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Estimates of Adult Fall Chinook Salmon Spawner Abundance and Viable Salmonid Population Parameters in the Washington Portion of the Lower Columbia River Evolutionarily Significant Unit, 2013-2017

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Abstract

In 1999, Chinook salmon (*Oncorhynchus tshawytcha*) in the LCR Evolutionarily Significant Unit (ESU) were listed as threatened under the Endangered Species Act. As a result, WDFW began to strategically implement more intensive escapement monitoring for adult fall Chinook salmon on select populations over the next decade in an effort to improve estimates. In 2010, WDFW modified and expanded its existing fall Chinook salmon escapement monitoring program to ensure estimates of viable salmonid population parameters were being monitored for all populations within the LCR ESU and that these parameters met the National Oceanic and Atmospheric Administration Fisheries guidelines for accuracy and precision (Crawford and Rumsey 2011). This report covers methods and results from spawn years 2013-2017 and updates previously reported results from spawn years 2010-2012 as models have been improved. We report only adult fall Chinook salmon estimates (classified as 60 cm and larger) due to challenges in obtaining sufficient jacks to estimate accurately. Adult abundance was estimated using a variety of methods including weir counts, Lincoln-Petersen and Jolly-Seber mark-recapture models, area-under-the-curve based on live counts, redd expansion based on census redd surveys, and peak count expansion depending on resources and survey conditions. Carcasses recoveries were used to determine the marked and unmarked proportion based a combination of adipose and ventral fin clips and coded-wire tags (CWTs). The marked and unmarked was further adjusted by juvenile mass mark rates from hatchery releases to account for hatchery production that was released unclipped and untagged (~1-3%). Annual estimates of natural-origin Tule fall Chinook salmon spawner abundance for the Washington portion of the LCR ESU ranged from a low of 7,065 in 2012 to a high of 18,941 in 2015. The larger Cascade stratum populations, the Cowlitz and Lewis, had the largest annual estimates of natural-origin Tule fall Chinook salmon spawner abundance. The three populations which comprise the Coast stratum (Grays/Chinook, Elochoman/Skamokawa, and Mill/Aber/Germ) and the Lower Gorge population had smallest annual estimates of natural-origin Tule fall Chinook salmon spawner abundance. Weir operations were successful at reducing the proportion of hatchery-origin spawners for some populations. However, the proportion of hatchery-origin spawners exceeded Hatchery Scientific Review Group recommendations for most populations in most years. Most Tule fall Chinook salmon populations were comprised of predominately hatchery-origin spawners except the Coweeman. Age structure varied by population, but most Tule fall Chinook salmon were age-3 and age-4. A total of 2,106 snouts were collected from the field and CWTs decoded successfully. CWT recoveries were uploaded to the regional database (Regional Mark Information System) and unexpanded CWT recoveries indicate most hatchery-origin Tule fall Chinook salmon returned to the basin of release or an adjacent basin. Bright stock fall Chinook salmon not native to this ESU are successfully spawning in the Grays/Chinook, Lower Gorge, Upper Gorge, and White Salmon populations. Assumption testing indicated our abundance and proportion estimates were relatively unbiased.

Introduction

The Washington Department of Fish and Wildlife (WDFW) has monitored most fall Chinook salmon (*Oncorhynchus tshawytcha*) populations in the lower Columbia River (LCR) for decades (WDFW 2019). However, much of this early work was focused on meeting data needs related to run reconstruction and forecasting (e.g. generating an escapement estimate). Peak count expansion (PCE) was the typical method used due to limited resources. This method consisted of conducting one to three annual spawning ground surveys within an index reach around the peak of spawning activity. The highest single weekly count of combined lives and deads was considered the peak count, which was expanded by a PCE factor for that basin. The PCE factor was either developed from a prior mark-recapture study within the basin (Tracy et al. 1967; Stockley 1965; Hymer 1991) or based on professional judgement. These estimates provided a coarse estimate of abundance for many years. However, this method can be difficult to meet all of the assumptions needed for an unbiased estimate (Parsons and Skalski 2010) and uncertainty was not quantified.

In 1999, Chinook salmon in the LCR Evolutionarily Significant Unit (ESU) were listed for protection under the Endangered Species Act (ESA). In a recent five-year review, the National Oceanic and Atmospheric Administration (NOAA) Fisheries concluded that these fish should remain listed as threatened under the ESA (NOAA 2016). Following the initial ESA listing, WDFW put forth considerable effort into improving escapement estimates. This was done systematically with the first efforts taking place on the Elochoman River in 2001-2003 followed by the Coweeman River in 2002-2004. In 2005, the Intensively Monitored Watershed project began on Mill, Abernathy, and Germany creeks, which included more intensive fall Chinook salmon monitoring (2005-2017). By the later part of the 2000s, the EF Lewis (2005-2007), Grays (2005-2017), Coweeman (2007-2017), and Elochoman (2009-2017) rivers were added as watersheds with more intensive adult fall Chinook salmon monitoring study designs.

The need for monitoring of additional indicators and unbiased and precise estimates of these indicators, especially for the fall Chinook populations, has been identified as a high priority for salmon management and recovery (LCFRB 2004, Rawding and Rodgers 2013, Crawford and Rumsey 2011). In 2010, WDFW modified and expanded its existing fall Chinook salmon escapement monitoring in the LCR. This new program had two objectives: (1) to estimate Viable Salmonid Population (VSP) parameters including abundance, diversity, and spatial structure by population (McElhaney et al. 2000) and (2) to recover coded-wire-tags (CWTs) from spawning fish to provide complete accounting of CWTs for hatchery effectiveness monitoring, salmon management, and forecasting.

This report focuses on updating analytical methods used to estimate VSP parameters for fall Chinook salmon in the LCR. We made several improvements to our models from what was initially reported in Rawding et al. (2014), Rawding et al. (2019), and Buehrens et al. (2019). These improvements include: (1) developing a hierarchical mixed effects model to facilitate basin-, year-, and basin- and year-specific estimates of apparent residence time and apparent females per redd, (2) modeling PCE hierarchically across years, (3) adjusting all estimates to exclude prespawn mortality so abundance estimates would represent spawners only, (4) improving models to better account for unclipped hatchery-origin spawners, and (5) transitioning from vague priors for age composition estimates to informative priors. As a result, we update 2012-2012 estimates with our improved models and report on 2013-2017 estimates for the first time. This report summarizes VSP parameters and CWT recoveries for 13 recognized fall Chinook salmon populations in the Washington portion of the LCR ESU and introduced Bright stocks spawning in the Grays, White Salmon, Upper Gorge, and Lower Gorge populations that are not recognized as part of the LCR ESU.

Methods

Study Area

The LCR is classified as the Cascade Crest to where the river enters the Pacific Ocean (Myers et al. 1998). LCR Chinook salmon are classified as spring, fall, or late fall based on when adults return to freshwater (NOAA 2013). Both spring and fall runs have been are included as part of the LCR ESU. Fall Chinook salmon were historically found throughout the entire range, while spring Chinook salmon historically were only found in the upper portions of basins with snowmelt driven flow regimes (western Cascade Crest and Columbia Gorge tributaries) (Myers et al 2006). Run timing was the predominant life history criteria used in identifying populations within the ESU (reviewed by Myers et al. 1998). The LCR ESU is divided into 32 populations (23 fall and late fall runs and 9 spring runs), some of which existed historically but are now extinct (Myers et al. 2006). For fall Chinook salmon, there are 13 Washington populations, 8 Oregon populations, and 2 populations (Lower and Upper Gorge) that are split between the states (Figure 1).

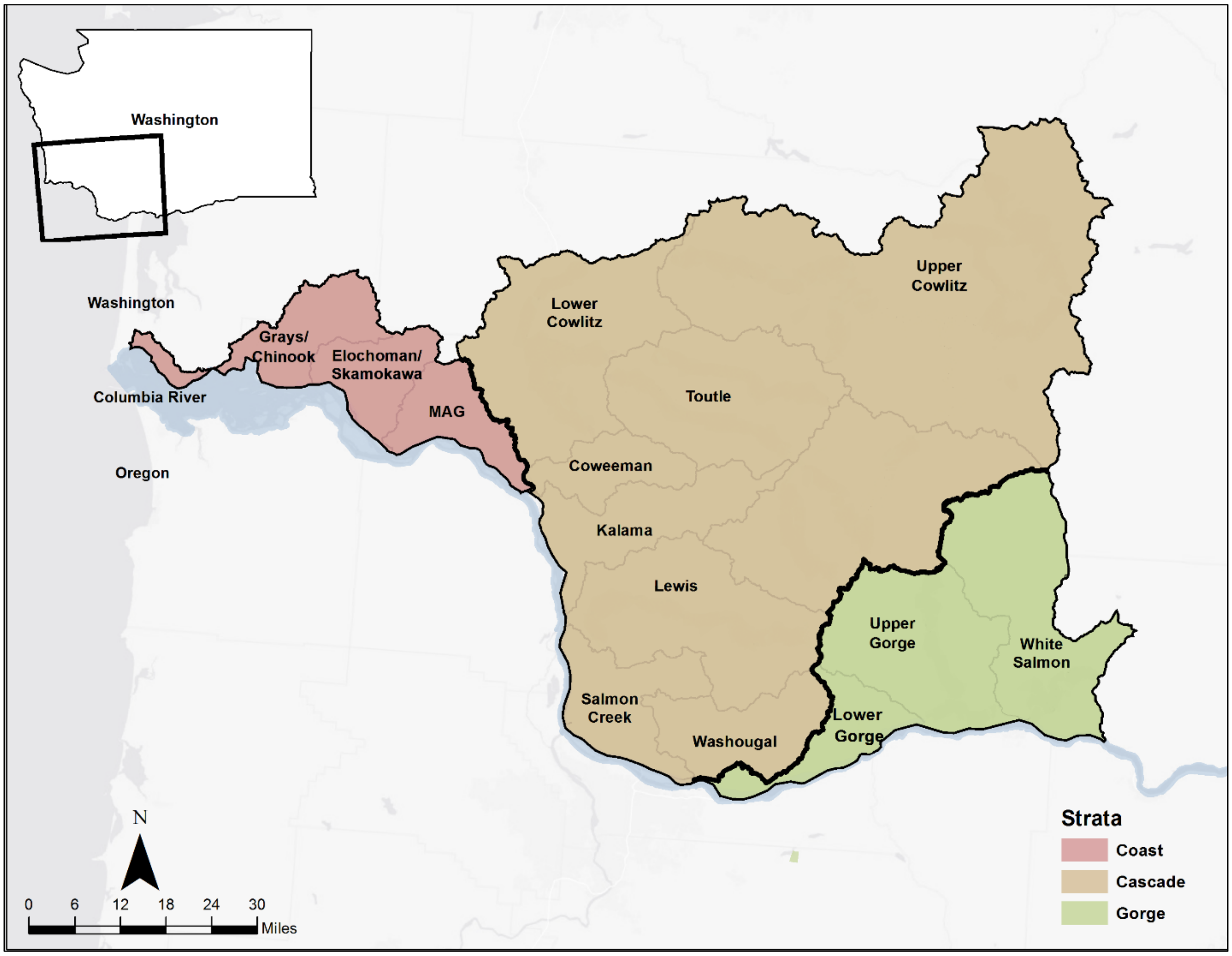

Figure 1. The Washington portion of the LCR Chinook salmon ESU including populations and strata (or Major Population Groups).

Sampling Frame

The sampling frame, or survey area, for fall Chinook salmon spawning ground surveys was developed using a logistic regression model to predict uppermost extent of Chinook salmon spawning habitat (Fransen et al. 2006; Rawding et al. 2010). We truncated this model at known barriers for better representation of the true distribution. This was used as a starting point to setup our annual sampling frame, which was adjusted based on a year-specific environmental conditions to ensure complete spatial coverage of Chinook salmon spawning activity. This was accomplished through either weekly, or standard, surveys or a combination of standard and supplemental surveys which are conducted one to three times annually around historical peak spawning activity. Detailed descriptions of the survey areas for each population are shown in Appendix A.

Study Design

We used a variety of methods to estimate adult fall Chinook salmon abundance (Table 2). We only reported on adults, defined as fish 60 cm and larger for this report, due to possible bias related to estimates of small fall Chinook salmon. The majority of small fall Chinook salmon are age-2 males and commonly referred to as jacks. We did not estimate abundance in Salmon

Creek as this population is believed to be extirpated and the upper NF Lewis as no adult fall Chinook salmon are currently present. We do not report the NF Lewis Bright fall Chinook population estimates as they are available in Bentley et al. (2018). However, we included NF Lewis Tule fall Chinook estimates from Bentley et al. (2018) with the idea of having a single report that contains all of the Tule fall Chinook salmon estimates for the Washington portion of the ESU. For the remaining populations, we used census counts when possible to estimate escapement because they are considered the gold standard for abundance estimates (Parsons and Skalski 2010). Sport harvest was subtracted if the population was subject to a fishery after the census. This approach was utilized for the Upper Cowlitz and Tilton populations. If a census was not possible at the weir (e.g., some fish pass the weir that are not counted), we implemented mark-recapture methods that included tagging adults that were passed above the weir and recovering tagged and untagged carcasses. This two-sample design is commonly called the Lincoln-Petersen (LP) model. When the closed population assumptions are met this is considered a robust monitoring design (Schwarz and Taylor 1998). This study design was implemented in the Elochoman, Green, Coweeman, Kalama, and Washougal rivers. In these watersheds, other study designs were implemented to estimate the population of fish that spawn below the weir. In other locations, we marked and recaptured carcass and estimated abundance based on the Jolly-Seber (JS) model (Jolly 1965; Seber 1965; Sykes and Botsford 1986). This mark-recapture study design provides biased and imprecise estimates if recoveries are too sparse or if flooding displaces carcasses so that recaptures are not available for a period. Although this design was implemented in most watersheds without a weir, it was only reliable in some place in certain years. If a census or mark-recapture estimate was not available, we used redd counts to estimate the number of females and expanded the number of females to total adults based on the sex ratio (Gallagher and Gallagher 2005). Redd counts were used when we assessed that that we met the assumptions for this method (e.g., negligible super imposition, etc.). For the remaining populations, we either used an area-under-the-curve (AUC) estimate based on the apparent residence time of fish classified as spawners (Parken et al. 2003) or peak count expansion (PCE).

Table 1. Methods used to estimate fall Chinook salmon spawner abundance, 2010-2017. AUC is area-under-the curve based on live counts, Redds is redd-based estimate based on census redd surveys and expanded to adults based on females per redd and the sex ratio, LP is the Lincoln-Petersen mark-recapture estimate from tagging of live fish at the weir and carcass recoveries, JS is the Jolly-Seber mark-recapture estimate from carcass tagging, PCE is a peak count expansion estimate based on the ratio of the peak count to the population estimate, tGMR is transgenerational mark-recapture, and BEM is bright eye method (Bentley et al. 2018).

Subpopulation	Spawn Year							
	2010	2011	2012	2013	2014	2015	2016	2017
Grays (abv weir)	Redds	JS	Redds	AUC	AUC	AUC	AUC	Redds
Grays (blw weir)	Redds	Redds	Redds	AUC	AUC	AUC	AUC	Redds
Skamokawa	AUC	AUC	AUC	AUC	AUC	AUC	AUC	AUC
Elochoman (abv weir)	LP	LP	LP	Redds	LP	LP	LP	LP
Elochoman (blw weir)	Redds	Redds	Redds	Redds	Redds	Redds	Redds	Redds
Mill (Tule)	JS	JS	AUC	AUC	JS	JS	AUC	AUC
Abernathy (Tule)	AUC	JS	AUC	AUC	JS	JS	AUC	AUC
Germany (Tule)	JS	JS	AUC	JS	JS	JS	AUC	AUC
Lower Cowlitz (Tule)	PCE	PCE	PCE	PCE	PCE	PCE	PCE	PCE
Tilton (Tule)	Census	Census	Census	Census	Census	Census	Census	Census
Upper Cowlitz/Cispus (Tule)	Census	Census	Census	Census	Census	Census	Census	Census
Green (Tule) (abv weir)	LP	LP	LP	LP	LP	Census	LP	LP
Green (Tule) (blw weir)	Redds	Redds	Redds	Redds	Redds	Redds	Redds	Redds
SF Toutle (Tule)	AUC	AUC	AUC	Redds	Redds	Ratio	Ratio	Redds
Coweeman (Tule) (abv weir)	tGMR	LP	LP	Redds	LP	LP	Redds	LP
Coweeman (Tule) (blw weir)	tGMR	Redds	Redds	Redds	Redds	Redds	Redds	Redds
Kalama (Tule) (abv weir)	AUC	AUC	AUC	AUC	AUC	LP	LP	LP
Kalama (Tule) (blw weir)	AUC	AUC	AUC	AUC	AUC	AUC	AUC	AUC
NF Lewis (Tule)	BEM	BEM	BEM	JS	JS	JS	JS	JS
NF Lewis (Bright)	BEM	BEM	BEM	JS	JS	JS	JS	JS
Cedar (Tule) (abv ladder)	Census	Census	Census	Census	Census	Census	Census	Census
Cedar (Tule) (blw ladder)	JS	JS	AUC	AUC	AUC	AUC	AUC	AUC
EF Lewis (Tule)	AUC	AUC	AUC	JS	JS	JS	AUC	JS
Washougal (Tule) (abv weir)	JS	JS	JS	JS	LP	LP	JS	LP
Washougal (Tule) (blw weir)	JS	JS	JS	JS	JS	JS	JS	JS
Hamilton (Tule)	PCE	PCE	PCE	PCE	PCE	PCE	PCE	PCE
Hamilton (Bright)	PCE	AUC	AUC	AUC	AUC	AUC	AUC	AUC
Ives/Pierce (Tule)	PCE	PCE	PCE	PCE	PCE	PCE	PCE	PCE
Ives/Pierce (Bright)	AUC	AUC	AUC	AUC	AUC	AUC	AUC	AUC
Wind (Tule)	PCE	PCE	PCE	AUC	AUC	AUC	AUC	AUC
Wind (Bright)	PCE	PCE	PCE	AUC	AUC	AUC	AUC	AUC
Little White Salmon (Tule)	PCE	PCE	PCE	PCE	PCE	PCE	PCE	JS
Little White Salmon (Bright)	PCE	PCE	PCE	PCE	PCE	PCE	PCE	JS
White Salmon (Tule)	PCE	PCE	PCE	AUC	AUC	AUC	AUC	AUC
White Salmon (Bright)	PCE	NA	PCE	AUC	AUC	AUC	AUC	AUC

Data Collection

Regardless of the study design, it was our intent to collect biological information on all sampled live fish and carcasses. Biological data from individual fish included fork length, sex, location of any fin clips, scale samples, and tissue samples. Sex was determined based on morphometric differences in secondary sexual characteristics between males and females (Groot and Margolis 1991; Wydoski and Whitney 2003). Clip status was determined by examining for the presence or absence of fin clips. The vast majority (97-100%) of salmon released from hatchery programs in the LCR are fin clipped. This allows hatchery-origin (HOR) and natural-origin (NOR) salmon to be distinguished from one another based on a visual assessment of fin clips. The mass mark that is typically applied is an adipose fin clip, but ventral and pectoral fin clips are sometimes used as well. Scales were collected scales were taken from the preferred area, as described in Crawford et al. (2007b). In addition, tissue samples were collected from adipose intact Chinook salmon at each of many sites. These tissue samples were placed in numbered vials with 100% nondenatured ethanol (Crawford et al. 2007b) and archived in the WDFW genetics lab for future analysis. In addition, salmon trapped at weirs were double Floy® tagged with unique numbers. Tag were placed on both sides of the posterior edge of the dorsal fin. An operculum punch was used as a secondary mark to assess and account for tag loss.

Spawning ground surveys were scheduled weekly over the presumed fall Chinook salmon spawning distribution and timing (Rawding et al. 2014, Rawding et al. 2019, and Buehrens et al. 2019). Due to limited resources, some sampling frames were surveyed once, termed supplemental survey, near the peak of spawning (Appendix A). These surveys collected multiple data types by reach including: 1) identification and enumeration of live fish associated spawn sites and associated with non-spawning sites by reach, 2) identification and enumeration of redds, 3) identification and enumeration of carcasses including the collection of biological data described above, 4) double tagging of carcasses in good condition with plastic tags on the inside of the operculum, 5) inspection of carcasses for Floy® and opercle tags, and 6) recording of environmental conditions that may influence observer efficiency. In addition, the locations of all observed redds were collected using handheld GPS units. Further detail of data collection protocols can be found in Rawding et al. (2014).

Data Management

On spawning ground surveys, field data were recorded using a combination of scale cards, datasheets (2013-2016), and iPads (2017). At weirs, field data were recorded using a combination of scale cards and Panasonic Toughpads using forms developed in Microsoft Access. Scale cards served as the field data storage tool for sampled fish. Lives, redds, and unsampled and previously sampled carcasses were stored on datasheets or iPads. All data were either uploaded or entered manually into WDFW's corporate database, Traps, Weirs, and Surveys (TWS). Scale cards and CWTs were processed following the procedure outlined in Rawding et al. (2014). After scale samples were aged in the WDFW ageing lab, scale cards were returned for entry into the TWS. CWTs were sent to the WDFW CWT lab in Olympia following the procedure outlined in Rawding et al. (2014). After CWTs were decoded, tag codes were uploaded to the WDFW CWT Access database, which was then uploaded to Regional Mark Information System (RMIS) and TWS. At the end of the field season, all data were QA/QC at a 1 in 1 rate for transcription errors and a series of standardized queries were used to find data outliers. Any errors or missing information found was corrected.

Statistical Analysis

Modeling Approach

Estimates of ART and AFpR were developed using a Bayesian framework using JAGS (Plummer 2003) from R studio using the *R2jags* package (Su and Yajima 2015). The outputs of these models were fed into independent data and model files for each fall Chinook salmon population where all estimates abundance, pHOS, sex, and age structure estimates were parameterized using a Bayesian framework using WinBUGS (Spiegelhalter et al. 2003) from R Studio using the *R2WinBUGS* package (Sturtz et al. 2005). All parameters were estimated from the posterior distribution. Since the formula of the posterior distribution is complex and difficult to directly calculate, samples from the posterior distribution were obtained using Markov chain Monte Carlo (MCMC) simulations (Gilks et al. 1995). WinBUGS is software package that implements MCMC simulations using a Metropolis within Gibbs sampling algorithm (Spiegelhalter et al. 2003) and has been used to estimate fish abundance (Rivot and Prevost 2002; Su et al. 2001; Link and Barker 2010). When possible, we used vague or uninformative priors so that the data had more influence on the posterior distribution than the priors did.

The goal was to have an effective sample size of 4,000 for each parameter of interest as this provides a 95% credible interval (CI) that has posterior probabilities between 0.94 and 0.96 (Lunn et al. 2012). To achieve this, we ran two chains with 100,000 iterations for a burn-in, followed by 400,000 iterations, in which every 100th iteration was saved using the Gibbs sampler in WinBUGS. Chains were thinned to reduce autocorrelation and save space given the large number of parameters that were monitored. We saved a total of 8,000 iterations for the posterior distribution of each of the parameters monitored. After running an individual file, we used the visible inspection of the two chains and the Brooks-Gelman-Rubin diagnostic test to examine convergence. All of the key parameters yielded values of less than 1.1. While it is impossible to conclude a simulation has converged, the above diagnostic tests did not detect that simulations did not converge. Therefore, for each of our reported estimates, we assume that our reported posterior distributions are accurate and represent the underlying stationary distributions of the estimated parameters.

Apparent Residence Time and Apparent Females per Redd Estimates

We used two separate but similar hierarchical mixed effect models using a Bayesian framework to derive estimates of ART and AFpR for use with AUC and redd expansion methods, respectively.

To develop estimates of ART, we used 50 mark-recapture estimates which spanned from 2002-2017 across nine LCR basins which were all adjusted to exclude prespawn mortalities, $N_{MR_{i,j}}$, paired with the estimate of fish days using counts of live Chinook salmon identified as spawners, $AUC_{i,j}$, to estimate apparent residence time, $ART_{i,j}$, with the subscript i and j denoting year- and basin-specific parameters, respectively (Parken et al. 2003) (eq.1):

$$ART_{i,j} = \frac{AUC_{i,j}}{N_{MR_{i,j}}} \quad (1)$$

The mean and variance of each of those 50 independent *ART* estimates (Appendix B; Table B1) were used as inputs to the *ART* hierarchical mixed effects model. Similar to the approach used to derive inputs to the ART model, we used 15 mark-recapture estimates from 2003-2006, 2009-2015, and 2017 across three LCR basins all of which were adjusted to exclude prespawn mortalities, $N_{MR_{i,j}}$, paired with census counts of new, unique redds, $New\ Redds_{i,j}$, and the proportion of females, $pF_{i,j}$, with the subscript i and j denoting year- and basin-specific parameters, respectively (eq. 2):

$$AFpR_{i,j} = \frac{(N_{MR_{i,j}} * pF_{i,j})}{New\ Redds_{i,j}} \quad (2)$$

The mean and variance of each of those 15 independent *AFpR* estimates (Appendix B; Table B2) were used as inputs to the AFpR hierarchical mixed effects model. The models used for *ART* and *AFpR* were identical to one another other than the nomenclature. To show the math used, we will use generic nomenclature to cover both models at one time where *A* represents both *ART* and *AFpR*. The observation model is defined by the following equation (eq. 3):

$$\mu_{logA_{i,j}} \sim Normal\ (\log(A_{i,j}), \sigma_{logA_{i,j}}) \quad (3)$$

where $\mu_{logA_{i,j}}$, $\sigma_{logA_{i,j}}$, and the log of $A_{i,j}$ are the log mean, standard deviation of the independent population- and year-specific estimate, and *A* is the population- and year-specific estimate after shrinkage via the hierarchical model, with the subscript i and j denoting year- and basin-specific parameters, respectively. This shrunk year-and population-specific estimate A was a log-linear function of a global mean μ, random basin- bas_j and year- yr_i effects, and a residual ε:

$$A_{i,j} \sim exp(logA_i, j) \quad (4)$$

$$log(A_{i,j}) = \mu + bas_j + yr_i + \varepsilon \quad (5)$$

Basin and year effects, and the residual each were normally distributed with means of $-\frac{\sigma^2}{2}$ in order to center the global mean μ on the mean of A after exponentiation.

$$\varepsilon \sim Normal\,(-\frac{\sigma^2}{2}, \sigma_{i,j}) \tag{6}$$
$$bas_j \sim Normal\,(-\frac{{\sigma_{bas}}^2}{2}, \sigma_{bas}) \tag{7}$$
$$yr_i \sim Normal\,(-\frac{{\sigma_{yr}}^2}{2}, \sigma_{yr}) \tag{8}$$

The global mean (μ) was given a vague normal prior with mean zero and precision of 0.01:

$$\mu \sim Normal(0,0.01) \tag{9}$$

The random effect and residual standard deviations were given half-normal hyperpriors (eqs. 10-12):

$$\sigma_{i,j} \sim HalfNormal\,(0,1) \tag{10}$$
$$\sigma_{bas} \sim HalfNormal\,(0,1) \tag{11}$$
$$\sigma_{yr} \sim HalfNormal\,(0,1) \tag{12}$$

This model, while fit to year- and population-specific independent estimates of ART and FpR, was used to generate random-effects shrinkage estimates of year-and population-specific FpR and ART (denoted A above in equations 4 and 5) which were then used in final year-and population-specific abundance models. To facilitate this, gamma shape and rate parameters were estimated from the posterior draws of ART and FpR, which were then used to generated gamma priors in final population specific models. Additionally, predictive distributions of FpR and ART were generated, for basins, years, or basin and year combinations that lacked FPR and ART estimates, and these predictive distributions could then be used in population and year-specific estimates in these cases.

Spawner Abundance Estimates

Census

Temporary weirs were operated to estimate abundance, control the number of HOR spawners, collect broodstock, and obtain biological data at several locations in LCR tributaries. Temporary weirs were installed and operated in the Grays River (river mile (RM) 8.5), Elochoman River (RM 2.7), Green River (RM 0.4), Coweeman River (RM 6.8 in 2013-2015, 2017 and RM 5.0 in 2016), Kalama River (RM 2.7), and the Washougal River (RM 11.9). Permanent fish collection facilities were also operated at the Barrier Dam on the Cowlitz River (RM 51.0) and at the Toutle Fish Collection Facility (TFCF) on the North Fork Toutle River (RM 12.0). No Chinook salmon were transported into the North Fork Toutle River because there are no main-stem release sites above the Sediment Retention Structure (SRS) for Chinook salmon trapped at the TFCF. In Cedar Creek, a tributary to the North Fork Lewis River, a ladder trap was operated in the fishway (RM 2.0). Since the recapture events above the trap were not successful, we assumed the ladder count was a census. There are five assumptions that we made for our weir count estimates: (1) counts were without error, (2) there was no fallback, (3) fisheries regulations were followed, (4) sport catch record card estimates are correct, and (5) survival of unclipped Chinook salmon caught and released in sport fisheries was 100%.

We queried the TWS Access database to summarize counts of fall Chinook salmon passed upstream by origin and sex at each of the weir sites. These counts were compared with alternative methods (in most cases LP estimates) to determine if counts of fall Chinook salmon passed upstream were significantly different than the alternative methods. If it was not, we assumed a census at the weir site and reported it as such.

Census counts were adjusted for prespawn mortality (except the Upper Cowlitz and Tilton) and any sport harvest to develop an estimate of spawners, $N_{c_{i,j}}$, using the following series of equations (eqs. 13-15) with the subscript i and j denoting year- and basin-specific parameters, respectively:

$$N_{c_{i,j}} = (W_{i,j} - C_{i,j}) * (1 - pPSM_{i,j}) \quad (13)$$

$$C_{i,j} \sim Normal(\mu_{C_{i,j}}, \sigma_{C_{i,j}}) \quad (14)$$

$$PSM\ Carc_{i,j}, \sim Binomial(pPSM_{i,j}, Carc_{i,j}) \quad (15)$$

where $W_{i,j}$ is the number of fall Chinook salmon put upstream, $C_{i,j}$ is the estimate of sport harvest based on catch record card data (Kraig 2015; Kraig and Scalici 2016; Kraig and Scalici 2017; Kraig and Scalici 2018; Kraig and Scalici 2019), $pPSM_{i,j}$ is the proportion of carcasses that were prespawn mortalities, , $\mu_{C_{i,j}}$and $\sigma_{C_{i,j}}$ are the sport harvest estimate mean and standard deviation from catch record cards, $PSM\ Carc_{i,j}$ is the number of female carcasses that were pre-spawn mortalities, and $Carc_{i,j}$ is the number of female carcasses that examined for spawn success.

Lincoln-Petersen

At each of the temporary weir sites (Grays, Elochoman, Green, Coweeman, Kalama, and Washougal), we implemented mark-recapture studies. All fall Chinook salmon released upstream were marked and tagged and subsequently recaptured at upstream traps, as carcasses during spawning ground surveys, or re-sighted as live fish on spawning ground surveys (see Methods: Data Collection).

The study design was developed based on stratified LP or Darroch closed population mark-recapture models because they are relatively robust to heterogeneity in capture and movement probabilities (Darroch 1961, Seber 1982). Using this study design, we recorded the number of fish marked and released above the trap, and the number of captured and recaptured fish (carcasses only for hypergeometric models and carcasses plus live spawners for binomial models) per week during spawning ground surveys. There are five assumptions of the LP estimator that must be met to provide an unbiased estimate of abundance (Seber 1982, Schwarz and Taylor 1998): (1) no tag loss, (2) no handling mortality, (3) all tagged and untagged fish are correctly reported, (4) the population is closed, and (5) equal capture probability during the tagging or recapture events, or marked fish mix uniformly with unmarked fish.

Before running our LP model, we tested for homogenous recovery probabilities. Biological data from carcasses were queried from the TWS Access database, ran through a set of standardized rulesets, and summarized in the program R (R Development Core Team 2017). First, biological data from carcass recoveries were filtered to exclude any fish without a fork length, clip status, or sex. Then, we assigned a categorical size ($\geq$ 80 cm or < 80 cm) to each fish. Next, we used a generalized linear model assuming a binomial distribution and using a logit link function to estimate the probability of recovery for Floy® tagged fall Chinook salmon during spawning ground surveys to determine whether LP abundance estimates could be pooled. Covariates included sex, origin, and categorical size, and all subsets of main effects models were compared and ranked using AICc (Burnham and Anderson 2002). When the null model, indicating homogenous recovery probabilities, was supported (ΔAIC value of <2), we pooled all fish. When the null model, indicating homogenous recovery probabilities, was not supported, we stratified by either sex, origin, or size, depending which was the best model based on the AICc ranking for a particular dataset.

Second, we tested for equal mixing of tagged and untagged carcasses spatially above each of the weir sites. Again, we queried the TWS Access database creating a matrix of tagged and untagged carcass recoveries from spawning ground surveys by pre-established reach as well as weir wash-ups (carcasses that wash up onto the weir structure and are sampled daily rather than on weekly spawning ground surveys). We logically grouped reaches together to ensure we had a minimum of three tagged and untagged per spatial location (reach) then conducted a series of chi-square tests to ensure there was equal mixing spatially.

Third, we queried the TWS Access database to create an extensive matrix of the number of fish tagged, the number of carcasses recoveries that were tagged from spawning ground surveys and weir wash-ups, and the total number of carcasses examined from spawning ground surveys and weir wash-ups by statistical week. This is what is typically known as a "DARR" table, or temporally stratified mark-recapture summary. Then, we used the package *DARR for R* (Bjorkstedt 2010) to take advantage of its built-in algorithms for initial pooling of periods. We then conducted two separate chi-square tests: (1) to determine whether the marked proportion is constant by recovery period and (2) to determine whether the recapture rate is constant by period.

Based on the results of these tests, we ran the DARR program to generate summary statistics for our pooled LP estimates including the number of marks (M), recaptures (R), and captures (C) which were the inputs into each individual population-level R file.

If estimates for a particular year and subpopulation were stratified by sex, origin, or categorical size, as described above, we summed the stratified estimates to develop an overall estimate. Next, estimated abundance via a “null model” where we did not stratify by sex, origin, or categorical size. We ran through the same steps listed above to ensure all of the pooling assumptions were met, and then compared with the null model estimate with the overall stratified estimate, by determining if 95% CI of the estimates overlapped. In all of the datasets we looked at from 2013-2017, the stratified estimates that were summed together were not significantly different than if we had not stratified estimates to begin with. As a result, we choose to report estimates that were not stratified by sex, origin, categorical size, or temporal stratum within the run.

After generating pooled mark-recapture summary statistics (marks, captures, recaptures) for a two-event closed population model, we needed to select a final mark-recapture model that would be appropriate for the data; specifically, whether or not sampling in the second event for recaptures had occurred with replacement or not. The hypergeometric distribution is appropriate to use when there is sampling without replacement such as salmon carcasses captured in the second event where they are mutilated and not available for recapture in future sampling events. The binomial distribution is appropriate to use when there is sampling with replacement such as live re-sights in the second event where the same fish is available for recapture in future sampling events. We most often used hypergeometric models based only on carcass recoveries as the second event, however, there were a handful of cases we used the binomial model due to small sample sizes when using carcass recoveries only.

LP estimates of the run size passing the weir, $N_{LP_{i,j}}$, were developed using either Binomial likelihoods (eqs. 16 and 17), when sampling of marked and unmarked fish above the weir occurred with replacement, or a Hypergeometric likelihood (eq.18) when sampling occurred without replacement. We used uninformative priors (eqs. 19 and 20):

$$R_{i,j} \sim \text{Binomial}(p_{i,j}, C_{i,j}) \quad (16)$$
$$M_{i,j} \sim \text{Binomial}(p_{i,j}, N_{LP_{i,j}}) \quad (17)$$
$$R_{i,j} \sim \text{Hypergeometric}(C_{i,j}, M_{i,j}, N_{LP_{i,j}}) \quad (18)$$
$$p_{i,j} \sim \text{Beta}(1,1) \quad (19)$$
$$N_{LP_{i,j}} \sim \text{Categorical}(\boldsymbol{\alpha}) \quad (20)$$

where $R_{i,j}$ is the number of recaptures, $C_{i,j}$ is the number of captures, $M_{i,j}$ is the number of fish marked or tagged at the weir site, $p_{i,j}$ is the probability of capture (Binomial likelihood only), and $N_{LP_{i,j}}$ is the runsize estimate with the subscript i and j denoting year- and basin-specific parameters, respectively.

where $\boldsymbol{\alpha}$ was a vector of consecutive integers ranging from the minimum possible run size to an assumed maximum plausible run size. The minimum possible run size was calculated by summing the number of unique animals encountered in event one $M_{i,j}$ and event two $C_{i,j}$ and subtracting the number of unique animals seen in both events $R_{i,j}$.

To estimate the number of spawners upstream of the weir, we used the same series of equations described in equations 13 through 15 in the census section of abundance estimates substituting the LP estimate, $N_{LP_{i,j}}$, for the number of fall Chinook salmon put upstream, $N_{c_{i,j}}$.

Jolly-Seber

The Jolly-Seber (JS) model estimates population abundance in mark-recapture studies where the population is open (Jolly 1965; Seber 1965) and has been widely used in estimating Pacific salmon spawning abundance from live fish (Schwarz et al. 1993; Jones and McPherson 1997; Rawding and Hillson 2003) but also using salmon carcasses (Parker 1968; Stauffer 1970; Sykes and Botsford 1986). The carcass tagging model has been used extensively in lower Columbia tributaries to estimate Chinook salmon abundance (McIssac 1977; Rawding et al. 2006, Rawding et al. 2014). Seber (1982) and Pollock et al. (1990) provide details of study design, assumptions, and analysis of mark-recapture experiments using the JS model. Five assumptions of the JS model that must be met in order to obtain unbiased population estimates from the model (Seber 1982) are: (1) equal catchability, (2) equal survival between periods, (3) no handling mortality, (4) no tag loss, and (5) instantaneous sampling.

We queried the TWS Access database for adult fall Chinook salmon carcasses that were tagged or carcasses with a Carcass Category 3 or 4 (denoted as loss on captures in the JS model) from for each individual survey year and subpopulation where carcass tagging studies were implemented. Biodata were then subset in the program R (R Development Core Team 2017) to include only carcasses that were tagged. Second, we conducted size and sex selectivity tests using a generalized linear model assuming a binomial distribution and using a logit link function to estimate the probability of recovery for carcass tagged fall Chinook salmon to determine whether abundance estimates could be pooled or needed to be stratified. Covariates included sex and fork length, and all subsets of main effects models. Results of the GLM tests were compared and ranked using AICc (Burnham and Anderson 2002). When the null model, indicating homogenous recovery probabilities, was supported (ΔAIC value of <2), we pooled all fish. When the null model, indicating homogenous recovery probabilities, was not supported, we stratified by either sex or size, depending which was the best model based on the AICc ranking for a particular dataset. When stratifying by size, we used an 80cm cutoff as described in Rawding et al. (2014) to classify fish into two groups, large and small. If stratifying was needed, we conducted the same series of tests described above with two independent datasets to ensure that the null model was the best model for each of the groups. Third, we re-summarized our data to include both tagged carcasses and loss on captures carcasses (Carcass Categories 3 and 4) and developed capture histories for individual carcasses. Fourth, we used the *RMark* package (Laake 2013) to generate JS summary statistics (e.g., *ni*, *mi*, *ui*, *Ri*, etc.) for each period (e.g. survey day). When needed, we pooled weekly summary statistics to ensure we met the JS modeling requirements for the number of marks and recaptures in individual periods. Finally, we evaluated the fit of four potential abundance models using a Bayesian Goodness of Fit (GOF) test using posterior predictive checks (Table 2) (Gelman et al. 2013, Rawding et al. 2014, Bentley et al. 2018).

Table 2. Model notation used for JS carcass tagging (from Lebreton et al. 1992). Model names indicate whether capture, survival, or entrance probabilities were allowed to vary over time ("T") or were held constant ("S = same").

Model	Probability of capture (p)	Probability of survival (φ)	Probability of entry (b^*)
TTT	varies over periods	varies over periods	varies over periods
STT	equal over periods	varies over periods	varies over periods
TST	varies over periods	equal over periods	varies over periods
SST	equal over periods	equal over periods	varies over periods

The Schwarz et al. (1993) "super population" JS model was parameterized using a Bayesian framework. A more detailed description of the model and its parameters can be found can be found in Appendix C, Rawding et al. (2014), and Bentley et al. (2018).

If abundance estimates generated out of the model for a particular year and subpopulation were stratified by sex or size, as described above, we summed the stratified estimates to develop an overall estimate. Next, we ran through the same series of steps listed above for the null model. In all of the datasets, the stratified estimates that were summed together were not significantly different from if we had not stratified estimates to begin with. As a result, we choose to report estimates that were not stratified by sex or size.

To estimate the number of spawners, we used the same series of equations as in the census section (eqs. 13-15) substituting the JS estimate, $N_{JS_{i,j}}$, for the number of fall Chinook salmon put upstream, $N_{c_{i,j}}$.

For the 2017 Little White Salmon fall Chinook subpopulation, we used the nadir in our weekly estimates of abundance, B^*_i, to determine a cutoff between Tule and Bright stocks. Then, pooled the periods prior to the nadir to generate a Tule fall Chinook salmon estimate of abundance and the periods after the nadir to generate a Bright fall Chinook salmon estimate of abundance.

Area-Under-the-Curve

In basins where we did not have a successful weir census or mark-recapture estimate, we used either area-under-the-curve (AUC) or redd expansion to estimate spawner abundance.

We used the approach described in Parken et al. (2003) where we classified live Chinook salmon into two categories: spawners and holders (see Methods: Data Collection). Only counts of spawners were used to develop the "curve". This helped ensure the accuracy of counts as fish identified as spawners tend to be more dispersed and in shallower water. There are several methods to develop the "curve", or estimate of fish days, including the Ames method, likelihood method, average spawner method, and trapezoidal method (Parsons and Skalski 2010). We choose to use the trapezoidal method. This method required a count of zero on the first and last survey of the spawning season with counts conducted at seven to ten day intervals throughout the spawning period (Figure 2).

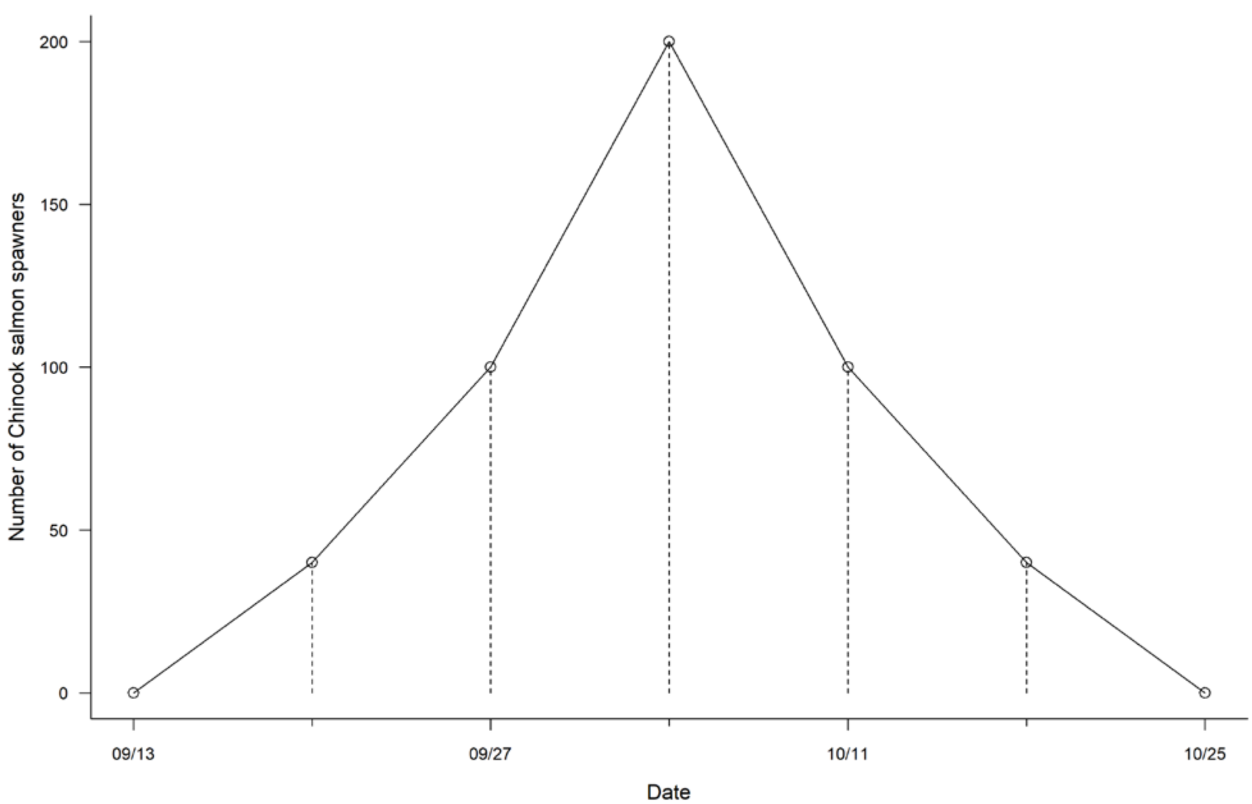

Figure 2. Example of a typical trapezoidal area-under-the-curve based on live counts of Tule fall Chinook salmon in the LCR.

Rawding and Rodgers (2013) identified the following assumptions that must be met for an unbiased AUC estimate: (1) complete spatial and temporal coverage throughout the spawning period, (2) counts of live fish are accurate, (3) ART is accurate for the specific basin and year, and (4) surveys occur every 7 to 10 days and surveys are not missed during peak spawning time (Hill 1997).

We queried counts of live Chinook salmon spawners from the TWS Access database by survey date and reach for each subpopulation. We excluded any supplemental survey reaches that were surveyed once near peak. Then, we summed counts across all weekly survey reaches for each survey date. Next, we used the following equation (eq. 21) to develop an estimate of fish days within the weekly survey area, $AUC_{index_{i,j}}$, with the subscript i and j denoting year- and basin-specific parameters, respectively (Parken et al. 2003; English et al. 1992):

$$AUC_{index_{i,j}} = \Sigma\,(0.5 * (x_{i,j} + x_{i,j-1}) * (t_{i,j} - t_{i,j} + 1)) \tag{21}$$

where x represents counts of live Chinook salmon at each interval, t represents the time or date of each survey when counts were conducted, with the subscript i denoting year-specific and j denoting basin-specific parameters.

If we had complete spatial coverage on weekly spawning ground surveys, confirmed by conducting supplemental surveys on peak spawning week (see Appendix A), the fish days, $AUC\ Index_{\,i,j}$, calculation was not adjusted. However, if fish were seen in the supplemental survey areas, we calculated the proportion of spawners within the weekly index area, $Sp\ Index_{i,j}$, based on the single peak week where supplemental and index were both surveyed using the following equation (eq. 22):

$$Sp_{index_{i,j}} \sim Binomial(pSp_{index_{i,j}}, Sp_{total_{i,j}}) \tag{22}$$

where $Sp_{index_{i,j}}$ is the number of spawners counted within the index, or weekly, survey reaches on the week supplemental surveys were conducted, $Sp_{total_{i,j}}$ is the total number of spawners counted with the index and supplemental reaches for that single week, and the derived parameter, $pSp_{index_{i,j}}$, is the proportion of spawners seen within the index area on peak with the subscript i and j denoting year- and basin-specific parameters, respectively.

Then, the estimate of fish days with in the index area, $AUC_{index_{i,j}}$, was expanded to the entire spatial distribution, $AUC_{i,j}$, by the proportion of spawners seen within the index areas, $pSp_{index_{i,j}}$, relative to the whole spatial distribution on peak using the following equation (eq. 23):

$$AUC_{i,j} = \frac{AUC_{index_{i,j}}}{pSp\ Index_{i,j}} \tag{23}$$

The two other key parameters that are typically needed to generate an unbiased AUC abundance estimate are observer efficiency and stream life. Independent estimates of each of these parameters are costly and often difficult to estimate independently (Rawding and Rodgers 2013). We instead used surrogate measure, apparent residence time (ART), which combines observer efficiency and stream life into a single parameter.

Using an estimate of ART (see Methods: Apparent Residence Time and Apparent Females per Redd Estimates), we used the following equation to develop an estimate of spawners, $N_{AUC_{i,j}}$(eq. 24):

$$N_{AUC_{i,j}} = \frac{AUC_{i,j}}{ART_{i,j}} \tag{24}$$

where the estimate of fish days, $AUC_{i,j}$, was divided by the apparent residence time, $ART_{i,j}$.

We did not make any adjustment to our estimate of spawners as we assumed any sport harvest and prespawn mortality would happen before fish were classified as spawners.

There are a few basins where we used AUC to estimate abundance that have both Tule and Bright stocks of fall Chinook salmon and have temporal separation between the two stocks (White Salmon River and Wind River). In these cases, we used the nadir in live spawner counts to dictate the break between Tule and Bright stocks. However, we still needed to end our Tule stock live count with a zero and start our Bright stock live with a zero. As a result, we assumed on the next survey after the nadir all live counts were Bright stock and assumed a zero count of Tule stock. Similarly, we projected out a zero for Bright stock on the survey prior to the nadir and assumed all lives were Tule stock. For the actual live count on the nadir, we assumed it was half Tule stock and half Bright stock (Figure 3).

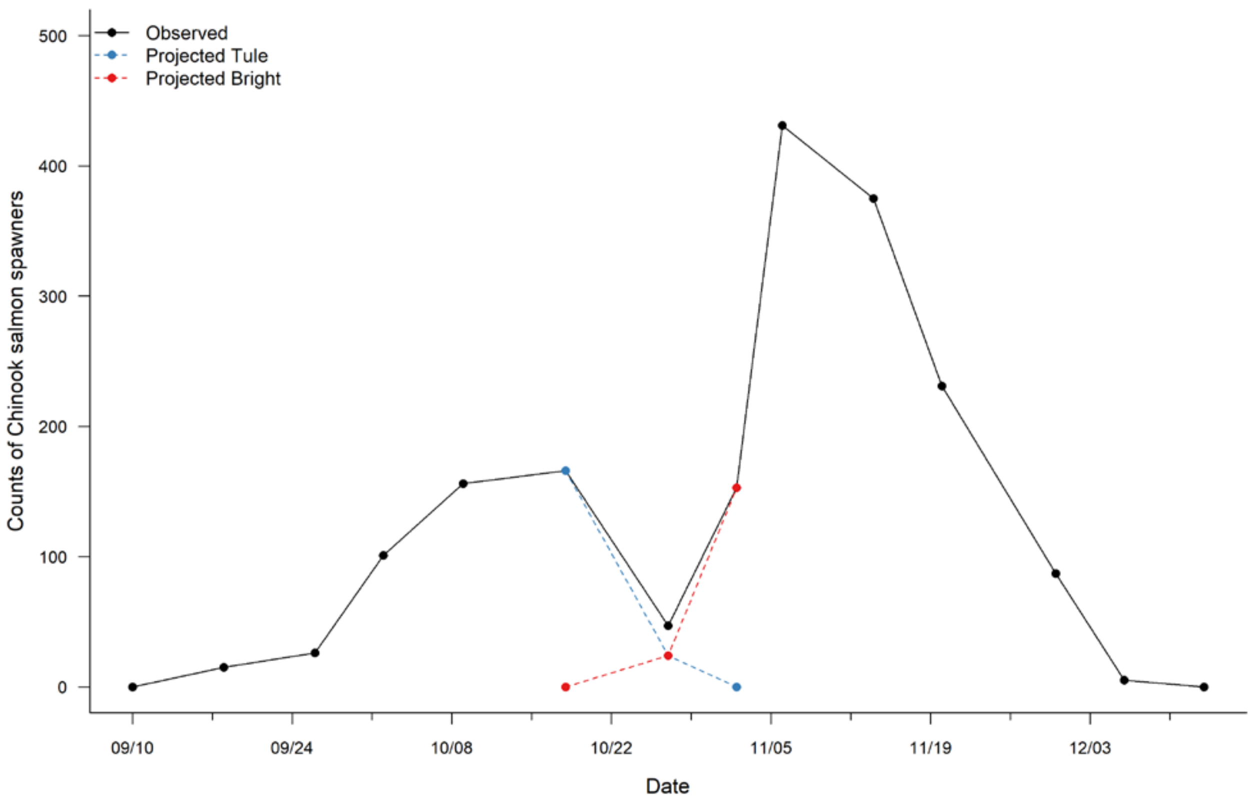

Figure 3. Example of partitioning observed live counts of fall Chinook salmon into observed and projected counts by stock.

Redd Expansion

Similar to AUC methods, redd expansion was used when census or mark-recapture estimates assumptions were not met. Redd expansion is based on census redd counts, which work when individual redds can be accurately identified. This often is populations with lower redd densities and in basins where water conditions are favorable. We attempted redd census methods on the Grays, Skamokawa, Elochoman, Coweeman, South Fork Toutle, Green below the weir site, and East Fork Lewis. The critical assumptions for using redd expansion to estimate spawner abundance are (Rawding and Rodgers 2013; Parsons and Skalski 2010): (1) complete spatial and temporal coverage throughout the spawning period, (2) all redds are accurately identified, (3) estimates of AFpR are consistent between the study population (one used to derive the females per redd estimate) and the treatment population. This assumes the methods used to identify and enumerate females per redd follow standard redd, and (4) AFpR and sex ratio from other streams or years accurately represent the females per redd and sex ratio for the population in the current year survey protocols.

Using a similar approach as we did with AUC methods, we queried counts of new, unique Chinook salmon redds from the TWS Access database by survey date and reach for each subpopulation. We excluded any supplemental survey reaches that were surveyed once near peak. Then, we summed redd totals across all weekly survey reaches for each survey date. If we had complete spatial coverage on weekly spawning ground surveys, confirmed by conducting supplemental surveys on peak spawning week (see Methods: Study Area and Sampling Frame), the census of new, unique redds, $Redds\ Index_{i,j}$,was not adjusted. However, if redds were seen in the supplemental survey areas, we adjusted the census of new redds within the index area to expand the number of new redds to the entire spatial distribution using the following equation (eq. 25) with the subscript i and j denoting year- and basin-specific parameters, respectively:

$$Redds_{index_{i,j}} \sim Binomial(pRedds_{index_{i,j}}, Redds_{total_{i,j}}) \quad (25)$$

where $Redds_{index_{i,j}}$ is the number of new, unique redds counted within the index, or weekly, survey area on the week supplemental surveys were conducted, $Redds_{total_{i,j}}$ is the total number of new redds counted with the index and supplemental areas for that single week, and the derived parameter, $pRedds_{index_{i,j}}$, is the proportion of redds seen within the index area on peak. To avoid potential bias, redds on supplemental surveys were classified using the same protocols as in the index area (as new, still visible, and not visible) based on color change and other redd characteristics (see Methods: Data Collection). This ensured that this expansion was accurate as only redds classified as new were used. This assumes that the proportion of redds observed outside of the index area on the single week when supplemental surveys were conducted are representative of what is outside of the index area the rest of the season. While this assumption may be not always be true, we believe this source of bias to be small as very little spawning typically occurs in supplemental areas.

Next, the original estimate of new, unique redds, $Redds_{index_{i,j}}$, which was only for the index area, was expanded to the entire spatial distribution by the proportion of redds seen within the index areas, $pRedds_{index_{i,j}}$, relative to complete spatial distribution on peak using the following equation (eq. 26):

$$Redds_{i,j} = \frac{Redds_{index_{i,j}}}{pRedds_{index_{i,j}}} \tag{26}$$

Redds are an indirect measure of the spawner abundance and rely on other parameters to yield an estimate of spawner abundance. These are typically females per redd, observer efficiency, and the sex ratio. Similar to AUC, we used an approach outlined in Rawding et. al. (2014) where we developed estimates of apparent female per redd, or AFpR, which combines observer efficiency and females per redd into a single parameter. Using an estimate of AFpR (see Methods: Apparent Residence Time and Apparent Females per Redd Estimates), we used following equation to develop an estimate of spawner abundance (eq. 27):

$$N_{Redds_{i,j}} = \frac{Redds_{i,j} * AFpR_{i,j}}{pF_{i,j}} \tag{27}$$

where, $Redds_{i,j}$, is the number of unique, new redds, $AFpR_{i,j}$ is apparent females per redd, and $pF_{i,j}$ is the proportion of females based on carcass recoveries during spawning ground surveys. We estimated $pF_{i,j}$ using the following equation (eq. 28):

$$Fcarc_{i,j} \sim Binomial(pF_{i,j}, Carc_{i,j}) \tag{28}$$

where $Fcarc_{i,j}$ and $Carc_{i,j}$ are the number of female carcasses and total carcasses examined for sex on spawning ground surveys.

We did not make any adjustments to our redd-based abundance estimates as we assumed any sport harvest and prespawn mortality would have happened before redds were constructed.

Peak Count Expansion

Beginning as early as the 1940s and continuing until the early 2000s, peak count expansion (PCE) was the primary method used to estimate escapement for fall Chinook salmon in LCR tributaries. While PCE can provide a statistically valid estimate, the assumptions of the PCE method are often tough to meet. We used PCE in a handful of places that were deemed a lower priority based on recovery goals or in places where spawner abundance was so low that it was the only reasonable method to estimate abundance (e.g. Lower Gorge).

There are a number of ways to estimate the PCE factor including the mean of the ratios (Parken et al. 2003), calibrated regression, and inverse prediction (Parsons and Skalski 2010). We developed PCE factors two different ways: (1) using the peak count of carcasses only which corresponded to the week with the count of carcasses (new carcasses and previously sampled carcasses) and (2) using the week with the largest total of lives (holders and spawners) and deads (new carcasses and previously sampled) combined. Rawding and Rodgers (2013) list the following critical assumptions for the PCE method: (1) the peak day of abundance is known and the survey takes place on the peak, (2) if the entire spawning distribution is not surveyed, the proportion of fish used in the index or indices is similar to that of the years used to develop the PCE factor, (3) observer efficiency is similar in all years, and (4) the proportion of fish observed on the peak day is similar across all years.

We used the following equation (eq. 29) to estimate year-specific peak count proportions, $PCP_{i,j}$, for all subpopulations and years when we had solid abundance estimates using other methods (Census, LP, JS, AUC or Redd Expansion) with the subscript i denoting year-specific and j denoting basin-specific parameters:

$$PC_{i,j} \sim Binomial(PCP_{i,j}, N_{i,j}) \tag{29}$$

where $N_{i,j}$ is spawner abundance estimate and $PC_{i,j}$ is the peak count with the subscript i and j denoting year- and basin-specific parameters, respectively.

Secondly, we generated hierarchical estimates of the PCE mean and variance across multiple years using year-specific PCEs. Rather than parameterize the hierarchical model in terms of the PCE, we parameterized the model as a function of the peak count proportion, which was the inverse of the peak count expansion, which were normally distributed random effects in logit space (eq. 30):

$$logit\ PCP_{i,j} \sim \text{Normal}\ (\mu_{logitPCP_j}, \sigma_{logitPCP_j}) \tag{30}$$

Where the logit of each PCP was modeled as a random variable that was normally distributed around a hierarchical mean, $\mu_{logitPCP_j}$, with a standard deviation, $\sigma_{logitPCP_j}$. The parameters of the hierarchical prior were then given vaguely informative hyperpriors (eqs. 31-32):

$$\mu_{logitPCP_j} \sim Normal\,(0, 2) \tag{31}$$
$$\tau_{logitPCP_j} \sim Uniform\ \ (0, 1) \tag{32}$$

The hyper prior corresponded to a 95% prior credible interval where the mean peak count proportion of the whole run was 0.2 -0.8. The inverse logit transformed mean across years, and the year-specific peak count proportions by basin(PCP), were then inverted to estimate the mean and year-specific PCE factors by basin using the equation (eq. 33):

$$PCE_{i,j} = \frac{1}{PCP_{i,j}} \tag{33}$$

When peak counts were used to estimate abundance for a particular basin and year, the year and population-specific estimate of $PCE_{i,j}$, and the peak count, $PC_{i,j}$ were simply multiplied to estimate abundance (eq. 34):

$$N_{PCE_{i,j}} = PCE_{i,j} * PC_{i,j} \tag{34}$$

where the $N_{PCE_{i,j}}$ is the year-specific estimate of abundance. In years where a year-specific PCE was not available and PCE was the only available method to estimate abundance, the hierarchical estimate of PCE was used:

$$N_{PCE_{i,j}} = hier\ PCE * PC_{i,j} \tag{34}$$

In these cases, the hierarchical estimate of *PCE* was obtained by using equation 30 to generate a predictive distribution for *PCP* in a year with no data. This predictive distribution for PCP was then converted to the hierarchical estimate of *PCE* using eq. 33.

Partitioning Estimates of Abundance by Origin, Age, and Sex

While achieving unbiased estimates of overall abundance is important, these data become more valuable when they are further partitioned by sex, age, and origin. This allows the evaluation of NOR abundance and productivity trends, hatchery influence, and diversity of populations.

One of the key indicators for salmon populations is the number of HOR spawners (Rawding and Rodgers 2013). Mass marking is where the adipose fin (or left ventral fin in the case of Select Area Brights (SABs)) is removed from juvenile salmon before they are released from hatchery facilities. This provides a simple visual cue on whether a fish was born in a hatchery or in the wild.

Prior to the implementation of mass marking, estimating the number of HOR spawners was difficult, as biologists had to rely on expansion of CWTs with often extremely small sizes that can lead to biased estimates. With mass marking, it can be relatively straightforward to estimate as most analysts simply multiple the spawner abundance by the proportion of clipped carcasses recovered on spawning ground surveys. While this can provide a reasonable estimate, there are situations where this may lead to significant bias. This is the case in several of our LCR populations where we have small NOR salmon populations with large hatchery programs where substantial proportions of returning hatchery adults spawn in the wild. This problem is exacerbated through selectively removing fin clipped fish at weir locations.

While the goal of mass marking is to fin clip 100% of fall Chinook salmon released from LCR hatchery facilities, there are a small proportion of hatchery fish that remain unclipped. There are a few potential reasons for this: (1) regeneration of the adipose fin, which may be due to a poor excision, (2) hatchery "leaking" (Hillson et al. 2017) fish prior to the mass marking taking place, or (3) fin clipping trailers simply missing fish. The first two are difficult to quantify without an extensive genetic and/or isotope analysis. We corrected for the last source of bias, fin-clipping trailers missing fin excision on some fish. When fin-clipping trailers operate, they do quality control and quality assurance checks on the fish being clipped at each facility. They typically randomly sample 500 fish, all of which have been through the fin clipping trailer, to access the quality of the fin clip being applied (*Eric Kinne, personal communication, WDFW*). This ratio of successful fin clipped to total fish examined is then applied to the overall release size to develop an estimate of clipped and unclipped fish released from each facility for each release year. These numbers are reported to the regional CWT database (RMIS).

Hinrichsen et al. (2012) demonstrated a novel approach to deal with these potential sources of bias. In our case, most hatchery releases had similar mass mark rates between facilities and age classes, generally between 97 and 100%. As a result, we took a more simplified approach and examined CWT recoveries from spawning ground surveys and weir operations to determine where the HOR spawners in a particular subpopulation were coming from (see Results: Coded-Wire-Tag Recoveries). Then, we choose the hatchery program that was the largest contributor to

HOR spawner abundance in the subpopulation based on the CWT information (Appendix D; Table D1) and looked up the number of clipped and unclipped fish released from that facility by brood year. We then assumed that the sample size of 500 fish was accurate for each facility and applied the successful mass mark rate from RMIS by facility and brood year (Appendix D; Table D2). This gave us the number of "satisfactory" fin-clips out of the sample size of 500. Then, we estimated the proportion of mass marked juveniles released from each facility and brood year, $pJ^{m}_{a_{i,j}}$, using the following equation (eq. 35):

$$J^{m}_{a_{i,j}} \sim Binomial\ (pJ^{m}_{a_{i,j}}, J^{u}_{a_{i,j}} + J^{m}_{a_{i,j}}) \qquad (35)$$

where $J^{m}_{a_{i,j}}$ represents the number of successful adipose clips (or LV clips for SABs) by age class and $J^{u}_{a_{i,j}}$ represents the number of unclipped fish by age with the superscripts *m*, *u*, *a*, *i*, and *j* denoting clipped fish, unclipped fish, age, year-specific, and basin-specific parameters, respectively,

We were then able to adjust our estimate of clipped and unclipped spawner abundance for each subpopulation by the hatchery specific mass mark rate for each age class using the methods described below. Failure to adjust NOR abundance estimates for unclipped hatchery fish could lead to positively biased natural abundance estimates.

To begin, we calculated the proportion of clipped fall Chinook salmon, $pMark_{w_{i,j}}$, based on carcass recoveries on spawning ground surveys (eq. 36) and used an uninformative prior (eq. 37). The inverse, the proportion of unclipped fall Chinook salmon, $pUnmark_{w_{i,j}}$, was estimated using equation 38.

$$Clip_{w_{i,j}} \sim Binomial(pMark_{w_{i,j}}, Carc_{w_{i,j}}) \qquad (36)$$
$$pMark_{w_{i,j}} \sim \text{Beta}(1,1) \qquad (37)$$
$$pUnmark_{w_{i,j}} = 1 - pMark_{w_{i,j}} \qquad (38)$$

where $Clip_{w_{i,j}}$ is the number of adipose-clipped, left ventral-clipped, or double index tag (DIT) (fish are released from a hatchery with no fin clips but are 100% coded-wire-tagged) carcasses encountered on spawning ground surveys and $Carc_{w_{i,j}}$ is the number of carcasses examined for adipose clips, left-ventral clips, and CWTs with the subscript *w* denoting parsed out above and below weir sites and *i* and *j* denoting year- and basin-specific parameters, respectively.

In populations where we had different stocks of fall Chinook salmon that were not estimated through independent abundance methods (e.g. SABs in the Grays/Chinook and Elochoman/Skamokawa populations), we used a similar equation as above to parse those fish out (eq. 39) and used an uninformative prior (eq. 40). The inverse, the proportion of adipose-clipped, $pAD_{w_{i,j}}$, was estimated using equation 41.

$$LV\ Clip_{w_{i,j}} \sim Binomial(pLV_{w_{i,j}}, Clip_{w_{i,j}}) \qquad (39)$$
$$pLV_{w_{i,j}} \sim \text{Beta}(1,1) \qquad (40)$$

$$pAD_{w_{i,j}} = 1 - pLV_{w_{i,j}} \tag{41}$$

where $LV\ Clip_{w_{i,j}}$ is the number of left ventral-clipped carcasses encountered on spawning ground surveys, which were assumed to be SABs released from ODFW or Clatsop County hatcheries or net pens in Youngs Bay, and $Clip_{w_{i,j}}$ is the number of carcasses examined for adipose-clips, left-ventral clips, and CWTs with the subscript w denoting parsed out above and below weir sites and i and j denoting year- and basin-specific parameters, respectively.

Then, we estimated the number of ad-clipped spawners, $S^{AD}_{w_{i,j}}$, LV-clipped spawners, $S^{LV}_{w_{i,j}}$, and unclipped spawners, $S^{U}_{w_{i,j}}$, using the three equations listed below (eqs. 42-44), where $pAD_{w_{i,j}}$ represents the either $pAD_{w_{i,j}}$ or $Clip_{w_{i,j}}$ depending on the basin.

$$S^{AD}_{w_{i,j}} = pAD_{w_{i,j}} {*} S_{w_{i,j}} \tag{42}$$
$$S^{LV}_{w_{i,j}} = pLV_{w_{i,j}} {*} S_{w_{i,j}} \tag{43}$$
$$S^{U}_{w_{i,j}} = pUnmark_{w_{i,j}} {*} S_{w_{i,j}} \tag{44}$$

where $S_{w_{i,j}}$ is the estimates of spawners from the various methods described above in the abundance methods sections reparametrized (e.g. $N_{census_{i,j}}$, $N_{JS_{i,j}}$, $N_{LP_{i,j}}$, $N_{AUC_{i,j}}$, $N_{Redds_{i,j}}$, $N_{Redds_{i,j}}$).

Then, we estimated the proportion of each age class for ad-clipped spawners, $pA^{AD}_{a,w_{i,j}}$, left ventral-clipped spawners, $pA^{LV}_{a,w_{i,j}}$, and unclipped spawners, $pA^{U}_{a,w_{i,j}}$ (eqs. 45-47) using informative priors for age proportions by clip type (eqs. 48-50).

$$SA^{AD}_{a,w_{i,j}} \sim Multinomial(pA^{AD}_{a,w_{i,j}}, SA^{AD}_{w_{i,j}}) \tag{45}$$
$$SA^{LV}_{a,w_{i,j}} \sim Multinomial(pA^{LV}_{a,w_{i,j}}, SA^{LV}_{w_{i,j}}) \tag{46}$$
$$SA^{U}_{a,w_{i,j}} \sim Multinomial(pA^{U}_{a,w_{i,j}}, SA^{U}_{w_{i,j}}) \tag{47}$$
$$pA^{AD}_{a,w_{i,j}} \sim Dirichlet\ (\alpha) \tag{48}$$
$$pA^{LV}_{a,w_{i,j}} \sim Dirichlet\ (\alpha) \tag{49}$$
$$pA^{U}_{a,w_{i,j}} \sim Dirichlet\ (\alpha) \tag{50}$$

where $SA^{AD}_{a,w_{i,j}}$, $SA^{LV}_{a,w_{i,j}}$, and $SA^{U}_{a,w_{i,j}}$ are the number of aged scale readings for each age class by clip type, $SA^{AD}_{w_{i,j}}$, $SA^{LV}_{w_{i,j}}$, and $SA^{U}_{w_{i,j}}$ are the total number of readable scale samples aged from ad-clipped, left ventral-clipped, and unclipped carcasses during spawning ground surveys, and α is a vector of values represented in Table 3.

Table 3. Weakly informative priors used to develop age structure estimates for fall Chinook salmon populations within the LCR ESU.

		Priors			
Stock	Clip Type	Age-3	Age-4	Age-5	Age-6
Below Bonneville Tule	AD	1.36	2.18	0.45	0.10
Below Bonneville Tule	UM	0.88	2.65	0.48	0.10
Select Area Bright	LV	2.93	1.05	0.50	0.00
Above Bonneville Tule	AD	2.91	1.06	0.10	0.00
Above Bonneville Tule	UM	2.06	1.80	0.14	0.00
Above Bonneville Bright	AD	0.56	2.65	0.78	0.10
Above Bonneville Bright	UM	0.61	2.49	0.89	0.10

For Tule fall Chinook salmon below Bonneville Dam, the ad-clipped weakly informative priors were based on combined age structure from 2012 to 2017 Kalama, Green, and Washougal rivers ad-clipped Chinook salmon carcasses recovered on spawning ground surveys. For unclipped age structure, the informative priors were based on combined age structure from 2012-2017 East Fork Lewis and Coweeman rivers unclipped carcasses recovered on spawning ground surveys.

For Select Area Bright fall Chinook salmon age structure, the informative priors were based on combined age structure from 2012 to 2017 Grays River LV-clipped Chinook salmon carcasses recovered on spawning ground surveys.

For Tule fall Chinook salmon above Bonneville, the age structure is quite different from Tule fall Chinook salmon below Bonneville Dam as fish mature and return at a younger age. Therefore, for the ad-clipped informative priors for the Upper Gorge and White Salmon populations were based on combined age structure from 2012 to 2017 Upper Gorge and White Salmon ad-clipped Tule fall Chinook salmon carcasses recovered on spawning ground surveys. For unclipped age structure, the informative priors for the Upper Gorge and White Salmon populations were based on combined age structure from 2012 to 2017 Upper Gorge and White Salmon unclipped Tule fall Chinook salmon carcasses recovered on spawning ground surveys.

For Bright fall Chinook salmon above Bonneville, the age structure is different from Tule fall Chinook salmon as they tend to be older. Therefore, for the ad-clipped informative priors for the Upper Gorge and White Salmon populations were based on combined age structure from 2012 to 2017 Upper Gorge and White Salmon ad-clipped Bright fall Chinook salmon carcasses recovered on spawning ground surveys. For unclipped age structure, the informative priors for the Upper Gorge and White Salmon populations were based on combined age structure from 2012 to 2017 Upper Gorge and White Salmon unclipped Bright fall Chinook salmon carcasses recovered on spawning ground surveys.

Next, we estimated the number of ad-clipped spawners, $S_{a,w_{i,j}}^{AD}$, left ventral-clipped spawners, $S_{a,w_{i,j}}^{LV}$, and unclipped spawners by age, $S_{a,w_{i,j}}^{U}$, using the following equations (eqs. 51-53):

$$S_{a,w_{i,j}}^{AD} = S_{w_{i,j}}^{AD} * pA_{a,w_{i,j}}^{AD} \tag{51}$$

$$S^{LV}_{a,w_{i,j}} = S^{LV}_{w_{i,j}} * pA^{LV}_{a,w_{i,j}} \quad (52)$$
$$S^{U}_{a,w_{i,j}} = S^{U}_{w_{i,j}} * pA^{U}_{a,w_{i,j}} \quad (53)$$

If weirs were being used for pHOS control in the subpopulation (e.g. selectively removing clipped fish) and/or for broodstock collection for integrated hatchery programs (e.g. removing both clipped and unclipped fish from system at the weir), the following equations (eqs. 54-56) were used to estimate the proportion of each age class by clip type of fish removed at weirs, $WpA^{AD}_{a_{i,j}}$, $WpA^{LV}_{a_{i,j}}$, and $WpA^{U}_{a_{i,j}}$.

$$WSA^{AD}_{a_{i,j}} \sim Multinomial(WpA^{AD}_{a_{i,j}}, WSA^{AD}_{i,j}) \quad (54)$$
$$WSA^{LV}_{a_{i,j}} \sim Multinomial(WpA^{LV}_{a_{i,j}}, WSA^{LV}_{i,j}) \quad (55)$$
$$WSA^{U}_{a_{i,j}} \sim Multinomial(WpA^{U}_{a_{i,j}}, WSA^{U}_{i,j}) \quad (56)$$

where $WSA^{AD}_{a_{i,j}}$, $WSA^{LV}_{a_{i,j}}$, and $WSA^{U}_{a_{i,j}}$ are the number of scale sampled aged for each age class by clip type from fish removed at a weir site and $WSA^{AD}_{i,j}$, $WSA^{LV}_{i,j}$, $WSA^{U}_{i,j}$ are the sum of total number of readable scales by age class by clip type from fish removed at a weir site.
Then, weir removals by age and clip type, $WR^{AD}_{a_{i,j}}$, $WR^{LV}_{a_{i,j}}$, and $WR^{U}_{a_{i,j}}$ were estimated using the following equations (eqs. 57-59):

$$WR^{AD}_{a_{i,j}} = WR^{AD}_{i,j} * WpA^{AD}_{a_{i,j}} \quad (57)$$
$$WR^{LV}_{a_{i,j}} = WR^{LV}_{i,j} * WpA^{LV}_{a_{i,j}} \quad (58)$$
$$WR^{U}_{a_{i,j}} = WR^{U}_{i,j} * WpA^{U}_{a_{i,j}} \quad (59)$$

where $WR^{AD}_{i,j}$ is the number of ad-clipped weir removals, $WR^{LV}_{a_{i,j}}$ is the number of left ventral-clipped weir removals, and $WR^{U}_{a_{i,j}}$ is the number of unclipped weir removals.

If fall Chinook salmon hatcheries were present in the basin, we used the equations above (eqs. 57-59) to estimate the proportion of each age class by clip type of fish removed at hatcheries the same as described above but substituting out WSA_a, WpA, WSA, WR_a, WpA, WR for HSA_a, $HSpA$, HSA, HSR_a, $HSpA$, HSR.

If a sport fishery was open for fall Chinook salmon within the subpopulation, we estimated catch, $C_{i,j}$, using equation 2 (see Methods: Abundance Estimates – Census). For places that had adipose-clipped and left ventral-clipped fish present in the system (e.g. Grays, Elochoman), we assumed the catch was split 50/50 between adipose-clipped and left ventral-clipped fall Chinook salmon.

We estimated sport catch by age and clip type using the following equations (eqs. 60-62):

$$C^{AD}_{a,w_{i,j}} = C^{AD}_{i,j} * pA^{AD}_{a,w_{i,j}} \quad (60)$$
$$C^{LV}_{a,w_{i,j}} = C^{LV}_{i,j} * pA^{LV}_{a,w_{i,j}} \quad (61)$$
$$C^{U}_{a,w_{i,j}} = C^{U}_{i,j} * pA^{U}_{a,w_{i,j}} \quad (62)$$

where $pA^{AD}_{a,w_{i,j}}$, $pA^{LV}_{a,w_{i,j}}$, and $pA^{U}_{a,w_{i,j}}$ were used as surrogates for the proportion of each age class by clip type. We assumed that the age structure from adipose-clipped and left ventral-clipped on the spawning grounds was the same as fish harvested in a tributary's sport fishery.

The proportion of carcasses that were prespawn mortalities by clip type, $pPSM^{AD}_{w_{i,j}}$, $pPSM^{LV}_{w_{i,j}}$, $pPSM^{U}_{w_{i,j}}$, were estimated using the following series of equations (eqs. 63-65):

$$PSM\ Carc^{AD}_{w_{i,j}} \sim Binomial\ (pPSM^{AD}_{w_{i,j}}, Carc^{AD}_{w_{i,j}}) \quad (63)$$
$$PSM\ Carc^{LV}_{w_{i,j}} \sim Binomial\ (pPSM^{LV}_{w_{i,j}}, Carc^{LV}_{w_{i,j}}) \quad (64)$$
$$PSM\ Carc^{U}_{w_{i,j}} \sim Binomial\ (pPSM^{U}_{w_{i,j}}, Carc^{U}_{w_{i,j}}) \quad (65)$$

where $PSM\ Carc^{AD}_{w_{i,j}}$, $PSM\ Carc^{LV}_{w_{i,j}}$, and $PSM\ Carc^{U}_{w_{i,j}}$ are the number of carcasses that were prespawn mortalities by clip type and $Carc^{AD}_{w_{i,j}}$, $Carc^{LV}_{w_{i,j}}, and\ Carc^{U}_{w_{i,j}}$ are the number of carcasses examined for spawn success.

Then, we estimated the number of prespawn mortalities by clip type using the following series of equations (eqs. 66-68):

$$PSM^{AD}_{w_{i,j}} = (S^{AD}_{w_{i,j}} * pPSM^{AD}_{w_{i,j}}) \quad (66)$$
$$PSM^{LV}_{w_{i,j}} = (S^{LV}_{w_{i,j}} * pPSM^{LV}_{w_{i,j}}) \quad (67)$$
$$PSM^{U}_{w_{i,j}} = (S^{U}_{w_{i,j}} * pPSM^{U}_{w_{i,j}}) \quad (68)$$

Next, we estimated the number of ad-clipped, $PSM^{AD}_{a,w_{i,j}}$, left ventral-clipped, $PSM^{LV}_{a,w_{i,j}}$, and unclipped, $PSM^{U}_{a,w_{i,j}}$, prespawn mortalities by age by using equations 66-68 above and substituting the estimate of spawners by clip type, $S^{AD}_{w_{i,j}}$, $S^{LV}_{w_{i,j}}$, and $S^{U}_{w_{i,j}}$ for the estimate of prespawn mortalities by clip type, $PSM^{AD}_{a,w_{i,j}}$, $PSM^{LV}_{a,w_{i,j}}$, and $PSM^{U}_{a,w_{i,j}}$. We assumed that the age composition of prespawn mortalities was the same as spawners.

Next, we developed an estimate of adipose-clipped, $R^{AD}_{a_{i,j}}$, left ventral clipped, $R^{LV}_{a_{i,j}}$, and unclipped, $R^{U}_{a_{i,j}}$, fall Chinook salmon by age returning to each subpopulation for each year using the following equations (eqs. 69-71):

$$R^{AD}_{a_{i,j}} = S^{AD}_{a,w=1_{i,j}} + S^{AD}_{a,w=2_{i,j}} + WR^{AD}_{a_{i,j}} + C^{AD}_{a,w=1_{i,j}} + C^{AD}_{a,w=2_{i,j}} + PSM^{AD}_{a,w=1_{i,j}} + PSM^{AD}_{a,w=2_{i,j}} \quad (69)$$
$$R^{LV}_{a_{i,j}} = S^{LV}_{a,w=1_{i,j}} + S^{LV}_{a,w=2_{i,j}} + WR^{LV}_{a_{i,j}} + C^{LV}_{a,w=1_{i,j}} + C^{LV}_{a,w=2_{i,j}} + PSM^{LV}_{a,w=1_{i,j}} + PSM^{LV}_{a,w=2_{i,j}} \quad (70)$$
$$R^{U}_{a_{i,j}} = S^{U}_{a,w=1_{i,j}} + S^{U}_{a,w=2_{i,j}} + WR^{U}_{a_{i,j}} + C^{U}_{a,w=1_{i,j}} + C^{U}_{a,w=2_{i,j}} + PSM^{U}_{a,w=1_{i,j}} + PSM^{U}_{a,w=2_{i,j}} \quad (71)$$

where 1 and 2 represent below and above weir, respectively.

Then, we estimated the proportion of mass marked juveniles released into the system for each age class separately for adipose-clipped and left ventral-clipped releases, $J^{AD}_{a_{i,j}}$ and $J^{LV}_{a_{i,j}}$, using the following equations (eqs. 72-73):

$$J^{AD}_{a_{i,j}} \sim Binomial\ (pJ^{AD}_{a_{i,j}}, J^{U}_{a_{i,j}} + J^{AD}_{a_{i,j}}) \tag{72}$$
$$J^{LV}_{a_{i,j}} \sim Binomial\ (pJ^{LV}_{a_{i,j}}, J^{U}_{a_{i,j}} + J^{LV}_{a_{i,j}}) \tag{73}$$

where $J^{AD}_{a_{i,j}}$ represents the number of successful adipose clips, $J^{LV}_{a_{i,j}}$ represents the number of successful left ventral clips, and $J^{U}_{a_{i,j}}$ represents the number of unclipped fish by age (Appendix D).

Next, we estimated the number of HOR fish returning to the basin by age, $HOR^{AD}_{a_{i,j}}$ and $HOR^{LV}_{a_{i,j}}$ using the following equations (eqs. 74-75):

$$HOR^{AD}_{a_{i,j}} = \max(0, \min\left(R^{U}_{a_{i,j}} + R^{AD}_{a_{i,j}}, \frac{R^{AD}_{a_{i,j}}}{pJ^{AD}_{a_{i,j}}}\right)) \tag{74}$$
$$HOR^{LV}_{a_{i,j}} = \max(0, \min\left(R^{U}_{a_{i,j}} + R^{LV}_{a_{i,j}}, \frac{R^{LV}_{a_{i,j}}}{pJ^{LV}_{a_{i,j}}}\right)) \tag{75}$$

The difference between the number of HOR fish and clipped fish returning to the subpopulation by age was derived using the following equations (eqs. 76-77):

$$ucHOR^{AD}_{a_{i,j}} = \max\ (0, HOR^{AD}_{a_{i,j}} - R^{AD}_{a_{i,j}}) \tag{76}$$
$$ucHOR^{LV}_{a_{i,j}} = \max\ (0, HOR^{LV}_{a_{i,j}} - R^{LV}_{a_{i,j}}) \tag{77}$$

NOR fish returning to the basin by age, $NOR_{a_{i,j}}$, was derived by the equation below (eq. 78):

$$NOR_{a_{i,j}} = \max\ (0, R^{U}_{a_{i,j}} - (ucHOR^{AD}_{a_{i,j}} + ucHOR^{LV}_{a_{i,j}}) \tag{78}$$

Then, the number of unclipped HOR fish by age was parsed out to weir removals, $ucHOWR_{a_{i,j}}$, hatchery swim-in pond removals, $ucHOHSR_{a_{i,j}}$, prespawn mortalities, $ucHOPSM^{U}_{a,w_{i,j}}$, and catch, $ucHOC^{U}_{a,w_{i,j}}$, by age based on the series of equations below (eqs. 79-82):

$$ucHOWR_{a_{i,j}} = (WR^{U}_{a_{i,j}} / R^{U}_{a_{i,j}}) * ucHOR_{a_{i,j}} \tag{79}$$
$$ucHOHSR_{a_{i,j}} = (HSR^{U}_{a_{i,j}} / R^{U}_{a_{i,j}}) * ucHOR_{a_{i,j}} \tag{80}$$
$$ucHOPSM^{U}_{a,w_{i,j}} = (PSM^{U}_{a,w_{i,j}} / R^{U}_{a_{i,j}}) * ucHOR_{a_{i,j}} \tag{81}$$
$$ucHOC^{U}_{a,w_{i,j}} = (C^{U}_{a,w_{i,j}} / R^{U}_{a_{i,j}}) * ucHOR_{a_{i,j}} \tag{82}$$

To estimate the number of unclipped HOR spawners by age, $ucHOS^{AD}_{a,w_{i,j}}$, and $ucHOS^{LV}_{a,w_{i,j}}$, we used the following equations (eqs. 83-84):

$$ucHOS_{a_{i,j}}^{AD} = ucHOR_{a_{i,j}}^{AD} - (ucHOWR_{a_{i,j}}^{AD} + ucHOHSR_{a_{i,j}}^{AD} + ucHOPSM_{a,w=1_{i,j}}^{AD} + ucHOPSM_{a,w=2_{i,j}}^{AD} + ucHOC_{a,w=1_{i,j}}^{AD} + ucHOC_{a,w=2_{i,j}}^{AD}) \tag{83}$$

$$ucHOS_{a_{i,j}}^{LV} = ucHOR_{a_{i,j}}^{LV} - (ucHOWR_{a_{i,j}}^{LV} + ucHOHSR_{a_{i,j}}^{LV} + ucHOPSM_{a,w=1_{i,j}}^{LV} + ucHOPSM_{a,w=2_{i,j}}^{LV} + ucHOC_{a,w=1_{i,j}}^{LV} + ucHOC_{a,w=2_{i,j}}^{LV}) \tag{84}$$

where 1 and 2 represent below and above weir, respectively.

To estimate the number of HOR spawners by clip type below each of the weir sites, the following equations were used (eqs. 85-88):

$$HOS_{a,w=1_{i,j}}^{AD} = S_{a,w=1_{i,j}}^{AD} + \left(\frac{S_{a,w=1_{i,j}}^{AD} + C_{a,w=1_{i,j}}^{AD} + PSM_{a,w=1_{i,j}}^{AD}}{S_{a,w=1_{i,j}}^{AD} + C_{a,w=1_{i,j}}^{AD} + PSM_{a,w=1_{i,j}}^{AD} + S_{a,w=2_{i,j}}^{AD} + WR_{a_{i,j}}^{AD} + HSR_{a_{i,j}}^{AD} + C_{a,w=2_{i,j}}^{AD} + PSM_{a,w=2_{i,j}}^{AD}}\right) * ucHOS_{a_{i,j}}^{AD} \tag{85}$$

$$HOS_{a,w=2_{i,j}}^{AD} = S_{a,w=2_{i,j}}^{AD} + \left(\frac{S_{a,w=2_{i,j}}^{AD} + WR_{a_{i,j}}^{AD} + HSR_{a_{i,j}}^{AD} + C_{a,w=2_{i,j}}^{AD} + PSM_{a,w=2_{i,j}}^{AD}}{S_{a,w=1_{i,j}}^{AD} + C_{a,w=1_{i,j}}^{AD} + PSM_{a,w=1_{i,j}}^{AD} + S_{a,w=2_{i,j}}^{AD} + WR_{a_{i,j}}^{AD} + HSR_{a_{i,j}}^{AD} + C_{a,w=2_{i,j}}^{AD} + PSM_{a,w=2_{i,j}}^{AD}}\right) * ucHOS_{a_{i,j}}^{AD} \tag{86}$$

$$HOS_{a,w=1_{i,j}}^{LV} = S_{a,w=1_{i,j}}^{LV} + \left(\frac{S_{a,w=1_{i,j}}^{LV} + C_{a,w=1_{i,j}}^{LV} + + PSM_{a,w=1_{i,j}}^{LV}}{S_{a,w=1_{i,j}}^{LV} + C_{a,w=1_{i,j}}^{LV} + PSM_{a,w=1_{i,j}}^{LV} + S_{a,w=2_{i,j}}^{LV} + WR_{a_{i,j}}^{LV} + HSR_{a_{i,j}}^{LV} + C_{a,w=2_{i,j}}^{LV} + PSM_{a,w=2_{i,j}}^{LV}}\right) * ucHOS_{a_{i,j}}^{LV} \tag{87}$$

$$HOS_{a,w=2_{i,j}}^{LV} = S_{a,w=2_{i,j}}^{LV} + \left(\frac{S_{a,w=2_{i,j}}^{LV} + WR_{a_{i,j}}^{LV} + HSR_{a_{i,j}}^{LV} + C_{a,w=2_{i,j}}^{LV} + PSM_{a,w=2_{i,j}}^{LV}}{S_{a,w=1_{i,j}}^{LV} + C_{a,w=1_{i,j}}^{LV} + PSM_{a,w=1_{i,j}}^{LV} + S_{a,w=2_{i,j}}^{LV} + WR_{a_{i,j}}^{LV} + HSR_{a_{i,j}}^{LV} + C_{a,w=2_{i,j}}^{LV} + PSM_{a,w=2_{i,j}}^{LV}}\right) * ucHOS_{a_{i,j}}^{LV} \tag{88}$$

where 1 and 2 represent below and above weir, respectively.

Finally, we developed estimates of NOR spawners by age, $NOS_{a,w}$, using the equations below (eqs. 89-90):

$$NOS_{a,w=1_{i,j}} = \max(0, S^{U}_{a,w=1_{i,j}} - ((HOS^{AD}_{a,w=1_{i,j}} - S^{AD}_{a,w=1_{i,j}}) + (HOS^{LV}_{a,w=1_{i,j}} - S^{LV}_{a,w=1_{i,j}}))) \tag{89}$$

$$NOS_{a,w=2_{i,j}} = \max(0, S^{U}_{a,w=2_{i,j}} - ((HOS^{AD}_{a,w=2_{i,j}} - S^{AD}_{a,w=2_{i,j}}) + (HOS^{LV}_{a,w=2_{i,j}} - S^{LV}_{a,w=2_{i,j}}))) \tag{90}$$

Spawn Timing

We used weekly counts of spawners and divided these counts by the total count of spawners to estimate the cumulative timing of spawning for each fall Chinook salmon population or subpopulation. Fish identified as spawners are defined as fish in spawnable habitat (see Data Collection). These fish may be staging to spawn, actively spawning, or protecting their redd post spawn. While it may not be a perfect surrogate for spawn timing, it should provide a reasonable estimate of spawn timing across years and populations. Redds could also be used but individual, unique redds were not tracked across all watersheds.

Spatial Structure

We used ArcMap 10.4.1 to display the spatial distribution of fall Chinook salmon redds for most populations. Individual locations of new, unique redds were georeferenced weekly through census redd surveys (Grays River, Elochoman River, Skamokawa, Coweeman River, South Fork Toutle River, and East Fork Lewis River) or on a single pass near peak where all visible redds were georeferenced (Green River, Kalama River, Washougal River, and White Salmon River). No individual redd locational data were collected from the following subpopulations: Mill Creek, Abernathy Creek, Germany Creek, lower Cowlitz River, upper Cowlitz River, Tilton River, Cedar Creek, North Fork Lewis River, Hamilton Creek, Ives Island, Wind River, Little White Salmon River, and Cowlitz River.

Strata and ESU abundance

To estimate strata and ESU abundance, we estimated the mean and standard deviation of the parameters of interest (total abundance, HOR abundance, and NOR abundance) using the posterior draws from each population and year. Then, we fit the mean and standard deviation to a normal distribution and summed each of the three abundance parameters by year to that strata scale (Table 4), and finally, to the ESU scale.

Table 4. Fall Chinook salmon populations within Washington's portion of the LCR Chinook salmon ESU and their associated strata (or Major Population Groups).

Strata	Population
Coast	Grays/Chinook
	Elochoman/Skamokawa
	Mill/Aber/Germ (MAG)
Cascade	Lower Cowlitz
	Upper Cowlitz
	Toutle
	Coweeman
	Kalama
	Lewis (Tule)
	Lewis (Bright)
	Salmon Creek
	Washougal
Gorge	Lower Gorge
	Upper Gorge
	White Salmon

Bright stocks spawning in the Lower Gorge, Upper Gorge, and White Salmon populations are not part of the federally listed LCR ESU and are not included in the table.

Coded-Wire-Tag Recoveries

The recovery of CWTs at the WDFW lab follows the procedures outlined in the tag recovery chapter (Blankenship and Hiezer 1978) of the Pacific Coast Coded Wire Tag Manual. All Chinook salmon CWT recoveries from spawning ground surveys and traps/weirs were entered into the WDFW CWT Access database and uploaded to the Regional Mark Information System (RMIS). RMIS is a coast-wide database that stores CWT and release data along with recovery and sampling data. We summarized unexpanded CWT recoveries from spawning ground surveys by population and hatchery release location.

Results

Apparent Residence Time and Apparent Females Per Redd

We used a two similar hierarchical mixed effect models to derive estimates of ART and AFpR for use with AUC and redd expansion estimates, respectively. Results from models had numerous outputs but can be generally summarized into four potential uses:

(1) Subpopulations that do not have estimates of ART/AFpR for any year and there are no estimates of ART/AFpR from other subpopulations for the year being estimated (unknown year, unknown subpopulation) (Table 5, Table 7).

(2) Subpopulations that do not have estimates of ART/AFpR for any year but there are estimates of ART/AFpR from other subpopulations for the year being estimated (known year, unknown subpopulation) (Table 5, Table 7).

(3) Subpopulations with estimates of ART/AFpR for some years but there are no estimates of ART/AFpR for the year being estimated (unknown year, known subpopulation) (Table 5, Table 7).

(4) Subpopulations with estimates of ART/AFpR for a specific subpopulation for at least one year and estimates of ART/AFpR for at least one other subpopulation for the year being estimated (known year, known subpopulation) (Table 6, Table 8).

Results from the models described above were used as inputs to individual population-level R files. The final ART/AFpR values were further refined based on the peak count relationship across years within a specific subpopulation and the final ART/AFpR values used to develop specific AUC and redd based estimates are reported in results by population.

Table 5. Estimates of apparent residence time of live fall Chinook salmon identified as spawners for either unknown years, unknown subpopulations, or unknown years and subpopulations (mean, SD, and 95% credible intervals of the posterior distribution) for spawn years 2010-2017.

Year	Subpopulation	Mean	SD	L 95% CI	U 95% CI
2010	Unknown	6.43	1.95	3.55	10.88
2011	Unknown	6.48	1.96	3.57	10.96
2012	Unknown	6.68	2.04	3.69	11.27
2013	Unknown	6.76	2.05	3.73	11.39
2014	Unknown	6.59	1.99	3.63	11.09
2015	Unknown	6.73	2.03	3.71	11.36
2016	Unknown	6.60	2.02	3.64	11.28
2017	Unknown	6.44	1.96	3.55	10.87
Unknown	Abernathy	7.65	1.34	5.33	10.57
Unknown	Coweeman	6.13	1.05	4.33	8.45
Unknown	EFL	5.94	1.07	4.13	8.28
Unknown	Elochoman	4.46	0.85	3.09	6.44
Unknown	Germany	7.18	1.22	5.05	9.86
Unknown	Grays	6.52	1.40	4.22	9.72
Unknown	Kalama	6.10	1.24	4.03	8.94
Unknown	Mill	6.80	1.13	4.84	9.31
Unknown	Washougal	7.08	1.21	4.99	9.72
Unknown	Unknown	6.56	2.00	3.62	11.18

Table 6. Estimates of apparent residence time of live fall Chinook salmon identified as spawners for known years and subpopulations (mean, SD, and 95% credible intervals of the posterior distribution) for spawn years 2010-2017.

Year	Subpopulation	Mean	SD	L 95% CI	U 95% CI
2010	Abernathy	7.49	1.24	7.39	10.20
2011	Abernathy	7.55	1.26	7.46	10.27
2012	Abernathy	7.79	1.37	7.68	10.76
2013	Abernathy	7.88	1.37	7.77	10.87
2014	Abernathy	7.68	1.28	7.57	10.42
2015	Abernathy	7.85	1.33	7.75	10.72
2016	Abernathy	7.69	1.35	7.59	10.68
2017	Abernathy	7.51	1.27	7.42	10.24
2010	Coweeman	6.00	0.99	5.92	8.18
2011	Coweeman	6.05	1.00	5.97	8.26
2012	Coweeman	6.24	1.07	6.15	8.59
2013	Coweeman	6.31	1.08	6.21	8.73
2014	Coweeman	6.15	1.03	6.07	8.41
2015	Coweeman	6.28	1.06	6.19	8.65
2016	Coweeman	6.16	1.06	6.06	8.53
2017	Coweeman	6.01	1.01	5.94	8.20
2010	East Fork Lewis	5.82	1.02	5.72	8.07
2011	East Fork Lewis	5.86	1.02	5.77	8.12
2012	East Fork Lewis	6.05	1.08	5.93	8.42
2013	East Fork Lewis	6.12	1.07	6.01	8.46
2014	East Fork Lewis	5.96	1.04	5.87	8.29
2015	East Fork Lewis	6.09	1.05	5.98	8.41
2016	East Fork Lewis	5.97	1.07	5.87	8.43
2017	East Fork Lewis	5.83	1.03	5.75	8.08
2010	Elochoman	4.37	0.81	4.26	6.31
2011	Elochoman	4.40	0.80	4.29	6.27
2012	Elochoman	4.54	0.86	4.43	6.56
2013	Elochoman	4.60	0.86	4.48	6.58
2014	Elochoman	4.48	0.83	4.36	6.43
2015	Elochoman	4.58	0.85	4.45	6.60
2016	Elochoman	4.49	0.86	4.36	6.50
2017	Elochoman	4.38	0.82	4.28	6.33
2010	Germany	7.03	1.14	6.94	9.55
2011	Germany	7.08	1.15	7.00	9.58
2012	Germany	7.31	1.25	7.20	10.11
2013	Germany	7.39	1.24	7.28	10.13
2014	Germany	7.21	1.19	7.11	9.83
2015	Germany	7.37	1.22	7.25	10.13
2016	Germany	7.22	1.23	7.10	9.94
2017	Germany	7.05	1.17	6.96	9.61
2010	Grays	6.38	1.34	6.25	9.41
2011	Grays	6.43	1.31	6.29	9.42
2012	Grays	6.64	1.43	6.48	9.93
2013	Grays	6.71	1.43	6.56	9.97
2014	Grays	6.54	1.37	6.40	9.66
2015	Grays	6.69	1.41	6.53	9.91

Table 7. Estimates of apparent residence time of live fall Chinook salmon identified as spawners for known years and subpopulations (mean, SD, and 95% credible intervals of the posterior distribution) for spawn years 2010-2017, continued.

Year	Subpopulation	Mean	SD	L 95% CI	U 95% CI
2016	Grays	6.55	1.41	6.40	9.76
2017	Grays	6.40	1.35	6.27	9.44
2010	Kalama	5.97	1.17	5.85	8.60
2011	Kalama	6.02	1.18	5.91	8.65
2012	Kalama	6.21	1.26	6.08	9.05
2013	Kalama	6.28	1.27	6.15	9.18
2014	Kalama	6.12	1.21	6.00	8.85
2015	Kalama	6.26	1.25	6.13	9.15
2016	Kalama	6.13	1.25	6.00	8.95
2017	Kalama	5.97	1.13	5.86	8.49
2010	Mill	6.66	1.07	6.56	9.02
2011	Mill	6.71	1.07	6.62	9.06
2012	Mill	6.92	1.16	6.82	9.50
2013	Mill	7.00	1.16	6.90	9.63
2014	Mill	6.82	1.09	6.73	9.25
2015	Mill	6.97	1.12	6.88	9.52
2016	Mill	6.83	1.14	6.74	9.43
2017	Mill	6.67	1.09	6.59	9.08
2010	Washougal	6.93	1.14	6.82	9.44
2011	Washougal	6.98	1.15	6.89	9.56
2012	Washougal	7.20	1.21	7.10	9.92
2013	Washougal	7.28	1.21	7.17	9.96
2014	Washougal	7.10	1.16	7.01	9.67
2015	Washougal	7.26	1.19	7.15	9.91
2016	Washougal	7.11	1.22	7.00	9.82
2017	Washougal	6.95	1.16	6.85	9.51

Table 8. Estimates of apparent females per redd of fall Chinook salmon for either unknown years, unknown subpopulations, or unknown years and subpopulations (mean, SD, and 95% credible intervals of the posterior distribution) for spawn years 2010-2017.

Year	Subpopulation	Mean	SD	L 95% CI	U 95% CI
2010	Unknown	1.33	3.38	0.39	3.11
2011	Unknown	1.35	3.59	0.39	3.17
2012	Unknown	1.42	3.61	0.42	3.27
2013	Unknown	1.45	3.87	0.42	3.39
2014	Unknown	1.44	3.39	0.42	3.31
2015	Unknown	1.41	3.73	0.43	3.27
2017	Unknown	1.43	3.68	0.42	3.34
Unknown	Coweeman	1.23	0.36	0.68	2.03
Unknown	East Fork Lewis	1.18	0.36	0.61	2.00
Unknown	Elochoman	1.18	0.41	0.57	2.13
Unknown	Unknown	1.38	3.46	0.40	3.28

Table 9. Estimates of apparent females per redd of fall Chinook salmon for known years and subpopulations (mean, SD, and 95% credible intervals of the posterior distribution) for spawn years 2010-2017.

Year	Subpopulation	Mean	SD	L 95% CI	U 95%CI
2010	Coweeman	1.19	0.32	0.68	1.90
2011	Coweeman	1.20	0.32	0.70	1.92
2012	Coweeman	1.27	0.34	0.73	2.04
2013	Coweeman	1.29	0.36	0.73	2.15
2014	Coweeman	1.29	0.34	0.73	2.08
2015	Coweeman	1.26	0.32	0.73	1.98
2017	Coweeman	1.27	0.35	0.72	2.06
2010	East Fork Lewis	1.14	0.33	0.62	1.89
2011	East Fork Lewis	1.15	0.34	0.64	1.91
2012	East Fork Lewis	1.21	0.35	0.68	2.01
2013	East Fork Lewis	1.23	0.34	0.69	2.02
2014	East Fork Lewis	1.23	0.35	0.68	2.05
2015	East Fork Lewis	1.20	0.32	0.68	1.93
2017	East Fork Lewis	1.21	0.35	0.69	2.01
2010	Elochoman	1.14	0.38	0.57	2.01
2011	Elochoman	1.15	0.38	0.58	2.04
2012	Elochoman	1.22	0.40	0.63	2.16
2013	Elochoman	1.23	0.40	0.63	2.18
2014	Elochoman	1.24	0.40	0.63	2.16
2015	Elochoman	1.20	0.36	0.64	2.04
2017	Elochoman	1.22	0.40	0.62	2.13

Overview of Adult Natural-Origin Spawner Abundance, pHOS, Age Structure, and Spawn Timing for Tule Fall Chinook Salmon by Population

The largest NOR Tule fall Chinook salmon spawner abundance estimates were in the Lewis, Lower Cowlitz, and Upper Cowlitz populations. The populations with the smallest NOR spawner abundance estimates were the three populations within the Coast stratum population (Grays/Chinook, Elochoman/Skamokawa, and MAG as well as the Lower Gorge population (Figure 4).

The Coweeman, Lower Cowlitz, and White Salmon populations had the lowest estimates of pHOS. The populations with the highest estimates of pHOS varied year to year. The Kalama had one of the highest pHOS levels prior to the implementation of the management strategy to remove HOR fall Chinook salmon at the lower river weir in 2015. MAG, Elochoman/Skamokawa, and Grays/Chinook were other populations with high estimates of pHOS (Figure 5) despite not having any in-basin releases of fall Chinook salmon.

Age structure for Tule fall Chinook salmon was dominated by age-3 and age-4 fish across all populations and years. In general, there tended to be more age-4 fish in NORs in comparison to HORs. This was especially prominent in the Gorge stratum. Age-5 fish were observed with more frequency in the Cascade stratum in comparison to the other two strata (Figure 6).

Spawn timing for Tule fall Chinook salmon was variable by population and year. In general, spawn timing has shifted slightly later for the ESU as a whole over the last eight years. The Coast stratum, except for the Grays, had the earliest spawn timing in most years. The latest spawning populations were the Grays and Washougal in most years, both of which may be influenced by later spawning Bright stocks (Figure 7).

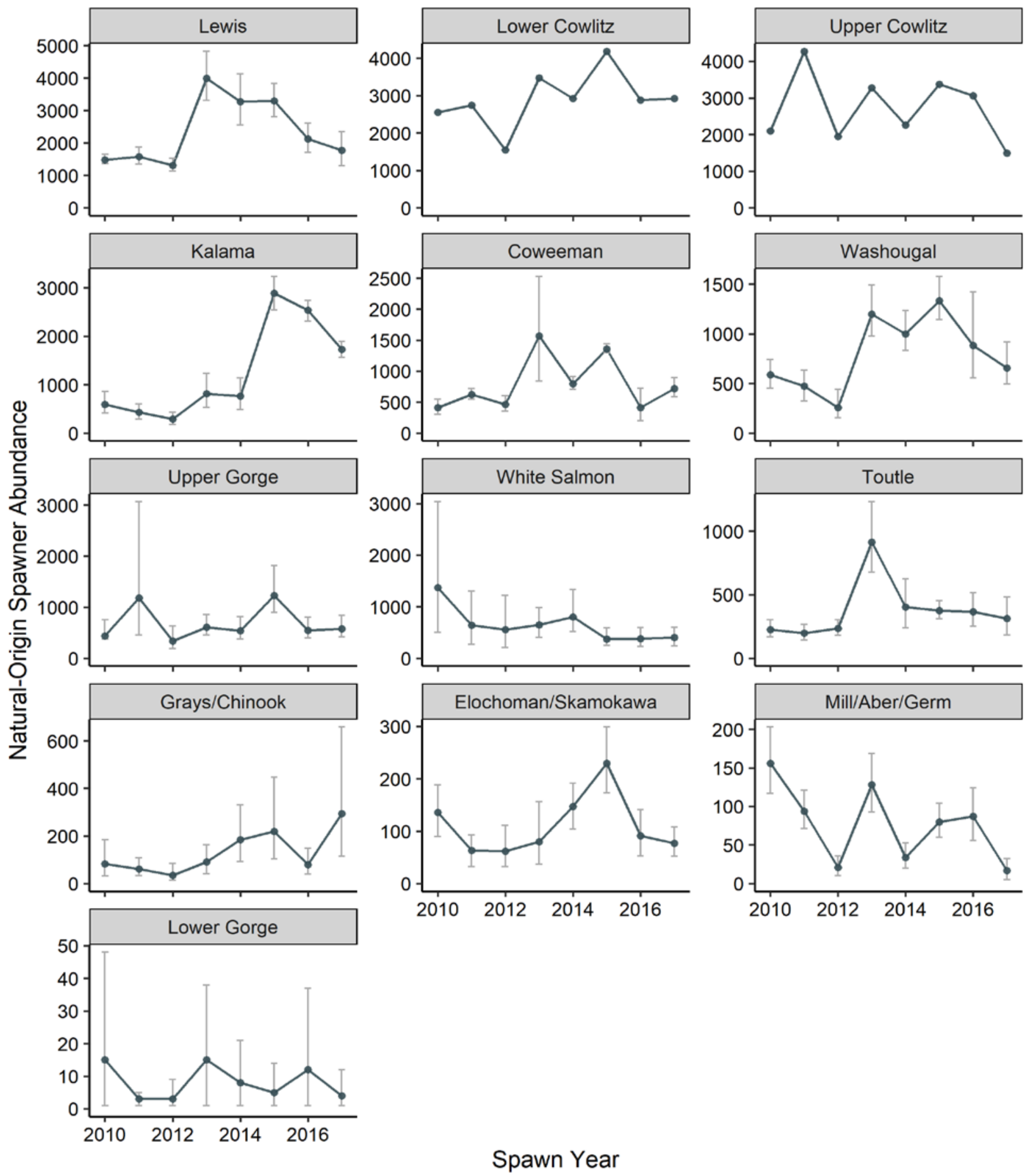

Figure 4. Estimates of adult natural-origin spawner abundance by population for Tule fall Chinook salmon populations within the Washington portion of the LCR ESU for spawn years 2010-2017. The blue circles represent means of the posterior distribution, the grey error bars represent the 95% credible intervals, and blue line represents the trend over the time series. Note the Salmon Creek population was not monitored. Estimates of precision are not available for the Lower Cowlitz population. Estimates of precision are underestimated for spawn years 2010-2012 for the Lewis population as no estimates of precision are currently available for the North Fork Lewis Tule fall Chinook subpopulation.

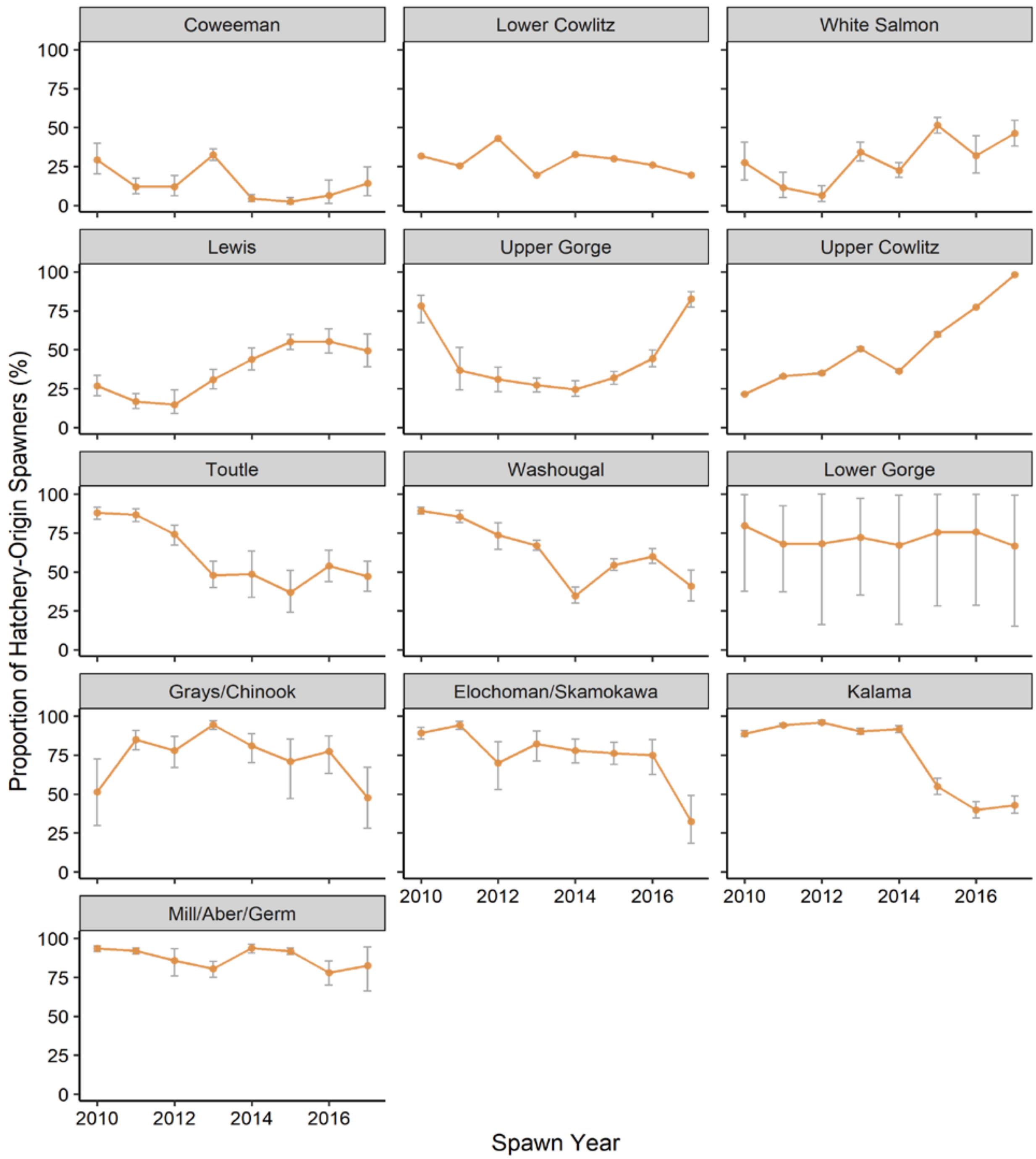

Figure 5. Estimates of adult proportion of hatchery-origin spawners by population for Tule fall Chinook salmon populations within the Washington portion of the LCR ESU for spawn years 2010-2017. The orange circles represent means of the posterior distribution, the grey error bars represent the 95% credible intervals, and orange line represents the trend over the time series. Note the Salmon Creek population was not monitored. Estimates of precision are not available for the Lower Cowlitz population. Estimates of precision are underestimated for spawn years 2010-2012 for the Lewis population as no estimates of precision are currently available for the North Fork Lewis Tule fall Chinook subpopulation.

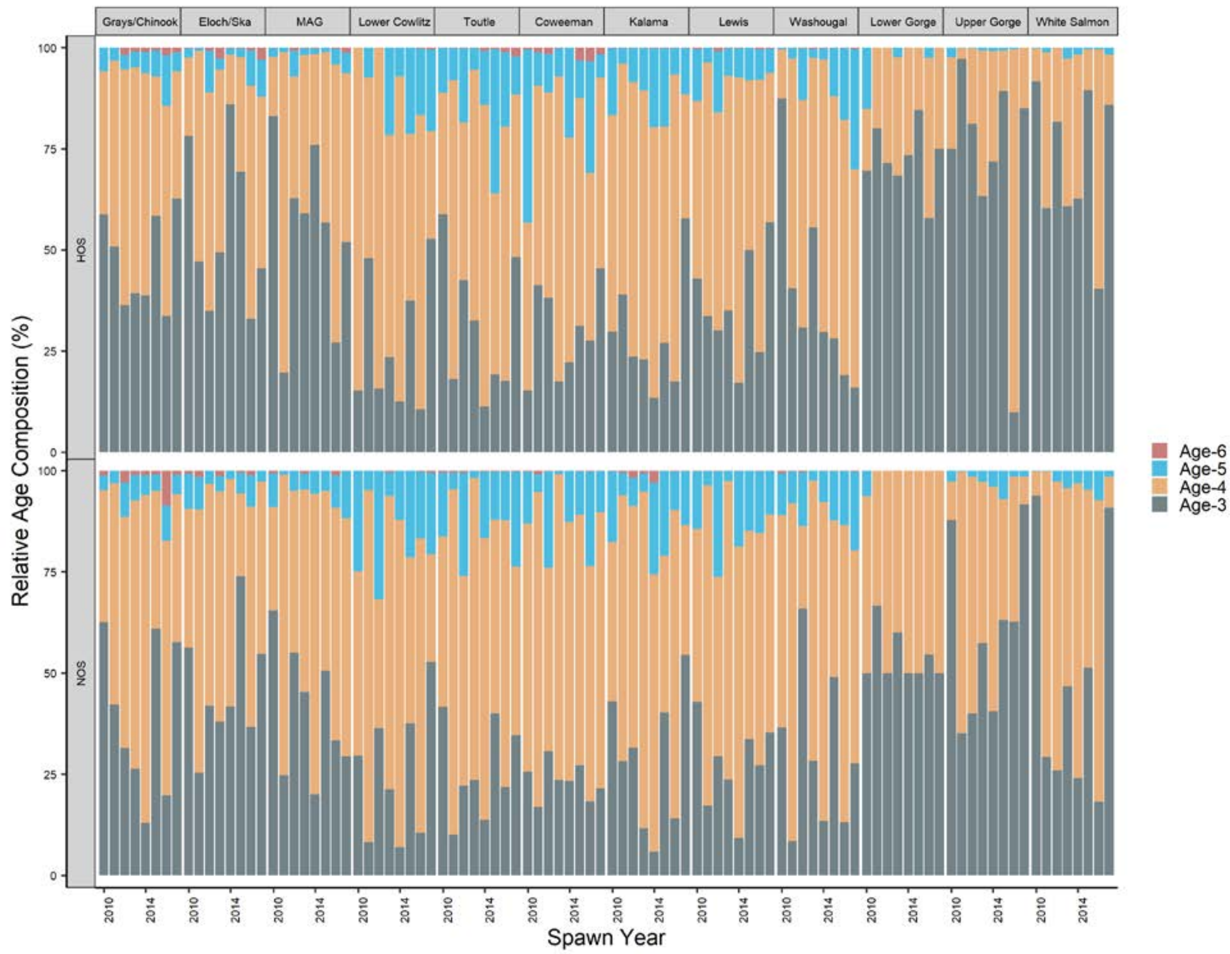

Figure 6. Estimates of relative age composition of adult Tule fall Chinook salmon spawners by population within the Washington portion of the LCR ESU for spawn years 2010-2017. Note the Salmon Creek population is not monitored.

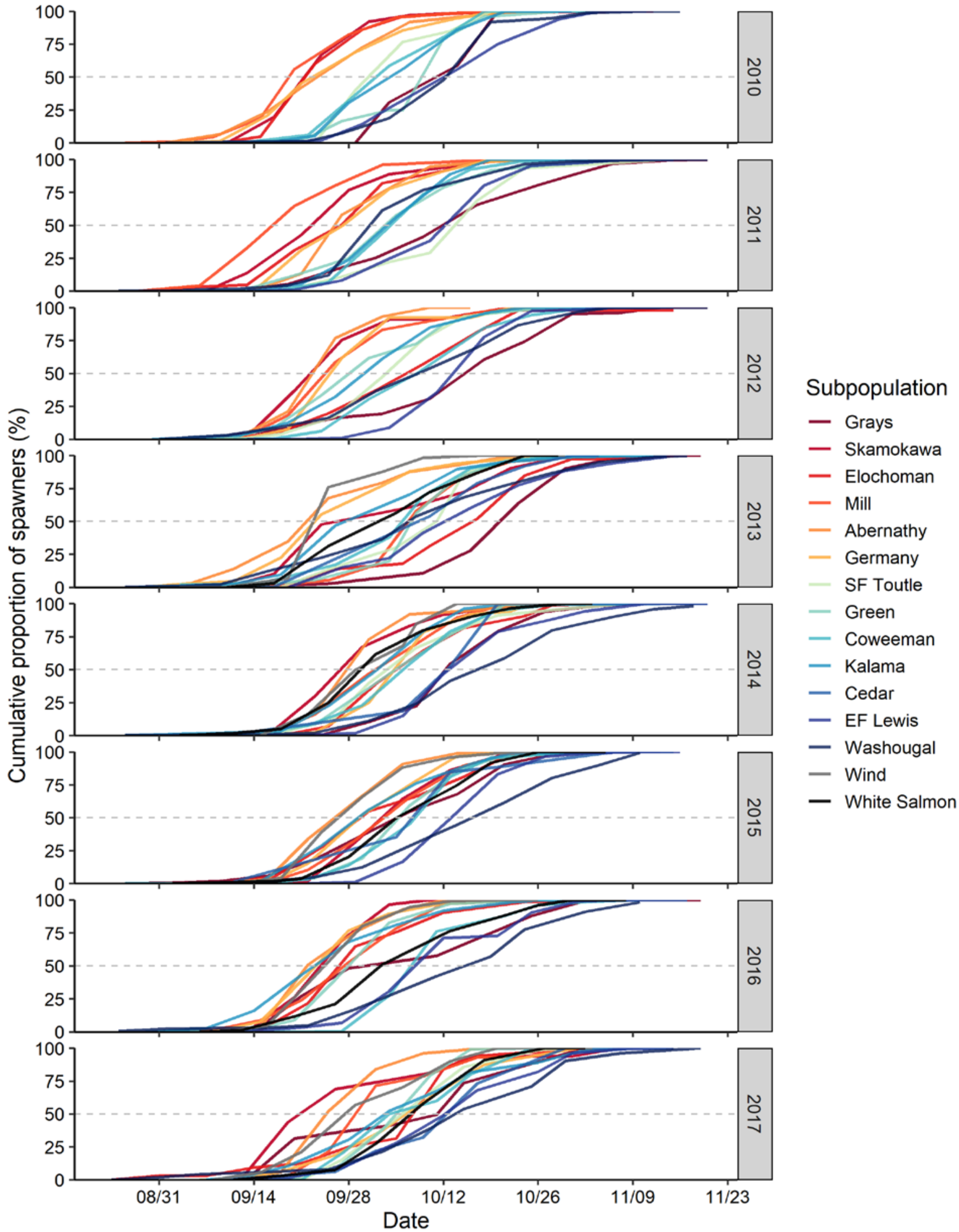

Figure 7. Spawn timing of adult Tule fall Chinook salmon spawners by population within the Washington portion of the LCR ESU based on cumulative counts of live adult Chinook salmon identified as spawners for spawn years 2010-2017. Note the Salmon Creek population was not monitored.

Estimates of Adult Spawner Abundance and Other Viable Salmonid Population Parameters by Population

Grays/Chinook

The Grays/Chinook fall Chinook population consists of the Grays and Chinook subpopulations. However, no monitoring for Chinook salmon was done in the Chinook River in spawn years 2013-2017 because populations are believed to be very small or non-existent due to the small size of the watershed, and habitat impacts including a partial barrier tide gate. In the Grays subpopulation, there are three stock components: HOR Tule fall Chinook salmon, HOR SAB fall Chinook salmon, and NOR fall Chinook salmon that are comprised of Tules, naturalized SABs, and their hybrids (Roegner et al. 2010).

Based on study design considerations, we reported estimates using trapezoidal AUC for spawn years 2013-2016 and redd expansion for spawn year 2017. We used basin- and year-specific estimates of apparent residence time for AUC estimates (Table 6) and year- and basin-specific proportion of females and year-specific estimates of apparent females per redd for the redd-based estimate (Table 7). These values were further refined based on the peak count relationship across years and the final values are reported in Table 9. Abundance estimation methods for 2010-2012 can be found in Table 1 and Rawding et al. (2014), Rawding et al. (2019), and Buehrens et al. (2019). We updated 2010-2012 adult fall Chinook salmon estimates with our improved models.

Over the last eight years, estimated total spawner abundance for the Grays/Chinook fall Chinook population, has ranged from a low of 160 adults in 2012 to a high of 1,644 adults in 2013 (Table 10). The proportion of hatchery-origin spawners has ranged from a low of 47.7% in 2017 to a high of 94.5% in 2013 (Figure 8, Table 10). NOR spawner abundance estimates have ranged from a low of 35 in 2012 to a high of 295 in 2017 (Figure 8, Table 10).

A total of 58 ad-clipped, 321 left ventral-clipped or ad+left ventral-clipped, and 63 unclipped carcasses were aged across spawn years 2013-2017. The age structure was similar between clip types and variable year to year but age-3 and age-4 were the dominate age classes for each clip type in all years (Appendix E: Table E1). Annual sex ratios were variable but close to evenly split between males and females (Table 10). The 50% spawn date for fall Chinook salmon in the Grays River was highly variable ranging from the last week of September to the third week of October in spawn years 2010-2017 (Figure 9).

In spawn years 2013-2017, most of the fall Chinook salmon redds were observed in the Grays River below the canyon and in the West Fork Grays River. There were very few fall Chinook salmon redds observed above the canyon on the upper Grays River (0-4% of the annual redds). There was also substantial use in two tributaries (Fossil and Hull creeks) with ~29% of the annual fall Chinook salmon redds found in these two tributaries in 2013. Fall Chinook salmon redd distribution is displayed in Figure 10.

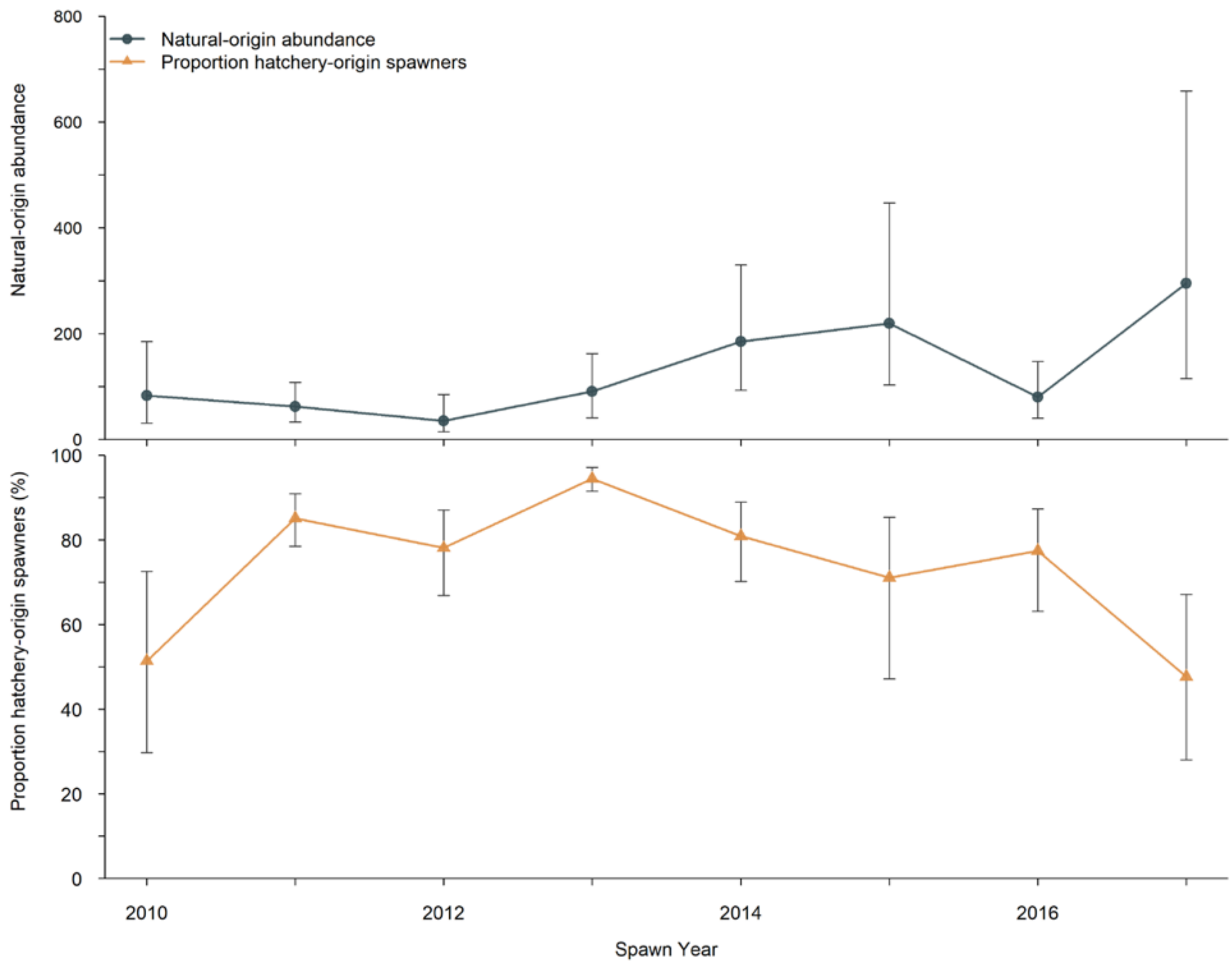

Figure 8. Estimates of adult natural-origin spawner abundance and the proportion of hatchery-origin spawners for the Grays/Chinook fall Chinook population for spawn years 2010-2017. The blue circles and orange triangles represent means of the posterior distribution for natural-origin abundance and proportion of hatchery-origin spawners, respectively. The grey error bars represent the 95% credible intervals.

Table 10. Estimates of apparent residence time and apparent females per redd (mean, standard deviation, and 95% credible intervals of the posterior distribution) used to develop total spawner abundance estimates for the adult Grays/Chinook fall Chinook population for spawn years 2010-2017.

Spawn Year	Parameter	Mean	SD	L 95% CI	U 95% CI
2010	AFpR	1.18	0.47	0.55	2.36
2011[a]	---	---	---	---	---
2012	AFpR	0.96	0.41	0.51	2.05
2013	ART	7.70	1.50	5.05	10.99
2014	ART	6.37	1.23	4.19	9.01
2015	ART	6.68	1.38	4.25	9.74
2016	ART	6.54	1.38	4.12	9.46
2017	AFpR	1.12	0.46	0.54	2.31

[a]JS used for 2011 estimate.

Table 11. Estimates of spawner abundance, including sex-, origin-, and stock-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Grays/Chinook fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	170	416	160	1,644	969	762	356	565
	SD	69	84	75	334	200	164	76	245
	L 95% CI	80	295	73	1,110	653	501	236	257
	U 95% CI	344	626	359	2,407	1,419	1,140	533	1,186
Males	Mean	67	154	67	874	404	311	171	303
	SD	33	35	35	209	139	85	59	143
	L 95% CI	24	100	27	557	203	176	73	124
	U 95% CI	147	238	159	1,378	743	511	306	671
Females	Mean	104	262	93	770	565	451	185	262
	SD	46	56	45	188	160	108	63	129
	L 95% CI	43	180	39	458	277	278	87	99
	U 95% CI	218	400	213	1,196	912	708	332	587
HOS SAB	Mean	70	292	69	1450	501	265	171	100
	SD	34	61	34	296	115	71	48	64
	L 95% CI	25	205	29	983	318	147	92	25
	U 95% CI	156	443	159	2,130	765	428	281	266
HOS Tule	Mean	17	62	56	102	283	278	104	170
	SD	12	17	28	30	77	95	33	94
	L 95% CI	3	36	23	54	164	117	54	54
	U 95% CI	51	101	128	172	460	491	186	409
NOS	Mean	83	62	35	91	185	219	80	295
	SD	40	19	19	31	61	95	27	141
	L 95% CI	31	33	14	41	93	103	40	115
	U 95% CI	185	108	85	162	330	447	147	658
pF	Mean	60.9%	63.0%	58.1%	46.9%	58.3%	59.2%	51.8%	46.3%
	SD	9.8%	4.0%	7.7%	6.3%	11.1%	6.5%	13.0%	9.6%
	L 95% CI	40.7%	55.0%	42.7%	32.1%	31.7%	46.6%	27.6%	27.7%
	U 95% CI	79.4%	70.6%	72.9%	58.1%	76.3%	72.4%	78.2%	65.1%
pHOS	Mean	51.4%	85.1%	78.1%	94.5%	80.9%	71.1%	77.4%	47.7%
	SD	11.1%	3.2%	5.2%	1.4%	4.9%	10.8%	6.0%	10.2%
	L 95% CI	29.8%	78.5%	66.9%	91.5%	70.2%	47.2%	63.1%	28.1%
	U 95% CI	72.6%	90.9%	87.1%	97.1%	88.9%	85.4%	87.3%	67.2%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

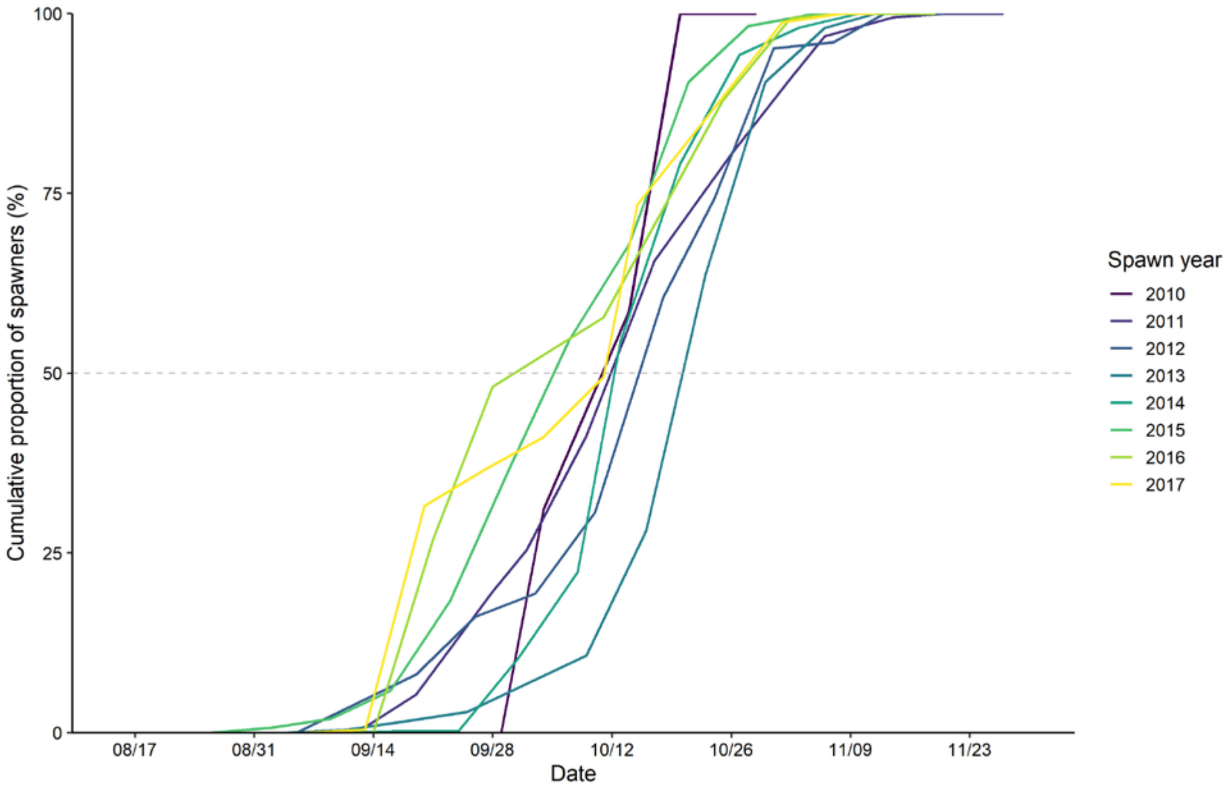

Figure 9. Spawn timing of the Grays/Chinook fall Chinook population based on cumulative counts of live adult Chinook salmon identified as spawners for spawn years 2010-2017.

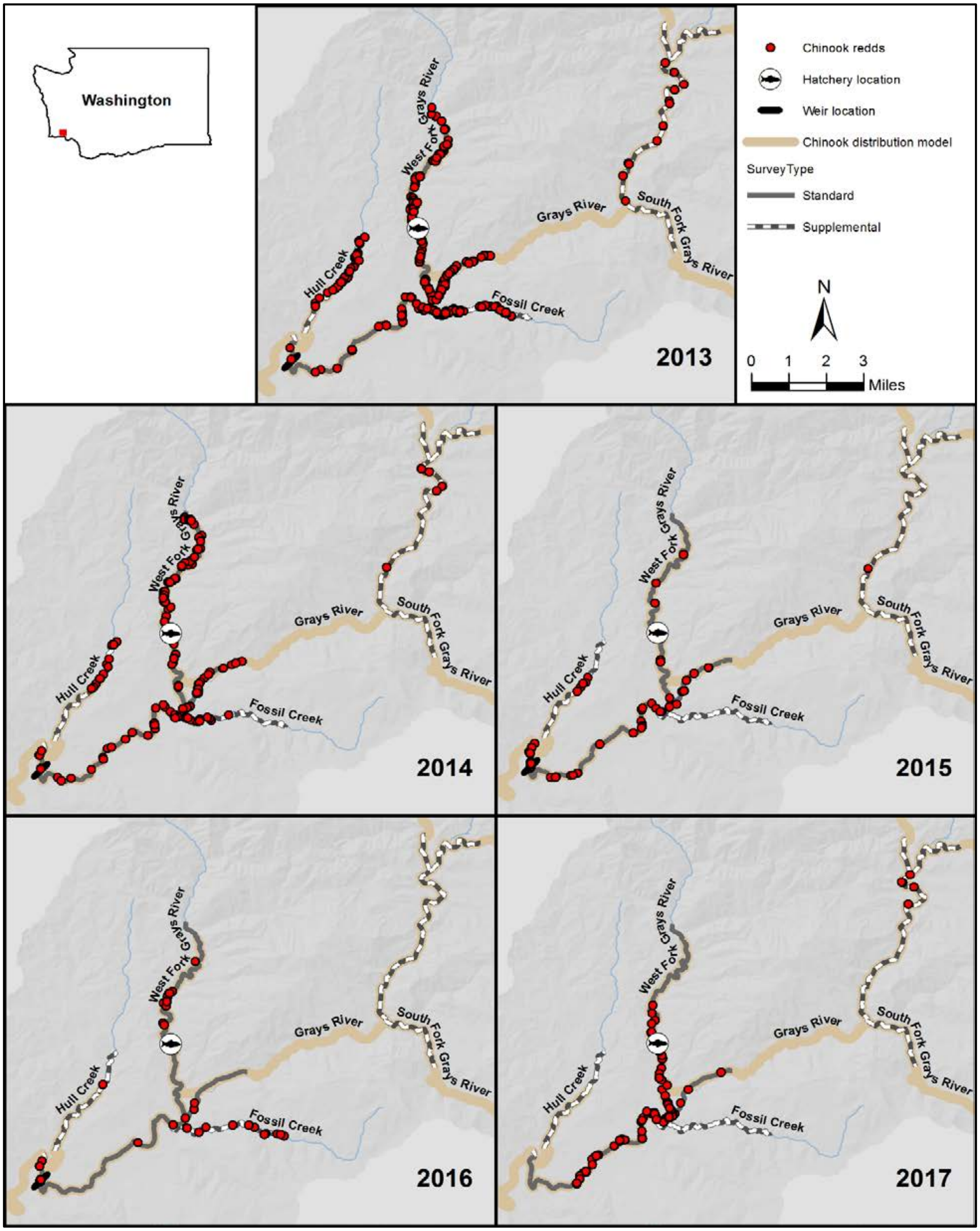

Figure 10. Redd distribution of Grays/Chinook fall Chinook population for spawn years 2013-2017. The grey colored layer represents the area surveyed, the black rectangle represents the weir location, and the individual redd locations are shown as a red colored circle. Note that no surveys were conducted in the Chinook River.

Elochoman/Skamokawa

The Elochoman/Skamokawa fall Chinook population consists of the Elochoman and Skamokawa subpopulations. Additionally, the Elochoman/Skamokawa fall Chinook population may be divided into three stock components: HOR Tule fall Chinook salmon, HOR SAB fall Chinook salmon, and NOR fall Chinook salmon. We report on the Elochoman and Skamokawa subpopulations individually (Appendix F: Tables F1-F4) but also combined them to develop population-level estimates.

For spawn years 2014-2017, we used the LP estimator for the area upstream of the weir site (RM 2.7) then adjusted that estimate to account for prespawn mortality and sport catch to derive an estimate of spawner abundance. Due to a small number of carcass recoveries, we choose to use a binomial model and pool carcass recoveries and live spawner counts to boost sample sizes. We tested for size and sex selectivity to ensure the equal catchability assumption of the LP estimator was not violated (Appendix H: Tables H1-H4). In 2013, when assumptions of the LP estimator were not met, we used redd expansion for the area upstream of the weir site to develop spawner abundance estimates. For the area downstream of the weir site, we used redd expansion based on census redd counts and year- and basin-specific proportion of females and apparent females per redd for all years (Table 7 and Table 8). These values were further refined based on the peak count relationship across years and the final values are reported in Table 11. For the Skamokawa subpopulation, we reported estimates using trapezoidal AUC for spawn years 2013-2017 using year-specific estimates of apparent residence time (Table 5). These values were further refined based on the peak count relationship across years and the final values are reported in Table 11. Abundance estimation methods for 2010-2012 can be found in Table 1 and Rawding et al. (2014), Rawding et al. (2019), and Buehrens et al. (2019). We updated 2010-2012 adult fall Chinook salmon estimates with our improved models.

Over the last eight years, estimated total spawner abundance for the Elochoman/Skamokawa fall Chinook population has ranged from a low of 114 adults in 2017 to a high of 1,260 adults in 2010 (Table 12). The proportion of hatchery-origin spawners has ranged from a low of 32.3% in 2017 to a high of 94.2% in 2011 (Figure 9, Table 12). NOR spawner abundance estimates has ranged from a low of 62 in 2012 to a high of 230 in 2015 (Figure 9, Table 12).

Scale samples from the Elochoman subpopulation were blended between live fish passed upstream at the weir and untagged carcasses recovered on spawning ground surveys (fish that were not sampled at the weir). For the Skamokawa subpopulation, only scale samples from carcasses were collected. Between the two subpopulations, a total of 288 ad-clipped, 11 left ventral-clipped or ad+left ventral-clipped, and 503 unclipped fish were aged across spawn years 2013-2017. The age structure was similar between clip types and variable year to year but age-3 and age-4 were the dominate age classes for each clip type in all years (Appendix E: Table E2). Annual sex ratios were relatively consistent with slightly more males in all of the years except one (Table 12). The 50% spawn date for fall Chinook salmon in the Elochoman/Skamokawa population was variable ranging from the last week of September to the mid-October in spawn years 2010-2017 (Figure 12).

In spawn years 2013-2017, most of the fall Chinook salmon redds in the Elochoman subpopulation were found between the Elochoman River intake for Beaver Creek Hatchery (RM

5.9) downstream to the Elochoman Valley Road Bridge (RM 4.3). However, in 2013, high stream flows in late September resulted in redd distribution higher in the basin with 47% of the annual redds observed above the Elochoman Salmon Hatchery (RM 9.5). For Skamokawa subpopulation, redd distribution was variable year to year and redds were observed up to a mile past the confluence of Standard and McDonald creeks. Fall Chinook salmon redd distribution is displayed in Figure 13.

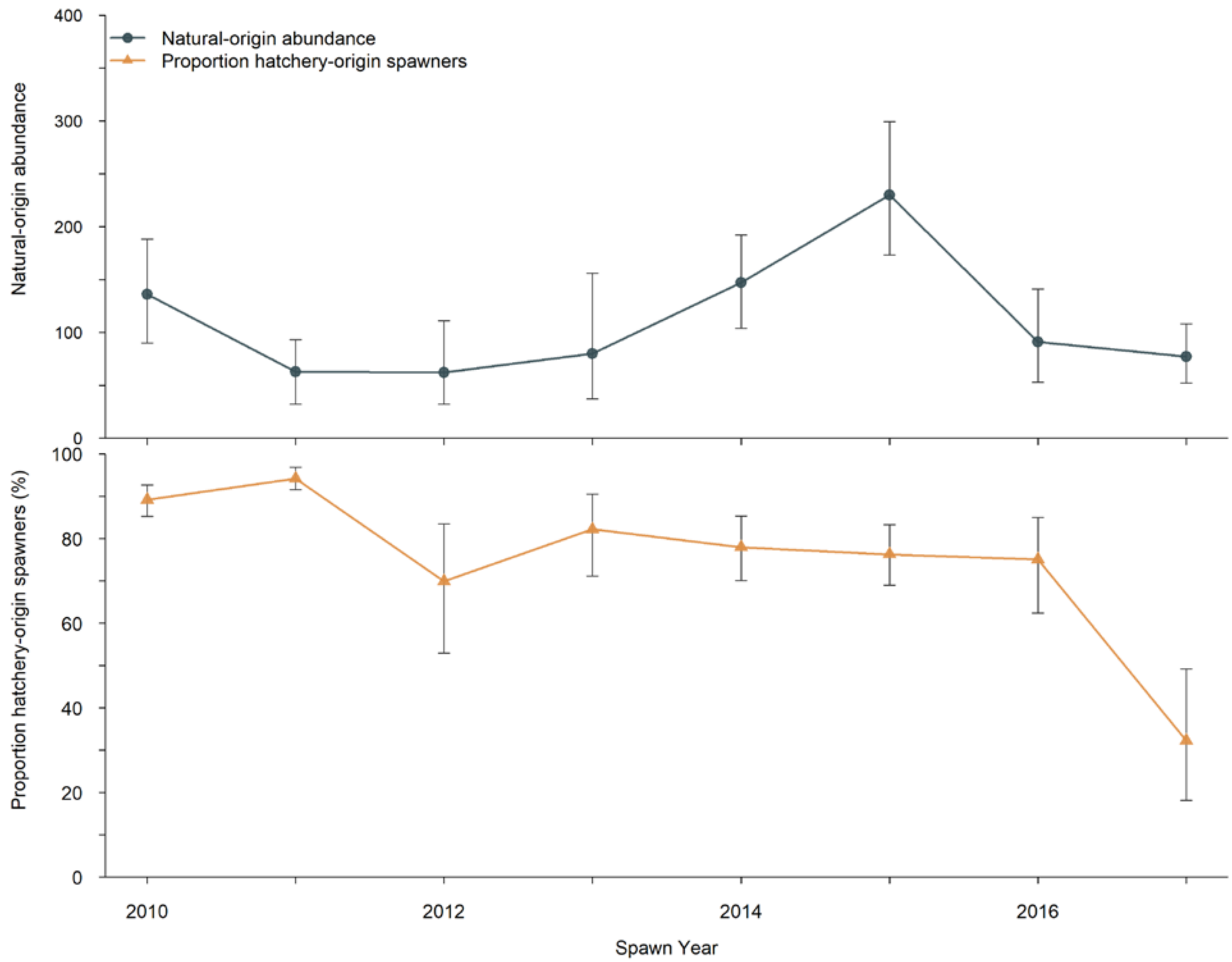

Figure 11. Estimates of adult natural-origin spawner abundance and the proportion of hatchery-origin spawners for the Elochoman/Skamokawa fall Chinook population for spawn years 2010-2017. The blue circles and orange triangles represent means of the posterior distribution for natural-origin abundance and proportion of hatchery-origin spawners, respectively. The grey error bars represent the 95% credible intervals.

Table 12. Estimates of apparent residence time and apparent females per redd (mean, standard deviation, and 95% credible intervals of the posterior distribution) used to develop total spawner abundance estimates for the adult Elochoman/Skamokawa fall Chinook population for spawn years 2010-2017.

Spawn Year	Subpopulation	Parameter	Mean	SD	L 95% CI	U 95% CI
2010	Elochoman	AFpR	1.16	0.35	0.60	1.99
2011	Elochoman	AFpR	1.16	0.35	0.59	1.93
2012	Elochoman	AFpR	1.21	0.35	0.62	2.00
2013	Elochoman	AFpR	0.98	0.30	0.54	1.67
2014	Elochoman	AFpR	1.24	0.37	0.63	2.08
2015	Elochoman	AFpR	1.22	0.35	0.65	1.98
2016	Elochoman	AFpR	1.21	0.54	0.53	2.55
2017	Elochoman	AFpR	1.15	0.35	0.59	1.95
2010	Skamokawa	ART	7.75	1.72	4.61	11.29
2011	Skamokawa	ART	6.21	1.23	3.95	8.77
2012	Skamokawa	ART	6.45	1.34	3.99	9.31
2013	Skamokawa	ART	8.39	1.92	4.93	12.39
2014	Skamokawa	ART	6.93	1.42	4.28	9.84
2015	Skamokawa	ART	8.00	1.77	4.76	11.63
2016	Skamokawa	ART	6.88	1.45	4.27	9.96
2017	Skamokawa	ART	6.46	1.81	3.38	10.50

Table 13. Estimates of spawner abundance, including sex-, origin-, and stock-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Elochoman/Skamokawa fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	1,260	1,083	206	448	680	989	368	114
	SD	116	93	37	102	120	194	69	26
	L 95% CI	1,063	937	149	295	504	715	263	79
	U 95% CI	1,521	1,295	290	689	975	1,459	530	175
Males	Mean	690	479	107	243	381	523	215	63
	SD	68	58	27	66	76	108	51	24
	L 95% CI	574	381	63	142	266	366	134	26
	U 95% CI	844	609	167	398	561	780	332	115
Females	Mean	570	604	99	205	300	466	153	51
	SD	59	55	27	53	59	99	42	20
	L 95% CI	473	509	56	123	209	321	87	18
	U 95% CI	707	721	158	330	440	705	249	94
HOS SAB	Mean	5	10	18	76	14	21	13	5
	SD	4	5	11	28	8	11	10	4
	L 95% CI	0	3	5	34	3	7	2	1
	U 95% CI	17	24	46	142	36	47	40	16
HOS Tule	Mean	1,119	1,010	126	292	520	738	264	32
	SD	109	88	28	71	112	174	61	15
	L 95% CI	933	871	83	183	357	494	171	14
	U 95% CI	1,363	1,211	191	457	797	1,168	406	70
NOS	Mean	136	63	62	80	147	230	91	77
	SD	26	15	21	31	23	32	23	15
	L 95% CI	90	32	32	37	104	173	53	52
	U 95% CI	188	93	111	156	192	299	141	108
pF	Mean	45.3%	55.8%	48.0%	46.0%	44.1%	47.1%	41.5%	44.7%
	SD	2.0%	3.0%	9.2%	6.7%	4.4%	3.7%	8.1%	15.1%
	L 95% CI	41.5%	50.0%	30.3%	33.0%	35.2%	39.9%	26.2%	16.8%
	U 95% CI	49.3%	61.6%	65.7%	59.2%	52.9%	54.3%	57.9%	73.0%
pHOS	Mean	89.2%	94.2%	69.9%	82.2%	78.0%	76.3%	75.1%	32.3%
	SD	1.9%	1.3%	7.9%	5.0%	4.0%	3.7%	5.8%	7.9%
	L 95% CI	85.3%	91.6%	53.0%	71.2%	70.1%	69.0%	62.4%	18.2%
	U 95% CI	92.7%	96.9%	83.5%	90.5%	85.4%	83.3%	85.0%	49.2%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

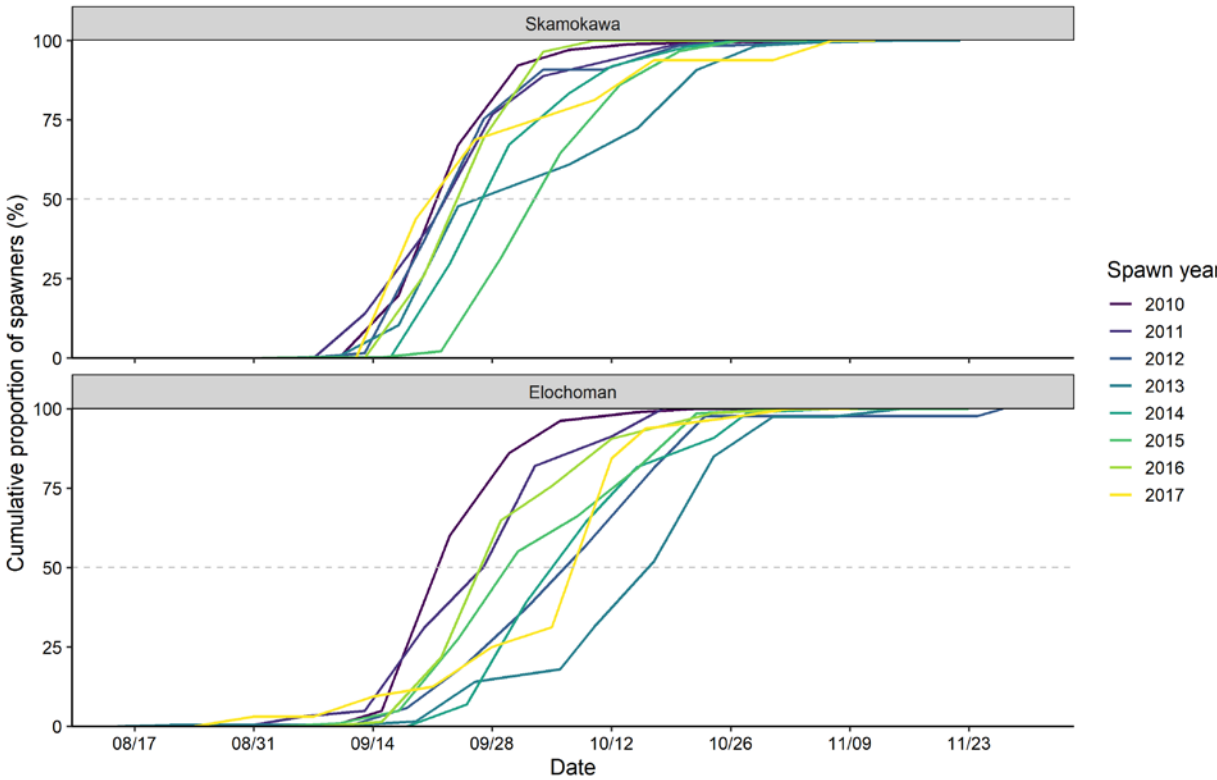

Figure 12. Spawn timing of the Elochoman/Skamokawa fall Chinook population based on cumulative counts of live adult Chinook salmon identified as spawners for spawn years 2010-2017.

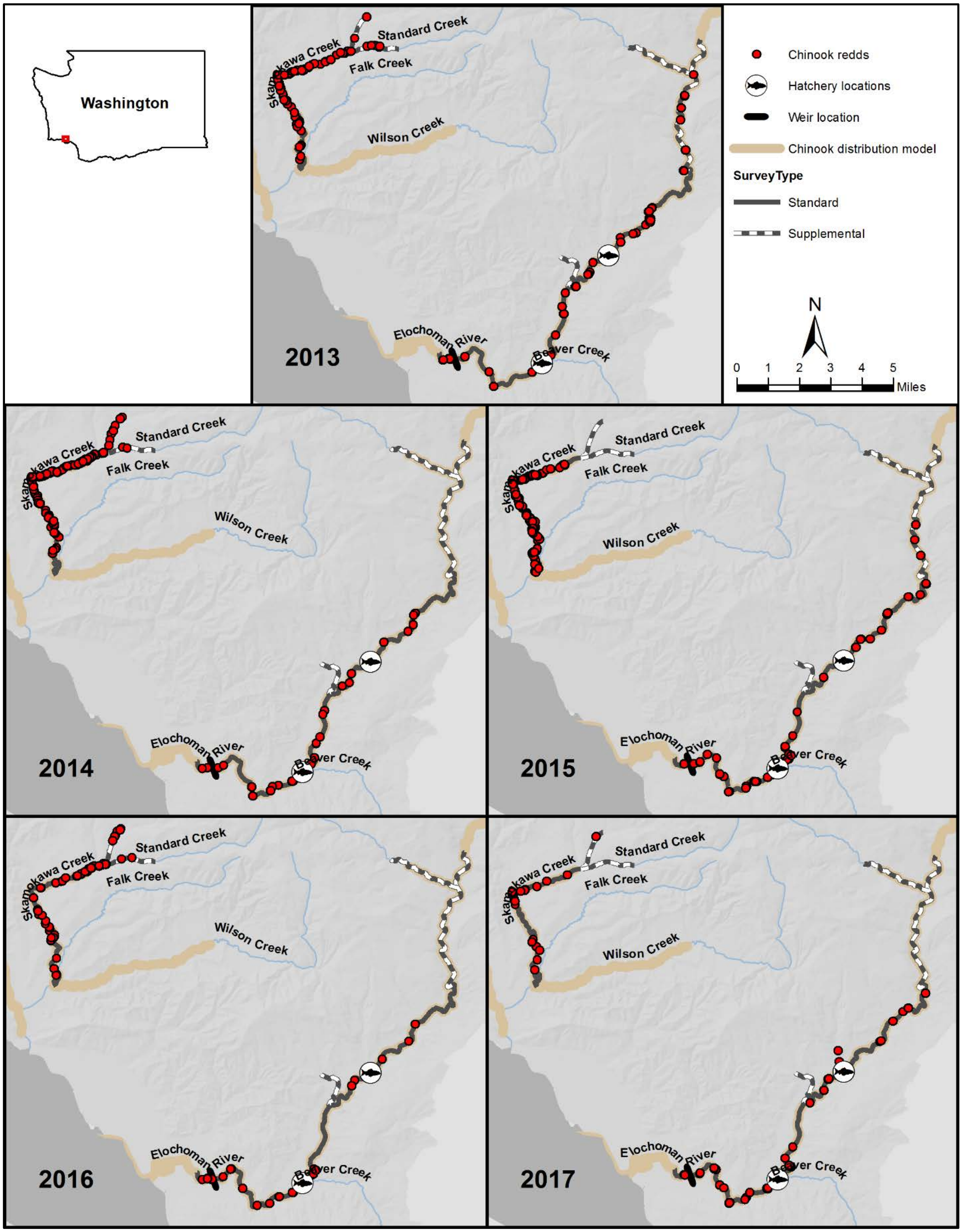

Figure 13. Redd distribution of the Elochoman/Skamokawa fall Chinook population for spawn years 2013-2017. The grey colored layer represents the area surveyed, the black rectangle represents the weir location, and the individual redd locations are shown as a red colored circle.

Mill/Aber/Germ (MAG)

The Mill/Aber/Germ (MAG) Tule fall Chinook population consists of three subpopulations: Mill, Abernathy, and Germany. These creeks enter the Columbia River within two miles of each other. We report on each subpopulations individually to be consistent with historic reporting and because the subpopulations are part of Washington State's Intensively Monitored Watershed (IMW) program, which requires reporting at this scale (Appendix F: Tables F5-F10). We also combine subpopulation estimates to develop and report estimates at the population-level.

For the Mill and Abernathy subpopulations, fall Chinook salmon abundance estimates were developed using the JS model for 2014 and 2015, which was adjusted for prespawn mortality to develop an estimate of spawners. We conducted additional analyses to test for size and sex selectivity to ensure the equal catchability assumption of the JS model was met, GOF to ensure the data fit the different JS models, and model selection to help inform the best model to use for the data (Appendix G: Tables G1-G8). For 2013, 2016, and 2017, a small number of recaptures required us to use an alternative method. For these years, we used trapezoidal AUC using basin- and year-specific estimates of ART (Table 6). These values were further refined based on the peak count relation across years and the final values are reported in Table 13. For the Germany subpopulation, fall Chinook salmon abundance estimates were developed using the JS model for 2013, 2014, and 2015, which was adjusted for prespawn mortality to develop an estimate of spawners. We conducted additional analyses to test for size and sex selectivity to ensure the equal catchability assumption of the JS model was met, GOF to ensure the data fit the different JS models, and model selection to help inform the best model to use for the data (Appendix G: Tables G9-G14). For 2016 and 2017, a small number of recaptures required us to use an alternative method. For these years, we used trapezoidal AUC using basin- and year-specific estimates of ART (Table 6). These values were further refined based on the peak count relation across years and the final values are reported in Table 13. Abundance estimation methods for 2010-2012 can be found in Table 1 and Rawding et al. (2014), Rawding et al. (2019), and Buehrens et al. (2019). We updated 2010-2012 adult fall Chinook salmon estimates with our improved models.

Over the last eight years, estimated total spawner abundance for the MAG Tule fall Chinook population has ranged from a low of 95 adults in 2017 to a high of 2,410 adults in 2010 (Table 14). The proportion of hatchery-origin spawners has ranged from a low of 78.1% in 2016 to a high of 93.8% in 2014 (Figure 14, Table 14). NOR spawner abundance estimates has ranged from a low of 17 in 2017 to a high of 156 in 2010 (Figure 14, Table 14).

A total of 1,303 ad-clipped and 169 unclipped carcasses were aged across spawn years 2013-2017. The age structure varied year to year but age-3 and age-4 were the dominate age classes for each clip type in all years (Appendix E: Table E3). Annual sex ratios were quite variable between years (Table 14). The 50% spawn date for fall Chinook in the MAG population ranged from the third week of September to the first week of October in spawn years 2010-2017 (Figure 15).

We do not report on redd distribution for the MAG Tule fall Chinook population as individual redd locations were not georeferenced.

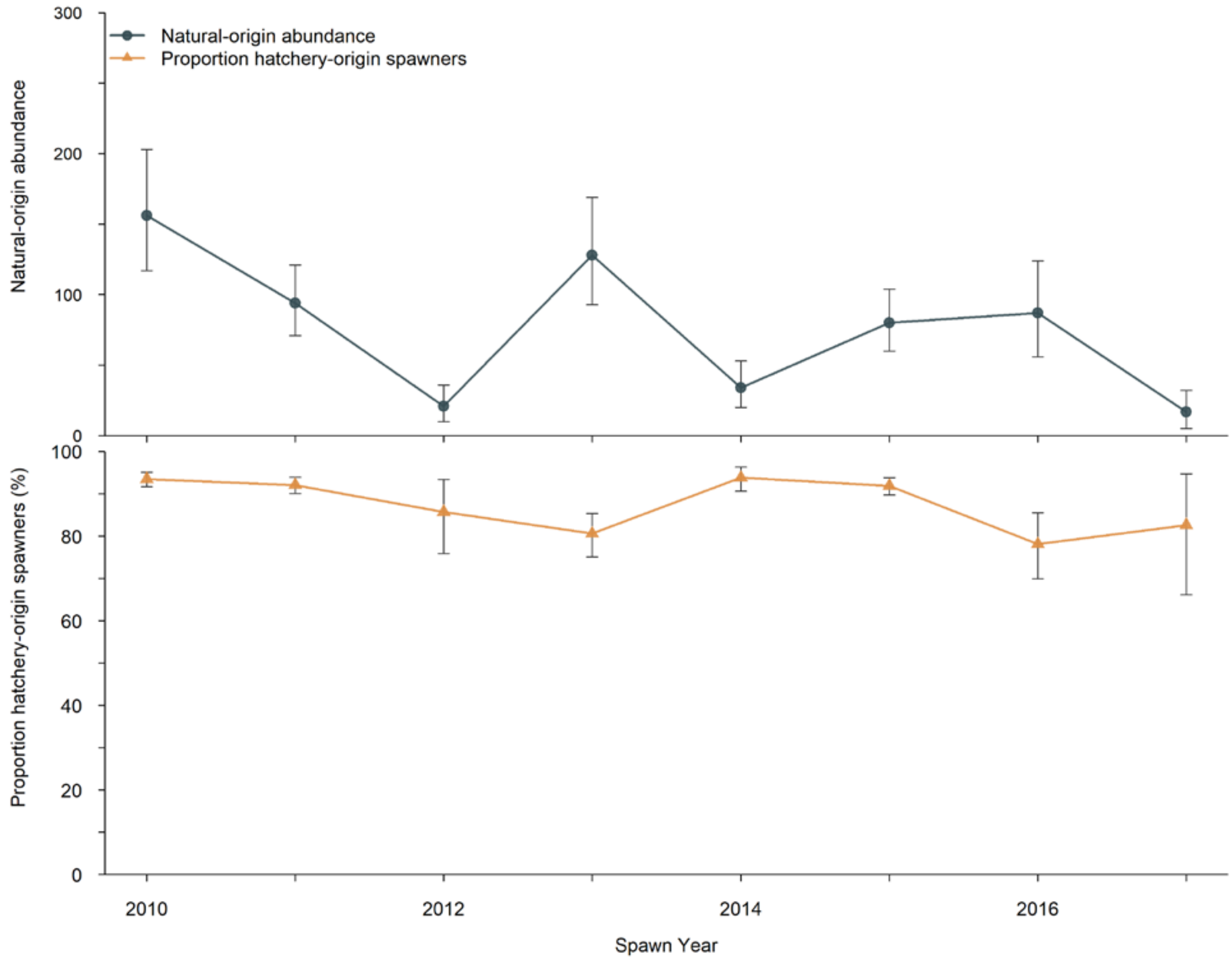

Figure 14. Estimates of adult natural-origin spawner abundance and the proportion of hatchery-origin spawners for the MAG Tule fall Chinook population for spawn years 2010-2017. The blue circles and orange triangles represent means of the posterior distribution for natural-origin abundance and proportion of hatchery-origin spawners, respectively. The grey error bars represent the 95% credible intervals.

Table 14. Estimates of apparent residence time (mean, standard deviation, and 95% credible intervals of the posterior distribution) used to develop total spawner abundance estimates for the adult MAG Tule fall Chinook population for spawn years 2010-2017.

Spawn Year	Subpopulation	Parameter	Mean	SD	L 95% CI	U 95% CI
2010[a]	Mill	ART	---	---	---	---
2011[a]	Mill	ART	---	---	---	---
2012	Mill	ART	6.89	1.04	4.95	8.98
2013	Mill	ART	7.55	1.19	5.42	10.09
2014[a]	Mill	ART	---	---	---	---
2015[a]	Mill	ART	---	---	---	---
2016	Mill	ART	6.84	1.04	4.92	9.00
2017	Mill	ART	4.08	0.29	3.39	4.48
2010	Abernathy	ART	8.24	1.29	5.93	10.95
2011	Abernathy	ART	---	---	---	---
2012	Abernathy	ART	7.18	0.83	5.42	8.57
2013	Abernathy	ART	7.87	1.04	5.81	9.78
2014[a]	Abernathy	ART	---	---	---	---
2015[a]	Abernathy	ART	---	---	---	---
2016	Abernathy	ART	6.28	0.60	4.95	7.22
2017	Abernathy	ART	8.17	1.31	5.80	10.92
2010	Germany	ART	7.03	1.12	5.02	9.43
2011	Germany	ART	7.00	1.03	5.03	9.00
2012[a]	Germany	ART	---	---	---	---
2013	Germany	ART	7.40	1.23	5.19	9.98
2014	Germany	ART	7.17	1.13	5.10	9.51
2015	Germany	ART	7.07	0.94	5.12	8.63
2016[a]	Germany	ART	---	---	---	---
2017[a]	Germany	ART	---	---	---	---

[a]JS used for final estimate.

Table 15. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult MAG Tule fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	2,410	1,192	147	657	554	989	397	95
	SD	109	55	14	49	39	42	35	8
	L 95% CI	2,217	1,100	124	572	495	921	339	81
	U 95% CI	2,646	1,319	178	762	646	1,083	473	114
Males	Mean	1,277	468	84	352	309	475	160	32
	SD	66	28	11	33	26	27	22	9
	L 95% CI	1,156	418	64	291	266	427	122	16
	U 95% CI	1,414	527	107	420	367	534	207	51
Females	Mean	1,133	725	63	306	245	514	236	63
	SD	67	38	10	31	23	28	28	11
	L 95% CI	1,015	659	44	251	206	465	187	43
	U 95% CI	1,278	811	85	371	296	575	295	85
HOS	Mean	2,254	1,098	126	530	520	908	310	78
	SD	104	52	13	43	38	39	32	10
	L 95% CI	2,069	1,011	102	452	461	843	254	60
	U 95% CI	2,482	1,219	155	622	608	997	380	100
NOS	Mean	156	94	21	128	34	80	87	17
	SD	22	13	7	20	9	11	17	7
	L 95% CI	117	71	10	93	20	60	56	5
	U 95% CI	203	121	36	169	53	104	124	32
pF	Mean	47.0%	60.8%	43.0%	46.5%	44.2%	52.0%	59.6%	66.6%
	SD	1.5%	1.5%	5.7%	3.1%	2.6%	1.8%	4.4%	9.3%
	L 95% CI	44.1%	57.9%	32.3%	40.6%	39.1%	48.5%	50.7%	47.2%
	U 95% CI	50.1%	63.6%	54.1%	52.6%	49.4%	55.5%	67.9%	83.2%
pHOS	Mean	93.5%	92.1%	85.7%	80.6%	93.8%	91.9%	78.1%	82.6%
	SD	0.9%	1.0%	4.5%	2.6%	1.5%	1.1%	4.0%	7.4%
	L 95% CI	91.7%	90.1%	75.9%	75.1%	90.6%	89.7%	69.9%	66.2%
	U 95% CI	95.1%	93.9%	93.4%	85.4%	96.3%	93.8%	85.5%	94.7%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

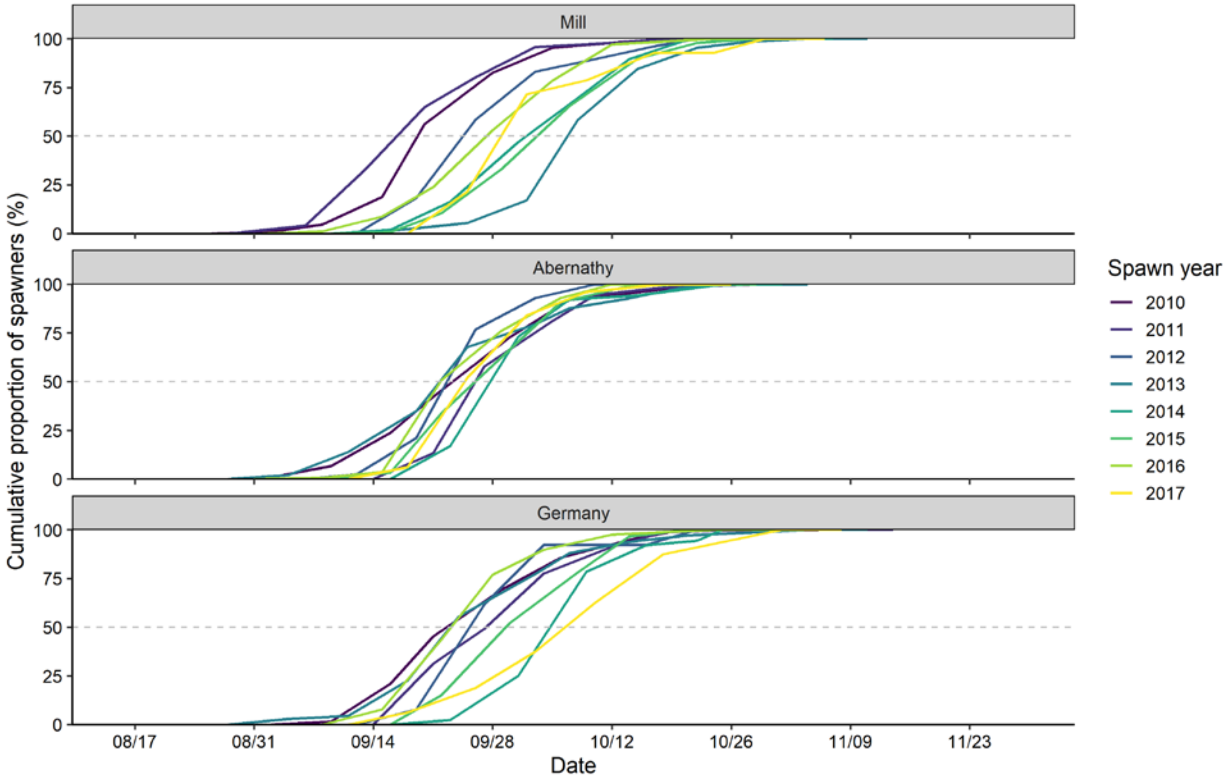

Figure 15. Spawn timing of MAG Tule fall Chinook population based on cumulative counts of live adult Chinook salmon identified as spawners for spawn years 2010-2017.

Lower Cowlitz

We did not use the same analytical approach for the Lower Cowlitz Tule fall Chinook population as we did with other populations. However, we wanted to include these estimates in order to have a comprehensive report with estimates from all of the Washington populations within the LCR ESU. Field and analytical methods used to develop estimates specific to only the Lower Cowlitz Tule fall Chinook population can be found in Gleizes et al. (2014).

Over the last eight years, estimated total spawner abundance has ranged from a low of 2,725 adults in 2017 to a high of 5,981 adults in 2015 (Table 15). The proportion of hatchery-origin spawners has ranged from a low of 19.4% in 2017 to a high of 43.0% in 2012 (Figure 16, Table 15). NOR spawner abundance estimate has ranged from a low of 1,553 in 2012 to a high of 4,186 in 2015 (Figure 16, Table 15).

The age structure varied year to year but age-4 fish were the dominate age class in most years. More age-5 fish were seen in this population than most LCR Tule fall Chinook populations (Appendix E: Table E4). We do not report on sex ratios, spawn timing, or redd distribution for the Lower Cowlitz Tule fall Chinook population.

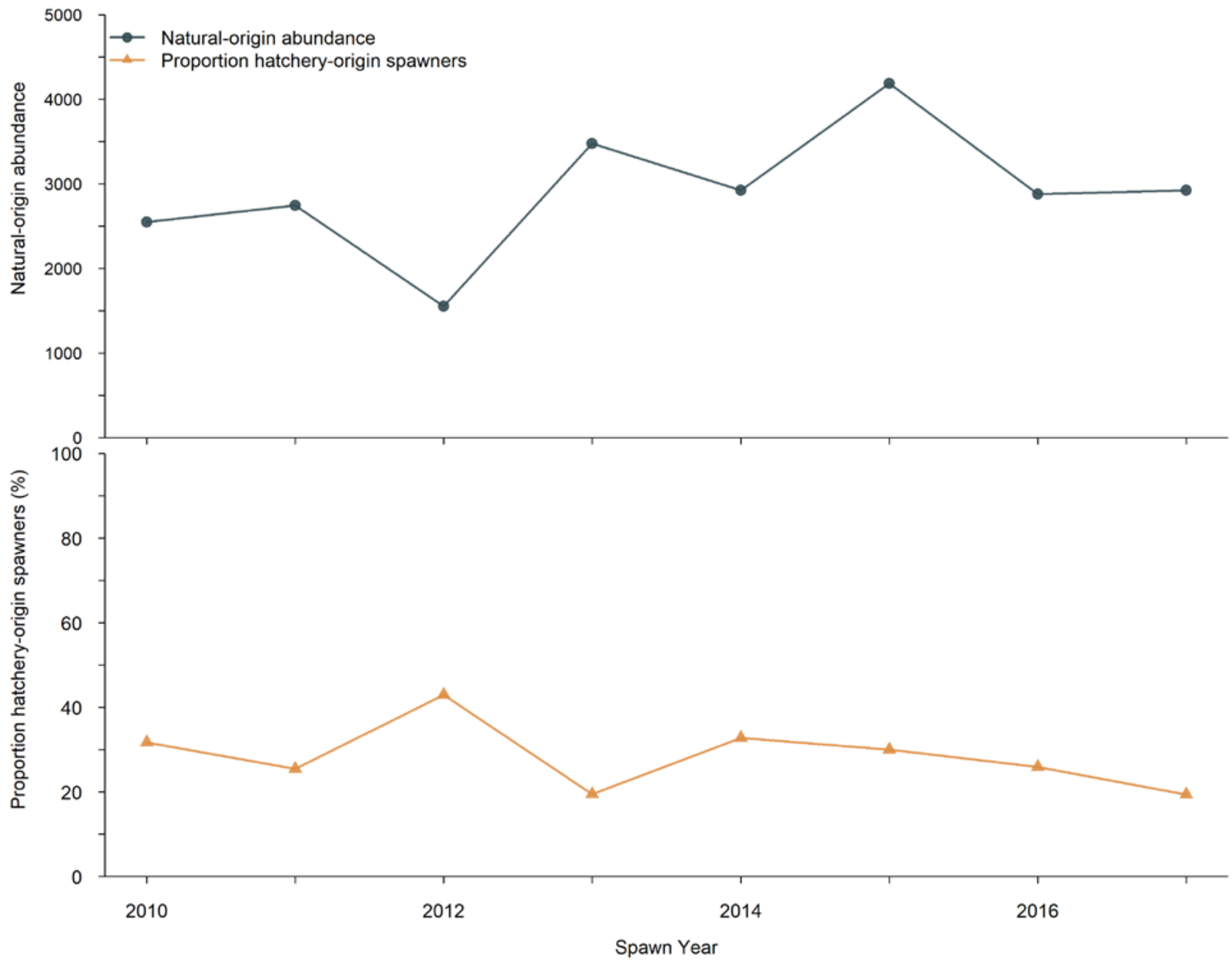

Figure 16. Estimates of adult natural-origin spawner abundance and the proportion of hatchery-origin spawners for the Lower Cowlitz Tule fall Chinook population for spawn years 2010-2017. The blue circles and orange triangles represent means of the posterior distribution for natural-origin abundance and proportion of hatchery-origin spawners, respectively.

Table 16. Estimates of spawner abundance, including sex- and origin-specific estimates, for the adult Lower Cowlitz Tule fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	3,734	3,685	2,725	4,320	4,347	5,981	3,885	3,630
	SD	---	---	---	---	---	---	---	---
	L 95% CI	---	---	---	---	---	---	---	---
	U 95% CI	---	---	---	---	---	---	---	---
HOS	Mean	1,184	940	1,172	843	1,424	1,795	1,007	706
	SD	---	---	---	---	---	---	---	---
	L 95% CI	---	---	---	---	---	---	---	---
	U 95% CI	---	---	---	---	---	---	---	---
NOS	Mean	2,550	2,745	1,553	3,477	2,923	4,186	2,878	2,924
	SD	---	---	---	---	---	---	---	---
	L 95% CI	---	---	---	---	---	---	---	---
	U 95% CI	---	---	---	---	---	---	---	---
pHOS	Mean	31.7%	25.5%	43.0%	19.5%	32.8%	30.0%	25.9%	19.4%
	SD	---	---	---	---	---	---	---	---
	L 95% CI	---	---	---	---	---	---	---	---
	U 95% CI	---	---	---	---	---	---	---	---

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors. No estimate of precision is available.

Upper Cowlitz

The Upper Cowlitz Tule fall Chinook population consists of two subpopulations: the Tilton and Upper Cowlitz. We report on these two subpopulations separately (Appendix F: Table F11-F12) then combine them to develop and report estimates at the population-level.

Spawner abundance estimates for Tule fall Chinook salmon in the Upper Cowlitz population were based on fish captured at the Barrier Dam, trucked, and released into the Tilton, upper Cowlitz, and Cispus rivers. Prior to being transported, fall Chinook salmon were classified as males, females, and jacks and their clip status was recorded. However, scales were not taken to determine age structure. We subtracted the sport harvest from the number of salmon released upstream and assumed no fall back or no mortality due to transportation.

Over the last eight years, total spawner abundance for the Upper Cowlitz Tule fall Chinook population has ranged from a low of 1,520 adults in 2017 to a high of 12,914 adults in 2011 (Table 16). The proportion of hatchery-origin spawners ranged from a low of 44.9% in 2017 to a high of 66.7% in 2013 (Figure 17, Table 16). NOR spawner abundance estimates have ranged from a low of 1,494 in 2017 to high of 4,264 in 2011 (Figure 17, Table 16). Annual sex ratios were variable but close to evenly split between males and females for most years (Table 16).

We do not report on age structure, spawn timing, or redd distribution for the Upper Cowlitz Tule fall Chinook population as the study design was not set-up to evaluate these metrics.

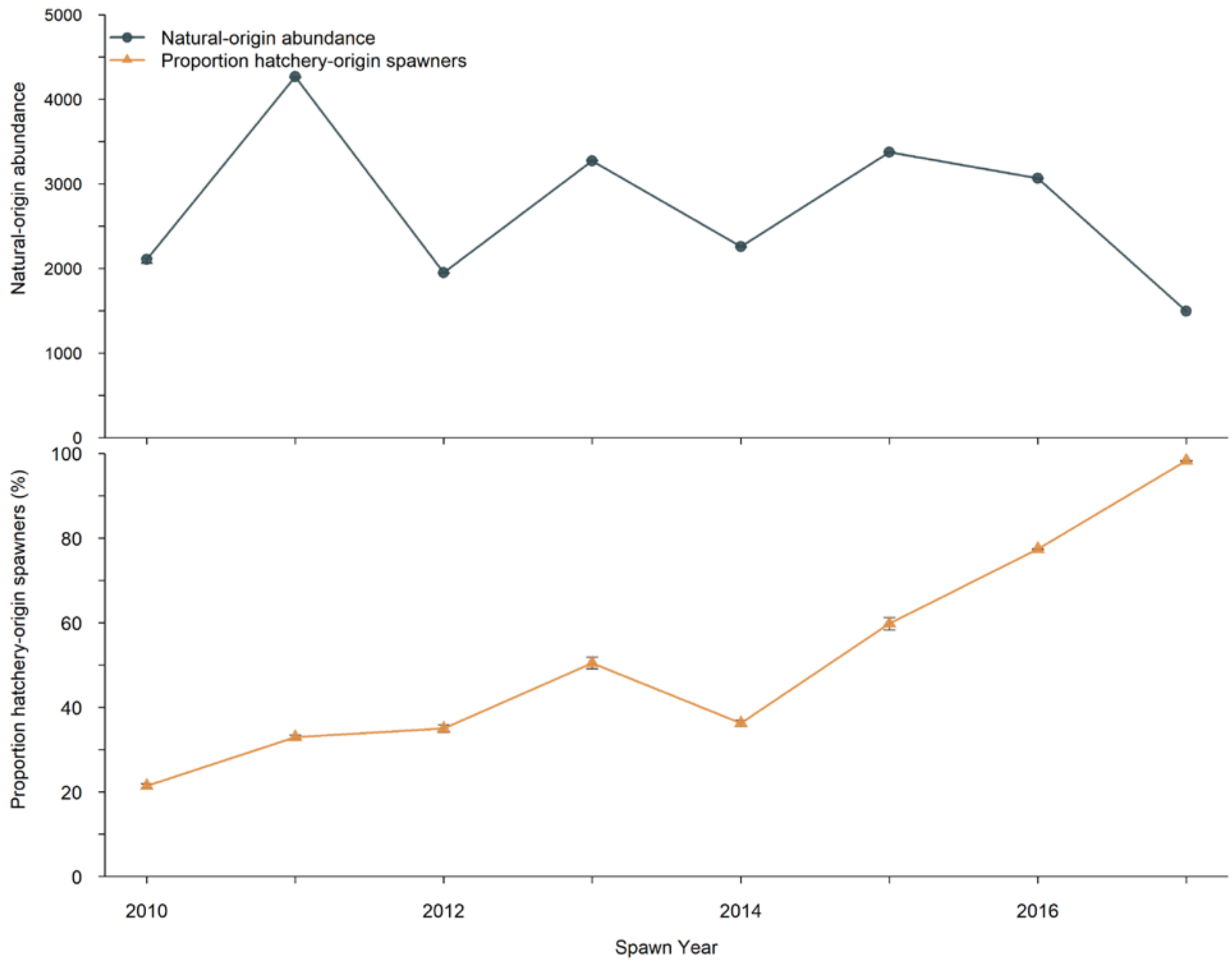

Figure 17. Estimates of adult natural-origin spawner abundance and the proportion of hatchery-origin spawners for the Upper Cowlitz Tule fall Chinook population for spawn years 2010-2017. The blue circles and orange triangles represent means of the posterior distribution for natural-origin abundance and proportion of hatchery-origin spawners, respectively. The grey error bars represent the 95% credible intervals.

Table 17. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Upper Cowlitz Tule fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	9,808	12,914	5,564	6,488	6,231	5,647	3,959	1,520
	SD	106	101	71	91	65	73	1	1
	L 95% CI	9,600	12,720	5,425	6,310	6,104	5,504	3,956	1,518
	U 95% CI	10,020	13,110	5,702	6,667	6,358	5,791	3,961	1,522
Males	Mean	5,744	6,815	2,583	4,327	2,995	3,143	1,811	682
	SD	53	50	35	45	32	37	1	1
	L 95% CI	5,641	6,717	2,514	4,238	2,932	3,071	1,810	682
	U 95% CI	5,848	6,913	2,652	4,417	3,058	3,215	1,813	684
Females	Mean	4,063	6,099	2,980	2,161	3,236	2,505	2,147	837
	SD	53	50	35	45	32	37	1	1
	L 95% CI	3,960	6,001	2,911	2,072	3,173	2,433	2,146	837
	U 95% CI	4,167	6,197	3,049	2,251	3,299	2,577	2,149	839
HOS	Mean	7,704	8,651	3,616	3,215	3,972	2,272	894	26
	SD	107	101	71	91	65	73	3	1
	L 95% CI	7,494	8,453	3,477	3,036	3,844	2,129	890	24
	U 95% CI	7,915	8,848	3,755	3,395	4,099	2,416	901	28
NOS	Mean	2,104	4,264	1,948	3,273	2,259	3,375	3,064	1,494
	SD	15	5	2	3	3	1	3	0
	L 95% CI	2,062	4,251	1,943	3,268	2,251	3,372	3,058	1,494
	U 95% CI	2,119	4,271	1,950	3,280	2,263	3,377	3,068	1,494
pF	Mean	41.4%	47.2%	53.6%	33.3%	51.9%	44.4%	54.2%	55.1%
	SD	0.1%	0.0%	0.0%	0.2%	0.0%	0.1%	0.0%	0.0%
	L 95% CI	41.3%	47.2%	53.5%	32.8%	51.9%	44.2%	54.2%	55.1%
	U 95% CI	41.6%	47.3%	53.7%	33.8%	52.0%	44.5%	54.3%	55.1%
pHOS	Mean	78.5%	67.0%	65.0%	49.5%	63.7%	40.2%	22.6%	1.7%
	SD	0.3%	0.3%	0.5%	0.7%	0.4%	0.8%	0.1%	0.1%
	L 95% CI	78.0%	66.5%	64.1%	48.1%	63.0%	38.7%	22.5%	1.6%
	U 95% CI	79.1%	67.5%	65.9%	50.9%	64.5%	41.7%	22.8%	1.8%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

Toutle
The Toutle Tule fall Chinook population consists of the Green and South Fork Toutle subpopulations. A third subpopulation may exist in the North Fork Toutle River, but this area was not surveyed due to high sediment loads resulting from the eruption of Mt. Saint Helens, which caused poor survey conditions, and have historically resulted in zero or negligible use by spawners. We report on the Green and South Fork Toutle subpopulations individually (Appendix F: Table F13-F16) then combine to develop and report estimates at the population-level.

For the Green subpopulation, our LP mark-recapture study design verified that we had a census of fall Chinook salmon passed upstream in 2015. In spawn years 2013, 2014, 2016, and 2017, we used LP estimates for the area upstream of the weir (RM 0.4). We used only carcasses recoveries upstream of the weir site and a hypergeometric model for our LP estimates in 2013, 2014, and 2016. In 2017, low abundance forced us to pooled carcass recoveries and live spawner counts upstream of the weir site to boost sample sizes; as a result, we used a binomial model for this year. We tested for size and sex selectivity to ensure the equal catchability assumption of the LP estimator was not violated (Appendix H: Tables H5-H7). Both the LP estimates and the census count were adjusted for prespawn mortality and sport catch to develop an estimate of spawners for the area upstream of the weir. For the area downstream of the weir, we used redd expansion based on census redd counts using year- and basin-specific estimates of proportion females and year-specific estimates of AFpR (Table 7). These values were further refined based on the peak count relationship across years and the final values are reported in Table 17. For the South Fork Toutle subpopulation, we used redd expansion using year- and basin-specific proportion of females and year-specific estimates of AFpR for spawn years 2013, 2014, and 2017 (Table 7). These AFpR values were further refined based on the peak count relationship across years and the final values are reported in Table 17. For spawn years 2015 and 2016, turbid water conditions throughout the spawning season resulted in only a handful of surveys being conducted early each year. This left limited options in estimating abundance for these two years. Rather than report no estimates, we used the ratio of the total return in the South Fork Toutle to Green in years where we had solid estimates for both subpopulations (2010-2014). We then applied this ratio to our Green estimates for 2015 and 2016 to develop South Fork Toutle subpopulation estimates. These estimates lined up well with what we would have expected estimates to be based on previous years' estimates. While we report on these estimates, they should taken with caution. Abundance estimation methods for 2010-2012 can be found in Table 1 and Rawding et al. (2014), Rawding et al. (2019), and Buehrens et al. (2019). We updated 2010-2012 adult fall Chinook salmon estimates with our improved models.

Over the last eight years, estimated total spawner abundance for the Toutle Tule fall Chinook population has ranged from a low of 594 adults in 2017 to a high of 1,917 adults in 2010 (Table 18). The proportion of hatchery-origin spawners has ranged from a low of 36.8% to a high of 88.1% in 2010 (Figure 18, Table 18). NOR spawner abundance estimates has ranged from a low of 198 in 2011 to a high of 914 in 2013 (Figure 18, Table 18).

Scale samples from the Green subpopulation were blended between live fish passed upstream at the weir and untagged carcasses recovered on spawning ground surveys (fish that were not sampled at the weir). For the South Fork Toutle subpopulation, scale samples from carcasses were collected. Between the two subpopulations, 406 ad-clipped and 1287 unclipped fish were aged across spawn years 2013-2017. The age structure varied year to year but age-3 and age-4 were the dominate age classes (Appendix E: Table E5). Annual sex ratios were variable but close to evenly split between males and females (Table 18). The 50% spawn date for Tule fall Chinook in the Toutle population was variable but typically occurred during the first two weeks of October during spawn years 2010-2017 (Figure 19). Spawn timing data was not available for the South Fork Toutle River in 2015 and 2016 due to poor visibility.

Redds were not georeferenced for the Green subpopulation in 2013. In spawn years 2014-2017, most of the fall Chinook salmon redds in the Green subpopulation were found in lower four miles of the Green River. For the South Fork Toutle subpopulation, redds were not georeferenced in 2015. In spawn years 2013-2014 and 2016-2017, redd distribution in the South Fork Toutle River was relatively consistent year to year with most of the redds observed in the reach between the mouth of Johnson Creek (RM 4.6) and the South Fork Toutle Road Bridge (RM 1.1). Johnson Creek, a tributary to the lower South Fork Toutle River, had 16% of the annual redds observed in the subpopulation in 2013 (a high stream flow year) but there was little use in other years. Fall Chinook salmon redd distribution is displayed in Figure 19.

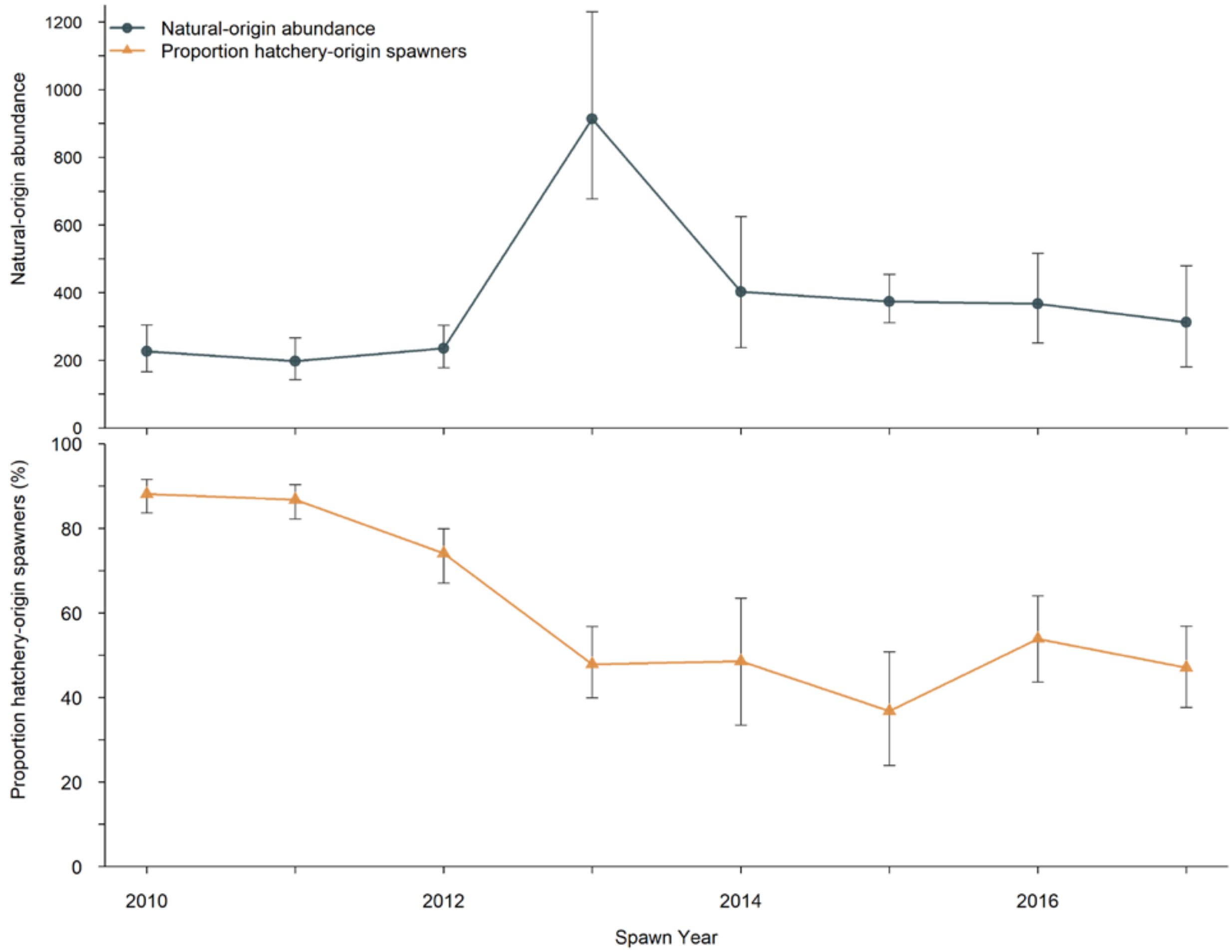

Figure 18. Estimates of adult natural-origin spawner abundance and the proportion of hatchery-origin spawners for the Toutle Tule fall Chinook population for spawn years 2010-2017. The blue circles and orange triangles represent means of the posterior distribution for natural-origin abundance and proportion of hatchery-origin spawners, respectively. The grey error bars represent the 95% credible intervals.

Table 18. Estimates of apparent females per redd (mean, standard deviation, and 95% credible intervals of the posterior distribution) used to develop total spawner abundance estimates for the adult Toutle Tule fall Chinook population for spawn years 2010-2017.

Spawn Year	Subpopulation	Parameter	Mean	SD	L 95% CI	U 95% CI
2010[a]	Green	AFpR	---	---	---	---
2011[a]	Green	AFpR	---	---	---	---
2012	Green	AFpR	1.30	0.67	0.28	2.75
2013	Green	AFpR	1.28	0.67	0.21	2.72
2014[a]	Green	AFpR	---	---	---	---
2015[a]	Green	AFpR	---	---	---	---
2016	Green	AFpR	1.41	0.67	0.29	2.76
2017	Green	AFpR	1.56	0.64	0.50	2.85
2010	South Fork Toutle	AFpR	1.23	0.64	0.28	2.64
2011[a]	South Fork Toutle	AFpR	---	---	---	---
2012	South Fork Toutle	AFpR	1.30	0.65	0.29	2.71
2013	South Fork Toutle	AFpR	1.11	0.37	0.54	2.02
2014[a]	South Fork Toutle	AFpR	---	---	---	---
2015[a]	South Fork Toutle	AFpR	---	---	---	---
2016	South Fork Toutle	AFpR	1.28	0.65	0.27	2.66
2017	South Fork Toutle	AFpR	0.85	0.33	0.40	1.66

[a]Alternate methods used for final estimate.

Table 19. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Toutle Tule fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	1,917	1,498	907	1,754	783	598	803	594
	SD	166	90	60	216	151	88	165	149
	L 95% CI	1,554	1,331	796	1,420	542	467	529	348
	U 95% CI	2,175	1,681	1,029	2,233	1,130	806	1,133	904
Males	Mean	1,187	683	481	804	315	369	400	285
	SD	108	60	46	130	90	65	82	78
	L 95% CI	965	569	393	581	179	265	268	163
	U 95% CI	1,368	806	566	1,068	537	543	599	464
Females	Mean	730	815	425	950	468	229	403	309
	SD	69	68	43	131	99	49	97	81
	L 95% CI	592	690	349	731	298	146	244	173
	U 95% CI	844	962	512	1,256	683	331	607	478
HOS	Mean	1,690	1,300	672	839	380	225	436	281
	SD	168	86	55	124	97	71	113	82
	L 95% CI	1,339	1,135	570	640	218	116	246	144
	U 95% CI	1,941	1,472	789	1,101	604	400	686	460
NOS	Mean	227	198	235	914	403	374	367	312
	SD	35	33	33	143	99	36	70	78
	L 95% CI	166	143	178	677	238	311	251	181
	U 95% CI	305	267	303	1,230	625	454	516	480
pF	Mean	38.1%	54.4%	46.9%	54.2%	59.9%	38.3%	50.0%	52.0%
	SD	1.5%	3.0%	3.6%	4.2%	7.2%	5.9%	4.5%	4.5%
	L 95% CI	35.3%	48.5%	39.9%	46.2%	45.1%	27.6%	40.7%	43.5%
	U 95% CI	41.2%	60.4%	53.8%	62.2%	74.3%	49.7%	58.3%	60.4%
pHOS	Mean	88.1%	86.8%	74.1%	47.9%	48.6%	36.8%	53.9%	47.1%
	SD	2.1%	2.1%	3.3%	4.5%	7.9%	6.7%	5.3%	5.0%
	L 95% CI	83.7%	82.2%	67.1%	39.9%	33.5%	24.0%	43.7%	37.7%
	U 95% CI	91.6%	90.4%	79.9%	56.8%	63.5%	50.8%	64.0%	56.9%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

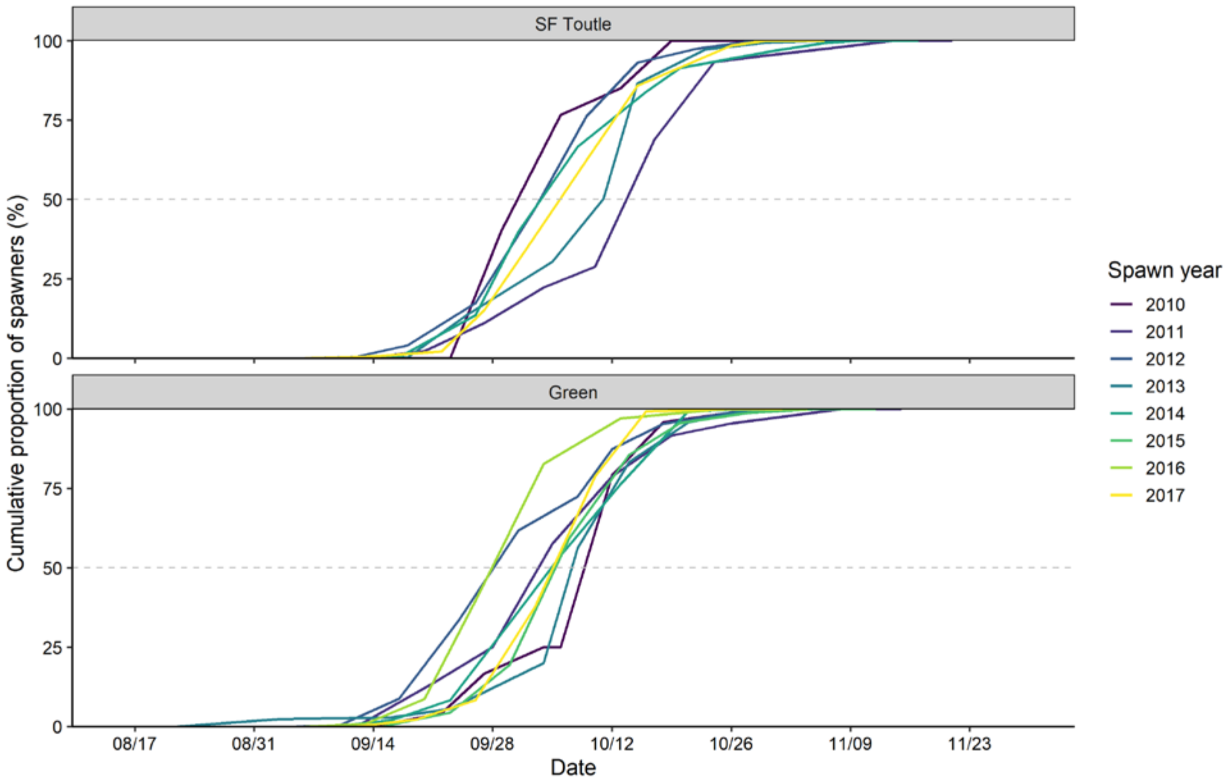

Figure 19. Spawn timing of the Toutle Tule fall Chinook population based on cumulative counts of live adult Chinook salmon identified as spawners for spawn years 2010-2017. Spawn timing data was not available for the South Fork Toutle River in 2015 and 2016 due to poor visibility.

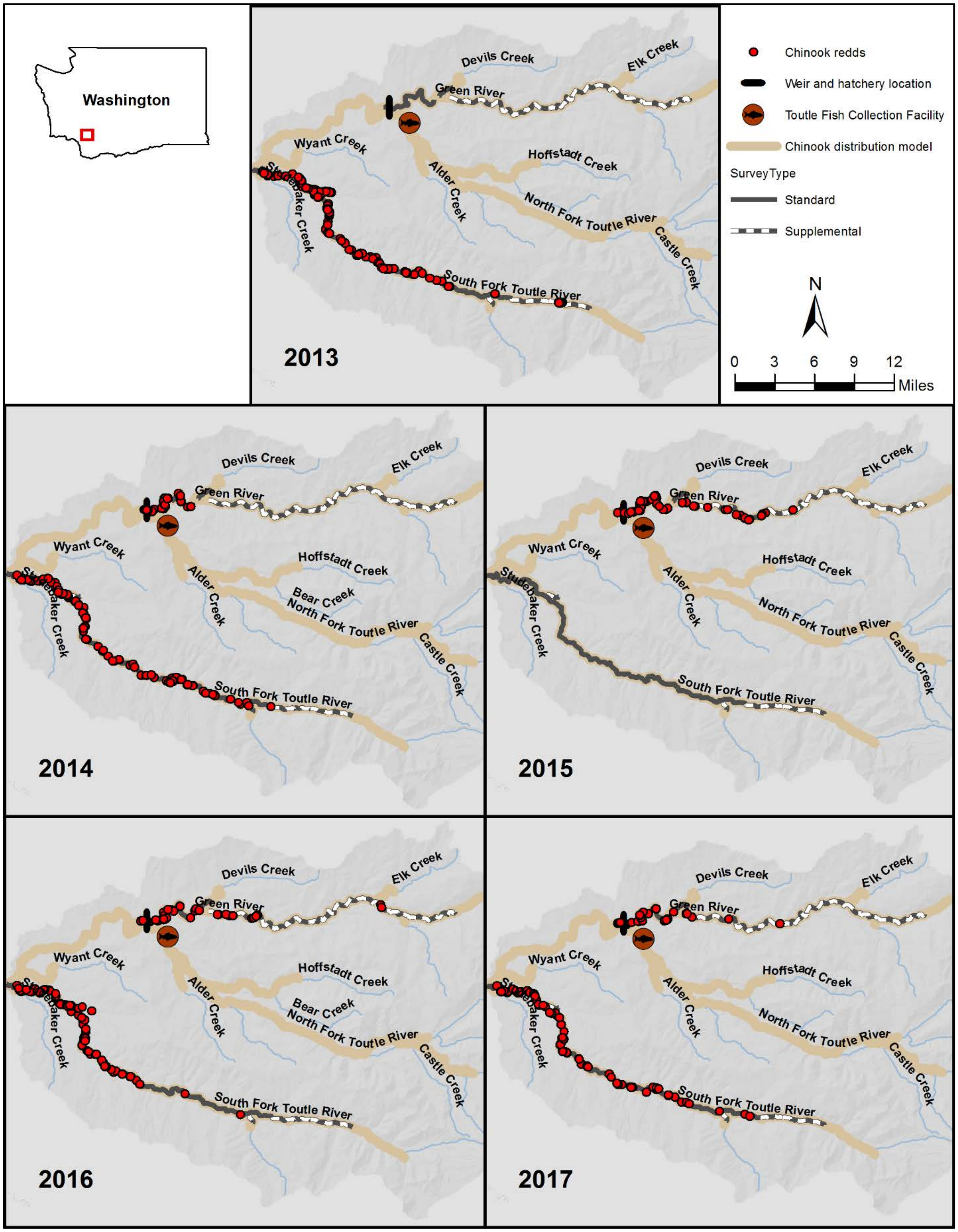

Figure 20. Redd distribution of the Toutle fall Chinook population for spawn years 2013-2017. The grey colored layer represents the area surveyed, the black rectangle represents the weir location, and the individual redd locations are shown as a red colored circle.

Coweeman

For the Coweeman population, we estimated adult spawner abundance using the LP estimator for the area upstream of the weir site (RM 6.8) in 2014, 2015, and 2017. We only used carcass recoveries upstream of the weir site and, therefore, used a hypergeometric model. We tested for size and sex selectivity to ensure the equal catchability assumption of the LP estimator was not violated (Appendix H: Tables H8-H10). These LP estimates were then adjusted for prespawn mortality to develop a spawner estimate upstream of the weir site. In 2013 and 2016, when assumptions of the LP estimator were not met, we used redd expansion for the area upstream of the weir site to develop spawner abundance estimates. For the area downstream of the weir, we used redd expansion for all years with year- and basin-specific estimates of proportion females and year- and basin-specific estimates of AFpR (Table 8). These values were further refined based on the peak count relationship across years and the final values are reported in Table 17. Abundance estimation methods for 2010-2012 can be found in Table 1 and Rawding et al. (2014), Rawding et al. (2019), and Buehrens et al. (2019). We updated 2010-2012 adult fall Chinook salmon estimates with our improved models.

Over the last eight years, total spawner abundance for the Coweeman Tule fall Chinook population has ranged from a low of 439 adults in 2016 to high of 2,322 adults in 2013 (Table 20). The proportion of hatchery-origin spawners ranged from a low of 2.3% in 2015 to a high of 32.5% in 2013 (Figure 21, Table 20). NOR spawner abundance estimates has ranged from a low of 411 in 2016 to a high of 1,568 in 2013 (Figure 21, Table 20).

Scale samples were blended between live fish passed upstream at the weir and untagged carcasses recovered on spawning ground surveys (fish that were not sampled at the weir) for spawn years 2014, 2015, and 2017. For 2013 and 2016, we only used carcasses recovered on spawning ground surveys due to weir failure in late September and the potential for scale samples collected at the weir to be biased as only the early portion of the run was captured. A total of 195 ad-clipped and 1,467 unclipped fish were aged across spawn years 2013-2017. Age structure was variable year to year but age-3 and age-4 were the dominate age classes (Appendix E: Table E6). Annual sex ratios were variable but close to evenly split between males and females in most years with the exception of 2010 when males represented nearly 80% of the spawner abundance (Table 20). The 50% spawn date for fall Chinook salmon in the Coweeman River ranged from approximately October 2 to October 9 in spawn years 2010-2017 (Figure 22).

Redd distribution was variable in spawn years 2013-2017. In 2013, a high streamflow year, over 28% of the observed redds were found in tributaries (Goble, Mullholland, Baird creeks) and redds were observed as high as RM 29 on the Coweeman River. However, in 2014 and 2015, all of the observed redds were found in the Coweeman River and were observed as high as RM 28 and 25, respectively. In 2016 and 2017, 83 and 92% of the observed redds were found in the Coweeman River and redds were observed as high as RM 28 in both years. Fall Chinook salmon redd distribution is displayed in Figure 23.

Table 20. Estimates of apparent females per redd (mean, standard deviation, and 95% credible intervals of the posterior distribution) used to develop total spawner abundance estimates for the adult Coweeman Tule fall Chinook population for spawn years 2010-2017.

Spawn Year	Parameter	Mean	SD	L 95% CI	U 95% CI
2010	AFpR	1.19	0.30	0.67	1.83
2011	AFpR	1.20	0.31	0.67	1.87
2012	AFpR	1.26	0.33	0.70	1.97
2013	AFpR	1.29	0.35	0.70	2.04
2014	AFpR	1.29	0.33	0.72	2.03
2015	AFpR	1.26	0.31	0.71	1.94
2016	AFpR	1.22	0.34	0.65	1.95
2017	AFpR	1.27	0.33	0.70	2.01

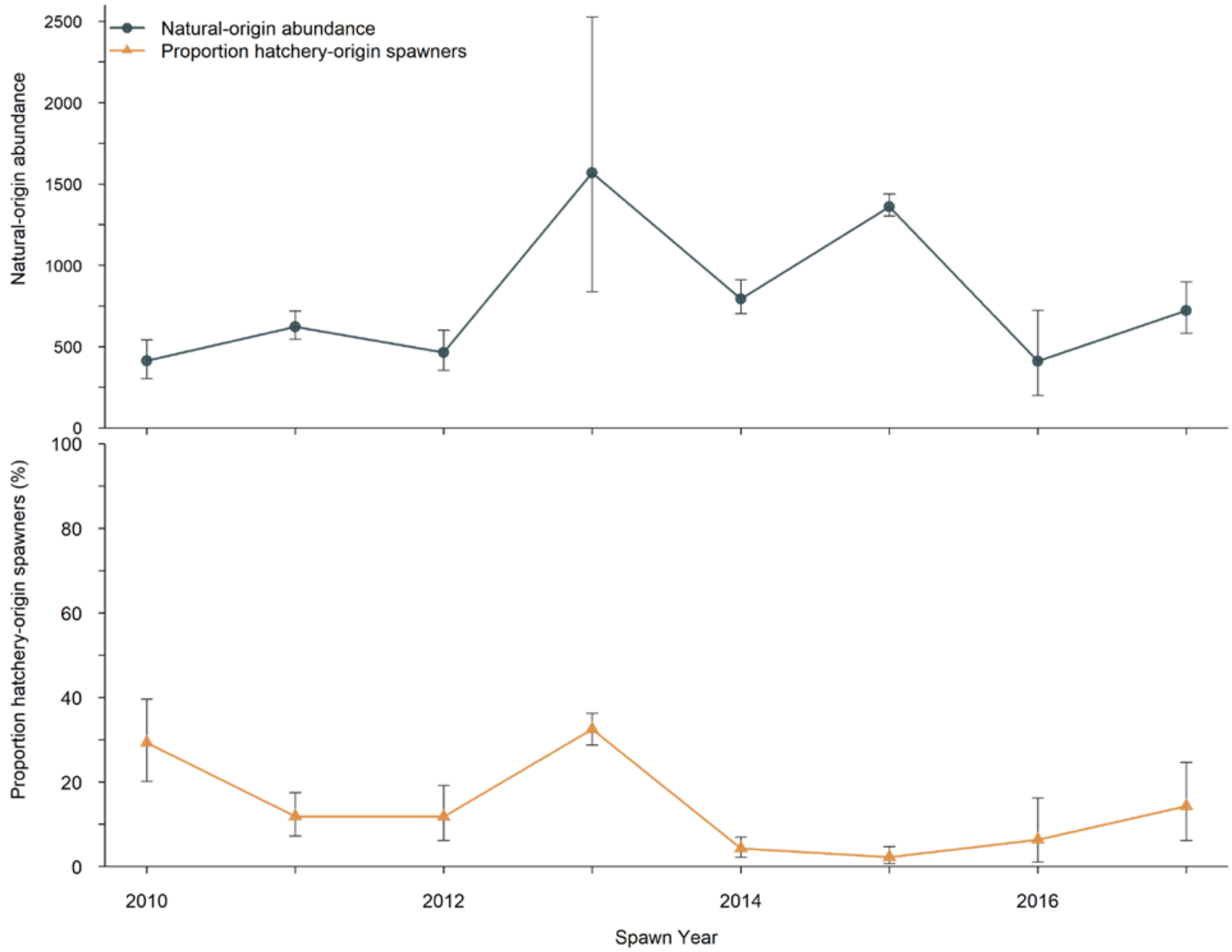

Figure 21. Estimates of adult natural-origin spawner abundance and the proportion of hatchery-origin spawners for the Coweeman Tule fall Chinook population for spawn years 2010-2017. The blue circles and orange triangles represent means of the posterior distribution for natural-origin abundance and proportion of hatchery-origin spawners, respectively. The grey error bars represent the 95% credible intervals.

Table 21. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Coweeman Tule fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	584	707	526	2,322	830	1,391	439	841
	SD	75	52	73	629	57	40	143	82
	L 95% CI	449	619	402	1,253	734	1,326	216	709
	U 95% CI	743	819	690	3,737	957	1,484	766	1,030
Males	Mean	452	337	278	1,179	375	645	209	405
	SD	64	36	48	322	36	42	78	71
	L 95% CI	336	272	194	634	307	563	90	280
	U 95% CI	587	415	384	1,893	451	731	388	555
Females	Mean	132	370	248	1,143	455	747	230	436
	SD	31	38	46	314	43	44	84	72
	L 95% CI	79	302	169	617	377	665	103	306
	U 95% CI	201	453	348	1,835	546	838	427	588
HOS	Mean	171	85	63	754	36	32	28	120
	SD	37	21	22	209	11	15	21	42
	L 95% CI	107	50	29	404	18	11	4	51
	U 95% CI	251	130	114	1,224	60	68	83	214
NOS	Mean	413	622	463	1,568	794	1,359	411	721
	SD	61	45	63	428	53	35	135	81
	L 95% CI	304	545	356	838	703	1,303	200	582
	U 95% CI	544	720	602	2,527	912	1,439	724	897
pF	Mean	22.6%	52.3%	47.2%	49.2%	54.8%	53.7%	52.5%	51.9%
	SD	4.5%	3.8%	5.6%	1.9%	3.4%	2.7%	8.2%	6.9%
	L 95% CI	14.5%	44.9%	36.5%	45.4%	48.2%	48.4%	36.6%	38.2%
	U 95% CI	32.1%	59.6%	58.2%	53.1%	61.4%	59.0%	68.3%	65.0%
pHOS	Mean	29.3%	11.9%	11.8%	32.5%	4.3%	2.3%	6.4%	14.3%
	SD	5.1%	2.6%	3.4%	1.9%	1.2%	1.0%	4.1%	4.8%
	L 95% CI	20.2%	7.3%	6.2%	28.8%	2.3%	0.8%	1.1%	6.2%
	U 95% CI	39.7%	17.5%	19.2%	36.3%	7.0%	4.8%	16.3%	24.7%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

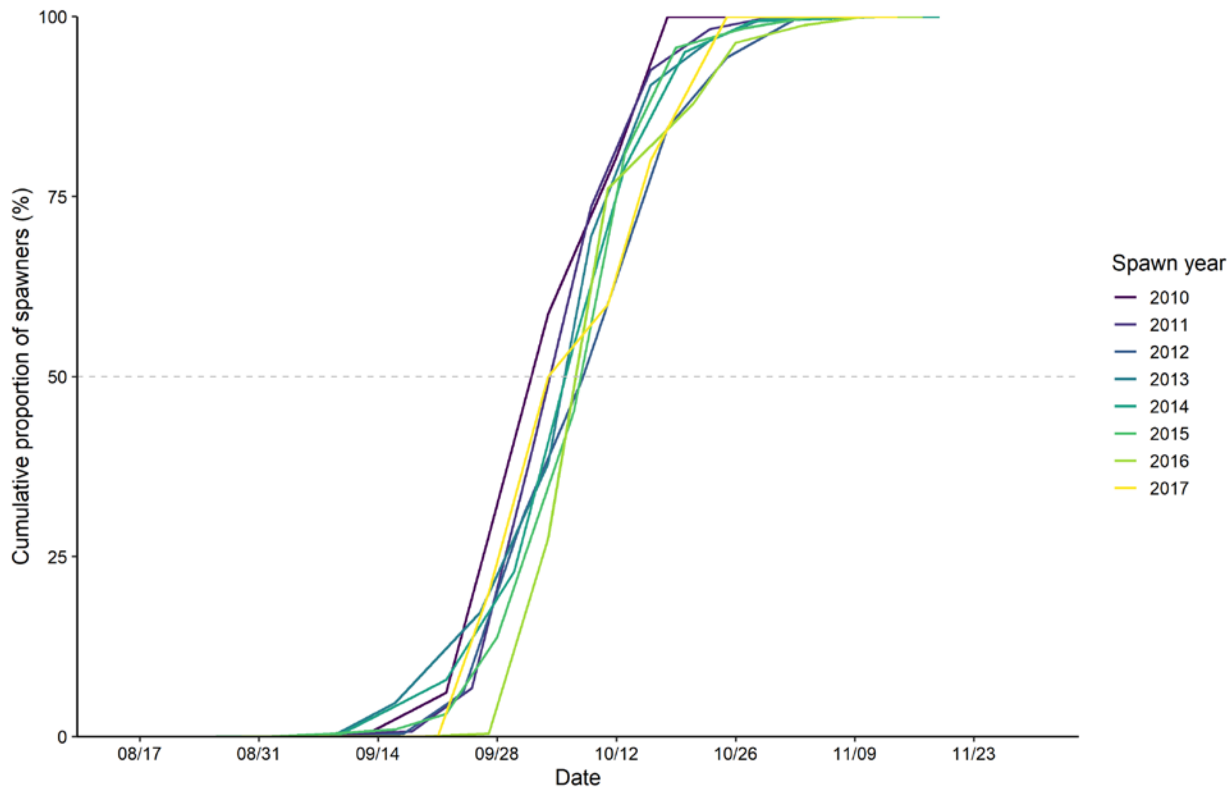

Figure 22. Spawn timing of the Coweeman fall Chinook population based on cumulative counts of live adult Chinook salmon identified as spawners for spawn years 2010-2017.

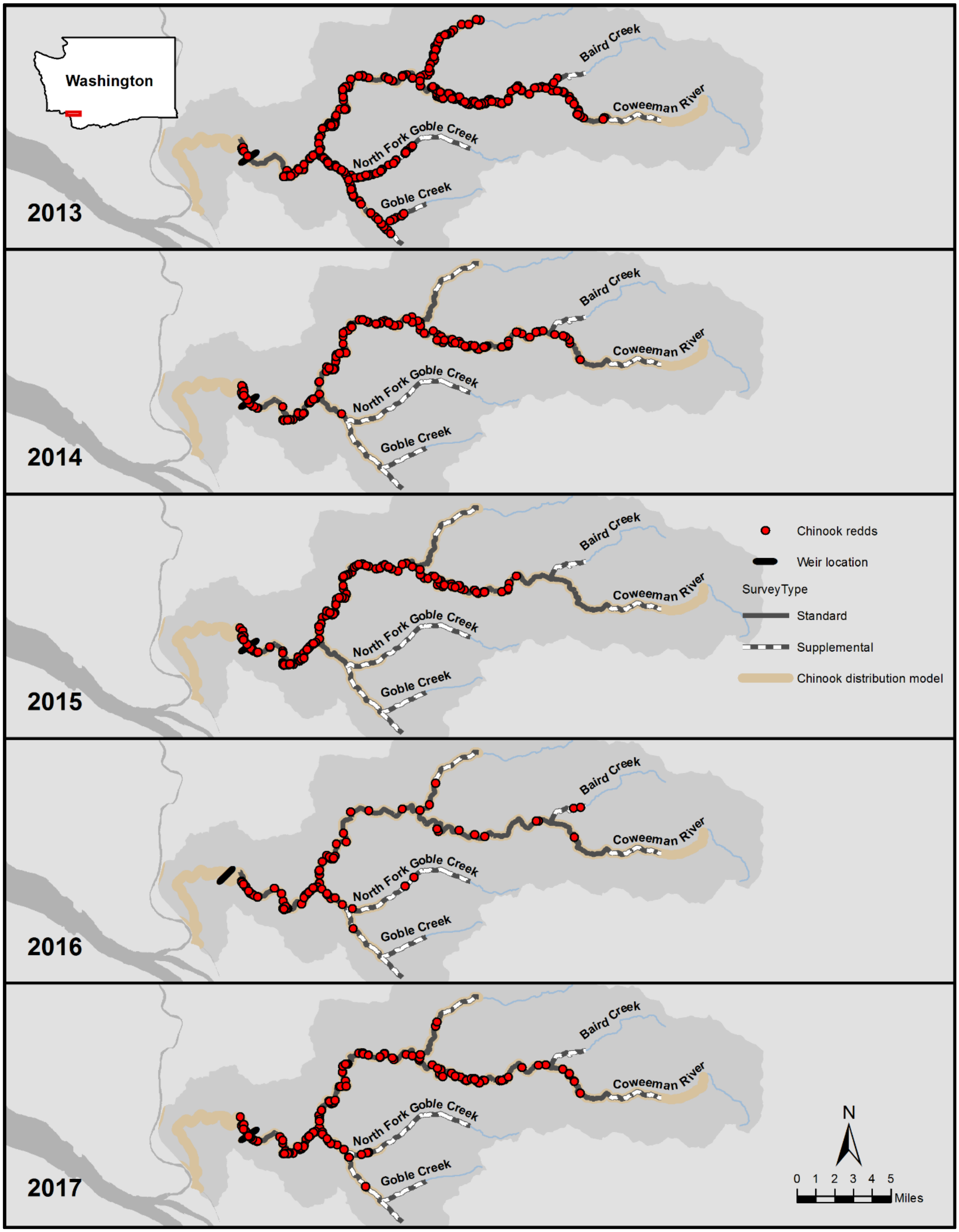

Figure 23. Redd distribution of the Coweeman fall Chinook population for spawn years 2013-2017. The grey colored layer represents the area surveyed, the black rectangle represents the weir location, and the individual redd locations are shown as a red colored circle.

Kalama

For the Kalama fall Chinook population, we used trapezoidal AUC using basin- and year-specific estimates of apparent residence time to develop spawner abundance estimates for 2013 and 2014 (Table 6). These values were further refined based on the peak count relationship across years and the final values are reported in Table 25. After the new Modrow Weir facility went into operation (2015), we used LP estimates for the area upstream of the weir (RM 2.7). We used only carcasses recoveries upstream of the weir site and, therefore, used a hypergeometric model and adjusted for prespawn mortality and sport catch to develop a spawner estimate upstream of the weir site. Downstream of the weir, we used trapezoidal AUC using basin- and year-specific estimates of apparent residence time (Table 6). These values were further refined based on the peak count relationship across years and the final values are reported in Table 25. Abundance estimation methods for 2010-2012 can be found in Table 1 and Rawding et al. (2014), Rawding et al. (2019), and Buehrens et al. (2019). We updated 2010-2012 adult fall Chinook salmon estimates with our improved models.

Over the last eight years, total spawner abundance for the Kalama fall Chinook population has ranged from a low of 3,041 adults in 2017 to a high of 9,451 adults in 2014 (Table 22). The proportion of hatchery-origin spawners was high from 2010 to 2014 ranging from a low of 88.8% in 2010 to a high of 96.1% in 2012. The implementation of using an instream weir to control pHOS has resulted in dramatically lower pHOS . Between 2015-2017, pHOS ranged from a low of 39.8% in 2016 to a high of 54.9% in 2015 (Figure 24, Table 22). NOR spawner abundance estimates has ranged from a low of 288 in 2012 to a high of 2,889 in 2015 (Figure 24, Table 22).

Scale samples were collected from carcasses recovered on spawning ground surveys. A total of 1,395 ad-clipped and 1,228 unclipped fish were aged across spawn years 2013-2017. Age structure was variable year to year but age-4 were the dominate age class in most years (Appendix E: Table E7). Annual sex ratios were consistent year to year and nearly evenly split between males and females. However, all years had slightly more females than males (Table 22). The 50% spawn date for fall Chinook salmon in the Kalama River ranged from approximately September 22 to October 4 in spawn years 2010-2017 (Figure 25).

In spawn years 2013-2017, redd distribution was relatively consistent across years with the exception of 2015. The reach from the canyon (RM 9.5) to the WDFW Access site just downstream of the sink hole (RM 5.3) had the most observed redds each of the years with the exception of 2015. In 2015, the most observed redds were in the reach directly downstream of the weir (RM 2.7 to 1.2). Fall Chinook salmon redd distribution is displayed in Figure 26.

Table 22. Estimates of apparent residence time (mean, standard deviation, and 95% credible intervals of the posterior distribution) used to develop total spawner abundance estimates for the adult Kalama Tule fall Chinook population for spawn years 2010-2017.

Spawn Year	Parameter	Mean	SD	L 95% CI	U 95% CI
2010	ART	6.83	1.13	4.72	9.08
2011	ART	5.75	0.94	4.16	7.85
2012	ART	5.99	1.00	4.31	8.29
2013	ART	7.71	1.45	5.10	10.67
2014	ART	6.27	0.98	4.48	8.37
2015	ART	6.41	1.24	4.22	9.06
2016	ART	6.18	1.23	4.01	8.80
2017	ART	5.97	1.11	3.99	8.34

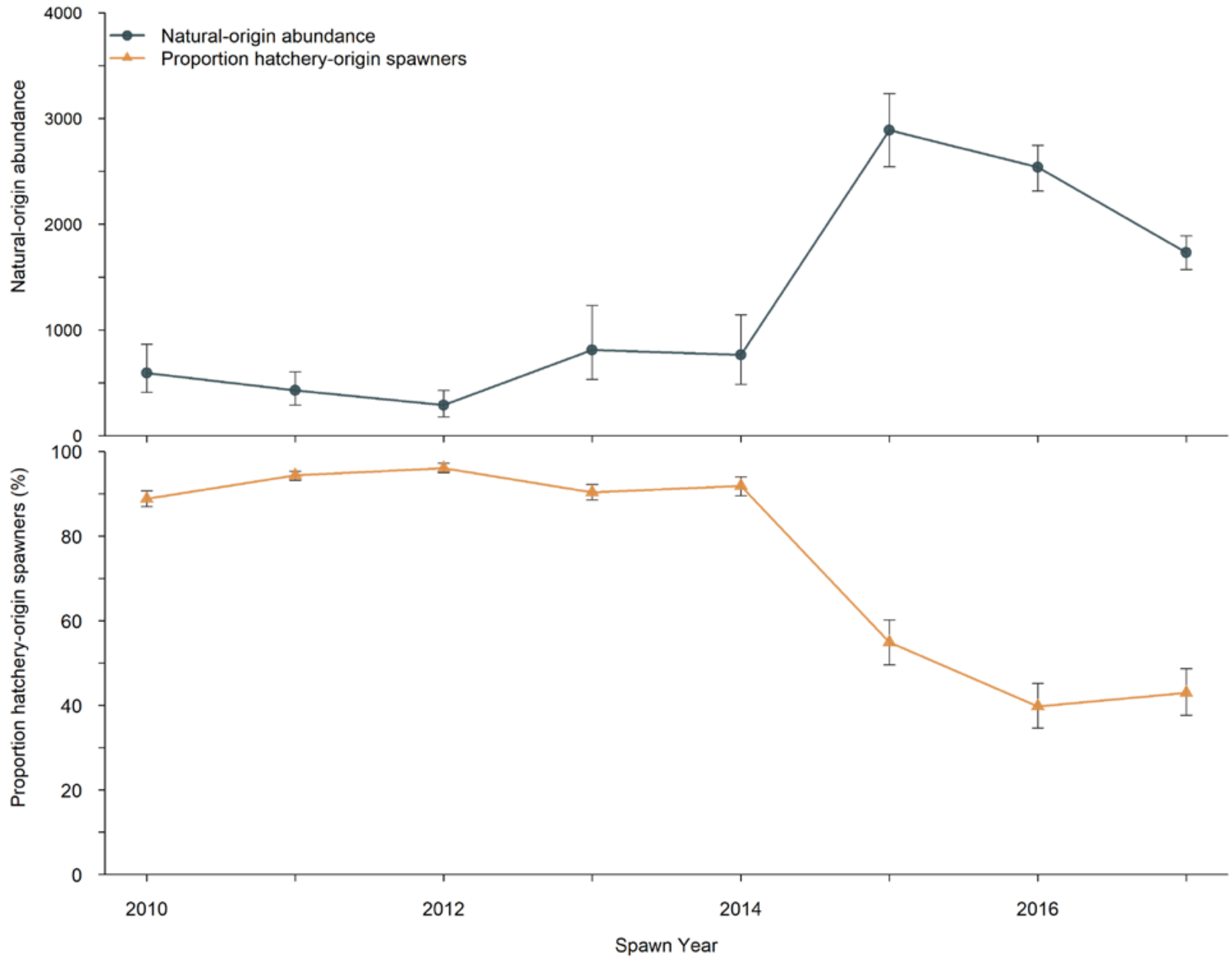

Figure 24. Estimates of adult natural-origin spawner abundance and the proportion of hatchery-origin spawners for the Kalama Tule fall Chinook population for spawn years 2010-2017. The blue circles and orange triangles represent means of the posterior distribution for natural-origin abundance and proportion of hatchery-origin spawners, respectively. The grey error bars represent the 95% credible intervals.

Table 23. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Kalama Tule fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	5,315	7,591	7,477	8,487	9,451	6,423	4,226	3,041
	SD	939	1,224	1,229	1,677	1,524	482	201	168
	L 95% CI	3,887	5,419	5,259	5,913	6,899	5,581	3,852	2,757
	U 95% CI	7,482	10,220	10,110	12,390	12,910	7,466	4,635	3,416
Males	Mean	2,500	3,172	3,056	3,671	4,704	3,146	1,818	1,482
	SD	466	541	554	767	810	264	132	98
	L 95% CI	1,786	2,227	2,086	2,464	3,365	2,669	1,575	1,306
	U 95% CI	3,592	4,333	4,263	5,450	6,535	3,707	2,088	1,692
Females	Mean	2,815	4,419	4,421	4,816	4,747	3,276	2,408	1,559
	SD	515	735	760	981	812	278	148	103
	L 95% CI	2,014	3,121	3,068	3,289	3,390	2,782	2,132	1,376
	U 95% CI	4,008	5,997	6,073	7,088	6,573	3,880	2,708	1,784
HOS	Mean	4,722	7,162	7,189	7,675	8,687	3,534	1,687	1,309
	SD	835	1,157	1,182	1,517	1,395	396	173	141
	L 95% CI	3,457	5,112	5,056	5,336	6,347	2,841	1,370	1,063
	U 95% CI	6,658	9,652	9,713	11,190	11,850	4,386	2,045	1,612
NOS	Mean	593	428	288	812	764	2,889	2,539	1,732
	SD	117	81	64	180	168	176	110	82
	L 95% CI	410	289	179	531	484	2,540	2,313	1,569
	U 95% CI	864	603	428	1,231	1,144	3,233	2,745	1,890
pF	Mean	53.0%	58.2%	59.1%	56.7%	50.2%	51.0%	57.0%	51.3%
	SD	2.6%	2.3%	3.0%	2.9%	2.9%	1.9%	2.3%	1.8%
	L 95% CI	47.7%	53.5%	53.2%	51.0%	44.6%	47.2%	52.5%	47.7%
	U 95% CI	58.1%	62.7%	65.0%	62.3%	55.8%	54.8%	61.4%	54.9%
pHOS	Mean	88.8%	94.4%	96.1%	90.4%	91.9%	54.9%	39.8%	43.0%
	SD	0.9%	0.6%	0.6%	0.9%	1.1%	2.7%	2.7%	2.8%
	L 95% CI	87.0%	93.2%	95.0%	88.6%	89.6%	49.6%	34.7%	37.7%
	U 95% CI	90.7%	95.4%	97.2%	92.2%	94.0%	60.2%	45.2%	48.7%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

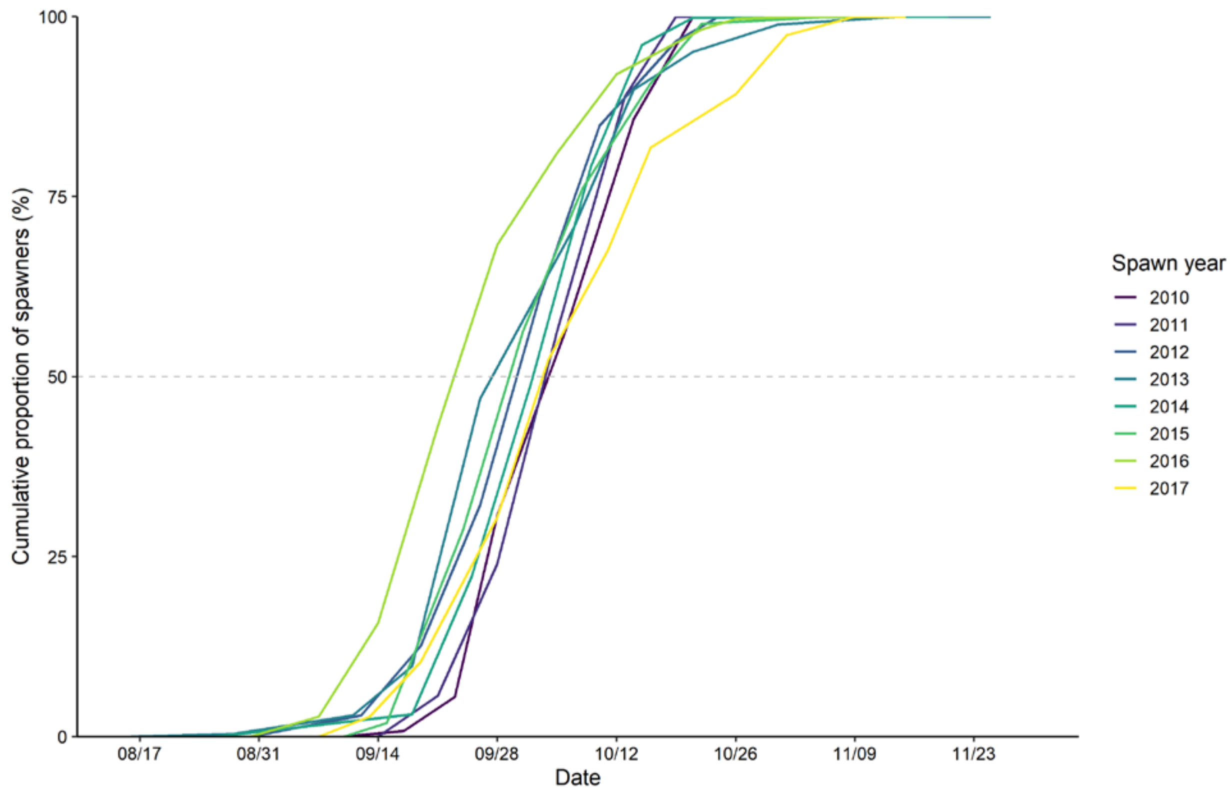

Figure 25. Spawn timing of the Kalama fall Chinook population based on cumulative counts of live adult Chinook salmon identified as spawners for spawn years 2010-2017.

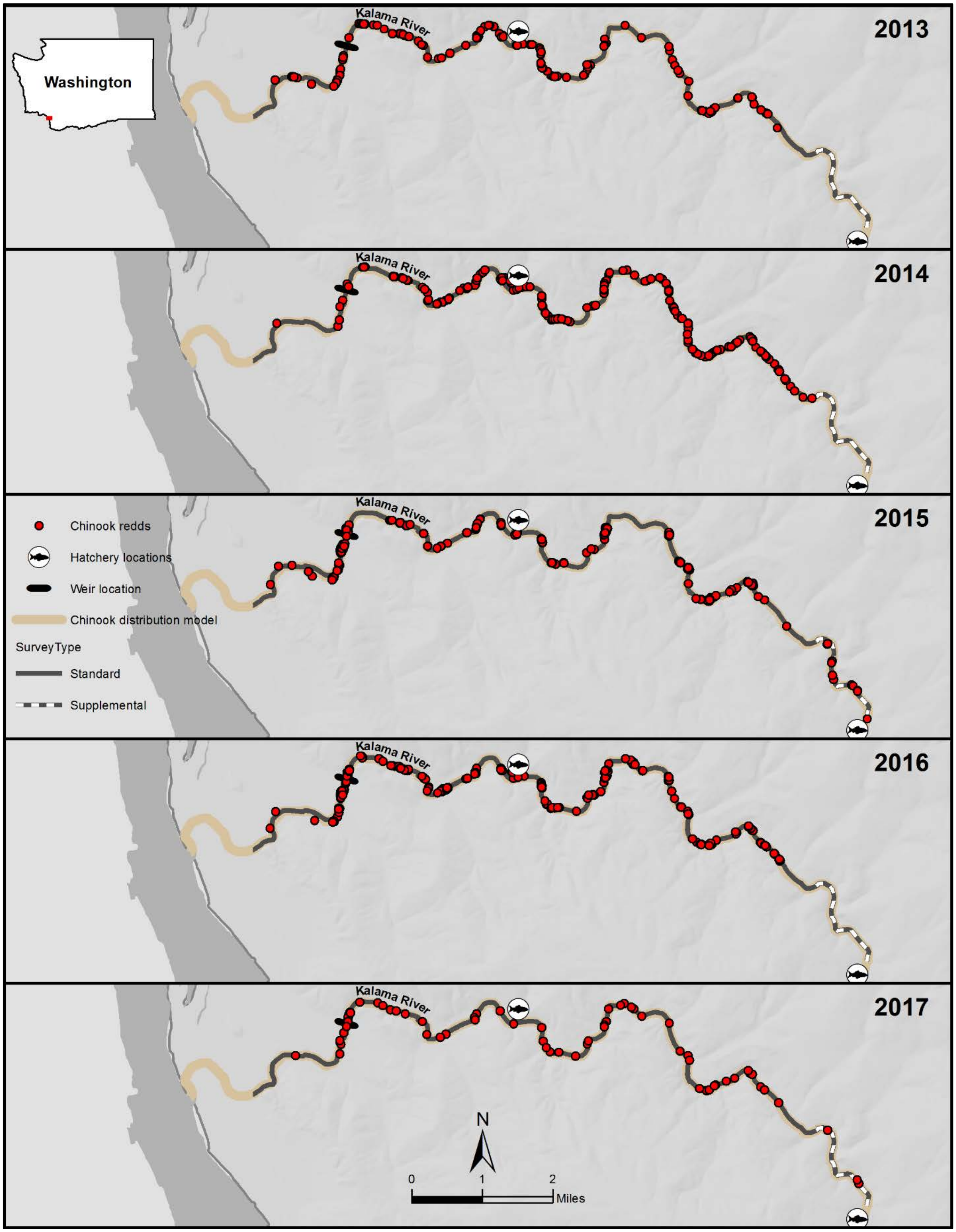

Figure 26. Redd distribution of the Kalama fall Chinook population for spawn years 2013-2017. The grey colored layer represents the area surveyed, the black rectangle represents the weir location, and the individual redd locations are shown as a red colored circle.

Lewis
The Lewis fall Chinook population consists of the three major subpopulations: North Fork Lewis, East Fork Lewis, and Cedar. Additionally, the Lewis fall Chinook population may be divided into a Tule and a Bright population. In general, most of the Bright fall Chinook salmon in this population spawn in the North Fork Lewis River with minimal spawning occurring in the other two subpopulations while Tule fall Chinook salmon are found in all three of the subpopulations. We report estimates on two of the three subpopulations (Cedar and East Fork Lewis) for Tule fall Chinook salmon (Appendix F: Tables F17-F20). Estimates for Tule and Bright stocks of fall Chinook salmon spawning in the North Fork Lewis subpopulation for spawn years 2013-2017 can be found in Bentley et al. (2018). We combine North Fork Lewis Tule fall Chinook salmon estimates from Bentley et al. (2018) with our East Fork Lewis and Cedar subpopulation estimates to develop population-level estimates of Tule fall Chinook salmon for the Lewis population for spawn years 2013-2017. We combined North Fork Lewis Tule fall Chinook salmon estimates for spawn years 2010-2012 (Shane Hawkins, personal communication, WDFW) with our East Fork Lewis and Cedar estimates for same spawn years to develop population-level estimates.

Lewis - Tule
For the North Fork Lewis River subpopulation, Tule fall Chinook salmon spawner abundance estimates were based on carcass tagging using the JS model (Bentley et al. 2018). For the East Fork Lewis subpopulation, we used JS estimates for 2013, 2014, 2015, and 2017. For 2016, our JS failed due to the small number of recaptures. As a result, we used trapezoidal AUC using basin- and year-specific estimate of apparent residence time (Table 6). These values were further refined based on the peak count relationship across years and the final values are reported in Table 23. For our JS estimates, we conducted additional analyses to test for size and sex selectivity to ensure the equal catchability assumption of the JS model was met, GOF to ensure the data fit the different JS models, and model selection to help inform the best model to use for the data (Appendix G: Tables G15-G22). For the Cedar subpopulation, spawner estimates were generated assuming a census at the Grist Mill Ladder Trap (RM 2.0) and using AUC for the area downstream of the ladder. We used AUC using basin- and year-specific estimate of apparent residence time (Table 5). These values were further refined based on the peak count relationship across years and the final values are reported in Table 23. Abundance estimation methods for 2010-2012 can be found in Table 1 and Rawding et al. (2014), Rawding et al. (2019), and Buehrens et al. (2019). We updated 2010-2012 adult fall Chinook salmon estimates with our improved models.

Over the last eight years, estimated total spawner abundance for the Lewis Tule fall Chinook population has ranged from a low of 2,192 adults in 2011 to a high of 7,316 adults in 2015 (Table 24). The proportion of hatchery-origin spawners has ranged from a low of 14.6% in 2012 to a high of 55.5% in 2016 (Figure 27, Table 24). NOR spawner abundance estimates has ranged from a low of 1,308 in 2012 to a high of 3,994 in 2013 (Figure 27, Table 24).

We do not report on age structure by origin at the population-level. However, subpopulation estimates are available for the East Fork and Cedar subpopulations (Appendix F: Tables F26-F43). Scale samples from the East Fork Lewis subpopulation were collected from carcasses. For the Cedar subpopulation, scale samples were collected from carcasses for area downstream of the ladder and blended between live fish passed upstream at the ladder and from untagged carcasses for the area upstream of the ladder.

The 50% spawn date for fall Chinook salmon was very consistent for the East Fork Lewis River ranging from approximately October 12 to October 16 while Cedar Creek was a little earlier and more variable with 50% spawn dates ranging from approximately October 8 to October 13 in spawn years 2010-2017 (Figure 41). Spawn timing data was not available for the North Fork Lewis River for spawn years 2010-2017, Cedar Creek in 2010-2012, and Cedar Cree in 2016 due to the study designs implemented.

Redds were not georeferenced in the North Fork Lewis and Cedar subpopulations as the study design was not set-up to monitor these metrics. For the East Fork Lewis subpopulation, redd distribution was relatively consistent across years (2013-2017) with the highest density of redds in the reach that spans Lewisville Park (RM 14.3-13.0) in four out of five years. There was also substantial use in a tributary of the East Fork Lewis River, Rock Creek, in spawn years 2013 and 2017 with 11.7% and 16.7% of the total observed redds in the East Fork Lewis subpopulation occurring in this tributary. Fall Chinook salmon redd distribution is displayed in Figure 29.

Table 24. Estimates of apparent females per redd (mean, standard deviation, and 95% credible intervals of the posterior distribution) used to develop total spawner abundance estimates for the adult Lewis Tule fall Chinook population for spawn years 2010-2017.

Spawn Year	Subpopulation	Parameter	Mean	SD	L 95% CI	U 95% CI
2010	East Lewis	ART	5.85	0.92	4.21	7.82
2011	East Lewis	ART	5.30	0.89	3.76	7.22
2012	East Lewis	ART	5.70	0.94	4.02	7.68
2013[a]	East Lewis	ART	---	---	---	---
2014[a]	East Lewis	ART	---	---	---	---
2015[a]	East Lewis	ART	---	---	---	---
2016	East Lewis	ART	6.56	1.05	4.61	8.73
2017[a]	East Lewis	ART	---	---	---	---
2010[a]	Cedar	ART	---	---	---	---
2011[a]	Cedar	ART	---	---	---	---
2012[a]	Cedar	ART	---	---	---	---
2013	Cedar	ART	7.78	1.97	4.39	12.13
2014	Cedar	ART	7.92	1.96	4.47	12.16
2015	Cedar	ART	7.59	1.71	4.48	10.98
2016	Cedar	ART	4.38	0.65	2.86	5.26
2017	Cedar	ART	7.44	1.86	4.28	11.58

[a]Alternate methods used for final estimates.

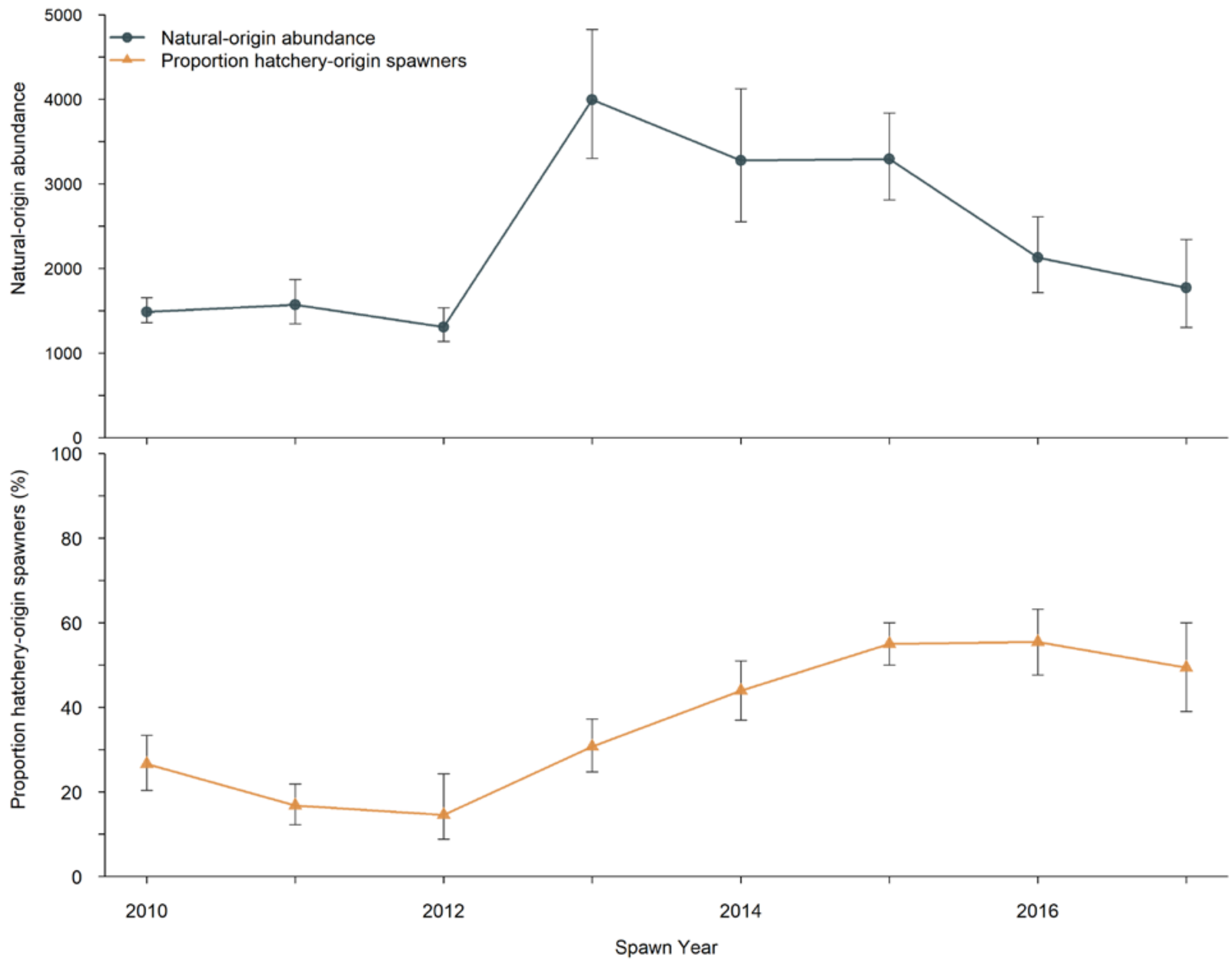

Figure 27. Estimates of adult natural-origin spawner abundance and the proportion of hatchery-origin spawners for the Lewis Tule fall Chinook population for spawn years 2010-2017. The blue circles and orange triangles represent means of the posterior distribution for natural-origin abundance and proportion of hatchery-origin spawners, respectively. The grey error bars represent the 95% credible intervals. Estimates of precision are underestimated for spawn years 2010-2012 as no estimates of precision are currently available for the North Fork Lewis Tule fall Chinook subpopulation.

Table 25. Estimates of spawner abundance, including origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Lewis Tule fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	2,350	2,192	2,561	5,764	5,830	7,316	4,787	3,503
	SD	93	143	124	436	447	359	391	381
	L 95% CI	2,192	1,979	1,718	4,952	5,015	6,644	4,058	2,811
	U 95% CI	2,561	2,533	2,186	6,664	6,745	8,060	5,597	4,306
HOS	Mean	865	646	602	1,769	2,554	4,024	2,659	1,732
	SD	37	27	44	199	192	247	312	275
	L 95% CI	804	597	554	1,419	2,205	3,566	2,105	1,273
	U 95% CI	950	705	709	2,199	2,952	4,541	3,314	2,358
NOS	Mean	1,485	1,572	1,308	3,994	3,277	3,292	2,128	1,771
	SD	75	134	103	390	401	262	234	267
	L 95% CI	1,359	1,348	1,138	3,303	2,554	2,812	1,713	1,302
	U 95% CI	1,656	1,871	1,533	4,822	4,124	3,838	2,611	2,342
pHOS	Mean	26.7%	16.8%	14.6%	30.8%	43.9%	55.0%	55.5%	49.4%
	SD	3.3%	2.5%	4.0%	3.2%	3.5%	2.6%	4.0%	5.4%
	L 95% CI	20.4%	12.3%	8.9%	24.8%	37.0%	50.0%	47.7%	39.0%
	U 95% CI	33.5%	21.9%	24.3%	37.3%	51.0%	60.0%	63.3%	60.1%

The sum of abundance by clip status may not equal the total abundance estimate due to rounding errors.

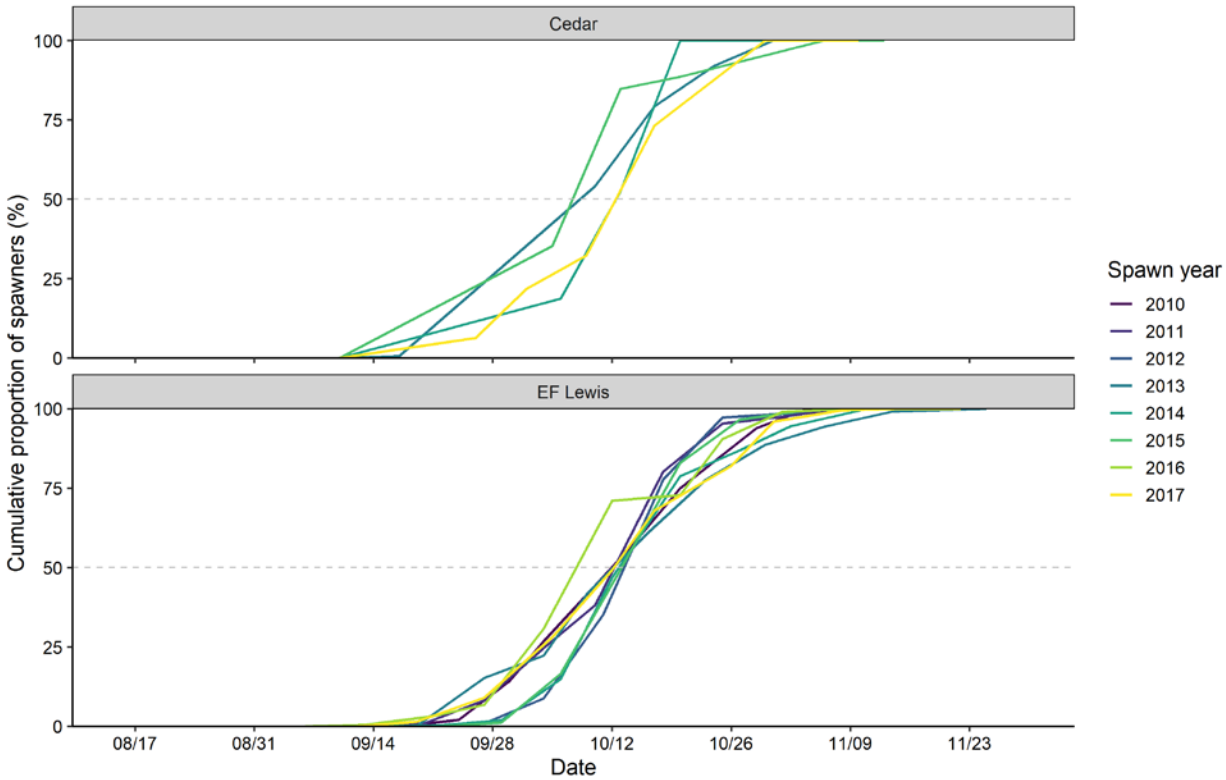

Figure 28. Spawn timing of the Lewis Tule fall Chinook population based on cumulative counts of live adult Chinook salmon identified as spawners for spawn years 2010-2017. Spawn timing data was not available for the North Fork Lewis River for spawn years 2010-2017 and Cedar Creek in 2010-2012 and 2016.

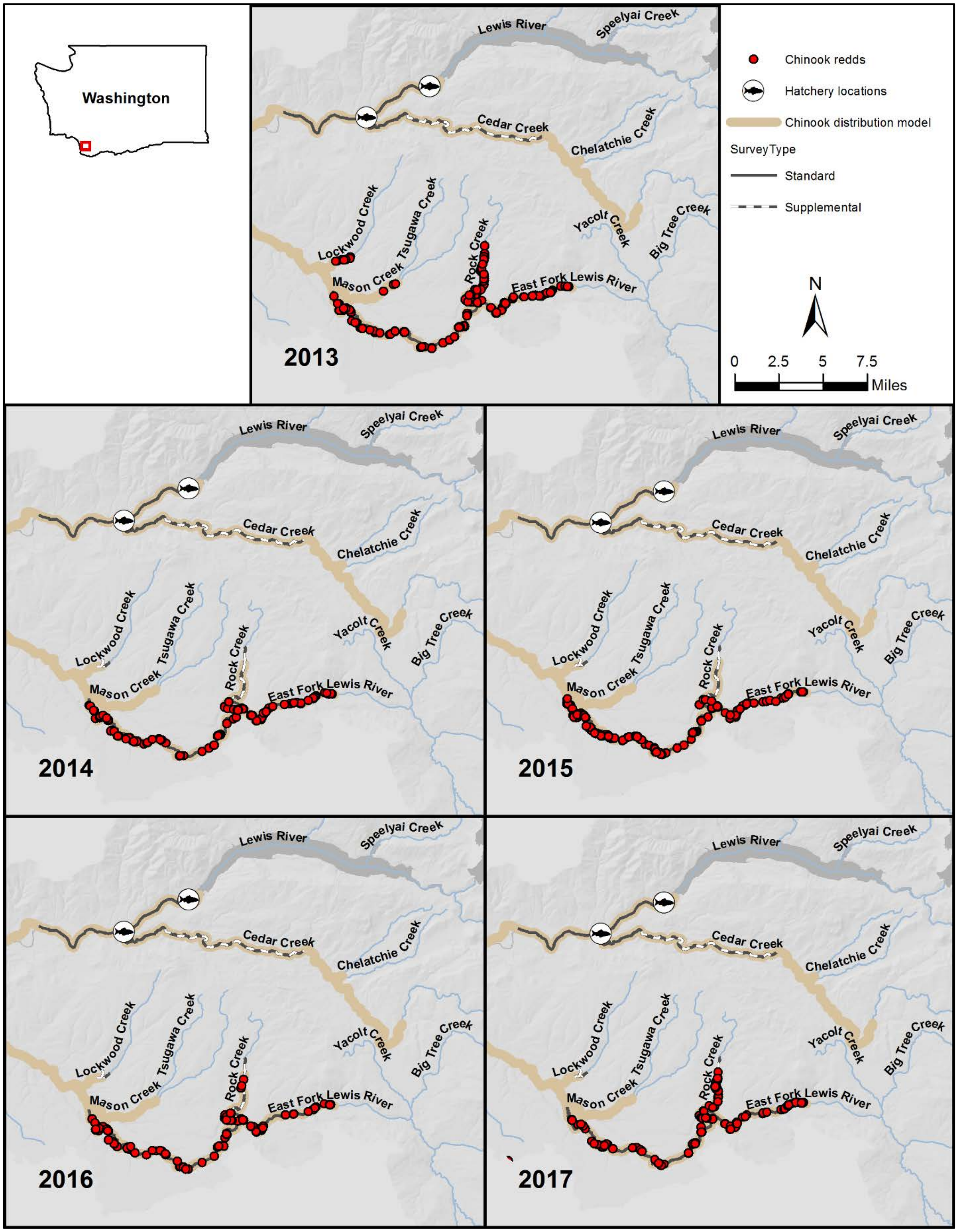

Figure 29. Redd distribution of the Lewis Tule fall Chinook population for spawn years 2013-2017. The grey colored layer represents the area surveyed, the black rectangle represents the weir location, and the individual redd locations are shown as a red colored circle.

Lewis - Bright

We do not report on Lewis Bright fall Chinook salmon as those estimates are available in Bentley et al. (2018).

Washougal

The Washougal fall Chinook population is perceived as solely a Tule fall Chinook population but there is some evidence that Bright fall Chinook salmon are spawning in the lower river. Currently it is unknown whether this population is genetically distinct from the rest of the Washougal fall Chinook population or belongs to a different population. Consequently, we treated all Washougal fall Chinook salmon as a single population for reporting purposes.

For the Washougal fall Chinook population, abundance was estimated through carcass tagging using JS model then adjusted for prespawn mortality to develop an estimate of spawners for the area between Dougan Falls and the mouth in 2013. For 2014, 2015, and 2017, we used LP estimates for the area upstream of the weir (RM 11.9). We used only carcasses recoveries upstream of the weir site and, therefore, used a hypergeometric model. These LP estimates were then adjusted for prespawn mortality, sport catch, and hatchery recruitment to develop an estimate of spawners. Below the weir site for the same years, we used developed JS estimates via carcass tagging. These estimates above and below the weir were summed to develop an overall population-level estimate. In 2016, abundance was estimated through carcass tagging using JS model for the area between Washougal Hatchery and the mouth, which was added to the census count of fish passed upstream of Washougal Hatchery. This total was then adjusted for prespawn mortality to develop an estimate of spawners for the entire population. We conducted additional analyses to test for size and sex selectivity to ensure the equal catchability assumption of the JS and LP model was met (Appendix G: Tables G23-G32; Appendix H: Tables H11-H13). For our JS estimates, we also conducted two additional tests: (1) GOF to ensure the data fit the different JS models and (2) model selection to help inform the best model to use for the data (Appendix G: Tables G23-G32). Abundance estimation methods for 2010-2012 can be found in Table 1 and Rawding et al. (2014), Rawding et al. (2019), and Buehrens et al. (2019). We updated 2010-2012 adult fall Chinook salmon estimates with our improved models.

Over the last eight years, total spawner abundance for the Washougal fall Chinook population has ranged from a low of 965 adults in 2012 to a high of 5,530 adults in 2010 (Table 25). The proportion of hatchery-origin spawners ranged from a low of 34.7% in 2014 to a high of 89.3% in 2010 (Figure 30, Table 25). NOR spawner abundance estimates has ranged from a low of 256 in 2012 to a high of 1,332 in 2015 (Figure 30, Table 25).

Scale samples were collected from carcasses recovered on spawning ground surveys. A total of 1,875 ad-clipped and 1,763 unclipped fish were aged across spawn years 2013-2017. Age structure was variable year to year but age-3 and age-4 were the dominate age classes (Appendix E: Table E8). Sex ratios were consistent year to year and nearly evenly split between males and females. However, all but two years had slightly more females than males (Table 25). The 50% spawn date for fall Chinook salmon in the Washougal River ranged from approximately October 1 to October 18 in spawn years 2010-2017 (Figure 32).

Redd distribution was variable year to year. The reach from Salmon Falls (RM 15.5) to the Canyon Creek Road Bridge (RM 13.6) on the Washougal River had the most observed redds in 2013, 2016, and 2017. The lowermost reach (RM 3.5 to 0) on the Washougal River had the most observed redds in 2014. The one-mile reach directly downstream of the weir site (RM 11.9 to 10.9) on the Washougal River had the most observed redds in 2015. Fall Chinook salmon redd distribution is displayed in Figure 32.

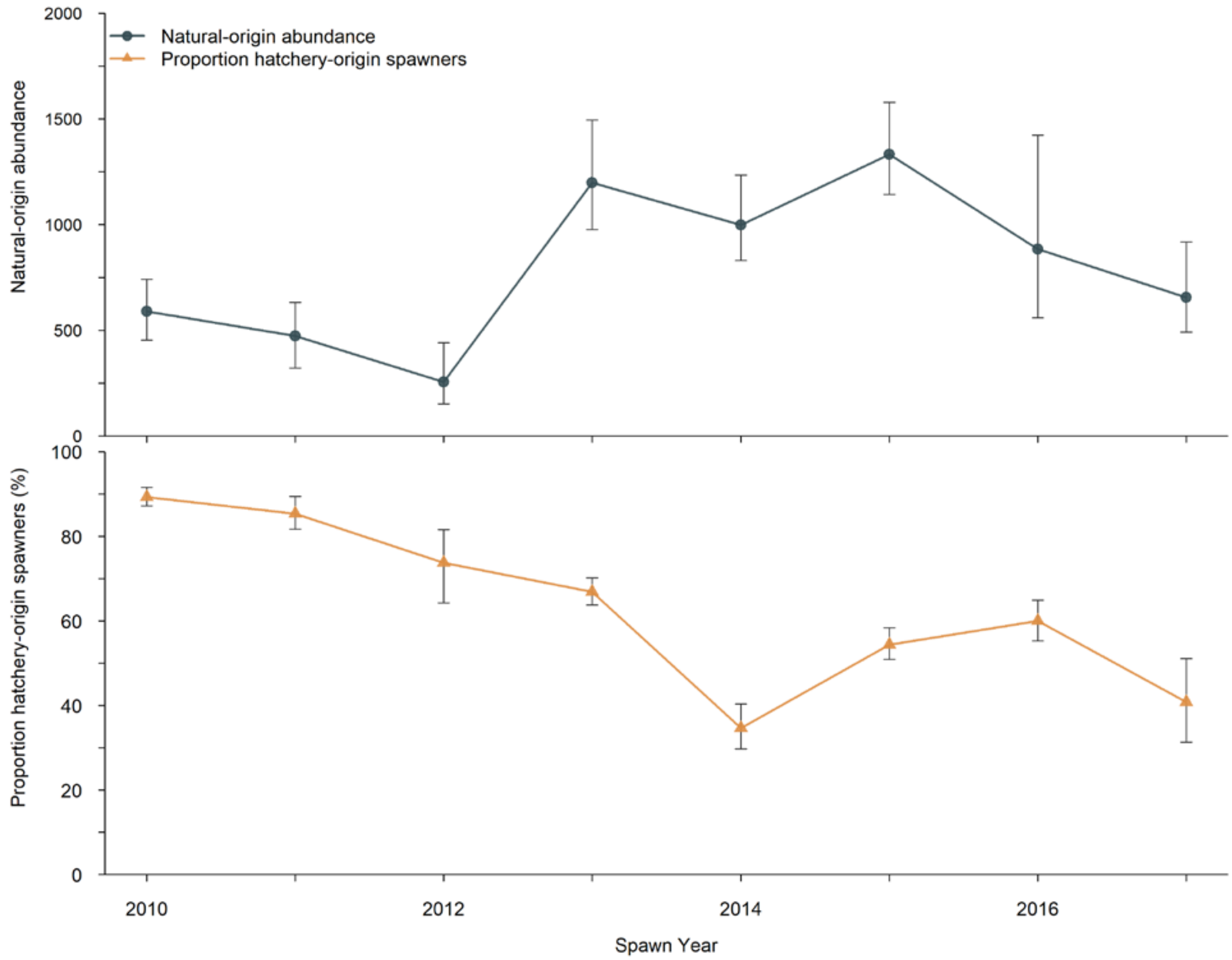

Figure 30. Estimates of adult natural-origin spawner abundance and the proportion of hatchery-origin spawners for the Washougal fall Chinook population for spawn years 2010-2017. The blue circles and orange triangles represent means of the posterior distribution for natural-origin abundance and proportion of hatchery-origin spawners, respectively. The grey error bars represent the 95% credible intervals.

Table 26. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Washougal fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	5,530	3,224	965	3,612	1,529	2,925	2,198	1,112
	SD	378	241	144	326	146	247	515	196
	L 95% CI	4,905	2,811	745	3,090	1,296	2,549	1,455	808
	U 95% CI	6,385	3,754	1,305	4,347	1,868	3,513	3,411	1,566
Males	Mean	2,946	1,193	400	1,873	704	1,385	663	416
	SD	216	96	69	176	63	111	162	90
	L 95% CI	2,582	1,029	294	1,589	595	1,205	427	271
	U 95% CI	3,428	1,402	565	2,272	844	1,638	1,047	623
Females	Mean	2,584	2,031	565	1,739	825	1,540	1,535	696
	SD	196	156	84	162	97	146	363	135
	L 95% CI	2,249	1,763	433	1,475	671	1,316	1,012	483
	U 95% CI	3,025	2,377	758	2,107	1,052	1,886	2,405	1,001
HOS	Mean	4,941	2,751	709	2,414	531	1,592	1,316	456
	SD	343	203	90	216	67	160	299	114
	L 95% CI	4,374	2,399	563	2,067	416	1,339	876	281
	U 95% CI	5,721	3,194	911	2,894	677	1,963	2,033	721
NOS	Mean	589	473	256	1,197	997	1,332	883	655
	SD	74	79	74	132	101	110	227	111
	L 95% CI	453	321	152	977	830	1,143	558	491
	U 95% CI	740	631	441	1,494	1,234	1,577	1,422	918
pF	Mean	46.7%	63.0%	58.6%	48.2%	53.9%	52.6%	69.8%	62.6%
	SD	1.5%	1.1%	2.6%	1.3%	2.2%	1.3%	2.1%	4.8%
	L 95% CI	43.8%	60.9%	53.3%	45.7%	49.6%	50.1%	65.7%	53.1%
	U 95% CI	49.6%	65.1%	63.7%	50.5%	58.4%	55.1%	73.8%	71.8%
pHOS	Mean	89.3%	85.4%	73.8%	66.9%	34.7%	54.4%	60.0%	40.8%
	SD	1.1%	2.0%	4.4%	1.6%	2.7%	1.9%	2.5%	5.0%
	L 95% CI	87.2%	81.7%	64.3%	63.8%	29.8%	50.9%	55.3%	31.4%
	U 95% CI	91.6%	89.5%	81.6%	70.2%	40.4%	58.4%	64.9%	51.1%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

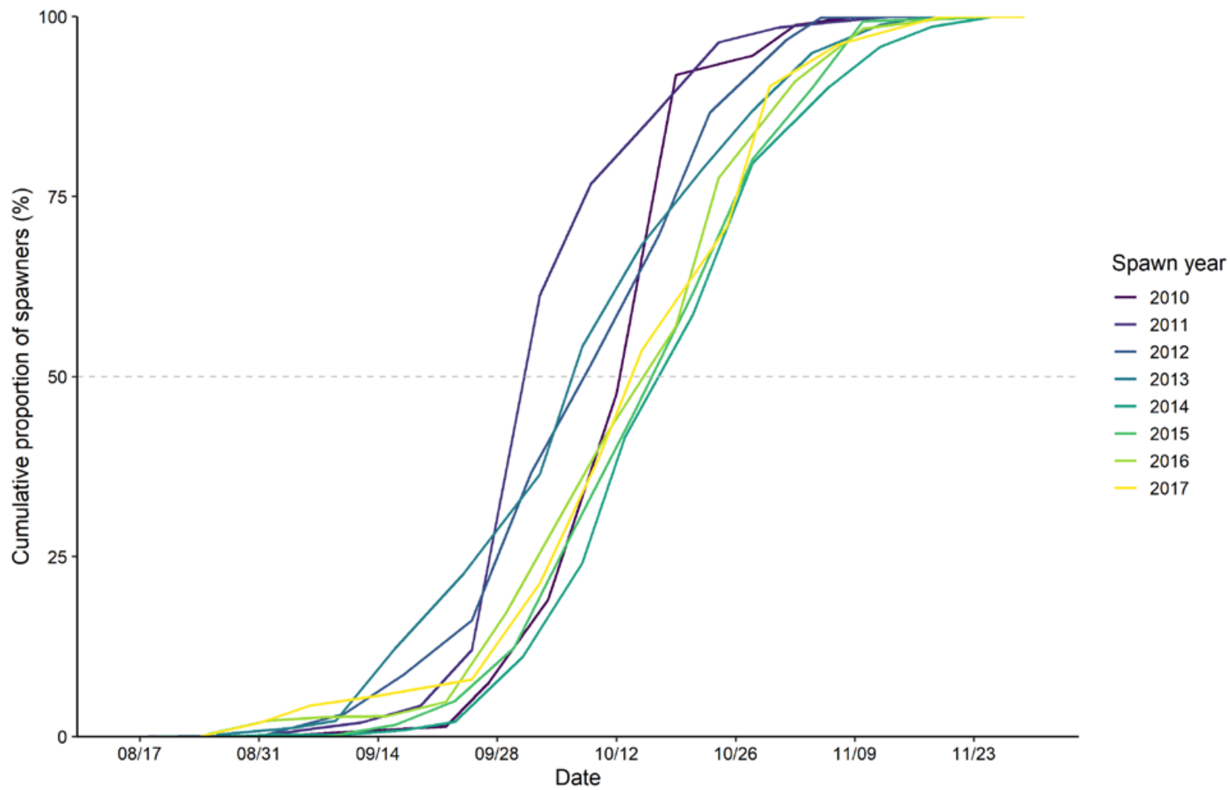

Figure 31. Spawn timing of the Washougal fall Chinook population based on cumulative counts of live adult Chinook salmon identified as spawners for spawn years 2010-2017.

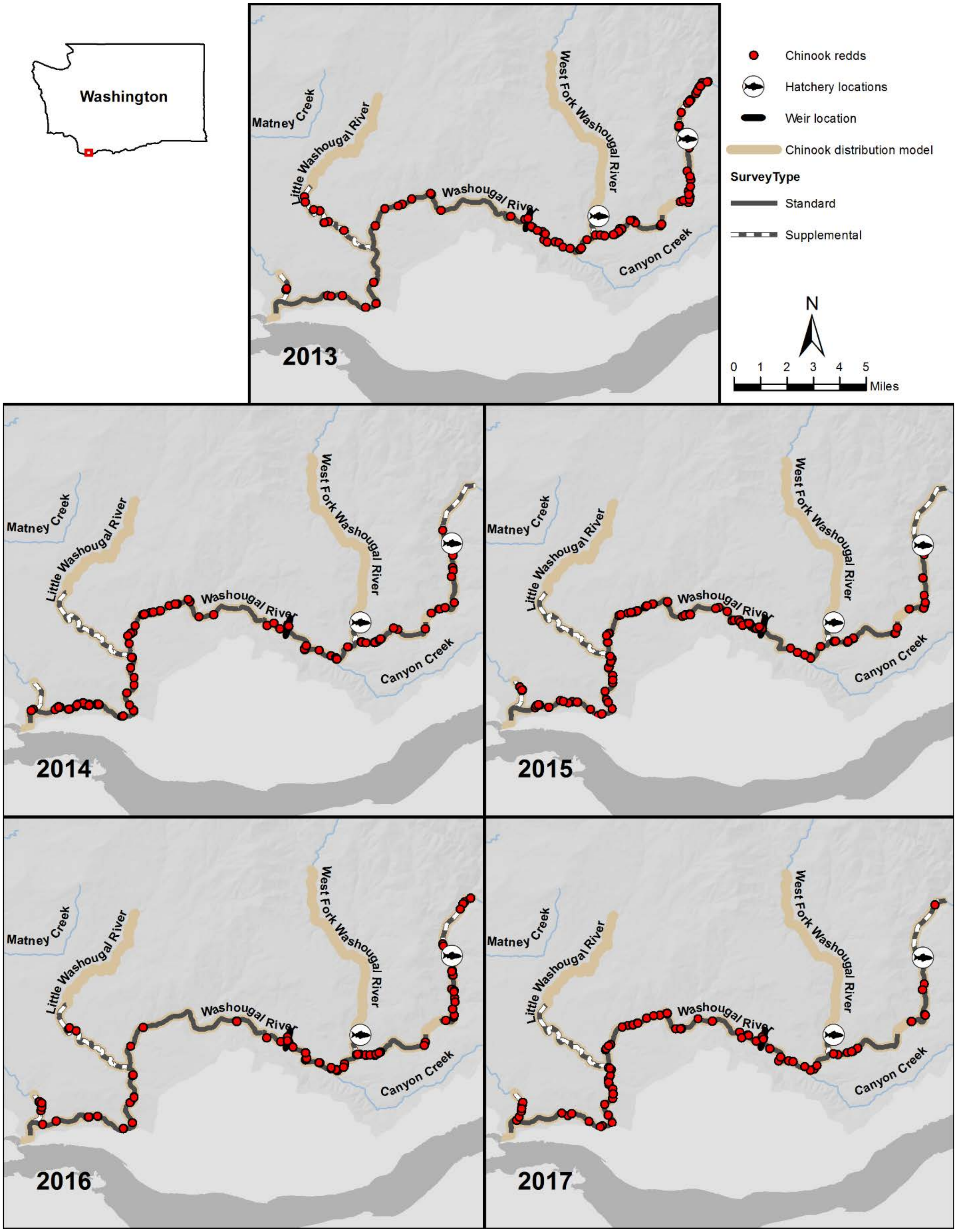

Figure 32. Redd distribution of the Washougal fall Chinook population for spawn years 2013-2017. The grey colored layer represents the area surveyed, the black rectangle represents the weir location, and the individual redd locations are shown as a red colored circle.

Lower Gorge
The Lower Gorge population consists of the main-stem Columbia River below Bonneville Dam (Ives/Pierce Island), Hamilton Creek, Hardy Creek, and several other smaller tributaries that enter the Columbia River between Bonneville Dam and the Washougal River. In Hardy Creek and some of the other smaller tributaries, surveys are conducted as part of other regional VSP monitoring programs. These surveys show there is some sparse, sporadic use by fall Chinook salmon, but it appears to be in large abundance years with higher streamflow in these tributaries. The Lower Gorge fall Chinook population may be divided into a Tule population and a Bright population.

We only report estimates on two subpopulations for both Tule and Bright stocks: the main-stem Columbia River below Bonneville Dam (also known as Ives Island) and Hamilton Creek (Appendix F: Tables F21-F24). We also combine the subpopulation estimates into population-level estimates of Tule and Bright stocks.

This is first time we have reported on the Lower Gorge fall Chinook population. We report on estimates from 2010-2017.

Lower Gorge - Tule
For the Ives Island (main-stem Columbia River below Bonneville Dam) subpopulation, Tule fall Chinook salmon spawner abundance estimates from 2010 to 2017 were based on a PCE factor of 2.61 (95% CI 1.84-3.66) developed for Ives Island Bright fall Chinook subpopulation. This expansion factor was applied to the largest single day combined count of lives and deads for each year. For the Hamilton Creek subpopulation, no Tule fall Chinook salmon spawner abundance estimates were developed. Hamilton Creek flows subterranean in the summer and early fall months, which hinders anadromous adult fish passage. Limited surveys conducted in early October have confirmed there is no Tule fall Chinook salmon presence in Hamilton Creek over the last few years. Therefore, the population-level estimates for the Lower Gorge Tule fall Chinook were comprised of only the Ives Island subpopulation.

Over the last eight years, total spawner abundance has ranged from a low of 8 adults in 2011 to a high of 74 adults in 2010 (Table 26). Estimates of the proportion of hatchery-origin spawners is very uncertain (Figure 33, Table 26). NOR spawner abundance estimates have ranged from a low of 3 in 2011 to a high of 15 in 2010 (Figure 33, Table 26). The age structure and sex ratios are very uncertain due to small sample sizes (Appendix E: Table E9; Table 26). We do not report on spawn timing or spatial structure for the Lower Gorge Tule fall Chinook population as the study design was not set-up to evaluate these metrics.

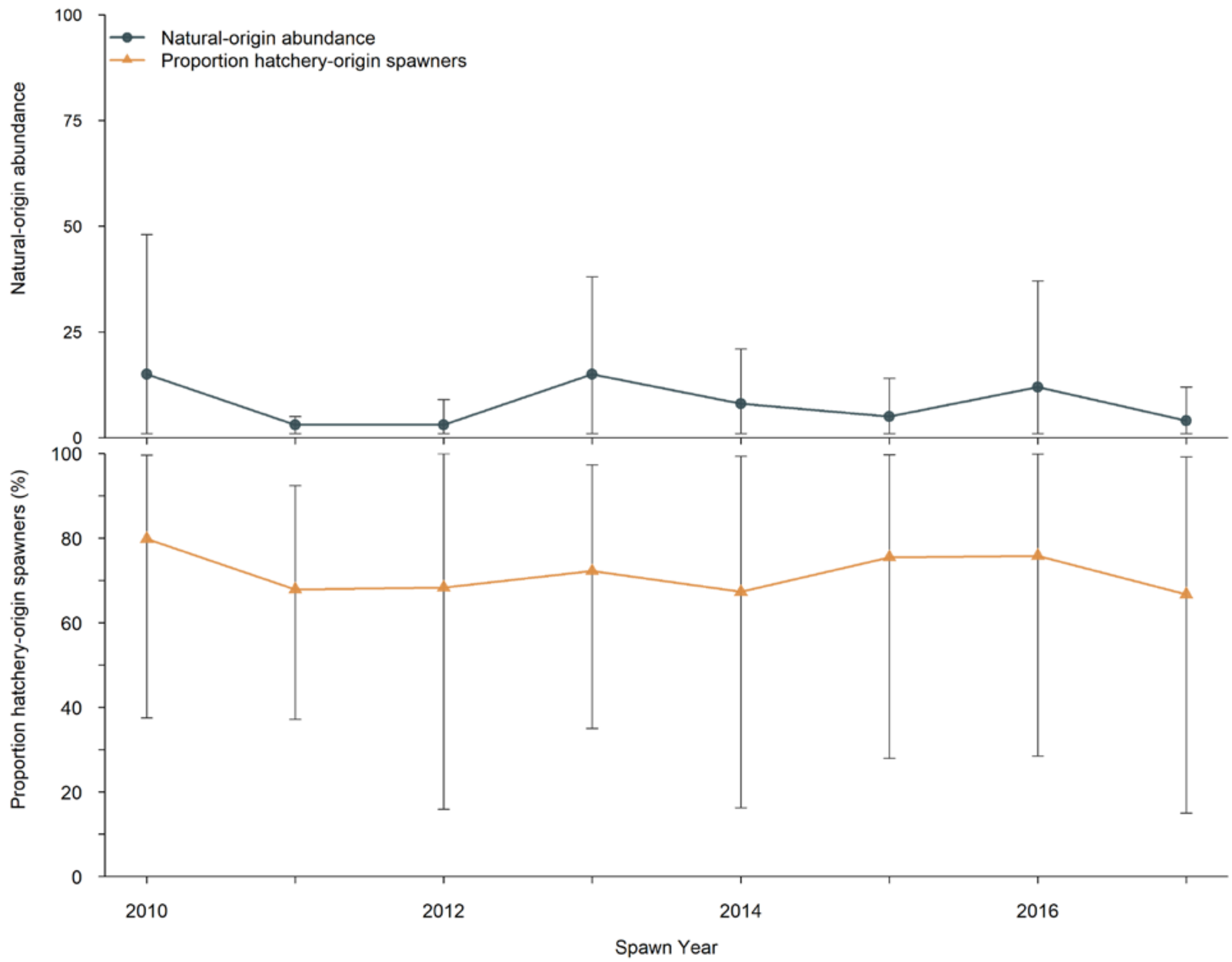

Figure 33. Estimates of adult natural-origin spawner abundance and the proportion of hatchery-origin spawners for the Lower Gorge Tule fall Chinook population for spawn years 2010-2017. The blue circles and orange triangles represent means of the posterior distribution for natural-origin abundance and proportion of hatchery-origin spawners, respectively. The grey error bars represent the 95% credible intervals.

Table 27. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Lower Gorge Tule fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	74	8	11	55	24	18	50	13
	SD	13	1	2	10	4	3	9	2
	L 95% CI	52	6	7	39	17	13	35	9
	U 95% CI	104	11	15	78	33	26	70	19
Males	Mean	59	4	7	39	16	9	17	9
	SD	16	1	3	11	6	4	12	4
	L 95% CI	27	2	2	19	4	2	1	2
	U 95% CI	91	7	12	62	27	18	44	15
Females	Mean	15	4	4	16	8	9	33	4
	SD	12	1	3	9	6	4	13	3
	L 95% CI	0	1	0	2	0	2	8	0
	U 95% CI	46	6	9	37	21	18	57	12
HOS	Mean	59	5	7	40	16	14	38	9
	SD	16	2	3	12	6	4	12	4
	L 95% CI	26	3	2	18	4	5	14	2
	U 95% CI	90	8	12	62	27	22	60	15
NOS	Mean	15	3	3	15	8	5	12	4
	SD	13	1	3	10	6	4	10	3
	L 95% CI	0	1	0	1	0	0	0	0
	U 95% CI	48	5	9	38	21	14	37	12
pF	Mean	19.7%	45.4%	33.3%	28.7%	32.6%	50.3%	66.3%	33.2%
	SD	16.3%	14.4%	23.7%	15.8%	23.2%	21.9%	23.7%	23.6%
	L 95% CI	0.6%	18.6%	1.2%	4.4%	1.3%	10.1%	15.9%	1.2%
	U 95% CI	60.3%	74.1%	84.8%	64.4%	83.0%	90.2%	98.7%	83.3%
pHOS	Mean	79.8%	67.9%	68.3%	72.2%	67.3%	75.5%	75.8%	66.7%
	SD	16.8%	14.5%	24.2%	16.9%	24.1%	20.0%	19.9%	24.1%
	L 95% CI	37.5%	37.2%	15.9%	35.0%	16.3%	28.0%	28.5%	15.0%
	U 95% CI	99.6%	92.4%	100.0%	97.3%	99.4%	99.7%	99.9%	99.2%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

Lower Gorge - Bright

For the Ives Island (main-stem Columbia River below Bonneville Dam) subpopulation, Bright fall Chinook salmon spawner abundance estimates were based on trapezoidal AUC using year-specific estimates of apparent residence time (Table 5). These values were further refined based on the peak count relationship across years and the final values are reported in Table 27. It should be noted that there have been fall Chinook salmon documented spawning in deep water in the Ives Island subpopulation (Mueller 2004). If these fish are not observed as spawners on surveys, our estimates of spawner abundance are biased low. For the Hamilton Creek subpopulation, Bright fall Chinook salmon spawner abundance estimate for 2010 was based on a PCE factor of 2.06 (95% CI 1.14-4.96). This expansion factor was applied to the largest single day combined count of lives and deads. For 2011-2017, abundance estimates were based on trapezoidal AUC using year-specific estimates of apparent residence time (Table 6). These values were further refined based on the peak count relationship across years and the final values are reported in Table 27.

Over the last eight years, total spawner abundance for the Lower Gorge Bright fall Chinook population has ranged from a low of 670 in 2010 to a high of 8,514 in 2016 (Table 28). The proportion of hatchery-origin spawners has ranged from a low of 2.9% in 2017 to a high of 21.8% in 2013 (Figure 34, Table 28). NOR spawner abundance estimates have ranged from a low of 631 in 2012 to a high of 8,240 in 2016 (Figure 34, Table 28).

Scale samples were collected from carcasses recovered on spawning ground surveys. A total of 243 ad-clipped and 1,904 unclipped fish were aged across spawn years 2013-2017. Age structure was variable year to year but age-4 was the dominate age (Appendix E: Table E10). Sex ratios were consistent year to year and nearly evenly split between males and females. However, all years with the exception of one had slightly more females than males (Table 28). The 50% spawn date for Bright fall Chinook in the Lower Gorge was variable year to year ranging from approximately November 1 to November 17 in spawn years 2010-2017 (Figure 35). Spawn timing data was not available for Hamilton Creek in spawn year 2010 due the study design that was implemented.

We do not report on redd distribution for the Lower Gorge Bright fall Chinook population as individual redd locations were not georeferenced.

Table 28. Estimates of apparent residence time (mean, standard deviation, and 95% credible intervals of the posterior distribution) used to develop total spawner abundance estimates for the adult Lower Gorge Bright fall Chinook population for spawn years 2010-2017.

Spawn Year	Subpopulation	Parameter	Mean	SD	L 95% CI	U 95% CI
2010	Ives Island	ART	5.63	0.84	4.18	7.60
2011	Ives Island	ART	8.43	1.23	5.81	10.78
2012	Ives Island	ART	6.52	0.96	4.82	8.65
2013	Ives Island	ART	6.02	0.88	4.50	8.04
2014	Ives Island	ART	6.97	0.97	5.18	9.05
2015	Ives Island	ART	7.77	1.11	5.49	9.98
2016	Ives Island	ART	5.12	0.78	3.88	7.01
2017	Ives Island	ART	8.09	1.15	5.74	10.35
2010	Hamilton[a]	ART	---	---	---	---
2011	Hamilton	ART	6.50	1.81	3.44	10.46
2012	Hamilton	ART	6.55	1.82	3.43	10.56
2013	Hamilton	ART	3.48	0.57	2.30	4.44
2014	Hamilton	ART	5.31	1.00	3.38	7.20
2015	Hamilton	ART	7.33	1.62	4.32	10.75
2016	Hamilton	ART	6.98	1.48	4.23	10.04
2017	Hamilton	ART	8.55	2.21	4.72	13.41

[a]Peak count expansion used for Hamilton Creek spawner abundance estimates in 2010.

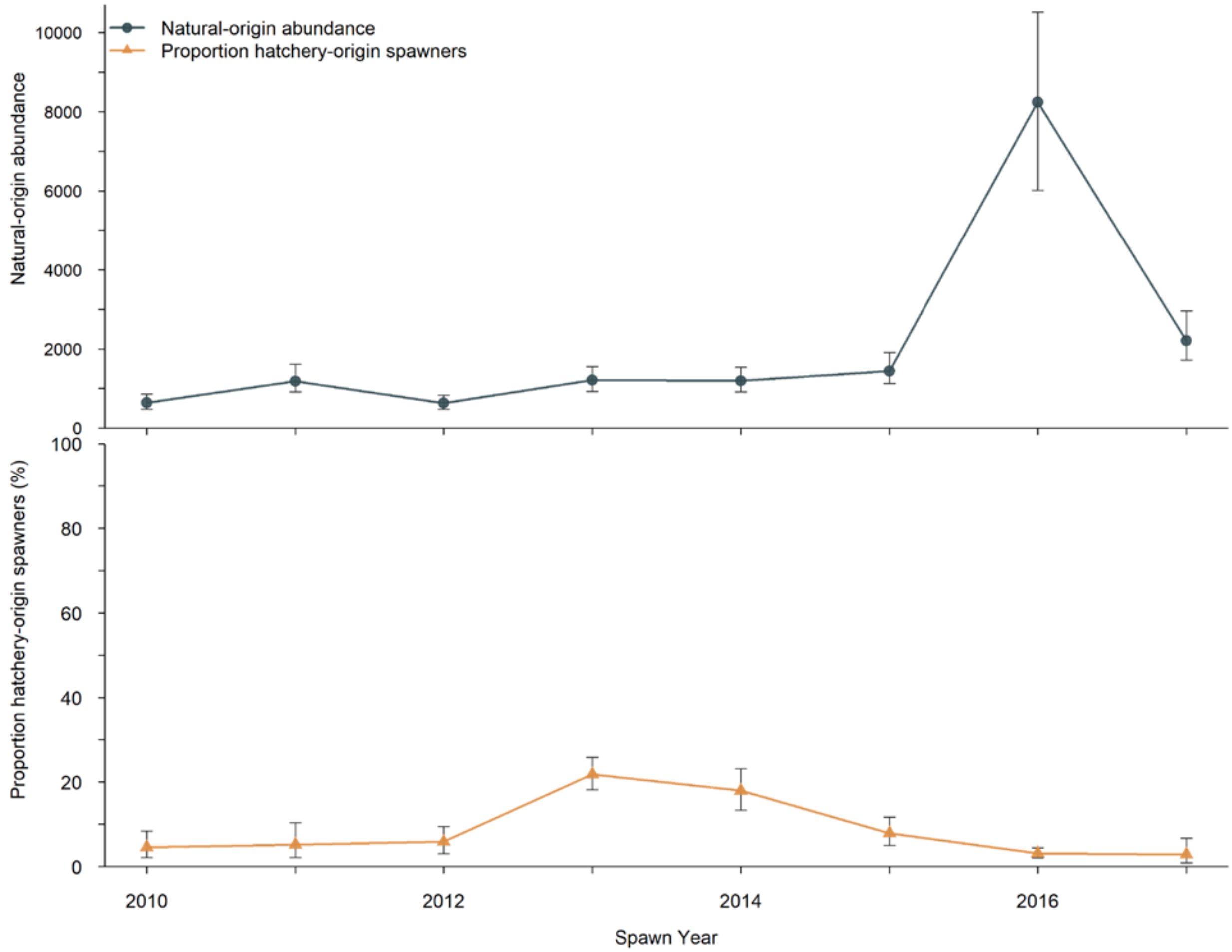

Figure 34. Estimates of adult natural-origin spawner abundance and the proportion of hatchery-origin spawners for the Lower Gorge Bright fall Chinook population for spawn years 2010-2017. The blue circles and orange triangles represent means of the posterior distribution for natural-origin abundance and proportion of hatchery-origin spawners, respectively. The grey error bars represent the 95% credible intervals.

Table 29. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Lower Gorge Bright fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	670	1,246	671	1,554	1,451	1,569	8,514	2,268
	SD	104	183	96	193	186	217	1,168	325
	L 95% CI	501	969	510	1,206	1,129	1,229	6,237	1,776
	U 95% CI	909	1,692	889	1,967	1,865	2,082	10,880	3,029
Males	Mean	323	531	209	801	643	554	3,186	744
	SD	54	90	36	114	93	87	471	155
	L 95% CI	228	393	147	594	484	412	2,284	494
	U 95% CI	442	749	289	1,044	843	753	4,164	1,087
Females	Mean	347	715	462	753	808	1,015	5,328	1,525
	SD	63	113	73	92	116	151	737	247
	L 95% CI	249	538	342	589	609	778	3,910	1,138
	U 95% CI	489	982	623	951	1,069	1,369	6,797	2,111
HOS	Mean	31	65	39	339	261	125	275	65
	SD	14	28	13	47	50	33	61	35
	L 95% CI	14	26	19	256	177	74	172	20
	U 95% CI	65	134	70	442	374	200	410	156
NOS	Mean	639	1,181	631	1,215	1,190	1,445	8,240	2,204
	SD	97	175	90	159	157	200	1,136	319
	L 95% CI	477	918	480	924	919	1,129	6,016	1,719
	U 95% CI	861	1,611	834	1,556	1,538	1,909	10,510	2,958
pF	Mean	51.7%	57.4%	68.8%	48.5%	55.7%	64.7%	62.6%	67.2%
	SD	4.0%	3.5%	3.6%	2.4%	3.2%	2.9%	1.7%	4.9%
	L 95% CI	44.0%	50.6%	61.5%	44.0%	49.3%	58.8%	59.1%	57.3%
	U 95% CI	59.4%	64.1%	75.6%	53.3%	61.9%	70.3%	65.9%	76.5%
pHOS	Mean	4.6%	5.2%	5.9%	21.8%	18.0%	7.9%	3.2%	2.9%
	SD	1.6%	2.1%	1.7%	1.9%	2.5%	1.7%	0.6%	1.5%
	L 95% CI	2.2%	2.2%	3.1%	18.2%	13.3%	5.0%	2.1%	0.9%
	U 95% CI	8.4%	10.4%	9.5%	25.8%	23.2%	11.7%	4.5%	6.7%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

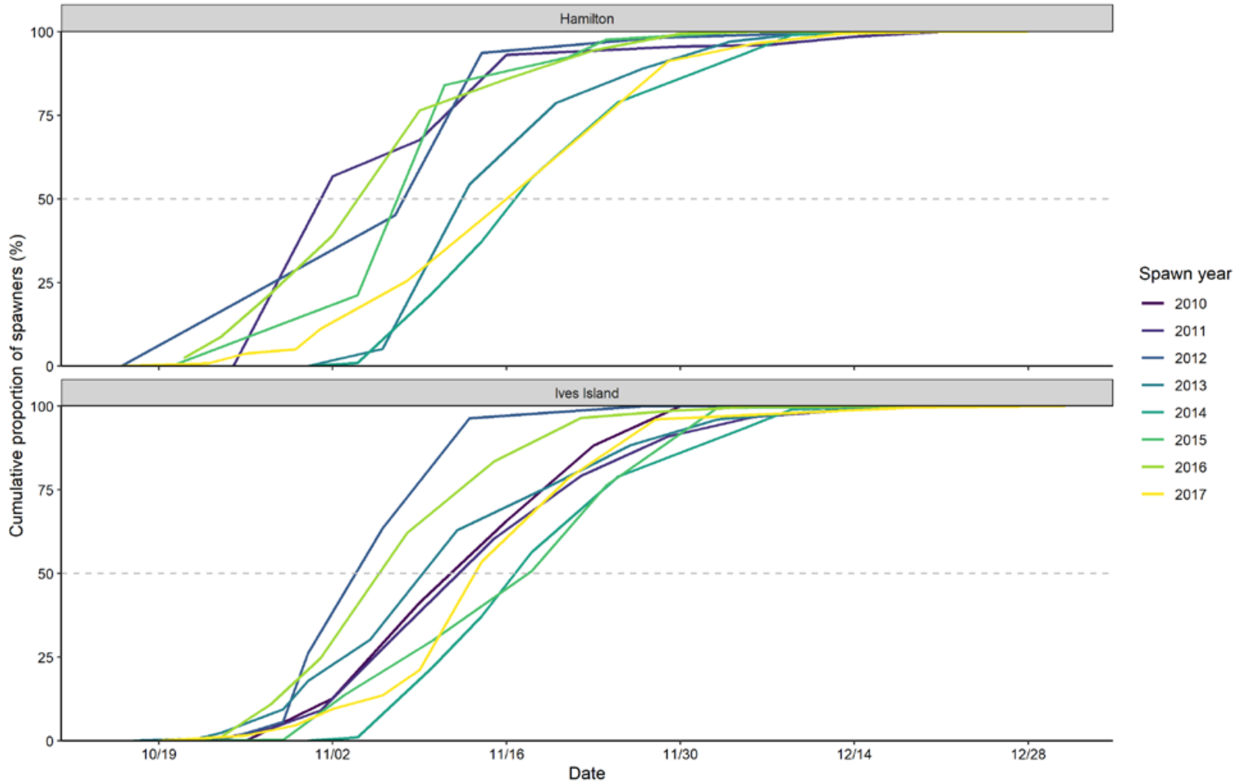

Figure 35. Spawn timing of the Lower Gorge Bright fall Chinook population based on cumulative counts of live adult Chinook salmon identified as spawners for spawn years 2010-2017. Spawn timing data was not available for Hamilton Creek in spawn year 2010.

Upper Gorge

The Upper Gorge fall Chinook population consists of the Wind and Little White Salmon subpopulations. Additionally, the Upper Gorge fall Chinook salmon population may be divided into a Tule population and a Bright population. We report estimates on each subpopulation for both Tule and Bright stocks (Appendix F: Tables F25-F32). We also combine the subpopulation estimates into population-level estimates of Tule and Bright stocks.

In 2013, we expanded our VSP monitoring program for Chinook salmon to populations within the LCR ESU but upstream of Bonneville Dam, which included the Upper Gorge. As a result, we transitioned from PCE to AUC methods for the Wind subpopulation. We continued to use peak count expansion for the Little White Salmon subpopulation until 2017 when a carcass tagging study was implemented and JS was used.

Upper Gorge - Tule

For the Wind subpopulation, Tule fall Chinook salmon spawner abundance was estimated using trapezoidal AUC and year-specific estimates of apparent residence time (Table 5). These values were further refined based on the peak count relationship across years and the final values are reported in Table 29. For the Little White Salmon, in 2013-2016, Tule fall Chinook salmon spawner abundance was estimated based on a PCE of 3.67 (95%CI 1.56-7.73). This expansion factor was applied to the largest single day count of deads. In 2017, spawner abundance was estimated through carcass tagging using JS model, which was adjusted for prespawn mortality.

We conducted additional analyses to test for size and sex selectivity to ensure the equal catchability assumption of the JS model was met, GOF to ensure the data fit the different JS models, and model selection to help inform the best model to use for the data (Appendix G: Tables G33-G34). Abundance estimation methods for 2010-2012 can be found in Table 1 and Rawding et al. (2014), Rawding et al. (2019), and Buehrens et al. (2019). We updated 2010-2012 adult fall Chinook salmon estimates with our improved models.

Over the last eight years, total spawner abundance for the Upper Gorge Tule fall Chinook population has ranged from a low of 565 in 2010 to a high of 3,826 in 2015 (Table 30). The proportion of hatchery-origin spawners has ranged from a low of 17.4% in 2017 to a high of 75.4% in 2014 (Figure 36, Table 30). NOR spawner abundance has ranged from a low of 338 in 2012 to a high of 1,225 in 2015 (Figure 36, Table 30).

Scale samples were collected from carcasses recovered on spawning ground surveys. A total of 1,444 ad-clipped and 798 unclipped fish were aged across spawn years 2013-2017. Age structure was variable year to year but HORs tended to be heavier to age-3 while NOR spawners were more evenly split between age-3 and age-4 (Appendix E: Table E11). Annual sex ratios were quite variable ranging from 34.4% to 69.2% females (Table 30). The 50% spawn date for Tule fall Chinook salmon in the Wind River was relatively consistent ranging from approximately September 22 to September 29 in spawn years 2013-2017 (Figure 37). Spawn timing information was not available for the Wind River in spawn years 2010-2012 or for Little White Salmon River subpopulation for spawn years 2010-2017 due to the study design that was implemented.

We do not report spatial structure for the Upper Gorge Tule fall Chinook population as individual redd locations were not georeferenced.

Table 30. Estimates of apparent residence time (mean, standard deviation, and 95% credible intervals of the posterior distribution) used to develop total spawner abundance estimates for the adult Upper Gorge Tule fall Chinook population for spawn years 2010-2017.

Spawn Year	Subpopulation	Parameter	Mean	SD	L 95% CI	U 95% CI
2010[a]	Wind	ART	---	---	---	---
2011[a]	Wind	ART	---	---	---	---
2012[a]	Wind	ART	---	---	---	---
2013	Wind	ART	5.72	0.79	3.98	6.96
2014	Wind	ART	5.35	0.75	3.70	6.64
2015	Wind	ART	6.99	1.16	4.53	8.99
2016	Wind	ART	7.19	1.27	4.55	9.37
2017	Wind	ART	8.93	2.26	4.87	13.48

[a]PCE methods were used for 2010-2012 estimates.

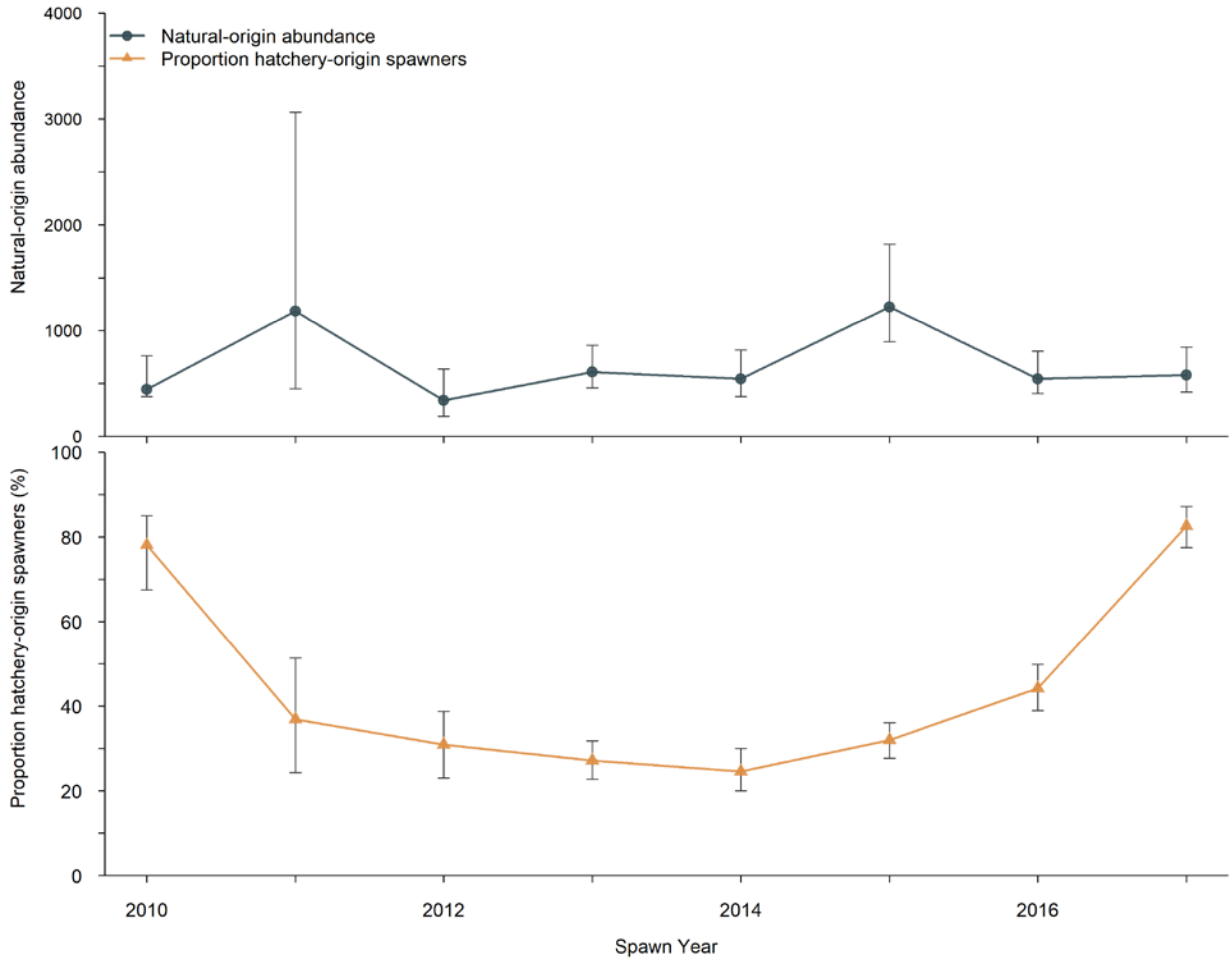

Figure 36. Estimates of adult natural-origin spawner abundance and the proportion of hatchery-origin spawners for the Upper Gorge Tule fall Chinook population for spawn years 2010-2017. The blue circles and orange triangles represent means of the posterior distribution for natural-origin abundance and proportion of hatchery-origin spawners, respectively. The grey error bars represent the 95% credible intervals.

Table 31. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Upper Gorge Tule fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	565	3,084	1,090	2,239	2,191	3,826	1,231	697
	SD	156	1,407	349	346	357	693	231	123
	L 95% CI	486	1,639	704	1,794	1,709	2,924	929	516
	U 95% CI	953	6,665	1,962	3,105	3,052	5,579	1,807	994
Males	Mean	371	1,269	436	778	1,016	1,661	567	215
	SD	108	600	144	134	166	317	111	44
	L 95% CI	299	646	274	596	785	1,237	417	148
	U 95% CI	625	2,787	792	1,105	1,423	2,454	843	321
Females	Mean	194	1,815	654	1,461	1,176	2,165	663	482
	SD	56	822	213	229	207	397	129	86
	L 95% CI	141	962	413	1,157	892	1,630	489	355
	U 95% CI	325	3,943	1,178	2,033	1,665	3,152	985	688
HOS	Mean	124	1,898	752	1,631	1,651	2,602	687	120
	SD	43	752	245	259	259	477	135	23
	L 95% CI	78	1,140	497	1,282	1,298	1,970	499	82
	U 95% CI	228	3,759	1,351	2,266	2,295	3,809	1,019	172
NOS	Mean	441	1,186	338	608	541	1,225	544	577
	SD	134	752	124	106	122	238	106	109
	L 95% CI	376	451	189	456	375	893	402	419
	U 95% CI	759	3,063	636	860	815	1,818	802	842
pF	Mean	34.4%	59.0%	60.0%	65.3%	53.6%	56.6%	53.9%	69.2%
	SD	3.7%	3.0%	3.1%	2.3%	2.3%	2.1%	2.6%	2.8%
	L 95% CI	27.5%	53.1%	53.8%	60.6%	49.1%	52.5%	48.8%	63.6%
	U 95% CI	41.9%	64.9%	65.9%	69.7%	58.3%	60.8%	59.0%	74.4%
pHOS	Mean	21.9%	63.1%	69.1%	72.8%	75.4%	68.0%	55.8%	17.4%
	SD	4.5%	7.1%	4.0%	2.3%	2.5%	2.1%	2.8%	2.5%
	L 95% CI	15.0%	48.6%	61.2%	68.2%	70.0%	63.9%	50.2%	12.8%
	U 95% CI	32.5%	75.8%	76.9%	77.2%	80.0%	72.3%	61.0%	22.6%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

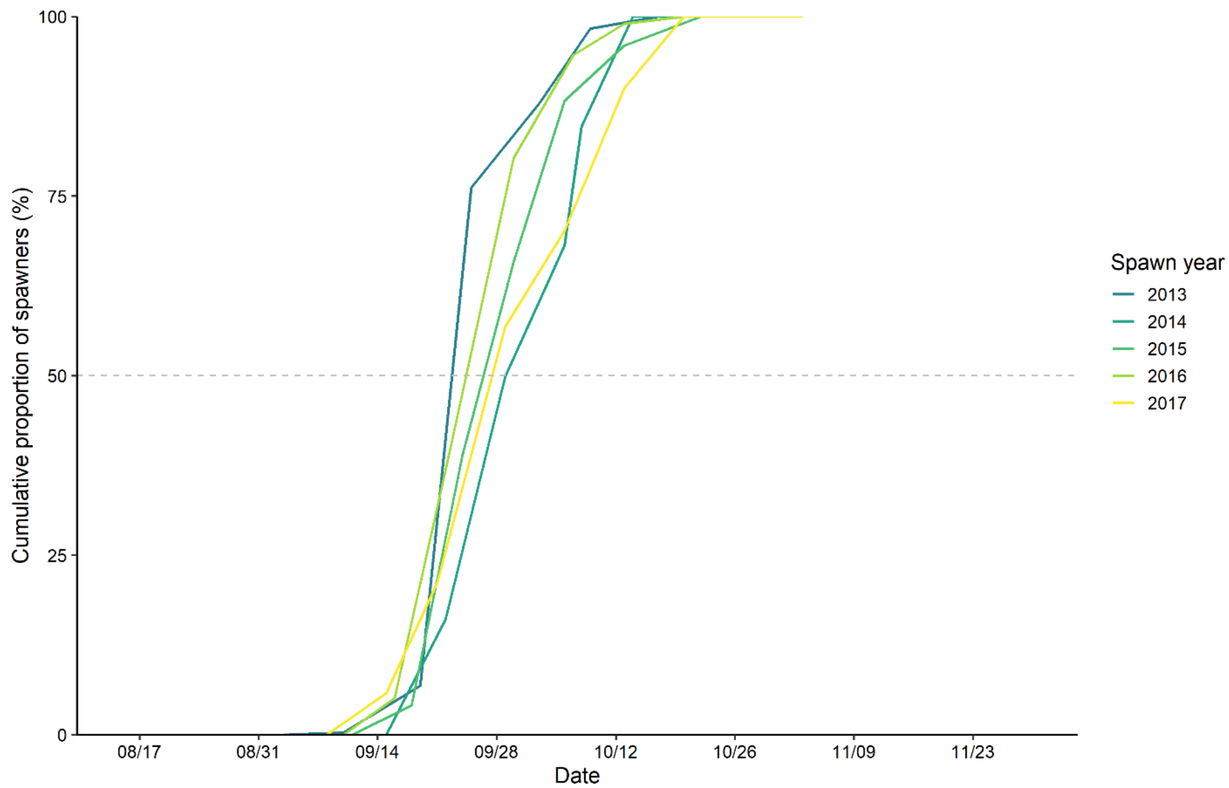

Figure 37. Spawn timing of the Upper Gorge Tule fall Chinook population based on cumulative counts of live adult Chinook salmon identified as spawners for spawn years 2013-2017. Only the Wind River is shown. Spawn timing information was not available for the Wind River in spawn years 2010-2012 or the Little White Salmon River in spawn years 2010-2017.

Upper Gorge - Bright

For the Wind River subpopulation, Bright fall Chinook salmon spawner abundance estimates from 2013-2017 were based on trapezoidal AUC year-specific estimates of apparent residence time (Table 5). These values were further refined based on the peak count relationship across years and the final values are reported in Table 31. For the Little White Salmon subpopulation, a carcass tagging study was implemented in 2017 for the first time since 1966 to reassess the PCE factor that has been used for the last 50+ years to estimate spawner abundance. For 2017, we report on spawner abundance using the JS model adjusted for prespawn mortality. For 2013-2016 estimates, we redeveloped the PCE factor based on the 2017 JS estimate paired with weekly counts. This new PCE factor was based on counts of deads only (new + previously sampled + unsampled carcasses) to remove any error associated with live fish recruiting to the hatchery between weekly surveys. This PCE factor of 3.36 (95% CI 2.42-4.73) was applied to the single day peak count of carcasses within the index area (RM 1.2 to 0) to develop abundance estimates for 2010 to 2016. Abundance estimation methods for 2010-2012 can be found in Table 1 and Rawding et al. (2014), Rawding et al. (2019), and Buehrens et al. (2019). We updated 2010-2012 adult fall Chinook salmon estimates with our improved models.

Over the last eight years, population-level spawner abundance has ranged from a low of 578 in 2012 to a high of 9,828 in 2013 (Table 32). The proportion of hatchery-origin spawners has ranged from a low of 42.8% in 2010 to a high of 83.7% in 2013 (Figure 38, Table 32). NOR spawner abundance has ranged from a low of 200 in 2012 to a high of 1,601 in 2013 (Figure 38, Table 32).

Scale samples were collected from carcasses recovered on spawning ground surveys. A total of 1,886 ad-clipped and 860 unclipped fish were aged across spawn years 2013-2017. Age structure was variable year to year but age-4 was the dominate age class (Appendix E: Table E12). Annual sex ratios were consistently heavy to females (Table 32). The 50% spawn date for Bright fall Chinook salmon in the Upper Gorge population was within the first 10 days of November in spawn years 2013-2017 (Figure 39). Spawn timing information was not available for the Wind subpopulation in spawn years 2010-2012 or for Little White Salmon River subpopulation for spawn years 2010-2017 due to the study design that was implemented.

We do not report spatial structure for the Upper Gorge Bright fall Chinook population as individual redd locations were not georeferenced.

Table 32. Estimates of apparent residence time (mean, standard deviation, and 95% credible intervals of the posterior distribution) used to develop total spawner abundance estimates for the adult Upper Gorge Bright fall Chinook population for spawn years 2010-2017.

Spawn Year	Subpopulation	Parameter	Mean	SD	L 95% CI	U 95% CI
2010[a]	Wind	ART	---	---	---	---
2011[a]	Wind	ART	---	---	---	---
2012[a]	Wind	ART	---	---	---	---
2013	Wind	ART	6.71	1.19	4.57	9.38
2014	Wind	ART	6.45	1.15	4.41	9.01
2015	Wind	ART	7.04	1.26	4.72	9.77
2016	Wind	ART	5.83	1.07	4.01	8.24
2017	Wind	ART	8.16	1.52	5.15	11.13

[a]PCE methods were used for 2010-2012 estimates.

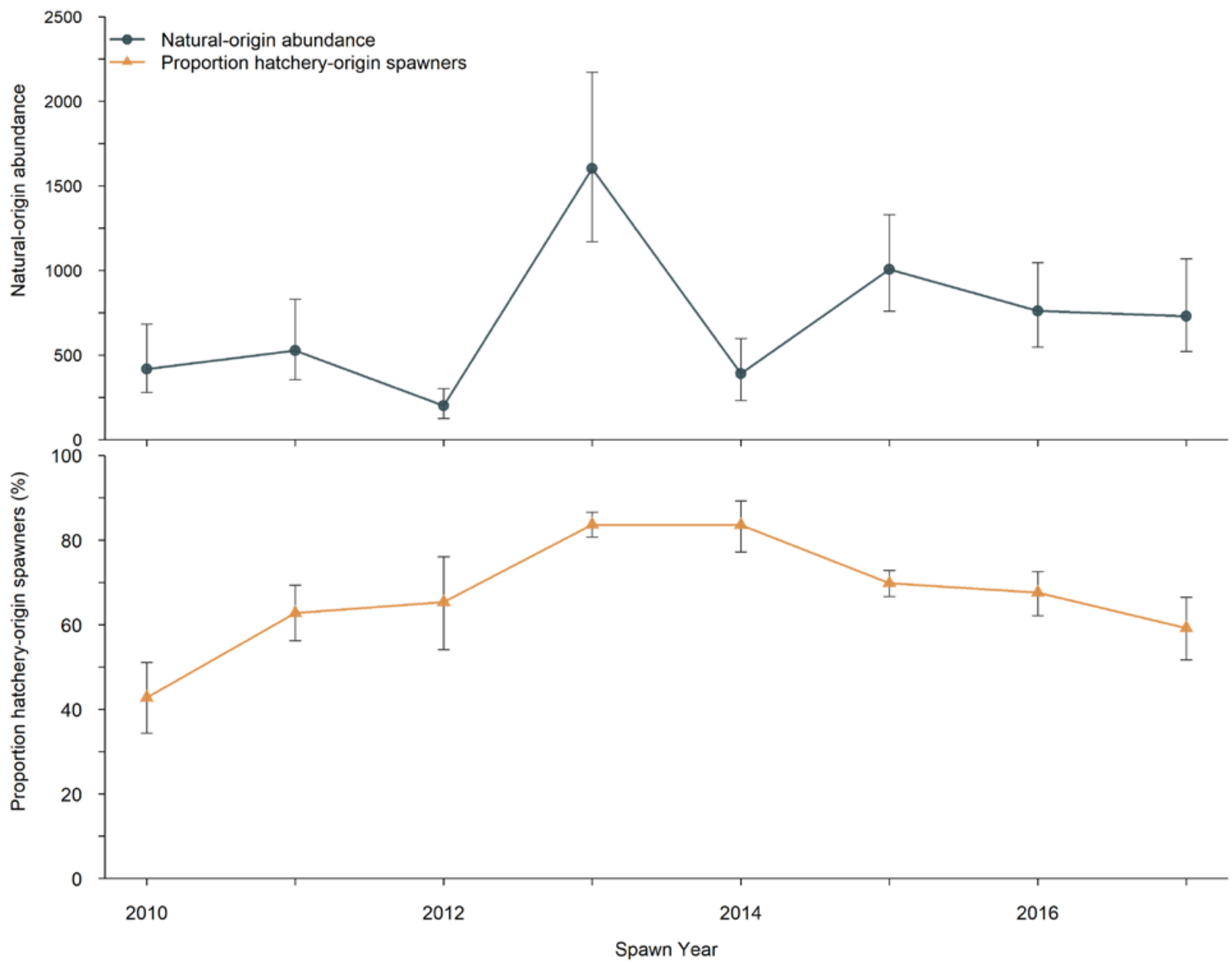

Figure 38. Estimates of adult natural-origin spawner abundance and the proportion of hatchery-origin spawners for the Upper Gorge Bright fall Chinook population for spawn years 2010-2017. The blue circles and orange triangles represent means of the posterior distribution for natural-origin abundance and proportion of hatchery-origin spawners, respectively. The grey error bars represent the 95% credible intervals.

Table 33. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Upper Gorge Bright fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	726	1,418	578	9,828	2,371	3,327	2,344	1,788
	SD	165	339	91	1,250	309	436	313	276
	L 95% CI	523	1,008	434	7,695	1,846	2,594	1,811	1,382
	U 95% CI	1,105	2,202	788	12,630	3,057	4,306	3,020	2,458
Males	Mean	260	504	253	3,791	634	1,091	605	405
	SD	64	135	52	516	121	154	94	77
	L 95% CI	179	337	167	2,938	429	833	446	284
	U 95% CI	391	812	372	4,934	907	1,435	808	583
Females	Mean	466	914	325	6,036	1,737	2,236	1,739	1,382
	SD	110	219	62	787	243	300	236	228
	L 95% CI	327	648	226	4,690	1,325	1,725	1,336	1,051
	U 95% CI	723	1,397	463	7,790	2,269	2,903	2,255	1,945
HOS	Mean	308	890	378	8,227	1,981	2,321	1,583	1,058
	SD	61	216	68	1,049	263	308	211	170
	L 95% CI	223	628	270	6,453	1,539	1,807	1,222	800
	U 95% CI	442	1,381	532	10,600	2,563	3,003	2,034	1,466
NOS	Mean	418	527	200	1,601	390	1,006	761	730
	SD	116	138	46	257	92	144	128	139
	L 95% CI	278	354	125	1,169	233	759	547	521
	U 95% CI	682	831	302	2,170	597	1,330	1,046	1,069
pF	Mean	64.1%	64.5%	56.2%	61.4%	73.3%	67.2%	74.2%	77.3%
	SD	3.4%	3.3%	5.8%	1.8%	3.7%	1.8%	2.0%	3.0%
	L 95% CI	57.3%	57.9%	44.7%	57.9%	65.7%	63.6%	70.1%	71.1%
	U 95% CI	70.7%	70.6%	67.4%	65.0%	80.1%	70.7%	78.1%	82.9%
pHOS	Mean	42.8%	62.8%	65.4%	83.7%	83.6%	69.8%	67.6%	59.2%
	SD	4.2%	3.4%	5.6%	1.5%	3.1%	1.6%	2.6%	3.8%
	L 95% CI	34.4%	56.3%	54.1%	80.7%	77.2%	66.7%	62.2%	51.7%
	U 95% CI	51.1%	69.4%	76.1%	86.6%	89.3%	72.9%	72.6%	66.5%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

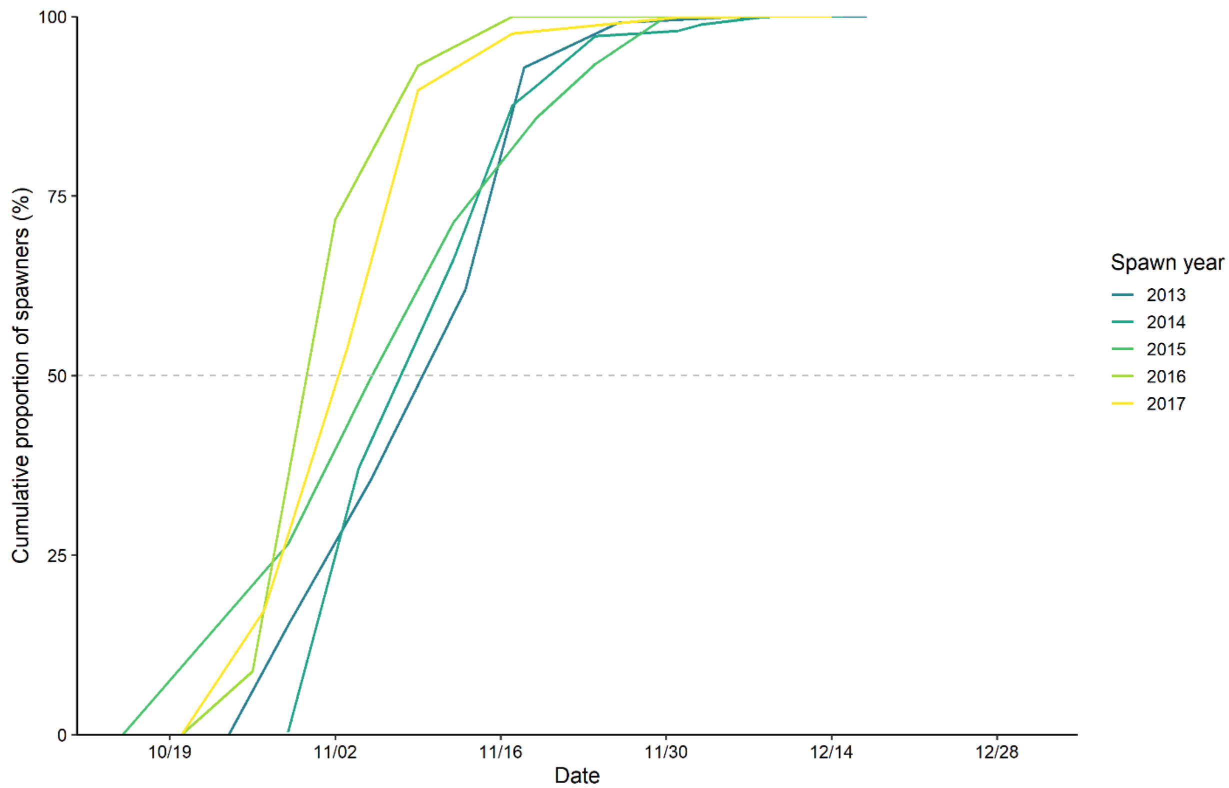

Figure 39. Spawn timing of the Upper Gorge Bright fall Chinook population based on cumulative counts of live adult Chinook salmon identified as spawners for spawn years 2013-2017. Only the Wind River is shown. Spawn timing information was not available for the Wind River in spawn years 2010-2012 or the Little White Salmon River in spawn years 2010-2017.

White Salmon

In 2013, we expanded our VSP monitoring program for Chinook salmon to populations upstream of Bonneville Dam but still within the LCR ESU, which included the White Salmon. The White Salmon fall Chinook population may be divided into a Tule population and a Bright population. Abundance and biological information are reported separately for Bright and Tule populations.

White Salmon - Tule

Tule fall Chinook salmon spawner abundance estimates for 2013-2017 were based on trapezoidal AUC using year-specific estimates of apparent residence time (Table 5). These values were further refined based on the peak count relationship across years and the final values are reported in Table 33. Abundance estimation methods for 2010-2012 can be found in Table 1 and Rawding et al. (2014), Rawding et al. (2019), and Buehrens et al. (2019). We updated 2010-2012 adult fall Chinook salmon estimates with our improved models.

Over the last eight years, total spawner abundance for the White Salmon Tule fall Chinook population has ranged from a high of 1,887 adults in 2010 to a low of 565 adults in 2016 (Table 34). The proportion of hatchery-origin spawners has been relatively variable ranging from a low of 6.4% in 2012 to a high of 51.5% in 2015 (Figure 40, Table 34). NOR spawner abundance estimates have ranged from a low of 375 in 2015 to a high of 1,369 in 2010 (Figure 40, Table 34).

Scale samples were collected from carcasses recovered on spawning ground surveys. A total of 393 ad-clipped and 665 unclipped fish were aged across spawn years 2013-2017. Age structure was variable year to year but HOR spawners tended to be heavier to age-3 while NOR spawners were more evenly split between age-3 and age-4 (Appendix E: Table E13). Annual sex ratios were consistently heavy to females in the years post dam removal (Table 34). The 50% spawn date for Tule fall Chinook salmon in the White Salmon ranged from the last few days of September through the first week of October in spawn years 2013-2017 (Figure 41). Spawn timing information was not available for the White Salmon population in spawn years 2010-2012 due to the study design that was implemented.

The United States Fish and Wildlife Service led spawning ground surveys in collaboration with WDFW staff in 2014. As a result, WDFW did not georeference Tule fall Chinook salmon redds this year. In spawn years 2013 and 2015-2017, the redd distribution for Tule fall Chinook salmon redds was concentrated in the lowermost reaches with between 50% and 91% of the observed redds in the reach between the RM 1 and RM 0. All but a handful of redds (two in 2015 and one in 2016) were found below the old Condit Dam site. Tule fall Chinook salmon redd distribution is displayed in Figure 42.

Table 34. Estimates of apparent residence time (mean, standard deviation, and 95% credible intervals of the posterior distribution) used to develop total spawner abundance estimates for the adult White Salmon Tule fall Chinook population for spawn years 2010-2017.

Spawn Year	Parameter	Mean	SD	L 95% CI	U 95% CI
2010[a]	ART	---	---	---	---
2011[a]	ART	---	---	---	---
2012[a]	ART	---	---	---	---
2013	ART	6.59	1.48	4.13	10.03
2014	ART	8.65	1.95	4.93	12.53
2015	ART	7.82	1.62	4.76	11.19
2016	ART	6.04	1.41	3.85	9.34
2017	ART	5.88	1.36	3.75	9.09

[a]PCE methods were used for 2010-2012 estimates.

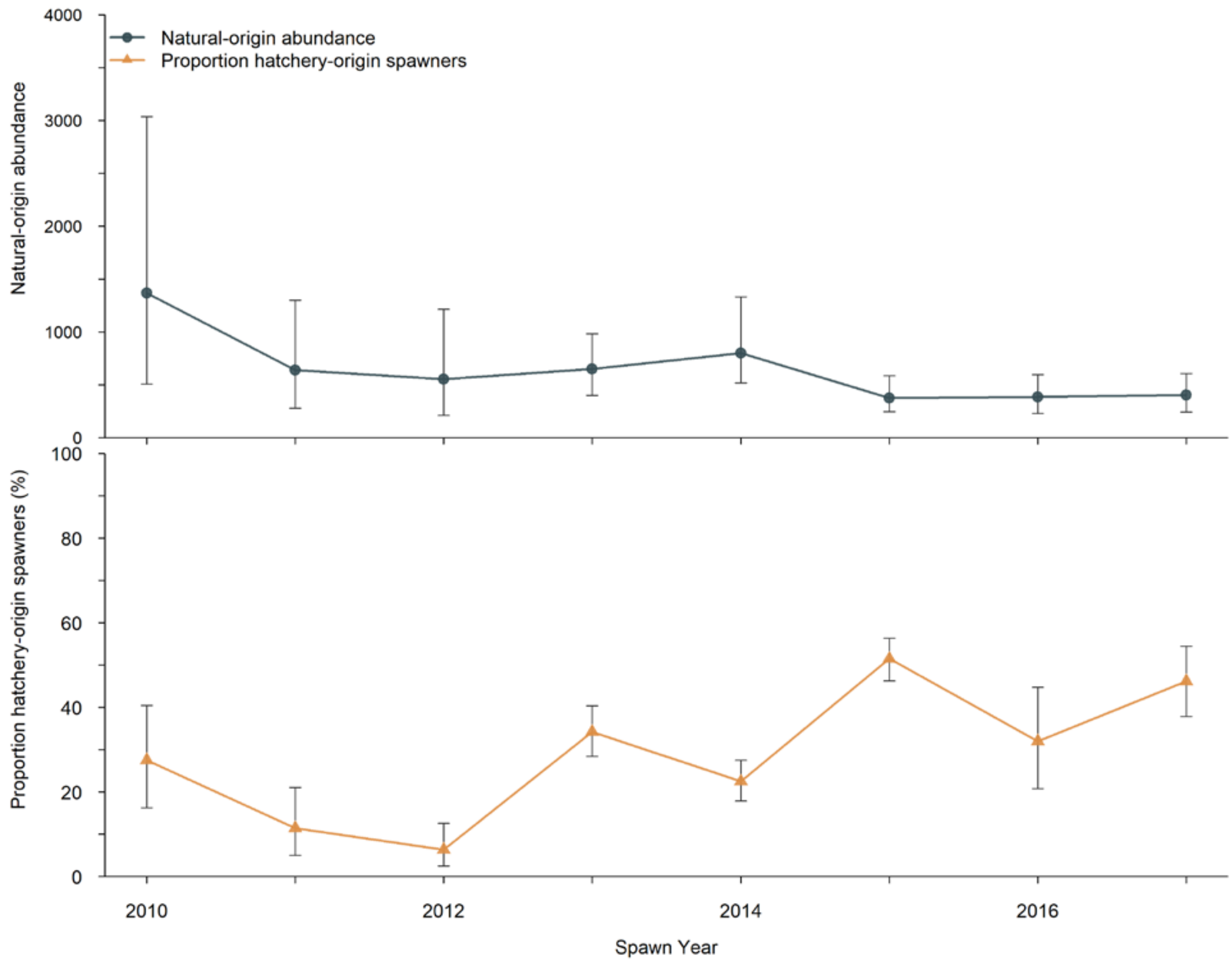

Figure 40. Estimates of adult natural-origin spawner abundance and the proportion of hatchery-origin spawners for the White Salmon Tule fall Chinook population for spawn years 2010-2017. The blue circles and orange triangles represent means of the posterior distribution for natural-origin abundance and proportion of hatchery-origin spawners, respectively. The grey error bars represent the 95% credible intervals.

Table 35. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult White Salmon Tule fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	1,887	723	593	984	1,034	773	565	747
	SD	954	309	300	221	271	178	129	167
	L 95% CI	708	311	226	616	674	516	347	459
	U 95% CI	4,158	1,465	1,296	1,494	1,712	1,212	843	1,113
Males	Mean	1,198	374	134	260	257	221	195	158
	SD	613	166	72	65	73	54	56	43
	L 95% CI	450	156	48	155	158	143	103	88
	U 95% CI	2,670	778	302	408	436	352	319	255
Females	Mean	689	349	459	724	777	552	371	588
	SD	358	155	234	165	205	128	91	134
	L 95% CI	253	146	174	450	501	366	218	360
	U 95% CI	1,557	712	1,011	1,094	1,288	868	573	885
HOS	Mean	518	83	38	336	233	398	181	345
	SD	295	49	26	82	66	94	55	84
	L 95% CI	170	25	9	205	141	261	94	205
	U 95% CI	1,245	203	103	525	396	629	306	530
NOS	Mean	1,369	640	555	648	801	375	384	402
	SD	705	276	282	148	212	88	95	95
	L 95% CI	507	277	212	401	519	248	227	241
	U 95% CI	3,034	1,300	1,215	983	1,332	587	595	606
pF	Mean	36.6%	48.3%	77.4%	73.6%	75.2%	71.5%	65.6%	78.8%
	SD	4.2%	5.3%	3.6%	2.7%	2.5%	2.2%	5.9%	3.3%
	L 95% CI	28.7%	38.1%	70.0%	68.0%	70.2%	67.1%	53.8%	72.1%
	U 95% CI	44.9%	58.8%	84.0%	78.8%	79.8%	75.7%	76.8%	84.9%
pHOS	Mean	27.5%	11.5%	6.4%	34.2%	22.5%	51.5%	32.0%	46.2%
	SD	6.2%	4.2%	2.7%	3.1%	2.4%	2.6%	6.1%	4.2%
	L 95% CI	16.3%	5.0%	2.5%	28.4%	17.9%	46.3%	20.8%	37.9%
	U 95% CI	40.5%	21.1%	12.6%	40.4%	27.5%	56.4%	44.8%	54.5%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

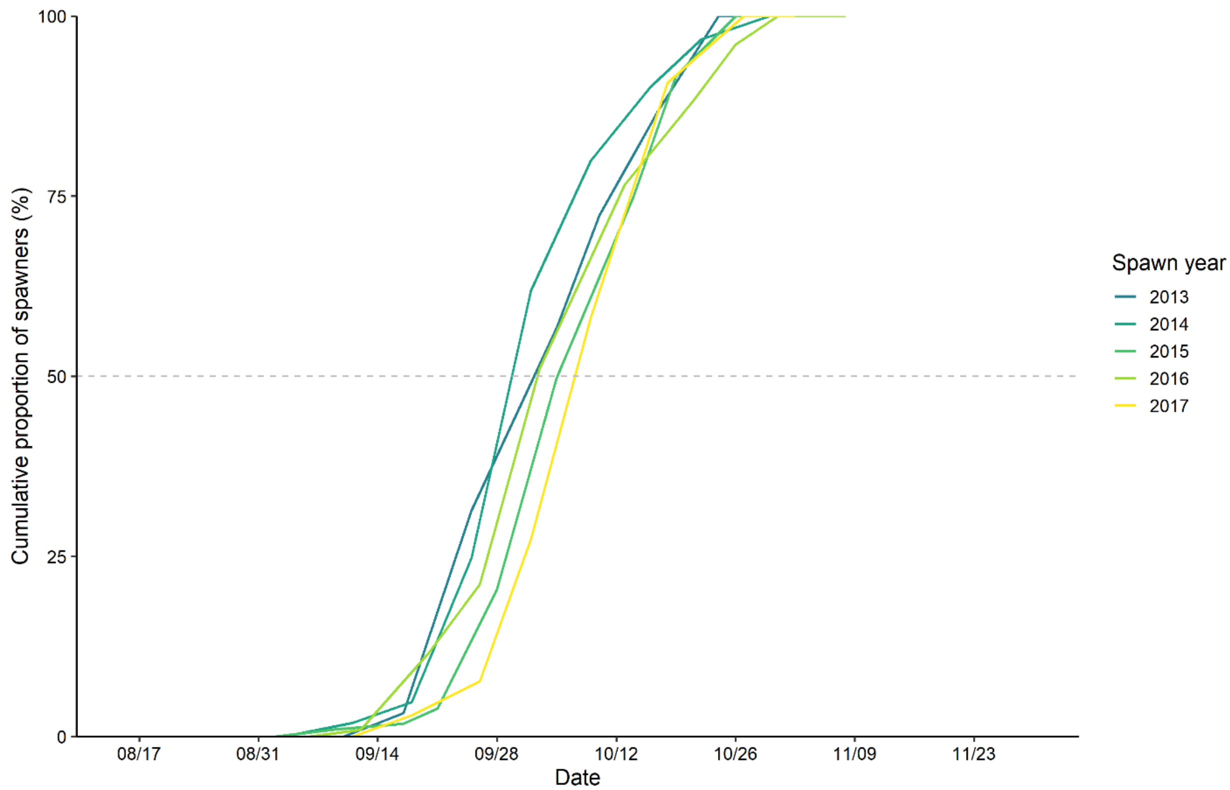

Figure 41. Spawn timing of the White Salmon Tule fall Chinook population based on cumulative counts of live adult Chinook salmon identified as spawners for spawn years 2013-2017. Spawn timing information was not available for the White Salmon population in spawn years 2010-2012.

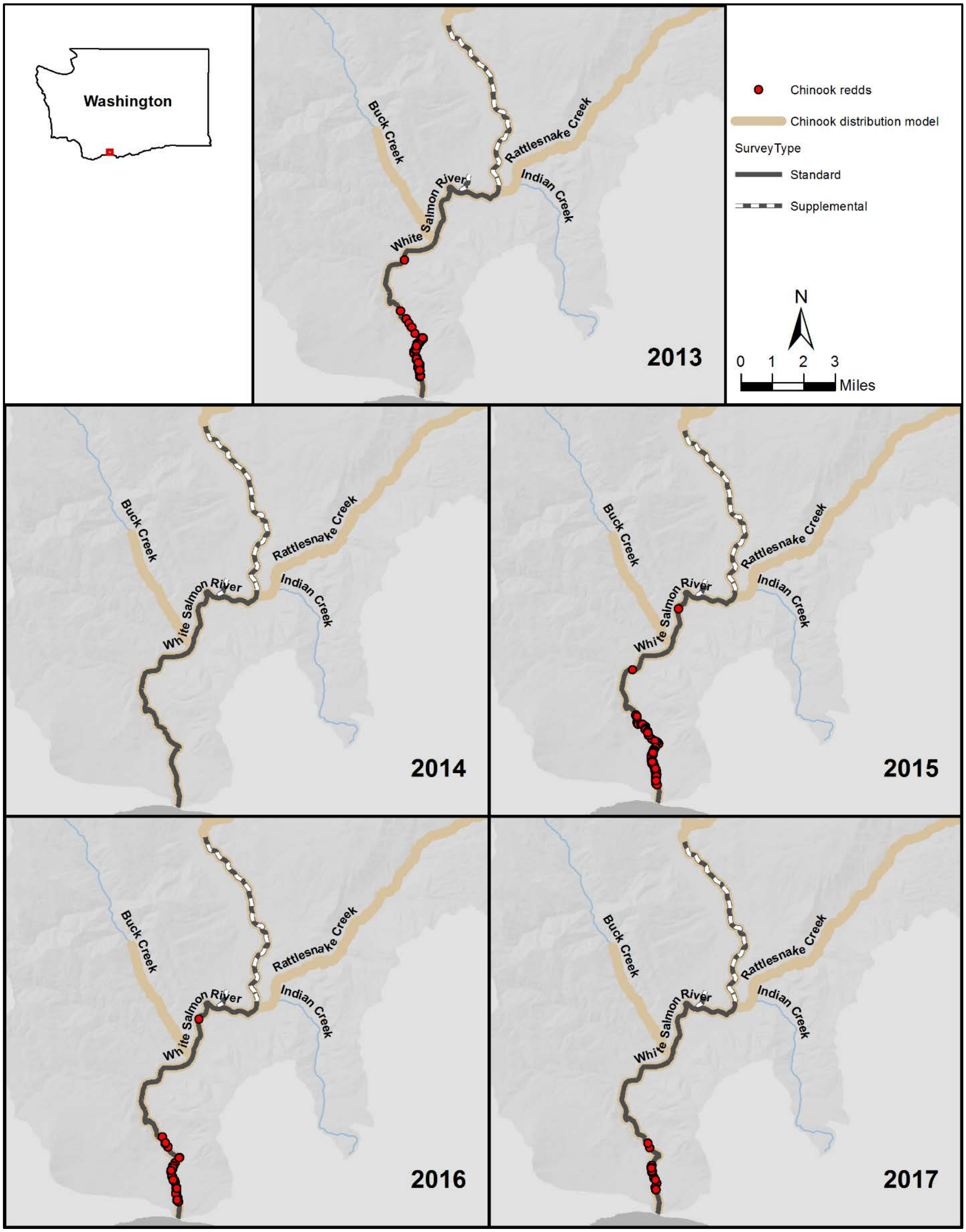

Figure 42. Redd distribution of White Salmon Tule fall Chinook population for spawn years 2013-2017. The grey colored layer represents the area surveyed, the black rectangle represents the weir location, and the individual redd locations are shown as a red colored circle.

White Salmon - Bright

Bright fall Chinook salmon spawner abundance estimates for 2013-2017 were based on trapezoidal AUC using year-specific estimates of apparent residence time (Table 5). These values were further refined based on the peak count relationship across years and the final values are reported in Table 35. Abundance estimation methods for 2010-2012 can be found in Table 1 and Rawding et al. (2014), Rawding et al. (2019), and Buehrens et al. (2019). We updated 2010-2012 adult fall Chinook salmon estimates with our improved models.

Over the last eight years, total spawner abundance for the White Salmon Bright fall Chinook population has ranged from a low of 1,104 adults in 2012 to a high of 8,686 adults in 2015 (Table 36). The proportion of hatchery-origin spawners has been high ranging from a low of 32.7% in 2012 to a high of 80.0% in 2015 (Figure 43, Table 36). NOR spawner abundance estimates have ranged from a low of 487 in 2017 to a high of 1,741 in 2015 (Figure 43, Table 36).

Scale samples were collected from carcasses recovered on spawning ground surveys. A total of 393 ad-clipped and 665 unclipped fish were aged across spawn years 2013-2017. The age structure was similar year to year with age-4 fish being the dominate age class and more age-5 fish than age-3 fish (Appendix E: Table E14). Sex ratios were consistently heavy to females for all years (Table 36). The 50% spawn date for Bright fall Chinook salmon in the White Salmon ranged from approximately November 3 to November 9 in spawn years 2013-2017 (Figure 44). Spawn timing information was not available for the White Salmon population in spawn years 2010-2012 due to the study design that was implemented.

In spawn years 2013-2017, redd distribution of Bright fall Chinook salmon redds was similar to that of Tule fall Chinook salmon with most of the observed found in the lowermost reaches with between 52% and 91% of the observed redds in the reach between the RM 1 and RM 0. There were more Bright fall Chinook salmon redds above the old Condit Dam site than Tule fall Chinook salmon redds but the number of redds was still very minimal relative to the number of redds in the lower reaches. Bright fall Chinook salmon redd distribution is displayed in Figure 45.

Table 36. Estimates of apparent residence time (mean, standard deviation, and 95% credible intervals of the posterior distribution) used to develop total spawner abundance estimates for the adult White Salmon Bright fall Chinook population for spawn years 2010-2017.

Spawn Year	Parameter	Mean	SD	L 95% CI	U 95% CI
2010[a]	ART	---	---	---	---
2011[a]	ART	---	---	---	---
2012[a]	ART	---	---	---	---
2013	ART	6.72	1.60	3.95	10.17
2014	ART	7.38	1.72	4.40	11.03
2015	ART	7.40	1.73	4.41	11.11
2016	ART	6.81	1.59	4.07	10.22
2017	ART	8.23	2.09	4.60	12.76

[a]PCE methods were used for 2010-2012 estimates.

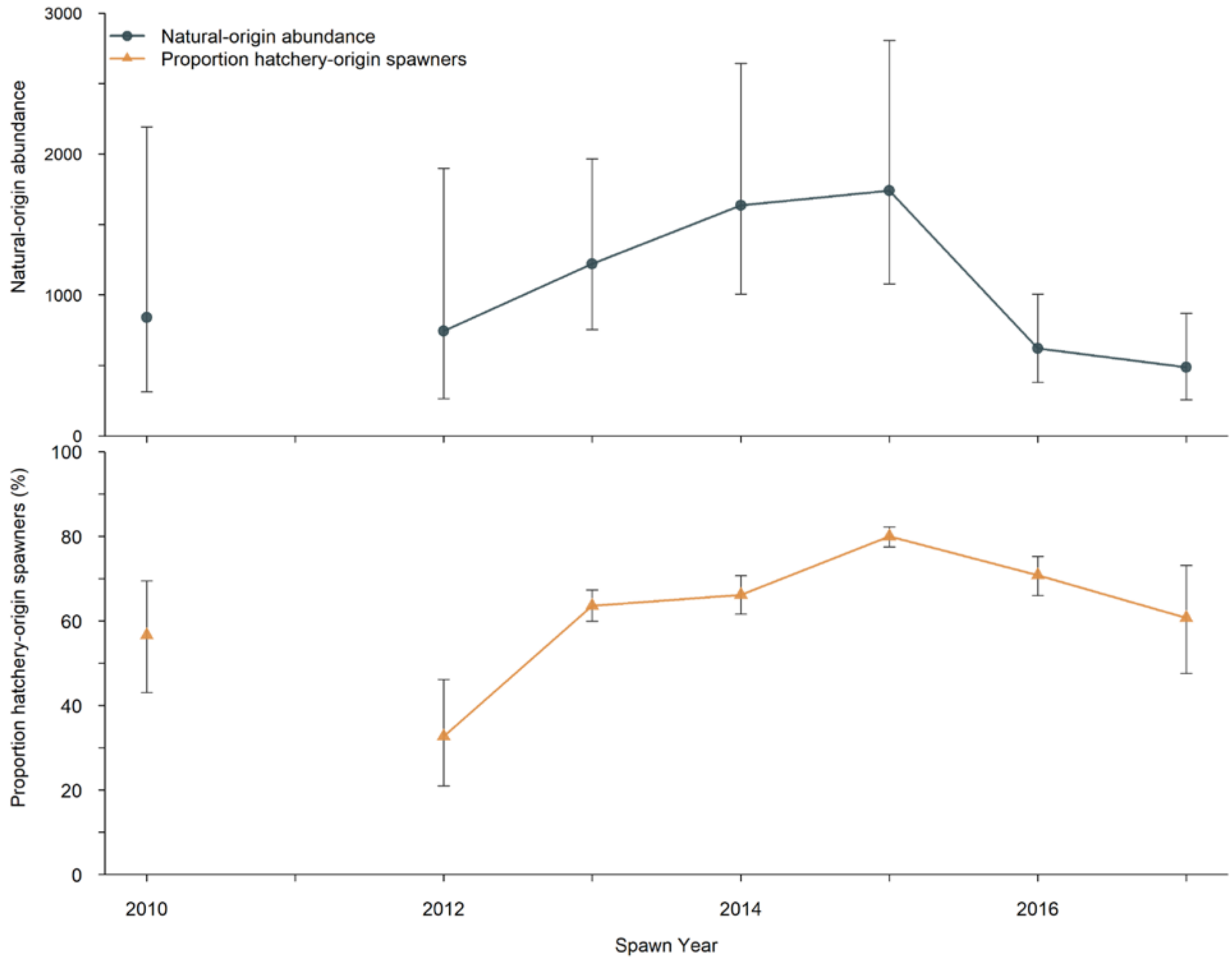

Figure 43. Estimates of adult natural-origin spawner abundance and the proportion of hatchery-origin spawners for the White Salmon Bright fall Chinook population for spawn years 2010-2017. The blue circles and orange triangles represent means of the posterior distribution for natural-origin abundance and proportion of hatchery-origin spawners, respectively. The grey error bars represent the 95% credible intervals.

Table 37. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult White Salmon Bright fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	1,933	NA	1,104	3,355	4,844	8,686	2,128	1,241
	SD	1,202	NA	726	856	1,219	2,141	531	345
	L 95% CI	773	NA	401	2,091	3,064	5,473	1,341	748
	U 95% CI	4,916	NA	2,827	5,381	7,672	13,810	3,373	2,072
Males	Mean	767	NA	263	925	1,517	2,716	476	241
	SD	480	NA	178	243	404	689	127	92
	L 95% CI	296	NA	91	565	930	1,677	288	107
	U 95% CI	1,945	NA	679	1,487	2,456	4,370	778	456
Females	Mean	1,166	NA	841	2,430	3,327	5,970	1,652	1,000
	SD	733	NA	555	623	850	1,481	415	285
	L 95% CI	466	NA	305	1,511	2,085	3,748	1,032	590
	U 95% CI	2948	NA	2,133	3,892	5,293	9,515	2,634	1,688
HOS	Mean	1,093	NA	361	2,135	3,208	6,944	1,508	753
	SD	685	NA	253	550	813	1,714	380	227
	L 95% CI	420	NA	114	1,320	2,016	4,360	943	423
	U 95% CI	2,796	NA	976	3,422	5,076	11,040	2,391	1,295
NOS	Mean	841	NA	743	1,221	1,636	1,741	621	487
	SD	558	NA	496	316	430	443	163	159
	L 95% CI	314	NA	266	755	1,008	1,079	380	256
	U 95% CI	2193	NA	1,899	1,964	2,642	2,806	1,006	870
pF	Mean	60.3%	NA	76.2%	72.4%	68.7%	68.7%	77.6%	80.6%
	SD	3.3%	NA	3.4%	1.7%	2.7%	1.9%	2.1%	5.0%
	L 95% CI	53.8%	NA	69.1%	69.1%	63.2%	65.1%	73.4%	69.8%
	U 95% CI	66.7%	NA	82.5%	75.6%	73.9%	72.3%	81.6%	89.3%
pHOS	Mean	56.6%	NA	32.7%	63.6%	66.2%	80.0%	70.8%	60.7%
	SD	6.9%	NA	6.6%	1.9%	2.3%	1.2%	2.4%	6.6%
	L 95% CI	43.1%	NA	21.0%	59.9%	61.6%	77.5%	66.0%	47.6%
	U 95% CI	69.5%	NA	46.2%	67.3%	70.7%	82.2%	75.3%	73.1%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

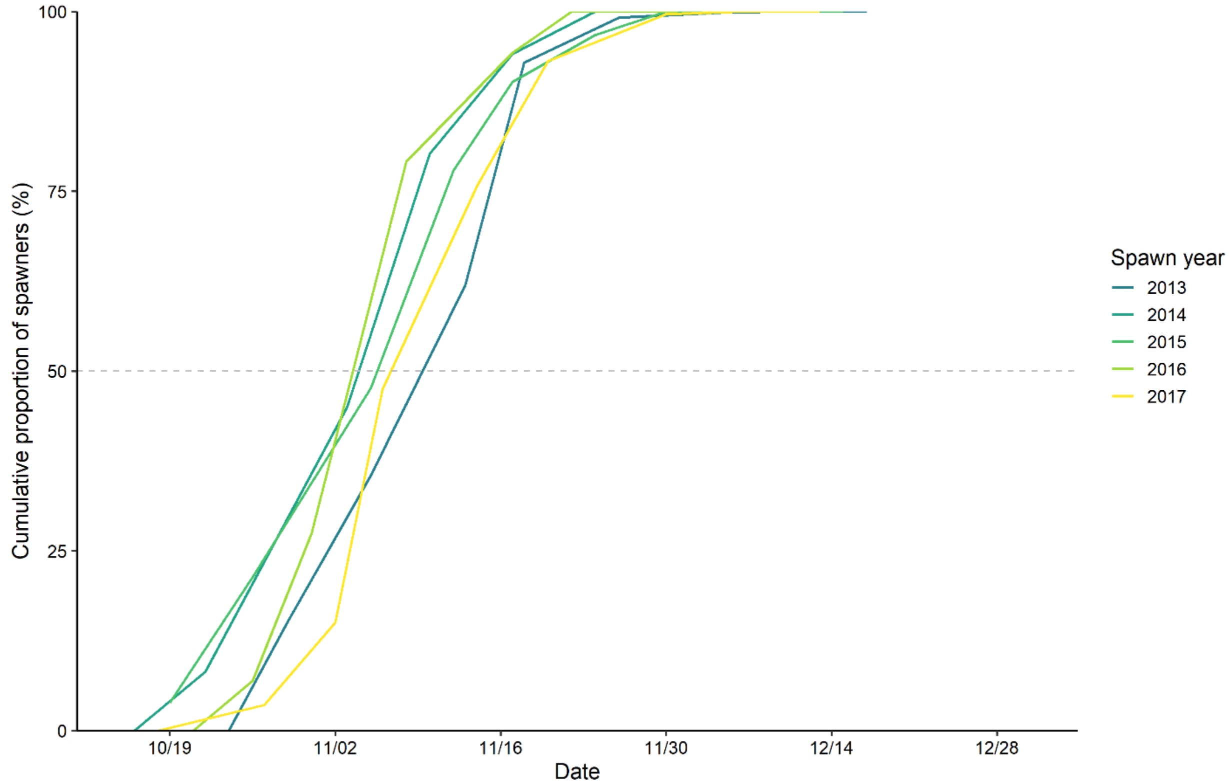

Figure 44. Spawn timing of the White Salmon Bright fall Chinook population based on cumulative counts of live adult Chinook salmon identified as spawners for spawn years 2013-2017. Spawn timing information was not available for the White Salmon population in spawn years 2010-2012.

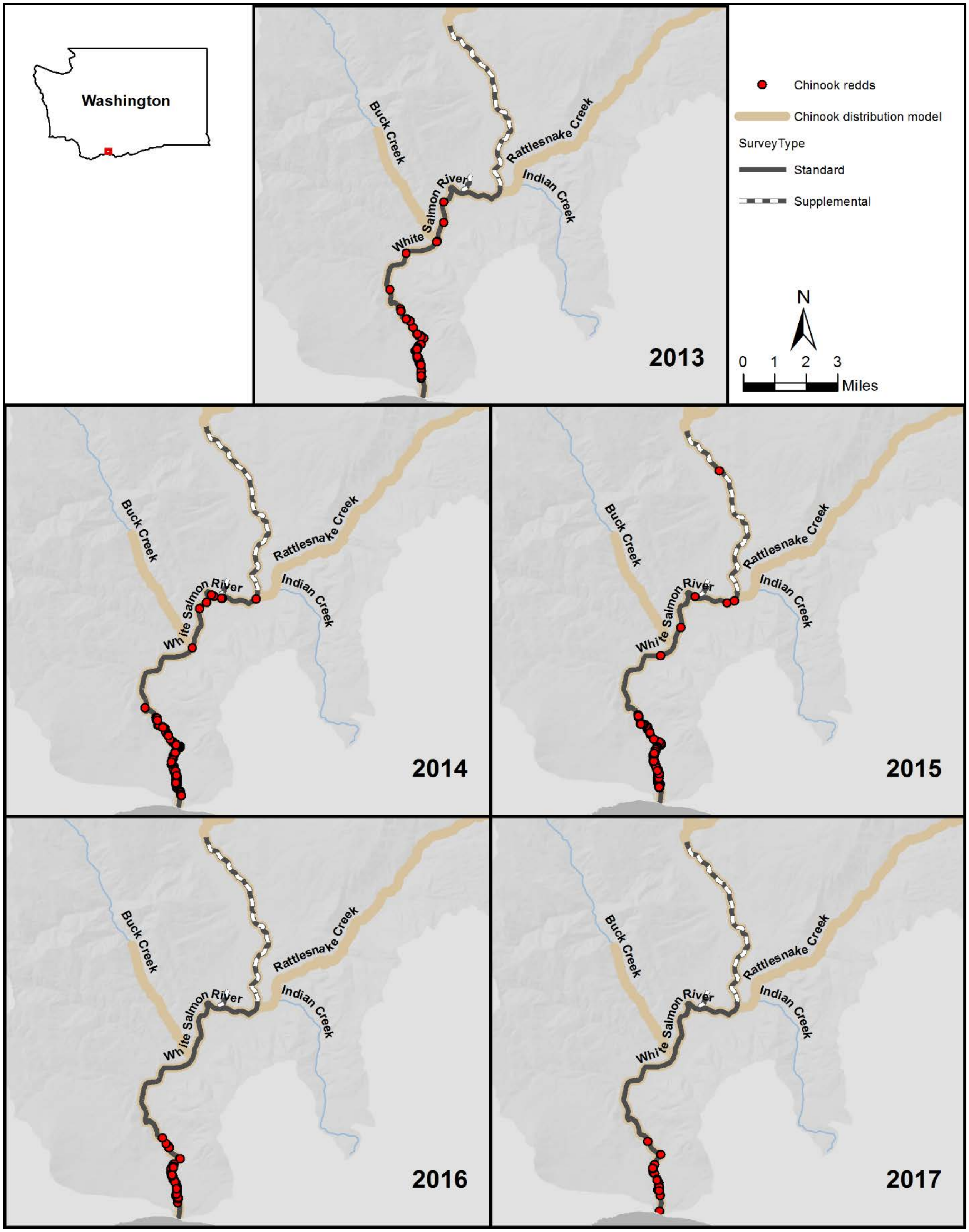

Figure 45. Redd distribution of the White Salmon Bright fall Chinook population for spawn years 2013-2017. The grey colored layer represents the area surveyed, the black rectangle represents the weir location, and the individual redd locations are shown as a red colored circle.

Strata and ESU Summary
Individual population estimates were summed to provide fall Chinook salmon estimates by strata and at the ESU-scale for Washington populations by stock (e.g. Tules, Lewis River Brights, Bonneville Brights, and Select Area Brights).

For the Washington portion of LCR ESU, the estimated total spawner abundance of Tule fall Chinook salmon over the last eight years has ranged from a low of 16,472 in 2017 to a high of 38,774 in 2013. The proportion of hatchery-origin spawners for Tule fall Chinook salmon at the ESU-level has ranged from a low of 32.7% in 2017 to a high of 71.3% in 2010 and NOR spawner abundance estimates have ranged from a low of 7,065 in 2012 to a high of 18,941 in 2015 (Tables 52-59).

Our estimates of Bright stock fall Chinook salmon at the ESU-scale estimates were further separated into three distinct groups: Lewis River Brights, Bonneville Brights, and Select Area Brights. Lewis River Brights are only estimated in the North Fork Lewis River and the cumulative annual spawner estimates ranged from a low of 7,268 in 2017 to a high of 20,803 in 2014. This stock is comprised of all NOR spawners (Bentley et al. 2018). Bonneville Brights are found within the Lower Gorge, Upper Gorge, and White Salmon populations and are comprised of a mix of HOR and NOR spawners. The cumulative annual spawner estimate of Bonneville Brights spawning within the ESU ranged from a low of 1,418 in 2011 to a high of 13,183 in 2013. Select Area Brights are typically only observed in the Coast stratum. To develop ESU-scale estimates, we summed Bright estimates from the Grays/Chinook and Elochoman/Skamokawa populations. The cumulative annual spawner estimates of SABs within the ESU ranged from a low of 75 in 2010 to a high of 1,526 in 2013 (Tables 52-59).

Table 38. Estimates of total spawner abundance, spawner abundance by origin, and the proportion of hatchery- and natural-origin spawners (mean, standard deviation, and 95% credible intervals of the posterior distribution), for adult fall Chinook salmon at the strata and ESU-scale for the Washington portion of the LCR ESU, 2010 spawn year.

		Tule				Bright		
		Coast Stratum Total	Cascade Stratum Total	Gorge Stratum Total	ESU Total	Lewis Brights ESU Total	Bonn Brights ESU Total	Select Area Brights ESU Total
Abundance	Mean	3,840	29,238	2,526	35,604	9,294	2,659	75
	SD	294	1,757	1,123	1,426	-	1,213	38
	L 95% CI	3,264	25,794	325	32,803	-	281	1
	U 95% CI	4,416	32,682	4,727	38,405	-	5,037	149
HOS	Mean	3,390	21,277	701	25,368	-	1,401	75
	SD	225	1,527	354	984	-	688	38
	L 95% CI	2,949	18,284	7	23,439	-	53	1
	U 95% CI	3,831	24,270	1,395	27,297	-	2,749	149
NOS	Mean	375	7,961	1,825	10,161	9,294	1,259	-
	SD	88	377	852	740	-	570	-
	L 95% CI	203	7,222	155	8,710	-	142	-
	U 95% CI	547	8,700	3,495	11,612	-	2,376	-
pHOS	Mean	88.3%	72.8%	27.8%	71.3%	0.0%	52.7%	100.0%
	SD	5.6%	4.1%	15.9%	4.0%	-	35.3%	-
	L 95% CI	77.3%	64.8%	0.0%	63.5%	-	0.0%	-
	U 95% CI	99.3%	80.8%	58.9%	79.0%	-	100.0%	-
pNOS	Mean	11.7%	27.2%	72.2%	28.7%	100.0%	47.3%	0.0%
	SD	1.4%	1.1%	39.6%	2.4%	-	30.4%	-
	L 95% CI	8.9%	25.0%	0.0%	24.1%	-	0.0%	-
	U 95% CI	14.5%	29.5%	100.0%	33.4%	-	100.0%	-

All Lewis Brights are within the Cascade stratum, Bonneville Brights are within the Gorge stratum, and Select Area Brights are within the Coast stratum. Lewis Bright estimates are from Shane Hawkins, personal communication, WDFW. Lewis Bright estimates include jacks where other estimates do not. Estimates of precision are not available for Lewis Brights or North Fork Lewis Tule fall Chinook. The sum of abundance by clip status may not equal the total abundance estimate due to rounding errors.

Table 39. Estimates of total spawner abundance, spawner abundance by origin, and the proportion of hatchery- and natural-origin spawners (mean, standard deviation, and 95% credible intervals of the posterior distribution), for adult fall Chinook salmon at the strata and ESU-scale for the Washington portion of the LCR ESU, 2011 spawn year.

		Tule				Bright		
		Coast Stratum Total	Cascade Stratum Total	Gorge Stratum Total	ESU Total	Lewis Brights ESU Total	Bonn Brights ESU Total	Select Area Brights ESU Total
Abundance	Mean	2,691	31,837	3,815	38,343	8,205	1,418	302
	SD	232	1,851	1,717	1,921	-	339	66
	L 95% CI	2,236	28,209	450	34,577	-	754	173
	U 95% CI	3,146	35,465	7,180	42,109	-	2,082	431
HOS	Mean	2,170	21,535	1,986	25,691	-	890	302
	SD	157	1,595	803	1,406	-	216	66
	L 95% CI	1,862	18,409	412	22,935	-	467	173
	U 95% CI	2,478	24,661	3,560	28,447	-	1,313	431
NOS	Mean	219	10,302	1,829	12,350	8,205	527	-
	SD	47	377	1,029	822	-	138	-
	L 95% CI	127	9,563	0	10,738	-	257	-
	U 95% CI	311	11,041	3,846	13,962	-	797	-
pHOS	Mean	80.6%	67.6%	52.1%	67.0%	0.0%	62.8%	100.0%
	SD	5.6%	4.6%	27.9%	5.0%	-	21.4%	-
	L 95% CI	69.6%	58.7%	0.0%	57.3%	-	20.9%	-
	U 95% CI	91.7%	76.6%	100.0%	76.7%	-	100.0%	-
pNOS	Mean	19.4%	32.4%	47.9%	33.0%	100.0%	37.2%	0.0%
	SD	1.1%	1.4%	27.7%	2.7%	-	13.2%	-
	L 95% CI	17.2%	26.9%	0.0%	27.7%	-	11.4%	-
	U 95% CI	21.5%	35.1%	100.0%	38.3%	-	63.1%	-

All Lewis Brights are within the Cascade stratum, Bonneville Brights are within the Gorge stratum, and Select Area Brights are within the Coast stratum. Lewis Bright estimates are from Shane Hawkins, personal communication, WDFW. Lewis Bright estimates include jacks where other estimates do not. Estimates of precision are not available for Lewis Brights or North Fork Lewis Tule fall Chinook. The sum of abundance by clip status may not equal the total abundance estimate due to rounding errors.

Table 40. Estimates of total spawner abundance, spawner abundance by origin, and the proportion of hatchery- and natural-origin spawners (mean, standard deviation, and 95% credible intervals of the posterior distribution), for adult fall Chinook salmon at the strata and ESU-scale for the Washington portion of the LCR ESU, 2012 spawn year.

		Tule				Bright		
		Coast Stratum Total	Cascade Stratum Total	Gorge Stratum Total	ESU Total	Lewis Brights ESU Total	Bonn Brights ESU Total	Select Area Brights ESU Total
Abundance	Mean	513	20,075	1,694	22,282	8,143	1,682	87
	SD	126	1,701	651	1,334	-	732	45
	L 95% CI	266	16,741	418	19,667	-	248	0
	U 95% CI	760	23,409	2,970	24,897	-	3,116	175
HOS	Mean	308	14,023	797	15,128	-	739	87
	SD	69	1,464	274	1,216	-	262	45
	L 95% CI	173	11,154	260	12,745	-	226	0
	U 95% CI	443	16,892	1,334	17,511	-	1,252	175
NOS	Mean	118	6,051	896	7,065	8,143	943	-
	SD	47	339	409	348	-	498	-
	L 95% CI	26	5,387	94	6,383	-	0	-
	U 95% CI	210	6,715	1,698	7,747	-	1,919	-
pHOS	Mean	60.0%	69.9%	47.0%	67.9%	0.0%	43.9%	100.0%
	SD	12.8%	7.4%	19.4%	6.8%	-	24.7%	-
	L 95% CI	34.9%	55.4%	9.1%	54.6%	-	0.0%	-
	U 95% CI	85.2%	84.3%	85.0%	81.2%	-	92.3%	-
pNOS	Mean	40.0%	30.1%	53.0%	32.1%	100.0%	56.1%	0.0%
	SD	6.8%	2.0%	23.2%	2.5%	-	38.4%	-
	L 95% CI	26.6%	26.2%	7.5%	27.3%	-	0.0%	-
	U 95% CI	53.4%	34.1%	98.4%	36.9%	-	100.0%	-

All Lewis Brights are within the Cascade stratum, Bonneville Brights are within the Gorge stratum, and Select Area Brights are within the Coast stratum. Lewis Bright estimates are from Shane Hawkins, personal communication, WDFW. Lewis Bright estimates include jacks where other estimates do not. Estimates of precision are not available for Lewis Brights or North Fork Lewis Tule fall Chinook. The sum of abundance by clip status may not equal the total abundance estimate due to rounding errors.

Table 41. Estimates of total spawner abundance, spawner abundance by origin, and the proportion of hatchery- and natural-origin spawners (mean, standard deviation, and 95% credible intervals of the posterior distribution), for adult fall Chinook salmon at the strata and ESU-scale for the Washington portion of the LCR ESU, 2013 spawn year.

		Tule				Bright		
		Coast Stratum Total	Cascade Stratum Total	Gorge Stratum Total	ESU Total	Lewis Brights ESU Total	Bonn Brights ESU Total	Select Area Brights ESU Total
Abundance	Mean	2,749	32,747	3,278	38,774	17,351	13,183	1,526
	SD	485	3,375	577	1,963	450	1,515	324
	L 95% CI	1,798	26,132	2,147	34,927	16,500	10,214	891
	U 95% CI	3,700	39,362	4,409	42,621	18,300	16,152	2,161
HOS	Mean	924	17,509	2,007	20,440	328	10,362	1,526
	SD	144	2,356	353	1,593	49	1,184	324
	L 95% CI	642	12,891	1,315	17,318	255	8,040	891
	U 95% CI	1,206	22,127	2,699	23,562	435	12,684	2,161
NOS	Mean	299	15,235	1,271	16,805	17,022	2,822	-
	SD	82	1,276	264	664	428	407	-
	L 95% CI	138	12,734	754	15,503	16,220	2,024	-
	U 95% CI	460	17,736	1,788	18,107	17,910	3,620	-
pHOS	Mean	33.6%	53.5%	61.2%	52.7%	2.0%	78.6%	100.0%
	SD	5.4%	5.7%	11.3%	4.9%	0.0%	12.7%	-
	L 95% CI	23.1%	42.3%	39.1%	43.1%	2.0%	53.6%	-
	U 95% CI	44.1%	64.6%	83.4%	63.2%	2.0%	100.0%	-
pNOS	Mean	66.4%	46.5%	38.8%	47.3%	98.0%	21.4%	0.0%
	SD	2.2%	3.3%	7.4%	2.8%	0.0%	3.9%	-
	L 95% CI	62.0%	40.0%	24.3%	41.8%	98.0%	13.7%	-
	U 95% CI	70.8%	53.0%	53.2%	52.7%	99.0%	29.1%	-

All Lewis Brights are within the Cascade stratum, Bonneville Brights are within the Gorge stratum, and Select Area Brights are within the Coast stratum. Lewis Bright estimates include jacks where other estimates do not. Jacks made up 3-5% of the total abundance. There are no hatchery Brights in the Lewis; estimates of hatchery Brights are a minor side effect of apportioning JS abundance estimates with raw biological data collected from carcasses (see Bentley et al. 2018). The sum of abundance by clip status may not equal the total abundance estimate due to rounding errors.

Table 42. Estimates of total spawner abundance, spawner abundance by origin, and the proportion of hatchery- and natural-origin spawners (mean, standard deviation, and 95% credible intervals of the posterior distribution), for adult fall Chinook salmon at the strata and ESU-scale for the Washington portion of the LCR ESU, 2014 spawn year.

		Tule				Bright		
		Coast Stratum Total	Cascade Stratum Total	Gorge Stratum Total	ESU Total	Lewis Brights ESU Total	Bonn Brights ESU Total	Select Area Brights ESU Total
Abundance	Mean	2,203	29,001	3,249	34,453	20,803	7,215	515
	SD	359	2,390	632	1,682	620	1,258	123
	L 95% CI	1,499	24,317	2,010	31,155	19,670	4,750	274
	U 95% CI	2,907	33,685	4,488	37,751	22,050	9,680	756
HOS	Mean	1,323	17,584	1,900	20,807	314	5,189	515
	SD	227	1,827	331	1,447	58	854	123
	L 95% CI	878	14,003	1,251	17,972	215	3,514	274
	U 95% CI	1,768	21,165	2,549	23,642	438	6,864	756
NOS	Mean	366	11,417	1,350	13,133	20,489	2,026	-
	SD	93	825	340	525	604	440	-
	L 95% CI	184	9,800	684	12,103	19,380	1,164	-
	U 95% CI	548	13,034	2,016	14,163	21,690	2,888	-
pHOS	Mean	60.1%	60.6%	58.5%	60.4%	1.0%	71.9%	100.0%
	SD	9.1%	5.9%	11.5%	5.1%	0.0%	17.2%	-
	L 95% CI	42.2%	49.0%	35.9%	50.3%	1.0%	38.1%	-
	U 95% CI	77.9%	72.2%	81.1%	70.4%	2.0%	100.0%	-
pNOS	Mean	39.9%	39.4%	41.5%	39.6%	99.0%	28.1%	0.0%
	SD	3.5%	2.7%	9.5%	2.4%	0.0%	7.8%	-
	L 95% CI	33.1%	34.1%	23.0%	34.9%	98.0%	12.8%	-
	U 95% CI	46.8%	44.6%	60.1%	44.3%	99.0%	43.4%	-

All Lewis Brights are within the Cascade stratum, Bonneville Brights are within the Gorge stratum, and Select Area Brights are within the Coast stratum. Lewis Bright estimates include jacks where other estimates do not. Jacks made up 3-5% of the total abundance. There are no hatchery Brights in the Lewis; estimates of hatchery Brights are a minor side effect of apportioning JS abundance estimates with raw biological data collected from carcasses (see Bentley et al. 2018). The sum of abundance by clip status may not equal the total abundance estimate due to rounding errors.

Table 43. Estimates of total spawner abundance, spawner abundance by origin, and the proportion of hatchery- and natural-origin spawners (mean, standard deviation, and 95% credible intervals of the posterior distribution), for adult fall Chinook salmon at the strata and ESU-scale for the Washington portion of the LCR ESU, 2015 spawn year.

		Tule				Bright		
		Coast Stratum Total	Cascade Stratum Total	Gorge Stratum Total	ESU Total	Lewis Brights ESU Total	Bonn Brights ESU Total	Select Area Brights ESU Total
Abundance	Mean	2,740	30,281	4,617	37,638	18,915	12,013	286
	SD	400	1,289	874	1,008	992	2,185	82
	L 95% CI	1,956	27,755	2,904	35,663	17,120	7,731	125
	U 95% CI	3,524	32,807	6,330	39,613	21,080	16,295	447
HOS	Mean	1,924	13,474	3,014	18,412	280	9,265	286
	SD	308	962	575	729	74	1,741	82
	L 95% CI	1,320	11,588	1,887	16,983	206	5,852	125
	U 95% CI	2,528	15,360	4,141	19,841	481	12,678	447
NOS	Mean	529	16,807	1,605	18,941	18,635	2,747	-
	SD	138	620	330	435	979	466	-
	L 95% CI	259	15,592	958	18,089	16,850	1,834	-
	U 95% CI	799	18,022	2,252	19,793	20,740	3,660	-
pHOS	Mean	70.2%	44.5%	65.3%	55.5%	1.0%	77.1%	100.0%
	SD	9.9%	1.9%	14.6%	1.6%	0.0%	20.2%	-
	L 95% CI	50.8%	40.7%	36.7%	52.3%	1.0%	37.6%	-
	U 95% CI	89.6%	48.3%	93.9%	58.7%	3.0%	100.0%	-
pNOS	Mean	29.8%	55.5%	34.7%	51.1%	99.0%	22.9%	0.0%
	SD	4.1%	1.6%	7.7%	1.8%	0.0%	5.7%	-
	L 95% CI	21.7%	52.3%	19.6%	47.6%	98.0%	11.7%	-
	U 95% CI	37.8%	58.7%	49.8%	54.6%	99.0%	34.0%	-

All Lewis Brights are within the Cascade stratum, Bonneville Brights are within the Gorge stratum, and Select Area Brights are within the Coast stratum. Lewis Bright estimates include jacks where other estimates do not. Jacks made up 1-4% of the total abundance. There are no hatchery Brights in the Lewis; estimates of hatchery Brights are a minor side effect of apportioning JS abundance estimates with raw biological data collected from carcasses (see Bentley et al. 2018). The sum of abundance by clip status may not equal the total abundance estimate due to rounding errors.

Table 44. Estimates of total spawner abundance, spawner abundance by origin, and the proportion of hatchery- and natural-origin spawners (mean, standard deviation, and 95% credible intervals of the posterior distribution), for adult fall Chinook salmon at the strata and ESU-scale for the Washington portion of the LCR ESU, 2016 spawn year.

		Tule				Bright		
		Coast Stratum Total	Cascade Stratum Total	Gorge Stratum Total	ESU Total	Lewis Brights ESU Total	Bonn Brights ESU Total	Select Area Brights ESU Total
Abundance	Mean	1,121	20,297	1,846	23,264	9,360	4,472	184
	SD	180	1,416	369	767	243	616	58
	L 95% CI	768	17,522	1,123	21,761	8,912	3,264	70
	U 95% CI	1,474	23,072	2,569	24,767	9,863	5,680	298
HOS	Mean	678	8,027	906	9,611	48	3,091	184
	SD	126	921	202	507	51	435	58
	L 95% CI	431	6,222	510	8,617	23	2,239	70
	U 95% CI	925	9,832	1,302	10,605	181	3,943	298
NOS	Mean	258	12,270	940	13,468	9,311	1,382	-
	SD	67	779	211	404	229	207	-
	L 95% CI	127	10,743	526	12,676	8,873	976	-
	U 95% CI	389	13,797	1,354	14,260	9,763	1,788	-
pHOS	Mean	60.5%	39.5%	49.1%	41.3%	0.0%	69.1%	100.0%
	SD	9.0%	2.7%	10.6%	2.6%	1.0%	13.6%	-
	L 95% CI	42.9%	34.2%	28.4%	36.3%	0.0%	42.4%	-
	U 95% CI	78.1%	44.9%	69.8%	46.3%	2.0%	95.8%	-
pNOS	Mean	39.5%	60.5%	50.9%	58.7%	100.0%	30.9%	0.0%
	SD	4.2%	2.8%	10.6%	2.6%	1.0%	6.3%	-
	L 95% CI	31.4%	54.9%	30.1%	53.6%	98.0%	18.5%	-
	U 95% CI	47.7%	66.0%	71.7%	63.7%	100.0%	43.2%	-

All Lewis Brights are within the Cascade stratum, Bonneville Brights are within the Gorge stratum, and Select Area Brights are within the Coast stratum. Lewis Bright estimates include jacks where other estimates do not. Jacks made up 2-4% of the total abundance. There are no hatchery Brights in the Lewis; estimates of hatchery Brights are a minor side effect of apportioning JS abundance estimates with raw biological data collected from carcasses (see Bentley et al. 2018). The sum of abundance by clip status may not equal the total abundance estimate due to rounding errors.

Table 45. Estimates of total spawner abundance, spawner abundance by origin, and the proportion of hatchery- and natural-origin spawners (mean, standard deviation, and 95% credible intervals of the posterior distribution), for adult fall Chinook salmon at the strata and ESU-scale for the Washington portion of the LCR ESU, 2017 spawn year.

		Tule				Bright		
		Coast Stratum Total	Cascade Stratum Total	Gorge Stratum Total	ESU Total	Lewis Brights ESU Total	Bonn Brights ESU Total	Select Area Brights ESU Total
Abundance	Mean	774	14,241	1,457	16,472	7,268	3,029	105
	SD	279	977	292	587	355	442	68
	L 95% CI	227	12,326	885	15,322	6,664	2,163	0
	U 95% CI	1,321	16,156	2,029	17,622	8,084	3,895	238
HOS	Mean	280	4,630	474	5,384	118	1,811	105
	SD	119	655	111	366	62	284	68
	L 95% CI	47	3,346	256	4,667	56	1,255	0
	U 95% CI	513	5,914	692	6,101	250	2,367	238
NOS	Mean	389	9,609	983	10,981	7,268	1,217	-
	SD	163	619	207	380	355	211	-
	L 95% CI	70	8,396	577	10,237	6,664	803	-
	U 95% CI	708	10,822	1,389	11,725	8,084	1,631	-
pHOS	Mean	36.2%	32.5%	32.5%	32.7%	2.0%	59.8%	100.0%
	SD	16.9%	2.7%	7.6%	2.5%	1.0%	12.8%	-
	L 95% CI	3.0%	27.3%	17.7%	27.8%	1.0%	34.7%	-
	U 95% CI	69.3%	37.7%	47.4%	37.6%	3.0%	84.9%	-
pNOS	Mean	63.8%	67.5%	67.5%	67.3%	98.0%	40.2%	0.0%
	SD	24.3%	3.2%	13.8%	3.3%	1.0%	9.1%	-
	L 95% CI	16.1%	61.1%	40.4%	60.8%	97.0%	22.4%	-
	U 95% CI	100.0%	73.8%	94.5%	73.8%	99.0%	58.1%	-

All Lewis Brights are within the Cascade stratum, Bonneville Brights are within the Gorge stratum, and Select Area Brights are within the Coast stratum. Lewis Bright estimates include jacks where other estimates do not. Jacks made up 1-2% of the total abundance. There are no hatchery Brights in the Lewis; estimates of hatchery Brights are a minor side effect of apportioning JS abundance estimates with raw biological data collected from carcasses (see Bentley et al. 2018). The sum of abundance by clip status may not equal the total abundance estimate due to rounding errors.

Coded-Wire-Tag Recoveries

We summarized all the unexpanded CWT recoveries from spawn years 2013-2017 (Table 45). It should be noted that juvenile tagging rates between hatchery facilities can be substantially different and sample rates on spawn ground surveys can vary between populations as well. However, these unexpanded CWTs can provide a general idea of where HOR spawners originated. In the Coast stratum, populations were impacted the most from hatchery releases from Deep River Net Pens and ODFW's Big Creek Hatchery. Within the Cascade stratum, populations with hatchery releases of fall Chinook salmon (Toutle, Kalama, and Washougal) saw most of CWT recoveries come from within the basin. However, releases of fall Chinook salmon from the two hatchery facilities on the Kalama River impacted pHOS levels not only in the Kalama River but also the Lower Cowlitz, Toutle, Coweeman, Lewis populations, and to a much lesser degree the Washougal population. In the Gorge stratum, the Lower Gorge population saw the most CWT recoveries from fall Chinook salmon that originated at hatchery facilities outside of the ESU (further upstream) but also saw contributions from nearby Bonneville Hatchery and

Little White Salmon National Fish Hatchery. For the Upper Gorge and White Salmon populations, Little White Salmon Bright fall Chinook were the primary source of HOR spawners with a lesser contribution from Spring Creek National Fish Hatchery and Bonneville Hatchery. CWT data for fisheries and carcass recoveries are presented in annual reports for missing production groups (Harlan and Wadsworth 2015).

Table 46. Unexpanded coded-wire-tag recoveries by population and basin of hatchery release for fall Chinook salmon for spawn years 2013-2017.

	Recovery Location by Population											
Hatchery Release Basin	Grays/ Chinook	Elochoman/ Skamokawa	MAG	L. Cowlitz	Toutle	Coweeman	Kalama	Lewis	Washougal	Lower Gorge	Upper Gorge	White Salmon
Youngs Bay	60.0% (3)	0% (0)	1.3% (2)	4.5% (1)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)
Deep River Net Pens	40.0% (2)	60.0% (3)	40.7% (61)	4.5% (1)	0% (0)	1.0% (1)	1.0% (1)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)
Big Creek	0% (0)	40.0% (2)	58.0% (87)	0% (0)	0% (0)	0% (0)	3.8% (4)	0.4% (1)	0% (0)	0% (0)	0% (0)	0% (0)
Cowlitz	0% (0)	0% (0)	0% (0)	41.0% (9)	0% (0)	0% (0)	0% (0)	1.5% (4)	0% (0)	0% (0)	0% (0)	0% (0)
Green	0% (0)	0% (0)	0% (0)	0% (0)	66.7% (4)	0% (0)	0% (0)	0.4% (1)	0% (0)	0% (0)	0% (0)	0% (0)
Coweeman (W)	0% (0)	0% (0)	0% (0)	4.5% (1)	0% (0)	96.2% (102)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)
Kalama	0% (0)	0% (0)	0% (0)	36.5% (8)	33.3% (2)	2.8% (3)	88.5% (93)	17.8% (49)	1.6% (1)	0% (0)	0% (0)	0% (0)
North Fork Lewis (W)	0% (0)	0% (0)	0% (0)	4.5% (1)	0% (0)	0% (0)	0% (0)	76.2% (210)	0% (0)	0% (0)	0% (0)	0% (0)
Washougal	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	4.8% (5)	2.2% (6)	95.2% (58)	6.3% (1)	0% (0)	0% (0)
Tanner Creek (Bonn.)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	18.8% (3)	1.6% (17)	1.3% (4)
Little White Salmon	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	18.8% (3)	94.5% (989)	90.0% (277)
Spring Creek H.	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	1.6% (1)	0% (0)	1.4% (15)	4.5% (14)
Out of ESU release	0% (0)	0% (0)	0% (0)	4.5% (1)	0% (0)	0% (0)	1.9% (2)	1.5% (4)	1.6% (1)	56.1% (9)	2.5% (26)	4.2% (13)
Total CWT Recoveries	5	5	150	22	6	106	105	275	61	16	1047	308

Discussion

We implemented several methods to estimate fall Chinook salmon spawning abundance. We used weirs and traps when possible to attempt to get complete census counts where possible. When weir counts were not a census, they provide an ideal platform for live tagging for LP estimates upstream of weir sites. When weirs or traps were not present, we attempted carcass mark-recapture (using a JS model) in most populations. However, in many cases, these estimates failed due to low abundance and a lack of adequate recaptures. When neither LP nor JS mark-recapture estimates were possible, we used the next tier of methods to estimate abundance, which included AUC based on live counts of Chinook salmon identified as spawners or redd expansion based on redd census surveys. For lower priority populations (based on recovery designations), we used peak count expansion. There are assumptions associated with each method that must be met to ensure unbiased estimates. We tested some of the key assumptions for mark-recapture models directly (Appendices F and G).

ART and AFpR

One of the key assumptions of AUC and redd expansion methods is that ART and AFpR are accurate and appropriate to use for a specific year and population. There are several methods that can be used to develop estimates of residence time, females per redd, and observer efficiency independently. However, most are cost prohibitive. As a result, we used methods described by Parken et al. (2013) and Rawding et al. (2014) to develop inputs to a new mixed effect model. Mixed models of ART and AFpR provided several benefits: 1) they allowed us to “shrink” independently generated year- and population-specific estimates via year-, population- and residual random effect variances, and 2) they enabled us to generate predictive estimates of ART and AFpR for years and basins where data were not available, including propagating the uncertainty contained within the multi-level model into predictions, and thus abundance estimates for these locations and years.

Prespawn Mortality

All of the estimates in the report exclude prespawn mortality, which was highly variable depending on the origin, population, and year. Spawner estimates are important to assess recovery and are needed to accurately estimate productivity. In order to reconstruct returns to the mouths of each tributary, the following would need to be added to the spawner abundance estimates: (1) prespawn mortality, (2) hatchery escapements that are not returned to the river, (3) removal of fish at weirs, and (4) sport catch. While we do not report on any of the above in this report, these numbers are available by request.

Effects of Unclipped and Untagged Hatchery Fish

The small proportion of HOR fish that remain unclipped may lead to bias in NOR abundance and pHOS estimates. We adjusted estimates of clipped and unclipped spawners in all subpopulations except the Lower Cowlitz and North Fork Lewis to correct for bias related to unclipped HOR spawners. There was no to minimal difference between adjusted and unadjusted estimates in populations with low levels of hatchery influence and NOR abundance greater than a few hundred fish (Coweeman, Lewis, White Salmon). In populations with in-basin fall Chinook salmon releases (Kalama, Toutle, and Washougal), the impact was variable by year. The largest estimate of unclipped HOR spawners was on the Kalama River in 2015 when we estimated 260 (95% CI 138-431). However, this did not have the largest potential bias correction impact, as the estimate of NOR abundance estimates was relatively large (~3,000). The largest potential biases were seen in years and populations when low NOR abundance was low and hatchery influence was high. These can be populations with in-basin hatchery releases, such as the Washougal in 2011 when we saw a positive NOR abundance bias approaching 55% if they had not been corrected, or in populations without in-basin hatchery releases such as the three Coast stratum populations. We saw NOR abundance biases of over 40% for each of the three Coast stratum populations in certain years (Wilson et al. 2019).

Age Composition

Rawding et al. (2014) used uniform priors for the Dirichlet distribution to develop proportions of each age class by origin. For this report, we stratified estimates above and below weirs in many populations, which resulted in data that was sparser for each independent dataset. Additionally, the removal of HOR fish at weirs and the elimination of a hatchery fall Chinook salmon program on the Elochoman resulted in lower overall abundance of fall Chinook salmon on the spawning grounds. We explored using the same uniform priors in this report, but the priors were having a substantial impact on the results of the posterior distribution. As a result, we chose to use weakly informative priors, which produced results that were similar to method of moments estimates and more biologically plausible.

In addition to prior influence, age structure relied on accurate ageing of scale samples. While aging is largely accurate, there is some error associated with scale ageing. Wilson (2016) compared Chinook salmon ages based on scale samples that were aged with CWTs collected from the same fish and found that older fish (age-5 and age-6) were regularly aged incorrectly as younger fish. While we do not believe this error is a major source of bias, since most of the LCR fall Chinook salmon stocks tend to be age-3 and age-4, this error was directional and work should be done in the future to explore developing a model to account for this potential source of error.

Precision of Abundance Estimates

For NOR spawner abundance estimates, we met the NOAA precision guideline (CV <15%) for the five primary populations of Tule fall Chinook salmon in the Washington portion of the LCR ESU half of the time (15 out of 30 year by population combinations) (Figure 46). In most cases, the precision of our mark-recapture estimates met the precision guideline but our AUC, redd expansion, and PCE methods did not. For the Toutle and Elochoman/Skamokawa populations, we had successful mark-recapture estimates in conjunction with weir operations for part of the population (e.g. Green subpopulation and Elochoman subpopulation), which gave us very precise estimates, but we had to rely on AUC or redd expansion for the other portions of the population (e.g. South Fork Toutle subpopulation and Skamokawa subpopulation).

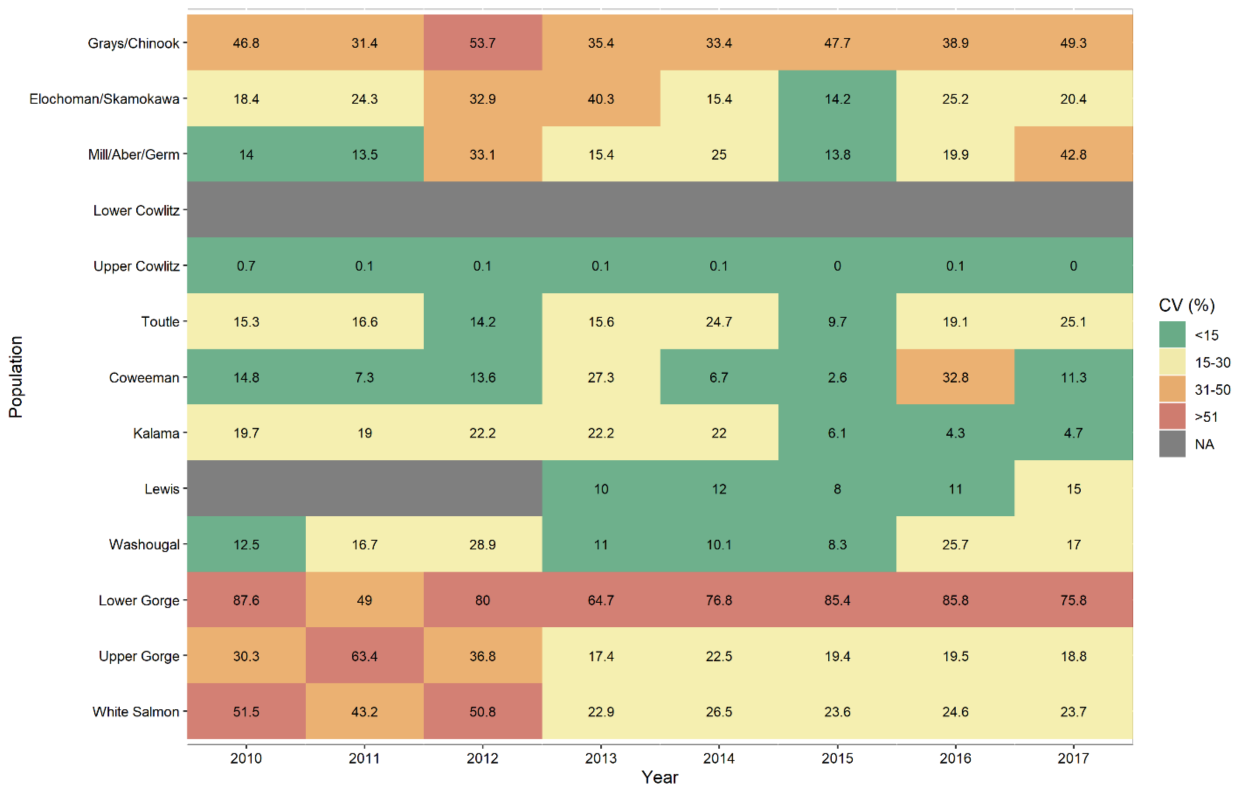

Figure 46. Coefficient of variation (CV) for adult natural-origin spawner estimates by population for Tule fall Chinook salmon within the Washington portion of the LCR ESU for spawn years 2010-2017. Note the Salmon Creek population is not monitored. Estimates of precision are not available for the Lower Cowlitz population. No estimates of uncertainty are currently available for the North Fork Lewis subpopulation for spawn years 2010-2012. As a result, population-level estimates of precision are not underestimated and, therefore, not reported here.

Washougal Later "Bright" Population

In the Washougal River, there is evidence of a possible second unique fall Chinook salmon population that exhibits later spawn timing and different spatial distribution from that of earlier spawners. To illustrate this point, we examined counts of live Chinook salmon identified as spawners in the Washougal River in 2016 (Figure 47). Currently, WDFW and NOAA makes no distinction between the early- and later-timed Chinook salmon so we reported abundance estimates as a single population. There are three plausible explanations for these Chinook salmon: (1) they are part of the life history diversity of the extant Washougal Tule fall Chinook population, (2) they are strays from the nearby Sandy River "bright" populations that have established themselves in the lower Washougal River, or (3) they are strays from artificial propagation programs that have established themselves in the lower Washougal River, similar to Bright stocks in the Lower Gorge, Upper Gorge, and White Salmon populations. If either explanation 2 or 3 is true, our NOR Tule fall Chinook salmon estimates for the Washougal River are overestimated as the vast majority of these lower Washougal River Chinook salmon spawners tend to be unclipped. If scenario 3 is true, these fish are not currently part of the ESA-listing for the LCR ESU for populations upstream of the Washougal and a decision would need to be made as to whether to report them separately in the Washougal fall Chinook population.

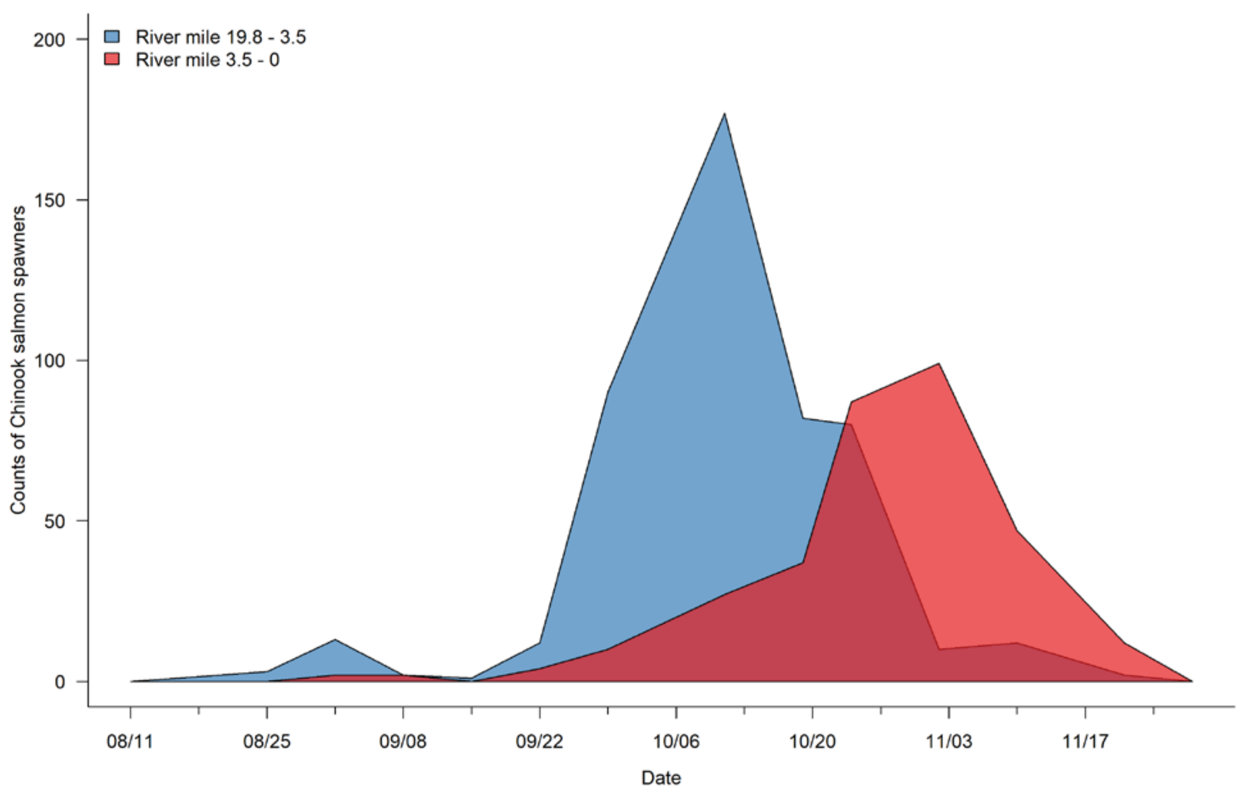

Figure 47. Spawn timing of the Washougal River fall Chinook population based on counts of live Chinook salmon identified as spawners, spawn year 2016. The two different colored polygons represent spawning in the lowermost section (red) compared to the rest of the spawning distribution (blue).

Recommendations

Over the last decade or so there has been a significant shift in the monitoring of fall Chinook salmon populations in the LCR to estimate VSP parameters (McElhany et al. 2000), and other important management indicators (Rawding and Rodgers 2013). While great progress has been made in the LCR region, opportunities remain for improvement. Therefore, we recommend the following:

(1) **Continue to improve modeling.**

- Explore the use of covariates, hierarchical and space-state models.
- Develop a comprehensive Lewis fall Chinook population model that incorporates all of the different subpopulations into a single analysis file.
- Use more detailed data inputs and improve models to develop sex ratios by origin and age structure by sex and origin.
- Incorporate CWT sample sizes and juvenile tag rates as model inputs to develop estimates of uncertainty around CWT expansions and stock compositions.
- Work towards developing unbiased estimates with associated uncertainty of fall Chinook salmon jacks, age-2 fish.
- Develop a model to bias correct age structure with the associated uncertainty. We used scale readings to develop age structure and there is some error associated with scale reading, which may be a directional bias. CWTs (known ages) could be used to help truth scale readings.

(2) **Improve Cowlitz River fall Chinook salmon abundance estimates.**

- Refine fall Chinook salmon abundance estimation methods for the Lower Cowlitz River using transgenerational genetic mark-recapture methods as described by Rawding et al. (2014) or recreate the carcass tagging study done by Hymer (1994) using current regional protocols for carcass tagging and current flight methods.
- Incorporate uncertainty into abundance estimates for the Lower Cowlitz fall Chinook population.
- Incorporate Lower Cowlitz fall Chinook population estimates into the regional Bayesian framework and update 2010-2017 estimates using this framework.
- Incorporate results from the US Geological Survey’s radio tag study into current Upper Cowlitz models to account for prespawn mortality and fall back in Tilton, Upper Cowlitz, and Cispus rivers (Kock et al. 2016).
- Implement a subsampling protocol at the Barrier Dam to develop age structure estimates for the upper Cowlitz River trap and haul program.

(3) **Continue to improve on fall Chinook salmon study designs and monitoring with a specific emphasis on the following:**

- Refine and continue to develop basin- and year-specific estimates of ART and AFpR with paired count and mark-recapture data. Specific emphasis should be put on the Skamokawa and South Fork Toutle subpopulations in an effort to meet NOAA precision guidelines for primary populations.
- Implement a subsampling protocol at Modrow Weir on the Kalama River. This would allow the collection of biological data and the application of Floy® tags to ensure unbiased LP estimates. No size or sex selectivity tests are currently conducted due to the current study design.
- Explore better ways to parse out spring and fall Chinook salmon in the lower Kalama River. There is substantial overlap temporally with some overlap spatially.
- Continue carcass tagging studies on the Little White Salmon River with the goal of obtaining three years of mark-recapture estimates paired with counts to redevelop that subpopulation's PCE factor. Then, switch the carcass tagging effort to the Wind River subpopulation and continue to conduct a carcass tagging study in that subpopulation for three years in an effort to redevelop the Wind River PCE factor.
- Develop an expansion factor for the deep-water spawning activity in the Ives Island subpopulation. Data collected from prior studies (Mueller 2004) may provide the data needed.
- Expand the current fall Chinook salmon VSP monitoring program to ensure spawn timing and georeferenced redd data are being collected for all subpopulations within the ESU.
    - Based on the current study designs, spawn timing data were unavailable for following fall Chinook subpopulations/populations: Lower Cowlitz, North Fork Lewis, Lower Gorge Tule, Little White Salmon Tule, and Little White Salmon Bright.
    - Based on the current study designs, redd data were unavailable for the following subpopulations/populations: Mill, Abernathy, Germany, Lower Cowlitz, Upper Cowlitz, Tilton, Cedar, North Fork Lewis, Hamilton, Ives Island, Wind, Little White Salmon, and Cowlitz.

(4) **Continue to refine bias correction methods based on mass marking for NOR abundance estimates.**

- Increase sample size to 5000 for hatchery QA/QC to accurately estimate mass mark rate.
- Ensure QA/QC associated with mass marking is done consistently across all LCR hatchery facilities, sample sizes are adequate, and make raw QA/QC data available.
- Explore the use of otolith microchemistry and/or staple isotope analyses to compare known hatchery reared Chinook salmon (e.g. CWT positive adipose clipped Chinook salmon that return to a hatchery facility within a basin) with unclipped Chinook salmon carcasses found on the spawning ground surveys in basins with hatchery programs (e.g. Green, Washougal, or Kalama). This could be a valuable tool in ensuring reported mass marks are accurate and our estimates of NOR spawners are not biased in populations with large hatchery programs.

(5) **Use genetics as a tool to improve the current knowledge of the LCR fall Chinook salmon population structure.**

- Redevelop the LCR fall Chinook salmon genetic baseline. The original baseline was developed prior to mass marking and at a time when hatchery stocks were regularly transferred from one basin to another. This likely resulted in a homogenized group of genetic samples that is likely not representative of current conditions. Genetic samples have been collected systematically over the last decade from NOR Chinook salmon from most LCR populations.
- If the genetic resolution is available, explore using genetics to parse out fall Chinook salmon spawning in the lower Washougal River to the appropriate stocks.

(6) **Update the spawner abundance estimates on the Washougal River so that the later timed component is estimated independently.** Since the timing of these fish is similar to Bright stocks and is far later than any Tule population timing, these fish should likely not be included in the Tule population estimates for the Washougal River.

(7) **Expand the Chinook salmon VSP monitoring program to include spring Chinook salmon where applicable.** This has already been done for the White Salmon spring Chinook population. The Kalama spring Chinook population is another population to consider.

References

Allen, M.B., R.O. Engle, J.S. Zendt, F.C. Shrier, J.T. Wilson, and P.J. Connolly. 2016. Salmon and Steelhead in the White Salmon River after the Removal of Condit Dam–Planning Efforts and Recolonization Results. Fisheries 41:190-203.

Bentley, K., D. Rawding, S. Hawkins, J. Holowatz, S. Nelsen, J. Grobelny, and T. Buehrens. 2018. Estimates of escapement and an evaluation of abundance methods for North Fork Lewis River fall-run Chinook salmon, 2013-2017. Washington Department of Fish and Wildlife, Olympia, Washington.

Bjorkstedt, E.P. 2010. DARR 2.0.2: DARR for R. http://swfsc.noaa.gov/textblock.aspx?Division=FED&id=3346

Blankenship, L., and A. Heizer. 1978. Pacific Coast Coded Wire Tag Manual. Pacific States Marine Fisheries Commission. Portland, OR.

Buehrens, T., J. Wilson, D. Rawding, and B. Glaser. 2019. Fall Chinook Salmon Abundance Estimates and Coded-Wire-Tag Recoveries in Washington's Lower Columbia River Tributaries in 2012. *in* Lower Columbia River Fisheries and Escapement Evaluation in Southwest Washington, 2012. Edited by Daniel Rawding, Bryce Glaser, Thomas Buehrens, and Todd Hillson. Washington Department of Fish and Wildlife, Southwest Region. FPA 19-06.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multi-model inference: a practical information-theoretic approach. Springer-Verlag, New York.

Cousens, N., G. Thomas, C. Swann, and M. Healey. 1982. A review of salmon escapement estimation techniques. Canadian Technical Report of Fisheries and Aquatic Sciences 1108:122.

Crawford, B., T.R. Mosey, and D.H. Johnson. 2007a. Foot-based Visual Surveys for Spawning Salmon. Pages 435-442 in D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O-Neil, and T. N. Pearsons, editors. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Crawford, B., T.R. Mosey, and D.H. Johnson. 2007b. Carcass Counts. Pages 59-86 in D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O-Neil, and T. N. Pearsons, editors. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Crawford, B.A. and S. Rumsey. 2011. Guidance for monitoring recovery of Pacific Northwest salmon and steelhead listed under the federal Endangered Species Act. NOAA-Fisheries, Portland, OR. 125 pp.

Darroch, J. N. 1961. The two-sampled capture–recapture census when tagging and sampling are Stratified. Biometrika 48:241–260.

English, K.K., R.C. Bocking, and J.R. Irvine. 1992. A robust procedure for estimating salmon escapement based on area-under-the-curve method. Canadian Journal of Fisheries and Aquatic Science 49:1982-1989.

Fransen, B.R., S.D. Duke, L.G. McWethy, J.K. Walter, and R.E. Bilby. 2006. A logistic regression model for predicting the upstream extent of fish occurrence based on geographical information systems data. North American Journal of Fisheries Management 26:960-975.

Gallagher, S. P., and C. M. Gallagher. 2005. Discrimination of Chinook and coho salmon and steelhead redds and evaluation of the use of redd data for estimating escapement in several unregulated streams in northern California. North American Journal of Fisheries Management 25:284–300.

Gallagher, S.P., P.K.J. Hahn, and D.H. Johnson. 2007. Redd Counts. Pages 197-234 in D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O-Neil, and T. N. Pearsons, editors. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Gelman, A, J. Carlin, A. Stern, and D.B. Rubin. 2013. Bayesian Data Analysis. Third edition. Boca Raton, FL. Chapman and Hall/CRC Press.

Gilks, W., S. Richardson, and D. Spiegelhalter. 1995. Markov Chain Monte Carlo in Practice. Interdisciplinary Statistics, Chapman & Hall, Suffolk, UK.

Gleizes, C., J. Serl, M. Zimmerman, B. Glaser, and W. Dammers. 2014. Lower Cowlitz River Monitoring and Evaluation. Washington Department of Fish and Wildlife, Toledo, Washington.

Groot, C., and L. Margolis. 1991. Pacific Salmon Life Histories. UBC Press. Vancouver, BC. 564pp.

Hankin, D.G., J.H. Clark, R.B. Deriso, J.C. Garza, G.S. Morishima, B.E. Riddell, C. Schwarz, and J.B. Scott. 2005. Report of the Expert Panel on the Future of the Coded Wire Tag Program for Pacific Salmon. PSC Tech. Rep. No. 18, November 2005. 300 p (includes agency responses as appendices).

Harlan, L. and T.F. Wadsworth. 2015. Report on the Coded-Wire Tag Program for Chinook and Coho Salmon Produced by WDFW Columbia River Basin Hatcheries. Washington Department of Fish and Wildlife, Vancouver, Washington.

Hill, R. A. 1997. Optimizing aerial count frequency for area-under-the-curve method of estimating escapement. North American Journal of Fisheries Management 17:461-466.

Hillson, T., K. Bentley, D. Rawding, and J. Grobelny. 2017. Lower Columba River juvenile chum salmon monitoring: abundance estimates for chum, Chinook, coho, and steelhead. Washington Department of Fish and Wildlife, Vancouver, Washington. FPT 17-02.

Hinrichsen, R.A., R. Sharma & T.R. Fisher. 2012. Precision and Accuracy of Estimators of the Proportion of Hatchery-Origin Spawners, Transactions of the American Fisheries Society, 141:2, 437-454.

Hymer, J. 1991. Estimating the Population Size of Natural Spawning Bright Fall Chinook in the Big White Salmon River, 1989. Washington Department of Fisheries.

HSRG (Hatchery Scientific Review Group). 2014. On the Science of Hatcheries: An updated perspective on the role of hatcheries in salmon and steelhead management in the Pacific Northwest. A. Appleby, H.L. Blankenship, D. Campton, K. Currens, T. Evelyn, D. Fast, T. Flagg, J. Gislason, P. Kline, C. Mahnken, B. Missildine, L. Mobrand, G. Nandor, P. Paquet, S. Patterson, L. Seeb, S. Smith, and K. Warheit. June 2014. Available online: http://hatcheryreform.us

Jolly, G. M. 1965. Explicit estimates from capture-recapture data with both death and immigration: stochastic model. Biometrika 52:225-247.

Jones, E. L., and S. A. McPherson. 1997. Relationship between observer counts and abundance of coho salmon in Steep Creek, Northern Southeast Alaska. Alaska Department of Fish and Game, Fishery Data Series Number 97-25, Anchorage, Alaska.

Kock, T.J., Ekstrom, B.K., Liedtke, T.L., Serl, J.D., and M. Kohn. 2016. Behavior patterns and fates of adult steelhead, Chinook salmon, and coho salmon released into the upper Cowlitz River Basin, Washington, 2005–09 and 2012: U.S. Geological Survey Open-File Report 2016-1144, 36 p., http://dx.doi.org/10.3133/ofr20161144.

Kraig, E. 2015. 2013 Washington State Sport Catch Report. Washington Department of Fish and Wildlife, Olympia, WA

Kraig, E. and T. Scalici. 2016. 2014 Washington State Sport Catch Report. Washington Department of Fish and Wildlife, Olympia, WA

Kraig, E. and T. Scalici. 2017. 2015 Washington State Sport Catch Report. Washington Department of Fish and Wildlife, Olympia, WA

Kraig, E. and T. Scalici. 2018. 2016 Washington State Sport Catch Report. Washington Department of Fish and Wildlife, Olympia, WA

Kraig, E. and T. Scalici. 2019. 2017 Washington State Sport Catch Report. Washington Department of Fish and Wildlife, Olympia, WA

Laake, J.L. 2013. RMark: An R Interface for Analysis of Capture-Recapture Data with MARK. AFSC Processed Rep 2013-01, 25pp. Alaska Fish Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

LCFRB. 2010. Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan, Volume I and II. Lower Columbia Fish Recovery Board, Kelso, WA.

Lebreton, J. B., K. P. Burnham, J. Clobert, and D. R. Anderson. 1992. Modeling survival and testing biological hypothesis using marked animals: a unified approach with case studies. Ecological Monographs 62:67-118.

Link, W.A., and R.J. Barker. 2010. Bayesian Inference with ecological applications. Academic Press. New York, NY. 339 pp.

Lunn, D., C. Jackson, N. Best, A. Thomas, and D. Spiegelhalter. 2012. The BUGS Book: A practical introduction to Bayesian analysis. CRC Press. Boca Raton, FL.

McElhany P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainright, and E.P. Bjorkstedt. 2000. Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-42. 156pp.

McIssac, D. 1977. Total spawner population estimate for the North Fork Lewis River based on carcass tagging, 1976. Washington Department of Fisheries, Columbia River Laboratory Progress Report No. 77-01, Olympia, Washington.

Mueller, R.P. 2004. Deepwater Spawning of Fall Chinook Salmon (Oncorhynchus tshawytscha) Near Ives and Pierce Island of the Columbia River – Annual Report 2003. Bonneville Power Administration Project No. 1999-00301 (BPA Report DOE/BP-00000652-19).

Myers and 10 co-authors. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS-NWFSC-35. 443pp.

Myers, J. M., C. Busack, D. Rawding, A. R. Marshall, D. J. Teel, D. M. Van Doornik, M. T. Maher. 2006. Historical population structure of Pacific salmonids in the Willamette River and lower Columbia River basins. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-73, 311 pp.

NOAA. 2013. ESA recovery plan for Lower Columbia River Coho Salmon, Lower Columbia River Chinook Salmon, Columbia River Chum Salmon, and Lower Columbia River Steelhead. Prepared by the National Marine Fisheries Service, Northwest Region.

NOAA. 2016. Five year review: summary and evaluation of Lower Columbia River Chinook, Columbia River Chum, Lower Columbia River Coho, and Lower Columbia River Steelhead. Portland, OR. 77pp.

NWMT. 2001. Northwest Marine Technologies CWT Detection Manual. Northwest Marine Technology. WA.

Parken, C. K., R. E. Bailey, and J. R. Irvine. 2003. Incorporating uncertainty into area under the curve and peak count salmon escapement estimation. North American Journal of Fisheries Management 23:78-90.

Parker, R. R. 1968. Marine mortality schedule of pink salmon on the Bella Coola River, central British Columbia. Canadian Journal of Fisheries Research Board 25:757-794.

Parsons, A. L., and J. R. Skalski. 2010. Quantitative assessment of salmonid escapement. Reviews in Fisheries Science, 18(4): 301-314.

Plummer, M. 2003. JAGS: A program for analysis of Bayesian graphical models using Gibbs sampling. Proceeding of the 3rd International Workshop on Distribution Statistical Computing (DSC 2003), March 20-22, Vienna, Austria.

Pollock, J. H., J. D. Nichols, C. Brownie, and J. E. Hines. 1990. Statistical inference for capture-recapture experiments. Wildlife Monographs 107:1-97.

R Development Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria. https://www.R-project.org.

Rawding, D., and T. Hillson. 2003. Chum salmon escapement estimates for Lower Columbia River tributaries. Washington Department of Fish and Wildlife, Vancouver, Washington.

Rawding, D., T. Hillson, B. Glaser, K. Jenkins, and S. VanderPloeg. 2006. Abundance and spawning distribution of Chinook salmon in Mill, Abernathy, and Germany creeks during 2005. Washington Department of Fish and Wildlife, Vancouver, Washington.

Rawding, D., and J. Rodgers. 2013. Evaluation of the Alignment of Lower Columbia River Salmon and Steelhead Monitoring Program with Management Decisions, Questions, and Objectives. Pacific Northwest Aquatic Monitoring Partnership (PNAMP). 153pp.

Rawding, D.J., C.S. Sharpe, and S.M. Blankenship. 2014. Genetic-Based Estimates of Adult Chinook Salmon Spawner Abundance from Carcass Surveys and Juvenile Out-Migrant Traps. Transactions of the American Fisheries Society, 143:55-67.

Rawding, D., S. VanderPloeg, A. Weiss, and D. Miller. 2010. Preliminary Spawning Distribution of Tule Fall Chinook Salmon in Washington's portion of the Lower Columbia River Evolutionarily Significant Unit Based on Field Observation, GIS Attributes, and Logistic Regression. Washington Department of Fish and Wildlife. Olympia, WA. 17pp.

Rawding, D., J. Wilson, B. Glaser, S. VanderPloeg, J. Holowatz, T. Buehrens, S. Gray, and C. Gleizes. 2014. Fall Chinook Salmon Abundance Estimates and Coded-Wire-Tag Recoveries in Washington's Lower Columbia River Tributaries in 2010. *in* Lower Columbia River Fisheries and Escapement Evaluation in Southwest Washington, 2010. Edited by Daniel Rawding, Bryce Glaser, and Thomas Buehrens. Washington Department of Fish and Wildlife, Southwest Region. FPT 14-10.

Rawding, D., J. Wilson, B. Glaser, and T. Buehrens. 2019. Fall Chinook Salmon Abundance Estimates and Coded-Wire-Tag Recoveries in Washington's Lower Columbia River Tributaries in 2011. *in* Lower Columbia River Fisheries and Escapement Evaluation in Southwest Washington, 2011. Edited by Daniel Rawding, Bryce Glaser, Thomas Buehrens, and Todd Hillson. Washington Department of Fish and Wildlife, Southwest Region. FPT 19-01.

Rivot, E., and E. Prevost. 2002. Hierarchical Bayesian analysis of capture-mark-recapture data. Canadian Journal of Fisheries and Aquatic Sciences 53:2157-2165.

Roegner, G.C., E. W. Dawley, M. Russell, A. Whiting, and D. J. Teel. 2010. Juvenile Salmonid Use of Reconnected Tidal Freshwater Wetlands in Grays River, Lower Columbia River Basin, Transactions of the American Fisheries Society, 139:4, 1211-1232.

Schwarz, C. J., R. E. Bailey, J. R. Irvine, and F. C. Dalziel. 1993. Estimating salmon escapement using capture-recapture methods. Canadian Journal of Fisheries and Aquatic Sciences 50:1181-1197.

Schwarz, C. J., and G. G. Taylor. 1998. The use of stratified-Petersen estimator in fisheries management: estimating pink salmon (*Oncorhynchus gorbuscha*) on the Frazier River. Canadian Journal of Fisheries and Aquatic Sciences 55:281-297.

Seber, G. A. F. 1965. A note on the multiple-recapture census. Biometrika 52:249-259.

Seber, G. A. F. 1982. The estimation of animal abundance. Charles Griffin and Company Limited, London.

Smith, C.T. and R. Engle. 2011. Persistent reproductive isolation between sympatric lineages of fall Chinook salmon in the White Salmon River, Washington. Transactions of the American Fisheries Society 140:699-715.

Spiegelhalter, D., A. Thomas, N. Best, and D. Lunn. 2003. WinBUGS User Manual, Version 1.4. MCR Biostatistics Unit, Institute of Public Health and Epidemiology and Public Health. Imperial College School of Medicine, UK.

Stauffer, G. 1970. Estimates of population parameters of the 1965 and 1966 adult Chinook salmon runs in the Green-Duwamish River. University of Washington, Seattle, Washington.

Stockley, C. 1965. 1964 Report of Columbia River Fall Stream Population Study. Washington Department of Fisheries.

Sturtz, S., W. Ligges, and A. Gelman. R2WinBUGS: A Package for Running WinBugs from R. Journal of Statistical Software, January 2005, Volume 12, Issue 3, 16pp.

Su, T-S., and M. Yajima. 2015. R2jags: using R to run JAGS. R package, version 0.5-7.

Su, Z., M. D. Adikison, and B. W. VanAlen. 2001. A hierarchical Bayesian model for estimating historical salmon escapement and timing. Canadian Journal of Fisheries and Aquatic Sciences 58:1648-1662.

Sykes, S. D., and L. W. Botsford. 1986. Chinook salmon, Oncorhynchus tshawytscha, spawning escapement based on multiple mark-recaptures of carcasses. Fisheries Bulletin 84:261-270.

Tracy, H.B. and C.E. Stockley. 1967. 1966 Report of Lower Columbia River Tributary Fall Chinook Salmon Stream Population Study. Washington Department of Fisheries.

U.S. Geological Survey, 2016, The StreamStats program for Washington, online at http://water.usgs.gov/osw/streamstats/washington.html, accessed on April 25, 2018.

Wilson, J. 2016. Fall Chinook salmon scale vs coded wire tag age discrepancies. Washington Department of Fish and Wildlife, MEMORANDUM.

WDFW. 2019. Salmonid Stock Inventory available at: http://wdfw.wa.gov/mapping/salmonscape/index.html

Wilson, J., T. Buehrens, E. Olk. 2019. 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. Washington Department of Fish and Wildlife, Ridgefield, WA.

Wydoski, R. S., and R. R. Whitney. 2003. Inland Fishes of Washington. Second edition. American Fisheries Society, Bethesda, MD, in association with University of Washington Press, Seattle, WA.

Zimmerman, C.E., and L.M. Zubkar. 2007. Weirs. Pages 385-398 in D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O-Neil, and T. N. Pearsons, editors. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Appendix A – Study Area Descriptions and Sampling Frames for Spawning Ground Surveys for Washington's Lower Columbia River for Fall Chinook Salmon Populations

This appendix provides study area descriptions, tables, and maps of the sampling frame for fall Chinook salmon spawning ground surveys conducted in Washington's portion of the LCR ESU.

Grays/Chinook

The Grays/Chinook fall Chinook population is a contributing population within the Coast stratum. It is comprised of two distinct subpopulations: Grays and Chinook.

The Chinook River enters the Columbia River near the town of Chinook, Washington near the mouth of the Columbia River. We did not include the Chinook River in our sampling frame for several reasons: (1) there is a tide gate near the mouth which limits anadromous adult fish passage, (2) the WDFW Chinook salmon distribution model does not predict any use in the basin, and (3) a limited number of surveys have been conducted as part of other regional monitoring programs, which begin in mid-to-late October, and no adult Chinook have been observed spawning during these surveys.

The Grays River has a drainage area of 124 square miles and enters the Columbia River at RM 22.1 downstream of the town of Rosburg, Washington. It is a rainfall-dominated system with an annual rainfall of 108 inches (USGS 2016). The main-stem Grays River is divided into the upper and lower basin by a three-mile canyon section. Major tributaries include Hull, Fossil, Mitchell, and Crazy Johnson creeks, and the East, West, North, and South forks of the Grays River. Currently, there are not any releases of fall Chinook salmon into the system. However, there have been hatchery releases in the system in the past. From 1947 to 1997, the Grays River Hatchery raised and released as many as 18 million fall Chinook salmon annually in the basin (LCFRB 2010). The weekly sampling frame included 6.2 miles on the main-stem Grays River below the canyon, 5.2 miles on West Fork Grays (also below the canyon), and an additional 4.1 miles above the canyon. Supplemental surveys were done twice; once during the last week of September for the typical Coast stratum Tule fall Chinook salmon peak and, again, around mid-October during SAB fall Chinook salmon peak (Figure A1) (Table A1).

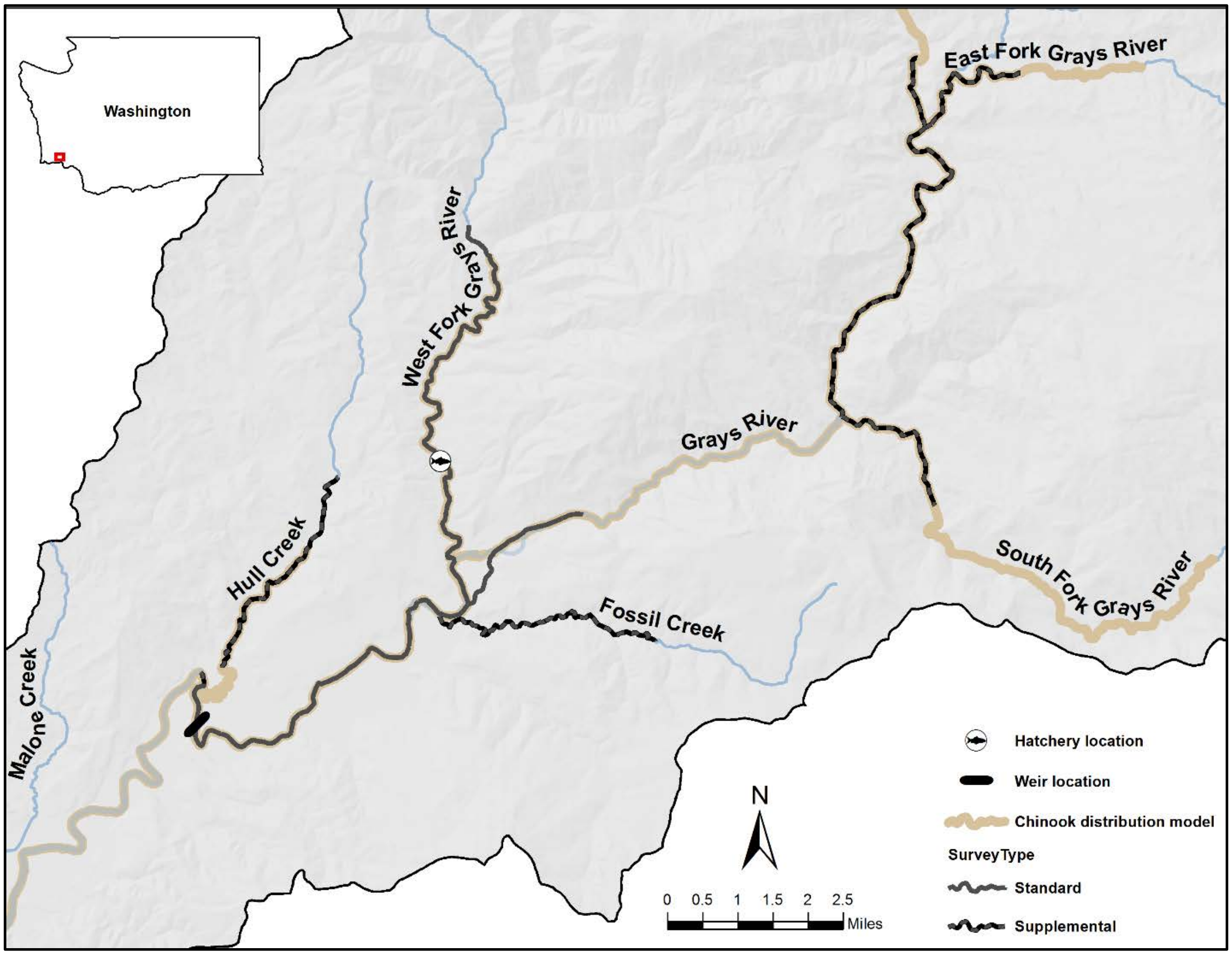

Figure A1. Map of the Grays River basin showing the survey area for fall Chinook salmon in 2013-2017 spawn years.

Table A1. Description of fall Chinook salmon spawning ground surveys by reach conducted in the Grays River basin in 2013-2017 spawn years.

Subpopulation	Reach	Lower RM	Upper RM	Total RMs	Survey Type
Grays River	GRY 1 X	7.88	8.00	0.12	Supplemental
	GRY 1A	8.00	8.48	0.48	Standard
	GRY 1B	8.48	9.00	0.52	Standard
	GRY 2	9.00	10.00	1.00	Standard
	GRY 3	10.00	10.26	0.26	Standard
	GRY 4	10.26	11.00	0.74	Standard
	GRY 5	11.00	11.50	0.50	Standard
	GRY 6A	11.50	11.87	0.37	Standard
	GRY 6B	11.87	12.00	0.13	Standard
	GRY 7	12.00	12.59	0.59	Standard
	GRY 8	12.59	13.00	0.41	Standard
	GRY 9	13.00	14.00	1.00	Standard
	GRY 10	14.00	14.21	0.21	Standard
	GRY 11	17.47	20.70	3.23	Standard
	GRY 12	20.70	21.54	0.84	Standard
	GRY 13	21.54	22.29	0.75	Standard
West Fork Grays River	WFG 1	0.00	0.49	0.49	Standard
	WFG 2	0.49	1.00	0.51	Standard
	WFG 3	1.00	1.76	0.76	Standard
	WFG 4	1.76	2.00	0.24	Standard
	WFG 5	2.00	2.57	0.57	Standard
	WFG 6	2.57	3.00	0.43	Standard
	WFG 7	3.00	3.60	0.60	Standard
	WFG 8	3.60	4.00	0.40	Standard
	WFG 9	4.00	4.75	0.75	Standard
	WFG10	4.75	5.17	0.42	Standard
Fossil Creek	FC 1	0.00	0.42	0.42	Supplemental
	FC 2	0.42	1.42	1.00	Supplemental
	FC 3	1.42	2.80	1.38	Supplemental
Hull Creek	HUL 1	0.99	2.63	1.64	Supplemental
	HUL 2	2.63	3.56	0.93	Supplemental
East Fork Grays River	EFG 1	0.00	0.07	0.07	Supplemental
	EFG 2	0.07	0.72	0.65	Supplemental
	EFG 3	0.72	1.56	0.84	Supplemental
South Fork Grays River	SFG 1	0.00	0.36	0.36	Supplemental
	SFG 2	0.36	1.61	1.25	Supplemental

Elochoman/Skamokawa

The Elochoman/Skamokawa fall Chinook population is a primary population within the Coast stratum. It is mainly comprised of two subpopulations: Elochoman and Skamokawa.

The Elochoman River has a drainage area of 79 square miles and enters the Columbia River at RM 35.5 near the town of Cathlamet, Washington. It is a rainfall-dominated system with an annual rainfall of 90 inches (USGS 2016). Major tributaries include Beaver, Duck, Clear, and Otter creeks, and the West, North, and East forks of the Elochoman River. Currently, there are not any releases of fall Chinook salmon into the system. However, there have been hatchery releases in the system in the past. From 1950 to 2008, the Elochoman Hatchery raised and released as many as 7 million fall Chinook salmon annually in the basin (LCFRB 2010). The weekly sampling frame included 10.7 miles on the Elochoman River. Supplemental surveys were done once on the Elochoman River above the standard weekly survey area as well as on the West Fork Elochoman River and Beaver, Duck, and Clear creeks during the last week of September (Figure A2) (Table A2).

Skamokawa Creek has a drainage area of 57 square miles and enters the Columbia River at RM 33.3 in the town of Skamokawa, Washington. It is a rainfall-dominated system with an annual rainfall of 97 inches (USGS 2016). Major tributaries include Standard, McDonald, and Falk creeks, and the Left Fork Skamokawa Creek. There are not any releases of fall Chinook salmon into the system. The weekly sampling frame included 4.9 miles on Skamokawa Creek. Supplemental surveys were done on McDonald, Standard, and Wilson creeks once during the last week of September (Figure A2) (Table A2).

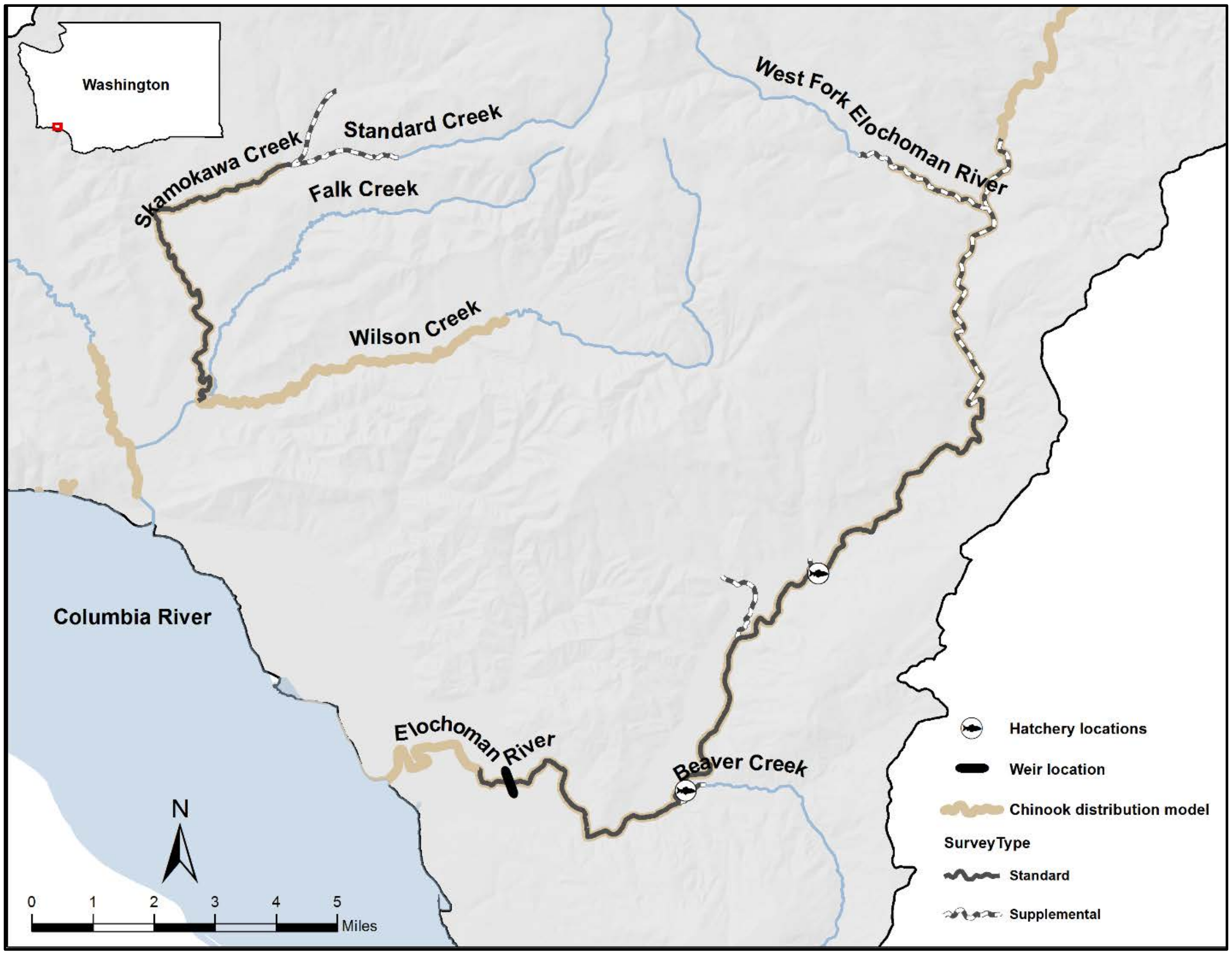

Figure A2. Map of the Elochoman and Skamokawa basins showing the survey area for fall Chinook salmon in 2013-2017 spawn years.

Table A2. Description of fall Chinook salmon spawning ground surveys by reach conducted in the Elochoman and Skamokawa basins in 2013-2017 spawn years.

Subpopulation	Reach	Lower RM	Upper RM	Total RMs	Survey Type
Elochoman River	ELO 1	2.25	2.73	0.48	Standard
	ELO 2	2.73	4.31	1.58	Standard
	ELO 3	4.31	5.94	1.63	Standard
	ELO 4	5.94	7.25	1.31	Standard
	ELO 5	7.25	8.00	0.75	Standard
	ELO 6	8.00	9.46	1.46	Standard
	ELO 7	9.46	12.86	3.40	Standard
	ELO 8	12.86	15.70	2.84	Supplemental
	ELO 9	15.70	16.69	0.99	Supplemental
West Fork Elochoman River	WFE	0.00	1.76	1.76	Supplemental
Beaver Creek	BVR	0.00	0.40	0.40	Supplemental
Clear Creek	CLR	0.00	0.20	0.20	Supplemental
Duck Creek	DUC	0.00	1.10	1.10	Supplemental
Skamokawa Creek	SKA 1	1.90	3.06	1.16	Standard
	SKA 2A	3.06	3.57	0.51	Standard
	SKA 2B	3.57	4.11	0.54	Supplemental
	SKA 2C	4.11	4.54	0.43	Standard
	SKA 3	4.54	5.01	0.47	Standard
	SKA 4	5.01	5.88	0.87	Standard
	SKA 5	5.88	6.75	0.87	Standard
McDonald Creek	MCD 1	0.00	1.01	1.01	Supplemental
Standard Creek	STA 1	0.00	1.03	1.03	Supplemental
	STA 2	1.00	1.27	0.27	Supplemental
Wilson Creek	WLS 1	5.11	6.40	1.29	Supplemental

Mill/Aber/Germ (MAG)

The MAG fall Chinook population is a primary population within the Coast stratum. It is comprised of three main subpopulations: Mill, Abernathy, and Germany, and one ancillary creek, Coal Creek. All of which enter the Columbia River west of Longview, Washington.

Mill Creek has a drainage area of 29 square miles and enters the Columbia River at RM 53.7. It is a rainfall-dominated system with an annual rainfall of 74 inches (USGS 2016). Major tributaries include Hunter Creek and the South and North forks of Mill Creek. There are not any releases of fall Chinook salmon into the system (LCFRB 2010). The weekly sampling frame was adaptive. We started with weekly surveys on the lower three miles of Mill Creek and the lower 0.5 mile on the South Fork Mill Creek. This baseline survey area was expanded upstream each week as much as was needed during the season to stay a 0.5 mile above the uppermost Chinook salmon (Figure A3) (Table A3).

Abernathy Creek has a drainage area of 29 square miles and enters the Columbia River at RM 54.0. It is a rainfall-dominated system with an annual rainfall of 76 inches (USGS 2016). Major tributaries include Ordway, Cameron, Slide, Wiest, Erick, and Midway creeks. Currently, there are not any releases of fall Chinook salmon into the basin. However, fall Chinook salmon used to be released in the basin from 1960-1994. These releases averaged one million annually (LCFRB 2010). Similar to Mill Creek, the weekly sampling frame was adaptive. We started with weekly surveys on the lower three miles. This baseline survey area was expanded upstream each week as much as was needed during the season to stay a 0.5 mile above the uppermost Chinook salmon (Figure A3) (Table A3).

Germany Creek has a drainage area of 23 square miles and enters the Columbia River at RM 55.9. It is a rainfall-dominated system with an annual rainfall of 82 inches (USGS 2016). There are not any releases of fall Chinook salmon into the system (LCFRB 2010). Similar to Mill and Abernathy creeks, the weekly sampling frame was adaptive. We started with weekly surveys on the lower 2¾ miles. This baseline survey area was expanded upstream each week as much as was needed during the season to stay a 0.5 mile above the uppermost Chinook salmon (Figure A3) (Table A3).

Coal Creek has a drainage area of 27 square miles and enters the Columbia River at RM 56.3. It is a rainfall-dominated system with an annual rainfall of 58 inches (USGS 2016). Major tributaries include Harmony Creek and the East fork of Coal Creek. We put reduced effort into spawning ground surveys on Coal Creek due to the extremely low abundance of Chinook salmon in the creek. We conducted three surveys annually around the peak of spawning activity, which was typically the last week of September (Figure A3) (Table A3).

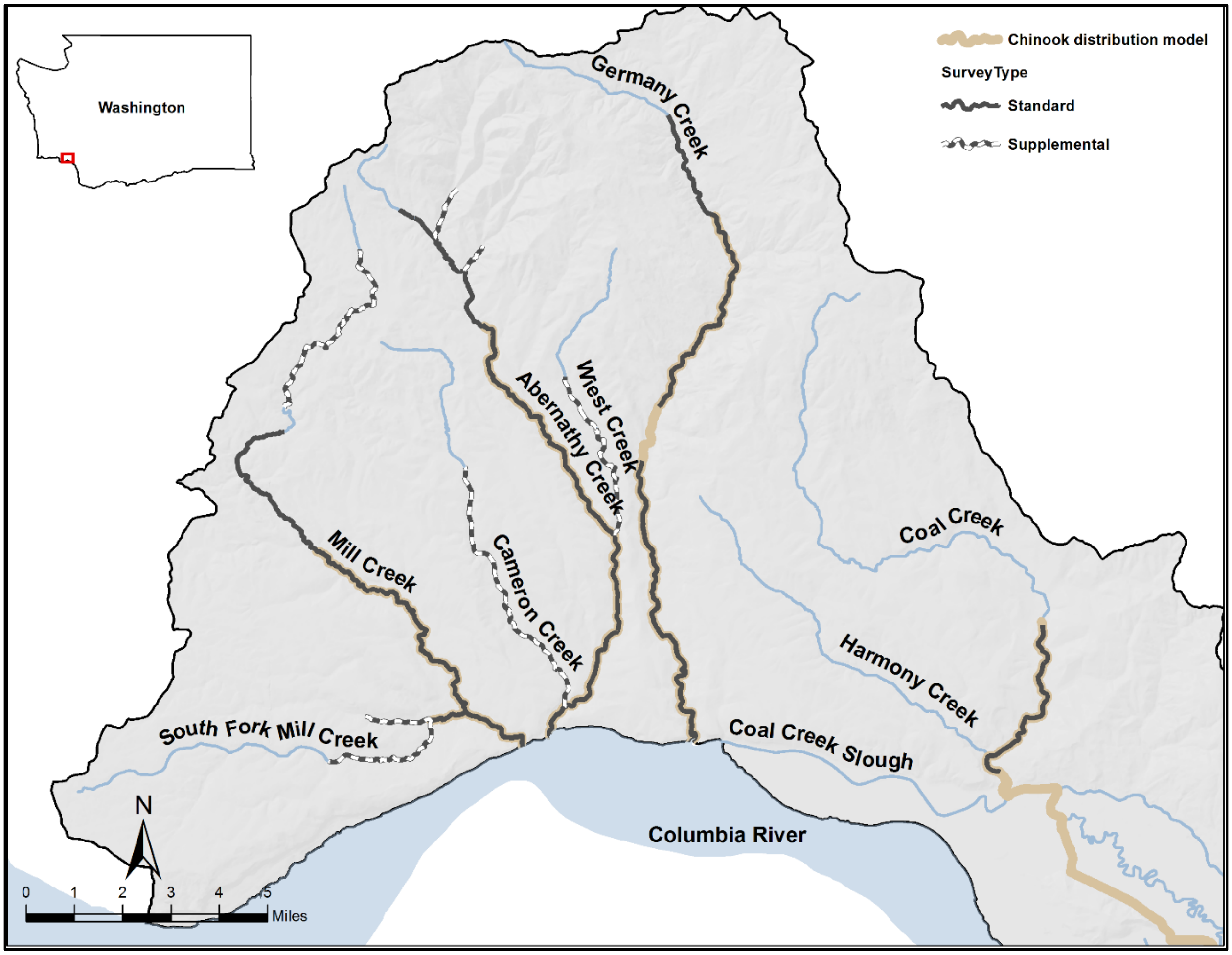

Figure A3. Map of the Mill, Abernathy, Germany, and Coal creek basins showing the survey area for fall Chinook salmon in 2013-2017 spawn years.

Table A3. Description of fall Chinook salmon spawning ground surveys by reach conducted in the Mill, Abernathy, Germany, and Coal creek basins in 2013-2017 spawn years.

Subpopulation	Reach	Lower RM	Upper RM	Total RMs	Survey Type
Germany Creek	GER 1	0	1.31	1.31	Standard
	GER 2	1.31	2.67	1.36	Standard
	GER 3	2.67	3.55	0.88	Standard
	GER 4	3.55	4.97	1.42	Standard
	GER 6	5.85	6.45	0.60	Standard
	GER 7	6.45	8.55	2.10	Standard
	GER 8	8.55	9.55	1.00	Standard
	GER 8	8.55	9.72	1.17	Standard
	GER 9	9.72	10.23	0.51	Standard
	GER 10	10.23	11.13	0.90	Standard
Abernathy Creek	AB 1	0	2.09	2.09	Standard
	AB 2	2.09	3.03	0.94	Standard
	AB 3	3.03	3.50	0.47	Standard
	AB 4	3.50	3.60	0.10	Standard
	AB 5	3.60	4.74	1.14	Standard
	AB 6	4.74	6.31	1.57	Standard
	AB 7	6.31	7.37	1.06	Standard
	AB 8	7.37	8.65	1.28	Standard
	AB 9	8.65	9.38	0.73	Standard
	AB 10	9.38	9.79	0.41	Standard
	AB X	9.79	10.05	0.26	Standard
Cameron Creek	CAM	0	4.24	4.24	Supplemental
Ordway Creek	ORD 1	0	0.72	0.72	Supplemental
Sara Creek	SAR	0	0.49	0.49	Supplemental
South Fork Ordway Creek	SFO 1	0	0.10	0.10	Supplemental
Wiest Creek	WST 1	0	1.89	1.89	Supplemental
	WST 2	1.89	2.21	0.32	Supplemental
	WST X	2.21	2.81	0.60	Supplemental
Mill Creek	MIL 1	0	1.16	1.16	Standard
	MIL 2	1.16	1.97	0.81	Standard
	MIL 3	1.97	2.78	0.81	Standard
	MIL 4	2.78	4.10	1.32	Standard
	MIL 5	4.10	5.64	1.54	Standard
	MIL 6	5.64	6.74	1.10	Standard
	MIL 7	6.74	7.28	0.54	Standard
	MIL 8	7.28	8.11	0.83	Standard
	MIL 10	8.69	10.50	1.81	Supplemental
	MIL 11	10.50	12.40	1.90	Supplemental
South Fork Mill Creek	SFM 1	0	0.57	0.57	Standard
	SFM 2	0.57	2.59	2.02	Supplemental
Spruce Creek	SPR 1	0	1	1	Supplemental
Coal Creek	COAL 1	0.50	0.86	0.36	Standard
	COAL 2	0.86	2.85	1.99	Standard
	COAL 3	2.85	3.49	0.64	Standard

Lower Cowlitz

The Lower Cowlitz fall Chinook population is a contributing population within the Cascade stratum. Mayfield Dam (RM 52), which was constructed in 1962, blocks all natural anadromous passage to the upper basin and serves as a division point between the upper and lower Cowlitz. The largest tributaries to the lower Cowlitz are the Toutle and Coweeman rivers. We cover the Upper Cowlitz, Toutle, and Coweeman in separate sections as they are distinct populations. Other major tributaries include Salmon, LaCamas, Olequa, Delameter, and Ostrander creeks. The lower Cowlitz River has a drainage area of 440 square miles, enters Carrolls Channel, which drains into the Columbia River at RM 67.8 near Longview, Washington. There have been fall Chinook salmon releases into the lower Cowlitz River since 1952 and annual releases have ranged from 4 to 14 million (LCFRB 2010). In recent years, the fall Chinook salmon program has been a combination of integrated and segregated program with a release goal of 3.5 million (*Cindy LeFleur, personal communication, WDFW*). The weekly sampling frame was 45.6 miles on the Cowlitz between the Barrier Dam near the Cowlitz Salmon Hatchery and Castle Rock (Gleizes et al. 2014) (Figure A4) (Table A4).

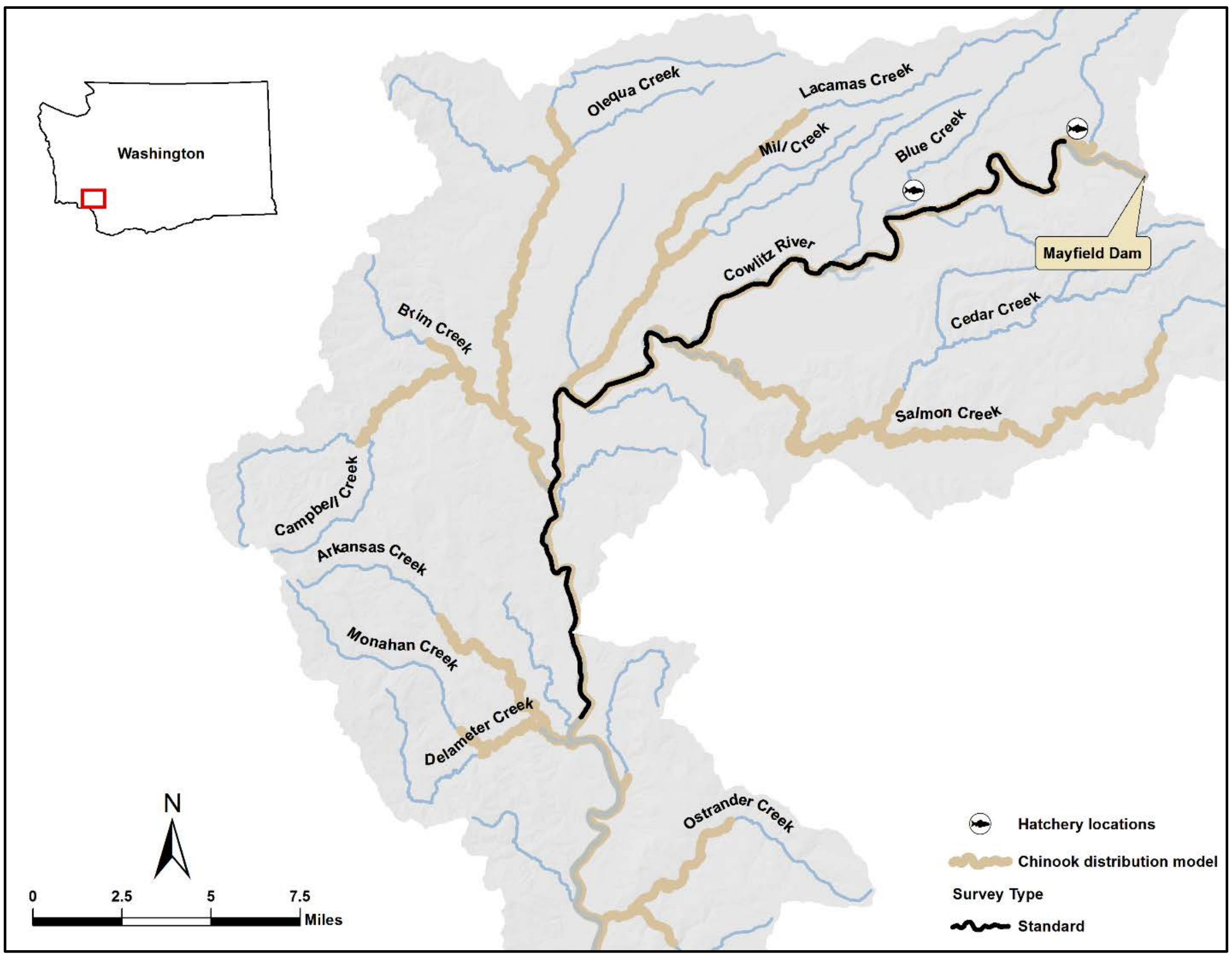

Figure A4. Map of the lower Cowlitz River basin showing the survey area for fall Chinook salmon in 2013-2017 spawn years.

Table A4. Description of fall Chinook salmon spawning ground surveys by reach conducted in the lower Cowlitz River basin in 2013-2017 spawn years.

Subpopulation	Reach	Lower RM	Upper RM	Total RMs	Survey Type
Cowlitz River	CWZ 10	49.64	49.98	0.34	Standard
Cowlitz River	CWZ 9	48.02	49.64	1.62	Standard
Cowlitz River	CWZ 7	42.18	48.02	5.84	Standard
Cowlitz River	CWZ 6	38.50	42.18	3.68	Standard
Cowlitz River	CWZ 5	33.82	38.5	4.68	Standard
Cowlitz River	CWZ 4	29.78	33.82	4.04	Standard
Cowlitz River	CWZ 3	19.42	29.78	10.36	Standard
Cowlitz River	CWZ 2	16.78	19.42	2.64	Standard
Cowlitz River	CWZ 1	4.84	16.78	11.94	Standard
Cowlitz River	CWZ 8	0	0.50	0.50	Standard – Side Channel

Upper Cowlitz

The Upper Cowlitz fall Chinook population is a stabilizing population within the Cascade stratum. Mayfield Dam (RM 52) blocks all natural anadromous passage to the upper basin and serves as a division point between the upper and lower Cowlitz River. The upper Cowlitz River has large drainage area of 1390 square miles. Major tributaries include the Cispus and Tilton rivers. There have been historical releases of fall Chinook salmon into the lower Cowlitz River, and there are still are to this day, but there are not any fall Chinook salmon hatchery releases above Mayfield Dam. Currently, no spawning ground surveys are conducted in the upper Cowlitz River. We report on fall Chinook salmon that are trapped and hauled from the Barrier Dam and released in the upper basin at several sites with an adjustment for sport harvest (Figure A5) (Table A5).

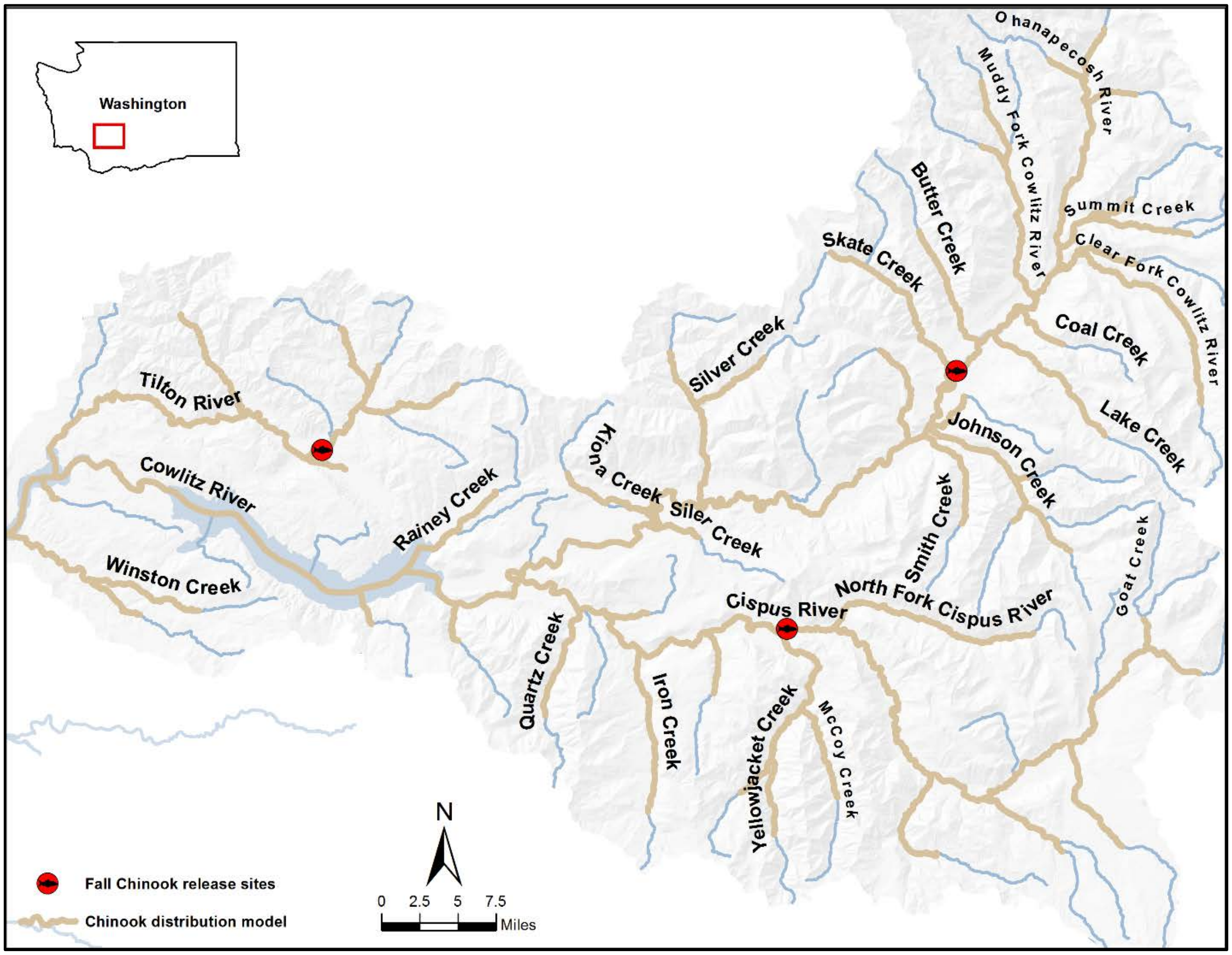

Figure A5. Map of the upper Cowlitz River basin showing the release sites of the trap and haul program for fall Chinook salmon in 2013-2017 spawn years.

Table A5. Description of fall Chinook salmon release locations in the upper Cowlitz River basin in 2013-2017 spawn years.

Subpopulation	RM	Description of Release Site
Cowlitz River	117.93	Packwood, WA at the Franklin Bridge
Tilton River	17.02	Morton, WA at Gust Backstrom Park
Cispus River	16.94	Near the NF23 and Cispus Road junction

Toutle

The Toutle fall Chinook population is a primary population within the Cascade stratum. It is comprised of three main subpopulations: North Fork Toutle, South Fork Toutle, and Green, all of which flow into the Toutle River which enters the Cowlitz River near the town of Castle Rock, Washington. Historical fall Chinook salmon spawning areas were devastated by the 1980 eruption of Mt. St. Helens (LCFRB 2010).

The North Fork Toutle River has a drainage area of 147 square miles. It originates on the northwestern slopes of Mt. St. Helens and flows to the west until it merges with the South Fork Toutle River to become the Toutle River near the town of Kid Valley, Washington. It has an annual rainfall of 94 inches (USGS 2016). Major tributaries include Alder, Hoffstadt, Bear, and Pullen creeks. There are not any releases of fall Chinook salmon into the system (LCFRB 2010). No spawning ground surveys are done for fall Chinook salmon in the North Fork Toutle River and any fall Chinook salmon that enter the Toutle Fish Collection Facility are released back downstream.

The South Fork Toutle River has a drainage area of 130 square miles. It merges with the North Fork Toutle River to become the Toutle River near the town of Kid Valley, Washington. Annual rainfall is 76 inches (USGS 2016). Major tributaries include Johnson, Bear, and Trouble creeks. There are not any releases of fall Chinook salmon into the system (LCFRB 2010). The weekly sampling frame included 19.6 miles on the South Fork Toutle River. Supplemental surveys were conducted once during the first or second week of October in the uppermost main-stem area (upstream 4.3 miles from the top of the weekly survey area) and in Bear and Johnson creeks (Figure A6) (Table A6).

The Green River has a drainage area of 74 square miles and enters the North Fork Toutle River at RM 11.0. Annual rainfall is 74 inches (USGS 2016). The North Toutle Hatchery, near the mouth of the Green River, has raised and released fall Chinook salmon into the system since 1951 with the exception of a ten-year period following the eruption of Mt. St. Helens when the hatchery was not operational. Annual releases of fall Chinook salmon have ranged from 0.5 to 7 million (LCFRB 2010). In recent years, the fall Chinook salmon program has been integrated with a release goal of 1.4 million (*Cindy LeFleur, personal communication, WDFW*). The weekly sampling frame included 4.3 miles on the Green River and the lower mile on Devils Creek. Supplemental surveys were done on the Green River from the top of the weekly survey area upstream 17 miles to near the mouth of Tradedollar Creek (Figure A6) (Table A6).

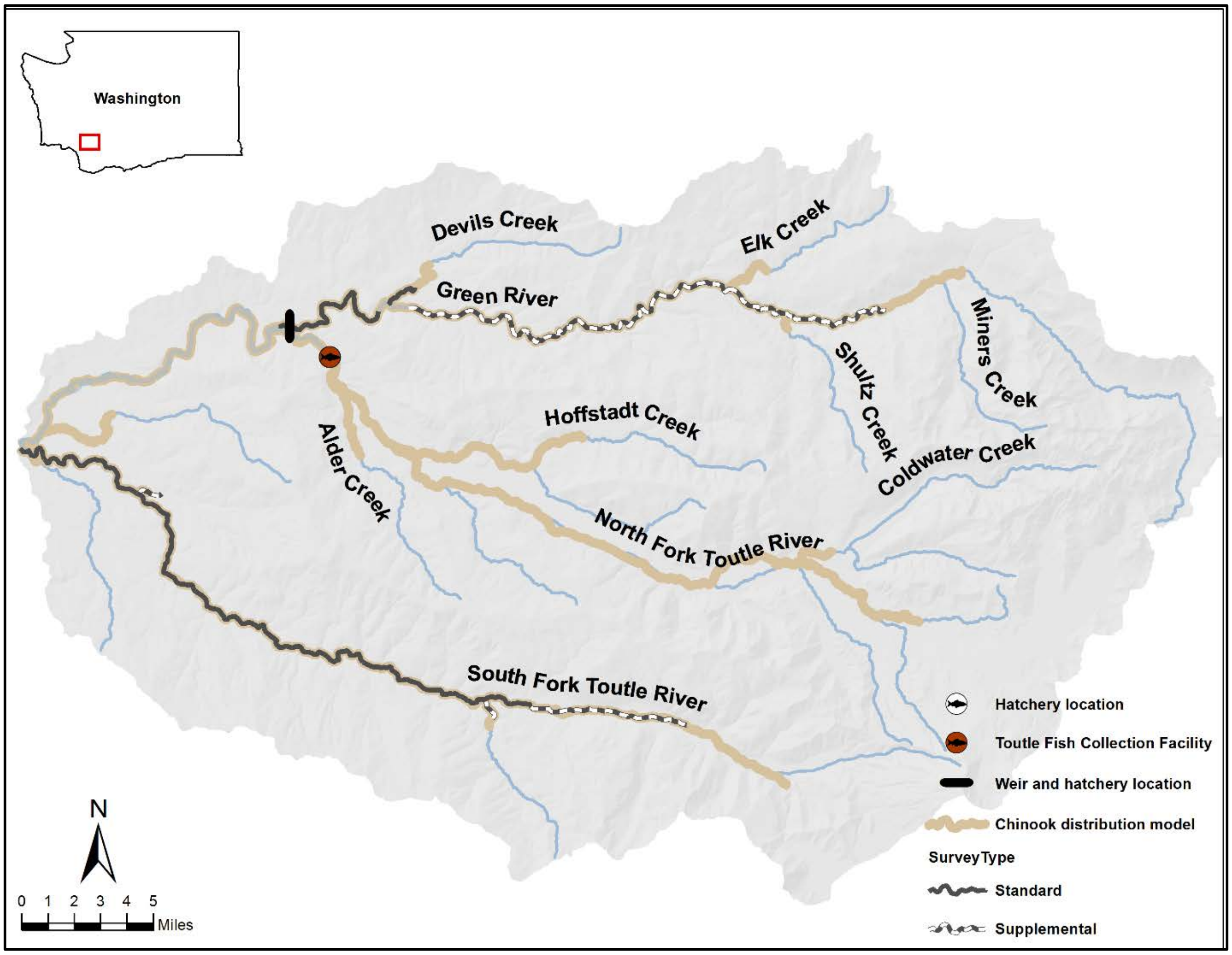

Figure A6. Map of the Toutle River basin showing the survey area for fall Chinook salmon in 2013-2017 spawn years.

Table A6. Description of fall Chinook salmon spawning ground surveys by reach conducted in the Toutle River basin in 2013-2017 spawn years.

Subpopulation	Reach	Lower RM	Upper RM	Total RMs	Survey Type
Green River	GMW	0.00	0.37	0.37	Standard
	GIW	0.37	1.56	1.19	Standard
	SU1	1.56	4.33	2.77	Standard
	SU2	5.33	8.62	3.29	Supplemental
	SU3	8.62	13.92	5.30	Supplemental
	SU4	13.92	15.56	1.64	Supplemental
	SU9	15.56	16.56	1.00	Supplemental
	SU5	16.56	17.65	1.09	Supplemental
	SU6	17.65	18.73	1.08	Supplemental
	SU7	18.73	19.56	0.83	Supplemental
	SU8	19.56	21.67	2.11	Supplemental
Devils Creek	IN2	0.00	1	1.00	Standard
South Fork Toutle River	SFM	0.00	1.11	1.11	Standard
	SJB	1.11	4.62	3.51	Standard
	SBJ	4.62	7.25	2.63	Standard
	SBU	7.25	10.7	3.45	Standard
	SCD	10.70	14.4	3.70	Standard
	SHC	14.40	19.59	5.19	Standard
	SRD	19.59	21.64	2.05	Supplemental
	SUR	21.64	23.92	2.28	Supplemental
Bear Creek	BEA	0.00	0.61	0.61	Supplemental
Johnson Creek	J1A	0.00	0.7	0.70	Supplemental

Coweeman

The Coweeman fall Chinook population is a primary population within the Cascade stratum. It enters the Cowlitz River at RM 1.2 near the town of Kelso, Washington. The Coweeman River has a drainage area of 129 square miles. It is a rainfall-dominated system with an annual rainfall of 70 inches (USGS 2016). Major tributaries include Goble, Mulholland, Baird, Skipper, O'Neil, and Brown creeks. Currently, there are not any releases of fall Chinook salmon into the system. However, historically there were releases in the basin. Fall Chinook salmon were released into the basin from 1951- 1979 from a variety of hatcheries including Spring Creek, Washougal, and Toutle (LCFRB 2010). The weekly sampling frame was adaptive. We began each year with weekly surveys on the main-stem Coweeman from the mouth of Brown Creek downstream to the end of spawnable habitat (uppermost tidal influence). This baseline survey area was expanded upstream to Washboard Falls on the Coweeman River and into Goble, Baird, and Mulholland as far upstream as needed to stay a 0.5 mile above the uppermost Chinook salmon (Figure A7) (Table A7).

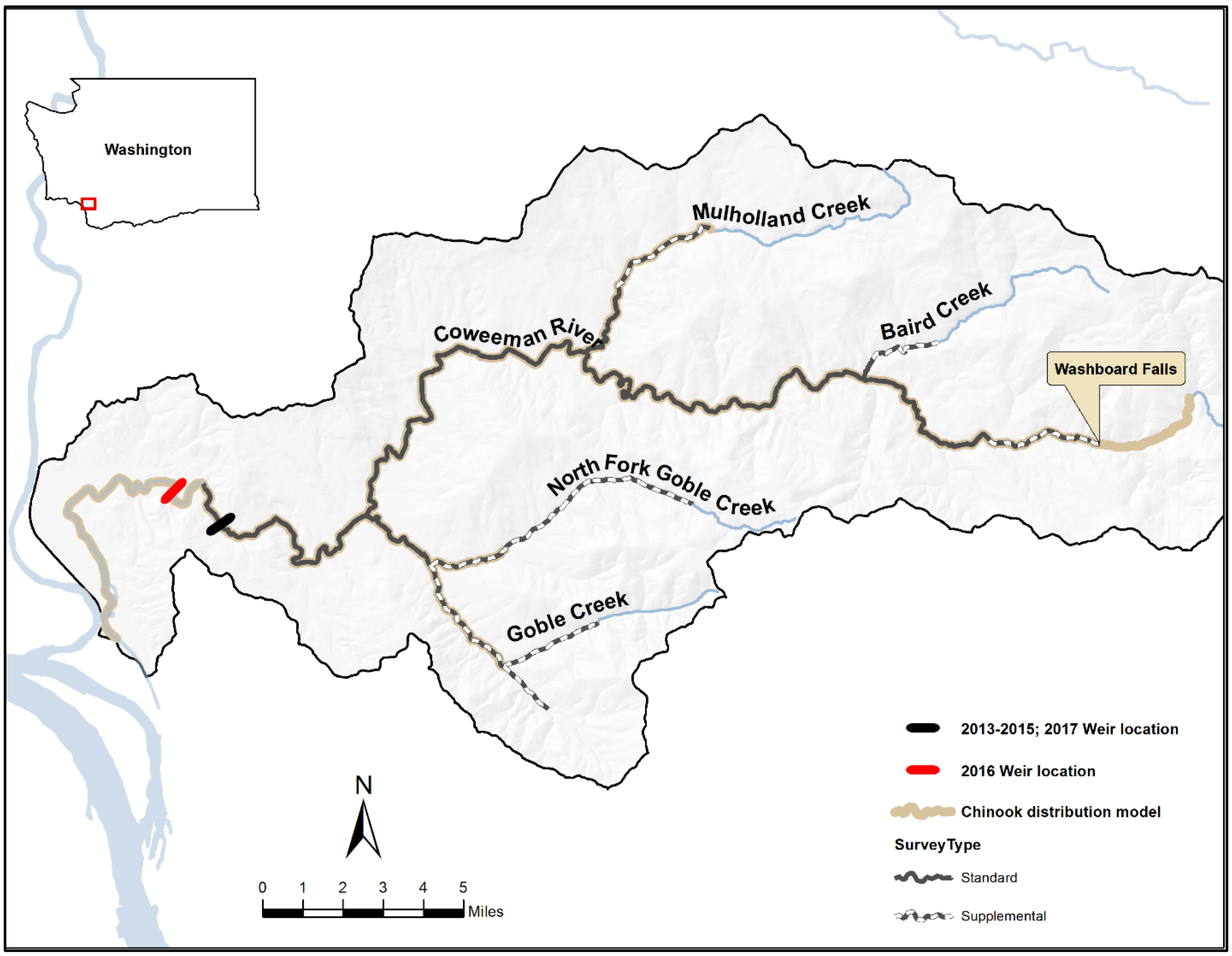

Figure A7. Map of the Coweeman River basin showing the survey area for fall Chinook salmon in 2013-2017 spawn years.

Table A7. Description of fall Chinook salmon spawning ground surveys by reach conducted in the Coweeman River basin in 2013-2017 spawn years.

Subpopulation	Reach	Lower RM	Upper RM	Total RMs	Survey Type
Coweeman River	CWM 1	5.93	6.00	0.07	Standard
	CWM 2	6.00	6.56	0.56	Standard
	CWM 3	6.56	6.77	0.21	Standard
	CWM 4	6.77	7.00	0.23	Standard
	CWM 5	7.00	7.21	0.21	Standard
	CWM 6	7.21	8.00	0.79	Standard
	CWM 7	8.00	8.67	0.67	Standard
	CWM 8	8.67	9.00	0.33	Standard
	CWM 9	9.00	10.00	1.00	Standard
	CWM 10	10.00	11.00	1.00	Standard
	CWM 11	11.00	11.18	0.18	Standard
	CWM 12	11.18	12.00	0.82	Standard
	CWM 13	12.00	13.00	1.00	Standard
	CWM 14	13.00	13.12	0.12	Standard
	CWM 15	13.12	14.00	0.88	Standard
	CWM 16	14.00	15.00	1.00	Standard
	CWM 17	15.00	15.84	0.84	Standard
	CWM 18	15.84	16.00	0.16	Standard
	CWM 19	16.00	17.00	1.00	Standard
	CWM 20	17.00	18.00	1.00	Standard
	CWM 21	18.00	18.37	0.37	Standard
	CWM 22	18.37	19.00	0.63	Standard
	CWM 23	19.00	20.00	1.00	Standard
	CWM 24	20.00	21.00	1.00	Standard
	CWM 25	21.00	21.20	0.20	Standard
	CWM 26	21.20	22.00	0.80	Standard
	CWM 27	22.00	23.00	1.00	Standard
	CWM 28	23.00	24.00	1.00	Standard
	CWM 29	24.00	25.00	1.00	Standard
	CWM 30	25.00	25.93	0.93	Standard
	CWM 31	25.93	26.00	0.07	Standard
	CWM 32	26.00	27.00	1.00	Standard
	CWM 33	27.00	28.00	1.00	Standard
	CWM 34	28.00	28.09	0.09	Standard
	CWM 35	28.09	29.00	0.91	Standard
	CWM 36	29.00	30.00	1.00	Supplemental
	CWM 37	30.00	31.00	1.00	Supplemental
	CWM 38	31.00	31.15	0.15	Supplemental
Goble Creek	G 1	0	0.41	0.41	Standard
	G 2	0.41	1.68	1.27	Standard
	G 3	1.68	3.53	1.85	Supplemental
	G 4	3.53	4.07	0.54	Supplemental
	G 5	4.07	4.90	0.83	Supplemental
	G 6	4.90	5.90	1.00	Supplemental
North Fork Goble Creek	NG 1	0	2.73	2.73	Supplemental
	NG 2	2.73	3.45	0.72	Supplemental
	NG 3	3.45	4.30	0.85	Supplemental
	NG 4	4.3	5.30	1.00	Supplemental
South Fork Goble Creek	SG 1	0	0.58	0.58	Supplemental
	SG 2	0.58	1.09	0.51	Supplemental
Mulholland Creek	M 1	0	1.59	1.59	Standard
	M 2	1.59	2.62	1.03	Supplemental
	M 3	2.62	3.69	1.07	Supplemental
Baird Creek	B 1	0	0.41	0.41	Standard
	B 2	0.41	1.10	0.69	Supplemental
	B 3	1.10	1.75	0.65	Supplemental

Kalama

The Kalama fall Chinook population is a contributing population within the Cascade stratum. It enters the Columbia River at RM 73.0 near the town of Kalama, Washington. The Kalama River has a drainage area of 206 square miles (USGS 2016). It is a rainfall-dominated system with an annual rainfall of 90 inches (USGS 2016). Major tributaries include Fallert, Summers, Gobar, Wildhorse, and Jacks creeks and Little Kalama and North Fork Kalama rivers. The Kalama has had releases of fall Chinook salmon in the basin since 1895 with annual releases ranging from 2 to 15 million over the last 50 years (LCFRB 2010). The fall Chinook salmon program is segregated and has had a release goal of 7 million (*Cindy LeFleur, personal communication, WDFW*). Lower Kalama Falls (RM 10.5) is natural barrier to upstream migration and all fall Chinook salmon are diverted into Kalama Falls Hatchery's ladder. The current management strategy is to exclude fall Chinook salmon from the upper basin. The weekly sampling frame included 7.9 miles on the Kalama River and 0.1 miles on Fallert Creek (e.g. Hatchery Creek). One supplemental survey was done during the first or second week of October between lower Kalama Falls and the top of the weekly index area (Figure A8) (Table A8).

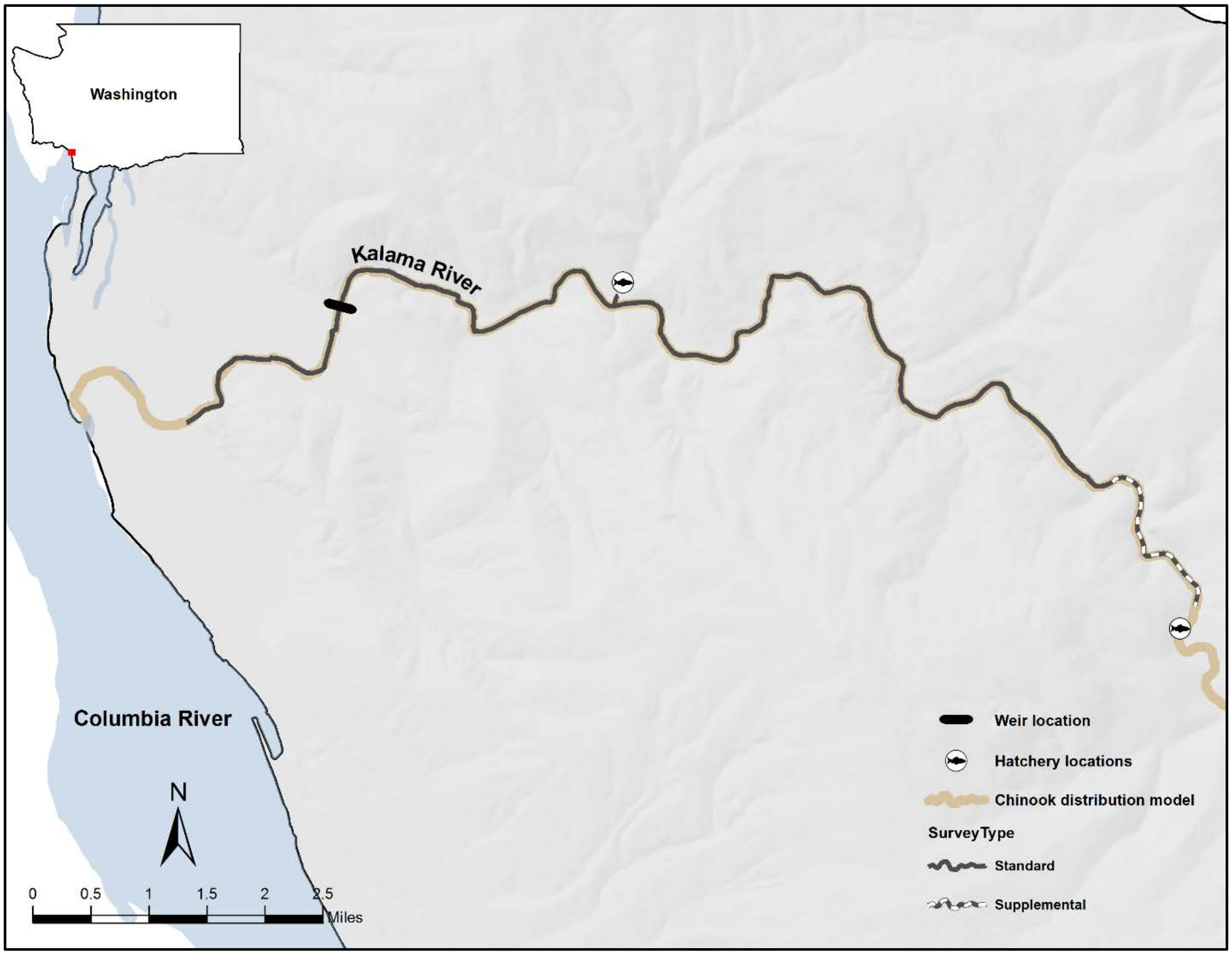

Figure A8. Map of the Kalama River basin showing the survey area for fall Chinook salmon in 2013-2017 spawn years.

Table A8. Description of fall Chinook salmon spawning ground surveys by reach conducted in the Kalama River basin in 2013-2017 spawn years.

Subpopulation	Reach	Lower RM	Upper RM	Total RMs	Survey Type
Kalama River	KAL 1	1.2	2.72	1.52	Standard
Kalama River	KAL 2	2.72	2.91	0.19	Standard
Kalama River	KAL 3	2.91	5.27	2.36	Standard
Kalama River	KAL 4	5.27	9.47	4.2	Standard
Kalama River	KAL 5	9.47	10.6	1.13	Supplemental
Hatchery Creek	HAT 1	0	0.07	0.07	Standard

Lewis

The Lewis fall Chinook population is a primary population within the Cascade stratum. Merwin Dam (RM 19.5), which was constructed in 1931, blocks all natural anadromous passage to the upper basin and serves as a division point between the upper and lower Lewis River. The Upper Lewis is not a recognized population but reintroduction efforts for Coho salmon, spring Chinook salmon and steelhead are currently underway. The Lewis fall Chinook population consists of both Tule and Bright stocks, which are both included as part of the federal ESA listing. The largest tributaries to the lower Lewis River are the East Fork Lewis River and Cedar Creek. The lower Lewis enters the Columbia River at RM 86.6 near Woodland, Washington.

The lower North Fork Lewis River, or lower Lewis River, is the one of few populations in the LCR with minimal hatchery influence and, in most years, meets or exceeds its viability target. There are not currently any fall Chinook salmon releases into the North Fork Lewis River. However, there were releases of hatchery fall Chinook salmon in the basin from 1932 until the mid-1980s (LCFRB 2010). The weekly sampling frame included 9.1 miles on the North Fork Lewis River (Figure A9) (Table A9).

Cedar Creek has a drainage area of 56 square miles and enters the Lewis River at RM 15.63. The weekly sampling frame included the lower 2.5 miles on the Cedar Creek. Supplemental surveys were done in October on Cedar Creek upstream an additional six miles from the top of the standard weekly survey area (Figure A9) (Table A9).

The East Fork Lewis River has a drainage area of 212 square miles and enters the Lewis River at RM 3.61. Lucia Falls (RM 21.2) blocks all anadromous fish passage except for steelhead. The lower basin is rainfall-dominated system with annual rainfall of 79 inches while the upper basin receives snow and rain (USGS 2016). Major tributaries include Mason, Lockwood, and Rock creeks. There have not been any releases of fall Chinook salmon into the system (LCFRB 2010). The weekly sampling frame included 15.6 miles on the East Fork Lewis River. Supplemental surveys were conducted once during the second or third week of October in Lockwood, Riley, and Mason creeks (Figure A9) (Table A9).

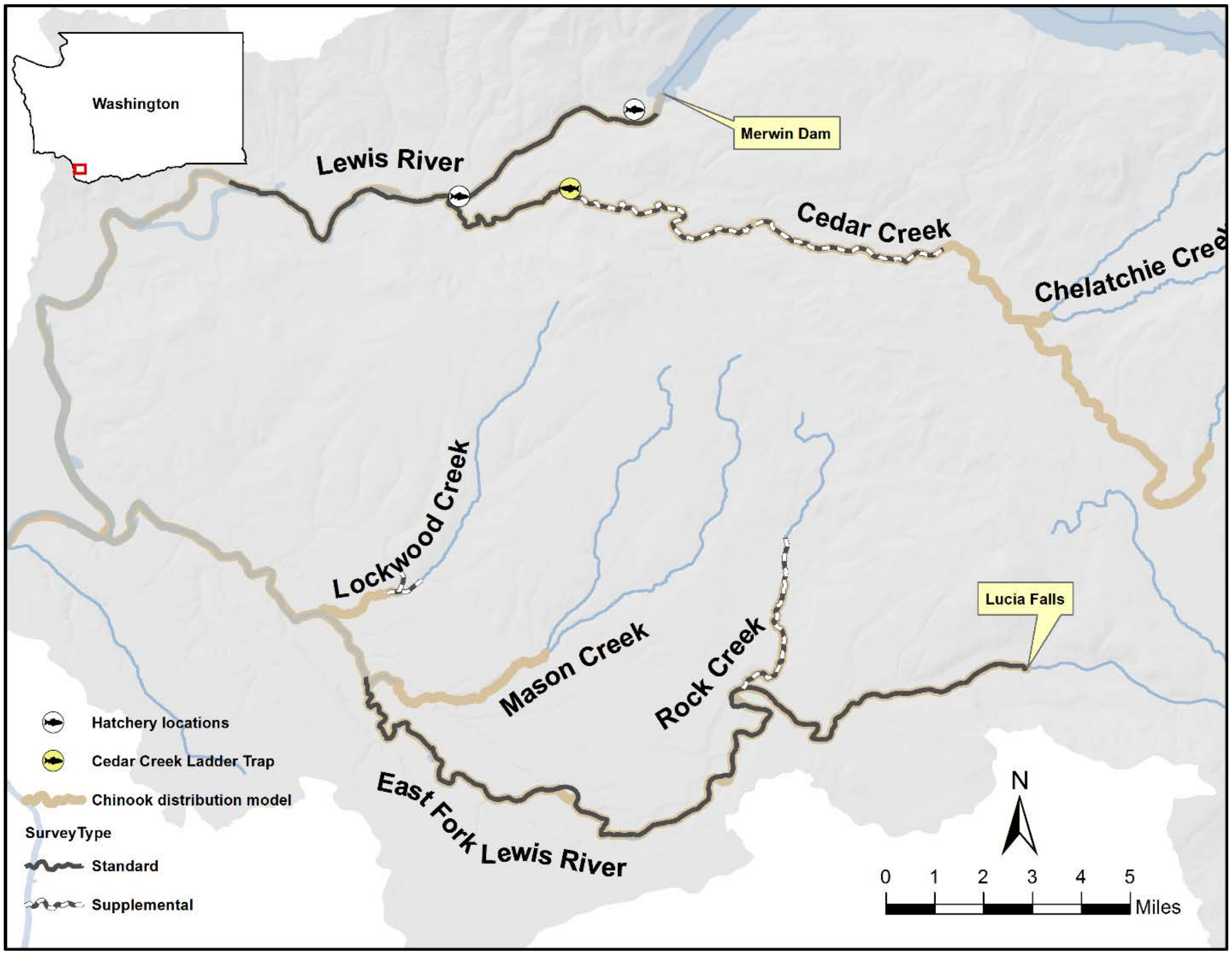

Figure A9. Map of the Lewis River basin showing the survey area for fall Chinook salmon in 2013-2017 spawn years.

Table A9. Description of fall Chinook salmon spawning ground surveys by reach conducted in the Lewis River basin in 2013-2017 spawn years.

Subpopulation	Reach	Lower RM	Upper RM	Total RMs	Survey Type
Cedar Creek	CED 1	0.00	1.00	1.00	Standard
Cedar Creek	CED 2	1.00	2.47	1.47	Standard
Cedar Creek	CED 3	2.47	4.37	1.90	Supplemental
Cedar Creek	CED 4	4.37	6.15	1.78	Supplemental
Cedar Creek	CED 5	6.15	9.15	3.00	Supplemental
East Fork Lewis River	EFL 1	5.63	10.14	4.51	Standard
East Fork Lewis River	EFL 2	10.14	13.00	2.86	Standard
East Fork Lewis River	EFL 3	13.00	14.30	1.30	Standard
East Fork Lewis River	EFL 4	14.30	18.78	4.48	Standard
East Fork Lewis River	EFL 5	18.78	21.20	2.42	Standard
Lockwood Creek	LOC 2	1.21	1.76	0.55	Supplemental
Riley Creek	RIL	0.00	0.30	0.30	Supplemental
Rock Creek	ROC 1	0.00	2.07	2.07	Supplemental
Rock Creek	ROC 2	2.07	2.78	0.71	Supplemental
North Fork Lewis River	NFL 1	18.40	19.10	0.70	Standard
North Fork Lewis River	NFL 2	17.80	18.40	0.60	Standard
North Fork Lewis River	NFL 3	16.80	17.80	1.00	Standard
North Fork Lewis River	NFL 4	15.70	16.80	1.10	Standard
North Fork Lewis River	NFL 5	10.00	15.70	5.70	Standard

Washougal

The Washougal fall Chinook population is a primary population within the Cascade stratum. It enters the Columbia River at RM 120.8 near the town of Washougal, Washington. The Washougal River has a drainage area of 209 square miles (USGS 2016). Annual rainfall is 85 inches (USGS 2016). Major tributaries include the Little Washougal and West Fork Washougal rivers and LaCamas, Jones and Boulder creeks. The Washougal River has had releases of fall Chinook salmon in the basin since the 1950s with annual releases ranging from 0.5 to 12 million over the last 50 years (LCFRB 2010). In recent years, the fall Chinook salmon program has been integrated with a release goal in the basin of 1.9 million (*Cindy LeFleur, personal communication, WDFW*). Salmon Falls (RM 15.5) was a natural barrier to fall Chinook salmon until a ladder was built to facilitate fish passage in the 1950s (LCFRB 2010). The weekly sampling frame included 19.3 miles on the Washougal River. Supplemental surveys were done once on the Washougal River above the top of the standard weekly survey area up to Dougan Falls and on LaCamas Creek, the Little Washougal River, and the West Fork Washougal River (Figure A10) (Table A10).

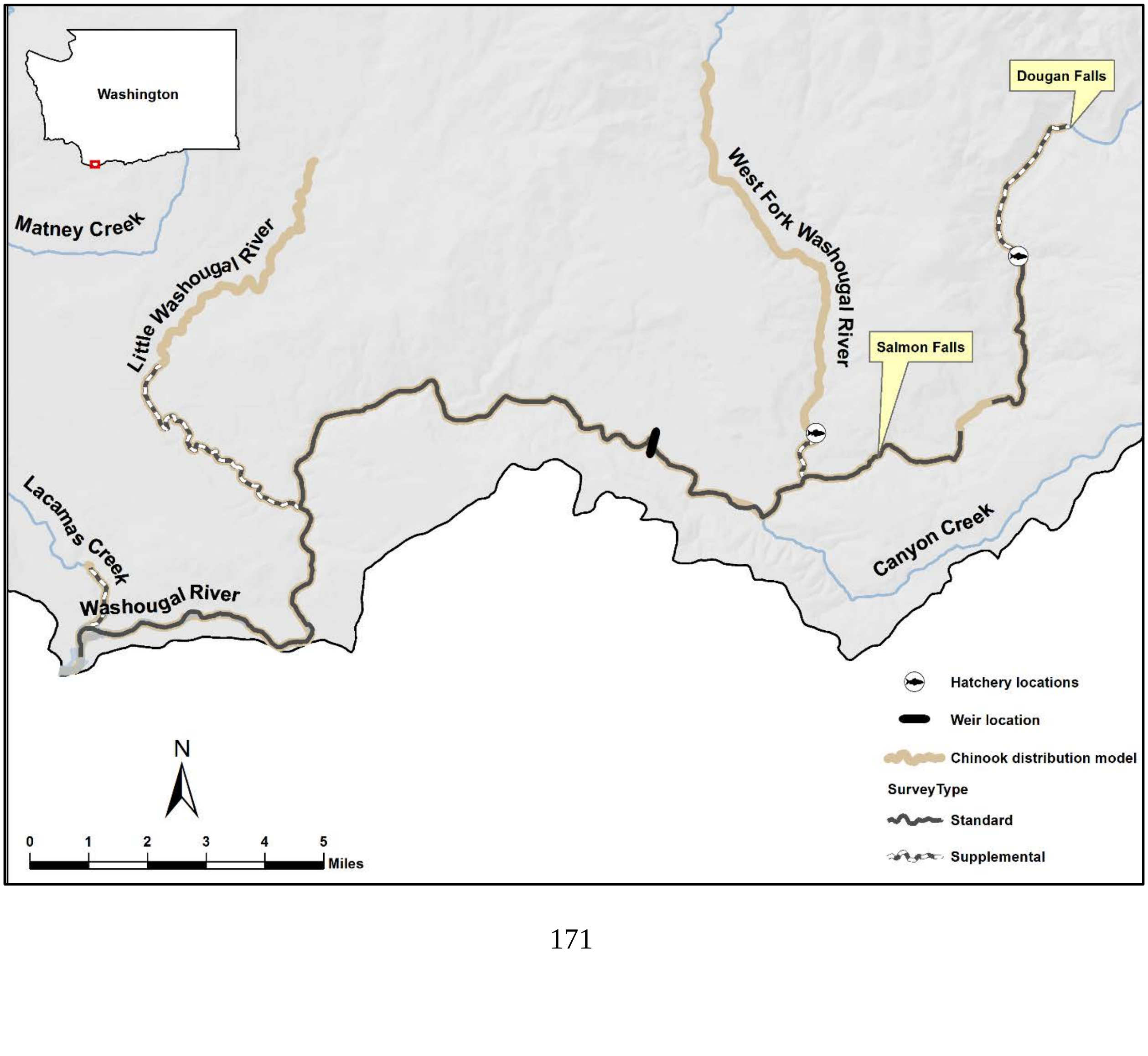

Figure A10. Map of the Washougal River basin showing the survey area for fall Chinook salmon in 2013-2017 spawn years.

Table A10. Description of fall Chinook salmon spawning ground surveys by reach conducted in the Washougal River basin in 2013-2017 spawn years.

Subpopulation	Reach	Lower RM	Upper RM	Total RMs	Survey Type
Washougal River	WSH 1	0.30	3.46	3.16	Standard
Washougal River	WSH 2	3.46	6.33	2.87	Standard
Washougal River	WSH 3	6.33	10	3.67	Standard
Washougal River	WSH 4	10.00	10.85	0.85	Standard
Washougal River	WSH 5	10.85	11.85	1.00	Standard
Washougal River	WSH 6	11.85	13.55	1.70	Standard
Washougal River	WSH 7	13.55	15.48	1.93	Standard
Washougal River	WSH 8	15.48	16.93	1.51	Standard
Washougal River	WSH 9	17.49	19.78	2.29	Standard
Washougal River	WSH 10	19.78	21.88	2.10	Supplemental
LaCamas Creek	LAC 1	0.00	0.22	0.22	Supplemental
LaCamas Creek	LAC 2	0.22	0.84	0.62	Supplemental
Little Washougal River	LWA 1	0.00	0.5	0.50	Supplemental
Little Washougal River	LWA 2	0.50	1.09	0.59	Supplemental
Little Washougal River	LWA 3	1.09	2.4	1.31	Supplemental
Little Washougal River	LWA 4	2.40	3.5	1.10	Supplemental
West Fork Washougal	NWA 1	0.00	0.6	0.60	Supplemental

Lower Gorge

The Lower Gorge fall Chinook population is a contributing population within the Gorge stratum. It is comprised of both Washington and Oregon streams. Several of the Washington streams are Gibbons, Lawton, Duncan, Woodward, Hardy and Hamilton creeks as well as main-stem Columbia River between Bonneville Dam and the mouth of the Washougal River. There are both Tule and Bright stocks of fall Chinook salmon spawning within the Lower Gorge population with Hamilton Creek and the main-stem Columbia River supporting most of the fall Chinook salmon spawning.

Hamilton Creek has a drainage area of 23 square miles and enters the Columbia River at RM 142.1 near the town of North Bonneville, Washington. It is a rainfall-dominated system with an annual rainfall of 87 inches (USGS 2016). Currently, there are not any releases of fall Chinook salmon into the system. There was a single year in 1977 where 50,000 fall Chinook salmon were released into the basin but those are the only hatchery releases that have been documented in Hamilton Creek. The weekly sampling frame included 1.7 miles on Hamilton Creek (Figure A11) (Table A11).

The main-stem Columbia River downstream of Bonneville Dam supports a spawning population of fall Chinook salmon. There is very little use by Tule fall Chinook salmon but there is substantial use by a non ESA-listed Bright stock. This population was discovered in 1994 (LCFRB 2010). The weekly sampling frame included 2.0 miles on the Columbia River from the upstream end of Ives Island downstream to the mouth of Duncan Creek (Figure A11) (Table A11).

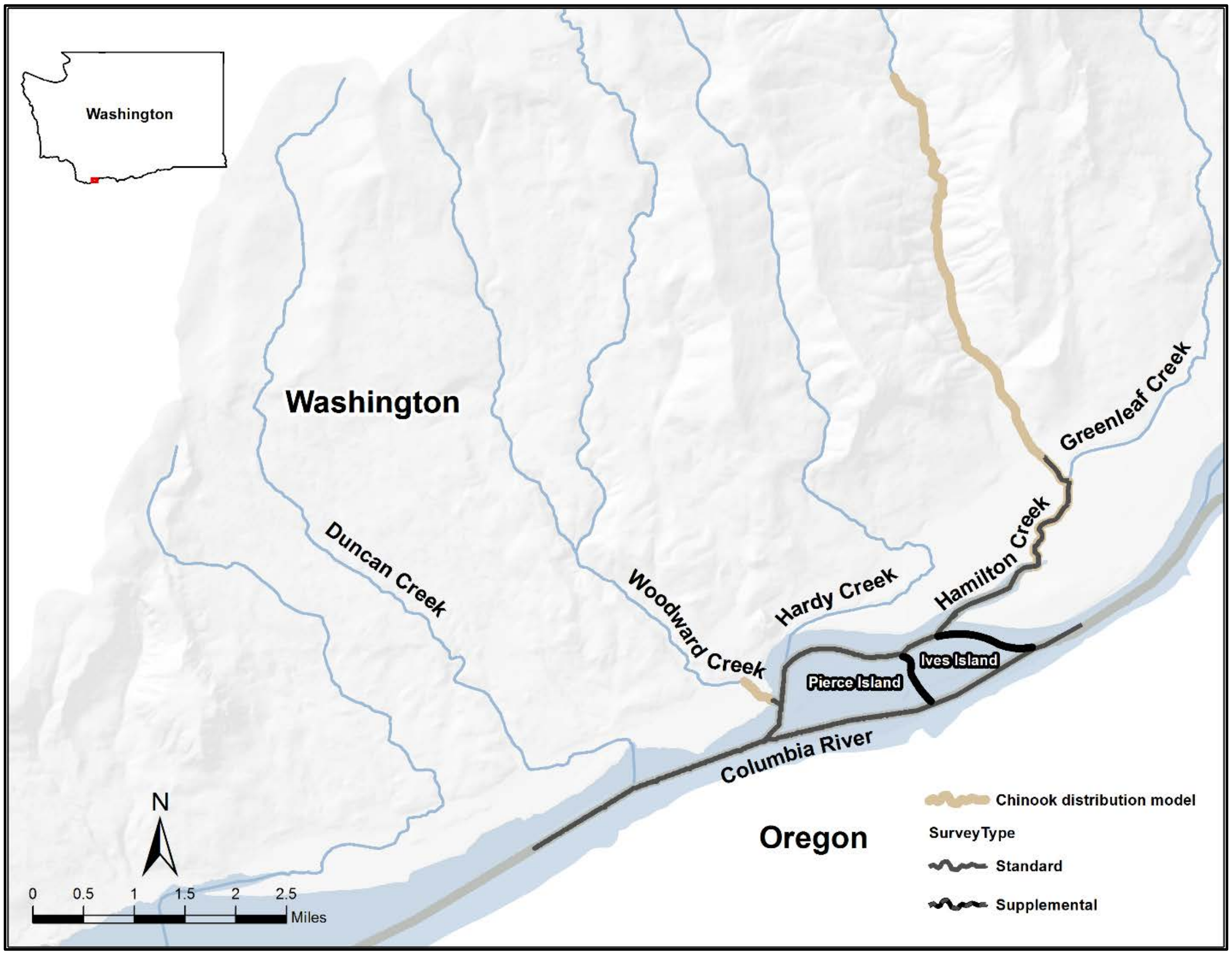

Figure A11. Map of Washington's portion of the Lower Gorge population showing the survey area for fall Chinook salmon in 2013-2017 spawn years.

Table A11. Description of fall Chinook salmon spawning ground surveys by reach conducted in the Lower Gorge population in 2013-2017 spawn years.

Subpopulation	Reach	Lower RM	Upper RM	Total RMs	Survey Type
Columbia River	Ives/Pierce	141.00	143.00	2.00	Standard
Hamilton Creek	HAM 1	0.00	0.58	0.58	Standard
Hamilton Creek	HAM 2	0.58	0.98	0.40	Standard
Hamilton Creek	HAM 3a	0.98	1.31	0.33	Standard
Hamilton Creek	HAM 3b	1.31	1.47	0.16	Standard
Hamilton Creek	HAM 4	1.47	1.72	0.25	Standard

Upper Gorge

The Upper Gorge fall Chinook population is a contributing population within the Gorge stratum. It is comprised of both Washington and Oregon streams. The largest Washington streams within this population are the Wind and Little White Salmon rivers other creeks include Dog, Rock, and Carson. There are both Tule and Bright stocks of fall Chinook salmon spawning within the Upper Gorge fall Chinook salmon population. Tule stocks are ESA-listed while the Bright stocks are not. The Wind and Little White Salmon rivers support most of the fall Chinook salmon spawning within this population.

Wind River has a drainage area of 226 square miles and enters the Columbia River at RM 155.3 just upstream of the town of Stevenson, Washington. It has an annual rainfall of 100 inches (USGS 2016). Shipherd Falls was a barrier for fall Chinook salmon until a ladder was built in 1956. Fall Chinook salmon have been observed up to Carson National Fish Hatchery (RM 18) (LCFRB 2010). However, the current management strategy is not to pass fall Chinook salmon upstream of Shipherd Falls. Currently, there are not any releases of fall Chinook salmon into the system. From 1899-1938, there were hatchery releases of fall Chinook salmon into the Wind River with annual releases ranging from 1-20 million (LCFRB 2010). The weekly sampling frame included 2.2 miles on the Wind River with a single supplemental survey done twice on the Little White Salmon; once around peak spawning activity for Tule fall Chinook salmon, and again, around peak spawning activity for Bright fall Chinook salmon (Figure A12) (Table A12).

The Little White Salmon River has a drainage area of 134 square miles and enters the Columbia River at RM 160.3. It has an annual rainfall of 73 inches (USGS 2016). The Little White Salmon River has had releases of fall Chinook salmon in the basin since 1896 with annual releases ranging from 1.5 to 40 million (LCFRB 2010). These fall Chinook salmon releases have been both Tule and Bright stocks. In recent years, the Bright fall Chinook program has been a segregated program with a release goal of 4.5 million (*Cindy LeFleur, personal communication, WDFW*). Historically, a barrier falls at RM 2.0 blocked fall Chinook salmon passage (LCFRB 2010). When the Little White Salmon Hatchery was built in the late 1800s, a barrier dam was also built downstream one mile of the historical barrier falls further limiting spawnable habitat (*Steve VanderPloeg, personal communication, WDFW*). The weekly sampling frame was 1.2 miles on Little White Salmon River as well as the shorelines of Drano Lake (Figure A12) (Table A12).

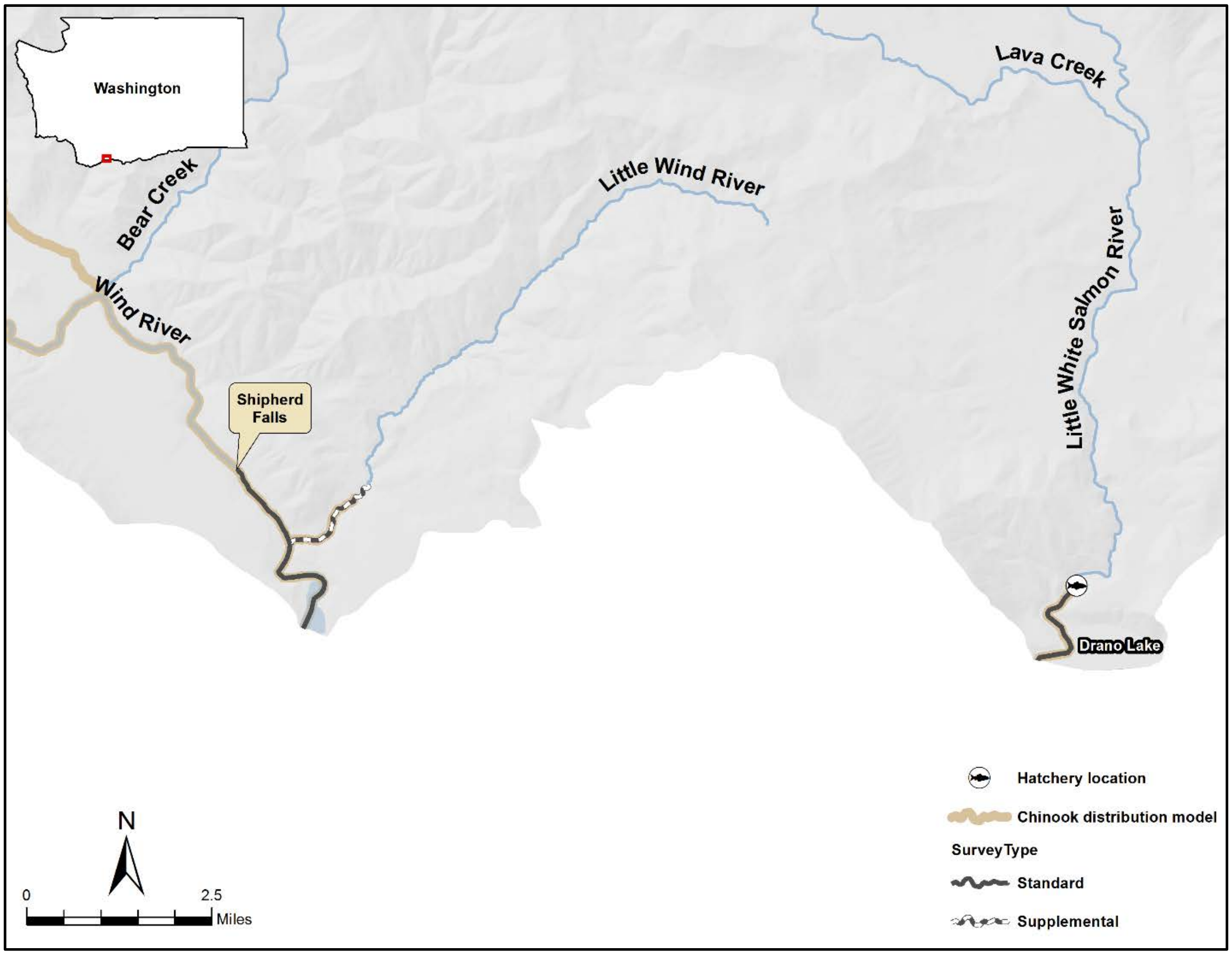

Figure A12. Map of Washington's portion of the Upper Gorge population showing the survey area for fall Chinook salmon in 2013-2017 spawn years.

Table A12. Description of fall Chinook salmon spawning ground surveys by reach conducted in the Upper Gorge population in 2013-2017 spawn years.

Subpopulation	Reach	Lower RM	Upper RM	Total RMs	Survey Type
Little White Salmon River	LWS 1	0	0.9	0.90	Standard
Little White Salmon River	LWS 2	0.90	1.20	0.30	Standard
Wind River	WIND 1	0	0.69	0.69	Standard
Wind River	WIND 2	0.69	1.28	0.59	Standard
Wind River	WIND 3	1.28	2.16	0.88	Standard
Little Wind River	LWI	0	1.09	1.09	Supplemental

White Salmon

The White Salmon fall Chinook population is a contributing population within the Gorge stratum. There are both Tule and Bright stocks present. However, Tule stocks are ESA-listed while the Bright stocks are not.

The White Salmon River begins on the south slope of Mt. Adams where it flows south until it enters the Columbia River at RM 166.5 near the town of Underwood, Washington. It has a drainage area of 391 square miles and an annual rainfall of 66 inches (USGS 2016). Condit Dam (RM 3.3) was a barrier to all anadromous fish passage for nearly 100 years. On October 26, 2011, Condit Dam was breached opening up miles of potential spawning habitat (Allen et al. 2016). Major tributaries include Rattlesnake, Buck, Mill, and Spring creeks. Naturally spawning fall Chinook salmon in the White Salmon River were the original source of broodstock for Spring Creek National Fish Hatchery in the early 1900s (Smith and Engle 2011). Currently, there are not any releases of fall Chinook salmon into the system. However, there have been releases of fall Chinook salmon into the White Salmon in the past (1924 to 1964). The weekly sampling frame included 7.8 miles on the White Salmon River. Supplemental surveys were done three times annually around peak for each of the stocks present in the system (e.g. Spring Chinook salmon , Tule fall Chinook salmon, and Bright fall Chinook salmon) (Figure A13) (Table A13).

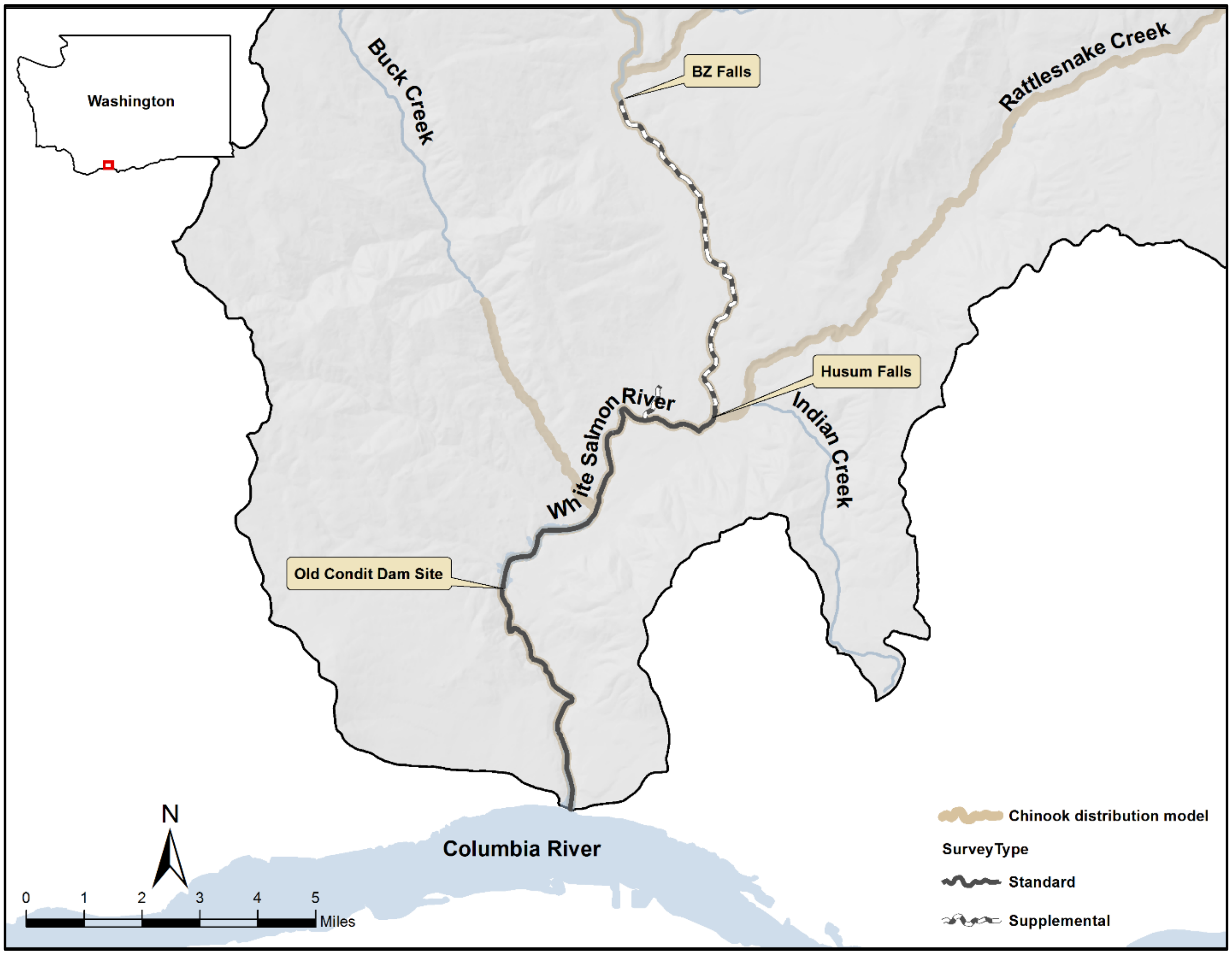

Figure A13. Map of the White Salmon River basin showing the survey area for fall Chinook salmon in 2013-2017 spawn years.

Table A13. Description of fall Chinook salmon spawning ground surveys by reach conducted in the White Salmon River basin in 2013-2017 spawn years.

Subpopulation	Reach	Lower RM	Upper RM	Total RMs	Survey Type
White Salmon River	WHS 1	0.00	1.00	1.00	Standard
White Salmon River	WHS 2	1.00	1.44	0.44	Standard
White Salmon River	WHS 3	1.44	2.00	0.56	Standard
White Salmon River	WHS 4A	2.00	2.2	0.20	Standard
White Salmon River	WHS 4B	2.20	3.00	0.80	Standard
White Salmon River	WHS 5	3.00	3.27	0.27	Standard
White Salmon River	WHS 6	3.27	4.00	0.73	Standard
White Salmon River	WHS 7A	4.00	4.26	0.26	Standard
White Salmon River	WHS 7B	4.26	4.86	0.60	Standard
White Salmon River	WHS 8	4.86	5.00	0.14	Standard
White Salmon River	WHS 9	5.00	6.00	1.00	Standard
White Salmon River	WHS 10	6.00	7.00	1.00	Standard
White Salmon River	WHS 11	7.00	7.79	0.79	Standard
White Salmon River	WHS 12	7.79	8.00	0.21	Supplemental
White Salmon River	WHS 13	8.00	9.00	1.00	Supplemental
White Salmon River	WHS 14	9.00	10.00	1.00	Supplemental
White Salmon River	WHS 15	10.00	11.00	1.00	Supplemental
White Salmon River	WHS 16	11.00	12.00	1.00	Supplemental
White Salmon River	WHS 17	12.00	12.34	0.34	Supplemental
Spring Creek	SPR	0.00	0.5	0.50	Supplemental

Appendix B – Inputs to Mixed Effects Model to Estimate Apparent Residence Time and Apparent Females per Redd

This appendix consists of tables of estimates of apparent residence time and apparent females per redd (AFpR) for adult fall Chinook salmon by subpopulation in LCR for 2003-2017. These estimates were derived using the framework described in Parken et al. (2003) where mark-recapture estimates were used as the basis to develop the ART and AFpR estimates. The tables in this appendix describe the abundance method, JS model (if applicable), year, and subpopulation for each of the model inputs.

Abbreviations used in the tables are as follows:

JS	Jolly-Seber (as described in the methods)
tGMR – LP	Transgenerational Genetic Mark-Recapture Lincoln-Petersen (Rawding et al. 2014)
LP	Lincoln-Petersen (as described in the methods)

Table B1. Estimates of apparent residence time for adult Chinook salmon by abundance method, JS model (if applicable), year, and subpopulation in LCR tributaries (mean and SD) for 2002-2017.

Year	Subpopulation	Mean	SD	Abundance Estimation Method	JS Model (if applicable)
2002	Coweeman	6.35	0.26	JS	STT
2003	Coweeman	6.10	0.22	JS	TST
2004	Coweeman	4.99	0.45	JS	TTT
2008	Coweeman	7.02	0.79	JS	STT
2009	Coweeman	7.43	1.10	JS	STT
2010	Coweeman	4.48	0.58	tGMR - LP	NA
2005	East Fork Lewis	5.87	0.89	JS	TST
2006	East Fork Lewis	6.08	1.14	JS	TTT
2013	East Fork Lewis	5.89	0.77	JS	TST
2014	East Fork Lewis	4.10	1.13	JS	TST
2015	East Fork Lewis	6.30	0.67	JS	TTT
2017	East Fork Lewis	5.17	1.51	JS	TTT
2009	Elochoman	3.18	0.17	LP	NA
2010	Elochoman	4.86	0.56	LP	NA
2011	Elochoman	3.77	0.19	LP	NA
2012	Elochoman	4.61	2.54	LP	NA
2013	Elochoman	3.81	3.20	LP	NA
2014	Elochoman	4.12	1.15	LP	NA
2015	Elochoman	7.11	1.84	LP	NA
2016	Elochoman	8.77	5.43	LP	NA
2005	Mill	5.48	0.44	JS	TTT
2006	Mill	7.55	0.92	JS	TTT
2007	Mill	6.84	0.54	JS	STT
2008	Mill	6.60	0.67	JS	TTT
2009	Mill	7.11	0.52	JS	TTT
2010	Mill	6.24	0.29	JS	STT
2011	Mill	6.67	0.42	JS	TTT
2014	Mill	7.94	0.71	JS	TTT
2015	Mill	6.59	0.32	JS	TTT
2005	Abernathy	7.03	0.37	JS	TTT
2009	Abernathy	7.92	0.80	JS	TST
2010	Abernathy	7.83	0.79	JS	TTT
2011	Abernathy	5.30	0.91	JS	TST
2014	Abernathy	8.97	1.41	JS	TST
2015	Abernathy	9.14	0.84	JS	TTT
2005	Germany	5.98	0.32	JS	TTT
2008	Germany	6.23	0.28	JS	STT
2010	Germany	7.34	0.34	JS	TTT
2011	Germany	8.12	0.47	JS	STT
2013	Germany	7.35	0.78	JS	TST
2015	Germany	9.10	1.32	JS	STT
2011	Grays	6.39	0.74	JS	TST
2009	Washougal	8.15	0.74	JS	TTT
2010	Washougal	5.54	0.44	JS	TTT
2012	Washougal	8.81	1.24	JS	STT

Table B2. Estimates of apparent residence time for adult Chinook salmon by abundance method, JS model (if applicable), year, and subpopulation in LCR tributaries (mean and SD) for 2002-2017, continued.

Year	Subpopulation	Mean	SD	Abundance Estimation Method	JS Model (if applicable)
2013	Washougal	9.84	0.84	JS	TTT
2014	Washougal	6.23	0.61	LP above weir + JS below weir	TTT
2015	Washougal	6.45	0.57	LP above weir + JS below weir	TTT
2017	Washougal	5.36	1.06	LP above weir + JS below weir	TTT
2017	Kalama	5.70	0.17	LP	NA

Table B3. Estimates of apparent females per redd (AFpR) for adult Chinook salmon by abundance method, JS model (if applicable), year, and subpopulation in LCR tributaries (mean and SD) for 2003-2017.

Year	Subpopulation	Mean	SD	Abundance Estimation Method	JS Model (if applicable)
2003	Coweeman	0.96	0.03	JS	TST
2004	Coweeman	1.07	0.10	JS	TTT
2009	Coweeman	0.85	0.14	JS	STT
2010	Coweeman	1.03	0.13	tGMR - LP	NA
2011	Coweeman	1.08	0.09	LP	NA
2012	Coweeman	1.46	0.21	LP	NA
2014	Coweeman	1.50	0.07	LP	NA
2015	Coweeman	1.61	0.02	LP	NA
2017	Coweeman	1.26	0.33	LP	NA
2005	EFL	1.08	0.18	JS	TST
2006	EFL	0.95	0.20	JS	TTT
2013	EFL	1.44	0.20	JS	TST
2015	EFL	0.91	0.11	JS	TTT
2017	EFL	1.74	0.59	JS	TTT
2015	Elochoman	1.11	0.22	LP	NA

Appendix C – Jolly-Seber Mark-Recapture Model Notation (Schwarz et al. 1993)

Table C1. Summary statistics used in the JS model (Schwarz et al. 1993)

Statistic	Definition/Equation
m_i	Number of fish captured at sample time i that were previously marked.
u_i	Number of fish captured at sample time i that were unmarked.
n_i	Number of fish captured at sample time i. $n_i = m_i + u_i$.
l_i	Number of fish lost on capture at time i.
R_i	Number of fish that were released after the ith sample. R_i need not equal n_i if there were losses on capture or injections of new fish at sample time i.
r_i	Number of R_i fish released at sample time i that were recaptured at one or more future sample times.
z_i	Number of fish captured before time i, not captured at time i, and captured after time i.
T_i	Number of fish captured at before time i and captured at or after time i. $T_i = m_i + z_i$.

Table C2. Fundamental parameters for the JS model under the salmon escapement super population model (Schwarz et al. 1993).

Parameter	Definition/Equation
s, tm	Number of sample times and length of interval between samples
p_i	Probability of capture at sample time i, $i = 1,\ldots, s$.
φ_i	Probability of a fish surviving and remaining in the population between sample time i and sample time $i + 1$, given it was alive and in the population at sample time i, $i = 1,\ldots, s$-1.
b^*_i	Probability that a fish enters the population between sample times i and i +1, $i = 0,\ldots, s$-1 under the constrain that $\sum b^*_i = 1$. These are referred to as entry probabilities.
v_i	Probability that a fish captured at time i will be released, $i = 1,\ldots, s$-1.
N	Total number of fish that enter the system before the last sample time or the escapement. This is referred to as the super population.

Table C3. Derived parameters for the JS model under the salmon escapement super population model (Schwarz et al. 1993).

Parameter	Definition/Equation
λ_i	Probability that a fish is seen again after sample time i, i = 1,…, s. $\lambda_i = \varphi_i\, p_{i+1} + \varphi_i\,(1 - p_{i+1})\, \lambda_{i+1}$, i = 1,…, s-1; $\lambda_s = 0$.
τ_i	Conditional probability that a fish is seen at sample time i given that it was seen at or after sample time i, i = 1,…, s. $\tau_i = p_i/(p_i + (1-p_{i+1})\,\lambda_i)$.
ψ_i	Probability that a fish enters the population between sample time i-1 and i and survives to the next sampling occasion. $\psi_i = b^*_0$, $\psi_{i+1} = \psi_i\,(1 - p_i)\varphi_i + b^*_i(\varphi_i - 1)/\log(\varphi_i)$
B^*_i	Number of fish that enter between sampling occasion i-1 and i, i = 0,…, s-1. These are referred to as gross births. $B^*_i = N\,(b^*_i)$

Table C4. The likelihoods for the Schwarz et al. (1993) model.

Description	Likelihood
Pr(first capture part a)	$u. \sim$ Binomial($\sum\psi_i p_i, N$), i = 0,…, s-1. $u. = \sum u_i$
Pr(first capture part b)	$u_i \sim$ Multinomial ($\psi_i p_i/\sum\psi_i p_i$, $u.$)), i = 0,…, s-1.
Pr(release on capture)	$R_i \sim$ Binomial(v_i, n_i), i = 1,…, s-1.
Pr(recapture part a)	$m_i \sim$Binomial(τ_i, T_i), i = 2,…, s-1.
Pr(recapture part b)	$r_i \sim$ Binomial(λ_i, R_i), i = 1,…, s-1.

Appendix D – Hatchery Mass Mark Rates Used in Development of Hatchery-Origin and Natural-Origin Spawner Abundance Estimates

The tables in this appendix describe data used for our model inputs for each subpopulation to bias correct estimates of HOR and NOR spawners. There are two tables included: (1) hatchery release locations used by subpopulation and race for spawn years 2010-2017 and (2) the proportion of successfully mass marked fall Chinook salmon (either adipose, left ventral, or adipose + left ventral-clipped) by stock, age, rearing site, and release site for spawn years 2011-2017.

Table D1. Hatchery release locations used for unclipped hatchery-origin spawner corrections by subpopulation and stock for fall Chinook salmon in spawn years 2010-2017.

Subpopulation	Stock	2010	2011	2012	2013	2014	2015	2016	2017
Grays	Tule	NA	Big Creek	Deep R. NP	Deep R. NP	Big Creek	Deep R. NP	Deep R. NP	Deep R. NP
	SAB	NA	SF Klask.	SF Klask.	SF Klask.	SF Klask.	SF Klask.	SF Klask.	SF Klask.
Skamokawa	Tule	NA	Big Creek	Deep R.NP	Deep R. NP	Big Creek	Deep R. NP	Deep R. NP	Deep R. NP
	SAB	NA	SF Klask.	SF Klask.	SF Klask.	SF Klask.	SF Klask.	SF Klask.	SF Klask.
Elochoman	Tule	NA	Elochoman	Big Creek	Big Creek	Big Creek	Big Creek	Big Creek	Big Creek
	SAB	NA	SF Klask.	SF Klask.	SF Klask	SF Klask	SF Klask	SF Klask	SF Klask
Mill	Tule	NA	Elochoman	Big Creek	Deep R. NP	Big Creek	Deep R. NP	Deep R. NP	Deep R. NP
Abernathy	Tule	NA	Big Creek	Big Creek	Big Creek	Big Creek	Big Creek	Big Creek	Big Creek
Germany	Tule	NA	Big Creek	Big Creek	Big Creek	Big Creek	Big Creek	Big Creek	Big Creek
Coweeman	Tule	NA	K.Falls	K.Falls	K.Falls	K.Falls	K.Falls	K.Falls	K.Falls
SF Toutle	Tule	NA	N.Toutle	N.Toutle	N.Toutle	N.Toutle	N.Toutle	N.Toutle	N.Toutle
Green	Tule	NA	N.Toutle	N.Toutle	N.Toutle	N.Toutle	N.Toutle	N.Toutle	N.Toutle
Kalama	Tule	NA	K.Falls	K.Falls	K.Falls	K.Falls	K.Falls	K.Falls	K.Falls
EF Lewis	Tule	NA	K.Falls	K.Falls	K.Falls	K.Falls	K.Falls	K.Falls	K.Falls
Cedar	Tule	NA	K.Falls	K.Falls	K.Falls	K.Falls	K.Falls	K.Falls	K.Falls
Washougal	Tule	NA	Wash.	Wash.	Wash.	Wash.	Wash.	Wash.	Wash.
Hamilton	Tule	NA	Bonn/Wash	Bonn./Wash.	Bonn	Bonn	Bonn	Bonn	Bonn
	Bright	NA	L.W.S	L.W.S	L.W.S	L.W.S	L.W.S	L.W.S	L.W.S
Ives	Tule	NA	Bonn/Wash.	Bonn./Wash.	Bonn	Bonn	Bonn	Bonn	Bonn
	Bright	NA	LWS	LWS	LWS	LWS	LWS	LWS	LWS
Wind	Tule	NA	Spring Ck.	Spring Ck.	Spring Ck.	Spring Ck.	Spring Ck.	Spring Ck.	Spring Ck.
	Bright	NA	L.W.S	L.W.S	L.W.S	L.W.S	L.W.S	L.W.S	L.W.S
L. White Salmon	Tule	NA	Spring Ck.	Spring Ck.	Spring Ck.	Spring Ck.	Spring Ck.	Spring Ck.	Spring Ck.
	Bright	NA	L.W.S	L.W.S	L.W.S	L.W.S	L.W.S	L.W.S	L.W.S
White Salmon	Tule	NA	Spring Ck.	Spring Ck.	Spring Ck.	Spring Ck.	Spring Ck.	Spring Ck.	Spring Ck.
	Bright	NA	L.W.S	L.W.S	L.W.S	L.W.S	L.W.S	L.W.S	L.W.S

Table D2. Estimates of juvenile fall Chinook salmon successfully mass marked through the removal of the adipose fin or left ventral fin by stock, age, rearing site, and release site for spawn years 2011-2017.

Year	Rearing Site	Release Site	Stock	Age-3	Age-4	Age-5	Age-6
2011	Deep River NP	Deep River	Tule	99.5%	NA	NA	NA
2012	Deep River NP	Deep River	Tule	100.0%	99.5%	NA	NA
2013	Deep River NP	Deep River	Tule	99.8%	100.0%	99.5%	NA
2014	Deep River NP	Deep River	Tule	100.0%	99.8%	100.0%	99.5%
2015	Deep River NP	Deep River	Tule	99.7%	100.0%	99.8%	100.0%
2016	Deep River NP	Deep River	Tule	99.8%	99.7%	100.0%	99.8%
2017	Deep River NP	Deep River	Tule	99.6%	99.8%	99.7%	100.0%
2011	SF Klaskanine H.	SF Klaskanine River	SAB	97.6%	94.9%	98.2%	100.0%
2012	SF Klaskanine H.	SF Klaskanine River	SAB	98.0%	97.6%	94.9%	98.2%
2013	SF Klaskanine H.	SF Klaskanine River	SAB	98.5%	98.0%	97.6%	94.9%
2014	SF Klaskanine H.	SF Klaskanine River	SAB	98.3%	98.5%	98.0%	97.6%
2015	SF Klaskanine H.	SF Klaskanine River	SAB	96.4%	98.3%	98.5%	98.0%
2016	SF Klaskanine H.	SF Klaskanine River	SAB	98.9%	96.4%	98.3%	98.5%
2017	SF Klaskanine H.	SF Klaskanine River	SAB	98.3%	98.9%	96.4%	98.3%
2011	Big Creek H.	Big Creek	Tule	98.1%	99.0%	99.2%	4.1%
2012	Big Creek H.	Big Creek	Tule	98.8%	98.1%	99.0%	99.2%
2013	Big Creek H.	Big Creek	Tule	99.8%	98.8%	98.1%	99.0%
2014	Big Creek H.	Big Creek	Tule	96.1%	99.8%	98.8%	98.1%
2015	Big Creek H.	Big Creek	Tule	99.9%	96.1%	99.8%	98.8%
2016	Big Creek H.	Big Creek	Tule	99.5%	99.9%	96.1%	99.8%
2017	Big Creek H.	Big Creek	Tule	100.0%	99.5%	99.9%	96.1%
2011	Kalama Falls H.	Kalama River	Tule	99.4%	99.5%	99.5%	99.3%
2012	Kalama Falls H.	Kalama River	Tule	98.7%	99.4%	99.5%	99.5%
2013	Kalama Falls H.	Kalama River	Tule	99.4%	98.7%	99.4%	99.5%
2014	Kalama Falls H.	Kalama River	Tule	98.8%	99.4%	98.7%	99.4%
2015	Kalama Falls H.	Kalama River	Tule	99.3%	98.8%	99.4%	98.7%
2016	Kalama Falls H.	Kalama River	Tule	98.7%	99.3%	98.8%	99.4%
2017	Kalama Falls H.	Kalama River	Tule	98.8%	98.7%	99.3%	98.8%
2011	North Toutle H.	Green River	Tule	98.6%	98.9%	93.6%	5.3%
2012	North Toutle H.	Green River	Tule	98.3%	98.6%	98.9%	93.6%
2013	North Toutle H.	Green River	Tule	98.5%	98.3%	98.6%	98.9%
2014	North Toutle H.	Green River	Tule	99.2%	98.5%	98.3%	98.6%
2015	North Toutle H.	Green River	Tule	98.7%	99.2%	98.5%	98.3%
2016	North Toutle H.	Green River	Tule	99.1%	98.7%	99.2%	98.5%
2017	North Toutle H.	Green River	Tule	99.1%	99.1%	98.7%	99.2%
2011	Washougal Salmon H.	Washougal River	Tule	98.5%	97.2%	97.2%	2.2%
2012	Washougal Salmon H.	Washougal River	Tule	99.3%	98.5%	97.2%	97.2%
2013	Washougal Salmon H.	Washougal River	Tule	98.9%	99.3%	98.5%	97.2%
2014	Washougal Salmon H.	Washougal River	Tule	99.0%	98.9%	99.3%	98.5%
2015	Washougal Salmon H.	Washougal River	Tule	99.6%	99.0%	98.9%	99.3%
2016	Washougal Salmon H.	Washougal River	Tule	99.8%	99.6%	99.0%	98.9%
2017	Washougal Salmon H.	Washougal River	Tule	99.6%	99.8%	99.6%	99.0%

Table D3. Estimates of juvenile fall Chinook salmon successfully mass marked through the removal of the adipose fin or left ventral fin by stock, age, rearing site, and release site for spawn years 2011-2017, continued.

Year	Rearing Site	Release Site	Stock	Age-3	Age-4	Age-5	Age-6
2011	Bonneville H.	Tanner Creek	Tule	96.4%	NA	NA	NA
2012	Bonneville H.	Tanner Creek	Tule	98.0%	96.4%	NA	NA
2013	Bonneville H.	Tanner Creek	Tule	98.8%	98.0%	96.4%	
2014	Bonneville H.	Tanner Creek	Tule	99.5%	98.8%	98.0%	96.4%
2015	Bonneville H.	Tanner Creek	Tule	98.9%	99.5%	98.8%	98.0%
2016	Bonneville H.	Tanner Creek	Tule	99.0%	98.9%	99.5%	98.8%
2017	Bonneville H.	Tanner Creek	Tule	100.0%	99.0%	98.9%	99.5%
2011	Little White Salmon NFH	L.White Salmon River	Bright	100.0%	100.0%	99.9%	100.0%
2012	Little White Salmon NFH	L.White Salmon River	Bright	100.0%	100.0%	100.0%	99.9%
2013	Little White Salmon NFH	L.White Salmon River	Bright	99.9%	100.0%	100.0%	100.0%
2014	Little White Salmon NFH	L.White Salmon River	Bright	99.9%	99.9%	100.0%	100.0%
2015	Little White Salmon NFH	L.White Salmon River	Bright	100.0%	99.9%	99.9%	100.0%
2016	Little White Salmon NFH	L.White Salmon River	Bright	100.0%	100.0%	99.9%	99.9%
2017	Little White Salmon NFH	L.White Salmon River	Bright	99.6%	100.0%	100.0%	99.9%
2011	Spring Creek NFH	Columbia River	Tule	100.0%	100.0%	100.0%	100.0%
2012	Spring Creek NFH	Columbia River	Tule	100.0%	100.0%	100.0%	100.0%
2013	Spring Creek NFH	Columbia River	Tule	100.0%	100.0%	100.0%	100.0%
2014	Spring Creek NFH	Columbia River	Tule	100.0%	100.0%	100.0%	100.0%
2015	Spring Creek NFH	Columbia River	Tule	100.0%	100.0%	100.0%	100.0%
2016	Spring Creek NFH	Columbia River	Tule	100.0%	100.0%	100.0%	100.0%
2017	Spring Creek NFH	Columbia River	Tule	100.0%	100.0%	100.0%	100.0%

Appendix E – Population-Level Estimates of Abundance by Age and Origin.

The tables in this appendix provide population-level estimates of abundance by age and origin for spawn years 2010-2017. The spawn year 2013-2017 are being first reported in this report while the 2010-2012 estimates have been updated from those previous reported in Rawding et al. (2014), Rawding et al. (2019), and Buehrens et al. (2019) as our Chinook salmon models have been updated.

Table E1. Estimates of spawner abundance by total age and stock (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Grays/Chinook fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS SAB Age-3	Mean	54	210	59	880	268	216	124	70
	SD	28	46	30	218	95	67	44	48
	L 95% CI	18	143	24	512	126	103	54	15
	U 95% CI	123	323	137	1,361	497	371	224	195
HOS SAB Age-4	Mean	15	78	9	565	228	46	45	29
	SD	11	21	7	179	85	31	26	26
	L 95% CI	3	46	2	313	81	7	10	3
	U 95% CI	44	127	28	997	414	122	109	94
HOS SAB Age-5	Mean	1	3	1	5	5	3	2	2
	SD	2	3	2	17	16	8	6	5
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	5	12	5	53	47	24	19	14
HOS Tule Age-3	Mean	10	31	20	40	109	163	35	107
	SD	8	11	12	16	49	81	19	66
	L 95% CI	1	16	6	16	39	33	8	29
	U 95% CI	31	56	51	78	227	337	79	279
HOS Tule Age-4	Mean	6	28	32	57	155	96	54	54
	SD	6	10	17	24	57	37	24	39
	L 95% CI	1	13	12	17	67	39	18	9
	U 95% CI	22	50	78	110	293	182	112	159
HOS Tule Age-5	Mean	1	2	2	4	15	18	13	8
	SD	2	2	3	6	21	17	12	12
	L 95% CI	0	0	0	0	0	1	1	0
	U 95% CI	7	7	10	22	76	64	45	42
HOS Tule Age-6	Mean	0	0	1	1	3	2	2	2
	SD	1	1	1	3	9	4	5	6
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	3	3	4	8	26	13	15	16
NOS Age-3	Mean	52	27	11	25	24	134	16	170
	SD	28	11	8	18	19	78	12	94
	L 95% CI	17	10	2	1	1	40	1	51
	U 95% CI	124	54	33	68	73	320	47	410
NOS Age-4	Mean	27	35	20	63	150	75	51	108
	SD	17	13	12	26	56	34	21	71
	L 95% CI	7	15	6	23	64	27	19	24
	U 95% CI	73	65	52	123	280	159	101	285
NOS Age-5	Mean	3	2	3	6	9	9	7	14
	SD	5	2	4	6	12	11	7	21
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	16	7	13	21	41	39	27	74
NOS Age-6	Mean	1	0	1	1	2	2	7	3
	SD	2	1	2	2	5	5	8	11
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	5	3	5	7	15	15	29	31

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table E2. Estimates of spawner abundance by total age and stock (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Elochoman/Skamokawa fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS SAB Age-3	Mean	3	7	14	61	9	13	10	4
	SD	3	4	9	24	6	7	8	3
	L 95% CI	0	2	3	26	2	4	1	1
	U 95% CI	13	18	36	117	25	32	30	12
HOS SAB Age-4	Mean	1	3	4	15	5	8	3	1
	SD	2	2	4	10	4	5	4	2
	L 95% CI	0	0	0	3	1	2	0	0
	U 95% CI	6	9	15	40	15	21	14	5
HOS SAB Age-5	Mean	0	0	0	1	0	0	0	0
	SD	0	1	1	2	1	1	1	0
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	1	2	3	7	2	3	3	1
HOS Tule Age-3	Mean	874	476	44	144	447	512	87	15
	SD	95	75	13	43	100	131	33	9
	L 95% CI	709	360	23	78	300	327	38	5
	U 95% CI	1,091	650	74	244	692	826	162	36
HOS Tule Age-4	Mean	217	526	68	132	64	209	152	14
	SD	41	36	19	38	20	53	43	8
	L 95% CI	144	459	39	72	33	127	83	4
	U 95% CI	305	597	115	222	112	330	250	35
HOS Tule Age-5	Mean	26	7	13	8	8	17	23	3
	SD	14	5	8	8	6	10	16	3
	L 95% CI	7	1	3	0	1	4	3	0
	U 95% CI	59	20	33	30	22	42	64	12
HOS Tule Age-6	Mean	2	1	1	8	1	1	2	1
	SD	3	2	2	8	2	3	5	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	11	6	7	29	6	9	17	4
NOS Age-3	Mean	77	16	26	30	61	170	33	41
	SD	21	10	11	15	13	24	11	9
	L 95% CI	40	2	10	11	37	128	17	27
	U 95% CI	120	39	52	68	89	223	58	60
NOS Age-4	Mean	47	41	34	45	82	47	49	32
	SD	16	13	12	18	14	17	15	9
	L 95% CI	20	15	16	19	57	14	26	19
	U 95% CI	84	66	63	89	110	82	84	53
NOS Age-5	Mean	12	5	2	3	3	12	7	2
	SD	8	4	2	3	3	5	5	3
	L 95% CI	1	0	0	0	0	5	1	0
	U 95% CI	32	17	7	12	10	23	18	9
NOS Age-6	Mean	1	1	0	1	0	1	1	0
	SD	2	2	1	1	1	2	2	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	9	6	3	5	3	5	5	3

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table E3. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult MAG Tule fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	1,872	216	79	313	396	515	84	41
	SD	92	19	11	32	31	30	17	10
	L 95% CI	1,708	182	59	256	344	464	55	23
	U 95% CI	2,068	256	103	380	467	581	120	61
HOS Age-4	Mean	329	870	38	207	117	383	213	33
	SD	29	44	8	25	15	23	28	9
	L 95% CI	277	795	23	162	92	341	164	18
	U 95% CI	390	969	55	261	150	432	273	52
HOS Age-5	Mean	52	12	8	9	7	10	12	4
	SD	9	4	4	5	3	4	6	4
	L 95% CI	35	6	2	2	2	4	3	0
	U 95% CI	72	21	18	21	15	18	27	13
HOS Age-6	Mean	1	0	1	1	1	0	1	1
	SD	2	1	1	2	1	1	2	2
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	6	3	4	6	3	3	7	6
NOS Age-3	Mean	102	23	11	58	7	41	29	5
	SD	18	6	5	12	5	8	9	3
	L 95% CI	71	13	4	37	0	28	13	1
	U 95% CI	142	36	22	84	17	57	50	12
NOS Age-4	Mean	40	69	8	64	26	36	50	10
	SD	9	10	4	13	6	7	13	5
	L 95% CI	24	50	2	41	15	23	29	2
	U 95% CI	61	92	17	93	40	50	79	21
NOS Age-5	Mean	13	1	1	5	2	4	7	2
	SD	4	1	1	3	2	2	5	2
	L 95% CI	6	0	0	1	0	1	1	0
	U 95% CI	24	5	5	13	6	9	18	7
NOS Age-6	Mean	1	0	0	1	0	0	1	0
	SD	1	1	1	1	1	1	1	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	4	2	2	5	2	2	5	3

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table E4. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Lower Cowlitz Tule fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	180	451	184	198	178	673	106	372
	SD	---	---	---	---	---	---	---	---
	L 95% CI	---	---	---	---	---	---	---	---
	U 95% CI	---	---	---	---	---	---	---	---
HOS Age-4	Mean	1,004	419	988	463	1,144	738	733	188
	SD	---	---	---	---	---	---	---	---
	L 95% CI	---	---	---	---	---	---	---	---
	U 95% CI	---	---	---	---	---	---	---	---
HOS Age-5	Mean	0	70	0	182	102	384	165	142
	SD	---	---	---	---	---	---	---	---
	L 95% CI	---	---	---	---	---	---	---	---
	U 95% CI	---	---	---	---	---	---	---	---
HOS Age-6	Mean	0	0	0	0	0	0	3	4
	SD	---	---	---	---	---	---	---	---
	L 95% CI	---	---	---	---	---	---	---	---
	U 95% CI	---	---	---	---	---	---	---	---
NOS Age-3	Mean	756	226	565	739	203	1,570	304	1,540
	SD	---	---	---	---	---	---	---	---
	L 95% CI	---	---	---	---	---	---	---	---
	U 95% CI	---	---	---	---	---	---	---	---
NOS Age-4	Mean	1,161	2,385	494	2,521	2,364	1,721	2,093	779
	SD	---	---	---	---	---	---	---	---
	L 95% CI	---	---	---	---	---	---	---	---
	U 95% CI	---	---	---	---	---	---	---	---
NOS Age-5	Mean	633	134	494	203	356	895	473	588
	SD	---	---	---	---	---	---	---	---
	L 95% CI	---	---	---	---	---	---	---	---
	U 95% CI	---	---	---	---	---	---	---	---
NOS Age-6	Mean	0	0	0	14	0	0	8	17
	SD	---	---	---	---	---	---	---	---
	L 95% CI	---	---	---	---	---	---	---	---
	U 95% CI	---	---	---	---	---	---	---	---

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors. No estimate of precision is available.

Table E5. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Toutle Tule fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	994	236	285	273	43	43	77	136
	SD	111	36	28	48	22	18	26	44
	L 95% CI	766	169	230	189	12	15	33	69
	U 95% CI	1,182	313	343	378	97	83	134	236
HOS Age-4	Mean	507	959	262	520	284	101	274	113
	SD	60	74	38	85	80	36	81	39
	L 95% CI	390	823	196	381	164	49	140	51
	U 95% CI	625	1,112	349	720	462	191	453	206
HOS Age-5	Mean	188	104	123	45	51	80	80	27
	SD	29	25	19	13	29	40	29	15
	L 95% CI	133	59	88	24	13	26	34	7
	U 95% CI	243	159	164	76	122	177	146	59
HOS Age-6	Mean	1	1	1	1	3	1	5	6
	SD	2	2	2	3	6	3	6	6
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	6	8	6	9	19	11	20	20
NOS Age-3	Mean	95	20	52	215	55	149	80	108
	SD	20	11	14	39	18	18	18	30
	L 95% CI	62	4	28	147	26	117	50	63
	U 95% CI	137	46	81	302	98	188	121	180
NOS Age-4	Mean	96	169	122	682	280	179	242	130
	SD	19	32	22	115	71	29	49	38
	L 95% CI	62	113	85	501	171	136	163	72
	U 95% CI	138	239	168	947	436	249	346	214
NOS Age-5	Mean	36	8	60	16	66	44	44	73
	SD	12	8	14	8	22	9	15	27
	L 95% CI	17	0	37	4	29	30	21	33
	U 95% CI	63	28	89	37	118	64	79	139
NOS Age-6	Mean	1	1	1	1	1	1	1	1
	SD	1	2	1	3	2	2	2	2
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	5	5	5	9	7	7	7	7

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table E6. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Coweeman Tule fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	26	35	24	132	8	10	8	55
	SD	12	12	11	42	5	8	9	26
	L 95% CI	7	16	8	65	2	1	0	17
	U 95% CI	56	65	51	232	19	29	32	117
HOS Age-4	Mean	71	42	32	568	20	18	12	57
	SD	22	13	13	159	7	10	11	27
	L 95% CI	36	20	12	303	8	5	1	17
	U 95% CI	122	73	64	930	37	44	43	121
HOS Age-5	Mean	73	7	6	53	8	3	8	7
	SD	22	5	5	21	5	4	8	8
	L 95% CI	37	1	1	23	2	0	0	0
	U 95% CI	124	21	19	104	20	14	30	31
HOS Age-6	Mean	1	1	1	1	0	1	1	2
	SD	2	2	2	1	1	2	2	4
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	6	6	5	5	3	5	5	12
NOS Age-3	Mean	106	105	142	369	185	370	75	155
	SD	28	20	35	107	17	20	38	24
	L 95% CI	58	69	82	192	154	333	23	114
	U 95% CI	166	147	220	609	219	413	168	208
NOS Age-4	Mean	254	485	210	1,186	509	843	239	492
	SD	46	42	40	326	40	31	87	58
	L 95% CI	173	410	140	635	440	788	107	393
	U 95% CI	353	574	296	1,915	599	911	438	617
NOS Age-5	Mean	53	28	110	12	100	145	96	73
	SD	20	11	29	8	13	17	45	16
	L 95% CI	22	12	60	2	76	117	33	49
	U 95% CI	99	52	177	32	127	182	204	110
NOS Age-6	Mean	1	5	1	1	0	2	1	1
	SD	2	4	3	1	1	2	4	3
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	7	17	10	5	2	8	12	9

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table E7. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Kalama Tule fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	1,409	2,789	1,697	1,759	1,172	954	295	756
	SD	283	485	346	406	316	145	62	93
	L 95% CI	963	1,938	1,099	1,124	660	697	188	592
	U 95% CI	2,062	3,835	2,449	2,696	1,885	1,265	431	953
HOS Age-4	Mean	2,522	4,090	4,884	5,095	5,802	1,890	1,280	402
	SD	470	686	832	1,033	993	236	148	64
	L 95% CI	1,799	2,892	3,409	3,498	4,133	1,467	1,015	292
	U 95% CI	3,608	5,584	6,713	7,509	8,063	2,390	1,590	541
HOS Age-5	Mean	788	281	604	815	1,696	684	110	150
	SD	178	85	166	221	403	115	35	31
	L 95% CI	507	146	330	465	1,029	482	56	98
	U 95% CI	1,194	475	973	1,326	2,602	936	191	219
HOS Age-6	Mean	2	3	5	5	18	6	2	1
	SD	6	7	12	13	42	7	4	2
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	18	21	37	41	141	24	13	7
NOS Age-3	Mean	255	121	91	95	45	1,163	358	943
	SD	63	45	48	53	28	124	54	80
	L 95% CI	153	47	22	20	4	930	257	778
	U 95% CI	401	222	205	224	116	1,414	468	1,093
NOS Age-4	Mean	234	282	172	675	524	1,117	1,934	556
	SD	61	67	63	160	122	142	107	55
	L 95% CI	136	167	60	422	318	841	1,717	451
	U 95% CI	376	427	305	1,039	797	1,398	2,139	665
NOS Age-5	Mean	104	24	20	37	174	607	239	232
	SD	36	19	25	30	52	96	42	35
	L 95% CI	47	1	0	3	90	429	163	168
	U 95% CI	187	74	88	114	295	805	328	305
NOS Age-6	Mean	1	2	5	5	22	2	8	1
	SD	3	5	11	11	23	5	8	2
	L 95% CI	0	0	0	0	1	0	0	0
	U 95% CI	11	16	38	38	81	16	29	6

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table E8. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Washougal fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	4,316	1,115	219	1,341	158	447	250	73
	SD	343	109	37	130	29	55	68	37
	L 95% CI	3,725	923	158	1,127	108	355	148	23
	U 95% CI	5,079	1,354	305	1,628	220	570	414	162
HOS Age-4	Mean	597	1,561	399	1,011	357	953	829	246
	SD	164	141	55	102	54	105	194	74
	L 95% CI	313	1,315	307	838	266	781	541	133
	U 95% CI	953	1,861	521	1,237	476	1,193	1,287	418
HOS Age-5	Mean	23	73	91	51	15	191	235	135
	SD	34	24	20	13	7	31	64	48
	L 95% CI	0	34	57	29	5	139	139	63
	U 95% CI	118	127	134	82	33	260	387	251
HOS Age-6	Mean	5	2	1	12	1	1	1	2
	SD	15	3	1	7	1	1	3	6
	L 95% CI	0	0	0	3	0	0	0	0
	U 95% CI	48	11	4	29	4	4	9	18
NOS Age-3	Mean	215	40	169	339	134	653	116	181
	SD	84	26	44	56	28	55	39	51
	L 95% CI	63	5	102	232	80	553	58	100
	U 95% CI	390	102	273	454	192	769	208	298
NOS Age-4	Mean	309	395	52	829	786	516	647	345
	SD	85	75	30	91	84	68	169	66
	L 95% CI	153	248	16	675	643	384	401	236
	U 95% CI	481	547	129	1027	975	657	1047	489
NOS Age-5	Mean	61	37	34	29	76	160	118	127
	SD	47	19	17	10	18	25	41	42
	L 95% CI	4	8	6	13	46	115	58	62
	U 95% CI	178	80	76	51	117	213	218	229
NOS Age-6	Mean	4	1	1	0	1	3	1	2
	SD	13	3	1	1	1	2	2	4
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	39	8	5	3	5	9	8	14

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table E9. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Lower Gorge Tule fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	41	4	5	28	11	11	22	6
	SD	15	1	3	11	6	4	11	3
	L 95% CI	14	2	1	10	2	4	5	1
	U 95% CI	72	7	10	50	23	19	44	13
HOS Age-4	Mean	9	1	2	12	4	2	15	2
	SD	8	1	2	7	4	2	9	2
	L 95% CI	0	0	0	2	0	0	2	0
	U 95% CI	30	3	6	30	14	8	37	8
HOS Age-5	Mean	9	0	0	1	0	0	1	0
	SD	8	0	1	2	1	1	2	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	30	1	2	6	4	2	7	2
NOS Age-3	Mean	8	2	2	9	4	2	6	2
	SD	8	1	2	7	4	2	7	2
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	29	4	6	27	14	9	24	8
NOS Age-4	Mean	7	1	2	6	4	2	5	2
	SD	7	1	2	5	3	2	6	2
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	26	2	6	19	13	8	21	7
NOS Age-5	Mean	1	0	0	0	0	0	0	0
	SD	2	0	0	1	1	1	1	0
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	5	0	1	4	3	2	4	1

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table E10. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Lower Gorge Bright fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	15	12	11	168	53	41	34	7
	SD	8	11	6	27	20	16	17	8
	L 95% CI	6	1	4	121	23	18	12	1
	U 95% CI	33	40	25	230	99	78	76	30
HOS Age-4	Mean	12	42	25	164	194	57	195	31
	SD	6	19	9	27	41	19	51	22
	L 95% CI	4	16	11	118	126	28	111	7
	U 95% CI	28	91	46	222	288	101	312	91
HOS Age-5	Mean	4	9	3	6	13	25	44	25
	SD	3	8	3	4	9	13	21	17
	L 95% CI	1	1	0	1	2	8	15	6
	U 95% CI	12	30	10	16	37	57	95	71
HOS Age-6	Mean	0	1	0	0	1	1	1	1
	SD	1	3	1	1	2	2	4	3
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	2	7	3	4	7	6	11	8
NOS Age-3	Mean	145	161	160	549	228	362	1,483	126
	SD	31	38	31	78	45	62	240	58
	L 95% CI	92	102	107	410	153	259	1,037	43
	U 95% CI	214	250	228	713	325	503	1,989	267
NOS Age-4	Mean	316	963	368	622	832	781	5,497	1146
	SD	56	147	57	86	118	117	766	211
	L 95% CI	225	737	272	468	625	594	3,994	809
	U 95% CI	440	1,325	497	805	1,093	1,049	7,058	1,626
NOS Age-5	Mean	177	56	102	44	123	301	1,209	929
	SD	36	20	26	12	30	62	202	177
	L 95% CI	117	27	62	24	73	201	836	638
	U 95% CI	258	103	162	71	190	443	1,630	1,321
NOS Age-6	Mean	1	2	1	0	7	1	50	3
	SD	2	4	2	1	7	3	26	9
	L 95% CI	0	0	0	0	0	0	14	0
	U 95% CI	6	13	6	4	27	9	112	27

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table E11. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Upper Gorge Tule fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	93	1,845	611	1,032	1,187	2,322	68	102
	SD	34	731	200	172	190	428	21	21
	L 95% CI	51	1,107	398	792	924	1,754	38	68
	U 95% CI	175	3,667	1,100	1,454	1,655	3,415	115	148
HOS Age-4	Mean	28	51	141	586	449	262	616	18
	SD	16	33	52	103	82	60	122	7
	L 95% CI	8	14	82	437	327	173	447	7
	U 95% CI	65	133	263	830	642	406	919	34
HOS Age-5	Mean	3	2	1	12	15	18	3	0
	SD	4	5	2	9	9	11	3	1
	L 95% CI	0	0	0	2	3	5	0	0
	U 95% CI	13	15	6	35	37	42	10	3
NOS Age-3	Mean	326	417	135	345	219	772	338	529
	SD	148	254	50	67	47	158	72	101
	L 95% CI	149	160	76	245	149	549	235	383
	U 95% CI	664	1,041	255	504	330	1,161	512	772
NOS Age-4	Mean	35	766	198	239	300	366	193	40
	SD	18	508	84	51	85	83	46	14
	L 95% CI	14	268	98	161	189	244	125	19
	U 95% CI	77	2,038	391	357	481	571	301	73
NOS Age-5	Mean	10	3	5	17	21	86	8	8
	SD	7	6	5	10	10	30	6	6
	L 95% CI	2	0	0	4	7	41	1	1
	U 95% CI	26	18	18	41	44	156	23	23

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table E12. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Upper Gorge Bright fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	173	199	156	1,250	100	512	88	21
	SD	48	62	39	201	37	84	22	13
	L 95% CI	111	119	92	913	44	368	52	6
	U 95% CI	275	336	245	1,692	189	698	136	54
HOS Age-4	Mean	95	587	201	6,257	1,571	1,199	1,207	476
	SD	22	145	46	815	224	171	167	90
	L 95% CI	59	406	124	4,873	1,198	908	918	332
	U 95% CI	145	918	304	8,096	2,070	1,577	1,571	678
HOS Age-5	Mean	40	95	20	717	306	608	270	558
	SD	12	31	13	129	75	100	48	109
	L 95% CI	21	54	5	500	183	440	188	388
	U 95% CI	69	162	52	1,007	477	835	372	817
HOS Age-6	Mean	1	10	1	2	3	1	19	4
	SD	2	10	3	6	9	3	9	6
	L 95% CI	0	0	0	0	0	0	6	0
	U 95% CI	5	35	9	20	27	10	42	18
NOS Age-3	Mean	100	73	65	153	29	284	109	64
	SD	29	29	24	41	19	51	29	24
	L 95% CI	59	34	27	86	3	200	63	31
	U 95% CI	162	139	119	245	75	395	174	121
NOS Age-4	Mean	184	422	80	926	261	466	557	341
	SD	54	115	26	180	72	76	98	80
	L 95% CI	113	276	39	626	141	334	393	220
	U 95% CI	300	678	138	1,327	421	634	771	530
NOS Age-5	Mean	134	31	54	507	98	255	94	323
	SD	49	12	21	90	41	47	28	77
	L 95% CI	75	12	22	356	35	175	49	207
	U 95% CI	239	61	102	706	194	359	159	502
NOS Age-6	Mean	1	1	1	15	2	1	1	1
	SD	2	3	3	10	5	2	2	4
	L 95% CI	0	0	0	2	0	0	0	0
	U 95% CI	5	9	8	41	17	6	7	12

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table E13. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult White Salmon Tule fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	475	50	31	204	146	356	73	296
	SD	272	32	22	53	44	84	31	74
	L 95% CI	156	13	7	119	84	232	27	173
	U 95% CI	1,140	132	87	325	252	560	147	459
HOS Age-4	Mean	42	32	7	123	83	40	107	43
	SD	34	23	7	35	28	13	39	18
	L 95% CI	6	7	1	68	43	21	48	16
	U 95% CI	127	89	25	208	148	71	198	85
HOS Age-5	Mean	1	1	0	9	4	2	1	6
	SD	6	3	1	6	4	2	3	6
	L 95% CI	0	0	0	1	0	0	0	0
	U 95% CI	13	6	3	24	16	9	10	21
NOS Age-3	Mean	1,284	187	144	302	192	193	70	365
	SD	663	88	76	75	56	48	28	87
	L 95% CI	478	74	52	182	115	123	28	218
	U 95% CI	2,867	398	327	475	329	306	137	555
NOS Age-4	Mean	82	451	396	317	584	165	287	31
	SD	56	199	204	76	157	41	75	15
	L 95% CI	19	192	150	191	374	104	163	10
	U 95% CI	223	933	882	490	974	267	456	65
NOS Age-5	Mean	2	1	15	28	25	18	28	6
	SD	6	3	12	12	12	8	17	6
	L 95% CI	0	0	2	10	9	7	5	0
	U 95% CI	17	10	45	58	54	36	69	22

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table E14. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult White Salmon Bright fall Chinook population for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	394	NA	62	270	229	1,207	82	35
	SD	258	NA	49	80	92	334	30	30
	L 95% CI	143	NA	16	152	96	709	38	3
	U 95% CI	1011	NA	180	460	450	2,013	154	115
HOS Age-4	Mean	501	NA	227	1,632	2,250	3,271	1,148	448
	SD	318	NA	164	423	582	830	293	150
	L 95% CI	187	NA	71	1,007	1,396	2,020	711	231
	U 95% CI	1278	NA	631	2,630	3,597	5,254	1,838	805
HOS Age-5	Mean	197	NA	71	226	727	2,423	265	268
	SD	129	NA	55	69	217	626	76	103
	L 95% CI	67	NA	18	125	405	1,469	149	120
	U 95% CI	526	NA	207	393	1,244	3,901	445	521
HOS Age-6	Mean	1	NA	1	7	2	43	13	2
	SD	4	NA	3	8	7	32	9	7
	L 95% CI	0	NA	0	0	0	5	2	0
	U 95% CI	9	NA	7	27	21	125	37	22
NOS Age-3	Mean	209	NA	69	173	68	298	43	43
	SD	150	NA	52	54	47	89	19	30
	L 95% CI	72	NA	18	92	11	166	15	7
	U 95% CI	561	NA	197	305	186	503	90	124
NOS Age-4	Mean	385	NA	501	897	961	739	461	210
	SD	256	NA	338	236	273	196	124	83
	L 95% CI	138	NA	178	548	563	442	278	91
	U 95% CI	1,011	NA	1,300	1,449	1,604	1,190	755	413
NOS Age-5	Mean	246	NA	172	139	604	704	111	233
	SD	171	NA	120	45	188	190	37	89
	L 95% CI	85	NA	56	71	323	420	56	105
	U 95% CI	667	NA	468	246	1,049	1,162	202	445
NOS Age-6	Mean	1	NA	1	12	3	1	6	2
	SD	3	NA	3	9	8	3	6	5
	L 95% CI	0	NA	0	1	0	0	0	0
	U 95% CI	8	NA	7	35	26	8	23	17

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Appendix F – Subpopulation-Level Estimates of Abundance, Abundance by Age, and Proportions by Origin, Sex, and Age.

The tables in this appendix provide estimates of abundance by origin, sex, and age and proportions by sex and origin at the subpopulation-level for spawn years 2010-2017. Like the population-level estimates in the main body of the report, the 2013-2017 are first being reported in this report while the 2010-2012 estimates have been updated from those previous reported in Rawding et al. (2014), Rawding et al. (2019), and Buehrens et al. (2019) as our Chinook salmon models have been updated.

Below are subpopulation-level estimates for the following populations: Elochoman/Skamokawa (Elochoman and Skamokawa), MAG (Mill, Abernathy, and Germany), Toutle (Green and South Fork Toutle), Upper Cowlitz (Upper Cowlitz and Tilton), Lewis (East Fork Lewis and Cedar), Lower Gorge (Ives Island and Hamilton), and Upper Gorge (Wind and Little White Salmon). There are two tables for each subpopulation with one table providing estimates of abundance, including abundance by origin and sex, and one table providing estimates of abundance by age and origin.

Table F1. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Elochoman fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	863	674	128	206	159	229	128	88
	SD	62	28	33	80	21	24	40	21
	L 95% CI	736	617	80	100	124	186	77	59
	U 95% CI	972	728	204	402	202	279	227	136
Males	Mean	479	259	64	131	76	119	82	48
	SD	37	28	24	56	22	25	33	21
	L 95% CI	404	206	26	58	38	73	37	15
	U 95% CI	547	316	119	270	122	172	162	92
Females	Mean	384	415	64	74	83	110	46	40
	SD	31	31	25	36	22	24	24	18
	L 95% CI	324	353	27	27	43	65	14	11
	U 95% CI	442	477	119	162	129	160	104	79
HOS Select Area Bright	Mean	1	5	16	26	7	7	5	2
	SD	1	4	11	17	6	6	5	1
	L 95% CI	0	1	3	6	1	1	0	0
	U 95% CI	3	16	43	69	25	23	20	6
HOS Tule	Mean	752	627	59	123	30	61	58	18
	SD	58	28	23	53	13	19	33	11
	L 95% CI	631	572	27	53	12	29	20	6
	U 95% CI	851	680	114	251	60	105	141	45
NOS	Mean	110	42	53	57	122	162	64	68
	SD	22	11	20	28	19	21	16	13
	L 95% CI	72	16	24	22	84	120	38	47
	U 95% CI	150	60	101	129	158	203	100	95
pF	Mean	44.5%	61.6%	50.3%	36.1%	52.3%	48.1%	36.0%	46.1%
	SD	1.6%	3.9%	13.8%	9.8%	11.9%	9.4%	14.1%	18.4%
	L 95% CI	41.5%	53.7%	24.0%	18.3%	28.6%	29.5%	11.7%	13.0%
	U 95% CI	47.6%	69.1%	76.8%	56.4%	74.6%	66.5%	65.5%	80.8%
pHOS	Mean	87.2%	93.8%	58.2%	72.3%	23.3%	29.3%	47.8%	22.2%
	SD	2.4%	1.7%	11.8%	8.1%	8.2%	7.6%	11.8%	7.6%
	L 95% CI	82.5%	91.1%	33.7%	54.8%	10.5%	15.6%	25.3%	9.9%
	U 95% CI	91.5%	97.5%	79.0%	86.1%	41.6%	45.1%	69.8%	39.5%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

Table F2. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Elochoman fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Select Area Bright Age-3	Mean	1	4	12	17	5	5	4	1
	SD	1	3	9	12	5	5	4	1
	L 95% CI	0	1	2	4	1	1	0	0
	U 95% CI	2	11	34	48	19	18	15	4
HOS Select Area Bright Age-4	Mean	0	2	3	9	2	2	1	0
	SD	0	2	4	8	3	2	2	1
	L 95% CI	0	0	0	1	0	0	0	0
	U 95% CI	1	6	14	29	9	8	7	2
HOS Select Area Bright Age-5	Mean	0	0	0	0	0	0	0	0
	SD	0	0	1	1	1	1	1	0
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	0	1	3	4	2	1	1	0
HOS Tule Age-3	Mean	580	157	14	68	15	12	19	6
	SD	57	24	9	32	9	8	17	5
	L 95% CI	468	112	3	25	2	2	2	1
	U 95% CI	686	208	37	150	38	32	62	19
HOS Tule Age-4	Mean	157	467	35	43	9	44	32	10
	SD	35	31	16	23	6	18	22	7
	L 95% CI	95	408	13	14	2	14	7	2
	U 95% CI	233	527	75	99	24	84	85	28
HOS Tule Age-5	Mean	14	2	9	5	6	4	7	2
	SD	11	3	7	6	5	4	9	3
	L 95% CI	1	0	1	0	1	0	0	0
	U 95% CI	41	11	28	21	18	16	30	10
HOS Tule Age-6	Mean	1	0	1	7	0	1	1	0
	SD	3	1	2	7	1	2	4	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	9	4	7	27	3	6	11	4
NOS Age-3	Mean	65	5	23	24	51	120	25	40
	SD	19	7	10	14	12	15	8	8
	L 95% CI	31	0	8	8	29	92	13	26
	U 95% CI	104	22	48	61	74	148	43	57
NOS Age-4	Mean	35	35	28	30	69	31	34	27
	SD	14	12	11	15	11	15	10	7
	L 95% CI	12	11	12	10	47	2	18	16
	U 95% CI	68	56	57	68	91	59	56	42
NOS Age-5	Mean	10	2	1	2	2	10	5	1
	SD	8	3	2	2	2	3	3	2
	L 95% CI	1	0	0	0	0	4	0	0
	U 95% CI	29	12	6	7	7	18	12	6
NOS Age-6	Mean	1	1	0	0	0	0	0	0
	SD	2	2	1	1	0	0	1	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	7	5	3	3	1	1	2	2

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table F3. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Skamokawa fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	397	409	78	242	521	760	240	26
	SD	99	89	18	61	118	192	56	16
	L 95% CI	257	278	52	156	351	493	158	12
	U 95% CI	641	619	121	391	811	1,226	375	63
Males	Mean	211	220	44	111	304	404	133	16
	SD	56	51	12	35	73	105	39	11
	L 95% CI	130	143	25	59	199	255	74	4
	U 95% CI	351	341	72	195	484	655	223	42
Females	Mean	186	189	35	131	216	356	107	10
	SD	51	45	10	39	54	96	34	9
	L 95% CI	113	122	19	74	136	223	54	1
	U 95% CI	311	295	60	226	348	588	185	31
HOS Select Area Bright	Mean	4	5	2	50	7	14	8	3
	SD	4	4	2	22	5	9	9	4
	L 95% CI	0	1	0	18	1	3	0	0
	U 95% CI	16	15	9	104	20	36	31	13
HOS Tule	Mean	367	383	67	169	490	678	205	14
	SD	92	84	16	47	112	173	50	10
	L 95% CI	237	259	43	99	327	437	130	3
	U 95% CI	592	579	105	282	765	1,099	326	39
NOS	Mean	26	21	9	23	25	68	26	9
	SD	13	10	5	14	12	24	17	7
	L 95% CI	8	6	2	5	8	33	4	1
	U 95% CI	58	45	22	57	53	125	67	27
pF	Mean	46.8%	46.2%	44.4%	54.1%	41.6%	46.9%	44.5%	39.9%
	SD	5.1%	4.3%	8.4%	8.3%	4.3%	3.7%	9.4%	20.2%
	L 95% CI	37.0%	37.8%	28.3%	37.4%	33.1%	39.6%	26.7%	6.6%
	U 95% CI	57.2%	54.6%	60.9%	70.1%	50.1%	54.1%	63.1%	81.1%
pHOS	Mean	93.5%	94.9%	88.4%	90.2%	95.3%	91.1%	89.1%	66.9%
	SD	2.8%	2.2%	5.9%	5.1%	1.9%	2.2%	6.3%	18.3%
	L 95% CI	86.9%	90.0%	74.6%	78.3%	90.7%	86.3%	74.0%	27.6%
	U 95% CI	97.8%	98.4%	97.1%	97.6%	98.3%	94.9%	98.0%	95.4%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

Table F4. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Skamokawa fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Select Area Bright Age-3	Mean	3	3	2	44	4	8	6	2
	SD	3	3	2	20	3	6	7	3
	L 95% CI	0	0	0	15	0	1	0	0
	U 95% CI	12	11	6	93	13	23	24	10
HOS Select Area Bright Age-4	Mean	1	1	1	6	3	6	2	1
	SD	2	2	1	6	3	5	3	2
	L 95% CI	0	0	0	0	0	1	0	0
	U 95% CI	5	6	3	22	10	18	11	5
HOS Select Area Bright Age-5	Mean	0	0	0	1	0	0	0	0
	SD	0	0	0	2	0	1	1	0
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	1	1	1	5	1	2	2	1
HOS Tule Age-3	Mean	295	319	29	76	432	500	68	9
	SD	76	71	9	28	99	130	28	7
	L 95% CI	185	214	15	34	286	315	26	2
	U 95% CI	485	488	52	142	677	814	133	25
HOS Tule Age-4	Mean	60	59	34	89	55	165	120	4
	SD	22	18	10	31	19	49	37	4
	L 95% CI	28	31	18	43	27	94	62	0
	U 95% CI	114	99	58	161	102	283	208	14
HOS Tule Age-5	Mean	12	5	3	3	2	13	16	1
	SD	9	4	3	5	3	9	13	2
	L 95% CI	2	0	0	0	0	2	1	0
	U 95% CI	34	15	11	18	10	35	50	5
HOS Tule Age-6	Mean	1	0	0	1	0	1	1	0
	SD	2	1	1	2	1	2	3	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	5	3	2	7	4	5	10	2
NOS Age-3	Mean	12	11	3	6	10	50	8	2
	SD	8	7	2	6	7	19	8	3
	L 95% CI	2	0	0	0	2	21	0	0
	U 95% CI	32	28	9	20	26	94	28	8
NOS Age-4	Mean	11	7	5	16	13	15	16	6
	SD	8	5	4	10	7	9	12	5
	L 95% CI	2	0	1	3	3	3	2	0
	U 95% CI	32	19	15	41	31	38	46	19
NOS Age-5	Mean	2	3	1	2	1	2	2	1
	SD	3	3	1	3	2	3	3	2
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	11	11	4	9	7	11	12	6
NOS Age-6	Mean	0	0	0	0	0	0	0	0
	SD	1	1	0	1	1	1	2	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	4	2	1	3	3	4	4	2

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table F5. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Mill fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	941	779	79	118	388	519	191	25
	SD	55	45	13	19	34	25	30	2
	L 95% CI	843	710	59	86	338	475	142	22
	U 95% CI	1,053	882	108	161	467	574	260	29
Males	Mean	568	278	41	64	222	227	65	12
	SD	36	21	9	16	22	16	16	4
	L 95% CI	503	243	26	37	187	197	40	4
	U 95% CI	643	322	60	99	272	262	100	21
Females	Mean	372	501	39	54	165	292	126	12
	SD	30	31	8	15	18	19	23	4
	L 95% CI	319	450	25	29	135	258	88	4
	U 95% CI	434	572	58	87	207	331	178	21
HOS	Mean	896	738	67	88	366	483	155	21
	SD	53	43	12	18	32	24	27	3
	L 95% CI	799	670	48	56	316	440	111	13
	U 95% CI	1,006	836	94	127	443	536	216	27
NOS	Mean	45	41	12	30	22	36	36	3
	SD	9	8	5	12	7	7	12	3
	L 95% CI	30	27	4	11	11	24	17	0
	U 95% CI	63	59	23	57	36	52	64	11
pF	Mean	39.6%	64.3%	48.8%	45.9%	42.6%	56.2%	66.0%	50.2%
	SD	1.9%	1.6%	7.3%	9.9%	2.9%	2.4%	6.0%	16.6%
	L 95% CI	35.9%	61.1%	34.5%	26.9%	36.8%	51.5%	53.5%	18.5%
	U 95% CI	43.3%	67.5%	63.1%	65.0%	48.3%	60.9%	77.0%	81.7%
pHOS	Mean	95.2%	94.7%	84.8%	74.4%	94.5%	93.0%	81.2%	86.5%
	SD	0.9%	1.0%	5.8%	9.1%	1.6%	1.3%	5.5%	12.2%
	L 95% CI	93.4%	92.6%	71.9%	54.6%	91.0%	90.2%	69.4%	55.5%
	U 95% CI	96.8%	96.5%	94.3%	89.8%	97.2%	95.4%	90.5%	99.9%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

Table F6. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Mill fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	783	77	41	37	267	199	31	8
	SD	49	10	9	12	26	16	11	4
	L 95% CI	695	60	26	17	226	169	14	2
	U 95% CI	885	98	61	64	327	232	56	16
HOS Age-4	Mean	78	651	20	49	94	275	115	12
	SD	11	39	6	14	13	18	22	4
	L 95% CI	57	588	10	25	72	241	78	5
	U 95% CI	102	738	34	80	122	314	166	20
HOS Age-5	Mean	35	10	6	2	5	8	8	1
	SD	8	3	3	3	3	3	5	2
	L 95% CI	22	5	1	0	1	3	1	0
	U 95% CI	50	17	15	10	11	16	21	5
HOS Age-6	Mean	0	0	0	0	0	0	0	0
	SD	1	0	1	1	0	0	1	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	2	1	2	4	1	1	3	2
NOS Age-3	Mean	21	8	8	12	5	14	9	1
	SD	6	3	4	7	4	4	5	1
	L 95% CI	12	3	2	2	0	7	1	0
	U 95% CI	34	15	18	28	14	24	22	3
NOS Age-4	Mean	14	33	3	17	16	20	23	2
	SD	4	7	2	8	5	5	9	2
	L 95% CI	7	20	0	5	9	12	9	0
	U 95% CI	24	48	9	36	26	31	44	8
NOS Age-5	Mean	9	0	1	1	0	2	5	0
	SD	3	1	1	2	1	1	4	1
	L 95% CI	4	0	0	0	0	0	0	0
	U 95% CI	17	2	3	8	3	5	14	3
NOS Age-6	Mean	0	0	0	0	0	0	0	0
	SD	0	0	0	1	0	0	1	0
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	2	1	1	3	1	1	3	1

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table F7. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Abernathy fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	336	122	43	160	81	356	162	49
	SD	54	22	5	23	10	32	17	8
	L 95% CI	246	92	35	127	67	313	140	36
	U 95% CI	456	175	56	213	105	434	203	67
Males	Mean	203	48	25	81	44	187	78	11
	SD	33	11	5	16	8	20	14	7
	L 95% CI	148	31	16	55	31	156	54	1
	U 95% CI	275	73	37	116	62	232	108	27
Females	Mean	133	74	17	79	37	169	84	38
	SD	22	15	5	15	7	19	14	9
	L 95% CI	96	52	9	53	26	140	60	21
	U 95% CI	183	110	28	113	52	213	115	57
HOS	Mean	314	105	38	126	75	326	127	44
	SD	51	20	6	20	10	30	17	9
	L 95% CI	229	76	28	94	59	285	100	29
	U 95% CI	426	152	51	172	98	398	165	63
NOS	Mean	22	18	5	34	6	30	35	5
	SD	7	6	3	10	3	7	10	5
	L 95% CI	11	9	1	18	2	18	17	0
	U 95% CI	38	31	13	58	14	45	58	17
pF	Mean	39.5%	60.8%	40.9%	49.2%	45.5%	47.5%	51.9%	77.8%
	SD	1.8%	5.4%	10.2%	6.4%	6.3%	3.0%	6.8%	13.2%
	L 95% CI	36.0%	50.0%	22.1%	36.6%	33.2%	41.7%	38.7%	46.9%
	U 95% CI	43.2%	71.2%	61.1%	61.8%	58.0%	53.5%	65.4%	97.0%
pHOS	Mean	93.5%	85.5%	88.5%	78.6%	92.4%	91.7%	78.6%	90.5%
	SD	1.7%	4.1%	7.2%	5.6%	3.9%	1.8%	6.0%	9.2%
	L 95% CI	89.8%	76.7%	71.1%	66.4%	83.6%	87.9%	65.8%	66.6%
	U 95% CI	96.4%	92.4%	98.5%	88.1%	98.0%	94.9%	89.0%	99.9%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

Table F8. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Abernathy fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	208	42	25	73	65	246	45	28
	SD	35	10	5	15	9	24	12	8
	L 95% CI	149	26	16	48	50	209	25	13
	U 95% CI	287	66	36	106	87	303	70	46
HOS Age-4	Mean	96	62	12	48	9	80	80	14
	SD	19	13	4	12	3	12	15	7
	L 95% CI	64	42	5	28	4	59	55	3
	U 95% CI	138	93	21	75	16	107	113	30
HOS Age-5	Mean	10	1	1	4	1	1	2	2
	SD	4	1	1	3	1	1	2	3
	L 95% CI	4	0	0	0	0	0	0	0
	U 95% CI	21	4	4	13	3	3	9	10
HOS Age-6	Mean	0	0	0	0	0	0	0	0
	SD	0	0	1	1	0	0	1	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	2	2	2	3	1	1	4	4
NOS Age-3	Mean	13	5	2	15	1	19	18	1
	SD	5	3	2	6	2	5	7	2
	L 95% CI	6	1	0	6	0	10	7	0
	U 95% CI	25	12	7	30	6	31	35	5
NOS Age-4	Mean	8	12	2	18	4	10	15	3
	SD	4	4	2	7	2	4	7	3
	L 95% CI	2	5	0	7	1	3	5	0
	U 95% CI	17	23	7	35	10	19	31	12
NOS Age-5	Mean	1	1	0	1	0	1	1	1
	SD	1	1	1	2	1	1	2	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	3	3	2	5	2	3	6	4
NOS Age-6	Mean	0	0	0	0	0	0	0	0
	SD	0	0	0	1	0	0	1	0
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	1	1	1	2	1	1	2	1

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table F9. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Germany fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	1,133	291	25	379	85	114	43	21
	SD	79	25	1	39	18	10	4	2
	L 95% CI	1,005	252	23	313	68	101	38	19
	U 95% CI	1,317	348	29	465	133	139	54	26
Males	Mean	505	141	18	206	43	60	17	9
	SD	44	15	4	25	12	8	7	4
	L 95% CI	426	116	9	163	25	46	6	1
	U 95% CI	600	175	25	259	70	80	31	18
Females	Mean	628	150	7	173	43	53	26	13
	SD	56	16	4	22	12	8	7	4
	L 95% CI	534	123	1	135	25	39	13	4
	U 95% CI	754	185	16	222	72	70	39	21
HOS	Mean	1,044	256	21	316	79	99	27	13
	SD	75	23	4	34	17	10	7	5
	L 95% CI	922	219	12	258	59	84	13	4
	U 95% CI	1,219	309	27	392	124	122	41	21
NOS	Mean	89	35	4	63	7	14	16	9
	SD	19	8	4	12	5	5	7	4
	L 95% CI	57	22	0	42	1	7	5	1
	U 95% CI	130	51	14	89	18	26	31	18
pF	Mean	55.4%	51.4%	28.6%	45.6%	50.0%	46.7%	59.8%	60.1%
	SD	2.7%	3.2%	15.9%	3.4%	9.0%	5.7%	14.7%	19.9%
	L 95% CI	50.1%	45.3%	4.3%	38.9%	32.7%	35.6%	29.9%	19.3%
	U 95% CI	60.5%	57.8%	64.0%	52.1%	67.8%	57.8%	86.2%	93.0%
pHOS	Mean	92.1%	88.0%	84.1%	83.4%	92.1%	87.3%	62.9%	60.4%
	SD	1.5%	2.4%	14.6%	2.7%	4.9%	4.1%	15.1%	20.4%
	L 95% CI	88.8%	83.0%	46.3%	77.8%	80.0%	78.1%	31.5%	19.3%
	U 95% CI	94.8%	92.3%	100.0%	88.3%	98.6%	94.0%	88.6%	93.9%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

Table F10. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Germany fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	881	97	14	203	63	70	8	5
	SD	70	12	4	25	15	9	5	3
	L 95% CI	767	75	6	160	43	55	1	1
	U 95% CI	1,039	124	21	259	102	90	19	12
HOS Age-4	Mean	155	157	6	110	14	28	17	7
	SD	20	16	3	17	6	6	6	3
	L 95% CI	121	129	1	81	5	17	7	1
	U 95% CI	198	194	13	146	30	42	31	15
HOS Age-5	Mean	7	2	1	3	1	1	2	1
	SD	4	2	2	2	2	1	2	1
	L 95% CI	2	0	0	0	0	0	0	0
	U 95% CI	16	6	6	9	6	4	8	5
HOS Age-6	Mean	1	0	0	0	0	0	0	0
	SD	1	0	1	1	1	0	1	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	5	1	2	2	3	1	3	2
NOS Age-3	Mean	68	10	1	32	0	7	2	3
	SD	16	4	1	8	1	3	2	3
	L 95% CI	40	3	0	18	0	3	0	0
	U 95% CI	105	20	5	49	4	15	8	10
NOS Age-4	Mean	18	24	3	29	6	5	13	4
	SD	7	6	3	8	4	3	6	3
	L 95% CI	7	14	0	16	1	1	3	0
	U 95% CI	36	37	10	45	15	12	26	12
NOS Age-5	Mean	4	1	0	2	1	2	1	1
	SD	3	1	1	2	1	1	2	1
	L 95% CI	1	0	0	0	0	0	0	0
	U 95% CI	12	3	3	8	4	5	6	5
NOS Age-6	Mean	0	0	0	0	0	0	0	0
	SD	1	0	0	1	0	0	1	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	3	2	1	2	2	1	2	2

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table F11. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Upper Cowlitz fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017[a]
Abundance	Mean	6,667	7,115	3,189	2,800	2,808	1,821	10	0
	SD	43	66	39	59	47	50	1	1
	L 95% CI	6,582	6,987	3,113	2,685	2,716	1,724	8	0
	U 95% CI	6,752	7,244	3,264	2,915	2,901	1,918	11	0
Males	Mean	3,803	4,324	1,384	2,035	1,369	1,007	3	0
	SD	22	33	19	29	24	25	0	1
	L 95% CI	3,760	4,259	1,347	1,977	1,323	959	2	0
	U 95% CI	3,845	4,388	1,422	2,093	1,415	1,056	4	0
Females	Mean	2,864	2,792	1,804	765	1,439	813	6	0
	SD	22	33	19	29	24	25	0	1
	L 95% CI	2,821	2,727	1,767	707	1,393	765	5	0
	U 95% CI	2,906	2,856	1,842	823	1,485	862	7	0
HOS	Mean	5,879	7,115	3,189	2,800	2,808	1,821	10	0
	SD	45	66	39	59	47	50	1	1
	L 95% CI	5,791	6,987	3,113	2,684	2,716	1,724	8	0
	U 95% CI	5,968	7,244	3,264	2,915	2,901	1,918	11	0
NOS	Mean	788	0	0	0	0	0	0	0
	SD	12	0	0	1	0	0	0	1
	L 95% CI	757	0	0	0	0	0	0	0
	U 95% CI	800	0	0	5	0	0	0	0
pF	Mean	43.0%	39.2%	56.6%	27.3%	51.2%	44.7%	65.6%	---
	SD	0.0%	0.1%	0.1%	0.5%	0.0%	0.1%	1.4%	---
	L 95% CI	42.9%	39.0%	56.4%	26.4%	51.2%	44.4%	63.7%	---
	U 95% CI	43.1%	39.4%	56.8%	28.2%	51.3%	44.9%	68.8%	---
pHOS	Mean	88.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	---
	SD	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	---
	L 95% CI	87.9%	100.0%	100.0%	99.8%	100.0%	100.0%	100.0%	---
	U 95% CI	88.7%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	---

The sum of abundance by clip status, sex, and age may not equal the total abundance estimate due to rounding errors.

[a] No fall Chinook salmon were hauled to Upper Cowlitz release sites in 2017.

Table F12. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Tilton fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	3,141	5,799	2,375	3,688	3,423	3,826	3,949	1,520
	SD	97	76	59	70	44	54	1	1
	L 95% CI	2,951	5,649	2,258	3,552	3,337	3,721	3,947	1,518
	U 95% CI	3,331	5,948	2,492	3,825	3,510	3,931	3,951	1,522
Males	Mean	1,941	2,492	1,199	2,292	1,626	2,135	1,808	682
	SD	48	38	30	35	22	27	1	1
	L 95% CI	1,846	2,417	1,141	2,224	1,583	2,083	1,807	682
	U 95% CI	2,037	2,566	1,257	2,360	1,670	2,187	1,809	684
Females	Mean	1,199	3,308	1,176	1,396	1,797	1,691	2,141	837
	SD	48	38	30	35	22	27	1	1
	L 95% CI	1,104	3,233	1,118	1,328	1,754	1,639	2,140	837
	U 95% CI	1,295	3,382	1,234	1,464	1,841	1,743	2,142	839
HOS	Mean	1,826	1,535	427	415	1,164	451	885	26
	SD	97	77	60	70	45	54	3	1
	L 95% CI	1,635	1,384	310	278	1,077	346	881	24
	U 95% CI	2,016	1,686	545	553	1,252	556	891	28
NOS	Mean	1,315	4,264	1,948	3,273	2,259	3,375	3,064	1,494
	SD	4	5	2	2	3	1	3	0
	L 95% CI	1,306	4,251	1,943	3,268	2,251	3,372	3,058	1,494
	U 95% CI	1,319	4,271	1,950	3,275	2,263	3,377	3,068	1,494
pF	Mean	38.2%	57.0%	49.5%	37.8%	52.5%	44.2%	54.2%	55.1%
	SD	0.4%	0.1%	0.0%	0.2%	0.0%	0.1%	0.0%	0.0%
	L 95% CI	37.4%	56.9%	49.5%	37.4%	52.4%	44.0%	54.2%	55.1%
	U 95% CI	38.9%	57.2%	49.5%	38.3%	52.6%	44.4%	54.2%	55.1%
pHOS	Mean	58.1%	26.5%	17.9%	11.2%	34.0%	11.8%	22.4%	1.7%
	SD	1.3%	1.0%	2.1%	1.7%	0.9%	1.2%	0.1%	0.1%
	L 95% CI	55.4%	24.5%	13.7%	7.8%	32.3%	9.3%	22.3%	1.6%
	U 95% CI	60.5%	28.4%	21.9%	14.5%	35.7%	14.1%	22.6%	1.8%

The sum of abundance by clip status, sex, and age may not equal the total abundance estimate due to rounding errors.

Table F13. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Green fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	1,767	1,436	692	1,249	511	433	672	386
	SD	163	89	33	132	109	78	151	130
	L 95% CI	1,416	1,269	629	1,020	336	322	422	171
	U 95% CI	2,000	1,620	762	1,526	744	622	974	651
Males	Mean	1,100	647	366	576	168	258	339	182
	SD	105	59	34	99	64	58	75	65
	L 95% CI	874	530	302	407	72	168	218	86
	U 95% CI	1,268	768	435	776	310	415	509	322
Females	Mean	666	789	325	673	343	175	333	204
	SD	67	67	33	91	86	45	88	70
	L 95% CI	535	665	267	498	200	100	182	85
	U 95% CI	777	939	392	860	535	273	516	347
HOS	Mean	1,570	1,263	506	659	202	121	342	161
	SD	166	85	36	101	64	62	102	68
	L 95% CI	1,220	1,104	434	470	95	36	167	54
	U 95% CI	1,817	1,431	583	862	347	280	562	313
NOS	Mean	197	173	185	590	309	312	330	225
	SD	32	32	29	94	89	28	66	69
	L 95% CI	141	120	136	421	169	263	222	116
	U 95% CI	268	239	242	780	505	376	466	369
pF	Mean	37.7%	54.9%	47.0%	54.0%	67.2%	40.4%	49.2%	52.8%
	SD	1.5%	3.1%	4.2%	5.5%	9.5%	7.5%	4.8%	4.5%
	L 95% CI	34.7%	48.9%	39.1%	43.8%	47.4%	26.9%	39.2%	44.2%
	U 95% CI	40.7%	61.1%	55.2%	64.2%	83.9%	55.5%	57.8%	61.5%
pHOS	Mean	88.8%	87.9%	73.2%	52.7%	39.7%	26.5%	50.2%	40.6%
	SD	2.1%	2.1%	3.9%	5.7%	10.1%	9.0%	6.1%	6.2%
	L 95% CI	84.3%	83.2%	65.1%	41.9%	21.2%	11.1%	37.2%	28.4%
	U 95% CI	92.3%	91.5%	80.3%	64.0%	59.9%	45.2%	61.0%	52.6%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

Table F14. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Green fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	947	216	260	244	28	19	54	64
	SD	110	36	26	45	19	13	22	31
	L 95% CI	725	152	212	167	4	3	22	19
	U 95% CI	1,132	293	312	345	76	55	105	140
HOS Age-4	Mean	454	945	140	376	137	45	226	74
	SD	57	73	20	63	52	28	75	34
	L 95% CI	344	809	102	260	58	11	96	23
	U 95% CI	561	1,096	183	511	262	119	384	154
HOS Age-5	Mean	169	100	106	39	35	56	57	17
	SD	28	25	17	12	26	37	25	11
	L 95% CI	119	55	74	21	4	11	18	3
	U 95% CI	223	153	144	65	101	146	114	47
HOS Age-6	Mean	1	1	1	1	2	1	5	5
	SD	1	2	1	2	6	2	5	6
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	5	7	4	6	19	7	19	18
NOS Age-3	Mean	83	13	39	157	50	131	71	77
	SD	18	10	11	31	17	13	16	24
	L 95% CI	52	0	20	104	25	105	44	41
	U 95% CI	122	36	64	224	88	157	107	134
NOS Age-4	Mean	84	152	91	418	213	139	218	88
	SD	18	31	17	68	62	22	46	32
	L 95% CI	53	97	61	296	118	107	145	43
	U 95% CI	122	220	129	560	349	193	318	161
NOS Age-5	Mean	29	7	55	14	45	42	41	60
	SD	11	8	13	7	17	8	14	25
	L 95% CI	13	0	34	3	17	27	20	25
	U 95% CI	54	27	84	30	85	58	76	123
NOS Age-6	Mean	0	1	0	1	1	0	0	0
	SD	1	2	1	3	2	1	1	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	3	5	3	7	4	4	3	4

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table F15. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult South Fork Toutle fall Chinook salmon subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	151	62	215	504	272	165	131	208
	SD	35	15	51	166	104	31	27	77
	L 95% CI	95	40	133	267	134	115	87	102
	U 95% CI	232	98	322	930	559	232	197	403
Males	Mean	86	37	115	228	147	111	60	103
	SD	24	10	32	83	64	26	21	45
	L 95% CI	50	20	67	110	66	65	25	45
	U 95% CI	140	60	182	415	330	173	108	225
Females	Mean	64	25	100	277	125	54	70	104
	SD	19	9	28	92	49	20	22	40
	L 95% CI	36	12	55	135	56	23	34	49
	U 95% CI	109	46	166	504	239	101	118	204
HOS	Mean	120	37	166	180	178	104	94	121
	SD	30	12	42	65	71	26	25	49
	L 95% CI	73	19	100	87	81	58	53	56
	U 95% CI	191	63	259	345	353	166	149	242
NOS	Mean	31	25	49	324	93	61	36	87
	SD	13	9	18	110	44	23	18	37
	L 95% CI	11	11	22	163	38	27	10	38
	U 95% CI	62	46	92	601	208	116	78	187
pF	Mean	42.7%	40.9%	46.6%	54.9%	46.3%	32.9%	53.9%	50.5%
	SD	7.4%	9.6%	6.9%	4.8%	7.5%	10.0%	12.2%	8.2%
	L 95% CI	28.4%	23.8%	32.8%	46.3%	31.7%	16.7%	30.1%	35.9%
	U 95% CI	56.9%	60.9%	60.4%	64.1%	60.3%	54.1%	77.4%	66.7%
pHOS	Mean	79.6%	60.1%	77.0%	35.8%	65.7%	62.9%	72.2%	58.2%
	SD	7.1%	11.3%	6.1%	4.8%	8.2%	11.1%	12.0%	8.6%
	L 95% CI	64.5%	36.9%	64.5%	26.9%	48.4%	41.1%	47.4%	40.7%
	U 95% CI	92.1%	79.4%	87.9%	44.9%	80.0%	82.6%	91.5%	74.2%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

Table F16. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult South Fork Toutle fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	47	20	25	29	15	24	23	72
	SD	15	8	11	16	11	12	12	33
	L 95% CI	23	8	8	9	2	5	6	30
	U 95% CI	83	37	51	68	42	52	53	160
HOS Age-4	Mean	53	13	123	145	147	56	48	39
	SD	17	7	32	52	61	19	18	20
	L 95% CI	27	5	74	72	66	25	20	12
	U 95% CI	93	29	196	276	284	101	84	92
HOS Age-5	Mean	19	4	17	7	16	23	23	9
	SD	9	3	9	6	12	13	13	9
	L 95% CI	6	0	5	0	2	6	5	1
	U 95% CI	41	13	42	21	48	54	54	35
HOS Age-6	Mean	0	0	0	1	0	1	1	1
	SD	1	1	2	2	1	2	2	2
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	3	2	4	5	4	6	5	5
NOS Age-3	Mean	13	6	13	57	5	18	10	31
	SD	7	4	8	24	6	12	8	18
	L 95% CI	3	1	3	23	0	2	1	8
	U 95% CI	29	17	33	112	21	49	28	83
NOS Age-4	Mean	12	17	31	264	67	40	24	42
	SD	7	7	13	93	34	18	14	21
	L 95% CI	3	7	11	133	25	14	5	13
	U 95% CI	28	34	62	501	152	79	57	94
NOS Age-5	Mean	6	1	5	2	21	3	2	13
	SD	5	1	5	4	14	5	4	10
	L 95% CI	1	0	0	0	4	0	0	2
	U 95% CI	18	5	18	12	58	15	13	40
NOS Age-6	Mean	0	0	0	0	1	1	1	1
	SD	1	1	1	1	2	2	2	2
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	3	2	3	4	4	6	6	5

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table F17. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Cedar fall Chinook salmon subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	466	326	219	994	728	851	337	714
	SD	72	36	81	185	112	143	42	135
	L 95% CI	354	265	142	717	551	645	275	512
	U 95% CI	630	404	417	1,437	989	1,190	439	1,029
Males	Mean	291	130	101	385	410	405	182	332
	SD	48	16	36	56	62	70	27	73
	L 95% CI	217	102	62	298	310	302	139	224
	U 95% CI	404	165	186	520	555	572	243	504
Females	Mean	175	196	118	609	317	446	155	382
	SD	29	25	54	138	55	78	31	71
	L 95% CI	128	154	65	404	231	334	106	274
	U 95% CI	240	253	245	942	447	634	227	547
HOS	Mean	184	153	95	520	417	497	165	366
	SD	35	24	43	102	77	95	27	77
	L 95% CI	127	111	51	368	296	354	123	248
	U 95% CI	264	204	201	765	599	730	230	548
NOS	Mean	282	173	124	473	311	354	171	348
	SD	52	25	50	92	55	68	34	73
	L 95% CI	199	128	70	336	220	250	120	236
	U 95% CI	398	226	239	695	437	512	249	519
pF	Mean	37.6%	60.2%	53.3%	60.9%	43.5%	52.4%	45.9%	53.7%
	SD	2.7%	2.9%	7.7%	3.3%	2.4%	2.1%	5.8%	3.5%
	L 95% CI	32.1%	54.4%	38.7%	54.5%	38.8%	48.2%	34.5%	46.7%
	U 95% CI	42.9%	65.8%	69.1%	67.3%	48.3%	56.7%	57.1%	60.3%
pHOS	Mean	39.5%	46.8%	43.3%	52.3%	57.2%	58.3%	49.3%	51.3%
	SD	5.0%	5.2%	8.7%	2.7%	4.7%	4.4%	6.4%	4.5%
	L 95% CI	30.0%	36.8%	27.1%	47.3%	47.8%	49.8%	36.2%	42.5%
	U 95% CI	49.6%	57.1%	60.8%	57.7%	66.1%	66.7%	61.1%	60.2%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

Table F18. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Cedar fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	82	42	26	177	67	242	42	219
	SD	15	9	15	31	14	44	14	48
	L 95% CI	55	28	9	129	44	172	20	146
	U 95% CI	116	61	64	250	100	345	77	329
HOS Age-4	Mean	77	105	52	302	326	213	114	125
	SD	19	18	27	68	63	47	23	36
	L 95% CI	48	74	23	198	226	144	77	72
	U 95% CI	123	144	117	468	471	330	167	211
HOS Age-5	Mean	25	6	16	41	24	42	9	21
	SD	9	3	13	14	8	13	5	9
	L 95% CI	12	2	3	21	12	22	3	8
	U 95% CI	46	12	48	75	44	74	22	44
HOS Age-6	Mean	0	0	1	0	0	0	1	1
	SD	1	0	2	1	1	1	2	2
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	2	2	5	3	2	2	7	5
NOS Age-3	Mean	153	14	46	113	48	173	82	182
	SD	28	5	16	18	11	31	20	38
	L 95% CI	107	7	25	83	30	122	52	124
	U 95% CI	215	25	81	155	72	245	129	271
NOS Age-4	Mean	102	153	30	357	238	135	84	154
	SD	21	23	17	80	44	31	21	41
	L 95% CI	68	112	12	239	167	89	53	93
	U 95% CI	151	201	69	552	337	206	136	254
NOS Age-5	Mean	28	6	47	2	25	45	5	11
	SD	10	3	30	2	8	14	5	6
	L 95% CI	14	2	16	0	13	25	0	3
	U 95% CI	50	13	119	9	44	77	18	26
NOS Age-6	Mean	0	0	1	0	0	0	1	0
	SD	1	0	2	1	1	1	2	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	2	2	5	3	2	2	6	4

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table F19. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult East Fork Lewis fall Chinook salmon subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	378	813	557	1,262	1,047	1,017	327	534
	SD	60	138	94	172	260	113	55	135
	L 95% CI	275	580	403	983	666	850	238	339
	U 95% CI	510	1,116	768	1,665	1,693	1,290	455	863
Males	Mean	184	326	256	659	407	557	104	224
	SD	34	61	49	94	105	66	24	61
	L 95% CI	128	224	175	507	252	455	64	137
	U 95% CI	261	464	368	878	663	717	158	368
Females	Mean	193	486	301	602	641	460	223	310
	SD	35	86	55	87	162	56	41	80
	L 95% CI	134	342	209	458	403	374	157	194
	U 95% CI	270	674	426	801	1,048	592	315	501
HOS	Mean	42	37	18	93	85	92	24	53
	SD	13	12	8	20	27	17	10	19
	L 95% CI	21	18	7	59	45	64	9	26
	U 95% CI	70	65	38	139	150	131	49	97
NOS	Mean	336	776	538	1,169	962	924	303	481
	SD	54	133	91	160	240	104	52	122
	L 95% CI	244	553	390	908	613	771	220	305
	U 95% CI	457	1,066	743	1,541	1,560	1,177	421	777
pF	Mean	51.2%	59.8%	54.0%	47.7%	61.2%	45.2%	68.3%	58.0%
	SD	4.4%	2.9%	4.0%	2.3%	2.7%	2.1%	5.0%	3.7%
	L 95% CI	42.6%	54.1%	46.0%	43.3%	55.7%	41.0%	58.1%	50.7%
	U 95% CI	60.0%	65.4%	61.8%	52.2%	66.5%	49.4%	77.6%	65.1%
pHOS	Mean	11.0%	4.6%	3.3%	7.4%	8.1%	9.1%	7.4%	9.9%
	SD	2.8%	1.3%	1.3%	1.3%	1.6%	1.3%	2.8%	2.3%
	L 95% CI	6.2%	2.5%	1.3%	5.1%	5.3%	6.6%	3.0%	5.9%
	U 95% CI	17.1%	7.3%	6.4%	10.0%	11.6%	11.8%	13.9%	15.0%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

Table F20. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult East Fork Lewis fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	16	22	8	38	18	51	5	19
	SD	7	8	5	12	9	12	4	9
	L 95% CI	5	9	2	19	6	32	0	7
	U 95% CI	32	41	19	65	40	78	15	41
HOS Age-4	Mean	22	14	9	53	55	34	14	30
	SD	8	6	5	15	19	9	8	12
	L 95% CI	9	5	3	30	26	19	4	13
	U 95% CI	42	30	22	86	101	55	33	59
HOS Age-5	Mean	3	1	1	1	12	6	5	4
	SD	3	2	1	2	7	4	4	3
	L 95% CI	0	0	0	0	3	2	0	0
	U 95% CI	11	6	5	7	30	15	16	13
HOS Age-6	Mean	0	0	0	0	0	0	0	0
	SD	1	1	1	1	1	1	1	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	2	2	2	3	3	2	4	3
NOS Age-3	Mean	112	150	149	275	70	257	48	110
	SD	23	33	33	46	24	35	16	33
	L 95% CI	73	95	94	199	34	201	23	61
	U 95% CI	165	224	223	378	128	338	84	187
NOS Age-4	Mean	162	598	263	855	679	522	187	293
	SD	31	104	50	120	172	63	37	77
	L 95% CI	111	423	181	661	429	426	128	182
	U 95% CI	232	829	376	1,132	1,107	673	272	481
NOS Age-5	Mean	61	28	126	38	213	144	68	78
	SD	16	11	29	12	59	23	19	25
	L 95% CI	35	12	78	19	125	106	37	42
	U 95% CI	95	52	191	65	354	196	112	141
NOS Age-6	Mean	0	0	0	0	0	0	0	0
	SD	1	1	1	1	1	1	1	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	3	3	4	3	4	2	4	3

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table F21. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Ives Island Bright fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	548	966	444	1,271	1,282	868	7,988	1,982
	SD	81	160	66	187	184	134	1,161	316
	L 95% CI	397	739	328	931	968	661	5,705	1,518
	U 95% CI	722	1,369	589	1,665	1,690	1,201	10,300	2,738
Males	Mean	278	422	162	743	549	334	3,061	632
	SD	48	76	32	113	90	60	469	151
	L 95% CI	191	310	108	538	393	238	2,169	392
	U 95% CI	384	608	232	985	747	474	4,042	977
Females	Mean	269	544	282	529	733	534	4,927	1,350
	SD	47	94	48	82	115	89	730	243
	L 95% CI	185	404	200	382	536	396	3,505	976
	U 95% CI	373	776	386	708	991	751	6,379	1,936
HOS	Mean	11	24	17	223	235	53	220	46
	SD	7	10	8	40	49	17	59	35
	L 95% CI	2	10	5	155	153	26	122	5
	U 95% CI	28	47	37	310	346	93	348	135
NOS	Mean	537	942	427	1,048	1,047	815	7,768	1,937
	SD	80	156	65	156	155	127	1,131	311
	L 95% CI	388	720	314	765	779	617	5,543	1,479
	U 95% CI	712	1,336	567	1,384	1,389	1,130	10,050	2,669
pF	Mean	49.2%	56.3%	63.5%	41.6%	57.2%	61.5%	61.7%	68.1%
	SD	4.5%	3.0%	4.7%	2.2%	3.5%	3.5%	1.8%	5.6%
	L 95% CI	40.3%	50.4%	54.1%	37.2%	50.0%	54.4%	58.1%	56.7%
	U 95% CI	57.8%	62.2%	72.5%	46.1%	64.0%	68.3%	65.2%	78.5%
pHOS	Mean	2.0%	2.5%	3.8%	17.5%	18.3%	6.1%	2.7%	2.3%
	SD	1.2%	0.9%	1.8%	1.8%	2.8%	1.7%	0.6%	1.7%
	L 95% CI	0.4%	1.1%	1.2%	14.2%	13.2%	3.2%	1.7%	0.3%
	U 95% CI	4.9%	4.6%	8.1%	21.2%	24.1%	10.0%	4.1%	6.6%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

Table F22. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Ives Island Bright fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	5	1	5	113	51	18	18	5
	SD	4	2	4	24	20	9	15	8
	L 95% CI	0	0	1	74	21	6	1	0
	U 95% CI	14	6	15	166	97	39	57	28
HOS Age-4	Mean	5	18	10	106	172	29	169	24
	SD	4	8	6	22	40	12	50	21
	L 95% CI	0	7	2	68	105	11	87	2
	U 95% CI	15	38	24	154	264	56	280	83
HOS Age-5	Mean	1	4	2	5	12	6	32	16
	SD	2	3	2	3	9	5	20	16
	L 95% CI	0	0	0	0	1	1	6	1
	U 95% CI	7	13	7	13	36	18	80	62
HOS Age-6	Mean	0	0	0	0	1	0	1	1
	SD	1	1	1	1	2	1	4	3
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	2	2	2	2	6	3	11	8
NOS Age-3	Mean	122	126	121	484	196	253	1,397	108
	SD	28	29	27	77	44	50	239	58
	L 95% CI	74	81	76	350	123	173	955	26
	U 95% CI	181	195	181	646	292	368	1,900	247
NOS Age-4	Mean	263	771	257	526	739	444	5,187	1,056
	SD	47	130	44	83	117	75	763	209
	L 95% CI	181	584	181	377	537	324	3,696	724
	U 95% CI	365	1,091	354	703	999	625	6,736	1,526
NOS Age-5	Mean	151	44	48	38	105	118	1,135	770
	SD	32	15	15	12	29	29	200	171
	L 95% CI	96	22	23	19	57	70	762	496
	U 95% CI	222	79	83	63	170	185	1,552	1,154
NOS Age-6	Mean	1	0	0	0	7	0	49	3
	SD	2	1	2	1	7	2	26	9
	L 95% CI	0	0	0	0	0	0	13	0
	U 95% CI	5	4	5	3	27	5	112	27

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table F23. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Hamilton Bright fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	123	280	227	282	169	701	526	286
	SD	65	87	69	52	36	171	124	80
	L 95% CI	68	160	129	214	120	453	348	170
	U 95% CI	295	489	399	415	256	1,125	829	483
Males	Mean	45	108	47	58	94	220	125	111
	SD	25	48	17	16	21	64	38	33
	L 95% CI	22	42	22	33	64	126	69	64
	U 95% CI	108	223	88	96	145	373	217	190
Females	Mean	78	171	180	224	75	481	401	175
	SD	42	62	56	43	18	122	97	50
	L 95% CI	41	81	102	165	50	305	261	102
	U 95% CI	189	319	316	332	116	784	635	296
HOS	Mean	20	40	22	116	26	72	55	19
	SD	12	26	10	26	8	28	18	8
	L 95% CI	8	8	9	76	13	32	29	8
	U 95% CI	51	109	47	177	46	140	97	39
NOS	Mean	102	239	204	167	143	630	471	267
	SD	55	79	63	35	31	155	112	75
	L 95% CI	55	130	116	116	101	405	311	158
	U 95% CI	244	429	361	252	219	1,010	743	452
pF	Mean	63.5%	61.3%	79.3%	79.4%	44.3%	68.7%	76.2%	61.2%
	SD	5.5%	11.3%	4.2%	4.1%	4.3%	4.7%	4.3%	3.5%
	L 95% CI	52.2%	38.5%	70.5%	70.9%	35.8%	59.1%	67.3%	54.0%
	U 95% CI	73.9%	81.8%	87.0%	87.0%	52.9%	77.6%	84.0%	68.0%
pHOS	Mean	16.8%	14.5%	9.9%	41.0%	15.4%	10.2%	10.5%	6.6%
	SD	4.4%	8.0%	3.1%	5.4%	3.6%	3.0%	2.2%	2.1%
	L 95% CI	9.0%	3.2%	4.7%	30.7%	9.1%	5.2%	6.5%	3.1%
	U 95% CI	26.3%	33.4%	16.8%	51.8%	23.1%	17.0%	15.1%	11.3%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

Table F24. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Hamilton Bright fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	10	10	6	56	2	23	16	2
	SD	7	11	4	15	2	13	8	2
	L 95% CI	3	1	1	33	0	6	6	0
	U 95% CI	27	39	16	91	7	55	34	8
HOS Age-4	Mean	8	24	15	58	23	29	27	7
	SD	5	18	7	15	8	15	10	4
	L 95% CI	2	3	5	34	11	9	12	2
	U 95% CI	21	69	33	94	41	66	52	17
HOS Age-5	Mean	2	5	1	2	1	19	12	9
	SD	2	7	2	2	1	12	6	5
	L 95% CI	0	0	0	0	0	4	3	3
	U 95% CI	9	25	6	7	4	49	28	21
HOS Age-6	Mean	0	1	0	0	0	0	0	0
	SD	0	2	1	1	0	2	1	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	1	6	2	2	1	5	2	1
NOS Age-3	Mean	23	35	38	65	32	108	86	19
	SD	14	23	15	16	10	38	25	8
	L 95% CI	9	6	17	40	17	53	49	7
	U 95% CI	58	95	74	103	55	201	148	39
NOS Age-4	Mean	53	192	111	96	93	337	310	90
	SD	30	67	36	22	21	90	76	28
	L 95% CI	26	97	60	63	62	205	201	50
	U 95% CI	130	355	199	150	146	559	494	160
NOS Age-5	Mean	26	12	55	6	18	184	75	158
	SD	15	13	20	4	7	55	23	46
	L 95% CI	11	0	27	1	8	101	41	92
	U 95% CI	64	48	104	16	34	314	129	269
NOS Age-6	Mean	0	1	0	0	0	1	0	0
	SD	1	4	1	1	1	2	1	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	2	12	3	2	2	7	3	2

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table F25. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Wind Tule fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	113	1,704	598	1,875	1,739	3,407	1,023	409
	SD	48	725	254	303	283	661	212	117
	L 95% CI	77	1156	406	1,508	1,371	2,563	758	252
	U 95% CI	228	3,433	1,205	2,649	2,457	5,087	1,561	697
Males	Mean	58	675	247	626	859	1,567	476	135
	SD	27	299	109	111	147	313	103	41
	L 95% CI	32	420	154	472	661	1,155	338	78
	U 95% CI	122	1,380	502	896	1,223	2,347	739	235
Females	Mean	55	1,029	351	1,250	881	1,840	547	274
	SD	26	441	151	207	150	364	118	80
	L 95% CI	30	672	227	983	678	1,362	392	167
	U 95% CI	113	2,062	711	1,769	1,248	2,764	848	467
HOS	Mean	85	1,353	483	1,376	1,403	2,290	569	46
	SD	37	580	206	227	230	451	122	17
	L 95% CI	53	903	322	1,091	1,102	1,703	405	23
	U 95% CI	172	2,739	974	1,948	1,978	3,436	879	87
NOS	Mean	28	351	115	499	336	1,118	455	363
	SD	15	160	54	93	66	232	99	104
	L 95% CI	12	200	64	367	241	804	324	223
	U 95% CI	63	734	239	726	495	1,694	697	621
pF	Mean	48.6%	60.4%	58.7%	66.6%	50.6%	54.0%	53.5%	67.1%
	SD	8.3%	4.0%	4.2%	2.5%	2.5%	2.1%	3.0%	3.5%
	L 95% CI	32.6%	52.6%	50.4%	61.7%	45.9%	50.0%	47.6%	60.1%
	U 95% CI	65.2%	68.1%	66.7%	71.4%	55.5%	58.1%	59.4%	73.7%
pHOS	Mean	75.3%	79.4%	80.7%	73.4%	80.7%	67.2%	55.6%	11.1%
	SD	7.1%	3.3%	3.4%	2.4%	2.0%	2.3%	3.1%	2.4%
	L 95% CI	60.0%	72.4%	73.8%	68.4%	76.7%	62.8%	49.6%	6.9%
	U 95% CI	88.0%	85.5%	86.9%	78.0%	84.5%	71.9%	61.5%	16.3%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

Table F26. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Wind Tule fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	61	1,317	388	849	1,017	2,059	41	39
	SD	29	565	167	146	171	408	14	15
	L 95% CI	30	876	253	653	785	1,527	20	19
	U 95% CI	128	2,640	780	1,213	1,444	3,108	74	75
HOS Age-4	Mean	23	35	95	515	374	225	528	7
	SD	16	25	45	96	73	56	114	4
	L 95% CI	5	7	50	376	268	142	377	2
	U 95% CI	60	97	199	746	551	359	817	17
HOS Age-5	Mean	1	1	0	12	11	6	0	0
	SD	3	4	1	9	8	6	1	1
	L 95% CI	0	0	0	1	2	0	0	0
	U 95% CI	7	10	4	34	32	23	3	2
NOS Age-3	Mean	23	148	76	291	178	721	301	333
	SD	12	74	37	60	40	156	70	96
	L 95% CI	9	68	38	203	118	503	206	203
	U 95% CI	53	317	165	436	273	1,104	473	569
NOS Age-4	Mean	4	202	39	191	146	323	148	25
	SD	3	99	21	44	34	80	39	13
	L 95% CI	1	99	16	123	94	207	91	8
	U 95% CI	10	440	88	296	226	521	242	55
NOS Age-5	Mean	1	1	1	17	13	73	5	5
	SD	1	4	2	10	7	28	5	5
	L 95% CI	0	0	0	4	3	31	0	0
	U 95% CI	4	12	5	40	31	140	19	19

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table F27. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Little White Tule fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	452	1,379	492	363	452	419	207	288
	SD	148	1202	237	165	217	202	92	41
	L 95% CI	408	256	209	229	192	178	139	217
	U 95% CI	804	4,404	1,036	751	952	883	425	375
Males	Mean	313	594	189	153	157	94	91	80
	SD	104	519	93	73	78	49	42	17
	L 95% CI	252	109	78	85	65	38	53	52
	U 95% CI	557	1,923	406	321	331	202	191	117
Females	Mean	139	786	303	211	295	325	116	208
	SD	49	690	149	96	142	156	53	32
	L 95% CI	98	144	127	121	126	137	70	153
	U 95% CI	251	2,524	636	435	629	685	242	276
HOS	Mean	39	545	269	255	248	312	118	75
	SD	21	476	130	123	118	150	58	16
	L 95% CI	14	100	114	108	107	133	50	47
	U 95% CI	87	1,762	567	535	518	641	246	110
NOS	Mean	343	834	223	102	204	107	84	213
	SD	166	734	112	53	103	55	42	33
	L 95% CI	146	153	92	39	80	41	34	157
	U 95% CI	723	2,663	478	224	438	235	181	284
pF	Mean	30.9%	56.9%	61.5%	58.0%	65.3%	77.6%	56.1%	72.1%
	SD	3.8%	3.8%	4.3%	4.6%	3.7%	3.3%	4.8%	4.2%
	L 95% CI	23.7%	49.4%	52.9%	48.9%	58.0%	71.0%	46.6%	63.5%
	U 95% CI	38.7%	64.4%	69.8%	66.8%	72.4%	83.7%	65.2%	80.0%
pHOS	Mean	10.2%	39.6%	54.8%	71.5%	55.0%	74.6%	58.6%	25.9%
	SD	2.6%	3.8%	4.4%	4.5%	4.1%	3.7%	4.9%	4.2%
	L 95% CI	5.6%	32.0%	46.2%	62.4%	47.1%	67.3%	48.8%	18.1%
	U 95% CI	15.7%	47.2%	63.2%	80.0%	63.1%	81.8%	68.1%	34.5%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

Table F28. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Little White Salmon fall Tule Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	32	528	223	183	170	263	27	63
	SD	18	461	108	90	83	127	15	15
	L 95% CI	11	97	93	76	72	113	10	39
	U 95% CI	72	1,718	472	389	359	546	61	95
HOS Age-4	Mean	5	17	46	72	75	37	89	11
	SD	4	22	26	37	38	21	43	6
	L 95% CI	0	1	16	28	30	13	37	3
	U 95% CI	15	70	102	155	163	83	186	25
HOS Age-5	Mean	2	1	0	0	3	12	2	0
	SD	3	4	1	1	4	9	3	1
	L 95% CI	0	0	0	0	0	2	0	0
	U 95% CI	10	8	4	3	13	31	9	3
NOS Age-3	Mean	303	269	59	54	42	51	36	196
	SD	147	243	33	30	25	28	19	31
	L 95% CI	128	48	22	19	11	17	13	143
	U 95% CI	640	869	133	123	100	117	79	262
NOS Age-4	Mean	32	564	160	47	154	43	45	15
	SD	18	498	82	27	78	24	25	6
	L 95% CI	11	104	65	17	63	15	17	5
	U 95% CI	72	1,828	340	106	324	95	99	30
NOS Age-5	Mean	8	1	4	0	8	13	3	3
	SD	7	5	5	1	6	9	3	3
	L 95% CI	2	0	0	0	1	3	0	0
	U 95% CI	25	11	17	4	24	33	10	10

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table F29. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Wind Bright fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	461	957	101	4,760	1,317	1,273	1,432	1,227
	SD	159	330	35	880	243	242	267	259
	L 95% CI	280	581	61	3,299	914	886	980	866
	U 95% CI	832	1,729	182	6,768	1,867	1,834	2,016	1,877
Males	Mean	152	367	45	2,136	357	442	377	231
	SD	59	133	17	406	102	94	82	70
	L 95% CI	85	210	25	1,462	192	289	241	126
	U 95% CI	274	678	83	3,069	589	659	556	396
Females	Mean	309	589	55	2,624	960	831	1,055	996
	SD	106	211	21	493	193	163	201	218
	L 95% CI	183	349	32	1,813	644	570	718	685
	U 95% CI	559	1,075	101	3,739	1,390	1,207	1,503	1,544
HOS	Mean	139	599	40	3,593	1,015	805	835	672
	SD	52	211	16	667	198	155	163	156
	L 95% CI	77	355	22	2,484	693	557	560	443
	U 95% CI	253	1,088	75	5,127	1,463	1,166	1,192	1,058
NOS	Mean	322	358	60	1,167	302	468	597	556
	SD	113	132	22	231	83	94	122	135
	L 95% CI	193	204	35	787	166	320	394	358
	U 95% CI	584	653	110	1,695	497	685	869	884
pF	Mean	67.0%	61.6%	55.0%	55.1%	72.9%	65.3%	73.7%	81.1%
	SD	4.4%	4.6%	6.4%	1.9%	5.8%	3.2%	2.9%	4.1%
	L 95% CI	58.0%	52.3%	42.4%	51.4%	61.1%	58.9%	67.7%	72.4%
	U 95% CI	75.5%	70.5%	67.3%	58.9%	83.3%	71.5%	79.2%	88.5%
pHOS	Mean	30.2%	62.6%	40.0%	75.5%	77.1%	63.2%	58.3%	54.7%
	SD	4.5%	4.6%	6.2%	1.6%	4.7%	2.2%	3.4%	5.3%
	L 95% CI	21.8%	53.5%	28.3%	72.2%	67.1%	58.7%	51.7%	44.5%
	U 95% CI	39.0%	71.5%	52.6%	78.6%	85.5%	67.5%	65.0%	64.9%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

Table F30. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Wind Bright fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	119	150	18	541	13	238	24	9
	SD	45	61	8	116	18	60	13	12
	L 95% CI	64	74	8	352	0	142	5	0
	U 95% CI	217	285	36	802	62	379	56	40
HOS Age-4	Mean	17	390	18	2,583	886	403	692	275
	SD	10	141	8	486	181	88	138	82
	L 95% CI	5	224	8	1,774	587	264	462	151
	U 95% CI	41	714	35	3,689	1,291	610	990	464
HOS Age-5	Mean	3	50	4	469	113	162	112	386
	SD	3	29	3	103	54	47	34	103
	L 95% CI	0	16	1	302	35	89	58	230
	U 95% CI	12	112	12	706	241	268	189	633
HOS Age-6	Mean	0	9	0	1	3	1	7	2
	SD	1	10	1	2	8	3	7	6
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	3	35	2	7	23	9	27	16
NOS Age-3	Mean	58	55	17	130	9	101	74	33
	SD	25	28	7	38	12	28	26	22
	L 95% CI	26	19	7	70	0	58	34	5
	U 95% CI	113	120	33	218	43	163	133	87
NOS Age-4	Mean	139	295	36	844	202	219	441	271
	SD	52	112	14	172	64	49	93	78
	L 95% CI	77	163	19	560	99	142	286	153
	U 95% CI	256	548	67	1,235	349	334	650	460
NOS Age-5	Mean	124	7	8	178	89	148	82	251
	SD	48	8	4	48	40	36	27	75
	L 95% CI	67	0	2	103	31	90	40	139
	U 95% CI	228	30	18	286	185	232	145	428
NOS Age-6	Mean	0	1	0	14	1	0	1	1
	SD	1	3	1	10	5	1	2	4
	L 95% CI	0	0	0	2	0	0	0	0
	U 95% CI	4	9	2	40	15	4	6	12

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Table F31. Estimates of spawner abundance, including sex- and origin-specific estimates (mean, standard deviation, and 95% credible intervals of the posterior distribution), for the adult Little White Bright fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Abundance	Mean	266	461	478	5,068	1,054	2,054	912	560
	SD	47	81	84	894	186	362	161	92
	L 95% CI	191	331	344	3,642	757	1,477	656	415
	U 95% CI	374	648	672	7,129	1,481	2,886	1,282	775
Males	Mean	108	136	208	1,656	277	649	228	174
	SD	23	27	49	322	66	122	46	32
	L 95% CI	71	94	128	1,148	173	456	155	121
	U 95% CI	160	198	320	2,408	425	934	333	246
Females	Mean	158	324	270	3,412	777	1,405	684	387
	SD	31	58	58	616	143	251	122	65
	L 95% CI	108	231	176	2,429	547	1,006	489	284
	U 95% CI	229	459	402	4,832	1,102	1,985	963	541
HOS	Mean	170	292	338	4,634	965	1,516	748	386
	SD	32	52	66	814	170	265	131	64
	L 95% CI	118	208	232	3,343	694	1,096	537	283
	U 95% CI	242	411	488	6,493	1,359	2,122	1,047	539
NOS	Mean	96	169	140	434	88	538	164	174
	SD	25	38	41	112	39	109	39	34
	L 95% CI	54	105	72	252	19	360	100	119
	U 95% CI	153	252	234	687	171	785	254	253
pF	Mean	59.3%	70.4%	56.5%	67.3%	73.7%	68.4%	75.0%	69.0%
	SD	4.8%	2.5%	6.9%	2.6%	4.1%	2.0%	2.3%	2.7%
	L 95% CI	49.6%	65.5%	43.0%	62.0%	65.5%	64.3%	70.3%	63.6%
	U 95% CI	68.7%	75.2%	69.7%	72.3%	81.2%	72.3%	79.4%	74.2%
pHOS	Mean	63.9%	63.4%	70.8%	91.5%	91.7%	73.9%	82.0%	68.9%
	SD	6.2%	4.1%	6.5%	1.5%	3.2%	2.1%	2.6%	2.9%
	L 95% CI	52.0%	56.5%	57.7%	88.5%	85.3%	69.7%	77.1%	63.3%
	U 95% CI	76.6%	72.8%	82.8%	94.2%	98.0%	78.1%	87.1%	74.6%

The sum of abundance by clip status and sex may not equal the total abundance estimate due to rounding errors.

Table F32. Estimates of spawner abundance by total age and origin (mean, standard deviation, and 95% credible intervals of the posterior distribution) for the adult Little White Salmon Bright fall Chinook subpopulation for spawn years 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
HOS Age-3	Mean	54	49	138	710	87	274	64	12
	SD	15	12	38	164	33	58	17	5
	L 95% CI	30	30	75	443	37	180	37	4
	U 95% CI	88	76	226	1,081	163	404	103	24
HOS Age-4	Mean	78	197	183	3,675	684	796	514	200
	SD	20	38	46	658	129	146	94	36
	L 95% CI	46	137	108	2,619	477	561	365	141
	U 95% CI	122	285	284	5,178	985	1,128	731	283
HOS Age-5	Mean	37	45	16	248	193	446	158	172
	SD	12	11	12	78	52	89	33	32
	L 95% CI	19	27	2	124	110	304	104	120
	U 95% CI	65	72	47	425	312	655	233	245
HOS Age-6	Mean	0	0	1	2	1	0	11	2
	SD	1	0	3	6	3	2	6	2
	L 95% CI	0	0	0	0	0	0	3	0
	U 95% CI	3	2	8	17	10	5	26	8
NOS Age-3	Mean	42	18	48	22	20	183	35	31
	SD	14	7	23	15	15	42	12	9
	L 95% CI	18	5	12	0	0	116	16	16
	U 95% CI	72	34	100	55	55	278	63	53
NOS Age-4	Mean	44	127	45	82	59	247	116	71
	SD	17	30	22	50	34	58	30	17
	L 95% CI	13	75	9	0	0	149	65	42
	U 95% CI	80	191	96	180	130	380	185	110
NOS Age-5	Mean	10	24	46	329	8	107	12	72
	SD	7	9	20	76	10	30	8	17
	L 95% CI	0	8	16	207	0	59	0	44
	U 95% CI	25	44	92	504	34	175	32	110
NOS Age-6	Mean	0	0	1	0	1	0	0	0
	SD	1	0	3	1	2	1	1	1
	L 95% CI	0	0	0	0	0	0	0	0
	U 95% CI	2	1	8	4	7	4	2	2

The sum of abundance by clip status and age may not equal the total abundance estimate due to rounding errors.

Appendix G –Size and Sex Selectivity, Goodness of Fit, and Model Selection of Carcass Tagging Data Used to Develop Jolly-Seber Abundance Estimates.

This appendix provides results of size and sex selectivity, Goodness of Fit (GOF), and model selection analyses conducted with carcass tagging data. We only report on successful JS estimates that were reported as final abundance estimates. Abundance estimates reported in these tables should not be considered final abundance estimates, as they are not adjusted for prespawn mortalities. They are simply reported here to show sensitivity to model selection.

We used a generalized linear model assuming a binomial distribution and using a logit link function to estimate the probability of recovery for carcass tagged individuals during spawning ground surveys to determine whether a pooled JS abundance estimate was appropriate. Covariates included, sex, categorical size (< 80 cm or ≥ 80 cm), and all subsets of main effects. Models were compared and ranked using AICc (Burnham and Anderson 2002). When GOF test suggested stratification by size or sex, we compared abundance estimates of stratified and unstratified models. Abundance was similar between the stratified and unstratified estimates. Therefore, the final model models were not stratified by sex or size. Using this approach our results should have negligible bias, but the 95% CI are more precise.

2014 Mill Creek

Results showed the best model would use a length plus sex covariate and there was considerably less support for the null model (Table G1). To address this potential source of bias, we stratified our carcass tagging dataset by categorical size using a fork length cutoff of 80 cm where carcasses between 60 cm and 79 cm were pooled and classified as our “small” group and carcasses 80 cm and larger were pooled and classified as our “large” group. We then ran the same test with each group. For both the large and small group, a model with a length covariate was still supported with considerably less support for the null model. The next step was stratifying the original dataset into two groups by sex, a male and a female group for all lengths 60 cm and larger. We ran the same GLM tests for these two new groups. For both groups, tests indicated a model that incorporates a length covariate was still the best model but both groups had substantial support for the null model as well (Δ AICc = 0.7 for females and 3.8 for males). We then choose to compare the two stratified estimates (males and females as separate datasets) with the pooled dataset (both sexes). To do this, we evaluated the fit of four potential abundance models for the three datasets (stratified females, stratified males, and non-stratified) using a Bayesian GOF test. Two of the Cormack Jolly-Seber (CJS) models showed acceptable fit in all three datasets (TT, ST) with the TS model showing acceptable fit in the pooled and female datasets but poor fit in the male dataset (Table G2). Model selection favored the TTT model in two of the datasets and had considerably less support in the other dataset (Δ DIC = 6.2) (Table G2). We ran the two stratified datasets using the TTT model and added the two posterior distributions together to develop an overall abundance estimate. This was compared with the posterior distribution of the non-stratified dataset, which was run with the TTT model to see if they were different. The two estimates were nearly identical; the pooled estimate was 426 (95% CI 377-430) and the combined stratified estimate was 438 (95% CI 390-513). We choose to use the dataset where all Chinook salmon 60 cm and larger were pooled for final estimates.

Table G1. Size and sex selectivity results using a generalized linear model for JS carcass tagging for adult fall Chinook salmon in Mill Creek, 2014.

Model	AICc	Δ AICc	AICc Weights
Len + Sex	376.1	0.0	0.61
Length + Sex + Sex*Len	378.2	2.1	0.22
Len	379.1	3.0	0.14
Sex	382.7	6.6	0.02
Null	384.4	8.3	0.01

Table G2. JS Model selection and CJS Goodness of Fit for adult fall Chinook salmon based on carcass tagging data in Mill Creek, 2014.

Dataset	Goodness of Fit		Model Selection				
	CJS Model	Bayesian p-value	JS Model	JS DIC	Δ DIC	DIC Weights	Abundance
Pooled	TT	0.48	TTT	151.8	0.0	0.52	426
	ST	0.36	STT	151.9	0.2	0.48	404
	TS	0.16	TST	164.7	12.8	0.00	438
	SS	0.00	SST	195.3	30.7	0.00	430
Females	ST	0.45	STT	120.4	0.0	0.87	178
	TS	0.64	TST	125.7	5.3	0.06	200
	TT	0.58	TTT	126.5	6.2	0.04	188
	SS	0.11	SST	127.2	6.8	0.03	193
Males	TT	0.23	TTT	141.6	0.0	0.97	247
	TS	0.00	TST	148.9	7.3	0.03	240
	ST	0.17	STT	235.2	93.6	0.00	247
	SS	0.00	SST	273.7	132.1	0.00	250

2015 Mill Creek

Results showed nearly equal support for all models (Table G3), therefore, we choose to use the null model and pooled all Chinook salmon 60 cm and larger.

Table G3. Size and sex selectivity results using a generalized linear model for JS carcass tagging for adult fall Chinook salmon in Mill Creek, 2015.

Model	AICc	Δ AICc	AICc Weights
Len + Sex	521.6	0.0	0.27
Len + Sex + Sex*Len	522.2	0.6	0.20
Len	522.3	0.7	0.19
Sex	522.4	0.8	0.18
Null	522.6	1.0	0.16

We evaluated the fit of four potential abundance models using a Bayesian GOF test. The results showed poor fit for the ST and SS CJS models and marginal fit for the TT and TS models (Table G4). Model selection showed the best fit for the STT with considerably less support for the TTT, and no support for the STT and TST models (Table G4). Based on the combination of GOF and model selection results, we choose to use the TTT for final abundance estimates.

Table G4. JS Model selection and CJS Goodness of Fit for adult fall Chinook salmon based on carcass tagging data in Mill Creek, 2015.

Goodness of Fit		Model Selection				
CJS Model	Bayesian p-value	JS Model	JS DIC	Δ DIC	DIC Weights	Abundance
ST	0.01	STT	123.2	0.0	0.93	547
TT	0.30	TTT	128.3	5.1	0.07	549
SS	0.00	SST	159.2	36.0	0.00	550
TS	0.34	TST	163.4	40.2	0.00	562

2014 Abernathy Creek

Results showed the most support for the null model (Table G5). Therefore, we used it and pooled all Chinook salmon 60 cm and larger.

Table G5. Size and sex selectivity results using a generalized linear model for JS carcass tagging for adult fall Chinook salmon in Abernathy Creek, 2014.

Model	AICc	Δ AICc	AICc Weights
Null	73.3	0.0	0.52
Sex	75.2	1.9	0.20
Len	75.4	2.1	0.18
Len + Sex	77.3	4.1	0.07
Len + Sex + Sex*Len	79.2	6.0	0.03

We evaluated the fit of four potential abundance models using a Bayesian GOF test. The results showed good fit for all models (Table G6). Model selection showed the TTT model as the best with substantial support for the other three models (Table G6). Based on the combination of GOF and model selection results, we choose to use the TTT for final abundance estimates.

Table G6. JS Model selection and CJS Goodness of Fit for adult fall Chinook salmon based on carcass tagging data in Abernathy Creek, 2014.

Goodness of Fit		Model Selection				
CJS Model	Bayesian p-value	JS Model	JS DIC	Δ DIC	DIC Weights	Abundance
TS	0.56	TST	54.8	0.0	0.42	90
SS	0.68	SST	55.5	0.7	0.30	97
TT	0.62	TTT	56.6	1.8	0.17	92
ST	0.71	STT	57.5	2.7	0.11	93

2015 Abernathy Creek

Results showed the most support for the null model (Table G7). Therefore, we used it and pooled all Chinook salmon 60 cm and larger.

Table G7. Size and sex selectivity results using a generalized linear model for JS carcass tagging for adult fall Chinook salmon in Abernathy Creek, 2015.

Model	AICc	Δ AICc	AICc Weights
Null	338.7	0.0	0.34
Sex	339.1	0.4	0.28
Len	340.5	1.8	0.14
Len + Sex	340.6	1.9	0.13
Len + Sex + Sex*Len	341.1	2.4	0.10

We evaluated the fit of four potential abundance models using a Bayesian GOF test. The results showed poor fit for the TS and ST models and marginal fit for the TT and ST models (Table G8). Model selection results showed the most support for the TST model with considerably less for the TTT model and essentially no support for the STT and SST models (Table G8). Based on the combination of GOF and model selection results, we choose to use the TTT for final abundance estimates.

Table G8. JS Model selection and CJS Goodness of Fit for adult fall Chinook salmon based on carcass tagging data in Abernathy Creek, 2015.

Goodness of Fit		Model Selection				
CJS Model	Bayesian p-value	JS Model	JS DIC	Δ DIC	DIC Weights	Abundance
TS	0.00	TST	124.7	0.0	0.90	369
TT	0.06	TTT	129.3	4.6	0.09	367
ST	0.11	STT	135.3	10.6	0.00	336
SS	0.00	SST	150.1	25.4	0.00	351

2013 Germany Creek

Results showed the most support for the model that incorporate length as a covariate (Table G9). We stratified our carcass tagging dataset by categorical size using a fork length cutoff of 80 cm where carcasses between 60 cm and 79 cm were pooled and classified as our "small" group and carcasses 80 cm and larger were pooled and classified as our "large" group. We then ran the same test with each group. For the small group, GLM results showed a model with sex as a covariate as the best with support for the null model (Δ AICc = 3.2). For the large group, the GLM results showed the null model as the best. We then choose to compare the two stratified estimates (large fish and small fish) ran separately but posterior distribution added together with the pooled dataset (all Chinook salmon 60 cm and larger). To do this, we evaluated the fit of four potential abundance models for the three datasets (stratified small fish, stratified large fish, and non-stratified) using a Bayesian GOF test. Results varied by dataset but the only model that had acceptable fit for all three datasets was the TT model (Table G10). Model selection favored the TTT model in two of the datasets and had considerably less support in the other dataset (Δ DIC = 4.2) (Table G10). We ran the two stratified datasets using the TTT model and added the two posterior distributions together to develop an overall abundance estimate. This was compared with the posterior distribution of the non-stratified dataset, which was run with the TTT model, to see if they were different. The pooled estimate was 419 (95% CI 350-526) and the combined stratified estimates was 459 (95% CI 374-616). We choose to use the dataset where all Chinook salmon 60 cm and larger were pooled for final estimates.

Table G9. Size and sex selectivity results using a generalized linear model for JS carcass tagging for adult fall Chinook salmon in Germany Creek, 2013.

Model	AICc	Δ AICc	AICc Weights
Len	244.6	0.0	0.48
Len + Sex	245.7	1.1	0.27
Len + Sex + Sex*Len	246.2	1.6	0.22
Null	251.7	7.1	0.01
Sex	251.8	7.2	0.01

Table G10. JS Model selection and CJS Goodness of Fit for adult fall Chinook salmon based on carcass tagging data in Germany Creek, 2013.

Dataset	Goodness of Fit		Model Selection				
	CJS Model	Bayesian p-value	JS Model	JS DIC	Δ DIC	DIC Weights	Abundance
Pooled	TT	0.58	TTT	176.5	0.0	0.88	419
	ST	0.01	STT	180.6	4.1	0.12	412
	TS	0.04	TST	202.8	26.2	0.00	373
	SS	0.00	SST	203.1	26.6	0.00	366
Small	TT	0.80	TTT	128.1	0.0	0.90	260
	ST	0.40	STT	132.9	4.8	0.08	252
	TS	0.07	TST	137.8	9.7	0.01	233
	SS	0.46	SST	138	9.9	0.01	231
Large	ST	0.02	STT	132.6	0.0	0.89	179
	TT	0.46	TTT	136.8	4.2	0.11	191
	SS	0.01	SST	145.2	12.6	0.00	163
	TS	0.38	TST	149	16.4	0.00	173

2014 Germany Creek

Results showed the most support for a model with a length covariate. However, it showed the reasonable support for the null model (Table G11). Therefore, we used it and pooled all Chinook salmon 60 cm and larger.

Table G11. Size and sex selectivity results using a generalized linear model for JS carcass tagging for adult fall Chinook salmon in Germany Creek, 2014.

Model	AICc	Δ AICc	AICc Weights
Len	21.1	0.0	0.42
Len + Sex + Sex*Len	21.7	0.6	0.31
Len + Sex	23.4	2.2	0.14
Null	24.2	3.1	0.09
Sex	25.8	4.7	0.04

We evaluated the fit of four potential abundance models using a Bayesian GOF test. The results showed acceptable fit for all four models (Table G12). Model selection suggested any of the four models had substantial support (Table G12). We choose to use the TST for final abundance estimates.

Table G12. JS Model selection and CJS Goodness of Fit for adult fall Chinook salmon based on carcass tagging data in Germany Creek, 2014.

Goodness of Fit		Model Selection				
CJS Model	Bayesian p-value	JS Model	JS DIC	Δ DIC	DIC Weights	Abundance
TS	0.61	TST	33.7	0.0	0.27	73
SS	0.74	SST	33.7	0.0	0.27	73
TT	0.61	TTT	34	0.3	0.23	81
ST	0.67	STT	34	0.3	0.23	81

2015 Germany Creek

Results showed substantial support for the null model (Table G13). Therefore, we used it and pooled all Chinook salmon 60 cm and larger.

Table G13. Size and sex selectivity results using a generalized linear model for JS carcass tagging for adult fall Chinook salmon in Germany Creek, 2015.

Model	AICc	Δ AICc	AICc Weights
Len + Sex + Sex*Len	86.4	0.0	0.34
Null	86.6	0.2	0.30
Len	87.5	1.1	0.19
Sex	88.7	2.4	0.10
Len + Sex	89.6	3.2	0.07

We evaluated the fit of four potential abundance models using a Bayesian GOF test. There was acceptable fit for all four models (Table G14). Model selection showed the most support for the TTT model (Table G14), which we used for final abundance estimates.

Table G14. JS Model selection and CJS Goodness of Fit for adult fall Chinook salmon based on carcass tagging data in Germany Creek, 2015.

Goodness of Fit		Model Selection				
CJS Model	Bayesian p-value	JS Model	JS DIC	Δ DIC	DIC Weights	Abundance
ST	0.59	STT	81.7	0.0	0.73	110
TT	0.57	TTT	83.9	2.2	0.24	115
SS	0.13	SST	88.4	6.7	0.03	114
TS	0.64	TST	91.3	9.7	0.01	124

2013 East Fork Lewis River

Results showed the best models would incorporate a length plus sex plus interaction, length, or length plus sex covariate. There was also support for the null model (Δ AICc = 2.7) (Table G15). We chose to use the null model and pooled all Chinook salmon 60 cm and larger.

Table G15. Size and sex selectivity results using a generalized linear model for JS carcass tagging for adult fall Chinook salmon in the East Fork Lewis River, 2013.

Model	AICc	Δ AICc	AICc Weights
Len + Sex + Sex*Len	443.5	0.0	0.38
Len	444.2	0.7	0.27
Len + Sex	444.8	1.3	0.20
Null	446.2	2.7	0.10
Sex	447.4	3.9	0.05

We evaluated the fit of four potential abundance models using a Bayesian GOF test. All of the models with showed poor fit with the TT model was the best of the four (Table G16). Model selection showed the most support for the TTT model (Table G16), which was used for final abundance estimates.

Table G16. JS Model selection and CJS Goodness of Fit for adult fall Chinook salmon based on carcass tagging data in the East Fork Lewis River, 2013.

Goodness of Fit		Model Selection				
CJS Model	Bayesian p-value	JS Model	JS DIC	Δ DIC	DIC Weights	Abundance
TS	0.00	TST	134.8	0.0	0.93	1,307
TT	0.03	TTT	139.9	5.1	0.07	1,344
ST	0.02	STT	152.8	18.1	0.00	949
SS	0.00	SST	229.3	94.6	0.00	1,040

2014 East Fork Lewis River

Results showed the best model was the null model (Table G17). Therefore, we used it and pooled all Chinook salmon 60 cm and larger.

Table G17. Size and sex selectivity results using a generalized linear model for JS carcass tagging for adult fall Chinook salmon in the East Fork Lewis River, 2014.

Model	AICc	Δ AICc	AICc Weights
Null	116.8	0.0	0.48
Len	118.6	1.7	0.20
Sex	118.8	2.0	0.18
Len + Sex	120.5	3.7	0.08
Len + Sex + Sex*Len	120.9	4.0	0.06

We evaluated the fit of four potential abundance models using a Bayesian GOF test. All of the models with the exception of the SS model showed acceptable fit (Table G18). Model selection showed the most support for the TST model with nearly equal support for the TTT model (Δ DIC = 0.4) (Table G18). We used the TTT model for final abundance estimates.

Table G18. JS Model selection and CJS Goodness of Fit for adult fall Chinook salmon based on carcass tagging data in the East Fork Lewis River, 2014.

Goodness of Fit		Model Selection				
CJS Model	Bayesian p-value	JS Model	JS DIC	Δ DIC	DIC Weights	Abundance
TS	0.14	TST	98.2	0.0	0.53	1,189
TT	0.69	TTT	98.7	0.4	0.43	1,144
ST	0.63	STT	103.6	5.3	0.04	814
SS	0.00	SST	121.5	23.2	0.00	989

2015 East Fork Lewis River

Results showed the best model was one that incorporated length as a covariate. There was considerably less support for the null model (Δ AICc = 4.1) (Table G19). To address this, we stratified our carcass tagging dataset by categorical size using a fork length cutoff of 80 cm where carcasses between 60 cm and 79 cm were pooled and classified as our "small" group and carcasses 80 cm and larger were pooled and classified as our "large" group. We then ran the same test with each group. For both the small and large group, the null model was the best model.

Table G19. Size and sex selectivity results using a generalized linear model for JS carcass tagging for adult fall Chinook salmon in the East Fork Lewis River, 2015.

Model	AICc	Δ AICc	AICc Weights
Len	500.3	0.0	0.45
Len + Sex	501.0	0.7	0.31
Len + Sex + Sex*Len	502.6	2.3	0.14
Null	504.3	4.1	0.06
Sex	505.1	4.8	0.04

Next, we evaluated the fit of four potential abundance models for the three datasets (stratified small fish, stratified large fish, and non-stratified) using a Bayesian GOF test. All of the models with the exception of the SS model showed acceptable fit with TT showing the best fit in all three cases (Table G20). Model selection showed the favorite a different model for each of the three datasets. However, the TTT model showed substantial support in all three cases (Table G20). We ran the two stratified datasets using the TTT model and added the two posterior distributions together to develop an overall abundance estimate. This was compared with the posterior distribution of the non-stratified dataset, which was run with the TTT model to see if there were different. The pooled estimate was 1018 (95% CI 875-1299) and the combined stratified estimates was 1124 (95% CI 920-1600). We choose to use the dataset where all Chinook salmon 60 cm and larger were pooled for final estimates.

Table G20. JS Model selection and CJS Goodness of Fit for adult fall Chinook salmon based on carcass tagging data in the East Fork Lewis River, 2015.

Dataset	Goodness of Fit		Model Selection				
	CJS Model	Bayesian p-value	JS Model	JS DIC	Δ DIC	DIC Weights	Abundance
Pooled	TT	0.28	TTT	105.5	0.0	0.52	1,018
	TS	0.14	TST	106.8	1.4	0.26	1,116
	ST	0.08	STT	107.2	1.8	0.21	931
	SS	0.00	SST	165.3	59.8	0.00	1,106
Small	ST	0.05	TST	88.9	0.0	0.66	735
	TT	0.34	TTT	90.5	1.5	0.31	738
	TS	0.40	STT	95.2	6.3	0.03	584
	SS	0.00	SST	122.6	33.7	0.00	680
Large	TS	0.13	STT	90.3	0.0	0.78	362
	TT	0.50	TTT	93.0	2.8	0.19	377
	ST	0.51	TST	96.8	6.5	0.03	414
	SS	0.00	SST	117.3	27	0.00	407

2017 East Fork Lewis River

Results showed the best model was the null model (Table G21). Therefore, we used it and pooled all Chinook salmon 60 cm and larger.

Table G21. Size and sex selectivity results using a generalized linear model for JS carcass tagging for adult fall Chinook salmon in the East Fork Lewis River, 2017.

Model	AICc	Δ AICc	AICc Weights
Null	65.3	0.0	0.39
Len	66.0	0.7	0.27
Sex	67.0	1.7	0.17
Len + Sex	68.1	2.8	0.10
Len + Sex +Sex*Len	68.9	3.6	0.07

We evaluated the fit of four potential abundance models using a Bayesian GOF test. All models showed acceptable fit with the TT model having the best fit (Table G22). Model selection showed the most support for the TTT model (Table G22), which we used for final abundance estimates.

Table G22. JS Model selection and CJS Goodness of Fit for adult fall Chinook salmon based on carcass tagging data in the East Fork Lewis River, 2017.

Goodness of Fit		Model Selection				
CJS Model	Bayesian p-value	JS Model	JS DIC	Δ DIC	DIC Weights	Abundance
TT	0.46	TTT	80.1	0.0	0.52	644
ST	0.39	STT	80.6	0.5	0.40	678
TS	0.35	TST	84.0	3.9	0.07	586
SS	0.09	SST	87.4	7.3	0.01	678

2013 Washougal River

Results showed substantial support for the null model (Δ AICc = 0.4) (Table G23). Therefore, we used it and pooled all Chinook salmon 60 cm and larger.

Table G23. Size and sex selectivity results using a generalized linear model for JS carcass tagging for adult fall Chinook salmon in the Washougal River, 2013.

Model	AICc	Δ AICc	AICc Weights
Sex	1569.0	0.0	0.29
Null	1569.4	0.4	0.23
Length + Sex	1569.9	0.9	0.18
Length	1569.9	0.9	0.18
Length + Sex + Sex*Len	1570.6	1.6	0.13

We evaluated the fit of four potential abundance models using a Bayesian GOF test. Three of the four models showed poor fit with the TT model showing marginal fit (Table G24). Model selection showed the most support for the TTT model with no support for the other three models (Table G24). We used the TTT model for final abundance estimates.

Table G24. JS Model selection and CJS Goodness of Fit for adult fall Chinook salmon based on carcass tagging data in the Washougal River, 2013.

Goodness of Fit		Model Selection				
CJS Model	Bayesian p-value	JS Model	JS DIC	Δ DIC	DIC Weights	Abundance
TT	0.08	TTT	226.7	0.0	1.00	3,966
ST	0.00	STT	266.2	39.4	0.00	3,214
TS	0.00	TST	287.2	60.5	0.00	3,743
SS	0.00	SST	406.0	179.3	0.00	2,932

2014 Washougal River – Below the Weir Site

Results showed the null model as the best model (Table G25). We used the null model and pooled all Chinook salmon 60 cm and larger.

Table G25. Size and sex selectivity results using a generalized linear model for JS carcass tagging for adult fall Chinook salmon in the Washougal River, 2014.

Model	AICc	Δ AICc	AICc Weights
Null	159.9	0.0	0.30
Sex	160.4	0.4	0.24
Len	160.4	0.5	0.23
Len + Sex	161.1	1.2	0.17
Len + Sex +Sex*Len	163.1	3.2	0.06

We evaluated the fit of four potential abundance models using a Bayesian GOF test (Table G26). All four models showed acceptable fit with the TT model having the best fit (Table G26). Model selection favored the TTT model, which we used for final abundance estimates.

Table G26. JS Model selection and CJS Goodness of Fit for adult fall Chinook salmon based on carcass tagging data in the Washougal River, 2014.

Goodness of Fit		Model Selection				
CJS Model	Bayesian p-value	JS Model	JS DIC	Δ DIC	DIC Weights	Abundance
TT	0.61	TTT	170.9	0.0	0.51	955
TS	0.64	TST	172.2	1.3	0.27	1,000
ST	0.31	STT	173.1	2.2	0.17	1,032
SS	0.16	SST	175.2	4.4	0.06	1,011

2015 Washougal River – Below the Weir Site

Results showed substantial support for models that incorporate length plus sex, sex, or length plus sex plus interaction and less support for the null model and length covariate models (Table G27). We choose to use the null model and pooled all Chinook salmon 60 cm and larger due as there was some support and we had concerns about sample sizes if we were to stratify into two groups (e.g. male and females) to minimal any substantial statistical biases.

Table G27. Size and sex selectivity results using a generalized linear model for JS carcass tagging for adult fall Chinook salmon in the Washougal River, 2015.

Model	AICc	Δ AICc	AICc Weights
Len + Sex	1434.8	0.0	0.41
Sex	1435.7	0.9	0.26
Len + Sex + Sex*Len	1436.4	1.5	0.19
Len	1437.7	2.9	0.10
Null	1439.3	4.5	0.04

We evaluated the fit of four potential abundance models using a Bayesian GOF test. Two of the four models had acceptable fit with the best fit for the TT model (Table G28). Model selection showed nearly equal support for the TTT and STT models (Table G28). Abundance estimates were sensitive to model selection. Based on the combination of GOF and model selection results, we choose to use the TTT model for final abundance estimates.

Table G28. JS Model selection and CJS Goodness of Fit for adult fall Chinook salmon based on carcass tagging data in the Washougal River, 2015.

Goodness of Fit		Model Selection				
CJS Model	Bayesian p-value	JS Model	JS DIC	Δ DIC	DIC Weights	Abundance
TT	0.52	TTT	210.1	0.0	0.53	3,339
ST	0.02	STT	210.4	0.2	0.47	2,620
TS	0.30	TST	252.7	42.5	0.00	4,569
SS	0.00	SST	545.3	335.2	0.00	2,595

2016 Washougal River

Results showed the null model as the best model (Table G29). We used the null model and pooled all Chinook salmon 60 cm and larger.

Table G29. Size and sex selectivity results using a generalized linear model for JS carcass tagging for adult fall Chinook salmon in the Washougal River, 2016.

Model	AICc	Δ AICc	AICc Weights
Null	289.6	0.0	0.51
Len	291.5	1.9	0.20
Sex	291.6	2.0	0.19
Len + Sex	293.5	3.9	0.07
Len + Sex + Sex*Len	295.5	5.9	0.03

We evaluated the fit of four potential abundance models using a Bayesian GOF test. All models showed acceptable fit with the TTT model having the best fit (Table G30). Model selection favored STT model with reasonable support for the TTT model (Table G30). The TTT model was used for final abundance estimates.

Table G30. JS Model selection and CJS Goodness of Fit for adult fall Chinook salmon based on carcass tagging data in the Washougal River, 2016.

Goodness of Fit		Model Selection				
CJS Model	Bayesian p-value	JS Model	JS DIC	Δ DIC	DIC Weights	Abundance
SS	0.11	SST	131.1	0.0	0.64	2,264
TT	0.19	TTT	133.9	2.7	0.17	2,355
ST	0.15	STT	134.3	3.2	0.13	2,536
TS	0.15	TST	136.0	4.8	0.06	1,991

2017 Washougal River – Below the Weir Site

Results showed the null model as the best model (Table G31). We used the null model and pooled all Chinook salmon 60 cm and larger.

Table G31. Size and sex selectivity results using a generalized linear model for JS carcass tagging for adult fall Chinook salmon in the Washougal River, 2017.

Model	AICc	Δ AICc	AICc Weights
Null	72.3	0.0	0.35
Len	73.0	0.6	0.26
Sex	73.8	1.5	0.17
Len + Sex	74.1	1.8	0.14
Len + Sex + Sex*Len	75.4	3.1	0.08

We evaluated the fit of four potential abundance models using a Bayesian GOF test. All models showed good fit with the exception of the SS model (Table G32). Model selection favored TTT model (Table G32), which was used for final abundance estimates.

Table G32. JS Model selection and CJS Goodness of Fit for adult fall Chinook salmon based on carcass tagging data in the Washougal River, 2017.

Goodness of Fit		Model Selection				
CJS Model	Bayesian p-value	JS Model	JS DIC	Δ DIC	DIC Weights	Abundance
TT	0.68	TTT	72.1	0.0	0.81	412
ST	0.37	STT	75.0	2.9	0.19	258
TS	0.57	TST	84.6	12.5	0.00	413
SS	0.00	SST	90.7	18.5	0.00	233

2017 Little White Salmon River

Results showed the null model as the best model (Table G33). We used the null model and pooled all Chinook salmon 60 cm and larger.

Table G33. Size and sex selectivity results using a generalized linear model for JS carcass tagging for adult fall Chinook salmon in the Little White Salmon River, 2017.

Model	AICc	Δ AICc	AICc Weights
Null	258.7	0.0	0.42
Length	259.5	0.8	0.28
Sex	260.7	2.0	0.15
Length + Sex	261.4	2.7	0.11
Length + Sex + Sex*Len	263.5	4.8	0.04

We evaluated the fit of four potential abundance models using a Bayesian GOF test. Two of the four models showed acceptable fit (TT, ST) and the other two had poor fit (TS, SS) (Table G34). Model selection favored TTT model with no support for the other three models (Table G34). The TTT model was used for final abundance estimates.

Table G34. JS Model selection and CJS Goodness of Fit for adult fall Chinook salmon based on carcass tagging data in the Little White Salmon River, 2017.

Goodness of Fit		Model Selection				
CJS Model	Bayesian p-value	JS Model	JS DIC	Δ DIC	DIC Weights	Abundance
TT	0.18	TTT	208.5	0.0	1.00	1,087
ST	0.15	STT	239.1	30.6	0.00	1,196
TS	0.00	TST	243.8	35.3	0.00	1,003
SS	0.00	SST	282.2	73.7	0.00	1,096

Appendix H –Size and Sex Selectivity Results from Tagging Data Used to Develop Lincoln-Petersen Abundance Estimates.

This appendix provides results of size and sex selectivity analyses conducted with tagging data used to develop Lincoln-Petersen (LP) abundance estimates.

We used a generalized linear model assuming a binomial distribution and using a logit link function to estimate the probability of recovery for Floy® tagged Chinook salmon during spawning ground surveys to determine whether LP abundance estimates could be pooled. Covariates included, categorical size (< 80 cm or ≥ 80 cm), and one instance origin (2013 Green River). Models were compared and ranked using AICc (Burnham and Anderson 2002).

We only report results of size and sex selectivity on successful LP estimates that were reported as final abundance estimates. We did not test for size or sex selectivity for our LP estimates above the weir site in the Kalama River for spawn years 2015-2017 due to Chinook salmon being batch marked and not measured at the tagging event. We also did not test for size or sex selectivity for our LP estimates above the weir site in the Green River for spawn year 2017, as there were only three carcasses recoveries. As a result, we choose to pool carcasses recoveries and live observations of adult spawners for final abundance estimates but carcass sample sizes were too small to test for size and sex selectivity.

2014 Elochoman River – Above the Weir Site

The null model, indicating homogenous recovery probabilities, had substantial support (Δ AICc = 0.3) (Table H1). Therefore, we used the null model and pooled all Chinook salmon 60 cm and larger. Our tests (described in the methods) indicated we met the assumptions that the marked proportion was constant by recovery period and the recapture rate was constant by period. However, sample sizes were insufficient to test for equal mixing in space. We choose to use the pooled LP estimator. Final estimates were of spawners upstream of the weir, which were developed by multiplying the run size estimate by the proportion of successful spawners and subtracting the estimated sport catch.

Table H1. Size and sex selectivity results using a generalized linear model for LP estimates based on live tagging at the weir and carcasses recoveries on subsequent spawning ground surveys above the weir site of adult fall Chinook salmon in the Elochoman River, 2014.

Model	AICc	Δ AICc	AICc Weights
Len	103.7	0.0	0.46
Null	104.0	0.3	0.39
Sex	106.0	2.3	0.15

2015 Elochoman River – Above the Weir Site

The null model, indicating homogenous recovery probabilities, had support (Δ AICc = 3.1) (Table H2). Therefore, we used the null model and pooled all Chinook salmon 60 cm and larger. Our tests (described in the methods) indicated we met the assumptions that the marked proportion was constant by recovery period and the recapture rate was constant by period. However, sample sizes were insufficient to test for equal mixing in space. We choose to use the pooled LP estimator. Final estimates were of spawners upstream of the weir, which were developed by multiplying the run size estimate by the proportion of successful spawners and subtracting the estimated sport catch.

Table H2. Size and sex selectivity results using a generalized linear model for LP estimates based on live tagging at the weir and carcasses recoveries on subsequent spawning ground surveys above the weir site of adult fall Chinook salmon in the Elochoman River, 2015.

Model	AICc	Δ AICc	AICc Weights
Len	139.3	0.0	0.77
Null	142.4	3.1	0.16
Sex	144.3	5.0	0.06

2016 Elochoman River – Above the Weir Site

The null model, indicating homogenous recovery probabilities, had support (Δ AICc = 3.1) (Table H3). Therefore, we used the null model and pooled all Chinook salmon 60 cm and larger. Sample sizes were insufficient to test the assumptions that the marked proportion was constant by recovery period, the recapture rate was constant by period, and mixing was equal in space. We choose to use the pooled LP estimator. Final estimates were of spawners upstream of the weir, which were developed by multiplying the run size estimate by the proportion of successful spawners and subtracting the estimated sport catch.

Table H3. Size and sex selectivity results using a generalized linear model for LP estimates based on live tagging at the weir and carcasses recoveries on subsequent spawning ground surveys above the weir site of adult fall Chinook salmon in the Elochoman River, 2016.

Model	AICc	Δ AICc	AICc Weights
Len	22.6	0.0	0.76
Null	25.7	3.1	0.16
Sex	27.2	4.6	0.07

2017 Elochoman River – Above the Weir Site

The null model, indicating homogenous recovery probabilities, was the best model (Table H4). Therefore, we used the null model and pooled all Chinook salmon 60 cm and larger. Sample sizes were insufficient to test the assumptions that the marked proportion was constant by recovery period, the recapture rate was constant by period, and mixing was equal in space. We choose to use the pooled LP estimator. Final estimates were of spawners upstream of the weir, which were developed by multiplying the run size estimate by the proportion of successful spawners and subtracting the estimated sport catch.

Table H4. Size and sex selectivity results using a generalized linear model for LP estimates based on live tagging at the weir and carcasses recoveries on subsequent spawning ground surveys above the weir site of adult fall Chinook salmon in the Elochoman River, 2017.

Model	AICc	Δ AICc	AICc Weights
Null	20.7	0.0	0.52
Len	21.9	1.2	0.28
Sex	22.5	1.8	0.21

2013 Green River – Above the Weir Site

The null model, indicating homogenous recovery probabilities, was not supported (ΔAICc = 7.9) (Table H5). The best model of Chinook salmon recovery probability included a single main effect of sex, where recovery probability was significantly greater for male fish (16%) than for female fish (7%). We stratified to estimate abundance of separately by sex then combined those estimates for an overall estimate of fish passing the weir site. This estimate was not significantly different from the pooled LP estimate (means of the posterior distributions were within 0.5% of one another with overlapping credible intervals), so we have chosen to report on the pooled LP estimate. Our tests (described in the methods) indicated we met the assumptions of equal mixing in space, marked proportion was constant by recovery period, and recapture rate was constant by period, which validates the use of a pooled LP estimator. Final estimates were of spawners upstream of the weir were developed by multiplying the run size estimate by the proportion of successful spawners and subtracting the estimated sport catch.

Table H5. Size and sex selectivity results using a generalized linear model for LP estimates based on live tagging at the weir and carcasses recoveries on subsequent spawning ground surveys above the weir site of adult fall Chinook salmon in the Green River, 2013.

Model	AICc	Δ AICc	AICc Weights
Sex	353.0	0.0	0.95
Null	360.9	7.9	0.02
Len	361.4	8.4	0.01
Origin	361.7	8.7	0.01

2014 Green River – Above the Weir Site

The null model, indicating homogenous recovery probabilities, was the best model (Table H6). Therefore, we used the null model and pooled all Chinook salmon 60 cm and larger. Our tests (described in the methods) indicated we met the assumptions of the marked proportion was constant by recovery period and the recapture rate was constant by period. However, sample sizes were insufficient to test for equal mixing in space. We choose to use the pooled LP estimator. Final estimates were of spawners upstream of the weir, which were developed by multiplying the run size estimate by the proportion of successful spawners and subtracting the estimated sport catch.

Table H6. Size and sex selectivity results using a generalized linear model for LP estimates based on live tagging at the weir and carcasses recoveries on subsequent spawning ground surveys above the weir site of adult fall Chinook salmon in the Green River, 2014.

Model	AICc	Δ AICc	AICc Weights
Null	71.5	0.0	0.51
Sex	72.9	1.4	0.26
Len	73.1	1.6	0.24

2016 Green River – Above the Weir Site

The null model, indicating homogenous recovery probabilities, was the best model (Table H7). Therefore, we used the null model and pooled all Chinook salmon 60 cm and larger. Our tests (described in the methods) indicated we met the assumptions of equal mixing in space, the marked proportion was constant by recovery period, and the recapture rate was constant by period, which validates the use of a pooled LP estimator. Final estimates were of spawners upstream of the weir, which were developed by multiplying the run size estimate by the proportion of successful spawners and subtracting the estimated sport catch.

Table H7. Size and sex selectivity results using a generalized linear model for LP estimates based on live tagging at the weir and carcasses recoveries on subsequent spawning ground surveys above the weir site of adult fall Chinook salmon in the Green River, 2016.

Model	AICc	Δ AICc	AICc Weights
Null	146.3	0.0	0.48
Sex	147.1	0.8	0.32
Len	148.1	1.8	0.19

2014 Coweeman River – Above the Weir Site

The null model, indicating homogenous recovery probabilities, was the best model (Table H8). Therefore, we used the null model and pooled all Chinook salmon 60 cm and larger. Our tests (described in the methods) indicated we met the assumptions of equal mixing in space, the marked proportion was constant by recovery period, and the recapture rate was constant by period, which validates the use of a pooled LP estimator. Final estimates were of spawners upstream of the weir, which were developed by multiplying the run size estimate by the proportion of successful spawners.

Table H8. Size and sex selectivity results using a generalized linear model for LP estimates based on live tagging at the weir and carcasses recoveries on subsequent spawning ground surveys above the weir site of adult fall Chinook salmon in the Coweeman River, 2014.

Model	AICc	Δ AICc	AICc Weights
Null	513.1	0.0	0.39
Len	513.3	0.2	0.36
Sex	514.0	0.9	0.25

2015 Coweeman River – Above the Weir Site

The null model, indicating homogenous recovery probabilities, was not supported (ΔAICc = 8.5) (Table H9). The best model of Chinook salmon recovery probability included a single main effect of categorical length, where recovery probability was significantly greater for large fish (31%) than for small fish (21%). We stratified to estimate abundance of large fish and small fish separately then combined those estimates for an overall estimate of fish passing the weir site. This estimate was not significantly different from the pooled LP estimate (means of the posterior distributions were within 1.5% of one another with overlapping credible intervals), so we have chosen to report on the pooled LP estimate. Our tests (described in the methods) indicated we met the assumptions of equal mixing in space, the marked proportion was constant by recovery period, and the recapture rate was constant by period, which validates the use of a pooled LP estimator. Final estimates were of spawners upstream of the weir, which were developed by multiplying the run size estimate by the proportion of successful spawners.

Table H9. Size and sex selectivity results using a generalized linear model for LP estimates based on live tagging at the weir and carcasses recoveries on subsequent spawning ground surveys above the weir site of adult fall Chinook salmon in the Coweeman River, 2015.

Model	AICc	Δ AICc	AICc Weights
Len	1350.9	0.0	0.96
Sex	1358.4	7.5	0.02
Null	1359.4	8.5	0.01

2017 Coweeman River – Above the Weir Site

The null model, indicating homogenous recovery probabilities, was the best model (Table H10). Therefore, we used the null model and pooled all Chinook salmon 60 cm and larger. Our tests (described in the methods) indicated we met the assumptions of equal mixing in space, the marked proportion was constant by recovery period, and the recapture rate was constant by period, which validates the use of a pooled LP estimator. Final estimates were of spawners upstream of the weir, which were developed by multiplying the run size estimate by the proportion of successful spawners.

Table H10. Size and sex selectivity results using a generalized linear model for LP estimates based on live tagging at the weir and carcasses recoveries on subsequent spawning ground surveys above the weir site of adult fall Chinook salmon in the Coweeman River, 2017.

Model	AICc	Δ AICc	AICc Weights
Null	208.1	0.0	0.57
Sex	210.0	1.9	0.22
Len	210.0	1.9	0.21

2014 Washougal River – Above the Weir Site

The null model, indicating homogenous recovery probabilities, was the best model (Table H11). Therefore, we used the null model and pooled all Chinook salmon 60 cm and larger. Our tests (described in the methods) indicated we met the assumptions of equal mixing in space, the marked proportion was constant by recovery period, and the recapture rate was constant by period, which validates the use of a pooled LP estimator. Final estimates were of spawners upstream of the weir, which were developed by multiplying the run size estimate by the proportion of successful spawners and subtracting sport catch.

Table H11. Size and sex selectivity results using a generalized linear model for LP estimates based on live tagging at the weir and carcasses recoveries on subsequent spawning ground surveys above the weir site of adult fall Chinook salmon in the Washougal River, 2014.

Model	AICc	Δ AICc	AICc Weights
Null	784.0	0.0	0.57
Sex	785.9	1.9	0.22
Len	786.0	2.0	0.21

2015 Washougal River – Above the Weir Site

The null model, indicating homogenous recovery probabilities, was the best model (Table H12). Therefore, we used the null model and pooled all Chinook salmon 60 cm and larger. Our tests (described in the methods) indicated we met the assumptions of equal mixing in space, the marked proportion was constant by recovery period, and the recapture rate was constant by period, which validates the use of a pooled LP estimator. Final estimates were of spawners upstream of the weir, which were developed by multiplying the run size estimate by the proportion of successful spawners and subtracting sport catch.

Table H12. Size and sex selectivity results using a generalized linear model for LP estimates based on live tagging at the weir and carcasses recoveries on subsequent spawning ground surveys above the weir site of adult fall Chinook salmon in the Washougal River, 2015.

Model	AICc	Δ AICc	AICc Weights
Len	924.0	0.0	0.51
Sex	924.8	0.8	0.35
Null	926.7	2.7	0.13

2017 Washougal River – Above the Weir Site

The null model, indicating homogenous recovery probabilities, was the best model (Table H13). Therefore, we used the null model and pooled all Chinook salmon 60 cm and larger. Our tests (described in the methods) indicated we met the assumptions of equal mixing in space, the marked proportion was constant by recovery period, and the recapture rate was constant by period, which validates the use of a pooled LP estimator. Final estimates were of spawners upstream of the weir, which were developed by multiplying the run size estimate by the proportion of successful spawners and subtracting sport catch.

Table H13. Size and sex selectivity results using a generalized linear model for LP estimates based on live tagging at the weir and carcasses recoveries on subsequent spawning ground surveys above the weir site of adult fall Chinook salmon in the Washougal River, 2017.

Model	AICc	Δ AICc	AICc Weights
Null	180.5	0.0	0.58
Len	182.4	1.9	0.22
Sex	182.5	2.0	0.21