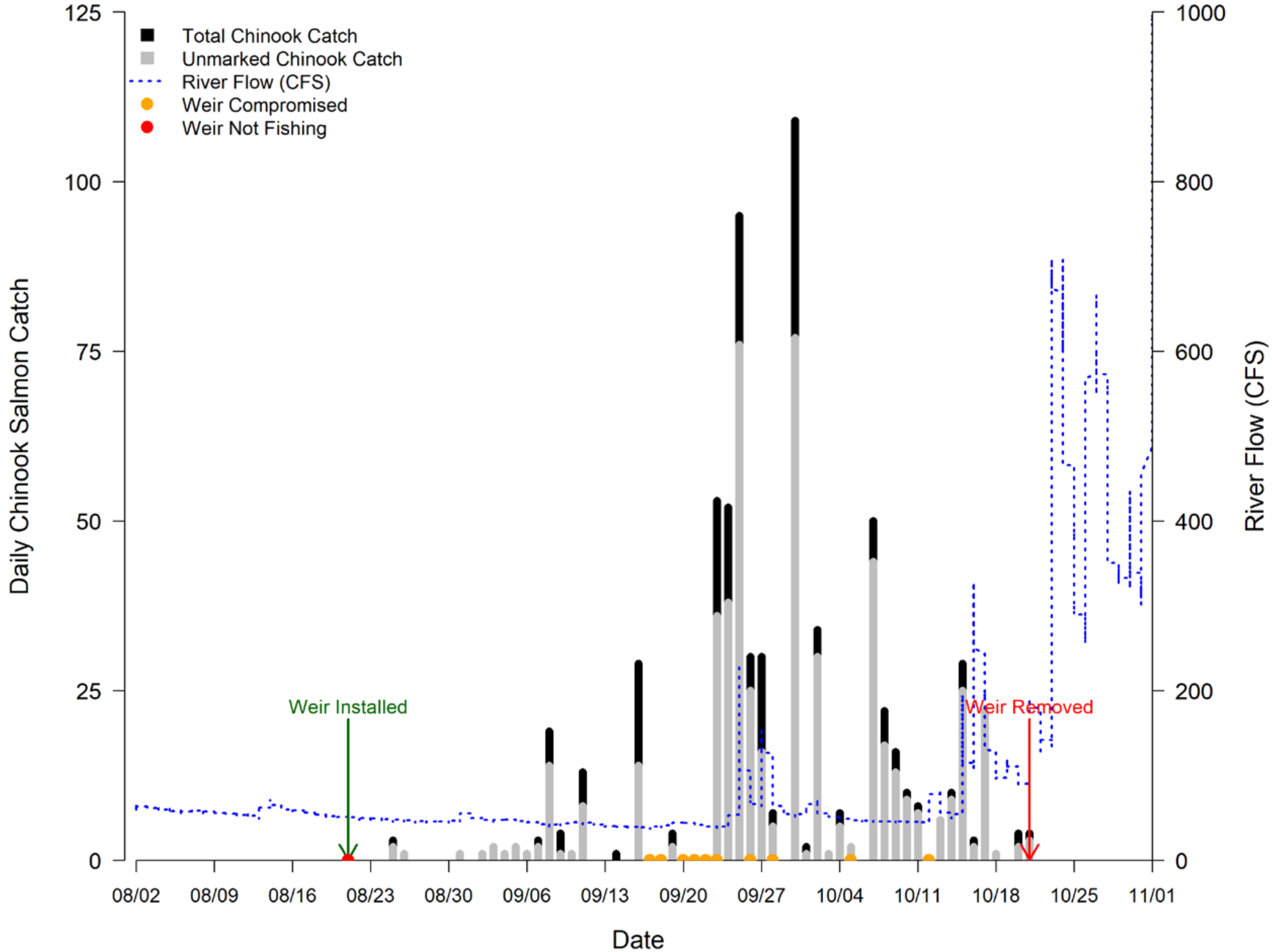

Figure A16. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Coweeman River Weir, 2014 (WDOE 2018).

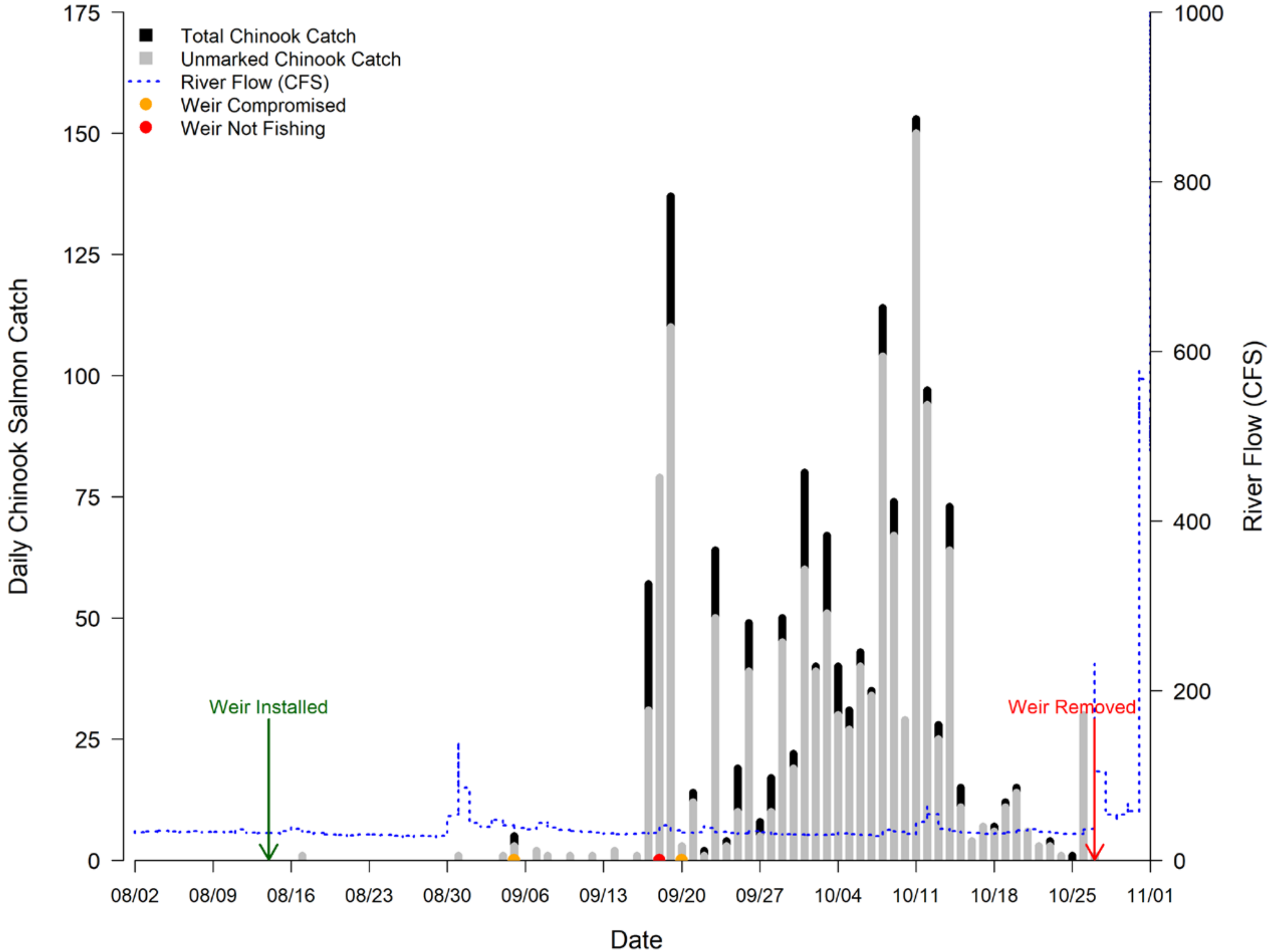

Figure A17. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Coweeman River Weir, 2015 (WDOE 2018).

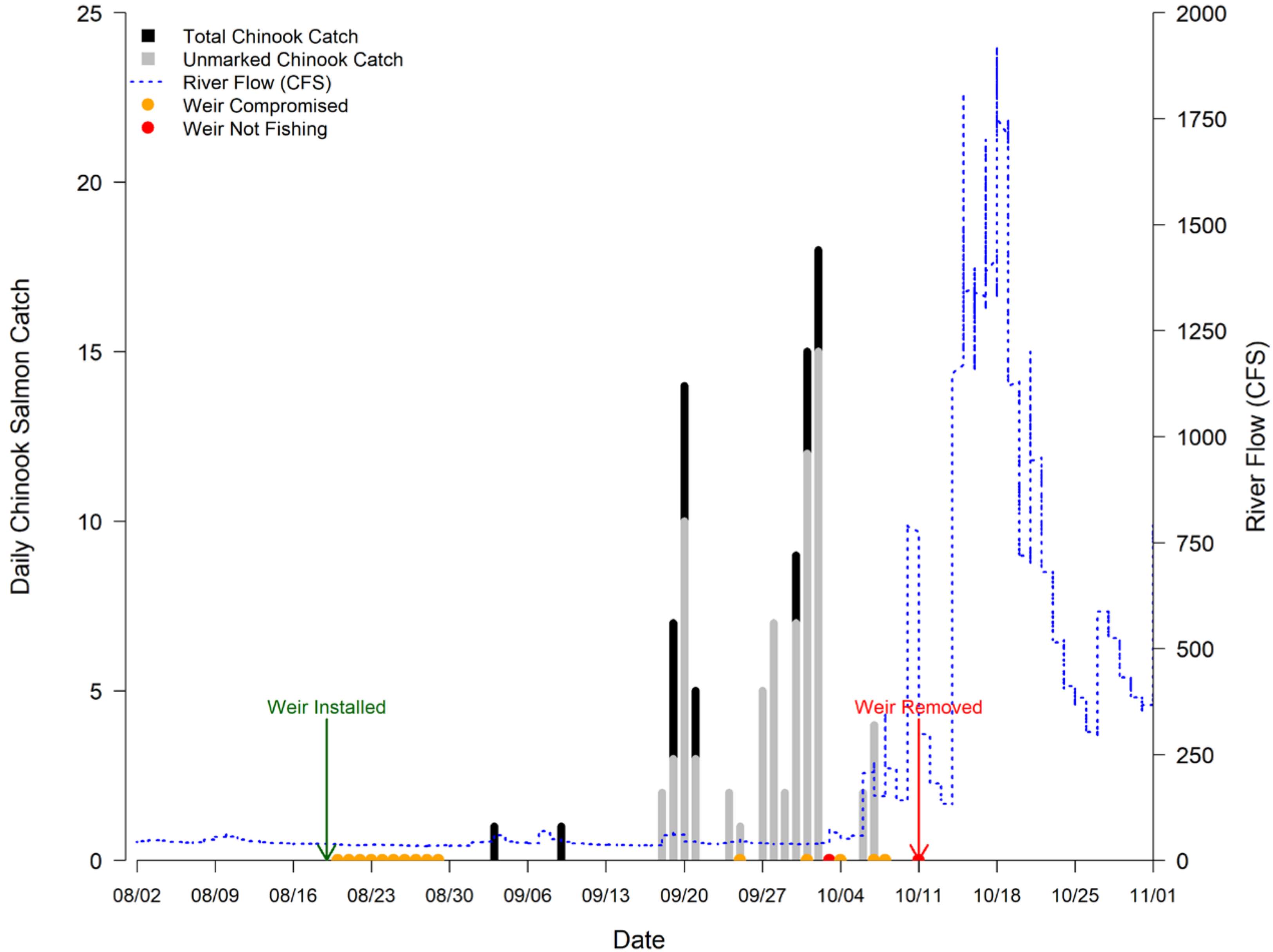

Figure A18. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Coweeman River Weir, 2016 (WDOE 2018).

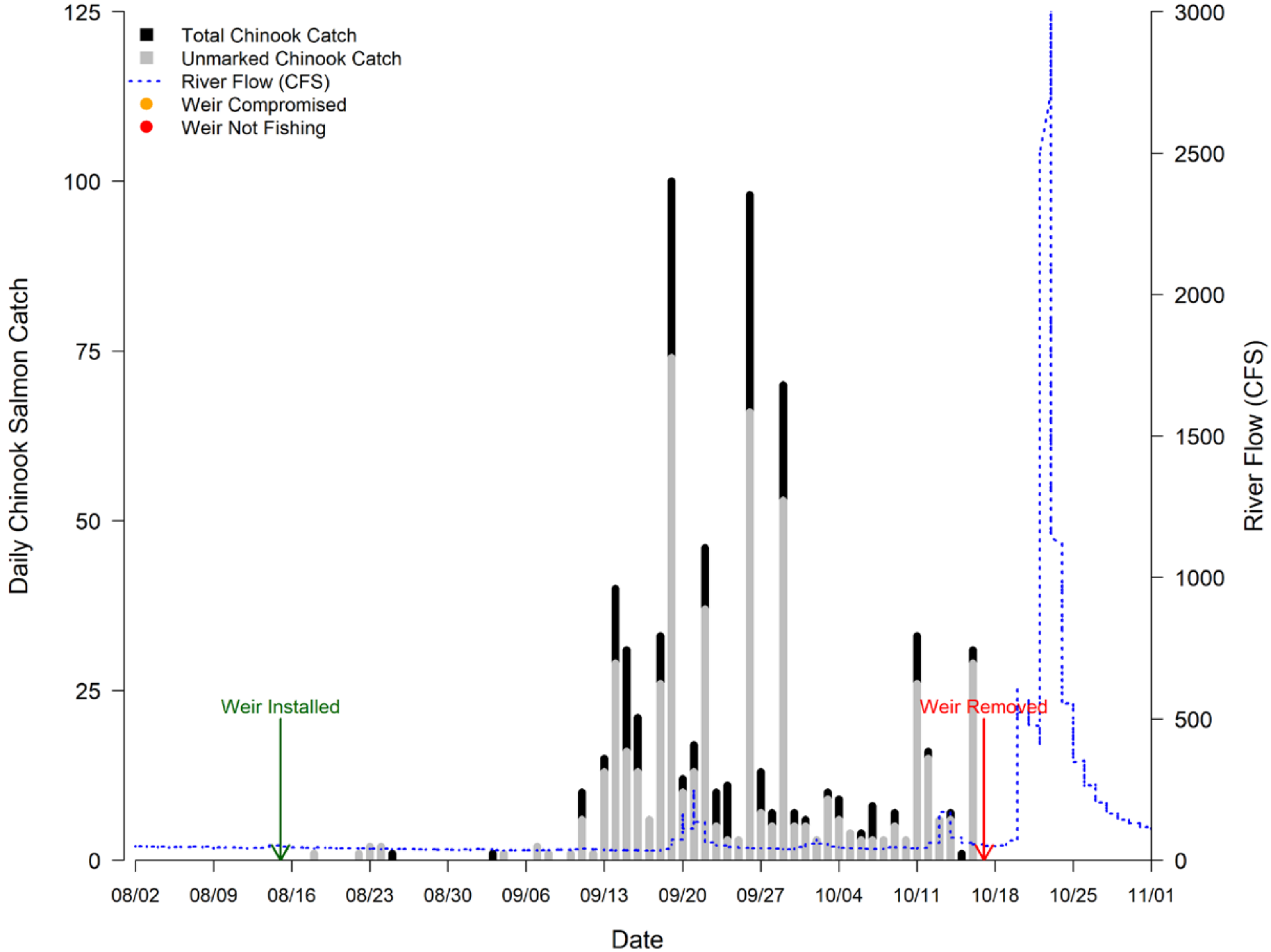

Figure A19. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Coweeman River Weir, 2017 (WDOE 2018).

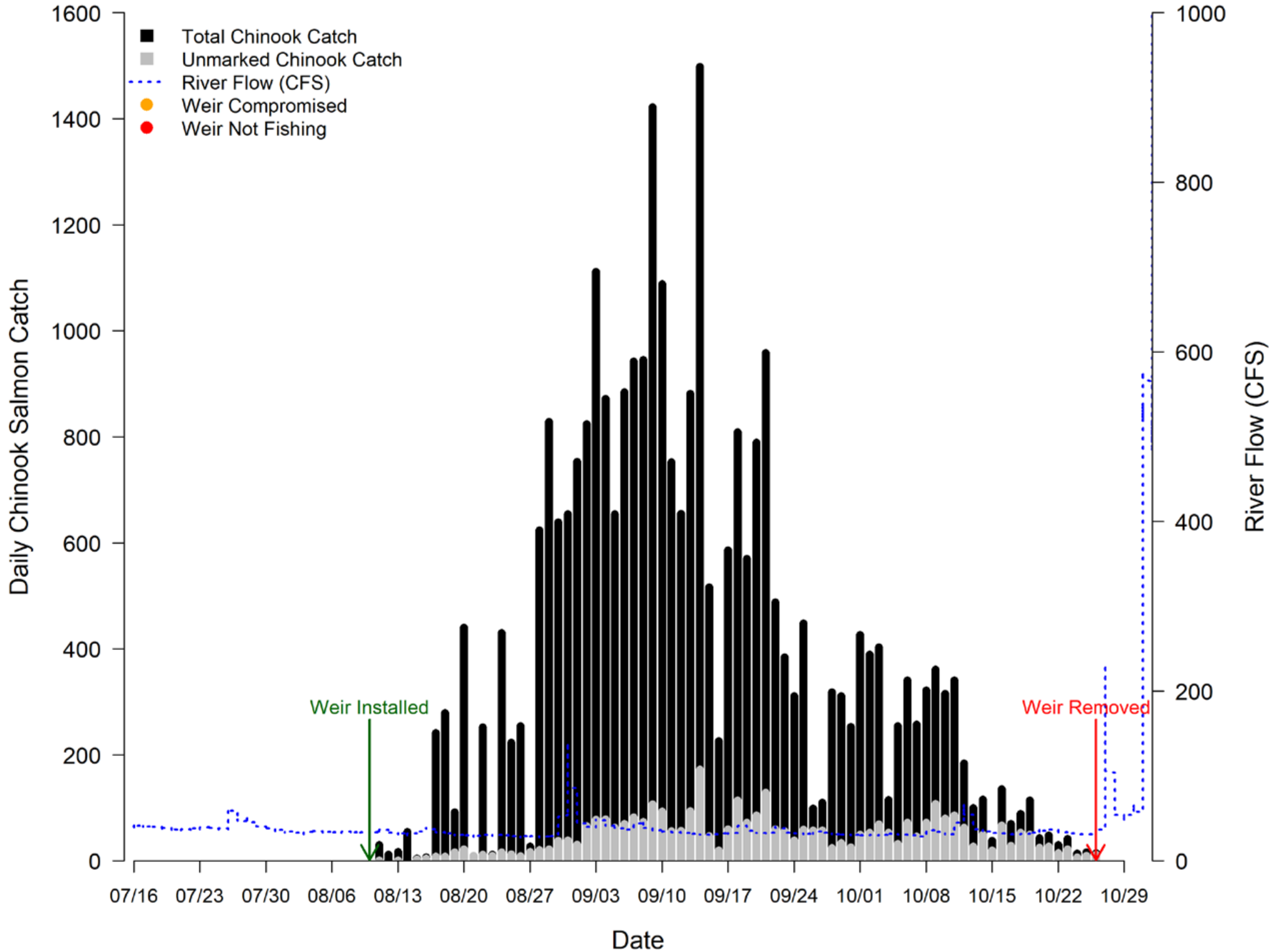

Figure A20. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Kalama River (Modrow) Weir, 2015 (WDOE 2018).

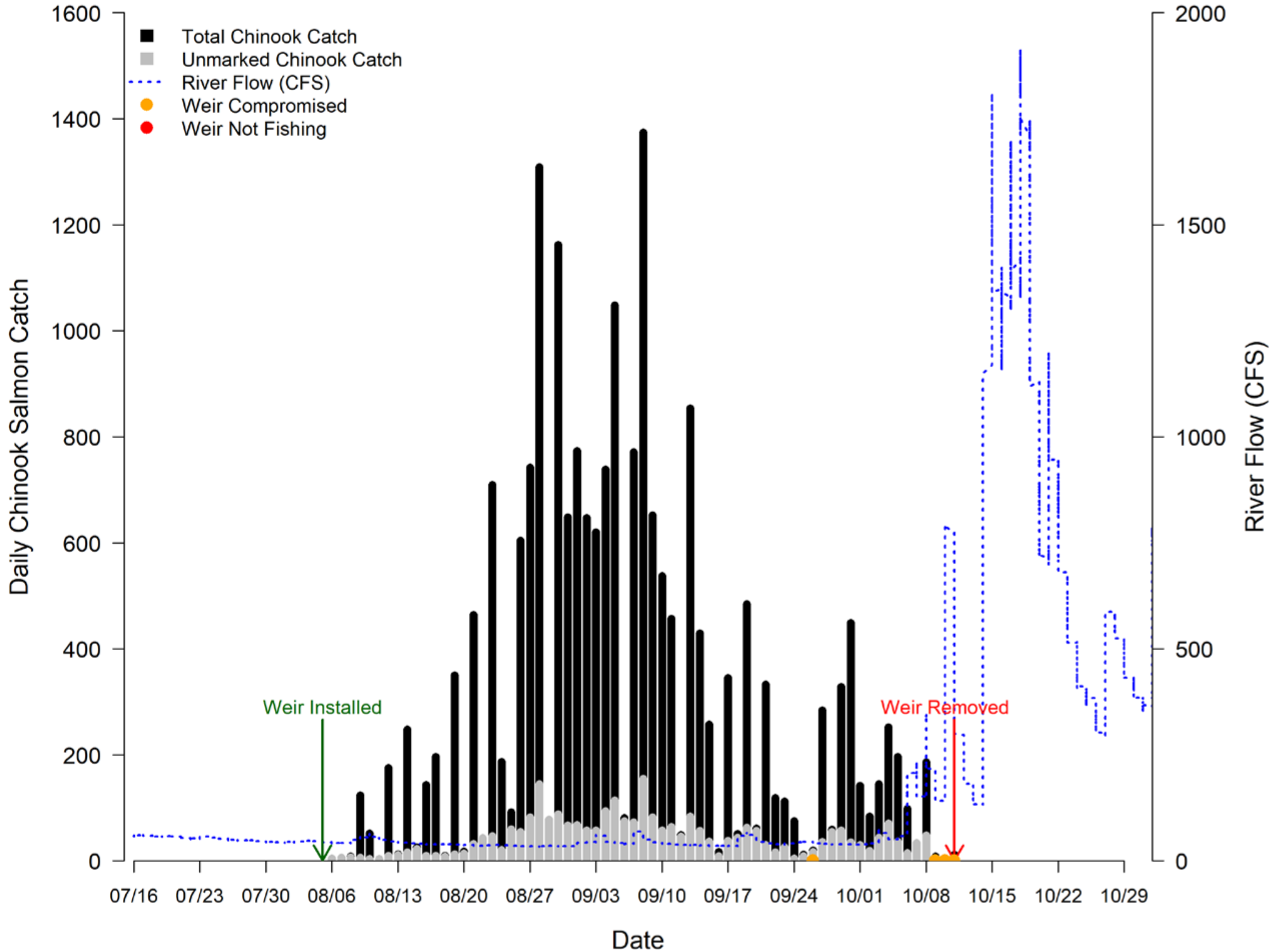

Figure A21. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Kalama River (Modrow) Weir, 2016 (WDOE 2018).

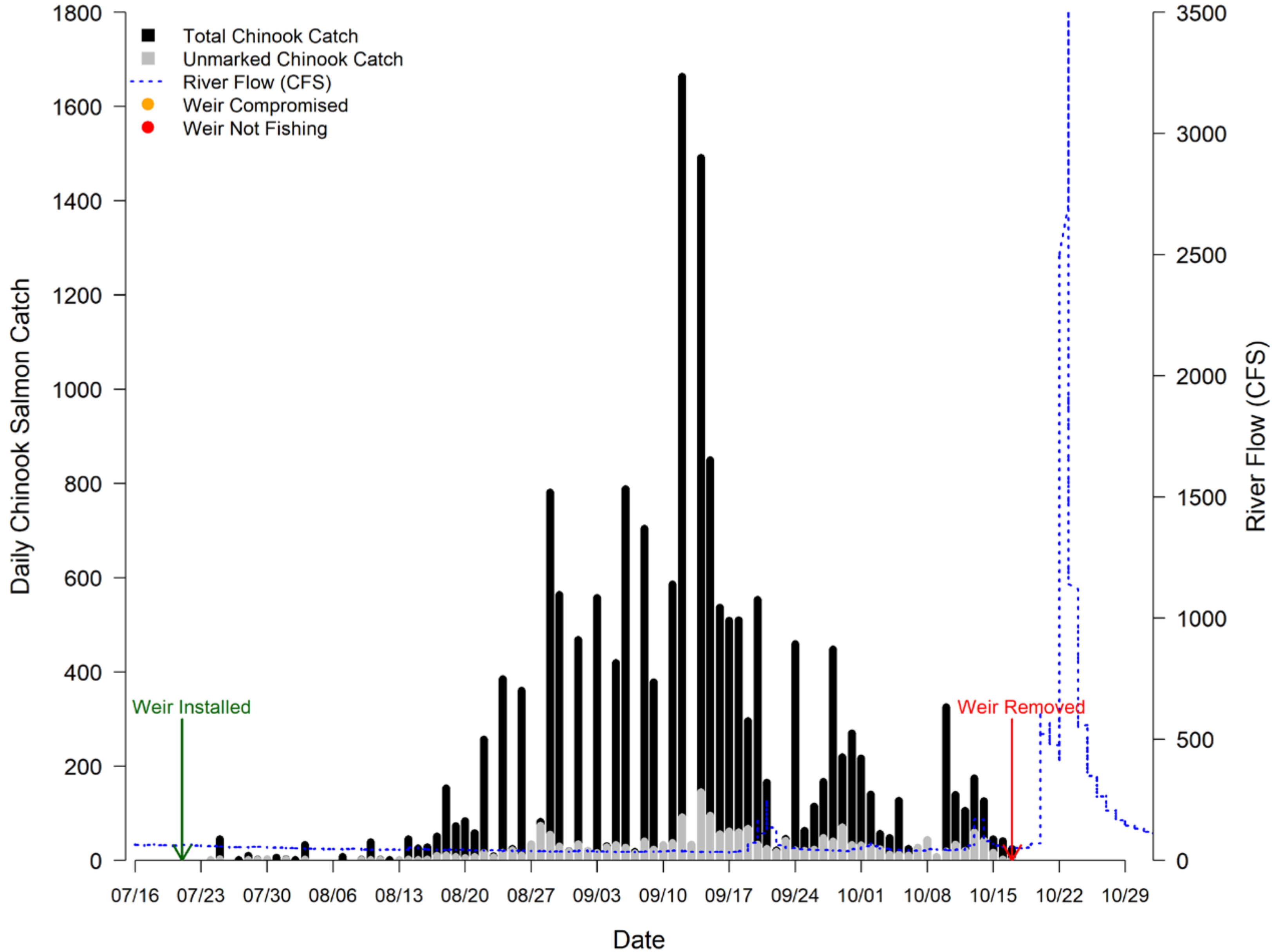

Figure A22. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Kalama River (Modrow) Weir, 2017 (WDOE 2018).

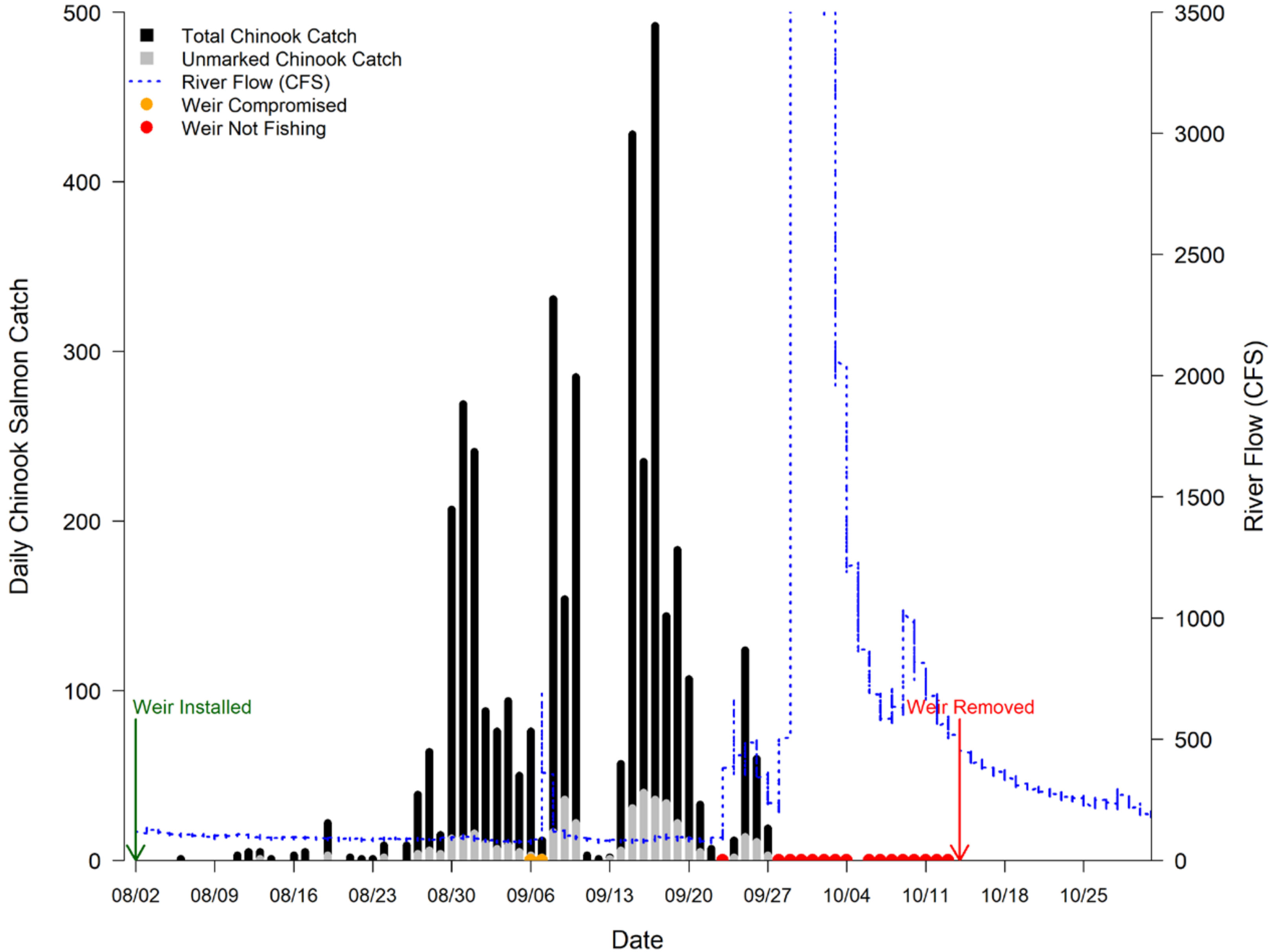

Figure A23. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Washougal River Weir, 2013 (WDOE 2018). Maximum cfs is 10,500.

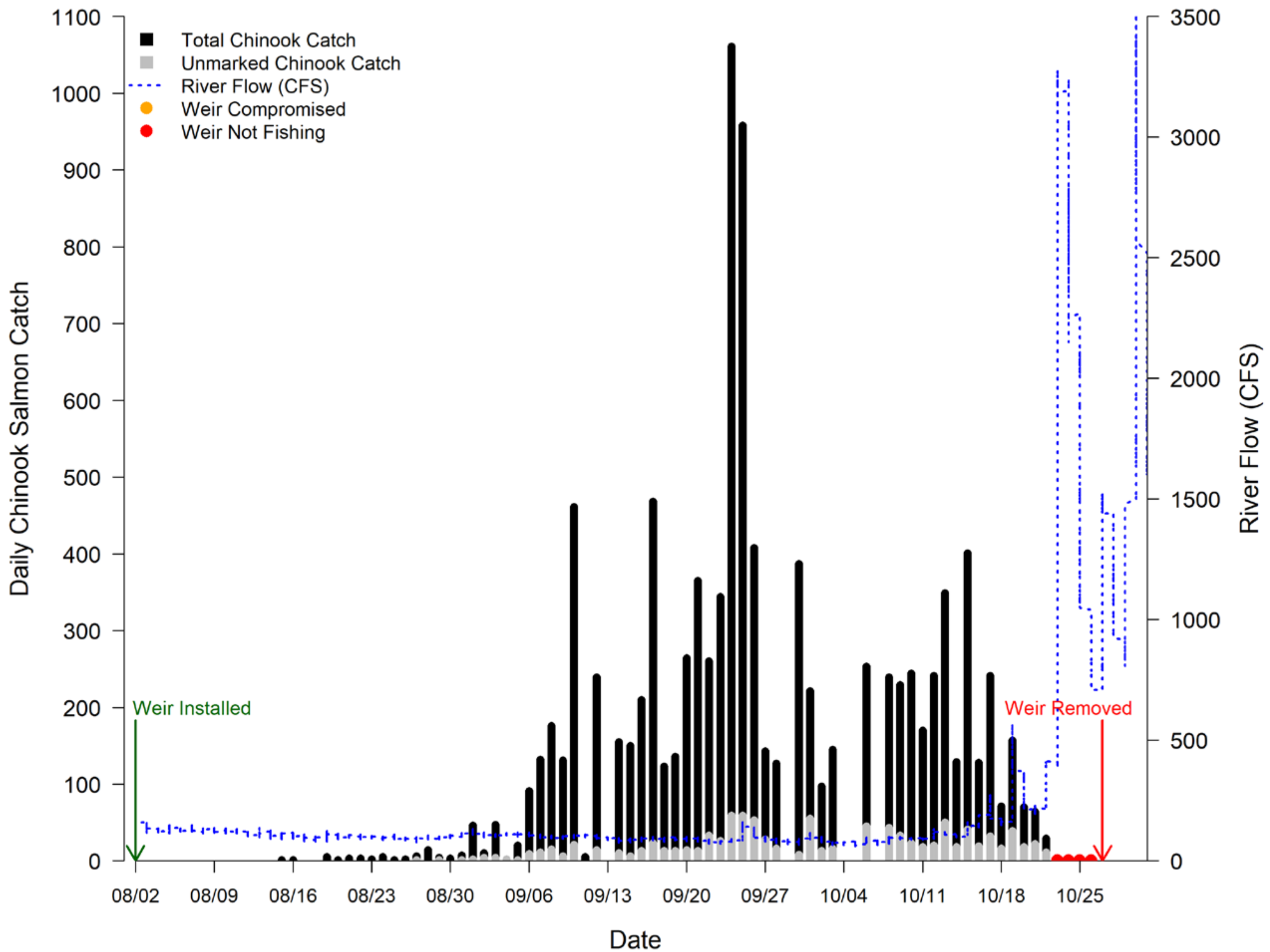

Figure A24. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Washougal River Weir, 2014 (WDOE 2018).

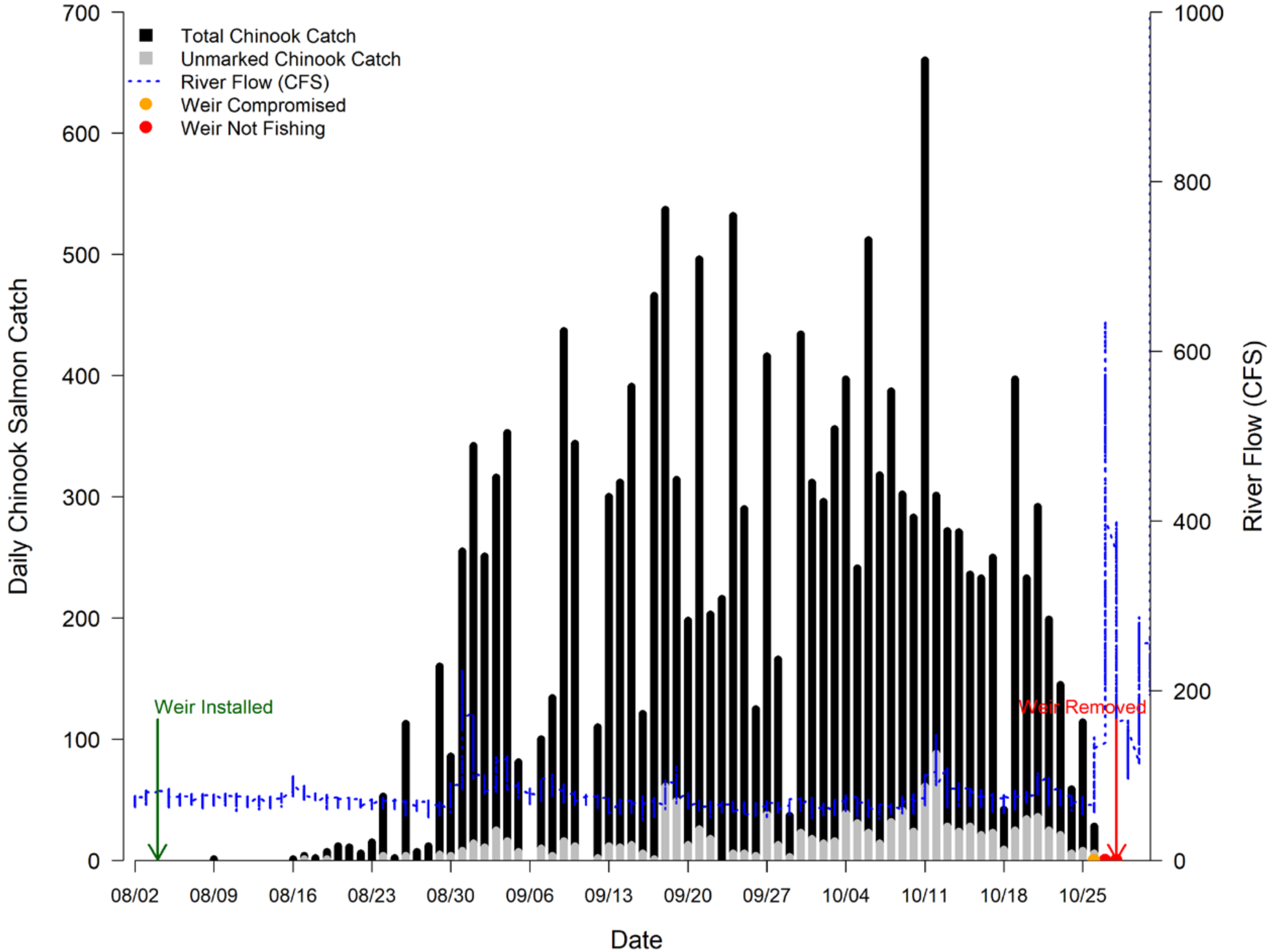

Figure A25. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Washougal River Weir, 2015 (WDOE 2018).

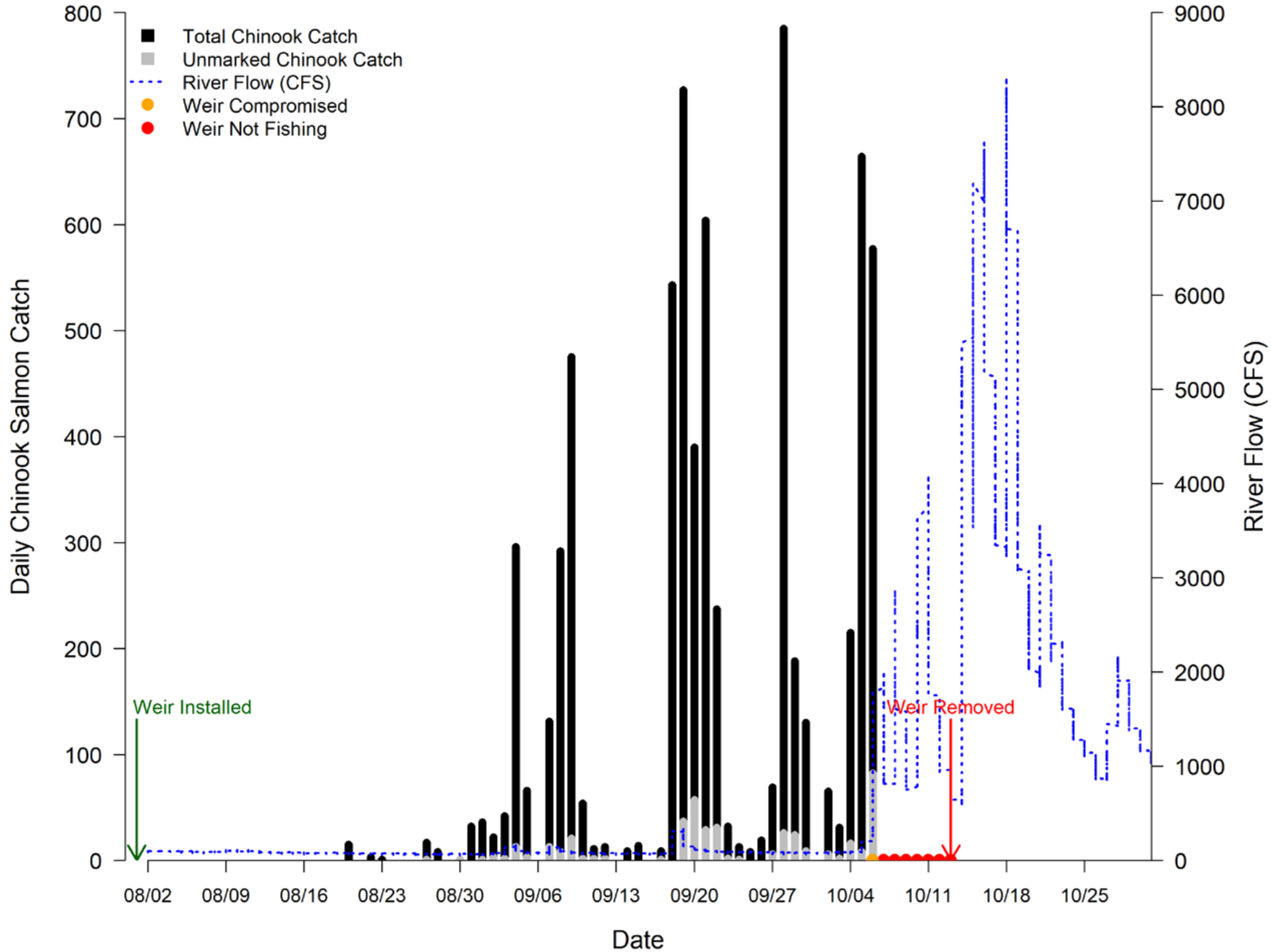

Figure A26. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Washougal River Weir, 2016 (WDOE 2018).

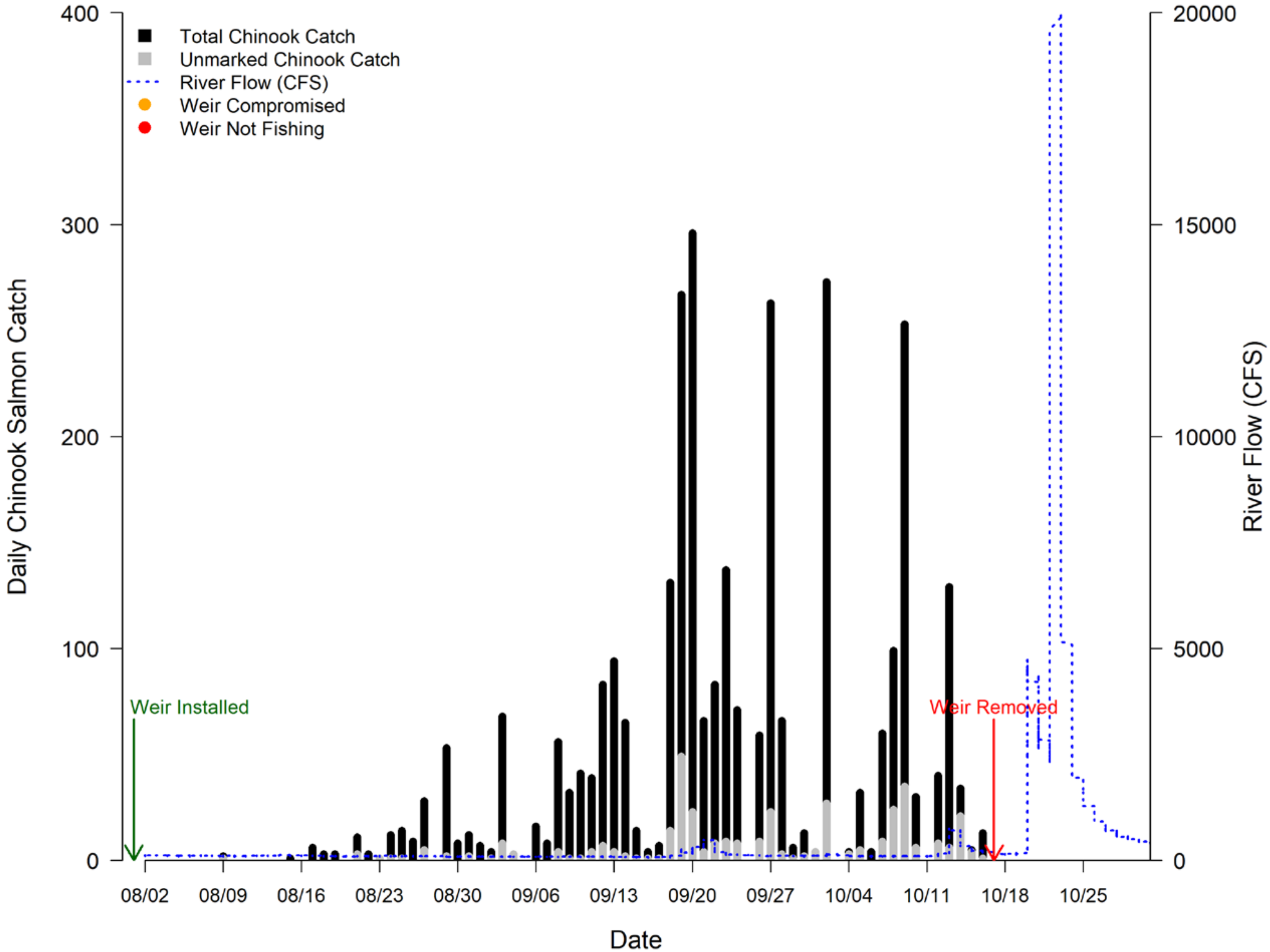

Figure A27. Total catch, unmarked catch, and streamflow (cfs) by date for fall Chinook salmon captured at Washougal River Weir, 2017 (WDOE 2018).

Appendix B – - Estimates of total spawner abundance, spawner abundance by origin, and the proportion of hatchery-origin and natural-origin spawners above and below each weir site for adult fall Chinook salmon.

Independent abundance estimates were generated for areas above and below each of the weirs using methods developed in Wilson et al. 2020. Abundance estimates are reported as total spawner abundance, spawner abundance by origin, and the proportion of hatchery-origin and natural-origin spawners of adult fall Chinook salmon. Tables below show the mean, standard deviation, upper and lower 95% credible intervals of the posterior distribution for each of the sites. Estimates prior to 2013 were updated and therefore included in these analyses. The following locations and years are included: Grays River Weir for 2008-2016 (rkm 17.22 for 2008-2010; rkm 16.50 for 2011-2012; rkm 13.65 for 2013-2016), Elochoman River Weir for 2009-2017 (rkm 4.39), Green River Weir for 2011-2017 (rkm 0.64), Coweeman River Weir for 2011-2017 (rkm 10.94 for 2011-2015 and 2017) (rkm 6.44 for 2016), Kalama River Weir for 2015-2017 (rkm 4.38), and Washougal River Weir for 2011-2017 (rkm 19.15).

Table B1. Estimates of total spawner abundance, spawner abundance by origin, proportion of hatchery-origin and natural-origin spawners above and below weir sites of adult fall Chinook salmon for the Grays River (mean, SD, and 95% credible intervals of the posterior distribution) for 2008-2017.

		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Above Weir Esc.	Mean	188	541	168	392	88	827	481	384	181	563
	SD	44	206	68	84	42	507	296	228	103	244
	L 95% CI	112	255	79	272	39	71	44	77	40	256
	U 95% CI	278	1,053	342	599	200	1,858	1,083	868	401	1,182
Above Weir HOS SAB Esc.	Mean	68	293	68	275	44	716	239	121	72	99
	SD	23	119	34	60	23	439	152	80	50	63
	L 95% CI	32	129	24	189	17	46	12	12	6	25
	U 95% CI	119	591	153	424	105	1,604	560	310	188	263
Above Weir HOS Tule Esc.	Mean	54	47	17	54	27	63	120	86	58	169
	SD	20	26	12	16	15	41	79	62	43	94
	L 95% CI	23	13	3	30	9	4	5	4	3	53
	U 95% CI	99	115	51	93	67	152	292	234	159	408
Above Weir NOS Esc.	Mean	67	201	83	62	17	52	122	177	50	295
	SD	22	85	40	19	11	34	80	111	29	141
	L 95% CI	31	85	31	33	6	14	24	53	19	115
	U 95% CI	116	411	185	108	46	135	300	431	131	658
Above Weir pHOS	Mean	64.7%	62.7%	50.8%	84.1%	80.5%	92.8%	72.7%	52.1%	67.4%	47.6%
	SD	8.1%	6.6%	11.2%	3.4%	7.3%	7.0%	10.0%	11.7%	15.9%	10.2%
	L 95% CI	48.0%	49.2%	28.9%	77.2%	63.8%	70.6%	40.9%	21.8%	23.5%	27.9%
	U 95% CI	79.4%	75.2%	72.3%	90.3%	92.2%	98.8%	84.3%	71.4%	88.4%	67.2%
Above Weir pNOS	Mean	35.3%	37.3%	49.2%	15.9%	19.5%	7.2%	27.3%	47.9%	32.6%	52.4%
	SD	8.1%	6.6%	11.2%	3.4%	7.3%	7.0%	10.0%	11.7%	15.9%	10.2%
	L 95% CI	20.6%	24.8%	27.7%	9.7%	7.8%	1.2%	15.7%	28.6%	11.6%	32.8%
	U 95% CI	52.0%	50.8%	71.1%	22.8%	36.2%	29.4%	59.1%	78.2%	76.5%	72.1%
Below Weir Esc.	Mean	6	79	2	24	72	817	488	378	175	2
	SD	4	33	2	13	35	514	303	239	111	3
	L 95% CI	1	34	0	7	30	36	23	17	7	0
	U 95% CI	17	161	8	56	166	1,864	1,104	868	401	10
Below Weir HOS SAB Esc.	Mean	4	57	2	17	25	735	262	144	99	1
	SD	3	24	2	9	13	462	167	93	64	2
	L 95% CI	0	25	0	6	9	33	13	7	4	0
	U 95% CI	13	117	6	40	59	1,677	618	341	233	5
Below Weir HOS Tule Esc.	Mean	0	2	0	7	29	39	163	192	46	1
	SD	0	2	0	4	15	27	107	123	31	1
	L 95% CI	0	1	0	3	11	2	8	9	2	0
	U 95% CI	1	6	2	17	70	103	392	453	114	3
Below Weir NOS Esc.	Mean	1	19	0	1	18	43	63	42	30	0
	SD	1	10	0	2	11	31	44	29	20	1
	L 95% CI	0	7	0	0	6	1	2	2	1	0
	U 95% CI	4	44	1	5	46	113	162	106	76	2
Below Weir pHOS	Mean	79.0%	75.6%	98.9%	98.2%	75.1%	94.9%	87.4%	88.9%	82.8%	84.4%
	SD	6.5%	5.4%	2.5%	3.2%	7.3%	1.6%	3.6%	2.3%	3.8%	5.4%
	L 95% CI	65.4%	64.6%	91.1%	89.3%	59.4%	91.6%	79.6%	84.3%	74.8%	74.9%
	U 95% CI	90.7%	85.5%	100.0%	100.0%	87.7%	97.9%	93.5%	93.1%	89.5%	100.0%
Below Weir pNOS	Mean	21.0%	24.4%	1.1%	1.8%	24.9%	5.1%	12.6%	11.1%	17.2%	15.6%
	SD	6.5%	5.4%	2.5%	3.2%	7.3%	1.6%	3.6%	2.3%	3.8%	5.4%
	L 95% CI	9.3%	14.5%	0.0%	0.0%	12.3%	2.1%	6.5%	6.9%	10.5%	0.0%
	U 95% CI	34.6%	35.4%	8.9%	10.7%	40.6%	8.4%	20.4%	15.8%	25.2%	25.1%

Table B2. Estimates of total spawner abundance, spawner abundance by origin, proportion of hatchery-origin and natural-origin spawners above and below weir sites of adult fall Chinook salmon for the Elochoman River (mean, SD, and 95% credible intervals of the posterior distribution) for 2009-2017.

		2009	2010	2011	2012	2013	2014	2015	2016	2017
Above Weir Esc.	Mean	1,259	853	674	76	162	152	205	73	66
	SD	50	62	28	23	64	20	20	14	11
	L 95% CI	1,180	726	616	43	79	118	167	50	47
	U 95% CI	1,369	962	728	131	317	192	244	104	88
Above Weir HOS SAB Esc.	Mean	14	1	5	14	23	7	6	5	1
	SD	14	1	4	10	16	6	6	5	1
	L 95% CI	0	0	1	2	4	1	1	0	0
	U 95% CI	53	3	16	41	64	25	22	20	5
Above Weir HOS Tule Esc.	Mean	989	742	627	15	93	24	39	12	4
	SD	61	58	28	10	42	12	15	8	2
	L 95% CI	878	621	572	3	37	8	15	2	1
	U 95% CI	1,106	841	680	41	196	53	73	32	10
Above Weir NOS Esc.	Mean	255	110	43	46	47	121	159	56	60
	SD	32	22	11	20	25	19	21	15	11
	L 95% CI	201	72	17	19	16	83	117	31	42
	U 95% CI	334	150	60	94	113	156	200	90	83
Above Weir pHOS	Mean	79.6%	87.1%	93.8%	38.7%	70.7%	20.3%	22.2%	23.3%	8.5%
	SD	2.7%	2.4%	1.7%	16.0%	10.2%	8.3%	7.7%	12.3%	4.5%
	L 95% CI	72.9%	82.3%	91.1%	11.2%	48.8%	7.6%	9.0%	5.2%	2.3%
	U 95% CI	84.0%	91.4%	97.5%	71.1%	87.8%	39.2%	38.7%	51.3%	19.3%
Above Weir pNOS	Mean	20.4%	12.9%	6.2%	61.3%	29.3%	79.7%	77.8%	76.7%	91.5%
	SD	2.7%	2.4%	1.7%	16.0%	10.2%	8.3%	7.7%	12.3%	4.5%
	L 95% CI	16.0%	8.6%	2.5%	28.9%	12.3%	60.8%	61.3%	48.7%	80.7%
	U 95% CI	27.1%	17.7%	8.9%	88.8%	51.2%	92.4%	91.0%	94.8%	97.7%
Below Weir Esc.	Mean	0	10	0	52	43	8	25	54	23
	SD	0	3	0	25	20	6	14	38	17
	L 95% CI	0	6	0	21	17	1	7	15	6
	U 95% CI	1	16	1	113	94	23	59	150	65
Below Weir HOS SAB Esc.	Mean	0	0	0	2	3	0	1	0	1
	SD	0	0	0	1	2	0	0	0	0
	L 95% CI	0	0	0	1	1	0	0	0	0
	U 95% CI	0	0	0	5	8	1	2	1	2
Below Weir HOS Tule Esc.	Mean	0	10	0	44	30	6	21	46	14
	SD	0	2	0	21	14	4	12	32	11
	L 95% CI	0	6	0	17	12	1	6	12	3
	U 95% CI	0	16	1	95	66	18	51	128	42
Below Weir NOS Esc.	Mean	0	0	0	6	9	1	3	8	8
	SD	0	0	0	4	5	1	2	6	6
	L 95% CI	0	0	0	2	3	0	0	2	2
	U 95% CI	1	1	0	15	23	4	8	24	23
Below Weir pHOS	Mean	59.3%	96.7%	96.9%	87.7%	78.3%	82.2%	89.7%	85.5%	65.6%
	SD	24.9%	0.9%	2.1%	3.3%	5.0%	4.0%	3.9%	3.5%	6.1%
	L 95% CI	14.3%	94.6%	93.0%	80.4%	67.5%	73.8%	82.0%	77.8%	53.1%
	U 95% CI	100.0%	98.1%	100.0%	93.2%	87.1%	89.2%	97.9%	91.5%	76.7%
Below Weir pNOS	Mean	40.7%	3.3%	3.1%	12.3%	21.7%	17.8%	10.3%	14.5%	34.4%
	SD	24.9%	0.9%	2.1%	3.3%	5.0%	4.0%	3.9%	3.5%	6.1%
	L 95% CI	0.0%	1.9%	0.0%	6.8%	12.9%	10.8%	2.1%	8.5%	23.3%
	U 95% CI	85.7%	5.4%	7.0%	19.6%	32.5%	26.2%	18.0%	22.2%	46.9%

Table B3. Estimates of total spawner abundance, spawner abundance by origin, proportion of hatchery-origin and natural-origin spawners above and below weir sites of adult fall Chinook salmon for the Green River (mean, SD, and 95% credible intervals of the posterior distribution) for 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Above Weir Esc.	Mean	1,682	1,382	655	1,082	429	303	375	84
	SD	162	87	32	100	98	15	55	15
	L 95% CI	1,322	1,224	597	901	283	266	285	59
	U 95% CI	1,905	1,563	722	1,285	655	321	491	112
Above Weir HOS Esc.	Mean	1,508	1,225	480	553	150	21	142	9
	SD	165	83	35	82	56	9	34	4
	L 95% CI	1,161	1,067	408	406	63	9	86	4
	U 95% CI	1,749	1,395	548	728	286	44	217	18
Above Weir NOS Esc.	Mean	174	158	174	528	280	282	233	75
	SD	30	31	28	86	86	17	44	15
	L 95% CI	119	106	127	368	144	240	159	50
	U 95% CI	245	225	231	706	476	308	327	104
Above Weir pHOS	Mean	89.6%	88.6%	73.4%	51.2%	35.2%	7.0%	37.9%	10.5%
	SD	2.1%	2.2%	4.1%	6.2%	11.2%	2.9%	7.2%	4.4%
	L 95% CI	84.9%	83.7%	64.7%	39.5%	16.1%	3.0%	24.2%	4.2%
	U 95% CI	93.3%	92.2%	80.3%	63.3%	58.3%	14.1%	52.9%	20.8%
Above Weir pNOS	Mean	10.4%	11.4%	26.6%	48.8%	64.8%	93.0%	62.1%	89.5%
	SD	2.1%	2.2%	4.1%	6.2%	11.2%	2.9%	7.2%	4.4%
	L 95% CI	6.7%	7.8%	19.7%	36.7%	41.7%	85.9%	47.1%	79.2%
	U 95% CI	15.1%	16.3%	35.3%	60.5%	83.9%	97.0%	75.8%	95.8%
Below Weir Esc.	Mean	85	54	37	168	82	130	297	303
	SD	28	19	12	95	46	78	144	129
	L 95% CI	47	27	21	28	14	27	59	89
	U 95% CI	156	101	63	387	183	320	594	569
Below Weir HOS Esc.	Mean	62	38	26	106	53	100	199	152
	SD	22	14	10	61	32	62	98	68
	L 95% CI	29	18	10	16	8	18	41	48
	U 95% CI	117	72	53	246	124	262	405	306
Below Weir NOS Esc.	Mean	23	16	11	62	30	30	98	150
	SD	12	8	8	40	21	24	50	68
	L 95% CI	6	5	1	9	4	4	19	44
	U 95% CI	53	35	30	165	84	91	211	290
Below Weir pHOS	Mean	72.9%	71.0%	70.1%	63.3%	64.1%	76.5%	67.2%	50.4%
	SD	10.3%	9.2%	17.4%	9.5%	13.1%	10.4%	4.8%	6.2%
	L 95% CI	50.1%	52.1%	31.6%	43.2%	38.4%	52.6%	57.7%	38.1%
	U 95% CI	90.3%	87.3%	96.1%	79.7%	86.4%	93.3%	76.4%	62.2%
Below Weir pNOS	Mean	27.1%	29.0%	29.9%	36.7%	35.9%	23.5%	32.8%	49.6%
	SD	10.3%	9.2%	17.4%	9.5%	13.1%	10.4%	4.8%	6.2%
	L 95% CI	9.7%	12.7%	3.9%	20.3%	13.6%	6.7%	23.6%	37.8%
	U 95% CI	49.9%	47.9%	68.4%	56.8%	61.6%	47.4%	42.3%	61.9%

Table B4. Estimates of total spawner abundance, spawner abundance by origin, proportion of hatchery-origin and natural-origin spawners above and below weir sites of adult fall Chinook salmon for the Coweeman River (mean, SD, and 95% credible intervals of the posterior distribution) for 2011-2017.

		2011	2012	2013	2014	2015	2016	2017
Above Weir Esc.	Mean	571	331	2,275	659	1,258	436	769
	SD	30	42	616	28	6	142	77
	L 95% CI	520	266	1,229	611	1,250	214	646
	U 95% CI	636	429	3,656	718	1,272	762	948
Above Weir HOS Esc.	Mean	49	18	725	20	10	27	102
	SD	13	12	201	9	6	21	39
	L 95% CI	27	3	390	7	3	3	40
	U 95% CI	79	49	1,180	40	24	83	191
Above Weir NOS Esc.	Mean	521	312	1,550	640	1,248	409	667
	SD	30	41	423	28	8	134	76
	L 95% CI	468	244	829	590	1,231	199	538
	U 95% CI	586	408	2,493	700	1,264	719	836
Above Weir pHOS	Mean	8.6%	5.6%	31.9%	3.0%	0.8%	6.2%	13.2%
	SD	2.3%	3.7%	1.9%	1.3%	0.4%	4.1%	4.8%
	L 95% CI	4.7%	0.8%	28.2%	1.0%	0.2%	0.9%	5.4%
	U 95% CI	13.5%	14.7%	35.7%	6.0%	1.9%	16.2%	23.9%
Above Weir pNOS	Mean	91.4%	94.4%	68.1%	97.0%	99.2%	93.8%	86.8%
	SD	2.3%	3.7%	1.9%	1.3%	0.4%	4.1%	4.8%
	L 95% CI	86.5%	85.3%	64.3%	94.0%	98.1%	83.8%	76.1%
	U 95% CI	95.3%	99.2%	71.8%	99.0%	99.8%	99.1%	94.6%
Below Weir Esc.	Mean	136	195	48	171	133	3	73
	SD	43	60	19	50	40	3	29
	L 95% CI	69	99	20	91	70	0	31
	U 95% CI	234	334	92	285	224	12	144
Below Weir HOS Esc.	Mean	35	44	29	16	22	1	18
	SD	16	18	12	7	14	2	17
	L 95% CI	12	18	11	7	4	0	1
	U 95% CI	73	87	59	32	56	5	61
Below Weir NOS Esc.	Mean	101	151	18	154	112	2	54
	SD	34	47	8	45	34	2	27
	L 95% CI	48	76	7	83	57	0	15
	U 95% CI	181	257	39	259	189	9	119
Below Weir pHOS	Mean	26.0%	22.6%	61.3%	9.4%	16.0%	33.7%	25.6%
	SD	8.4%	5.2%	8.5%	2.6%	8.3%	23.9%	19.5%
	L 95% CI	11.6%	13.2%	43.9%	5.0%	3.4%	1.4%	0.8%
	U 95% CI	44.1%	33.7%	77.3%	14.9%	35.3%	85.5%	71.6%
Below Weir pNOS	Mean	74.0%	77.4%	38.7%	90.6%	84.0%	66.3%	74.4%
	SD	8.4%	5.2%	8.5%	2.6%	8.3%	23.9%	19.5%
	L 95% CI	55.9%	66.3%	22.7%	85.1%	64.7%	14.5%	28.4%
	U 95% CI	88.4%	86.8%	56.1%	95.0%	96.6%	98.6%	99.2%

Table B5. Estimates of total spawner abundance, spawner abundance by origin, proportion of hatchery-origin and natural-origin spawners above and below weir sites of adult fall Chinook salmon for the Kalama River (mean, SD, and 95% credible intervals of the posterior distribution) for 2015-2017.

		2015	2016	2017
Above Weir Esc.	Mean	4,407	3,819	2,261
	SD	268	180	73
	L 95% CI	3,901	3,477	2,127
	U 95% CI	4,964	4,184	2,410
Above Weir HOS Esc.	Mean	1,942	1,426	738
	SD	235	162	83
	L 95% CI	1,522	1,127	588
	U 95% CI	2,442	1,762	914
Above Weir NOS Esc.	Mean	2,465	2,393	1,524
	SD	148	103	64
	L 95% CI	2,158	2,178	1,385
	U 95% CI	2,738	2,582	1,637
Above Weir pHOS	Mean	44.0%	37.3%	32.6%
	SD	3.4%	3.0%	3.1%
	L 95% CI	37.4%	31.7%	26.9%
	U 95% CI	50.7%	43.2%	39.0%
Above Weir pNOS	Mean	56.0%	62.7%	67.4%
	SD	3.4%	3.0%	3.1%
	L 95% CI	49.3%	56.8%	61.0%
	U 95% CI	62.6%	68.3%	73.1%
Below Weir Esc.	Mean	2,016	408	780
	SD	403	85	151
	L 95% CI	1,371	275	538
	U 95% CI	2,956	605	1,128
Below Weir HOS Esc.	Mean	1,592	261	571
	SD	319	57	112
	L 95% CI	1,083	172	392
	U 95% CI	2,336	394	831
Below Weir NOS Esc.	Mean	424	147	208
	SD	93	37	47
	L 95% CI	274	88	132
	U 95% CI	640	232	315
Below Weir pHOS	Mean	79.0%	64.1%	73.3%
	SD	1.8%	4.8%	2.8%
	L 95% CI	75.4%	54.6%	67.7%
	U 95% CI	82.4%	73.3%	78.7%
Below Weir pNOS	Mean	21.0%	35.9%	26.7%
	SD	1.8%	4.8%	2.8%
	L 95% CI	17.6%	26.7%	21.3%
	U 95% CI	24.6%	45.4%	32.3%

Table B6. Estimates of total spawner abundance, spawner abundance by origin, proportion of hatchery-origin and natural-origin spawners above and below weir sites of adult fall Chinook salmon for the Washougal River (mean, SD, and 95% credible intervals of the posterior distribution) for 2011-2017.

		2011	2012	2013	2014	2015	2016	2017
Above Weir Esc.	Mean	2,640	670	2,193	740	948	1,156	767
	SD	216	92	243	37	49	261	139
	L 95% CI	2,280	526	1,840	671	861	777	547
	U 95% CI	3,119	881	2,764	818	1,051	1,774	1,094
Above Weir HOS Esc.	Mean	2,317	556	1,603	243	365	939	330
	SD	186	75	175	37	47	208	101
	L 95% CI	2,003	437	1,342	178	281	633	176
	U 95% CI	2,743	728	2,016	320	464	1,429	568
Above Weir NOS Esc.	Mean	323	114	590	498	583	217	437
	SD	60	28	86	32	44	69	64
	L 95% CI	209	67	449	431	492	112	332
	U 95% CI	445	176	781	558	667	380	583
Above Weir pHOS	Mean	87.8%	83.1%	73.1%	32.7%	38.4%	81.4%	42.3%
	SD	1.9%	3.0%	2.1%	4.1%	4.2%	3.3%	6.6%
	L 95% CI	84.3%	77.0%	69.3%	25.2%	31.0%	74.8%	29.9%
	U 95% CI	91.6%	88.9%	77.4%	41.3%	47.2%	87.9%	55.5%
Above Weir pNOS	Mean	12.2%	16.9%	26.9%	67.3%	61.6%	18.6%	57.7%
	SD	1.9%	3.0%	2.1%	4.1%	4.2%	3.3%	6.6%
	L 95% CI	8.4%	11.1%	22.6%	58.7%	52.8%	12.1%	44.5%
	U 95% CI	15.7%	23.0%	30.7%	74.8%	69.0%	25.2%	70.1%
Below Weir Esc.	Mean	584	296	1,419	788	1,976	1,042	345
	SD	110	116	218	141	241	255	137
	L 95% CI	435	155	1,095	569	1,623	674	182
	U 95% CI	856	600	1,943	1,121	2,552	1,649	688
Below Weir HOS Esc.	Mean	434	153	812	288	1227	376	127
	SD	76	52	127	54	150	96	52
	L 95% CI	328	88	620	204	1,007	235	63
	U 95% CI	619	284	1,115	411	1,585	607	254
Below Weir NOS Esc.	Mean	150	143	607	500	749	666	218
	SD	42	69	98	96	99	169	90
	L 95% CI	84	58	460	351	597	422	111
	U 95% CI	250	327	841	726	977	1,071	451
Below Weir pHOS	Mean	74.6%	53.0%	57.2%	36.7%	62.1%	36.1%	36.9%
	SD	3.9%	6.5%	1.8%	2.9%	1.5%	3.2%	4.8%
	L 95% CI	67.3%	40.9%	53.7%	31.2%	59.2%	30.2%	27.7%
	U 95% CI	82.6%	66.3%	60.7%	42.6%	65.1%	42.6%	46.6%
Below Weir pNOS	Mean	25.4%	47.0%	42.8%	63.3%	37.9%	63.9%	63.1%
	SD	3.9%	6.5%	1.8%	2.9%	1.5%	3.2%	4.8%
	L 95% CI	17.4%	33.7%	39.3%	57.4%	34.9%	57.4%	53.4%
	U 95% CI	32.7%	59.1%	46.3%	68.9%	40.8%	69.8%	72.3%

Appendix C – The effect of unclipped hatchery-origin fish on the ability of weirs to achieve proportion of hatchery-origin spawner targets

This appendix contains figures showing the ability of weirs to achieve the proportion of hatchery-origin spawners (pHOS) targets described by HSRG in areas upstream of weirs as a result of removing marked fish. The figures show the resultant upstream pHOS, assuming all marked hatchery fish (and no unmarked fish) are removed at weirs, as a function of weir efficiency, the proportion of marked fish arriving to the weir, and the mass mark rate of hatchery fish (adipose clip or CWT). Included are three figures: one with a 96% mass mark rate (Figure C1), one with a 98% mass mark rate (Figure C2), and one with a 100% mass mark rate (Figure C3). These three scenarios cover the typical low, average, and high range of mass mark rates of fall Chinook salmon released from lower Columbia River hatchery facilities.

The resultant pHOS levels are divided into four groups: less than 5%, 6-10%, 11-30%, 31-100%, which correspond to HSRG target thresholds dependent on hatchery program type and population recovery designation: no hatchery program or segregated program: < 5% primary populations, < 10% contributing populations, no goal for stabilizing populations; integrated programs: < 30% primary populations, < 30% contributing populations, no goal for stabilizing populations.

Data points represent the lowest possible pHOS that could have occurred upstream of the weir for each year by location combination evaluated in this report (using the observed weir efficiency and marked proportion) if 100% of marked fish had been removed, no unmarked fish had been removed, and assuming the mass mark rate specified. The color (black, grey) of each datapoint indicates whether it was mathematically possible to meet the pHOS goal above the weir site. The shapes (square, triangle, and circle) indicate the HSRG pHOS target for each year by population datapoint. In cases where data points are grey, it was mathematically impossible to achieve pHOS targets for the area upstream of the weir based on the observed weir efficiency, marked proportion of the population and hypothetical mass mark rate.

Note that these figures are meant to be a tool to illustrate the potential for weirs to achieve pHOS targets upstream as a function of the mass mark rate, weir efficiency, and marked proportion of the population arriving at the weir, under the assumption that 100% of mass marked fish are removed. As reported previously herein, in actuality, less than 100% of marked fish were removed at weirs, and some unmarked fish were removed for broodstock. In addition, we used population- and year-specific mass rate rates in our pHOS estimates reported in the results section, and these estimates took into account spawners above and below the weirs, as well as those spawning in sub-basin areas without weirs.

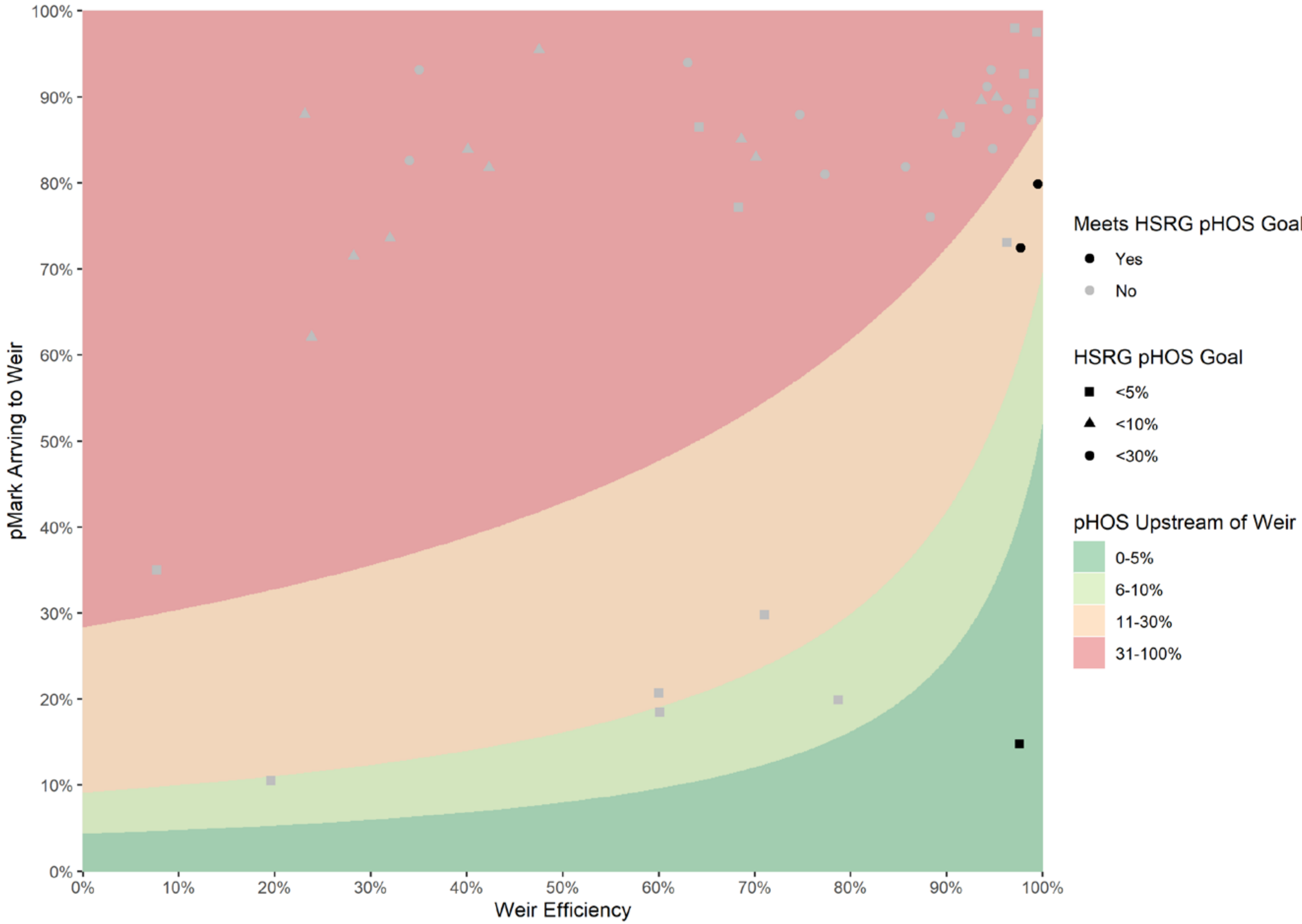

Figure C1. Effect of unclipped hatchery-origin fish on the ability of weirs to achieve proportion of hatchery-origin spawner (pHOS) targets with a hypothetical 96% mass mark rate. See the description at the beginning of this appendix for a thorough explanation of this figure.

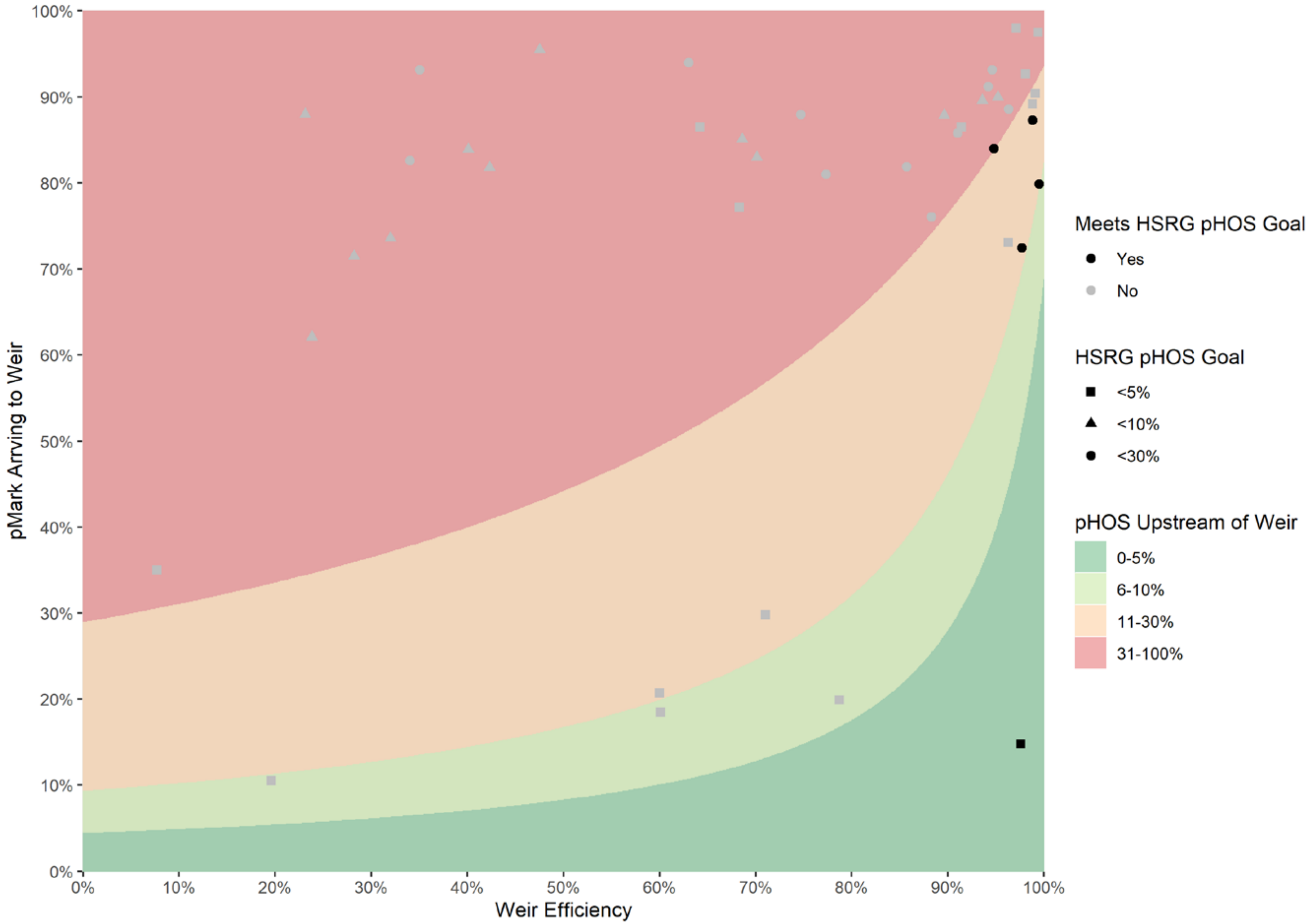

Figure C2. Effect of unclipped hatchery-origin fish on the ability of weirs to achieve proportion of hatchery-origin spawner (pHOS) targets with a hypothetical 98% mass mark rate. See the description at the beginning of this appendix for a thorough explanation of this figure.

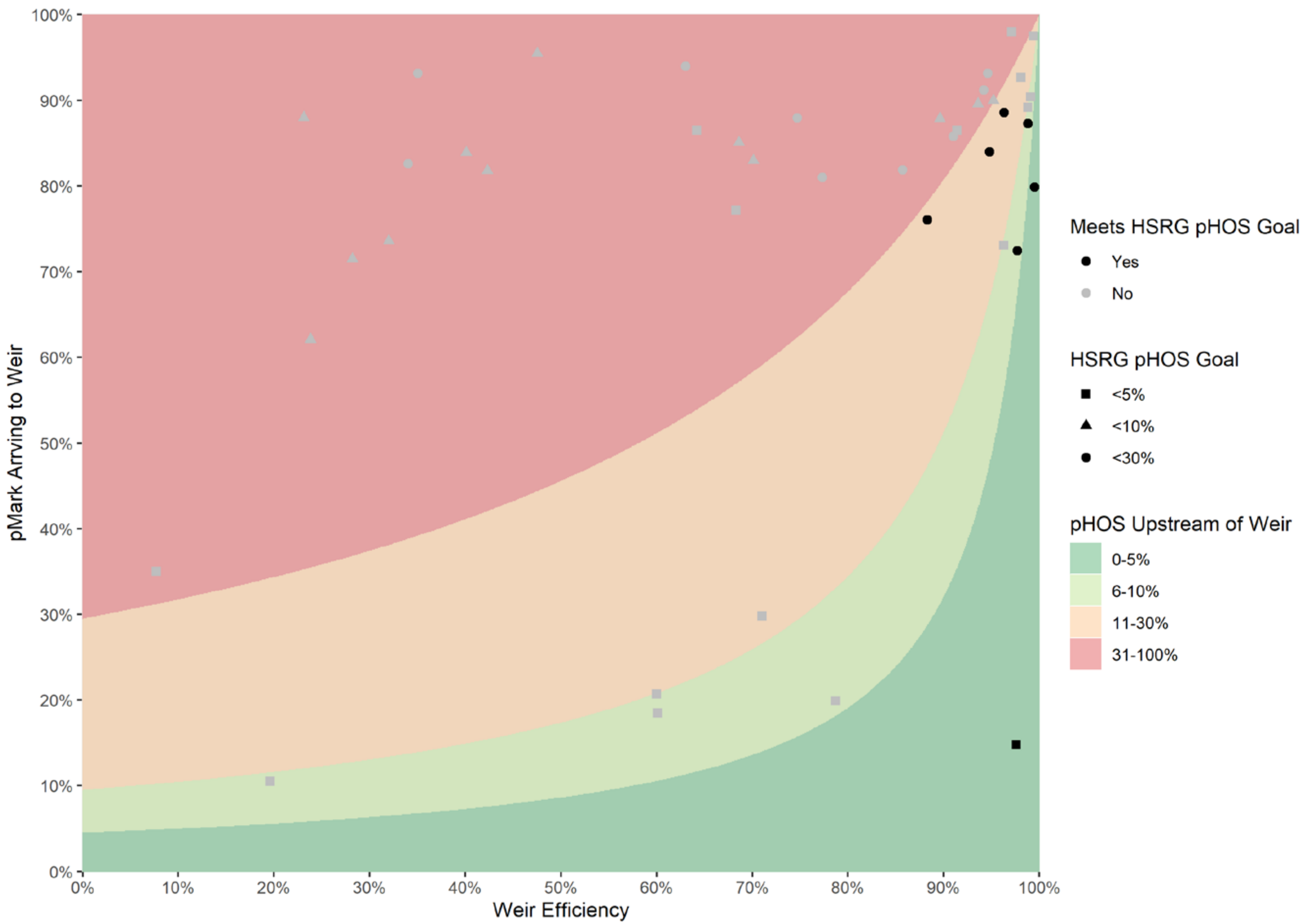

Figure C3. Effect of unclipped hatchery-origin fish on the ability of weirs to achieve proportion of hatchery-origin spawner (pHOS) targets with a hypothetical 100% mass mark rate. See the description at the beginning of this appendix for a thorough explanation of this figure.

Appendix D – Number of salmonids handled at each of the lower Columbia River tributary weirs used for fall Chinook salmon management.

Tables of salmonid catch by species, mark type (e.g. origin), sex, and disposition for each of the six fall Chinook salmon management weir sites for 2013-2017. Jacks are based on a fork length cutoff rather than aged scales or coded-wire-tag recoveries. For fall Chinook salmon, 60 cm and larger are considered adults and less than 60 cm are considered jacks. For coho salmon, 47 cm and larger are consider adults and less than 47 cm are considered jacks. These tables represent the total number of fish captured at each of the weir sites. Total spawning escapement may be more or less than weir totals depending on weir capture efficiency, sport harvest above weir sites, and prespawn mortality. Spawning escapement reported in Wilson et al. 2020 accounts for fish removed from fisheries and/or prespawn mortality.

Table D1. Number of salmonids handled at the Grays River Weir by mark category and disposition, 2013-2016.

		Number Trapped (Male/Female/Jack)				
Species	Mark	2013	2014	2015	2016	Disposition
Fall Chinook salmon	LV/ADLV	467 (139/326/2)	243 (37/84/122)	283 (85/140/58)	146 (51/87/8)	Removed
	AD	35 (23/5/7)	98 (54/22/22)	313 (160/145/8)	75 (28/39/8)	Removed
	None	40 (18/21/1)	37 (14/17/6)	97 (38/39/20)	53 (17/26/10)	Upstream
Coho salmon	AD	37 (20/17/0)	297 (180/106/11)	78 (39/28/11)	8 (3/1/4)	Upstream
	AD	0	107 (74/31/2)	5 (2/2/1)	0	Removed
	None	41 (16/18/7)	309 (140/159/10)	69 (36/30/3)	32 (16/8/8)	Upstream
Chum salmon	None	0	0	7 (5/2/0)	0	Upstream
	None	0	1 (0/1/0)	1 (0/1/0)	0	Downstream
Pink salmon	None	1 (1/0/0)	0	0	0	Upstream
Steelhead	AD	0	5 (2/3/0)	1 (0/1/0)	1 (1/0/0)	Upstream
	None	0	1 (1/0/0)	0	1 (0/1/0)	Upstream

LV= Left Ventral Fin Clip; AD = Adipose Fin Clip; Left ventral fin clips typically identify Select Area Bright (SAB) fall Chinook salmon from Oregon SAFE program releases.
Trap mortalities not included in table above. Grays River Weir was not operated in 2017.

Table D2. Number of salmonids handled at Elochoman River Weir by mark category and disposition, 2013-2017.

		Number Trapped (Male/Female/Jack)					
Species	Mark	2013	2014	2015	2016	2017	Disposition
Fall Chinook salmon	LV or ADLV	17 (7/9/1)	67 (25/28/14)	31 (9/16/6)	1 (0/1/0)	5 (3/2/0)	Removed
	AD	185 (120/68/7)	959 (557/375/27)	1,472 (802/660/10)	350 (168/170/3)[a]	164 (85/77/2)	Removed
	None	37 (17/20/0)	197 (88/85/24)	243 (122/110/11)	64 (27/32/5)	83 (26/54/3)	Upstream
Coho salmon	AD	2 (0/2/0)	1 (1/0/0)	4 (0/4/0)	0	0	Upstream
	AD	16 (9/7/0)	198 (95/103/0)	33 (13/20/0)	27 (19/7/1)	48 (25/23/0)	Removed
	None	58 (37/21/0)	368 (195/172/1)	121 (75/45/1)	74 (40/34/0)	53 (32/20/1)	Upstream
Chum salmon	None	30 (16/14/0)	0	2 (1/1/0)	0	0	Upstream
	None	0	1 (0/1/0)	0	0	1 (1/0/0)	Downstream
Steelhead	AD	8 (2/6/0)	26 (17/9/0)	3 (1/2/0)	4 (1/3/0)	10 (4/6/0)	Upstream
	None	0	7 (3/4/0)	1 (1/0/0)	2 (0/2/0)	3 (2/1/0)	Upstream

LV= Left Ventral Fin Clip; AD = Adipose Fin Clip; Left ventral fin clips typically identify Select Area Bright (SAB) fall Chinook salmon from Oregon SAFE program releases.
Trap mortalities are not included in this table.
[a] 9 unknown sex fish included in overall total but not in sex breakdown

Table D3. Number of salmonids handled at Green River Weir by mark category and disposition, 2013-2017.

		Number Trapped (Male/Female/Jack)					
Species	Mark	2013	2014	2015	2016	2017	Disposition
Fall Chinook salmon	AD	31 (12/12/7)	38 (13/17/8)	944 (510/423/11)	198 (150/35/13)	6 (3/1/2)	Removed
	AD	14 (6/5/3)	0	0	0	0	Upstream
	AD	22 (8/8/6)	24 (10/10/4)	937 (454/431/52)	899 (417/460/22)	25 (9/10/6)	Brood
	AD+RV	0	0	1 (1/0/0)	0	0	Removed
	LV	2 (1/1/0)	1 (0/1/0)	6 (3/3/0)	0	0	Removed
	LV	1 (0/1/0)	0	1(0/0/1)	0	0	Downstream
	None	29 (12/12/4)	26 (9/9/8)	336 (186/141/9)	237 (123/108/6)	19 (9/8/2)	Upstream
	None	23 (8/9/6)	20 (7/9/4)	176 (97/73/9)	117 (64/50/3)	15 (7/8/0)	Brood

AD = Adipose Fin Clip.
Trap mortalities are not included in this table.
Note this table only includes Chinook salmon totals; other species were captured while the weir was installed but may not represent the total seasonal catch. Comprehensive totals can be found in WDFW escapement reports for North Toutle Hatchery.

Table D4. Number of salmonids handled at Coweeman River Weir by mark category and disposition, 2013-2017.

		Number Trapped (Male/Female/Jack)					
Species	Mark	2013	2014	2015	2016	2017	Disposition
Fall Chinook salmon	AD	83 (48/35/0)	159 (88/68/3)	202 (113/87/2)	20 (13/7/0)	185 (105/79/1)	Removed
	LV	1 (0/1/0)	6 (2/2/2)	6 (1/4/1)	0	0	Removed
	None	87 (38/48/1)	514 (227/270/17)	1,321 (628/628/65)	66 (32/31/3)	524 (217/301/6)	Upstream
Coho salmon	AD	1 (1/0/0)	6 (0/3/3)	8 (2/6/0)	2 (1/1/0)	2 (1/1/0)	Removed
	None	6 (3/3/0)	158 (72/75/11)	286 (155/115/16)	21 (10/8/3)	161 (79/60/22)	Upstream
Steelhead	AD	0 (0/0/0)	11 (4/7/0)[a]	5 (1/4/0)	0	2 (0/2/0)	Upstream
	None	1 (0/1/0)	5 (1/4/0)	9 (3/6/0)	0	1 (0/1/0)	Upstream

LV= Left Ventral Fin Clip; AD = Adipose Fin Clip; Left ventral fin clips typically identify Select Area Bright (SAB) fall Chinook salmon from Oregon SAFE program releases.
Trap mortalities are not included in this table.
[a] Includes 1 AD+RV mark

Table D5. Number of salmonids handled at Kalama River Weir by mark category and disposition, 2015-2017.

		Number Trapped (Male/Female/Jack)			
Species	Mark	2015	2016	2017	Disposition
Fall Chinook salmon	AD	22,152 (10,788/10,844/520)	13,763 (5,328/7,820/615)	11,638 (5,850/5,548/240)	Removed
	AD	855 (346/482/27)	0	15 (10/3/2)	Upstream
	AD	3,321 (1,561/1,655/105)	3,826 (1,869/1,838/119)	3,436 (1,285/2,109/42)	Trucked for brood
	AD+RV	0	3 (2/1/0)	3 (1/2/0)	Removed
	None	2,790 (1,466/1,232/92)	2,648 (1,207/1,351/90)	1,753 (835/876/42)	Upstream
	None	369 (219/140/10)	0	42 (41/1/0)	Trucked for brood
Coho salmon	AD	1,805 (920/850/35)	606 (310/274/22)	323 (116/43/164)	Upstream
	AD	54 (24/30/0)	0	0	Trucked for brood
	None	122 (55/59/8)	80 (33/38/9)	110 (58/51/1)	Upstream
Chum salmon	None	0	0	8 (5/3/0)	Upstream
Pink salmon	AD	1 (0/1/0)	0	0	Upstream
	None	2 (1/1/0)	0	1 (1/0/0)	Upstream
Sockeye	None	0	0	2 (2/0/0)	Upstream
Steelhead	AD	1,041 (496/544/1)	735 (412/323/0)	393 (190/203/0)	Upstream
	AD+RV	426 (144/281/1)	253 (126/127/0)	28 (19/9/0)	Upstream
	AD+LV	51 (22/29/0)	53 (19/34/0)	45 (15/30/0)	Upstream
	None	162 (45/117/0)	153 (65/88/0)	159 (61/98/0)	Upstream

AD = Adipose Fin Clip.
Trap mortalities are not included in this table.

Table D6. Number of salmonids handled at Washougal River Weir by mark category and disposition, 2013-2017.

		Number Trapped (Male/Female/Jack)					
Species	Mark	2013	2014	2015	2016	2017	Disposition
Fall Chinook salmon	AD	1,680 (971/492/217)	5,825 (3,373/1,651/801)	11,925 (6,709/4,305/911)	5,087 (2,360/2,603/124)	937 (298/582/57)	Removed
	AD	119 (65/50/4)	0	0	0	0	Upstream
	AD	1,866 (906/909/51)	4,291 (1,889/2,298/104)	4,508 (1,924/2,398/186)	1,344 (640/678/26)	1,836 (817/967/52)	Brood
	None	376 (194/172/10)	713 (370/286/57)	817 (516/266/35)	237 (128/105/4)	260 (130/120/10)	Upstream
	None	0	259 (132/117/10)	286 (172/105/9)	165 (77/83/5)	88 (41/41/0)	Brood
Coho salmon	AD	7 (4/3/0)	693 (397/277/19) [a]	23 (21/1/1)	7 (4/3/0)	433 (322/102/9)	Upstream
	None	0 (0/0/0)	44 (30/14/0) [a]	6 (6/0/0)	0	23 (19/4/0)	Upstream
Pink salmon	None	0	0	1 (1/0/0)	0	0	Upstream
Sockeye	None	0	0	2 (1/1/0)	0	0	Upstream
Steelhead	AD	44 (17/27/0)	360 (247/113/0)	369 (190/179/0)	420 (208/212/0)	75 (40/35/0)	Upstream
	None	21 (4/15/2)	72 (24/48/0)	82 (32/50/0)	22 (4/18/0)	16 (8/8/0)	Upstream

AD = Adipose Fin Clip
Trap mortalities are not included in this table
[a] An additional 410 coho salmon were released upstream in 2014 without a sex

Appendix E – History, maps, and photos of lower Columbia River tributary weirs used for fall Chinook salmon management

The Grays River Weir was the first weir used in the lower Columba River for fall Chinook salmon management (Wilson et al. 2018). It was initially established and operated by WDFW Region 5 fish management in the fall of 2008 using Pacific Coast Salmon Restoration Fund (PCSRF) dollars. Funding to install and operate the weir shifted to Mitchell Act Monitoring and Evaluation Reform (MER) dollars in 2009. In 2011, the Grays River weir was moved from its original location just downstream of the Grays River Covered Bridge (rkm 17.22) to rkm 16.50 due to landowner constraints (Wilson and Glaser 2015; Wilson and Glaser 2019). Prior to the fall 2013 season, the weir was again moved downstream to a site just above Barr Road (rkm 13.65) (Figure E1) (Figure E2). The move was intended to put the weir into a wider, lower energy portion of the river that experiences more tidal influence to: (1) improve the ability of the weir to withstand freshets, and (2) encourage earlier recruitment of fish to the weir/trap. This weir is installed annually on a temporary substrate rail with a temporary live box. This weir is used to control proportion hatchery-origin spawners (pHOS) and as a monitoring platform to improve spawner estimates for fall Chinook salmon.

The Elochoman River Weir is located just above Foster Road near the head of tide at rkm 4.39. For several decades, this site and configuration were used to trap broodstock for the WDFW Elochoman Salmon Hatchery fall Chinook salmon program. After the closure of Elochoman Hatchery in 2008, the responsibility for weir operations transferred to fish management staff under Mitchell Act MER funding. During this transition, weir panels were rebuilt with 3.8 cm spacing (instead of the previous 7.6 cm spacing) between panel bars. In the fall of 2009, the fixed panel weir was operated under fish management with the goal of controlling pHOS and improving spawner estimates for fall Chinook salmon. This design continued through the fall of 2012 (Wilson and Glaser 2015; Wilson and Glaser 2019). In 2013, the Elochoman River Weir transitioned to a resistance board design rather than the fixed panel design that had been used for decades (Figure E3). This weir is installed annually on a permanent concrete sill and a permanent concrete live box. From 2009 to 2017, the operational goals have been to control pHOS and improve spawner estimates for fall Chinook salmon.

The Green River Weir has been used for many years as a tool to ensure broodstock collection goals were met for North Toutle Hatchery's programs. In 2010, the weir began to be used for fish management purposes (Wilson and Glaser 2014). This weir utilizes a hybrid resistance board design (Figure E4) and is located at rkm 0.64 at the North Toutle Hatchery. This weir is installed annually on a permanent concrete sill and fish are diverted into North Toutle Hatchery's adult holding pond. From 2010 to 2017, the operational goals have been to improve spawner estimates for fall Chinook salmon and to control pHOS and collect broodstock for coho and fall Chinook salmon.

The Coweeman River Weir was first installed and operated in 2011 (Wilson and Glaser 2015). This weir utilizes a full resistance board design. From 2011 to 2015, the weir was installed at rkm 10.94 approximately 0.8 kilometers above the head of tide (Figure E7). In 2016, landowner access made it necessary to move the weir from the site where it had been in previous years (Figure E5). A new site was found downriver from the previous site at rkm 6.44 (Figure E6). In 2017, the weir moved back to the original location at rkm 10.94. This weir is installed annually on a temporary substrate rail with a temporary live box. The weir configuration has changed slightly each year with the goal of improving fish recruitment. Some of the configuration improvements are a wider, opened top entry chute (instead of a narrow enclosed tunnel) and removable downstream wing walls that funnel upstream migrants directly to the entry chute. This weir is used to control pHOS and as a monitoring platform to improve spawner estimates for fall Chinook salmon.

The Kalama River Weir, or Modrow Weir, has been used to for decades as tool to ensure broodstock collection goals are met for Kalama Falls Hatchery's fall Chinook salmon program. The site is located just below Modrow Bridge at rkm 4.38. The infrastructure had a substantial overhaul during 2014 including a new sorting facility, new permanent concrete live box, reduced picket spacing (from 7.6 cm to 3.8 cm), and was transitioned from a fixed panel design to a resistance board design. This weir is installed annually on a permanent concrete sill with adjoining live box (Figure E8). Beginning in 2015, the operational goals have been to control pHOS and improve spawner estimates for fall Chinook salmon and to collect broodstock for Kalama Falls Hatchery's fall Chinook salmon program.

The Washougal River Weir was first installed and operated in 2011. This weir utilizes a hybrid resistance board/fix panel design (Figure E9) and is located at rkm 19.15. This weir is installed annually on a temporary substrate rail with a temporary live box. The operational goals are to control pHOS and improve spawner estimates for fall Chinook salmon and to collect broodstock for Washougal Salmon Hatchery's fall Chinook salmon program.

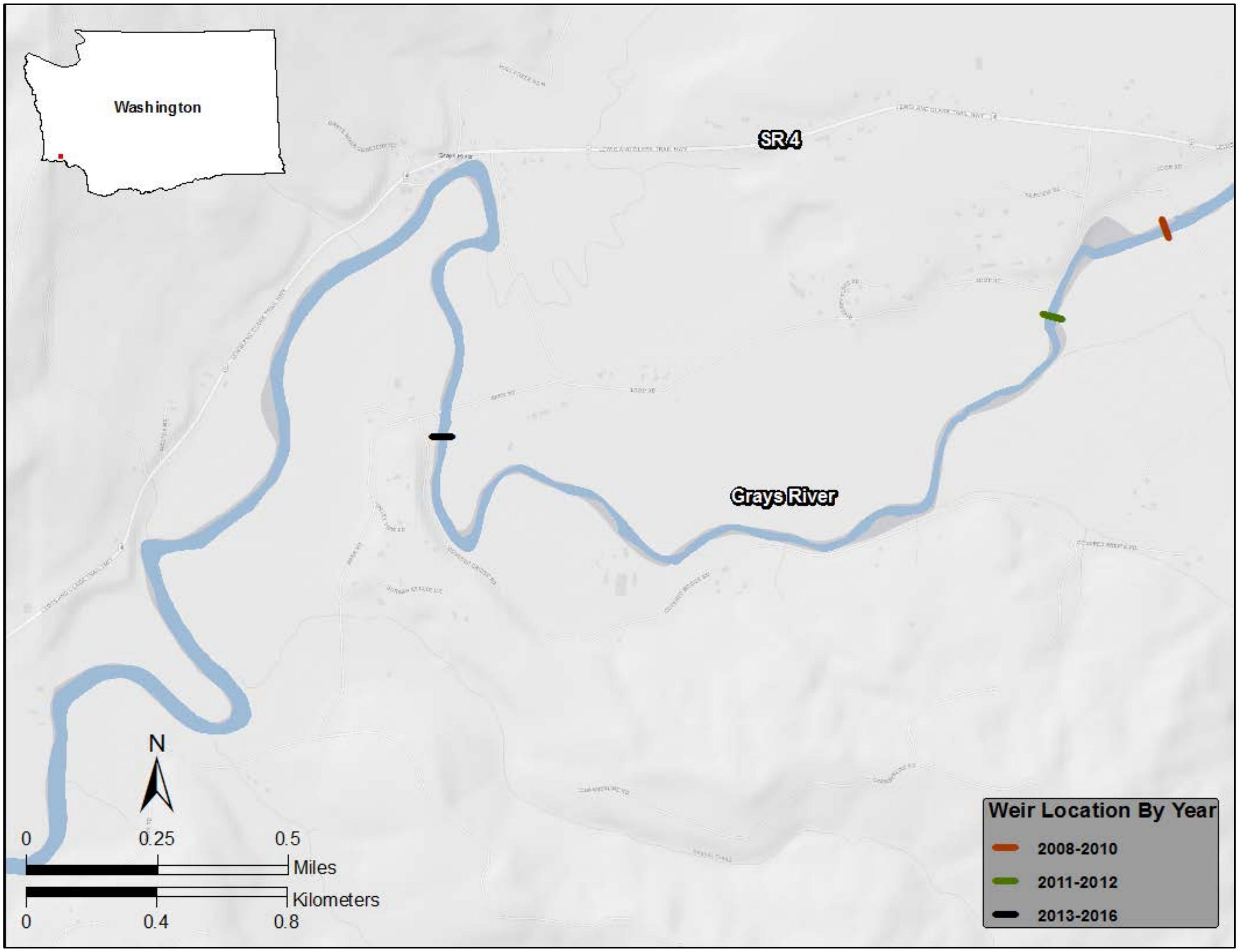

Figure E1. Location of weirs on the Grays River, 2008-2016.

Figure E2. 2016 Grays River Weir configuration.
Photo credit: Patrick Hulett (WDFW).

Figure E3. 2016 Elochoman River Weir configuration.
Photo credit: Patrick Hulett (WDFW).

Figure E4. 2013 Green River Weir configuration.
Photo credit: Amanda Danielson (WDFW).

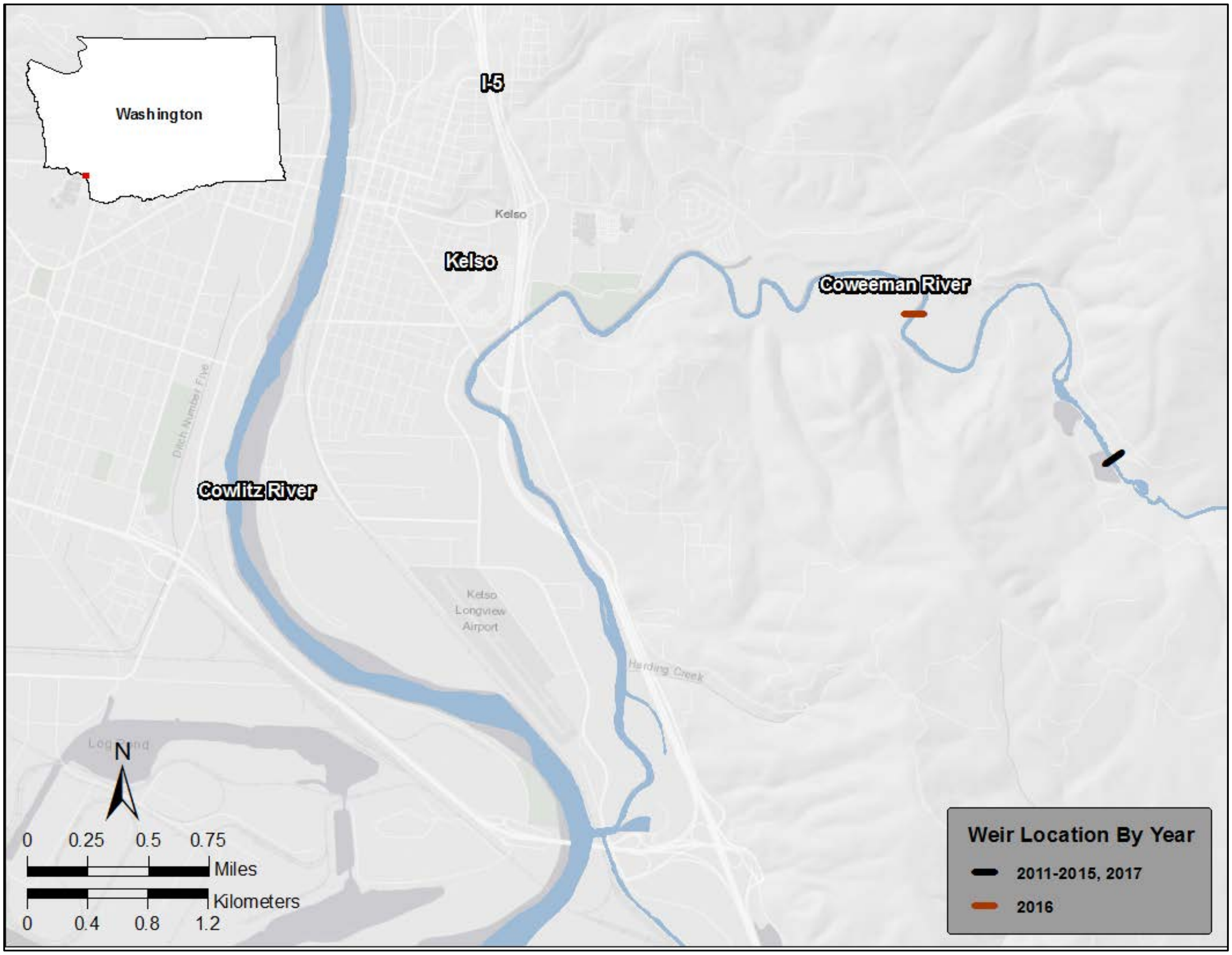

Figure E5. Location of weirs on the Coweeman River, 2011-2017.

Figure E6. 2016 Coweeman River Weir configuration.
Photo credit: Patrick Hulett (WDFW).

Figure E7. 2017 Coweeman River Weir configuration.
Photo credit: Patrick Hulett (WDFW).

Figure E8. 2016 Kalama River Weir configuration.
Photo credit: Quinten Daugherty (WDFW).

Figure E9. 2016 Washougal River weir configuration.
Photo credit: Elise Olk (WDFW).

Appendix F – Run Timing of adult fall Chinook salmon at lower Columbia River tributary weirs

Figures of cumulative run timing by mark type at the six lower Columbia River weirs used for fall Chinook salmon management. Run timing information for years prior to 2013 can be found in Wilson and Glaser 2014, Wilson and Glaser 2015, and Wilson and Glaser 2019.

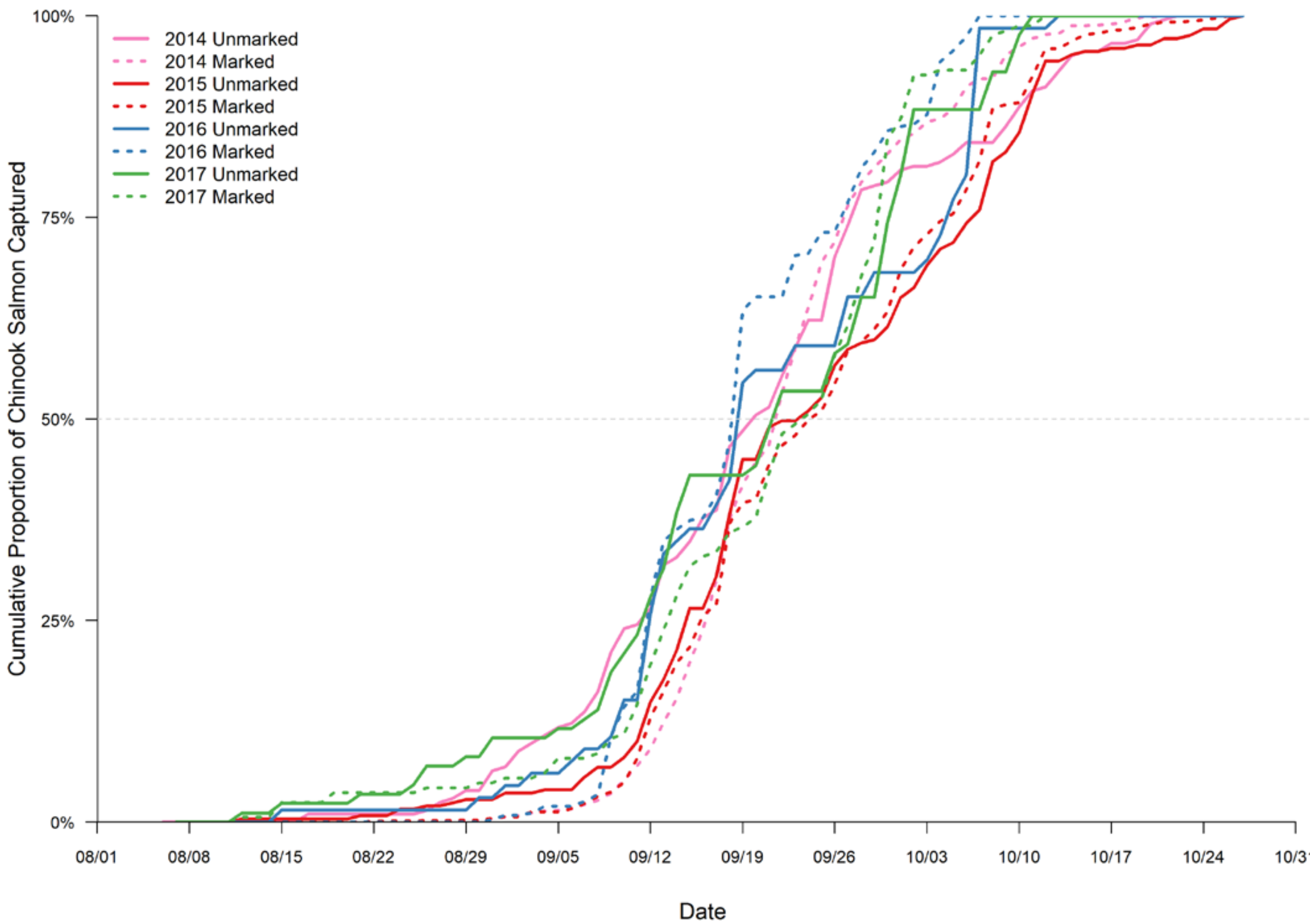

Figure F1. Adult fall Chinook salmon run timing by mark type at Elochoman River Weir for 2014-2017. Solid lines represents unmarked, or all fins intact (natural-origin and unclipped hatchery-origin spawners) and dashed lines indicate adipose fin clipped, (indicates hatchery-origin).

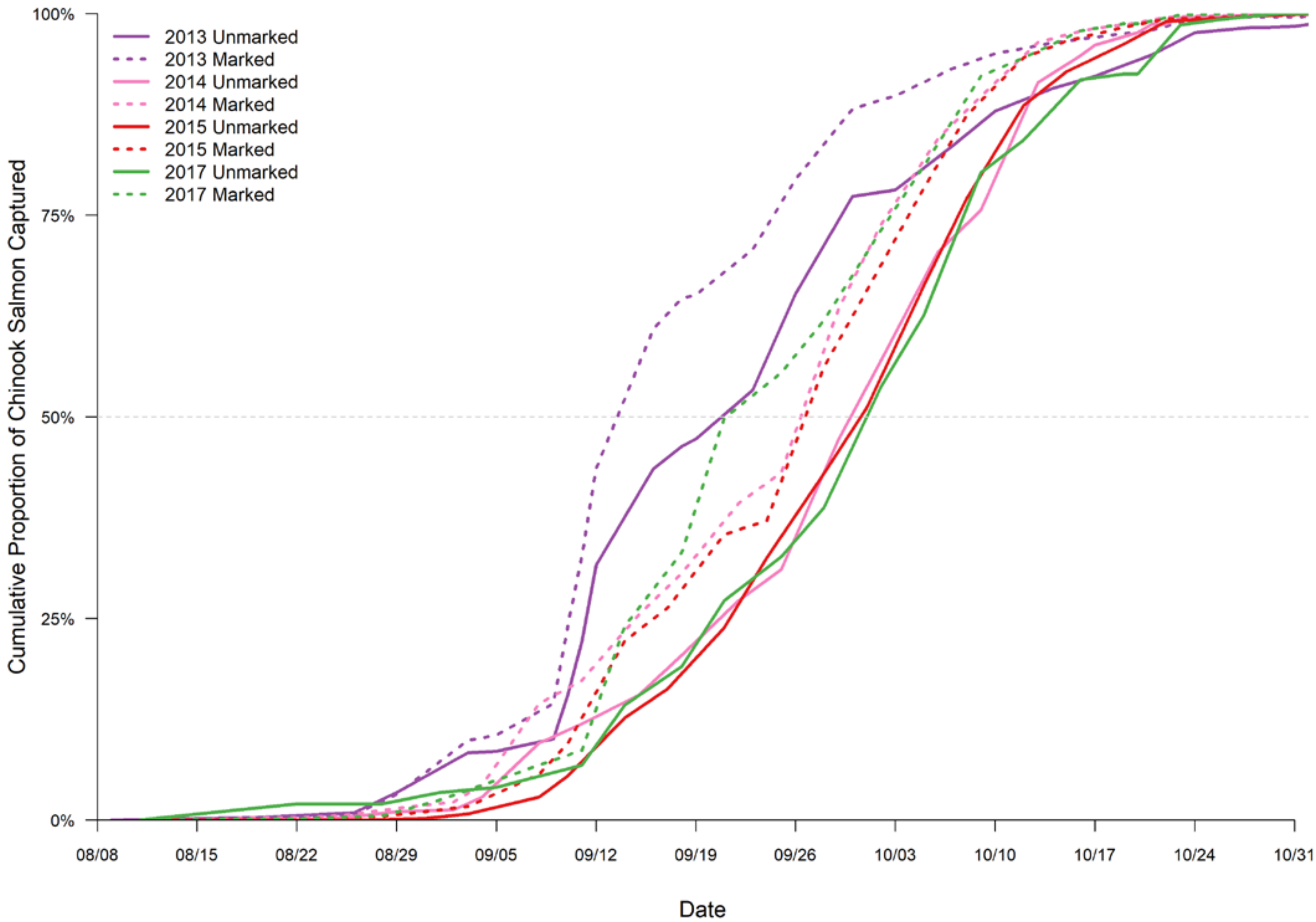

Figure F2. Adult fall Chinook salmon run timing by mark type at Green River Weir, 2013-2015, 2017. Solid lines represents unmarked, or all fins intact (natural-origin and unclipped hatchery-origin spawners) and dashed lines indicate adipose fin clipped, (indicates hatchery-origin).

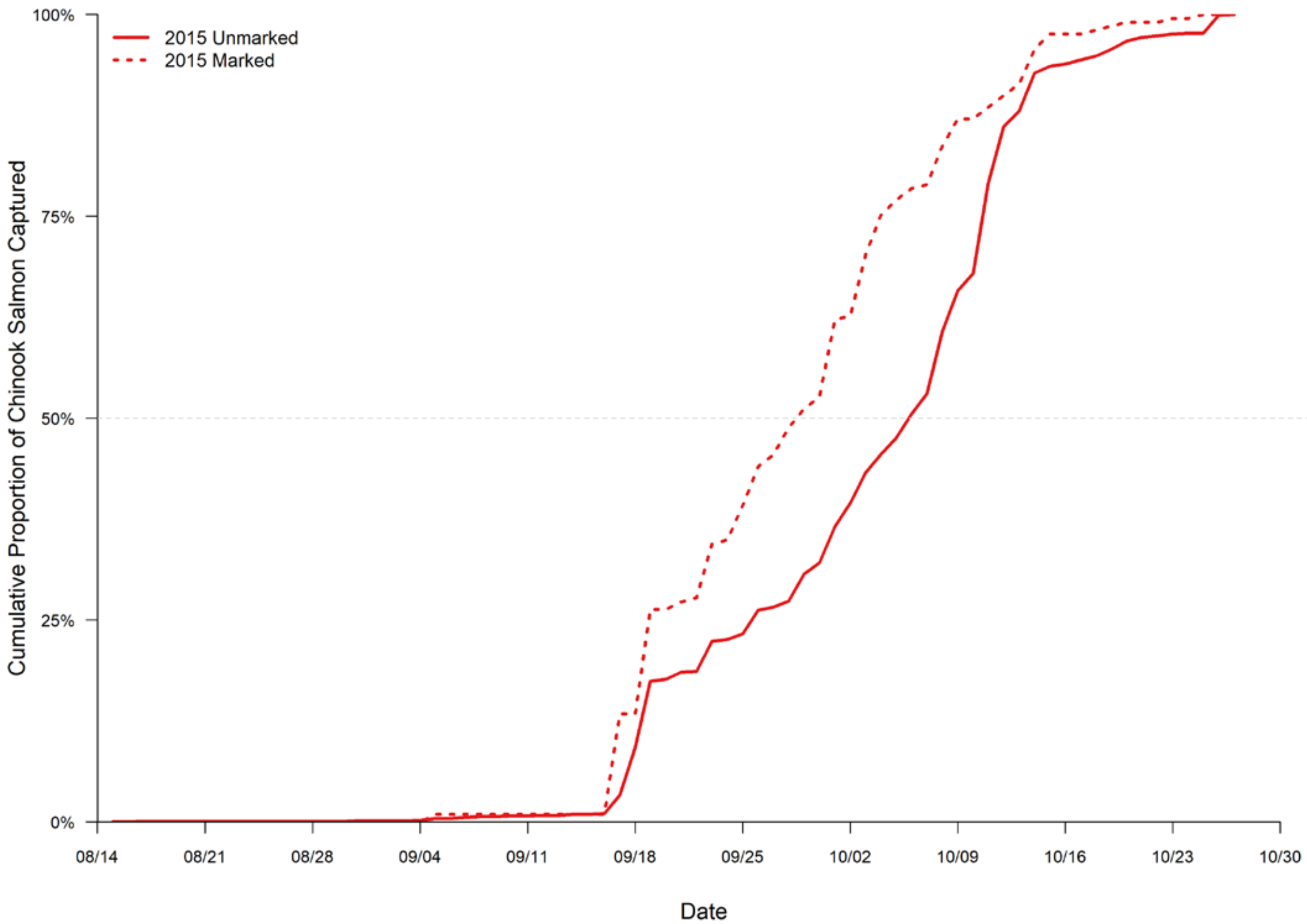

Figure F3. Adult fall Chinook salmon run timing by mark type at Coweeman River Weir, 2015. Solid lines represents unmarked, or all fins intact (natural-origin and unclipped hatchery-origin spawners) and dashed lines indicate adipose fin clipped, (indicates hatchery-origin).

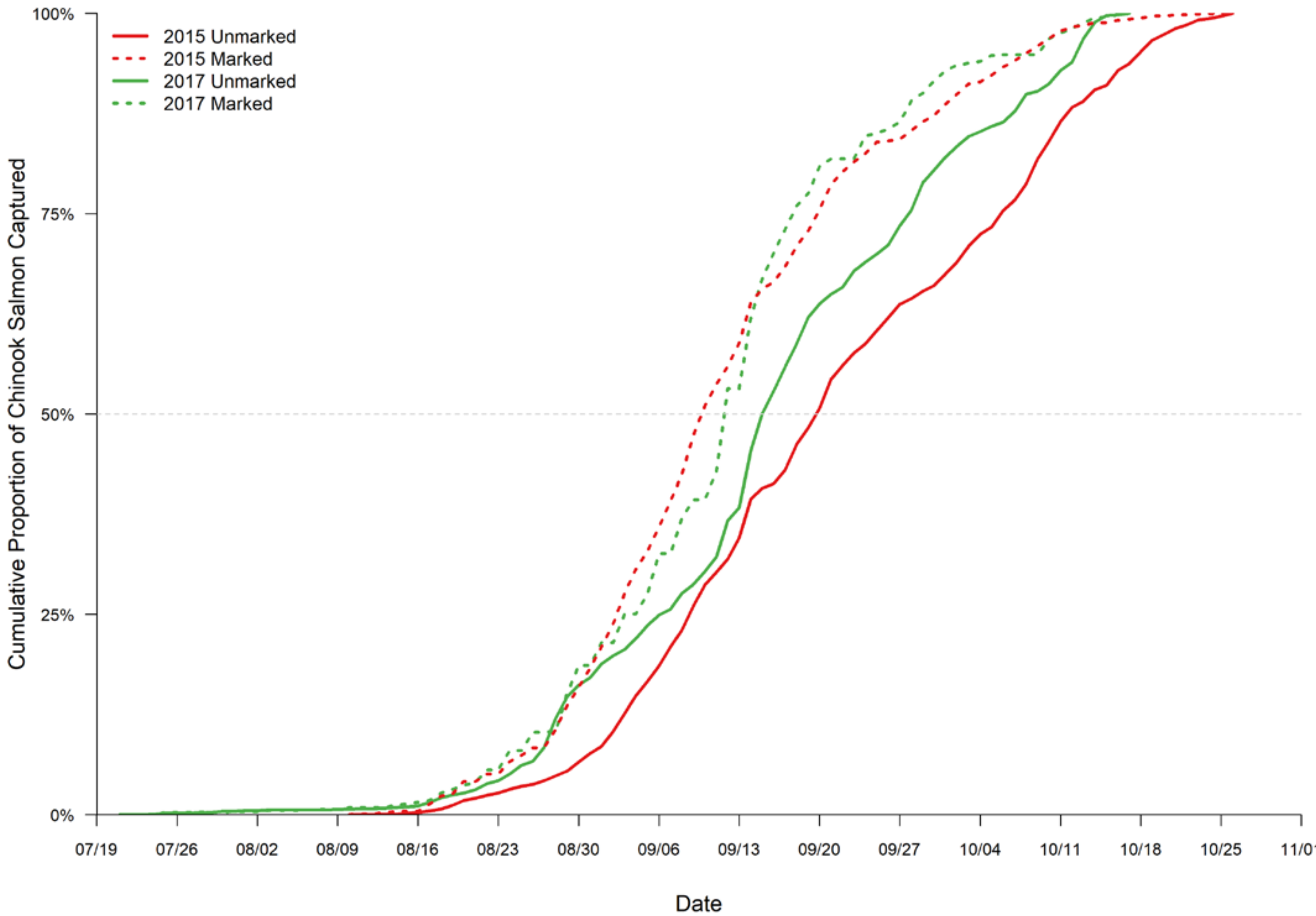

Figure F4. Adult fall Chinook salmon run timing by mark type at Kalama River Weir, 2015 and 2017. Solid lines represents unmarked, or all fins intact (natural-origin and unclipped hatchery-origin spawners) and dashed lines indicate adipose fin clipped, (indicates hatchery-origin).

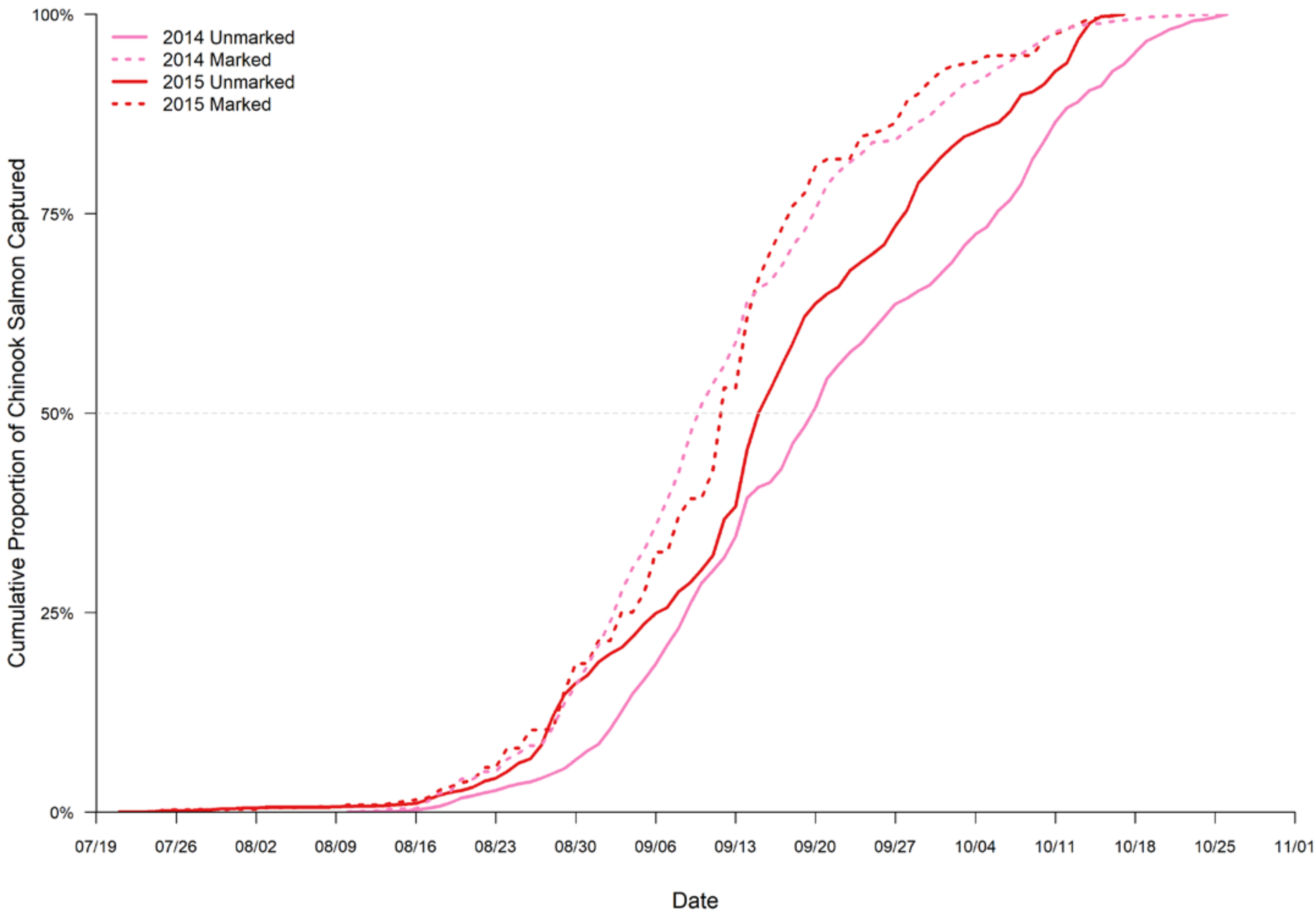

Figure F5. Adult fall Chinook salmon run timing by mark type at Washougal River Weir, 2014-2015. Solid lines represents unmarked, or all fins intact (natural-origin and unclipped hatchery-origin spawners) and dashed lines indicate adipose fin clipped (indicates hatchery-origin).