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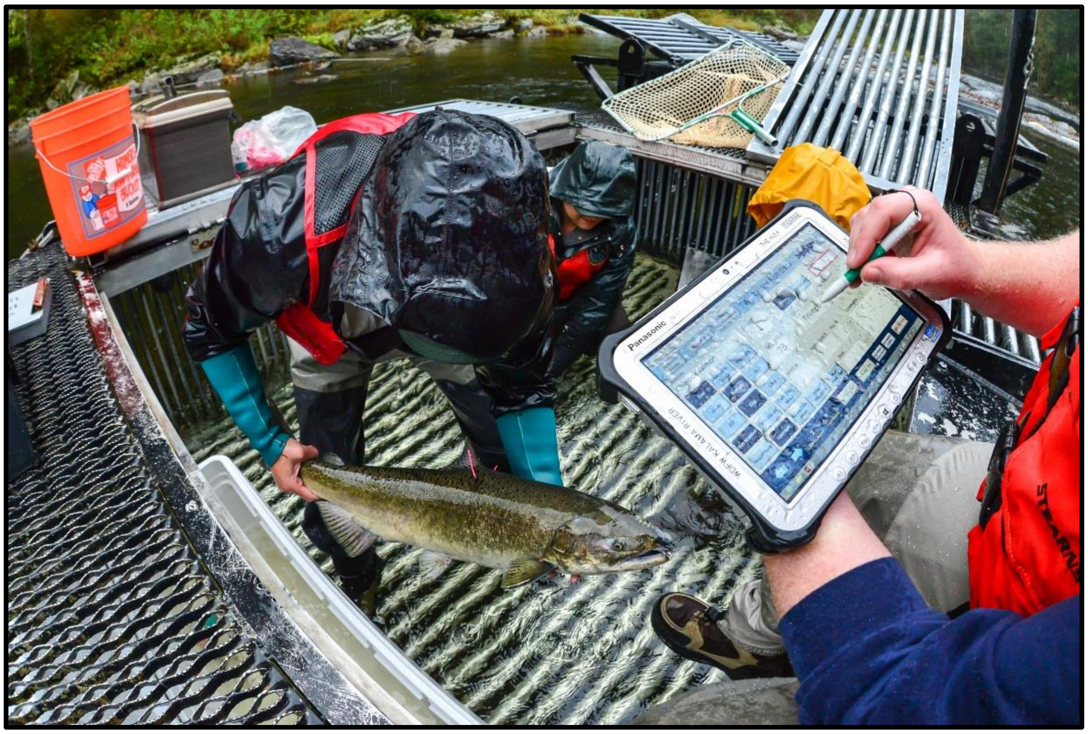
Population Monitoring of Chinook Salmon in the Washington Portion of the Lower Columbia River Evolutionarily Significant Unit, 2018-2019



Washington Department of FISH and WILDLIFE

by Kari Dammerman, Elise Olk, and Thomas Buehrens

On the cover*: WDFW field crew members collect biological data from a female Chinook salmon caught in the live box of a resistance-board weir located on the Washougal River. The Washougal River weir is one of seven weirs operated by WDFW in Southwest Washington where the primary objective is to decrease the number of hatchery-origin fish present in the river where natural-origin fish are spawning. Photo taken by Danny Warren.*

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Abstract

The Washington Department of Fish and Wildlife (WDFW) is one of several stakeholders that manages Pacific salmonids within the Columbia River basin. Following the listing of several species of Columbia River salmon and steelhead under the Endangered Species Act, the state mandated mass marking and WDFW adopted an adaptive management-based approach to limit the escapement of hatchery-origin fish in the Lower Columbia River by installing several resistance-board weirs. In 2010, WDFW restructured the agency's annual monitoring program for naturally spawning Spring and Fall Chinook salmon populations around the viable salmonid population (VSP) concept, and more recently, expanded efforts to characterize the effects of the weirs on natural populations including quantifying the proportion of hatchery-origin (pHOS) spawners above and below the weirs. In survey years 2018 and 2019, WDFW conducted weekly spawning ground surveys from August to December and operated seven resistance-board weirs to quantify adult spawner abundance, diversity, productivity, and spatial structure for Fall and Spring Chinook salmon present in Southwest Washington tributaries. Approximately 2100 Spring Chinook, 26600 early fall/tule (EFT) Chinook, and 60600 late fall/bright (LFB) Chinook total adult spawners were estimated for the twenty Spring and Fall Chinook populations in Southwest Washington when summing the two survey years. For designated populations within the Lower Columbia River Chinook Evolutionarily Significant Unit (ESU), the Lower Cowlitz had the highest adult spawner abundances of Spring Chinook and EFT Chinook in both survey years. The North Fork Lewis population is the only designated LFB Chinook population in the ESU, and had the highest overall spawner abundance of LFB Chinook in 2019 for all LFB Chinook populations monitored by WDFW. In 2018, the Lower Gorge population had the highest spawner abundance of LFB Chinook (specifically upriver bright Chinook) though these fish are not a designated population within the ESU. Most of the LFB Chinook that are not recognized as belonging to any established recovery population with the Lower Columbia River Chinook ESU were observed in the populations of the Gorge strata. Based on the minimum natural-origin spawner recovery goals set by the National Marine Fisheries Service, four of the thirteen designated Lower Columbia River Chinook populations are above their goals based on 5-year geometric means of the smoothed spawner abundances. Five additional Chinook populations are within 25-75% of their recovery goals. All the Lower Columbia River Spring Chinook populations are far from their minimum natural-origin spawner recovery goals with three populations believed to be at critically low abundance or extirpated. Based on limits outlined in the Mitchell Act Biological Opinion, estimated mean pHOS for one of the ten Chinook populations discussed in the BiOp is under the limit; however, full BiOp implementation has not yet occurred. Future work is needed to discern EFT from LFB Chinook in several tributaries, and assess the possible negative impacts that spawning LFB Chinook adults are having on recovery of natural-origin populations of EFT Chinook in the Lower Columbia River Chinook ESU.

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Background

The Washington Department of Fish and Wildlife (WDFW) is the agency tasked with protecting natural resources while providing sustainable recreational and commercial opportunities within the State of Washington. One area closely monitored by WDFW as well other state agencies, tribal fisheries managers, local partners, and federal entities is the management of Pacific salmonids in the Columbia River Basin. Throughout the 1900s, logging, agriculture, navigation, hydropower development, hatchery practices, and overharvest contributed to the decline of wild salmon and steelhead in the Columbia River Basin (Bottom et al. 2005; NMFS 2017). Consequently, following a series of status reviews by the National Marine Fisheries Service (NMFS), several species of Columbia River salmon and steelhead were placed on the Endangered Species List (NPCC 2020). Presently, there are 13 species listed as “threatened” or “endangered” under the Endangered Species Act (ESA) including Lower Columbia River (LCR) Chinook salmon (*Oncorhynchus tshawytscha*; NMFS 2020).

After the ESA listing of the LCR Chinook Evolutionarily Significant Unit (ESU), Washington State legislatures expanded existing coded-wire tagging (CWT) programs, mandating mass-marking (adipose fin clipping) of hatchery-origin (HOR) Chinook where feasible (Nandor et al. 2009; Senate Bill 5915 RCW 77.95.290). This external mark provided recreational and commercial fisherman a visual method for readily identifying HOR adults and allowed management agencies to implement mark-selective fisheries where only HOR fish were removed (harvested), thereby protecting natural-origin (NOR) stocks from direct harvest pressure. Mass-marking also provided fisheries managers the means to estimate abundance by origin for adult fish on the spawning grounds. Following these legislative changes, WDFW worked on enhancing the Chinook monitoring program in the Southwest region of the state by installing resistance-board weirs in several streams (Wilson et al. 2019, 2020).

In 2009, the Congressionally established Hatchery Scientific Review Group (HSRG) outlined several recommendations for hatchery reform in the Columbia River Basin including minimizing the adverse effects of HORs on NOR spawners (HSRG 2009). Following the HSRG’s guidance, the Washington Fish and Wildlife Commission that governs WDFW established new policies outlining adaptive management-based approaches for monitoring hatchery programs and improving viability of NOR salmonids in the state (FWC C-3617 and C-3619). With these new recommendations, WDFW’s Chinook monitoring program in Southwest Washington was restructured in 2010 to focus on two primary objectives: 1) annual assessment of population viability following the viable salmonid population (VSP) concept in McElhany et al. (2000), and 2) increased recovery of CWT data from the spawning grounds for adult forecasting and harvest rate estimation.

Recent amendments to WDFW’s Chinook monitoring program in Southwest Washington include the guidelines outlined by the National Marine Fisheries Service (NMFS) in the Biological Opinion (BiOp) associated with Mitchell Act hatchery funding (NMFS 2017). These guidelines include the continued operation and/or establishment of several fish weirs in LCR tributaries for minimizing the influence of HORs on ESA-listed NORs, and specific proportion of hatchery-origin spawner (pHOS) monitoring goals representing recovery viability levels for LCR Chinook (NMFS 2017). The purposes of this report are to present the 2018 and 2019 population viability parameters for the Chinook salmon populations monitored by WDFW in the Washington portion of the LCR, provide status updates on recovery goals and guidelines outlined in the NMFS 2017 BiOp, and discuss trends observed over the past ten years.

Monitoring Methods

LCR Chinook ESU: Washington Populations

The LCR Chinook ESU includes Spring and Fall Chinook salmon populations that originate from just east of the White Salmon and Hood Rivers to the Columbia River mouth (including some Willamette River tributaries; NMFS 2016). There are 32 historical populations in this ESU that NMFS has organized into major population groups known as the Coast, Cascade, and Gorge strata (NMFS 2013). Within these strata, there are seven Spring Chinook and thirteen Fall Chinook populations that originate from Southwest Washington tributaries (Figure 1). Spring Chinook typically return to freshwater in late spring as 3-year-old jacks or 4-5-year-old adults, and will reside in freshwater for months before spawning between late July to late September. The seven Spring Chinook populations originating from Southwest Washington include the Upper Cowlitz, Cispus, Tilton, Toutle, Kalama, North Fork Lewis, and White Salmon (Figure 1, Appendix A). All seven of these populations are considered at "high" or "very high" risk of extinction due to low abundances of NORs and in some tributaries, a high abundance of HOR spawners (NMFS 2016).

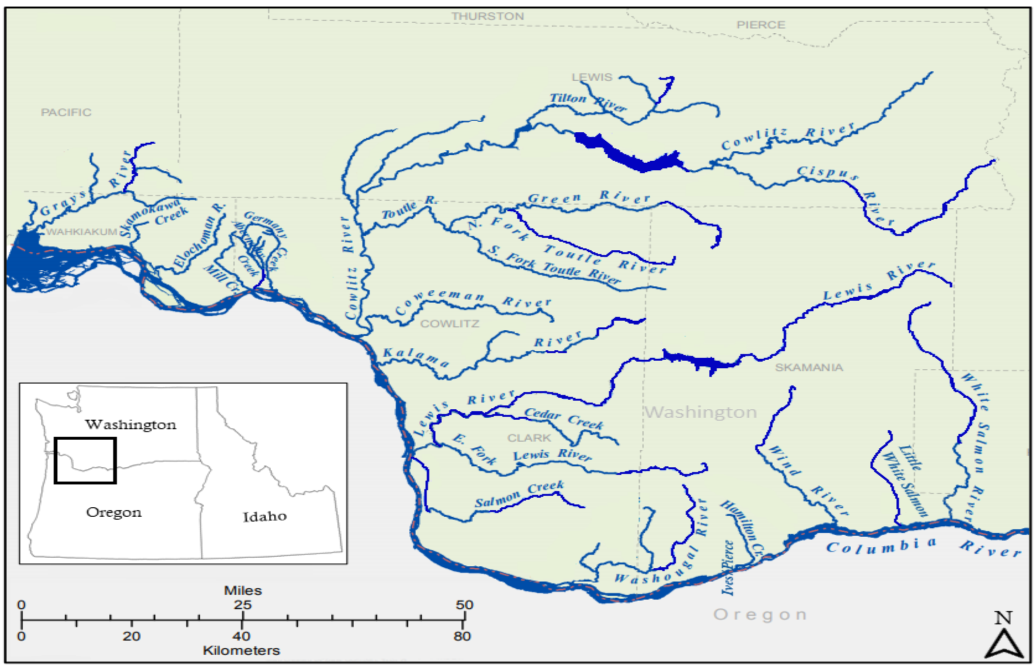

Figure 1. Spring and Fall Chinook salmon populations of the Lower Columbia River Chinook Evolutionarily Significant Unit that originate from Southwest Washington and are monitored by the Washington Department of Fish and Wildlife (WDFW). WDFW stock figure edited for inclusion in this report.

For Fall Chinook salmon, populations and individuals display additional run timing diversity with earlier spawning populations known as "early fall/tule (EFT)" and later spawning populations known as "late fall/brights (LFB)." Both runs typically return from the ocean at 3-5 years of age, spawning later in the year than Spring Chinook. The EFT Chinook often spawn between September and October, while the LFB Chinook spawn between October and December. They also have phenotypic differences with LFB Chinook often being light grey, chrome, or red in color, and having fewer spots than an EFT Chinook. The thirteen Fall Chinook populations that originate from Southwest Washington include the Coweeman, Lower Cowlitz, Upper Cowlitz, Elochoman/Skamokawa, Grays/Chinook, Toutle, Lewis, Kalama, North Fork Lewis, Washougal, Mill/Abernathy/Germany, White Salmon, and Salmon Creek (Figure 1, Appendix A; NMFS 2013; NMFS 2016). Of these thirteen populations, only the North Fork Lewis was recognized at the time of listing as having both an EFT and a LFB Chinook population, while the remaining populations were thought to be comprised of primarily or exclusively EFT Chinook. Regardless of run timing, most of the Fall Chinook populations in the LCR Chinook ESU are considered at "high risk" of extinction due to low NOR abundances, high harvest rates, and high numbers of spawning HORs (NMFS 2016).

WDFW Chinook Monitoring Program

The WDFW LCR Chinook monitoring program includes the seven Spring and thirteen Fall Chinook populations originating from Southwest Washington's Coast and Cascade strata as well as the Lower Gorge (Ives/Pierce and Hamilton) and Upper Gorge (Little White Salmon and Wind) Fall Chinook populations that are divided between Washington and Oregon (Figure 1, Appendix A). Additionally, abundance estimates are generated annually for late fall/bright Chinook stocks (select area brights (SAB) and upriver brights (URB)) that are not recognized by NFMS as part of the Washington portion of the LCR Chinook ESU, but have become established in several tributaries (NMFS 2013). WDFW's monitoring program has a long history with adult Chinook abundance estimates dating back to the 1960s (Salmon Conservation Reporting Engine (SCoRE)). The current adult Chinook monitoring program is centered around the VSP concept, which is based on annually quantifying four parameters: abundance, diversity, productivity, and spatial structure (McElhany et al. 2000).

To collect the data needed to quantify the VSP parameters, weekly spawning ground surveys (as well as supplemental surveys when needed during peak weeks) are conducted from August to December in each of the Southwest Washington tributaries except for the Cowlitz River, North Fork Lewis River, Chinook River, and Salmon Creek. Both the Cowlitz (Lower and Upper) and North Fork Lewis Rivers are monitored under different protocols and funding sources. Results for these systems are presented briefly in this report, but detailed information on the monitoring programs for these populations can be found in Serl et al. (2019, 2020) and Bentley et al. (2018), respectively. The Chinook River is not monitored given that no Fall Chinook are believed to be present in this tributary so estimates presented for the designated Grays/Chinook population are results from the Grays River. Salmon Creek, located in Clark County, is also no longer surveyed given that adult abundances are believed to be too low to monitor.

For each of the tributaries where spawning ground surveys occur, peak week is assigned as the week with the highest single weekly count of live and/or dead fish observed during surveys. For select tributaries (Kalama, Green/North Fork Toutle, Little White Salmon), only dead fish are considered for peak count given the way hatchery returns at nearby facilities are incorporated into abundance estimates. Individual redds are identified and flagged to allow for estimates of total unique redds. Redds are also spatially referenced using GPS coordinates throughout the season on all tributaries except in the Kalama, Washougal, Green/North Fork Toutle (above the weir), Lower Gorge, Upper Gorge, and White Salmon where only total redd count was quantified weekly. For carcasses encountered on the spawning grounds and live fish handled at the weirs, biological data including fork length, gill color, body condition, sex, spawn success, observable mark/fin clip status, and presence or absence of tags (CWT, Floy, or carcass) are recorded. Sex is assigned based on phenotypic characteristics including body size, girth, size of teeth, and presence or absence of a kype (Johnson et al. 2007). Spawn success is evaluated for each female carcass by slitting open her abdomen; fish that are visually estimated to have >75% of her eggs retained are recorded as pre-spawn mortalities. Fin clip status refers to whether the fish has an intact adipose, left ventral, or pectoral fin, which are marks used to distinguish HOR (clipped) from NOR (no clips) fish. Left ventral clips are used to distinguish HOR SAB Chinook from HOR EFT Chinook. Double index fish (HORs with CWTs, but no clip) are assigned as HORs as these fish are intentionally left unclipped by hatcheries as a mark-selective fishery impact evaluation method. Snouts are collected from carcasses containing a CWT for origin and age verification. Scale and tissue samples are taken from viable carcasses for aging and future genetic analysis, respectively. On the Coweeman, Green/North Fork Toutle, Elochoman, Grays, Cedar Creek, Washougal, and Little White Salmon Rivers, subsets of carcasses are uniquely tagged on the inside of the opercula and tracked weekly for potential mark-recapture modeling.

Abundances are estimated as the total number of adult spawners in each tributary after accounting for harvest (where applicable), mis-clips, and pre-spawn mortality rates. Estimates do not include jacks (fish under 60cm in fork length or verified as a jack based on CWT data). WDFW utilizes several methods for estimating adult Spring and Fall Chinook abundances using weir and spawning ground survey data including (in order of preference):

1. Census counts: all returning adults in the stream are counted. This method is typically used in closed systems where an impassable barrier allows for all fish to be observed and counted (Parsons and Skalski 2010).
2. Mark-recapture models: individual fish are marked at a barrier or by tagging carcasses. A Lincoln-Peterson (L-P, closed population) or Jolly-Seber (J-S, open population) modeling framework is then used to estimate adult abundance based on mark-recapture information (Schwarz et al. 1993).
3. Trapezoidal area-under-the-curve (AUC): the area under an escapement curve is estimated using the sum of “spawners” at each sampling interval multiplied by the difference in timing between sampling intervals and 0.5 as shown in English et al. (1992). The total AUC estimate, or sum of fish days, is then divided by mean residence time (days) to estimate escapement (Parsons and Skalski 2010). This method relies on classifying live fish as “spawners” or “holders” as described in Parken et al. (2003). Population and year-specific estimates of apparent residence time described in Wilson et al. (2020) were used in all AUC estimates.
4. Redd count expansion (RCE): the total number of new redds observed during surveys is multiplied by the number of females per redd to estimate abundance of spawning females. The sex ratio is then used to estimate total adult abundance (Gallagher and Gallagher 2005). Population and year-specific estimates of apparent females per redd described in Wilson et al. (2020) were used in all RCE estimates. The use of redds has been identified as the primary method utilized in the Pacific Northwest for estimating adult Chinook escapement (Parsons and Skalski 2010).
5. Peak count expansion (PCE): the peak count estimate of fish observed (lives, deads, or sum of lives and deads) within a selected area during the season is multiplied by a PCE factor (Parsons and Skalski 2010) that was either developed from previous mark-recapture studies or estimated based on professional knowledge (Wilson et al. 2020). PCE was the typical method used historically by WDFW for producing Chinook escapement estimates.

Monitoring methods utilized to determine adult abundances in 2018 and 2019 varied among runs, tributaries, and above and below the weirs (Table 1). Currently, there are seven, seasonal resistance-

Table 1. Methods used in 2018 and 2019 for estimating adult abundances above (AW) and below (BW) the weirs (where applicable) for spring (SPR) run, early fall/tule (EFT) run, and late fall/bright (LFB) run Chinook salmon populations in Southwest Washington. Populations are presented geographically from west to east and organized by major population group. Area surveyed specifies the river mileage (RM) covered during weekly spawning ground surveys.

Tributary	Run	Area Surveyed (RM)[1]	2018	2019
Coast Strata				
Grays (AW)	EFT, LFB	15.59	RCE	RCE
Grays (BW)	EFT, LFB	3.87	RCE	RCE
Chinook[2]	EFT	N/A	N/A	N/A
Elochoman (AW)	EFT, LFB	13.99	RCE	RCE
Elochoman (BW)	EFT, LFB	0.48	RCE	RCE
Skamokawa	EFT, LFB	4.85	AUC	AUC
Mill	EFT	12.97	PCE	AUC
Abernathy	EFT	10.05	PCE	AUC
Germany	EFT	11.13	PCE	AUC
Cascade Strata				
Lower Cowlitz	EFT	45.64	RCE	RCE
Upper Cowlitz	SPR	N/A	RCE/Census[3]	RCE/Census[3]
Upper Cowlitz (Cispus, Tilton)[2]	SPR	N/A	N/A	N/A
Upper Cowlitz	EFT	N/A	Census[3]	Census[3]
Toutle[2]	SPR	N/A	N/A	N/A
Green/North Fork Toutle (AW)	EFT	21.30	L-P	L-P
Green/North Fork Toutle (BW)	EFT	0.37	RCE	RCE
South Fork Toutle	EFT	23.92	RCE	RCE
Coweeman (AW)	EFT	26.03	L-P	L-P
Coweeman (BW)	EFT	0.84	RCE	RCE
Kalama	SPR	N/A	PCE	PCE
Kalama (AW)	EFT	7.95	L-P	L-P
Kalama (BW)	EFT	1.52	AUC	AUC
Cedar Creek (AW)	EFT	8.15	Census[4]	AUC
Cedar Creek (BW)	EFT	1.00	AUC[4]	AUC
East Fork Lewis	EFT	15.57	RCE	RCE
North Fork Lewis	SPR	N/A	PCE	PCE
North Fork Lewis	EFT, LFB	9.10	J-S	J-S
Salmon Creek[2]	EFT	N/A	N/A	N/A
Washougal (AW)	EFT	10.03	L-P	L-P
Washougal (BW)	EFT	11.40	J-S	J-S
Gorge Strata				
Lower Gorge: Ives/Pierce	EFT	2.00	PCE	PCE
Lower Gorge: Ives/Pierce	LFB	2.00	AUC	AUC
Lower Gorge: Hamilton[2]	EFT	1.72	N/A	N/A
Lower Gorge: Hamilton	LFB	1.72	AUC	AUC
Upper Gorge: Little White Salmon	EFT	1.20	PCE	PCE
Upper Gorge: Little White Salmon	LFB	1.20	PCE	J-S
Upper Gorge: Wind	EFT, LFB	2.16	AUC	AUC
White Salmon	SPR, EFT, LFB	12.34	AUC	AUC

[1]River miles were presented opposed to kilometers to stay consistent with historical and current reaches. Mileage reported does not include supplemental surveys. See Appendix A and Wilson et al. (2020) for additional details on supplemental surveys.
[2]No abundances were generated because the population is either extirpated, not surveyed, or no adults were observed.
[3]On the Cowlitz River, dams prevent fish passage to the Upper Cowlitz so annual spawner abundances are estimated using RCE from the Lower Cowlitz and adult returns to the Cowlitz Salmon Hatchery/Barrier Dam (see Serl et al. 2019, 2020).
[4]Methods presented were used above and below the Cedar Creek Grist Mill ladder trap as the weir was not operating until 2019.

board weirs being operated by WDFW for Fall Chinook monitoring in Southwest Washington tributaries. The purposes of these weirs are to enumerate HOR and NOR spawner abundances in the tributaries, control the proportion of HORs present, and to collect hatchery broodstock where applicable. Five of these weirs (Grays, Elochoman, Green/North Fork Toutle, Coweeman, and Washougal began operating between 2008-2011. A sixth weir (Kalama River commonly referred to as Modrow) that had been operating for broodstock collection was re-designed in 2015 to shift the primary purpose towards limiting HORs on the spawning grounds. The seventh weir (Cedar Creek) was constructed in 2018 and began operating in 2019.

At each of the weirs, HOR fish were quantified and then removed for broodstock or surplussed. NOR fish encountered at the Coweeman, Elochoman, and Grays weirs were enumerated, marked with two uniquely numbered Floy tags and left opercle punches (LOP), and passed upstream. At the Kalama weir (Modrow), NORs were given an LOP only before being passed upstream. At the Green/North Fork Toutle and Washougal weirs, up to 1/3 of NORs for the entire season are taken for broodstock, and the remaining NORs are given an LOP and two uniquely numbered Floy tags before being passed upstream. In 2018, NOR Chinook in Cedar Creek were caught at the Grist Mill ladder trap, counted, and given two LOPs and a uniquely numbered Floy tag before being passed upstream. Starting in 2019 when the weir was operating, NORs passing over the weir in Cedar Creek were given two right opercle punches (ROP) and passed upstream; NORs that subsequently swam into the Grist Mill ladder trap were given two LOPs and a uniquely numbered Floy tag before being passed upstream. On the Washougal and Kalama Rivers, NORs that recruited into hatcheries located upstream of the weirs (Appendix A) were counted, given an ROP, and placed either upstream (Washougal) or downstream (Kalama) of the hatchery to spawn. The LOPs, ROPs, and Floy tags used in the tributaries served several purposes: to generate an above weir abundance estimate using a mark-recapture (L-P) modeling framework, to estimate the number of adult live resights when conducting spawning ground surveys, and/or to prevent over-estimating the number of NORs in the stream when fish pass over barriers or into the hatcheries. To evaluate how effective the weirs were at controlling HORs, weir efficiency was calculated annually as the total number of fish handled at the weir divided by the sum of the above weir escapement and weir removals. Additionally, pHOS above and below the weir was estimated and compared to recovery goals identified by NMFS.

In addition to estimating annual adult spawner abundances, pHOS, and weir efficiency (where applicable), diversity metrics were monitored on each tributary by evaluating age structure, HOR to NOR abundance, and sex ratio. Additionally, spatial structure was assessed by examining redd counts and the distribution of HORs and NORs throughout the tributary. More detailed information on sampling methods, weir procedures, and Fall Chinook VSP parameters from 2010-2017 can be found in Buehrens et al. (2019), Rawding et al. (2019), and Wilson et al. (2019, 2020). As noted above, details about the Cowlitz River Spring and Fall Chinook monitoring work contracted to WDFW by Tacoma Power including maps of the system can be found in Serl et al. (2019, 2020), and additional information on the North Fork Lewis River Spring and Fall Chinook escapement estimates can be found on SCoRE and in Bentley et al. (2018).

Data Storage and Statistical Analysis

All data collected at the weirs and during spawning ground surveys were stored in WDFW’s Traps, Weirs, and Surveys (TWS) database. Scale cards and snouts containing CWTs were sent to WDFW’s aging lab and CWT lab, respectively, to determine age classes following protocols described in Rawding et al. (2014). CWT data were uploaded to the Regional Mark Information System (RMIS) database, which stores CWT releases, recoveries, and location information for anadromous salmonids in the Pacific Northwest. Quality assurance and quality control for all field data was conducted by multiple personnel to correct any errors or input missing information. Annual adult spawner abundances were reported in-house to the Salmonid Stock Inventory (SaSI), which transfers data to the publicly accessible SCoRE website.

Statistical analyses of data from all tributaries aside from the Cowlitz and North Fork Lewis were performed using Bayesian inference in WinBUGS (version 1.4.3, Lunn et al. 2000) and JAGS (v 4.3.0, Plummer 2003) called on from R (v 3.6.2, R Development Core Team) using packages "R2WinBUGS" (Sturtz et al. 2005) and "R2jags" (Su and Yajima 2020). Wilson et al. (2020) contains detailed information on analyses used including equations for each abundance calculation, prior distributions, model assumptions, and model statements. Briefly, population models (with all populations fit separately) included Markov Chain Monte Carlo (MCMC) simulations with two chains of 500,000 iterations, a burn-in of 100,000, and a thinning interval of 100 for an effective sample size of 8,000. Model convergence was evaluated by examining trace plots and quantifying the Gelman-Rubin diagnostic (Brooks and Gelman 1998). Model outputs including the means, medians, standard deviations, and 95% credible intervals were estimated for each parameter from the posterior distributions. Non-informative beta priors were used for estimating proportions that followed binomial distributions including HOR/NOR, male/females, pre-spawn mortality/non pre-spawn, and clipped/mis-clipped fish. The proportions of fish in each age class were fit using informative priors calculated from the observed age structures of carcasses recoveries in each tributary.

For Spring and Fall (EFT and LFB) Chinook populations, adult spawner abundances were estimated in the population models using methods identified in Table 1 and defined in the text. For all populations where L-P modeling was used to estimate above weir abundance (except the Green/North Fork Toutle), the number of marks out was the number of NORs given an LOP, ROP, and/or Floy tag and passed upstream at the weirs. The number of fish captured was the sum of all tagged/opercle-punched and untagged/non-opercle punched carcasses, and recaptures was the number of marked (tagged/opercle-punched) carcasses encountered during spawning ground surveys or as a mortality that washed up at the weir. A hypergeometric distribution was chosen for the L-P modeling given that all recaptured carcasses had their tails removed so a "without replacement" sampling was done (Rawding et al. 2014). For the Green/North Fork Toutle, the number of marks out was the same as other tributaries, but number of fish captured was all live fish seen during spawning ground surveys and recaptures were all tagged/opercle-punched, live resights given the lack of carcass recoveries. A binomial distribution was chosen for the L-P modeling for the Green/North Fork Toutle population as fish were not removed from the system after being "recaptured" (i.e., "with replacement" sampling; Rawding et al. 2014).

For populations where J-S modeling was used to estimate abundance (aside from the North Fork Lewis) based on carcasses tagged under the operculum, the number of carcasses tagged and recovered were filtered to determine if size (fork length) and sex influenced recovery probability. Logistic regressions with binomial errors and logit link functions were fit with all combinations of size and sex included as covariates except in the simplest null model. Models were compared using corrected AIC (Burnham and Anderson 2002). Based on model comparisons, the null model had the lowest corrected AIC and was the model of best fit for both survey years so capture histories were generated for each carcass without stratification. J-S summary statistics were calculated using package "RMark" (Laake 2013), and sampling periods (survey dates) were pooled when needed to fit J-S modeling requirements (Schwarz and Arnason 2010). Four abundance models based on constant or varying probabilities of capture, survival, and entry were fit. Model selection was based on the lowest deviance information criterion (DIC, Spiegelhalter et al. 2014) that was not within 2.0 of another model; if models were within 2.0 of each other, the most simplistic model was chosen as the best model. Abundance was estimated from the model of best fit.

For tributaries where RCE or AUC were used to estimate abundance, estimates of apparent females per redd and apparent residence time were derived using hierarchical, mixed effect models. Both variables (females per redd or residence time) were specified separately as a log-linear function of a global mean, random basin and year effects, and a residual error, which all followed normal distributions. A vague normal prior was specified for the global mean, and half-normal hyperpriors were specified for basin, year, and the residual error. The shape and rate parameters derived from the mixed models for each variable were input as priors for the gamma distributions in the population models to estimate population and year-specific estimates of apparent females per redd and apparent residence time. Lastly, for populations where PCE was used, a model with vaguely informative hyperpriors was used to model historical data around a hierarchical mean peak count proportion so that population and year-specific PCE factors could be generated rather than relying on one PCE factor for all basins (see additional modeling details in Wilson et al. 2020).

In each of the population models, adjustments were made to adult abundance estimates to account for harvest rates, pre-spawn mortalities, and HOR mis-clips. To account for the HOR EFT that were harvested in the sport fishery on the Elochoman, Grays, Kalama, Green/North Fork Toutle, and Washougal, harvest estimates were calculated from catch record card data that was supplied by fishermen and maintained by WDFW (E. Kraig, personal communication, WDFW). The number of harvested HORs above the weirs were added to the above weir abundance estimates to determine the total number of fish that passed over the weir for evaluating weir efficiency. To adjust for pre-spawn mortalities, the estimated number of HOR and NOR pre-spawns in the population based on the pre-spawn mortality rate observed during spawning ground surveys was subtracted from the adult abundance estimate. Both harvest data and pre-spawn mortality rates were also used to estimate the total number of adult returns to the mouth of each tributary; however, those numbers are not presented in this report. Lastly, adult abundances were adjusted for HOR mis-clips, which can occur when the adipose fin regenerates, the adipose fin is only partially cut during marking, or when fish are released or escape the hatchery before mass marking. Personnel subsample approximately 500 fish annually prior to release, and report the mis-clipped number to RMIS. Using the RMIS data, mis-clip rates (the number of mis-clipped fish divided by sample size) were assigned to each population based on the hatchery program that was known to be the largest contributor to HOR spawner abundance in the tributary from CWT recoveries. HOR and NOR spawner abundances were adjusted to account for mis-clipped HORs to avoid over-inflating NOR spawner abundances in the tributaries. Adult abundances reported in the text, tables, and figures below are the number of HOR and NOR spawners in each tributary after adjustments. Additional details regarding these adjustments and the statistical analyses discussed can be found in Wilson et al. (2020).

VSP Results by Population

Coast Strata

Grays/Chinook

As noted in the methods, no Chinook salmon are believed to be present in the Chinook River so results reported for the Grays/Chinook Fall Chinook population are based on Grays River monitoring. Additionally, straying HOR SAB Chinook (a stock of LFB Chinook) utilize spawning grounds in the Grays River. Given the temporal overlap in EFT and SAB Chinook distributions, adult abundances and pHOS estimates include SAB fish. In 2018, adult Fall Chinook were observed on the spawning grounds in the Grays River from August 29th to November 14th. Peak count of lives and deads in the reference sections was 227 fish, which occurred on September 26th. A total of 27 carcasses were sampled on the spawning grounds, which were all sampled above the weir. The sex composition of recovered carcasses was 13 females and 14 males; no pre-spawn females were sampled. At the weir, 106 HORs (26 LV-clipped SABs and 80 ad-clipped HORs) were removed, and 27 NORs were given an LOP and Floy tagged before being passed upstream. The number of recaptured and/or resighted tagged NORs was low (N=12). A total of 250 redds were tracked throughout the season with 50 observed above the weir, and 200 observed below the weir. Median (% CV) estimates of apparent residence time and apparent females per redd were 6.06 (18.28) days and 1.31 (36.23) females, respectively. Based on RCE, median adult abundance for the entire population was 670.30 (40.01, Table 2) with approximately 134 adults estimated above the weir and 535 adults below the weir. There were almost twice as many females as males. Nearly 45% of the adult abundance was NORs as median pHOS for the entire stream was 0.55 (0.05). Estimated median weir efficiency for the season was 51.93% as approximately 23 HORs were estimated to have gotten by the weir. Scales were taken from the 27 carcasses and from the 25 fish encountered at the weir for aging. Most adults were aged as 4-year-olds based on scales and CWTs (Table 2).

Table 2. Mean, median, standard deviation (SD), and 95% credible interval (CI) parameter estimates for the Grays/Chinook Fall Chinook population in survey years 2018 and 2019.

Parameter	2018				2019			
	Mean	**Median**	**SD**	**95% CI**	**Mean**	**Median**	**SD**	**95% CI**
Abundance	720.35	670.30	268.18	(343.00 – 1376.00)	590.84	560.40	197.47	(312.89 – 1058.03)
Females	453.24	416.85	222.29	(125.30 – 991.71)	349.33	324.65	147.40	(140.90 – 707.51)
Males	267.11	226.10	176.38	(57.42 – 729.15)	241.51	220.60	119.58	(76.94 – 534.72)
NORs	327.21	303.60	129.28	(148.00 – 638.94)	344.00	319.00	147.24	(129.40 – 694.91)
HOR EFT	260.95	241.20	105.70	(114.10 – 521.91)	147.49	127.30	91.01	(32.03 – 375.21)
HOR SAB[1]	132.18	120.60	57.70	(54.54 – 273.71)	99.35	80.78	72.83	(14.73 – 279.01)
pHOS	0.55	0.55	0.05	(0.44 – 0.65)	0.42	0.41	0.15	(0.16 – 0.72)
Age-3 NORs	89.35	74.54	60.36	(18.81 – 245.81)	94.07	76.67	70.59	(12.52 – 273.40)
Age-4 NORs	187.34	171.70	91.64	(56.92 – 415.81)	222.49	204.10	111.21	(62.71 – 494.21)
Age-5 NORs	43.96	31.06	41.74	(3.75 – 160.12)	22.81	9.79	34.56	(0.05 – 117.90)
Age-6 NORs	6.63	0.52	17.13	(0.00 – 53.12)	4.64	0.12	14.67	(0.00 – 44.42)
Age-3 HOR EFT	93.95	78.67	65.00	(16.19 – 257.82)	25.72	17.59	26.07	(2.31 – 97.35)
Age-4 HOR EFT	133.98	118.80	78.77	(26.29 – 332.61)	111.42	94.95	72.51	(21.95 – 295.51)
Age-5 HOR EFT	27.09	12.67	36.61	(0.21 – 131.41)	8.60	3.63	14.04	(0.08 – 47.26)
Age-6 HOR EFT	5.93	0.20	18.07	(0.00 – 55.64)	1.75	0.09	6.07	(0.00 – 14.65)
Age-3 HOR SAB	97.46	87.28	49.16	(30.89 – 218.30)	72.20	56.13	57.86	(9.35 – 220.51)
Age-4 HOR SAB	31.89	23.83	28.20	(2.38 – 105.20)	24.82	15.07	29.38	(1.06 – 101.01)
Age-5 HOR SAB	2.84	0.17	7.91	(0.00 – 25.54)	2.33	0.10	7.63	(0.00 – 21.74)
Age-6 HOR SAB	0.00	0.00	0.00	(0.00 – 0.00)	0.00	0.00	0.00	(0.00 – 0.00)

[1]As noted in the methods, the number of Select Area Brights (SAB), a stock of late fall/bright Chinook, encountered on the spawning grounds or at the weir are quantified annually and included in the adult abundance estimates for the population given the temporal overlap in EFT and SAB distribution.

In 2019, adult Fall Chinook were observed on the spawning grounds in the Grays River from August 21st to October 16th. Peak count of lives and deads in the reference sections was 223 fish, which occurred on October 2nd. A total of 12 carcasses were sampled with 5 from above the weir and 7 below the weir. The sex composition of recovered carcasses was 7 females and 5 males; no pre-spawn females were sampled. At the weir, 93 HORs (10 LV-clipped SABs and 83 ad-clipped HORs) were removed, and 7 NORs were given an LOP and Floy tagged before being passed upstream. The number of recaptured and resighted NORs was low (N=4). A total of 159 redds were tracked throughout the season with 7 observed above the weir, and 152 observed below the weir. Median (% CV) estimates of apparent residence time and apparent females per redd were 5.43 (15.94) days and 1.69 (30.32) females, respectively. Based on RCE, median adult abundance for the entire population was 560.40 (35.24, Table 2) with approximately 27 adults estimated above the weir and 532 adults below the weir. As observed in 2018, female returns outnumbered males. Nearly 59% of the adult abundance was NORs as median pHOS for the entire stream was 0.41 (35.43). Estimated median weir efficiency for the season was 77.87% as approximately 10 HORs were estimated to have gotten by the weir. Scales were taken from the 12 carcasses and 7 fish encountered at the weir for aging. Most adults were aged as 4-year-olds based on scales and CWTs (Table 2).

Comparing survey years (Table 2), adult abundance was higher in 2018, but so was the number of HORs leading to a higher pHOS. The observed sex ratio was comparable with females outnumbering males in both years. In 2018, NORs outnumbered the number of HOR early fall/tule, but did not outnumber total HORs. NOR abundance was slightly higher in 2019 despite a lower overall adult abundance. Regardless of origin, most fish were aged as 4-year-olds. Over the past ten years, HOR and NOR adult abundances for the population have showed similar trends with HORs outnumbering NORs from 2012-2016 (Figure 2). From 2017-2019, NORs outnumbered the estimated number of HOR EFTs and estimated number of HOR SABs, but only outnumbered the total sum of HORs in 2019. The largest return year to-date was 2013 for HORs and 2019 for NORs (Figure 2).

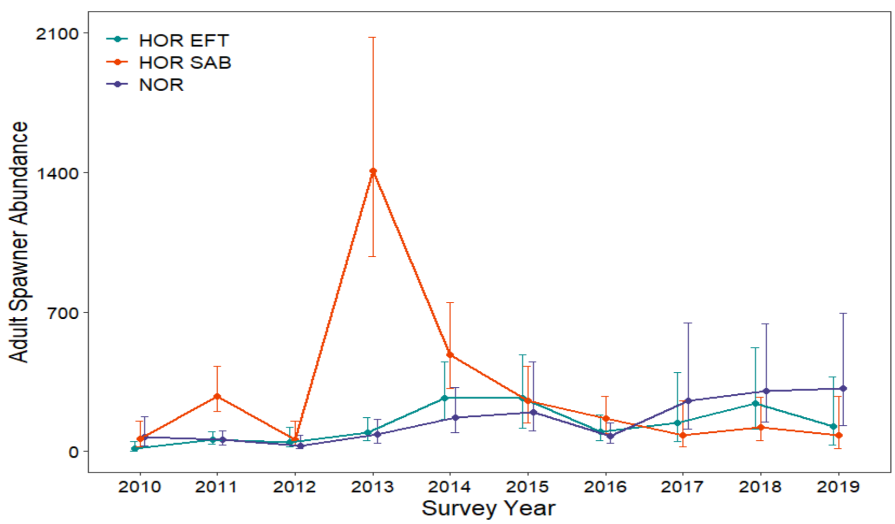

Figure 2. Estimated adult abundances of hatchery-origin (HOR) early fall/tule (EFT), HOR select area brights (SAB), and natural-origin (NOR) Fall Chinook salmon that spawned in survey years 2010 – 2019 for the Grays/Chinook population. Point estimates are medians and error bars represent the 95% credible intervals.

Elochoman/Skamokawa

As observed in the Grays River, straying HOR SAB Chinook utilize spawning grounds in the Elochoman and Skamokawa Rivers. Given the temporal overlap in EFT and SAB Chinook distributions, adult abundances and pHOS estimates include SAB fish. In 2018, adult Fall Chinook were observed on the spawning grounds of the Elochoman River from September 20th to December 6th. Peak count of lives and deads in the reference sections was 16 fish, which occurred on October 18th. No carcasses were sampled on the spawning grounds. At the weir, 68 HORs (one LV-clipped SAB and 66 ad-clipped HORs) were removed, and 17 NORs were given an LOP and Floy tagged before being passed upstream. Only 2 of the tagged NORs were recaptured as live resights so no L-P modeling was done. A total of 12 redds were quantified throughout the season, which were all observed above the weir. Median (% CV) estimates of apparent residence time and apparent females per redd were 3.67 (10.74) days and 1.05 (27.13) females, respectively. Based on RCE, median adult abundance for the entire river after adjustments was 29.76 (42.97, Table 3) with approximately 24 adults estimated above the weir and 5 adults below the weir. The number of males was roughly twice the number of females. Nearly 44% of the adult abundance was NORs as median pHOS for the Elochoman River was 0.56 (22.02). Estimated median weir efficiency for the season was 97.06% with approximately 13 HORs estimated to have gotten by the weir. Scales were taken from the 17 NORs encountered at the weir for aging.

Table 3. Mean, median, standard deviation (SD), and 95% credible interval (CI) parameter estimates for the Elochoman/ Skamokawa Fall Chinook population in survey years 2018 and 2019.

Parameter	2018 Mean	2018 Median	2018 SD	2018 95% CI	2019 Mean	2019 Median	2019 SD	2019 95% CI
Elochoman								
Abundance	32.75	29.76	14.07	(19.12 – 66.58)	65.32	62.28	21.14	(37.76 – 114.20)
Females	11.01	9.58	8.30	(1.02 – 29.20)	21.85	19.20	14.85	(2.57 – 54.92)
Males	21.75	20.30	11.44	(5.90 – 47.41)	43.46	41.67	18.90	(13.66 – 83.36)
NORs	13.86	14.12	4.52	(5.41 – 22.73)	26.32	26.63	11.05	(7.23 – 47.60)
HOR EFT	14.88	12.48	11.15	(3.59 – 41.38)	38.04	35.11	12.88	(24.16 – 71.05)
HOR SAB[1]	4.01	3.21	319	(0.30 – 11.96)	0.96	0.71	0.84	(0.07 – 3.14)
pHOS	0.56	0.56	0.12	(0.31 – 0.80)	0.61	0.59	0.10	(0.45 – 0.82)
Skamokawa								
Abundance	17.23	13.58	14.26	(6.08 – 50.32)	97.68	82.14	61.69	(42.69 – 242.71)
Females	11.45	8.92	10.69	(1.78 – 36.73)	73.10	61.81	48.66	(26.31 – 193.21)
Males	5.79	3.96	7.38	(0.15 – 22.74)	24.58	19.08	23.19	(2.55 – 80.62)
NORs	5.62	3.85	6.51	(0.09 – 22.36)	12.02	9.32	11.14	(1.97 – 37.83)
HOR EFT	7.74	5.65	8.39	(0.71 – 27.17)	82.56	69.60	52.31	(35.13 – 209.63)
HOR SAB[1]	3.78	2.26	5.54	(0.08 – 16.09)	3.03	1.75	4.10	(0.06 – 13.77)
pHOS	0.67	0.71	0.24	(0.16 – 0.99)	0.88	0.89	0.06	(0.73 – 0.97)
Population								
Abundance	49.99	45.23	20.05	(29.45 – 99.21)	162.99	148.10	65.03	(95.46 – 322.50)
Females	22.46	19.91	13.61	(6.13 – 54.76)	94.95	84.87	50.75	(39.40 – 217.40)
Males	27.54	25.53	13.67	(8.92 – 59.46)	68.05	63.42	29.90	(26.87 – 137.80)
NORs	19.57	18.34	7.92	(8.05 – 38.84)	38.41	37.08	15.70	(14.25 – 72.84)
HOR EFT	22.62	19.71	13.98	(7.23 – 57.10)	120.60	107.80	53.78	(67.87 – 248.41)
HOR SAB[1]	7.79	6.49	6.39	(1.16 – 21.78)	3.98	2.80	4.20	(0.46 – 14.83)
pHOS	0.60	0.60	0.12	(0.35 – 0.81)	0.76	0.76	0.07	(0.63 – 0.89)
Age-3 NORs	8.27	8.04	3.35	(2.71 – 15.42)	22.16	22.21	9.00	(6.54 – 39.20)
Age-4 NORs	9.05	7.92	5.26	(2.85 – 22.19)	13.63	11.85	8.62	(3.74 – 34.73)
Age-5 NORs	1.81	1.35	1.83	(0.14 – 6.13)	2.08	1.29	2.71	(0.06 – 8.81)
Age-6 NORs	0.24	0.04	0.67	(0.00 – 1.73)	0.45	0.07	1.12	(0.00 – 3.23)
Age-3 HOR EFT	7.64	6.26	6.10	(1.41 – 22.52)	51.47	45.11	31.10	(18.92 – 120.41)
Age-4 HOR EFT	11.85	9.98	8.40	(2.80 – 32.19)	59.14	53.09	30.42	(24.52 – 133.70)
Age-5 HOR EFT	2.57	1.66	3.30	(0.10 – 10.53)	8.22	5.90	8.32	(0.39 – 28.75)
Age-6 HOR EFT	0.56	0.10	1.52	(0.00 – 3.78)	1.77	0.39	3.68	(0.00 – 12.00)
Age-3 HOR SAB	5.56	4.51	4.56	(0.74 – 16.17)	2.83	1.94	3.05	(0.30 – 10.96)
Age-4 HOR SAB	1.05	1.39	2.86	(0.15 – 7.52)	1.05	0.58	1.53	(0.06 – 4.87)
Age-5 HOR SAB	0.19	0.02	0.60	(0.00 – 1.46)	0.11	0.01	0.50	(0.00 – 0.85)
Age-6 HOR SAB	0.00	0.00	0.00	(0.00 – 0.00)	0.00	0.00	0.00	(0.00 – 0.00)

[1]The number of Select Area Brights (SAB), a stock of late fall/bright Chinook, encountered on the spawning grounds or at the weir are quantified annually and included in the adult abundance estimates for the population given the temporal overlap in EFT and SAB distribution.

In Skamokawa Creek, adult Fall Chinook were observed on the spawning grounds from September 12th to October 2nd in 2018. Peak count of lives and deads in the reference sections was 3 fish, which occurred on September 25th. No carcasses were sampled on the spawning grounds. A total of 12 redds were encountered during the season. Median (% CV) estimates of apparent residence time and apparent females per redd were 6.08 (29.90) days and 1.27 (44.20) females, respectively. Using AUC, a median adult abundance of 13.58 (82.73) was estimated for Skamokawa with twice as many females estimated as males (Table 3). As seen in the Elochoman, HORs were abundant as median pHOS was 0.71 (35.76). For the entire Elochoman/Skamokawa population, median abundance in 2018 was 45.23 (40.10) adults with males being more abundant than females and HORs being more abundant than NORs (Table 3). Median pHOS for the population was 0.60 (19.64) with approximately 28 HOR EFT and 5 straying HOR SABs estimated for the tributaries. Most adults were Age-3 or Age-4 fish (Table 3).

In 2019, adult Fall Chinook were observed on the Elochoman River from September 26th to October 24th. Peak count of lives and deads in the reference sections was 12 fish, which occurred on September 26th. No carcasses were sampled on the spawning grounds. At the weir, 149 HORs (one LV-clipped SAB and 148 ad-clipped HORs) were removed, and 33 live NORs were given an LOP and Floy tagged before being passed upstream. Twenty-five of these marked NORs were recaptured as live resights. A total of 16 redds were observed throughout the season with 13 observed above the weir and 3 observed below the weir. Median (% CV) estimates of apparent residence time and apparent females per redd were 4.21 (18.35) days and 1.07 (28.50) females, respectively. Based on RCE, median adult abundance for the entire river after adjustments was 62.28 (32.37; Table 3) with approximately 48 estimated above the weir and 12 below the weir. As observed in 2018, males were more prevalent than females. About 40% of the adult abundance was NORs as median pHOS for the entire stream was 0.59 (16.17). Estimated median weir efficiency for the season was high (97.88%) even though 28 HORs were estimated to have gotten by the weir. Scales were taken from the 35 NORs encountered at the weir for aging.

In Skamokawa Creek, adult Fall Chinook were observed on the spawning grounds from September 24th to November 5th in 2019. Peak count of lives and deads in the reference sections was 31 fish, which occurred on October 1st. No carcasses were sampled on the spawning grounds. A total of 59 redds were encountered during the season. Median (% CV) estimates of apparent residence time and apparent females per redd were 5.85 (30.20) days and 1.25 (43.47) females, respectively. Based on AUC, median adult abundance after adjustments was 82.14 (63.16) for the stream with females outnumbering males (Table 3). As seen in the Elochoman, HORs were abundant with a median pHOS of 0.89 (7.28) for the stream. For the entire Elochoman/Skamokawa population, median abundance in 2019 was 148.10 (39.90) adults with females being were more abundant than males and HORs being more abundant than NORs (Table 3). Median pHOS for the population was 0.76 (8.86) with approximately 168 HOR EFT and 4 straying HOR SABs estimated for the tributaries. Most adults were Age-3 or Age-4 fish (Table 3).

Comparing both survey years, adult spawner abundance for the Elochoman/Skamokawa population was quite a bit higher in 2019, but so was the number of HOR adults resulting in an increase in pHOS. Males outnumbered females in 2018, but not in 2019. In both years, HORs outnumbered NORs with most fish being aged as 3 or 4-year-olds. Median NOR abundance was comparable across both years, and comparable to the number of NOR adult spawners observed over the past ten years (Figure 3). The range in NOR adult spawner abundance has shown little fluctuation over the past ten years, but HOR abundance has fluctuated considerably ranging from approximately 10 fish to just over 1400 (Figure 3). The largest return year to-date was 2015 for NORs and 2010 for HORs.

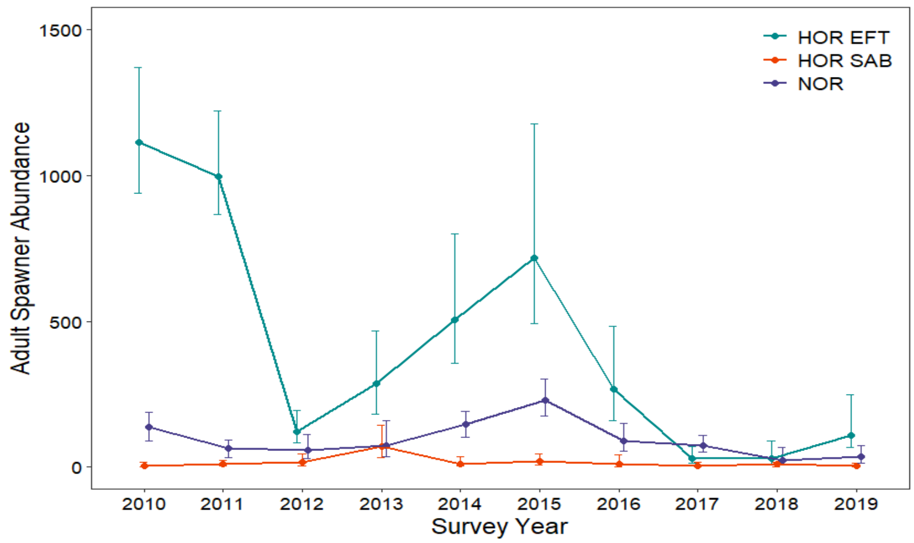

Figure 3. Estimated adult abundances of hatchery-origin (HOR) early fall/tule (EFT), HOR select area brights (SAB), and natural-origin (NOR) Fall Chinook salmon that spawned in survey years 2010 – 2019 for the Elochoman/Skamokawa population. Point estimates are medians and error bars represent the 95% credible intervals.

Mill/Abernathy/Germany

In 2018, adult EFT Chinook were observed in Mill, Abernathy, and Germany Creeks on September 17th through October 31st. Peak count in reference sections of Mill Creek was 1 fish observed on October 31st. Peak counts in reference sections of Germany and Abernathy were 1 and 6 fish, respectively, observed on September 24th. Only a single male carcass was sampled for the population on the spawning grounds in Abernathy Creek. Total redd count for the season in all three tributaries was 30 redds. No population-specific estimate for apparent females per redd was generated given that individual redds were not tracked. Median (% CV) estimates of apparent residence time were 6.35 (14.14), 7.33 (17.52), and 6.89 (16.79) days for Mill, Abernathy, and Germany Creeks, respectively. Based on AUC, median abundances after adjustments were 1.97 (80.14), 8.65 (48.99), and 1.31 (39.06) adults for Mill, Abernathy, and Germany Creeks, respectively. Median adult abundance for the entire population was 12.68 (38.40) with double the number of females as males (Table 4). Nearly 37% of the adult abundance was NORs as median pHOS for the entire population was 0.63 (30.32). Scales were taken from the single carcass for aging, and ages were estimated based on CWTs or prior age classes observed in the streams. Most of the adults were estimated as Age-4 fish (Table 4).

In 2019, adult EFT Chinook were observed in Mill, Abernathy, and Germany Creeks on September 25th through October 14th. Peak count in reference sections of Abernathy Creek was 142 fish observed on September 19th. Peak counts in reference sections of Mill and Germany Creeks were 10 and 42 fish, respectively, observed on October 2nd. For the 53 carcasses sampled in Abernathy Creek, 25 were males and 28 were females with no pre-spawn mortalities observed. Of the 11 carcasses sampled in Germany Creek, 4 were males and 7 were females with no pre-spawn mortalities observed. No carcasses were sampled in Mill Creek. Total redd count for the season in all three tributaries was 198 redds. A population-specific estimate for apparent females per redd was not generated given that individual redds were not tracked. Median (% CV) estimates of apparent residence time were 6.47 (19.19), 7.15 (17.26), and 6.82 (18.81) days for Mill, Abernathy, and Germany Creeks, respectively.

Based on AUC, median abundances after adjustments were 0.16 (20.00), 194.15 (18.88), and 66.12 (19.86) adults for Mill, Abernathy, and Germany Creeks, respectively. Median abundance for the entire population was 268.53 (14.89) adults with males outnumbering females (Table 4). HORs were abundant as median pHOS for the entire population was 0.96 (2.95). Scales were taken from 50 carcasses for aging. Most of the adults were Age-3 based on scales and CWTs (Table 4).

Table 4. Mean, median, standard deviation (SD), and 95% credible interval (CI) parameter estimates for the Mill/Abernathy/Germany early fall/tule Chinook population in survey years 2018 and 2019.

Parameter	2018				2019			
	Mean	**Median**	**SD**	**95% CI**	**Mean**	**Median**	**SD**	**95% CI**
Mill								
Abundance	2.57	1.97	2.06	(1.15 – 7.69)	0.16	0.16	0.03	(0.11 – 0.22)
Females	1.70	1.34	1.53	(0.30 – 5.59)	0.11	0.11	0.04	(0.03 – 0.18)
Males	0.87	0.61	1.08	(0.03 – 3.28)	0.05	0.05	0.04	(0.00 – 0.14)
NORs	1.71	1.35	1.60	(0.28 – 5.51)	0.11	0.11	0.04	(0.02 – 0.18)
HORs	0.86	0.60	0.99	(0.02 – 3.34)	0.05	0.05	0.04	(0.00 – 0.14)
pHOS	0.33	0.29	0.24	(0.01 – 0.84)	0.34	0.30	0.24	(0.01 – 0.84)
Abernathy								
Abundance	10.10	8.65	4.95	(6.47 – 22.26)	200.56	194.15	37.86	(146.90 – 287.90)
Females	6.75	6.17	4.29	(1.31 – 16.50)	105.64	102.40	24.09	(68.33 – 160.90)
Males	3.35	2.69	3.04	(0.12 – 10.75)	94.92	91.61	22.56	(59.87 – 148.20)
NORs	3.37	2.66	3.23	(0.09 – 10.54)	6.95	5.50	5.71	(0.53 – 21.99)
HORs	6.74	6.17	4.16	(1.28 – 16.92)	193.61	187.70	36.99	(141.50 – 279.00)
pHOS	0.67	0.71	0.24	(0.15 – 0.99)	0.97	0.97	0.03	(0.89 – 0.99)
Germany								
Abundance	1.48	1.31	0.58	(1.05 – 2.99)	67.80	66.12	13.47	(46.91 – 98.69)
Females	0.98	0.94	0.54	(0.21 – 2.26)	41.70	40.49	12.36	(21.12 – 70.11)
Males	0.50	0.42	0.43	(0.02 – 1.51)	26.10	25.02	10.21	(9.58 – 48.59)
NORs	0.50	0.40	0.45	(0.01 – 1.51)	5.10	3.43	5.29	(0.06 – 19.14)
HORs	0.98	0.95	0.53	(0.20 – 2.21)	62.70	61.14	13.45	(41.26 – 93.68)
pHOS	0.66	0.70	0.24	(0.15 – 0.99)	0.92	0.95	0.07	(0.72 – 0.99)
Population								
Abundance	14.16	12.68	5.44	(9.44 – 27.33)	268.53	263.30	39.98	(207.80 – 359.80)
Females	9.44	8.73	4.63	(3.48 – 20.35)	110.85	107.70	24.67	(72.17 – 167.00)
Males	4.71	4.04	3.27	(0.89 – 12.71)	157.68	155.20	25.97	(114.40 – 215.80)
NORs	5.58	4.85	3.63	(1.41 – 13.72)	12.16	10.50	7.76	(2.13 – 31.60)
HORs	8.58	7.94	4.35	(2.76 – 18.90)	256.37	251.10	39.10	(196.00 – 345.90)
pHOS	0.61	0.63	0.18	(0.22 – 0.89)	0.95	0.96	0.03	(0.88 – 0.99)
Age-3 NORs	1.19	0.84	1.25	(0.10 – 4.14)	3.47	2.59	3.21	(0.12 – 12.16)
Age-4 NORs	3.60	2.99	2.62	(0.77 – 9.74)	7.13	5.90	5.21	(1.01 – 20.61)
Age-5 NORs	0.66	0.38	0.89	(0.02 – 2.90)	1.30	0.69	1.75	(0.03 – 6.02)
Age-6 NORs	0.13	0.02	0.34	(0.00 – 1.00)	0.27	0.02	0.75	(0.00 – 2.22)
Age-3 HORs	3.72	3.18	2.54	(0.75 – 9.96)	172.66	169.35	31.32	(121.80 – 242.90)
Age-4 HORs	3.86	3.32	2.57	(0.94 – 9.75)	78.57	76.64	19.46	(45.75 – 122.80)
Age-5 HORs	0.82	0.48	1.01	(0.03 – 3.56)	4.22	2.79	4.37	(0.09 – 16.05)
Age-6 HORs	0.18	0.03	0.47	(0.00 – 1.52)	0.92	0.09	2.02	(0.00 – 6.89)

Comparing the population-level estimates between survey years (Table 4), adult abundance was significantly higher in 2019, but so was the number of HOR returns resulting in a considerable increase in pHOS. The observed sex ratio was skewed towards females in 2018, but male dominant in 2019. HORs outnumbered NORs in both return years. Over the past ten years, HORs have outnumbered NORs, but spawner abundances have been low since 2016 (Figure 4). The highest return year to-date was 2010 for both HORs and NORs (Figure 4). Notably, NOR Fall Chinook abundances for this population are considerably lower than most of the other Fall Chinook populations in the LCR Chinook ESU.

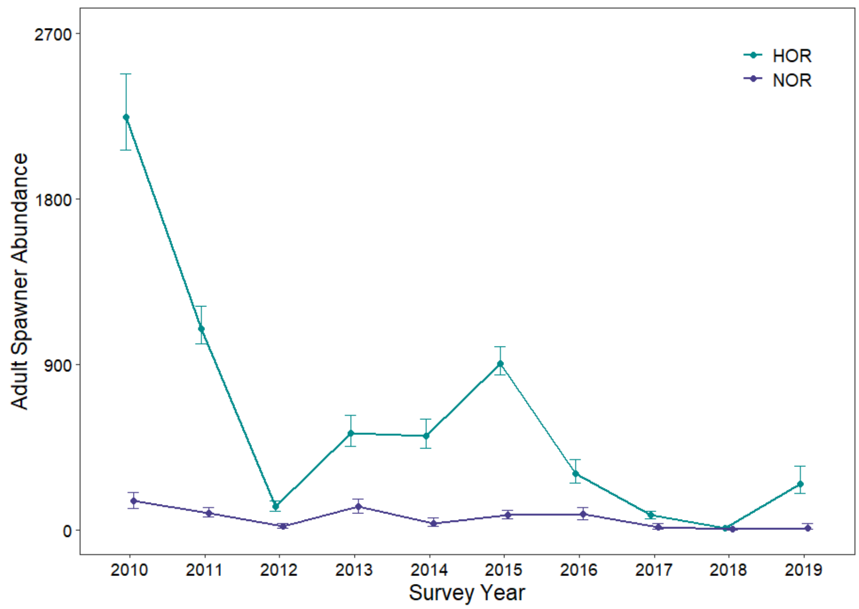

Figure 4. Estimated adult abundances of hatchery-origin (HOR) and natural-origin (NOR) early fall/tule Chinook salmon that spawned in survey years 2010 – 2019 for the Mill/Abernathy/Germany population. Point estimates are medians and error bars represent the 95% credible intervals.

Cascade Strata

Cowlitz

As mentioned in the methods, monitoring work done in the Cowlitz Basin is different than in other tributaries given that the work is contracted to WDFW from Tacoma Power. Brief details on the lower and upper watershed, methods used, and results from survey years 2018 and 2019 are presented below; however, detailed information for the Cowlitz Basin can be found in Serl et al. (2019, 2020). The Cowlitz Basin has multiple designated Chinook populations including the Lower Cowlitz Fall Chinook, Upper Cowlitz Spring Chinook, Cispus (historic) Spring Chinook, Tilton (historic) Spring Chinook, and Upper Cowlitz Fall Chinook. Both the Lower and Upper Cowlitz Fall Chinook populations consist of early fall/tule Chinook. In this basin, Spring and Fall Chinook abundances are estimated from a combination of RCE based on aerial and boat stream surveys, number of adult returns to the Cowlitz Salmon Hatchery/Barrier Dam, and the number of adults translocated into the upper basin above the dams (Table 1). Harvest estimates are generated from CRC data and creel surveys to estimate total escapement; however, only adult spawner abundances are presented in this report.

a) Lower Cowlitz Designated Population

In 2018 and 2019, aerial surveys during peak spawning and weekly boat stream surveys were conducted in the Lower Cowlitz. Redd counts from the aerial flights were multiplied by an expansion factor of 2.84 fish per redd that was specifically developed for aerial surveys in the basin. Boat surveys were conducted weekly to collect biological data from carcasses including run type (spring or fall), fork length, scales for aging, mark status, and presence/absence of a CWT. All Spring Chinook carcasses and NOR Fall Chinook carcasses that were encountered were sampled. A 25% subset of HOR Fall Chinook carcasses were sampled. Adult Spring Chinook were designated as fish over 59-cm in fork length, and adult Fall Chinook were designated as fish over 49-cm in fork length.

For the designated Lower Cowlitz Fall Chinook population, peak redd count observed on October 17^{th,} 2018 was 1251 redds. Based on RCE, the point estimate for total spawner abundance was 3553 fish. Excluding jacks, the adult spawner abundance for the population was 3229 Fall Chinook, which included 2728 NORs and 501 HORs for an adult pHOS of 16% (Table 5). Most adults were aged as Age-4 fish (Table 5; Serl et al. 2018). In 2019, peak redd count for the Lower Cowlitz Fall Chinook population was 1786 redds, and occurred on November 13th. The point estimate for total spawner abundance for the population using RCE was 5072 fish. Excluding jacks, the adult spawner abundance was 4931, which included 540 HORs and 4391 NORs for an adult pHOS of 11%. As seen in 2018, most adults were aged as Age-4 fish (Table 5; Serl et al. 2019).

Table 5. Parameter estimates for the Lower Cowlitz early fall/tule Chinook population in survey years 2018 and 2019. No credible intervals were generated for these estimates. Details can be found in Serl et al. (2019, 2020).

Year	Abundance	NORs	HORs	pHOS	NORs				HORs			
					Age-3	Age-4	Age-5	Age-6	Age-3	Age-4	Age-5	Age-6
2018	3229	2728	501	0.16	942	1687	99	0	173	310	18	0
2019	4931	4391	540	0.11	760	3486	145	0	93	429	18	0

Examining adult abundances over the past ten years for the Lower Cowlitz Fall Chinook population, NOR abundances have been higher than HORs, fluctuating between roughly 1600 and 4500 adults (Figure 5). The number of HOR spawning adults has slowly declined over three of the past five years.

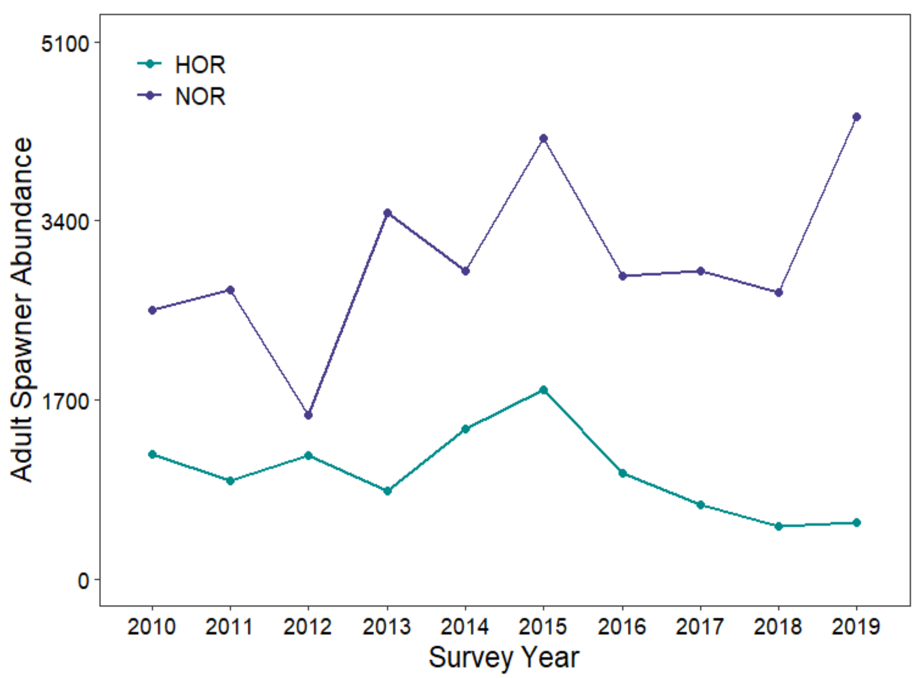

Figure 5. Estimated adult abundances of hatchery-origin (HOR) and natural-origin (NOR) early fall/tule Chinook salmon that spawned in surveys years 2010 – 2019 for the Lower Cowlitz Fall Chinook population. No credible intervals were generated for point estimates. Additional details can be found in Serl et al. (2020).

b) Upper Cowlitz Designated Populations

For designated populations from the upper watershed, fish passage is impeded by dams including the Cowlitz Salmon Hatchery/Barrier Dam. Both the designated Cispus (historic) and Tilton (historic) Spring Chinook populations that originated from the upper watershed are considered extirpated or very low abundance due to the lack of fish passage. For the designated Upper Cowlitz Spring Chinook population, annual abundances are estimated from the number of spawners in the Lower Cowlitz below the Barrier Dam and the adult returns to the Cowlitz Salmon Hatchery/Barrier Dam that are released into the Upper Cowlitz as part of a Cispus River reintroduction program.

Similar methods of RCE from aerial surveys and weekly boat stream surveys that was used for estimating Lower Cowlitz Fall Chinook abundances were used to quantify the number of Spring Chinook spawners in the Lower Cowlitz in 2018 and 2019. In 2018, peak redd count for Spring Chinook was 186 redds, which was observed on September 19th. Based on RCE, the point estimate for adult spawner abundance was 528 fish. These 528 adults were partitioned into 480 NORs and 48 HORs (Figure 6) based on a pHOS of 91% observed from carcasses recoveries (see Serl et al. 2019). In 2019, peak redd count for Spring Chinook was 153 redds, which was observed on September 18th. Based on RCE, the point estimate for adult spawner abundance was 435 fish. These 435 adults were partitioned into 409 NORs and 26 HORs (Figure 6) based on a pHOS of 94% observed from carcass recoveries (see Serl et al. 2020).

For the Spring Chinook that ascend the fish ladder into the Cowlitz Salmon Hatchery/Barrier Dam, a subset of HOR and NOR adults were transported by truck to the upper watershed as part of the reintroduction program. In 2018, a total of 2758 Spring Chinook returned to the Barrier Dam. Of these fish, 154 were NOR adults and 2514 were HOR adults based on fork length. A total of 779 adults (154 NORs and 625 HORs) were trucked and released into the Upper Cowlitz (Figure 6). In 2019, a total of 1569 Spring Chinook returned to the Barrier Dam. Of these fish, 55 were NOR adults and 1071 were HOR adults based on fork length. A total of 92 adults (37 NORs and 55 HORs) were trucked and released into the Upper Cowlitz (Figure 6). In both survey years, the remaining fish that were not trucked to the upper watershed were either surplussed, released into Riffe Lake (minijacks only), or utilized as hatchery broodstock (Serl et al. 2019, 2020).

Examining abundances over the past ten years for the Upper Cowlitz Spring Chinook population, the number of adult Spring Chinook spawning in the Lower Cowlitz ranges from approximately 80 to 1400 adults (Figure 6a). NOR spawner abundances have been considerably lower than HOR abundances except in 2018 and 2019 (Figure 6a). The number of Spring Chinook that return to the Barrier Dam and are trucked to the upper watershed annually as part of the reintroduction effort ranges from approximately 50 to 15000 adults (Figure 6b). Over the past ten years, the number of HORs being transported have greatly outnumbered the number of NORs, with the highest number of fish being trucked in 2015 (Figure 6b). Fewer adult Spring Chinook were transported in 2018 and 2019 than what was trucked upstream in 2010 – 2017 (Figure 6b).

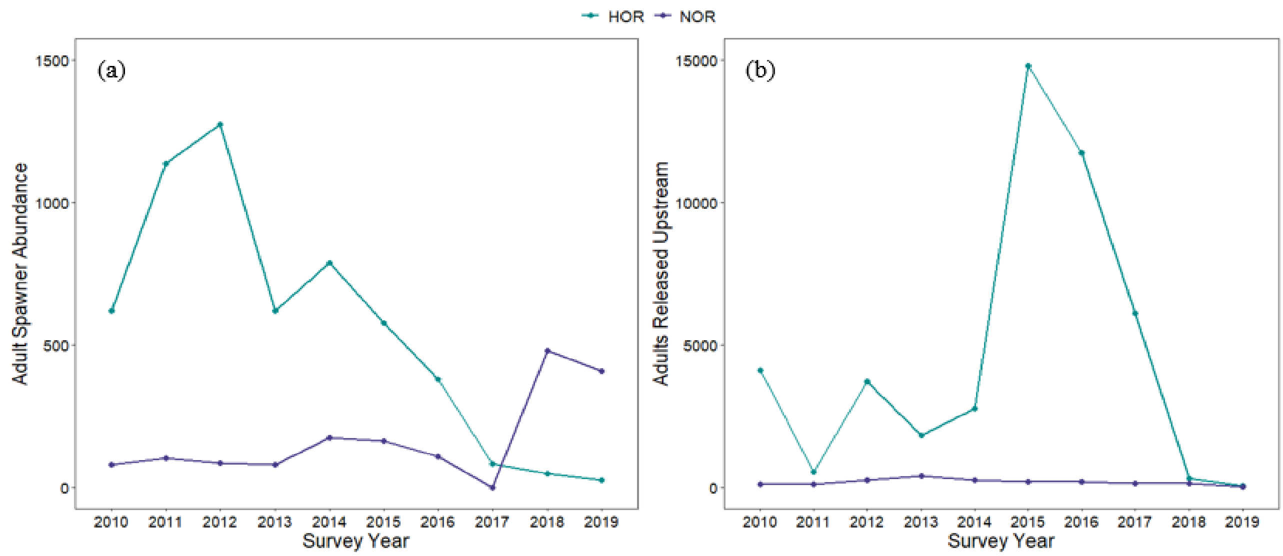

Figure 6. (a) Estimated number of hatchery-origin (HOR) and natural-origin (NOR) adult Spring Chinook salmon that spawned in the Lower Cowlitz River, and (b) the number of adult HOR and NOR Spring Chinook that returned to the Cowlitz Salmon Hatchery/Barrier Dam and were trucked upstream to the Upper Cowlitz/Cispus Rivers for the Upper Cowlitz Spring Chinook populations between 2010 – 2019. No credible intervals were generated for point estimates. Refer to Serl et al. (2020) for additional details.

For the designated Upper Cowlitz Fall Chinook population, abundances were estimated as the number of adult returns to the Cowlitz Salmon Hatchery/Barrier Dam that were trucked and released into the Tilton River as part of a reintroduction program. In 2018, a total of 2393 Fall Chinook returned to the Barrier Dam. Of these fish, 915 were NOR adults and 1081 were HOR adults based on fork length. A total of 674 adults (622 NORs and 52 HORs) were trucked and released into the Tilton River. In 2019, a total of 2388 Fall Chinook returned to the Barrier Dam. Of these fish, 919 were NOR adults and 1282 were HOR adults based on fork length. A total of 544 adults (543 NORs and 1 HOR) were trucked and released into the Tilton River. In both survey years, the remaining fish that were not trucked to the upper watershed were either surplussed, released into Mayfield Lake, or utilized as hatchery broodstock (Serl et al. 2019, 2020).

The number of adult Fall Chinook that return to the Barrier Dam and are trucked to the upper watershed annually as part of the reintroduction effort ranges from approximately 500 to 6500 adults. In eight of the past ten years, the number of NOR adults being transported have outnumbered the number of HOR adults (Figure 7). The highest number of NORs were transported in 2011, and the highest number of HORs were transported in 2014. Fewer adults were transported upstream in both 2018 and 2019 in comparison to the number of adults being trucked upstream in 2019 – 2017 (Figure 7).

Refer to Serl et al. (2019) and (2020) for additional survey information, maps of the Cowlitz Basin, and discussion of monitoring data implications for the Lower Cowlitz Fall Chinook, Upper Cowlitz Spring Chinook, and Upper Cowlitz Fall Chinook populations.

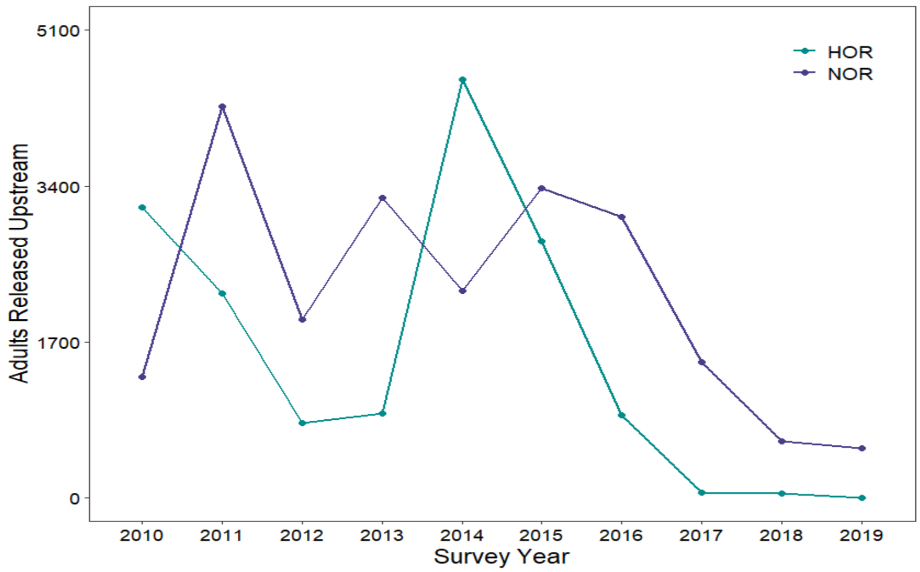

Figure 7. The number of hatchery-origin (HOR) and natural-origin (NOR) adult early fall/tule Chinook salmon that returned to the Cowlitz Salmon Hatchery/Barrier Dam and were trucked upstream to the Tilton River for the Upper Cowlitz Fall Chinook population in survey years 2010 – 2019. Refer to Serl et al. (2020) for additional details.

Toutle (Green/North Fork Toutle and South Fork Toutle)

The designated Toutle Spring Chinook population is believed to be at a very low abundance with a few early-migrating fish seen annually, but no monitoring plan is currently in place to differentiate Spring Chinook from Fall Chinook adults. Therefore, abundances are reported as zero for survey years 2018 and 2019. For the designated Toutle Fall Chinook population, the Green and North Fork Toutle Rivers are reported as one tributary in this report and on SCoRE given survey methodology.

In 2018, adult EFT Chinook were observed on the spawning grounds of the Green/North Fork Toutle River from September 17th to October 11th. Peak count of dead adults in the reference sections was 11, which occurred on October 11th. A total of 30 carcasses (7 above the weir, 23 below the weir) were sampled on the spawning grounds. The sex composition of sampled carcass was 22 females and 8 males. A total of two females, both from below the weir, were identified to be pre-spawn mortalities. At the weir, 1145 HORs and 31 NORs were removed as surplus, mortalities, and/or for brood. A total of 67 NORs were given an LOP and Floy tagged before being passed upstream. Seventeen of these tagged NORs were resighted. A total of 106 redds (71 above the weir, 35 below the weir) were tracked throughout the season. Median (% CV) estimates of apparent residence time and apparent females per redd were 5.98 (30.77) days and 1.16 (52.63) females, respectively. Median abundance above the weir based on L-P modeling was estimated as 91.61 (13.89) adults. Based on RCE, median abundance below the weir after adjustments was 51.05 (52.78) adults. Median abundance for the entire stream was estimated as 143.40 (21.66) adults with a higher number of females returning than males (Table 6). Nearly 57% of the adult abundance was NORs as median pHOS for the stream was 0.43 (26.97). Estimated median weir efficiency for the season was 83.30% with approximately 61 HORs estimated to have gotten by the weir. Scales were taken for aging from all 30 carcasses as well as the 98 NORs encountered at the weir.

On the South Fork Toutle, adult EFT Chinook were observed on the spawning grounds from September 18th to October 22nd in 2018. Peak count of live and dead fish in the reference sections was 17, which occurred on October 9th. Of the 12 carcasses sampled on the spawning grounds, 6 were female and 6 were male. No female pre-spawn mortalities were sampled. There were 97 redds tracked in the stream. Median (% CV) estimates of apparent residence time and apparent females per redd were 5.98 (29.86) days and 0.50 (47.00) females, respectively. Based on RCE, median abundance in the stream was 87.55 (45.15) adults with female returns being slightly higher than male returns (Table 6). Median pHOS was comparable to the Green/North Fork Toutle at 0.42 (32.32). Scales were taken from all 12 carcasses for aging. In 2018, median spawner abundance for the entire Toutle Fall Chinook population was estimated as 238.20 (22.15) adults with a higher number of females than males (Table 6). Nearly 57% of the adult abundance was NORs as median pHOS for the population was 0.43 (20.84). Most adults in the population returned as 4-year-olds based on scales and CWTs (Table 6).

Table 6. Mean, median, standard deviation (SD), and 95% credible interval (CI) parameter estimates for the Toutle early fall/tule Chinook population in survey years 2018 and 2019.

Parameter	2018				2019			
	Mean	Median	SD	95% CI	Mean	Median	SD	95% CI
Green/North Fork								
Abundance	146.73	143.40	31.78	(92.85 – 212.80)	320.48	303.65	105.89	(162.60 – 568.11)
Females	89.20	86.12	24.66	(49.49 – 141.00)	136.91	129.50	50.43	(58.53 – 252.80)
Males	57.53	56.13	11.38	(40.03 – 84.08)	183.58	171.00	62.85	(98.66 – 335.81)
NORs	82.18	81.88	15.37	(53.24 – 110.13)	82.36	82.32	32.99	(20.42 – 146.50)
HORs	64.56	61.41	27.47	(20.44 – 120.91)	238.13	221.60	106.01	(78.76 – 481.31)
pHOS	0.43	0.43	0.11	(0.20 – 0.64)	0.72	0.74	0.13	(0.43 – 0.94)
South Fork Toutle								
Abundance	97.23	87.55	43.90	(42.59 – 218.23)	145.66	136.60	50.03	(73.14 – 270.41)
Females	52.86	48.81	24.90	(20.07 – 115.71)	78.25	73.94	27.83	(36.14 – 147.50)
Males	44.37	39.29	26.54	(12.62 – 113.30)	67.41	61.44	31.70	(25.50 – 145.11)
NORs	55.74	49.27	29.33	(18.43 – 122.89)	33.32	29.64	18.82	(8.34 – 78.85)
HORs	41.49	36.76	23.54	(12.69 – 101.02)	112.34	104.90	41.96	(51.95 – 216.41)
pHOS	0.43	0.42	0.14	(0.18 – 0.72)	0.77	0.78	0.10	(0.55 – 0.93)
Population								
Abundance	243.97	238.20	54.05	(160.90 – 375.01)	466.15	451.70	116.57	(283.10 – 734.93)
Females	142.06	139.35	34.80	(85.65 – 221.25)	215.16	208.95	57.44	(121.00 – 340.31)
Males	101.90	96.87	28.86	(62.57 – 166.70)	250.99	240.30	69.89	(147.00 – 418.20)
NORs	137.92	133.45	32.95	(87.22 – 217.20)	115.68	115.10	37.82	(46.33 – 192.31)
HORs	106.05	101.70	36.27	(48.78 – 185.92)	350.47	334.55	113.39	(170.50 – 607.92)
pHOS	0.43	0.43	0.09	(0.26 – 0.61)	0.74	0.75	0.09	(0.55 – 0.90)
Age-3 NORs	19.00	15.53	13.22	(3.26 – 49.75)	59.09	58.75	23.39	(15.82 – 105.70)
Age-4 NORs	84.21	80.32	26.40	(44.72 – 144.94)	48.65	46.53	18.34	(19.48 – 91.49)
Age-5 NORs	32.96	31.01	15.76	(9.03 – 68.93)	7.28	5.53	6.33	(0.67 – 23.15)
Age-6 NORs	1.75	0.26	4.27	(0.00 – 12.46)	0.65	0.09	1.79	(0.00 – 5.03)
Age-3 HORs	37.42	34.82	15.95	(12.53 – 72.03)	63.64	58.44	31.07	(19.24 – 138.70)
Age-4 HORs	60.59	57.31	23.60	(25.50 – 112.82)	273.82	261.70	91.25	(132.29 – 481.50)
Age-5 HORs	7.03	5.52	5.88	(0.90 – 22.74)	10.71	7.47	10.55	(0.50 – 39.58)
Age-6 HORs	1.02	0.19	2.20	(0.00 – 7.09)	2.30	0.48	4.71	(0.00 – 15.98)

In 2019, adult EFT Chinook were observed on the spawning grounds of the Green/North Fork Toutle River from September 19th to November 4th. Peak count of dead fish in the reference sections was 17, which occurred on October 8th. A total of 32 carcasses (1 above the weir, 31 below the weir) were sampled on the spawning grounds. The sex composition of sampled carcasses was 16 females and 16 males. A total of three females, all below the weir, were identified to be pre-spawn mortalities. At the weir, 465 HORs and 45 NORs were removed as surplus, mortalities, and/or for brood. A total of 121 NORs were given an LOP and Floy tagged before being passed upstream. One tagged NOR was recaptured, and 19 were resighted. There were 142 redds tracked throughout the season (58 above the weir, 84 below the weir). Median (% CV) estimates of apparent residence time and apparent females per redd were 5.91 (33.20) days and 1.13 (48.83) females, respectively. Based on L-P modeling, median abundance above the weir after adjustments was 1186.60 (17.72) adults. Median abundance below the weir after adjustments based on RCE was 183.75 (51.77) adults. Median abundance for the entire stream was estimated as 303.65 (33.04) adults with males outnumbering females (Table 6). There was an abundance of HORs as median pHOS for the stream was 0.74 (18.50). Estimated median weir efficiency for the season was 95.70%, and approximately 39 HORs were estimated to have gotten by the weir. Scales were taken for aging from all 32 carcasses encountered on the spawning grounds as well as the 121 NORs encountered at the weir.

On the South Fork Toutle, adult EFT Chinook were observed on the spawning grounds from September 20^{th} to October 23^{rd} in 2019. Peak count of live and dead fish in the reference sections was 30, which occurred on October 7^{th}. Of the 17 carcasses sampled on the spawning grounds, 9 were female and 8 were male. No female pre-spawn mortalities were observed. There were 73 redds tracked in the stream. Median estimates of apparent residence time and apparent females per redd were 5.97 (33.49) days and 1.00 (35.58) females, respectively. Based on RCE, median abundance in the stream was 136.60 (34.35) adults with a slightly higher number of females than males (Table 6). Median pHOS was high at 0.78 (12.93) for the stream. Scales were taken from all 17 carcasses for aging. Median spawner abundance for the entire Toutle Fall Chinook population was estimated as 451.70 (25.01) adults with males outnumbering females (Table 6). Only 26% of adults were NORs as median pHOS for the entire population was 0.75 (12.40). Most adults in the population were 4-year-olds based on scales and CWTs (Table 6).

Comparing the population-level estimates between survey years (Table 6), adult spawner abundance was nearly double in 2019, but the number of HOR adults tripled resulting in a considerable increase in pHOS. The observed sex ratio was skewed towards females in 2018, but male dominant in 2019. HORs outnumbered NORs in 2019. Over the past ten years, HOR and NOR adult spawner abundances have shown similar distribution patterns with abundances slightly fluctuating each year (Figure 8). For five of the last ten years, HORs have outnumbered NORs, but abundances decreased in 2014 and have been under 700 adults for both HORs and NORs since then (Figure 8). The highest return year to-date was 2010 for HORs and 2013 for NORs (Figure 8).

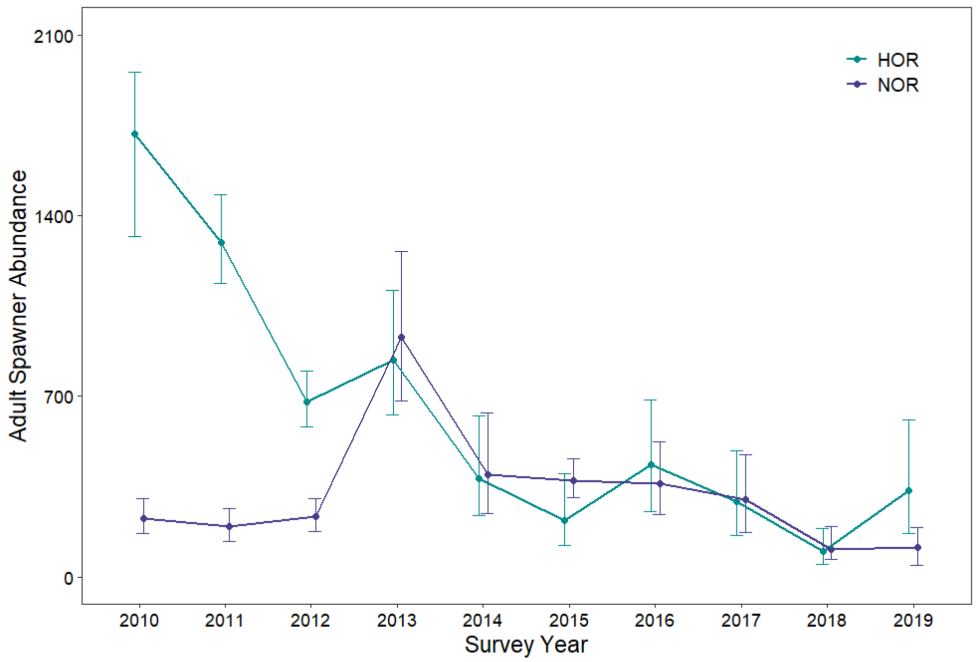

Figure 8. Estimated adult abundances of hatchery-origin (HOR) and natural-origin (NOR) early fall/tule Chinook salmon that spawned in survey years 2010 – 2019 for the Toutle population. Point estimates are medians and error bars represent the 95% credible intervals.

Coweeman

In 2018, adult EFT Chinook were observed on the spawning grounds from September 9th to November 6th. Peak count of lives and deads in reference sections was nine fish, which occurred on October 4th. A total of 16 carcasses (14 above the weir, 2 below the weir) were sampled on the spawning grounds. The sex composition of recovered carcasses was 10 females and 6 males, with one female identified as a pre-spawn mortality. At the weir, 60 HORs were removed and 198 NORs were given an LOP and Floy tagged before being passed upstream. Nine of these tagged NORs were recaptured. A total of 105 redds were tracked throughout the season with 98 observed above the weir, and 7 observed below the weir. Medan (% CV) estimates of apparent residence time and apparent females per redd were 5.86 (17.11) days and 1.15 (25.19) females, respectively. Based on L-P modeling, median adult abundance above the weir was 216.20 (14.22) adults. Median adult abundance below the weir based on RCE and after adjustments was 15.94 (49.40) adults. Median adult abundance for the entire population was estimated as 235.00 (13.62) with a slightly higher number of females than males (Table 7). Nearly 90% of the adult abundance was NORs as median pHOS for the population was 0.10 (54.24). Estimated median weir efficiency for the season was 77.21%, with14 HORs estimated to have gotten by the weir. Scales were taken for aging from the 16 carcasses as well as the 198 NORs encountered at the weir (N=212 total). Most adults returned as 4-year-olds based on scales and CWTs (Table 7).

In 2019, adult EFT Chinook were observed on the spawning grounds from September 9th to October 21st. Peak count of lives and deads in reference sections was 5 fish, which occurred on October 21st. A total of 4 carcasses (3 above the weir, 1 below the weir) were sampled on the spawning grounds. The sex composition of recovered carcasses was 3 females and 1 male; no pre-spawn females were observed. At the weir, 97 HORs were removed and 221 NORs were given an LOP and Floy tagged before being passed upstream. Six of these tagged NORs were recaptured. A total of 70 redds were tracked throughout the season with 58 observed above the weir, and 12 observed below the weir.

Median (% CV) estimates of apparent residence time and apparent females per redd were 5.81 (19.41) days and 1.23 (25.46) females, respectively. Median adult spawner abundance above the weir based on L-P modeling was 297.40 (32.29). Median spawner abundance below the weir using RCE and after adjustments was 28.99 (82.12) adults. Median adult abundance for the entire Fall Chinook population was estimated as 335.30 (30.25) with females outnumbering males (Table 7). Nearly 82% of the adult abundance was NORs as median pHOS for the population was 0.18 (69.06). Median weir efficiency for the season was 75.57% with approximately 65 HORs estimated to have gotten by the weir. Scales were taken for aging from 3 of the carcasses as well as the 221 live NORs encountered at the weir (N=224 total). Most adults were 3-year-olds based on scales and CWTs (Table 7).

Table 7. Mean, median, standard deviation (SD), and 95% credible interval (CI) parameter estimates for the Coweeman early fall/tule Chinook population in survey years 2018 and 2019.

Parameter	2018				2019			
	Mean	**Median**	**SD**	**95% CI**	**Mean**	**Median**	**SD**	**95% CI**
Abundance	243.68	235.00	33.19	(209.60 – 331.61)	365.98	335.30	110.70	(265.40 – 658.70)
Females	140.23	138.10	33.67	(82.51 – 212.00)	222.15	211.20	98.84	(76.70 – 459.01)
Males	103.46	101.10	31.12	(50.72 – 171.60)	143.82	131.50	82.04	(30.48 – 336.51)
NORs	215.53	209.20	33.56	(167.49 – 300.70)	286.74	268.00	106.07	(133.69 – 547.22)
HORs	28.15	24.70	15.79	(7.75 – 68.02)	79.24	63.88	62.69	(8.90 – 233.50)
pHOS	0.12	0.10	0.06	(0.03 – 0.27)	0.22	0.18	0.15	(0.03 – 0.58)
Age-3 NORs	53.64	52.17	11.44	(35.98 – 79.24)	183.56	171.10	71.20	(81.14 – 358.10)
Age-4 NORs	151.29	147.30	24.75	(115.4 – 213.51)	89.59	83.35	34.35	(42.15 – 175.11)
Age-5 NORs	10.39	9.79	4.08	(4.25 – 19.94)	12.88	11.31	7.58	(3.89 – 31.20)
Age-6 NORs	0.21	0.01	0.53	(0.00 – 1.80)	0.72	0.04	2.30	(0.00 – 6.11)
Age-3 HORs	9.14	7.10	7.54	(1.10 – 29.02)	27.23	17.84	29.28	(1.77 – 108.30)
Age-4 HORs	15.14	12.71	10.07	(3.22 – 41.33)	41.25	30.03	38.54	(3.04 – 144.00)
Age-5 HORs	3.22	1.85	4.15	(0.05 – 14.55)	8.74	3.61	15.26	(0.07 – 48.79)
Age-6 HORs	0.65	0.05	1.72	(0.00 – 5.15)	2.02	0.09	6.91	(0.00 – 18.91)

Comparing both return years (Table 7), adult spawner abundance was higher in 2019, but so was the number of HORs resulting in an increase in pHOS despite similar weir efficiencies. The observed sex ratio was comparable with females outnumbering males. NORs greatly outnumbered HORs, but notably the NOR returns in 2019 were younger with most fish being 3-year-olds. Median NOR abundances observed in 2018 and 2019 were slightly lower in comparison to previous survey years (Figure 9), but median HOR abundances were comparable. Over the past ten years, adult NOR EFT abundance in the Coweeman River has ranged from approximately 100 to 2500 adults with the highest abundance occurring in 2013 (Figure 9). Median HOR abundances have always been lower than NOR abundances, but follow similar patterns with 2013 being the highest abundance year to date.

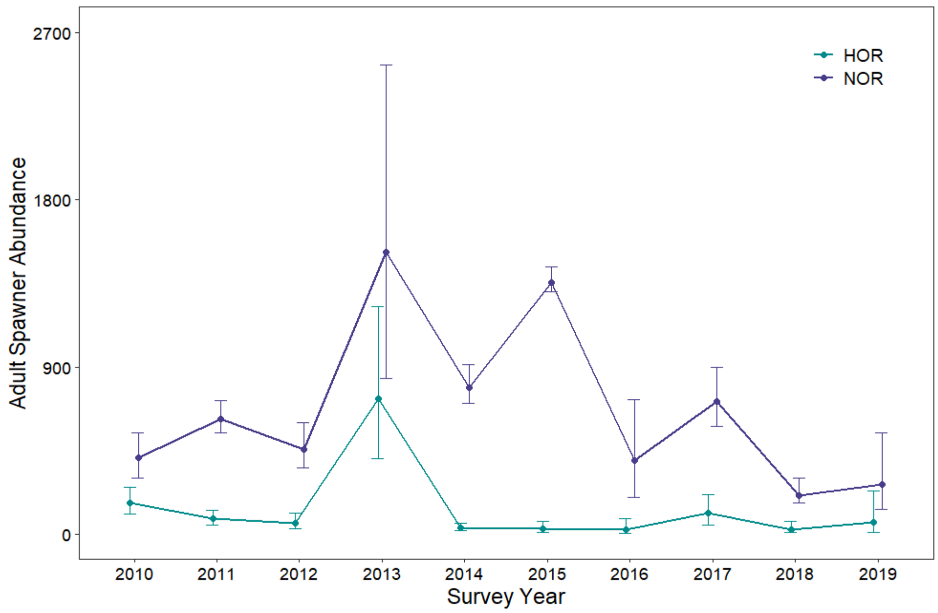

Figure 9. Estimated adult abundances of hatchery-origin (HOR) and natural-origin (NOR) early fall/tule Chinook salmon that spawned in survey years 2010 – 2019 for the Coweeman population. Point estimates are medians and error bars represent the 95% credible intervals.

Kalama

For the designated Kalama Spring Chinook population, adult abundances below Kalama Falls Hatchery were estimated based on spawning ground surveys and weir data collected downstream of the facility, and spawners abundances above the hatchery were a census count based on hatchery returns to the hatchery ladder trap (Appendix A). In 2018, a total of 20 Spring Chinook adult carcasses were sampled in August and September during weekly spawning ground surveys or as washups at the weir located downstream of the hatchery. All carcasses were identified as HORs given their lack of an adipose fin. Scales were taken from 17 of the carcasses for aging. Based on AUC, adult abundance below the hatchery was estimated as 53 adult Spring Chinook (all HORs). Approximately 65% of the adults (N=34) were estimated to be Age-4, and the remaining 35% (N=19) were estimated as Age-5 based on scale age data. In 2019, a total of three Spring Chinook adult carcasses washed up at the weir during the fall. All carcasses were identified as HORs given their lack of an adipose fin. Scales were taken from the three carcasses for aging. Based on AUC, adult abundance below the hatchery was estimated as nine adult Spring Chinook (all HORs). All nine of the fish were estimated as Age-4 based on scale age data. At the Kalama Falls Hatchery ladder trap, HORs were removed and NORs were passed upstream in both survey years. Above the hatchery, adult NOR spawner abundances were 57 adults in 2018 and 52 adults in 2019, and were a census count based on the assumption that all Spring Chinook passing the falls must use the ladder. Work is currently ongoing to evaluate this assumption.

Collectively, the overall Kalama Spring Chinook population spawner estimate was 110 adults in 2018 and 61 adults in 2019. These adult abundances were the lowest spawner abundances observed since 2010 (Figure 10). Prior to 2015, adult abundances were not separated by origin. HORs greatly outnumbered NORs from 2015-2017, and primarily spawned below Kalama Falls Hatchery. In the past two years, both HOR and NOR abundances have largely decreased (Figure 10). Overall, Kalama Spring Chinook population NOR spawner abundances are minimal compared to historic levels, and when compared to annual Fall Chinook salmon spawner abundances in the Kalama River (Figure 11).

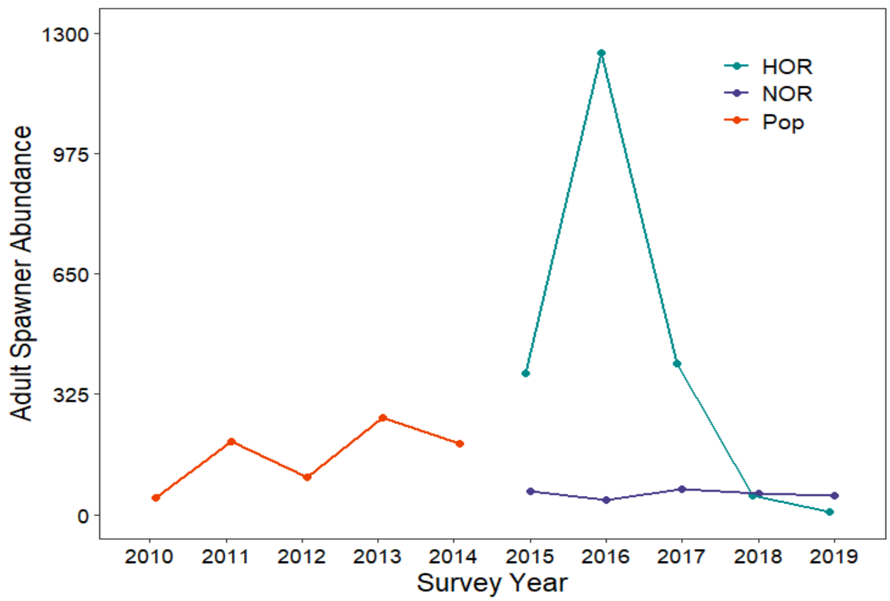

Figure 10. Estimated adult abundances of hatchery-origin (HOR), natural-origin (NOR), or the total population (Pop) of Spring Chinook salmon that spawned between 2010 – 2019 for the Kalama population. No credible intervals were generated for the point estimates. Raw estimates can be found on SCoRE.

In 2018, adult EFT Chinook were observed on the spawning grounds from September 19th to November 19th. Peak count of deads only in reference sections was 179 fish, which occurred on October 10th. A total of 760 carcasses (449 above the weir, 311 below the weir) were sampled on the spawning grounds. The sex composition of recovered carcasses was 471 females and 289 males. A total of 32 females (14 above the weir,18 below the weir) for the season were observed to be pre-spawn mortalities. At the weir, 9341 HORs were removed and 1400 NORs were given an LOP before being passed upstream. A total of 988 of these marked NORs were recaptured resulting in a median (% CV) abundance estimate of 1472.00 (1.81) adults above the weir based on L-P modeling. There were 1829 redds observed throughout the season with 1327 above the weir and 502 below the weir. Median apparent residence time was 5.12 (18.42) days; no population-specific apparent females per redd estimate was generated given that individual redds were not tracked throughout the season. Based on AUC, median abundance below the weir after adjustments was 1053.00 (19.15) adults. Median adult abundance for the entire population was 2523.00 (8.16) with females greatly outnumbering males (Table 8). Nearly 65% of the adult abundance was NORs as median pHOS for the entire stream was 0.35 (8.99). Estimated median weir efficiency for the season was 95.61%, and approximately 53 HORs were estimated to have gotten by the weir. Scales were taken from 685 carcasses for aging. Most adults returned as 4-year-olds based on scales and CWTs (Table 8).

In 2019, adult EFT Chinook were observed on the spawning grounds from September 20th to December 16th. Peak count of deads only in reference sections was 93 fish, which occurred on October 2nd. A total of 462 carcasses (173 above the weir, 289 below the weir) were sampled on the spawning grounds. The sex composition of recovered carcasses was 262 females and 200 males. A total of 17 females (5 above the weir, 12 below the weir) for the season were observed to be pre-spawn mortalities. At the weir, 10094 HORs were removed and 1006 NORs were given an LOP before being passed upstream. A total of 569 of these tagged NORs were recaptured resulting in a median (% CV) abundance estimate of approximately 1386.00 (4.33) adults above the weir based on L-P modeling.

There were 1677 redds observed throughout the season with 923 above the weir and 754 below the weir. Median apparent residence time was 4.32 (20.40) days; no population-specific apparent females per redd estimate was generated given that individual redds were not tracked throughout the season. Based on AUC, median abundance below the weir after adjustments was 1377.50 (21.49) adults. Median adult abundance for the entire population was estimated as 2724.00 (10.95) with slightly more female returns than males (Table 8). Nearly 54% of the adult abundance was NORs as median pHOS for the entire stream was 0.46 (7.49). Estimated median weir efficiency for the season was 93.10%, with 162 HORs estimated to have gotten by the weir. Scales were taken from 414 carcasses for aging. Most adults returned as 4-year-olds based on scales and CWTs (Table 8).

Table 8. Mean, median, standard deviation (SD), and 95% credible interval (CI) parameter estimates for the Kalama early fall/tule Chinook population in survey years 2018 and 2019.

Parameter	**2018**				**2019**			
	Mean	**Median**	**SD**	**95% CI**	**Mean**	**Median**	**SD**	**95% CI**
Abundance	2511.91	2523.00	195.70	(2200.00 – 2954.03)	2763.02	2724.00	302.48	(2283.00 – 3459.03)
Females	1554.72	1562.00	127.06	(1346.00 – 1837.00)	1561.56	1541.00	185.05	(1263.00 – 1984.00)
Males	957.19	962.90	88.47	(807.20 – 1154.00)	1201.46	1186.00	145.21	(959.30 – 1529.00)
NORs	1632.16	1638.00	80.38	(1488.00 – 1805.00)	1473.86	1466.00	116.67	(1268.00 – 1730.00)
HORs	879.75	887.00	140.83	(650.60 – 1199.00)	1289.16	1263.00	220.98	(933.20 – 1797.03)
pHOS	0.35	0.35	0.03	(0.29 – 0.41)	0.46	0.46	0.03	(0.40 – 0.53)
Age-3 NORs	395.21	396.70	44.47	(305.70 – 481.30)	562.59	558.70	86.50	(403.50 – 743.70)
Age-4 NORs	1198.37	1204.00	73.66	(1062.00 – 1351.00)	807.22	806.45	83.91	(645.10 – 974.40)
Age-5 NORs	37.74	37.27	15.38	(9.96 – 70.60)	102.64	100.00	29.84	(51.70 – 169.40)
Age-6 NORs	0.82	0.05	1.97	(0.00 – 6.52)	1.40	0.10	3.28	(0.00 – 10.86)
Age-3 HORs	293.43	294.70	55.85	(201.30 – 418.60)	370.21	362.60	81.63	(243.90 – 550.00)
Age-4 HORs	529.49	533.40	93.76	(374.10 – 739.30)	851.68	833.20	154.08	(602.00 – 1206.00)
Age-5 HORs	56.24	55.84	17.29	(28.36 – 95.62)	66.03	62.49	22.91	(31.41 – 120.60)
Age-6 HORs	0.60	0.07	1.32	(0.00 – 4.60)	1.24	0.14	2.83	(0.00 – 9.52)

Comparing both survey years (Table 8), adult spawner abundance was higher in 2019, but so was the number of HOR returns leading to an increase in pHOS. The observed sex ratio was comparable with females outnumbering males in both years. The number of NOR spawners outnumbered HORs in both years. Regardless of origin, most fish were aged as 4-year-olds. Comparing adult spawners abundances over the last ten years (Figure 11), HORs greatly outnumbered NORs from 2010-2014, but HOR abundance has dropped considerably since 2015 after the remodel and shift in protocols were implemented at the Modrow weir (Figure 11). The largest abundance year to-date was 2014 for HORs and 2015 for NORs (Figure 11).

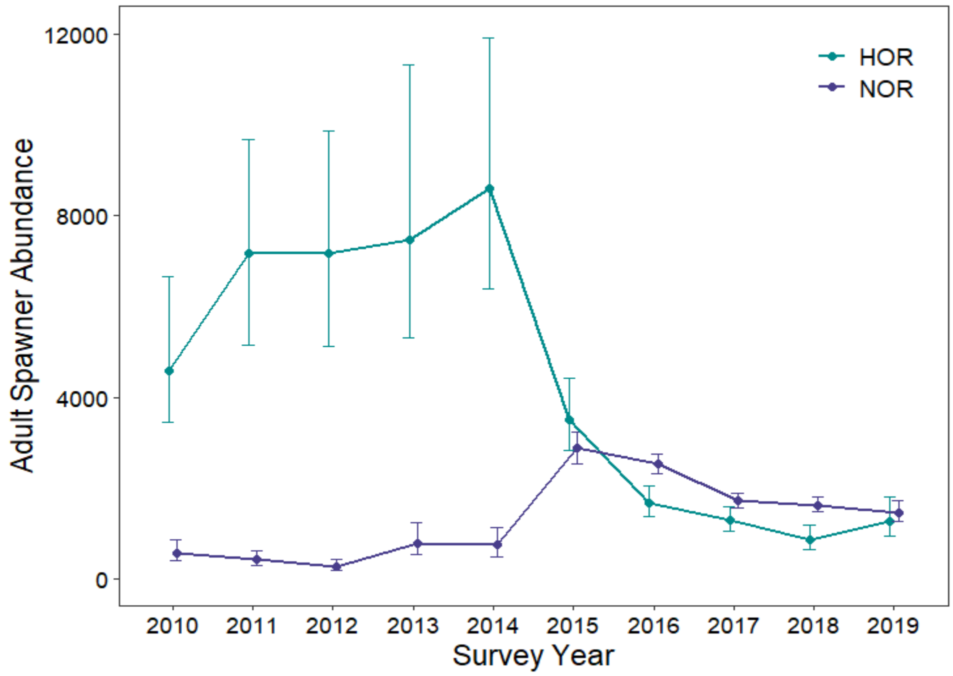

Figure 11. Estimated adult abundances of hatchery-origin (HOR) and natural-origin (NOR) early fall/tule Chinook salmon that spawned in survey years 2010 – 2019 for the Kalama population. Point estimates are medians and error bars represent the 95% credible intervals.

Lewis (Cedar Creek, East Fork Lewis, and North Fork Lewis)

As noted in the methods, there is a designated North Fork Lewis Spring Chinook population, a designated Lewis Fall Chinook population (which includes EFT that spawn in Cedar Creek, the East Fork Lewis, and the North Fork Lewis), and a designated North Fork Lewis Fall Chinook population that consists of LFB Chinook. The Spring Chinook, EFT, and LFB Chinook in the North Fork Lewis are monitored under different protocols and funding sources than the EFT Chinook monitored in Cedar Creek and the East Fork Lewis River. Abundance estimates for the North Fork Lewis from survey years 2018 and 2019 are presented in this report, but information on the monitoring program in this tributary can be found in Bentley et al. (2018) and on SCoRE.

In survey years 2018 and 2019, Spring Chinook abundances for the North Fork Lewis population were estimated from the peak count of lives and deads observed during spawning ground surveys and any mortalities observed at the Cedar Creek Grist Mill ladder trap and weir. A PCE factor of 3.00 was developed for the North Fork Lewis. Estimated age classes for the total spawner abundance was generated from scale age data taken from carcasses. In 2018, total adult Spring Chinook spawner abundance was estimated as 326 fish, which included 294 Age-4 fish, 32 Age-5 fish, and zero Age-6 fish. All of these adult spawners were HOR fish. In 2019, total adult Spring Chinook spawner abundance was estimated as 188 fish, which included 71 Age-4 fish, 109 Age-5 fish, and 8 Age-6 fish (Q. Daugherty, personal communication, WDFW). Five of these adult spawners were presumed NOR fish. Total adult spawner abundances in 2018 and 2019 were comparable to Spring Chinook spawner abundances observed over the past ten years for the North Fork Lewis population (Figure 12). The number of HOR spawners have greatly outnumbered NOR spawners for the past eight years (Figure 12).

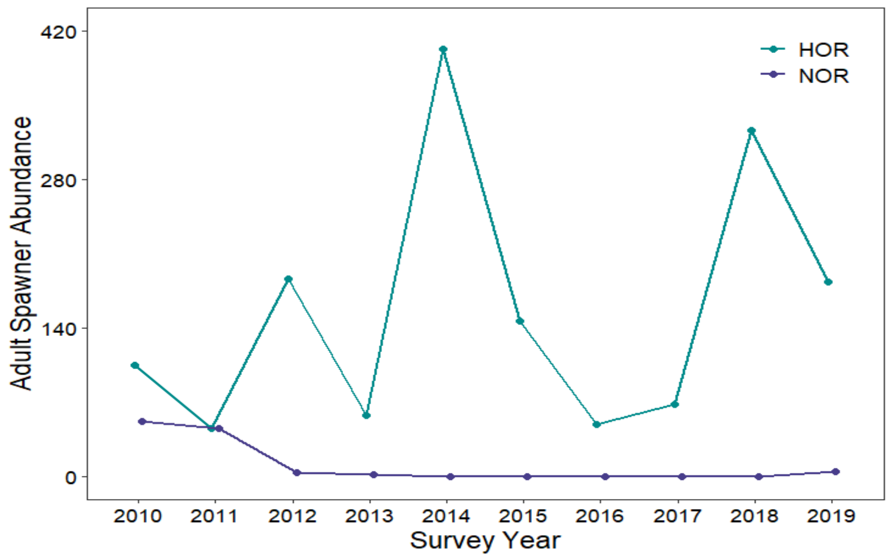

Figure 12. Estimated adult abundances of hatchery-origin (HOR) and natural-origin (NOR) Spring Chinook salmon that spawned in survey years 2010 – 2019 for the North Fork Lewis population. No credible intervals were generated for the point estimates.

For the Lewis Fall Chinook population, adult EFT Chinook were observed on the spawning grounds of Cedar Creek from September 24th to November 20th. Given that the Cedar Creek weir was not operational until 2019, results presented for 2018 include estimates produced above and below the Cedar Creek Grist Mill ladder trap located upstream of the current weir location (Appendix A). Peak count of lives and deads in the reference sections in 2018 was 82 fish, which occurred on October 15th. A total of 118 carcasses (61 below and 57 above the Grist Mill ladder trap) were sampled on the spawning grounds. The sex composition of recovered carcasses was 47 females and 71 males. No female pre-spawn mortalities were observed. At the ladder trap, 38 HORs were removed and 59 NORs were given an LOP and Floy tagged before being passed upstream. After adjustments, the above weir median (% CV) spawner estimate based on the census count at the ladder was 43.28 (15.71). A total of 386 redds were observed throughout the season. Median apparent residence time was 6.08 (25.87) days; no population-specific apparent females per redd estimate was generated given that individual redds were not tracked throughout the season. Based on AUC, median abundance below the ladder after adjustments was 112.30 (29.01) adults. Median adult abundance for the entire stream was 155.60 (21.41) with males outnumbering females (Table 9). Nearly 61% of the adult abundance was NORs as median pHOS for the stream was 0.39 (13.39). Scales were taken from 114 of the carcasses for aging. Most adults returned as 3 or 4-year-olds based on scales and CWTs (Table 9).

In 2018, adult EFT Chinook were observed on the East Fork Lewis spawning grounds from September 25th to November 28th. Peak count of lives and deads in reference sections was 29 fish, which occurred on October 16th. Of the 30 carcasses sampled, 17 were females and 13 were males. One female was observed to be a pre-spawn mortality. There were 196 redds tracked throughout the season. Median estimates of apparent residence time and apparent females per redd were 5.66 (18.36) days and 1.14 (27.75) females, respectively. Based on RCE, a median abundance of 321.30 (28.57) adults was estimated for the EF Lewis with females outnumbering males (Table 9). Nearly 95% of returns were NORs as median pHOS for the river was 0.05 (70.00). Scales were taken from 26 of the carcasses for aging. Most adults returned as 3 or 4-year-olds based on scales and CWTs (Table 9).

Table 9. Mean, median, standard deviation (SD), and 95% credible interval (CI) parameter estimates for the Lewis early fall/tule Chinook population in survey years 2018 and 2019.

Parameter	**2018**				**2019**			
	Mean	**Median**	**SD**	**95% CI**	**Mean**	**Median**	**SD**	**95% CI**
Cedar Creek								
Abundance	161.00	155.60	34.47	(110.30 – 244.81)	302.84	289.69	78.90	(190.72 – 493.42)
Females	72.78	69.77	17.68	(46.89 – 115.30)	144.42	137.53	46.00	(76.64 – 256.05)
Males	88.22	99.29	20.14	(58.51 – 137.11)	158.42	150.77	48.63	(86.05 – 273.48)
NORs	98.19	94.98	20.87	(66.43 – 149.30)	204.38	195.63	59.00	(118.17 – 346.29)
HORs	62.82	60.02	17.63	(37.17 – 104.60)	98.46		35.71	(46.90 – 186.17)
pHOS	0.39	0.39	0.05	(0.29 – 0.49)	0.33	0.32	0.08	(0.19 – 0.50)
Age-3 NORs	38.70	37.29	9.88	(23.65 – 62.03)	97.42	92.20	36.68	(43.34 – 185.22)
Age-4 NORs	56.72	54.83	13.60	(35.91 – 88.94)	81.52	76.38	32.92	(33.32 – 161.01)
Age-5 NORs	2.54	2.17	1.67	(0.44 – 6.69)	23.97	20.24	16.21	(4.35 – 64.86)
Age-6 NORs	0.23	0.02	0.55	(0.00 – 1.74)	1.47	0.12	3.83	(0.00 – 12.23)
Age-3 HORs	24.81	23.34	8.93	(11.81 – 45.80)	16.53	13.53	11.81	(2.59 – 47.29)
Age-4 HORs	34.69	32.89	11.12	(18.03 – 61.08)	64.94	60.37	26.58	(27.47 – 130.16)
Age-5 HORs	3.07	2.41	2.51	(0.32 – 9.53)	16.66	13.82	11.72	(2.81 – 46.91)
Age-6 HORs	0.24	0.02	0.64	(0.00 – 1.99)	0.33	0.00	1.07	(0.00 – 3.22)
EF Lewis								
Abundance	335.03	321.30	95.72	(187.60 – 562.80)	427.17	457.91	139.81	(208.23 – 753.14)
Females	201.79	196.20	52.53	(114.10 – 321.41)	234.59	256.14	65.26	(123.13 – 378.05)
Males	133.24	122.20	57.80	(52.56 – 275.70)	192.58	197.99	91.43	(69.29 – 419.37)
NORs	314.66	301.40	91.05	(174.20 – 531.70)	393.21	375.17	130.30	(189.80 – 694.46)
HORs	20.38	16.39	16.01	(2.23 – 61.55)	33.96	28.50	23.56	(5.92 – 95.71)
pHOS	0.06	0.05	0.04	(0.01 – 0.17)	0.08	0.07	0.05	(0.02 – 0.19)
Age-3 NORs	36.10	31.38	23.11	(6.61 – 94.15)	41.51	35.27	27.74	(6.89 – 111.99)
Age-4 NORs	183.45	174.30	61.72	(89.23 – 333.30)	241.47	228.41	88.59	(107.55 – 450.21)
Age-5 NORs	81.54	74.59	36.67	(29.14 – 172.10)	94.04	85.67	45.45	(30.10 – 205.99)
Age-6 NORs	13.56	9.55	13.33	(0.45 – 49.76)	16.19	11.22	16.64	(0.49 – 60.33)
Age-3 HORs	5.42	3.33	6.46	(0.16 – 22.91)	13.12	11.21	11.80	(1.19 – 45.00)
Age-4 HORs	12.74	9.62	11.14	(1.07 – 42.04)	17.78	13.78	14.56	(2.14 – 57.06)
Age-5 HORs	1.81	0.56	3.18	(0.00 – 11.38)	2.52	0.66	4.34	(0.00 – 14.69)
Age-6 HORs	0.41	0.01	1.47	(0.00 – 4.14)	0.55	0.00	2.01	(0.00 – 5.15)
North Fork Lewis								
Abundance	1592.00	N/A	138.00	N/A	1252.00	N/A	252.00	N/A
NORs	898.00	N/A	116.00	N/A	858.00	N/A	244.00	N/A
HORs	694.00	N/A	76.00	N/A	394.00	N/A	64.00	N/A
Age-3 NORs	249.00	245.00	56.00	(150.00 – 376.00)	269.00	250.00	111.00	(108.00 – 535.00)
Age-4 NORs	566.00	565.00	98.00	(367.00 – 770.00)	552.00	516.00	217.00	(236.00 – 1078.00)
Age-5 NORs	80.00	76.00	26.00	(38.00 – 141.00)	35.00	33.00	15.00	(14.00 – 71.00)
Age-6 NORs	3.00	2.00	2.00	(1.00 – 7.00)	2.00	2.00	1.00	(0.00 – 5.00)
Age-3 HORs	185.00	182.00	32.00	(131.00 – 255.00)	112.00	110.00	28.00	(61.00 – 172.00)
Age-4 HORs	477.00	470.00	68.00	(362.00 – 630.00)	262.00	261.00	57.00	(148.00 – 379.00)
Age-5 HORs	30.00	28.00	9.00	(15.00 – 51.00)	19.00	18.00	7.00	(8.00 – 36.00)
Age-6 HORs	2.00	2.00	1.00	(0.00 – 6.00)	1.00	1.00	1.00	(0.00 – 3.00)
Population								
Abundance	2090.52	2082.00	175.16	(1769.00 – 2458.00)	1976.99	1955.00	284.09	(1497.00 – 2593.03)
NORs	1313.08	1304.00	152.77	(1037.00 – 1642.03)	1457.02	1436.00	273.38	(994.00 – 2052.05)
HORs	777.45	773.00	85.13	(622.00 – 956.00)	519.97	514.00	78.19	(385.00 – 685.00)
pHOS	0.37	0.37	0.04	(0.30 – 0.45)	0.27	0.27	0.05	(0.18 – 0.37)

In 2019, the first year with a functioning weir located near the tributary mouth in Cedar Creek, adult EFT Chinook were observed on the spawning grounds from September 26^{th} to December 2^{nd}. Peak count of lives and deads in the reference sections was 90 fish, which occurred on October 16^{th}. A total of 38 carcasses (18 below the weir, 20 between the weir and the ladder) were sampled on the spawning grounds. The sex composition of recovered carcasses was 17 females and 21 males. No pre-spawn mortalities were observed. At the weir, 176 HORs were removed, 7 NOR mortalities were removed, and 167 NORs were given an ROP before being passed upstream. At the ladder, an additional 4 HORs were removed and 35 NORs were passed upstream. A total of 338 redds (227 above the weir, 111 below the weir) were observed throughout the season. No population-specific apparent females per redd estimate was generated given that individual redds were not tracked throughout the season. Median (% CV) apparent residence time was 6.78 (26.56) days. Based on AUC, median abundance between the weir and ladder after adjustments was 223.01 (25.68) adults, and median abundance below the weir after adjustments was 66.45 (29.76) adults. Median abundance for the entire stream was 289.69 (26.52) adults with males outnumbering females (Table 9). Nearly 68% of the adult abundance was NORs as median pHOS for the stream was 0.32 (24.41). Scales were taken from 30 of the carcasses for aging. Most adults returned as 4-year-olds, but a large portion of NORs returned as 3-year-olds based on scales and CWTs (Table 9).

In 2019, adult EFT Chinook were observed on the East Fork Lewis spawning grounds from September 24th to December 31st. Peak count of lives and deads in the reference sections was 51 fish, which occurred on October 1st. Of the 64 carcasses sampled, 36 were females and 28 were males. One female was observed to be a pre-spawn mortality. There were 217 redds tracked throughout the season. Median (% CV) estimates of apparent residence time and apparent females per redd were 5.67 (18.38) days and 1.14 (27.71) females, respectively. Based on RCE, a median abundance of 457.91 (29.15) adults was estimated for the EF Lewis with females outnumbering males (Table 9). Nearly 92% of returns were NORs as median pHOS for the river was 0.07 (57.77). Scales were taken from 56 of the carcasses for aging. Most adults returned as 4-year-olds based on scales and CWTs (Table 9).

Bentley et al. (2018) describe the monitoring program for Fall Chinook in the North Fork Lewis River. Briefly, in 2018 and 2019, boat stream surveys were conducted weekly between mid-September to mid-February to collect biological data from carcasses including presumed run type (EFT or LFB), fork length, scales for aging, mark status, and presence/absence of a CWT. Viable carcasses were tagged on the inside of the opercles, and a J-S modeling framework was used to estimate spawner abundances based on the number of tagged, untagged, and recovered carcasses. Total spawner abundances included jacks (Age-2 fish) so medians and credible intervals are not presented in this report for total abundances. The mean (% CV) adult spawner abundances reported for the North Fork Lewis River were 1592 (8.67) in 2018 and 1302 (29.19) in 2019 (K.Bentley, personal communication). These adult spawner abundances were much higher than the estimated number of adult spawners in Cedar Creek and the East Fork Lewis River in both survey years (Table 9).

All three tributaries had a higher abundance of NORs than HORs, and the majority of adult spawners based on CWTs and scale aging data were 4-year-olds in both survey years (Table 9). The rolled-up, median adult spawner abundance estimate for the Lewis Fall Chinook population was 2090.52 (8.38) adults in 2018 and 1976.99 (14.37) adults in 2019 (Table 9). No ages were generated for the rolled-up population estimate. Both HOR abundances and pHOS were higher in 2018 than in 2019. Comparing adult abundances over the past ten years for the Lewis Fall Chinook population, the 2018 and 2019 abundances were lower than observed in the past few years, but comparable to returns from 2010 – 2012 (Figure 13). Both HOR and NOR adult spawner abundances have followed a similar distribution pattern over the past ten years.

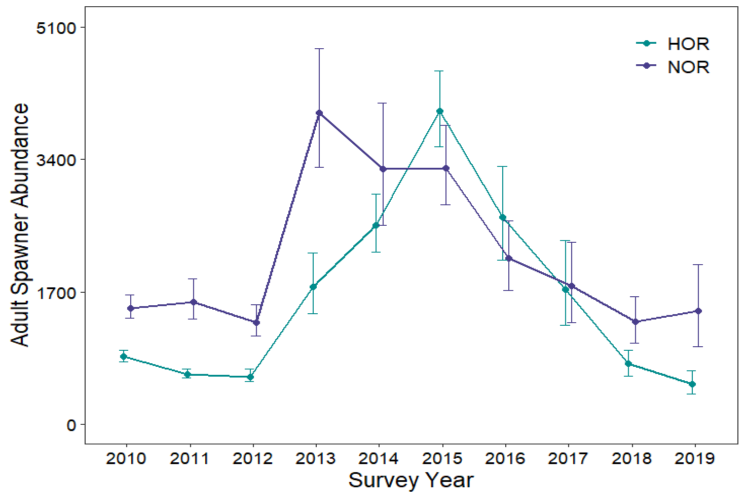

Figure 13. Estimated adult abundances of hatchery-origin (HOR) and natural-origin (NOR) early fall/tule Chinook salmon that spawned in survey years 2010 – 2019 for the Lewis population. Point estimates are means (as medians were not generated for all survey years) and error bars represent the 95% credible intervals.

In addition to EFT Chinook, the North Fork Lewis has a population of LFB Chinook that are part of the LCR ESU. In survey years 2018 and 2019, the LFB Chinook were monitored in conjunction with the EFT Chinook during weekly boat stream surveys, and abundances were generated using the same mark-recapture (J-S) modeling framework (Bentley et al. 2018). Total spawner abundances included jacks (Age-2 fish) so medians and credible intervals are not presented in this report. Mean (% CV) spawner abundances for adults only were 4139 (3.49) and 11454 (3.35) in survey years 2018 and 2019, respectively (K.Bentley, personal communication). Adult abundances reported to SCoRE were NOR fish only. Mean LFB Chinook abundances estimated for both survey years were comparable to mean abundances reported in previous years (Figure 14). Mean abundance has fluctuated from approximately 4600 to over 200000 fish with the largest return year to-date being 2014 (Figure 14; SCoRE). Refer to Bentley et al. (2018) for more information regarding the monitoring program for the North Fork Lewis Bright population.

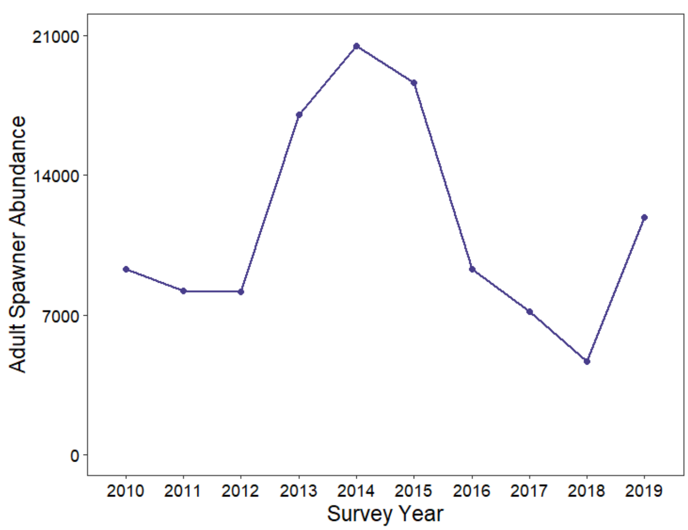

Figure 14. Estimated adult abundances of late fall/bright Chinook salmon that spawned in survey years 2010 – 2019 for the North Fork Lewis population. Point estimates are means and no credible intervals were generated for the adult only estimates.

Salmon Creek

The designated Salmon Creek Fall Chinook population located in Clark County, Washington, that consists of EFT Chinook is considered at too low of abundance to monitor on an annual basis. No abundance estimates for Fall Chinook have been estimated for this population in over ten years.

Washougal

The designated Fall Chinook population in the Washougal River consists of presumably EFT Chinook, but there have been some concerns over the past few years based on observed phenotypes and residence times that fish arriving later in the season may be LFB Chinook that are becoming established in the river. No genetic testing has yet been done to assess whether the late-spawning fish are genetically distinct from the early-spawning Chinook, so all adult spawners for survey years 2018 and 2019 are reported as Fall Chinook for the Washougal Fall Chinook population.

In 2018, adult Fall Chinook were observed on the spawning grounds from September 13th to November 26th. Peak count of lives and deads in reference sections was 77 fish, which occurred on October 24th. A total of 382 carcasses (43 above the weir, 339 below the weir) were sampled on the spawning grounds. The carcass sex ratio was 240 females and 142 males. A total of eight females, all below the weir, were observed to be pre-spawn mortalities. At the weir, 1341 HORs were removed and 103 NORs were given an LOP and Floy tagged before being passed upstream. Thirty-three of these tagged NORs were recaptured resulting in a median (% CV) abundance estimate of 228.40 (16.46) adults above the weir based on L-P modeling. There were 1438 redds observed throughout the season with 346 above the weir and 1092 below the weir. Median apparent residence time was 6.77 (17.41) days; no population-specific apparent females per redd estimate was generated given that redds were not tracked throughout the season. Based on the model of best fit (with capture, survival, and entry probabilities varying over time) using J-S modeling from carcass tagging data, median abundance below the weir after adjustments was 768.10 (14.60) adults. Median adult spawner abundance for the entire population was estimated as 1002.00 (11.91) with females greatly outnumbering males (Table 10). Nearly 89% of the adult abundance was NORs as median pHOS for the population was 0.11 (19.88). Estimated median weir efficiency for the season was 83.89% with approximately 61 HORs estimated to have gotten by the weir. Scales were taken from all 382 carcasses for aging. Most adults were 4-year-olds based on scales and CWTs (Table 10).

Table 10. Mean, median, standard deviation (SD), and 95% credible interval (CI) parameter estimates for the Washougal Fall Chinook population in survey years 2018 and 2019.

Parameter	2018				2019			
	Mean	Median	SD	95% CI	Mean	Median	SD	95% CI
Abundance	1018.90	1002.00	121.35	(829.70 – 1302.00)	1816.69	1798.00	142.80	(1587.98 – 2146.03)
Females	649.47	638.95	79.90	(520.10 – 831.71)	993.17	983.8	84.05	(854.40 – 1182.00)
Males	369.43	363.20	53.16	(283.50 – 490.70)	823.52	816.25	70.94	(704.30 – 983.70)
NORs	903.41	887.00	111.94	(730.60 – 1169.03)	1575.10	1555.00	132.62	(1367.00 – 1886.00)
HORs	115.49	112.30	26.10	(73.05 – 174.51)	241.59	239.8	30.23	(187.40 – 305.60)
pHOS	0.11	0.11	0.02	(0.08 – 0.16)	0.13	0.13	0.02	(0.11 – 0.16)
Age-3 NORs	284.66	279.80	42.14	(214.90 – 379.40)	520.76	516.25	52.56	(430.50 – 636.01)
Age-4 NORs	556.62	546.55	74.94	(439.40 – 732.10)	996.12	984.4	91.13	(849.00 – 1204.00)
Age-5 NORs	58.81	57.31	14.83	(34.64 – 92.86)	57.68	56.57	13.29	(35.21 – 87.43)
Age-6 NORs	3.32	2.41	3.17	(0.13 – 11.94)	0.55	0.05	1.22	(0.00 – 4.00)
Age-3 HORs	47.88	45.78	15.70	(23.60 – 84.54)	112.75	111.60	18.48	(80.58 – 152.80)
Age-4 HORs	54.71	52.27	17.37	(28.31 – 95.54)	124.09	122.70	21.07	(87.60 – 169.80)
Age-5 HORs	12.22	10.51	7.41	(2.78 – 31.57)	4.39	3.60	3.25	(0.48 – 12.70)
Age-6 HORs	0.68	0.06	1.74	(0.00 – 5.42)	0.36	0.04	0.83	(0.00 – 2.79)

In 2019, adult Fall Chinook were observed on the spawning grounds from August 29th to December 30th. Peak count of lives and deads in reference sections was 122 fish, which occurred on October 16th. A total of 877 carcasses (253 above the weir, 624 below the weir) were sampled on the spawning grounds. The sex composition of recovered carcasses was 480 females and 397 males. A total of 18 females (6 above the weir, 12 below the weir) were observed to be pre-spawn mortalities. At the weir, 2322 HORs were removed and 237 NORs were given an LOP and Floy tagged before being passed upstream. Ninety of these tagged NORs were recaptured resulting in a median (% CV) spawner abundance of 620.15 (7.22) adults above the weir based on L-P modeling. There were 2531 redds observed throughout the season with 955 above the weir and 1576 below the weir. Median apparent residence time was 6.83 (19.08) days; no population-specific apparent females per redd estimate was generated given that individual redds were not tracked throughout the season. Based on the model of best fit (with capture, survival, and entry probabilities varying over time) using J-S modeling from carcass tagging, median spawner abundance below the weir after adjustments was 1172.00 (11.41) adults. Median adult spawner abundance for the entire population was 1798.00 (7.86) with females slightly outnumbering males (Table 10). Nearly 87% of the adult abundance was NORs as median pHOS for the population was 0.13 (11.45). Due to high water, estimated median weir efficiency for the season was 57.53% with 150 HORs estimated to have gotten by the weir. Scales were taken from 701 carcasses for aging. Most adults were 4-year-olds based on scale aging data and CWTs (Table 10).

Comparing both survey years (Table 10), adult spawner abundance was higher in 2019, but so was the number of HOR adults resulting in a slight increase in pHOS. The observed sex ratio was comparable with females outnumbering males. NORs greatly outnumbered HORs in both years. Median NOR spawner abundances in 2018 and 2019 were slightly higher than those in 2017, but comparable to other years over the past ten years (Figure 15). Since 2017, median NOR abundances have increased annually while HOR abundances have decreased or remained low. The largest year to-date for HOR adults was 2010 when spawner abundance ranged from approximately 4300 to 5700 adults. Survey year 2019 was the largest abundance year for NOR Fall Chinook (Figure 15).

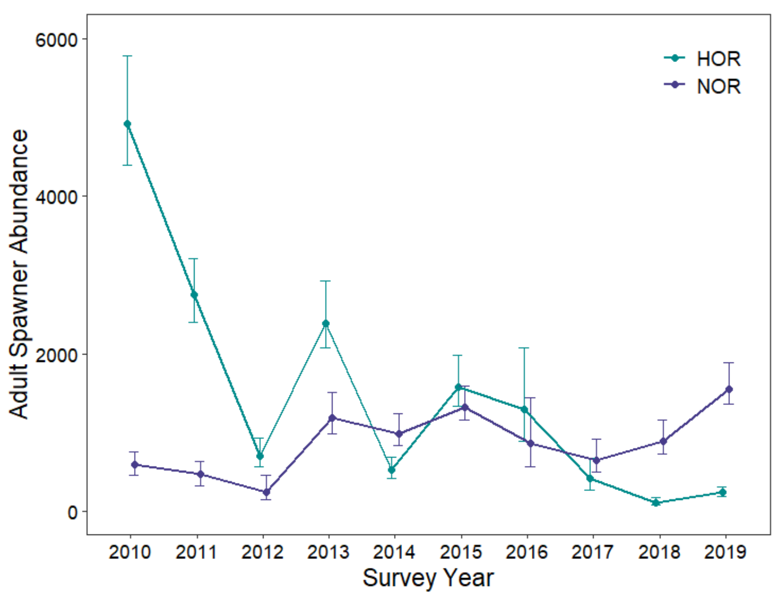

Figure 15. Estimated adult abundances of hatchery-origin (HOR) and natural-origin (NOR) Fall Chinook salmon that spawned in survey years 2010 – 2019 for the Washougal population. Point estimates are medians and error bars represent the 95% credible intervals.

Gorge Strata

Lower Gorge (Ives/Pierce and Hamilton)

In addition to EFT Chinook, a high abundance of Upriver Bright (URB) Chinook (a stock of LFB Chinook) have been established, presumably via straying from nearby hatchery programs utilizing that stock, and now use the spawning grounds at Ives/Pierce (a mainstem Columbia River spawning area below Bonneville Dam) and in Hamilton Creek. Given the inability to completely differentiate EFT and URB Chinook that temporally and spatially overlap on the spawning grounds, adult abundances reported were based on presumed run from field calls given the observed phenotypes and timing of spawning. Collective estimates of total spawner abundances by origin and observed pHOS are also presented for the Lower Gorge Fall Chinook population.

In 2018, no adult EFT Chinook were observed in Hamilton Creek due to low flows preventing access to spawning areas in September and October. The adult spawner abundance estimate reported for the Lower Gorge EFT Chinook population was based on monitoring data from Ives/Pierce. Adult EFT Chinook were observed on the Ives/Pierce spawning grounds from September 17th to October 11th. Peak count of lives and deads in reference sections was 13 fish, which occurred on October 4th. A total of 13 EFT Chinook carcasses were sampled with a sex composition for sampled carcasses of 1 female and 12 males. No pre-spawn mortalities were observed. There were 6 redds observed on the spawning grounds when EFT Chinook were present. No population-specific apparent females per redd estimate was generated given that individual redds were not tracked throughout the season. No apparent residence time estimate was generated for the Lower Gorge EFT Chinook population due to low abundance. Median (% CV) spawner abundance for the EFT Chinook population was 12.82 (17.24) adults estimated using the median apparent residence time of 5.54 (13.84) days estimated for the Ives/Pierce URB Chinook spawners. For the EFT Chinook, the number of males greatly outnumbered females (Table 11). Nearly 91% of the adult EFT Chinook abundance was NORs as median pHOS was estimated as 0.11 (68.17). Scales were taken from the 13 presumed EFT Chinook carcasses for aging. Most adults were 4-year-olds based on scale aging data and CWTs (Table 11).

In 2018, URB Chinook were observed on the Hamilton Creek spawning grounds from November 5th to December 5th. Peak count of lives and deads in the reference sections was 255. A total of 137 adult URB Chinook carcasses were sampled. The sex composition of recovered carcasses was 59 females and 78 males. A total of 3 females were observed to be pre-spawn mortalities. There were 111 redds observed on the spawning grounds while URB Chinook were present. Median (% CV) apparent residence time was 6.59 (19.56) days; no population-specific apparent females per redd estimate was generated given that individual redds were not tracked throughout the season. Based on AUC, median adult spawner abundance was 417.40 (21.98) with females outnumbering males (Table 11). Nearly 87% of the adult abundance was NORs as median pHOS for Hamilton Creek was 0.04 (40.03).

In 2018, URB Chinook were observed on the Ives/Pierce spawning grounds from October 4th to December 26th. Peak count of lives and deads in the reference sections was 6212. A total of 398 adult URB Chinook carcasses were sampled. The sex composition of recovered carcasses was 149 females and 249 males. No females were observed to be pre-spawn mortalities. There were 1900 redds observed on the spawning grounds while URB Chinook were present. Median (% CV) apparent residence time was 5.44 (14.01) days; no population-specific apparent females per redd estimate was generated given that individual redds were not tracked throughout the season. Based on AUC, median adult spawner abundance was 15660.00 (13.81) with males outnumbering females (Table 11). The majority of spawning adults were NORs as median pHOS for Ives/Pierce was 0.01 (46.21).

Table 11. Mean, median, standard deviation (SD), and 95% credible interval (CI) parameter estimates for the Lower Gorge Fall Chinook population in survey years 2018 and 2019.

Parameter			**2018**				**2019**	
	Mean	**Median**	**SD**	**95% CI**	**Mean**	**Median**	**SD**	**95% CI**
Population Early Fall/Tule								
Abundance	13.03	12.82	2.25	(9.32 – 18.11)	18.97	18.60	3.65	(13.72 – 26.59)
Females	1.74	1.48	1.16	(0.22 – 4.67)	9.48	9.27	3.66	(3.36 – 16.98)
Males	11.30	11.14	2.26	(7.44 – 16.15)	9.50	9.18	3.74	(3.33 – 17.15)
NORs	11.42	11.30	2.25	(7.45 – 16.39)	3.61	3.03	2.65	(0.23 – 10.12)
HORs	1.61	1.34	1.15	(0.19 – 4.43)	15.37	15.40	3.96	(8.43 – 23.08)
pHOS	0.12	0.11	0.08	(0.01 – 0.33)	0.81	0.84	0.13	(0.49 – 0.99)
Age-3 NORs	3.83	3.67	1.58	(1.32 – 7.34)	1.48	1.09	1.41	(0.00 – 5.25)
Age-4 NORs	6.74	6.61	1.96	(3.36 – 10.81)	1.21	0.79	1.33	(0.00 – 4.81)
Age-5 NORs	0.86	0.63	0.79	(0.03 – 3.00)	0.92	0.57	1.05	(0.02 – 3.76)
Age-6 NORs	0.00	0.00	0.00	(0.00 – 0.00)	0.00	0.00	0.00	(0.00 – 0.00)
Age-3 HORs	1.26	1.02	0.96	(0.12 – 3.67)	8.46	8.15	3.60	(2.66 – 15.54)
Age-4 HORs	0.33	0.19	0.39	(0.01 – 1.38)	6.70	6.30	3.24	(1.69 – 13.79)
Age-5 HORs	0.03	0.00	0.11	(0.00 – 0.31)	0.21	0.00	0.66	(0.00 – 2.04)
Age-6 HORs	0.00	0.00	0.00	(0.00 – 0.00)	0.00	0.00	0.00	(0.00 – 0.00)
Hamilton Upriver Brights								
Abundance	432.24	417.40	95.02	(296.30 – 661.12)	563.75	546.65	116.66	(395.90 – 832.71)
Females	321.17	309.10	72.34	(217.30 – 495.60)	243.51	235.40	55.88	(161.10 – 373.70)
Males	111.07	106.90	29.29	(67.43 – 180.80)	320.24	310.50	70.28	(216.30 – 483.20)
NORs	415.19	400.70	91.48	(283.79 – 633.70)	535.60	518.60	111.15	(375.30 – 795.60)
HORs	17.06	15.51	7.94	(5.91 – 36.90)	28.15	26.42	10.62	(12.85 – 53.37)
pHOS	0.04	0.04	0.02	(0.02 – 0.08)	0.05	0.05	0.02	(0.03 – 0.09)
Ives/Pierce Upriver Brights								
Abundance	15788.70	15660.00	2179.67	(11730.00 – 20560.00)	8216.90	8004.00	1302.96	(6350.98 – 11470.25)
Females	5922.78	5863.00	902.24	(4288.00 – 7896.03)	4888.06	4766.50	795.76	(3738.98 – 6822.30)
Males	9865.85	9791.00	1417.20	(7276.00 – 12930.00)	3328.85	3240.00	554.77	(2521.98 – 4687.00)
NORs	15617.63	15490.00	2156.74	(11609.75 – 20340.00)	8140.05	7930.00	1290.88	(6284.88 – 11360.00)
HORs	171.04	156.80	83.29	(51.92 – 370.81)	76.84	70.82	36.20	(25.61 – 161.50)
pHOS	0.02	0.01	0.01	(0.00 – 0.02)	0.01	0.01	0.00	(0.00 – 0.02)
Population Upriver Brights								
Abundance	16220.91	16090.00	2182.42	(12170.00 – 21030.25)	8780.63	8562.50	1310.63	(6898.93 – 12050.25)
Females	6243.95	6177.00	905.49	(4593.95 – 8229.13)	5131.57	5008.00	798.82	(3980.90 – 7090.05)
Males	9976.99	9898.00	1417.73	(7379.98 – 13030.25)	3649.08	3561.00	560.73	(2829.00 – 5021.05)
NORs	16032.76	15900.00	2159.20	(12030.00 – 20790.00)	8675.66	8461.00	1298.24	(6809.98 – 11860.25)
HORs	188.10	174.15	83.77	(66.83 – 388.12)	104.99	99.33	38.01	(48.51 – 193.10)
pHOS	0.01	0.01	0.00	(0.00 – 0.02)	0.01	0.01	0.00	(0.01 – 0.02)
Age-3 NORs	10666.09	10580.00	1481.32	(7922.83 – 13910.25)	1134.37	1107.00	197.87	(827.89 – 1594.00)
Age-4 NORs	4222.71	4172.50	672.84	(3021.00 – 5678.10)	7309.92	7133.50	1117.94	(5697.95 – 10040.25)
Age-5 NORs	976.35	951.90	236.43	(584.80 – 1509.05)	229.11	220.70	69.42	(119.20 – 391.00)
Age-6 NORs	167.63	152.30	86.35	(45.62 – 375.30)	2.27	0.21	5.74	(0.00 – 17.22)
Age-3 HORs	58.68	49.49	39.33	(10.86 – 160.11)	31.92	28.20	17.64	(8.91 – 75.94)
Age-4 HORs	109.30	97.91	58.09	(32.39 – 249.70)	62.70	57.81	26.51	(26.03 – 127.20)
Age-5 HORs	17.83	10.87	20.56	(0.72 – 74.78)	9.25	6.27	9.76	(0.52 – 34.87)
Age-6 HORs	2.29	0.12	7.13	(0.00 – 20.92)	1.13	0.09	3.13	(0.00 – 9.01)
Total Fall Chinook Spawners								
Abundance	16234.00	16089.00	2182.00	(12377.00 – 20915.00)	8800.00	8704.00	1311.00	(6510.00 – 11636.00)
NORs	16044.00	15901.00	2159.00	(12229.00 – 20676.00)	8679.00	8584.00	1298.00	(6413.00 – 11489.00)
HORs	190.00	174.00	83.80	(75.90 – 397.00)	120.00	115.00	38.20	(62.50 – 211.00)
pHOS	0.01	0.01	0.01	(0.00 – 0.03)	0.01	0.01	0.01	(0.01 – 0.03)

Median abundance for the entire Lower Gorge URB Chinook population was 16090.00 (13.45) adults with males outnumbering females (Table 11). NORs greatly outnumbered HORs as median pHOS for the entire URB Chinook population was 0.01 (44.53). Scales were taken from a total of 508 URB Chinook carcasses for aging. Most NORs were Age-3, but most HORs were Age-4 based on scale aging data and CWTs (Table 11).

As observed in 2018, no adult EFT Chinook were seen in Hamilton Creek during the early season in 2019 so the Lower Gorge Tule population estimates (Table 11) was based on adult EFT Chinook that spawned on the Ives/Pierce spawning grounds. Adult EFT Chinook were observed on the Ives/Pierce spawning grounds from October 3rd to October 10th. Peak count of lives and deads in the reference sections was 5 fish, which occurred on October 4th. A total of 6 carcasses were sampled with a sex composition of 3 males and 3 females; one of the females sampled was a pre-spawn mortality. There were 6 redds observed when EFT Chinook were expected to be present on the spawning grounds. No population-specific apparent females per redd estimate was generated given that individual redds were not tracked throughout the season. No apparent residence time estimate was generated for the Lower Gorge EFT Chinook population due to low abundance. Median (% CV) spawner abundance for the EFT Chinook population was 18.60 (19.22) adults estimated using the median apparent residence time of 8.29 (13.78) days estimated for the Ives/Pierce URB Chinook spawners. For the EFT Chinook, the number of males was the same as the number of females (Table 11). The number of HORs was much higher in 2019 as median pHOS was 0.84 (16.53). Scales were taken from the six EFT Chinook carcasses for aging. Most adults were 3-year-olds based on scale aging data and CWTs (Table 11).

In 2019, URB Chinook were observed on the Hamilton Creek spawning grounds from October 23rd to December 31st. Peak count of lives and deads in the reference sections was 352. A total of 302 adult URB Chinook carcasses were sampled. The sex composition of recovered carcasses was 162 females and 140 males. A total of 7 females were observed to be pre-spawn mortalities. There were 325 redds observed on the spawning grounds when URB Chinook were present. Median (% CV) apparent residence time was 5.96 (18.78) days; no population-specific apparent females per redd estimate was generated given that individual redds were not tracked throughout the season. Based on AUC, median adult spawner abundance was 546.65 (20.69) with males outnumbering females (Table 11). As seen in 2018, median pHOS was low at 0.05 (30.76) as 95% of the adults being NORs for Hamilton Creek.

In 2019, URB Chinook were observed on the Ives/Pierce spawning grounds from November 1st to December 30th. Peak count of lives and deads in the reference sections was 2980. A total of 398 adult URB Chinook carcasses were sampled. The sex composition of recovered carcasses was 320 females and 78 males. A total of 6 females were observed to be pre-spawn mortalities. There were 1526 redds observed on the spawning grounds when URB Chinook were present. Median (% CV) apparent residence time was 8.29 (13.78) days; no population-specific apparent females per redd estimate was generated given that individual redds were not tracked throughout the season. Based on AUC, median adult spawner abundance was 8004.00 (15.86) with females outnumbering males (Table 11). Median pHOS was low at 0.01 (43.49). Median abundance for the entire Lower Gorge URB Chinook population was 8562.50 (14.93) adults with females outnumbering males (Table 4). As seen in 2018, median pHOS was low at 0.01 (33.49).

Median abundance for the entire Lower Gorge URB Chinook population in 2019 was 8562.50 (15.31) adults with females outnumbering males (Table 11). NORs greatly outnumbered HORs as median pHOS for the entire URB Chinook population was 0.01 (40.00). Scales were taken from a total of 625 URB Chinook carcasses for aging. Most adults were Age-4 based on scale aging data and CWTs (Table 11).

Total adult Fall Chinook spawners abundances were estimated as 16089.00 (13.44) in 2018 and 8704.00 (14.90) in 2019. The number of NORs was considerably higher than the number of HORs (Table 11). Comparing both survey years (Table 11), adult abundance was near double in 2018 compared to 2019. The proportion of HOR adults was consistent across survey years. Median EFT and URB Chinook spawner abundances observed in 2018 and 2019 were comparable to adult spawner abundances observed over the past ten years (Figure 16). For most years, HORs have outnumbered NORs for EFT Chinook, but NORs greatly outnumber HORs for URB Chinook. The highest abundance of adults observed over the past ten years was 2010 for EFT Chinook (Figure 16a) and 2018 for URB Chinook (Figure 16b). Notably, EFT Chinook abundances for the Lower Gorge are considerably lower than most of the other Fall Chinook populations in the LCR Chinook ESU.

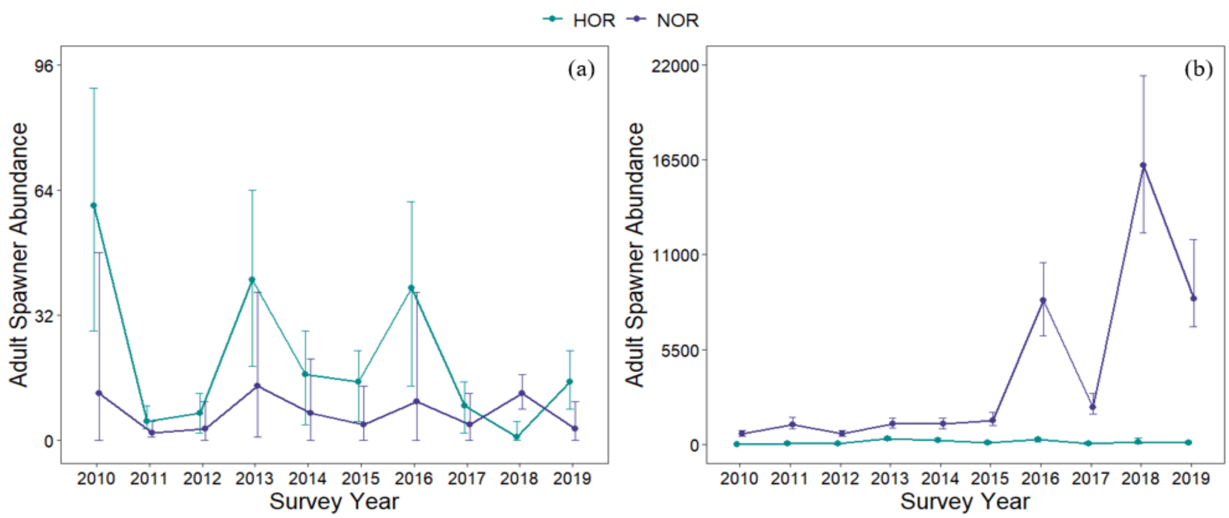

Figure 16. Estimated adult abundances of hatchery-origin (HOR) and natural-origin (NOR) early fall/tule (EFT) Chinook (a) and upriver bright (URB) Chinook (b) salmon that spawned in survey years 2010 – 2019 for the Lower Gorge population. Point estimates are medians and error bars represent the 95% credible intervals.

Upper Gorge (Little White Salmon and Wind)

As observed in the Lower Gorge populations, a high abundance of URB Chinook (a stock of LFB Chinook) have been established, presumably via straying from nearby hatchery programs utilizing that stock, and now use the spawning grounds in the Little White Salmon and Wind Rivers. Given the inability to completely differentiate EFT and URB Chinook that temporally and spatially overlap on the spawning grounds due to current monitoring protocols, adult abundances are reported based on presumed run from field calls given the observed phenotypes and timing of spawning. Collective estimates of total spawner abundances by origin and observed pHOS are also presented for the Upper Gorge Fall Chinook population (Table 12).

In 2018, adult EFT Chinook were observed in the Little White Salmon (LWS) from September 10th to October 24th. Peak count of deads only in the reference sections was 45 fish, which occurred on September 19th. Of the 11 EFT Chinook carcasses sampled, 10 were females and 1 was a male. One female was identified to be a pre-spawn mortality. A total of 34 redds were observed when adult EFT

Chinook were present on the spawning grounds. No estimates of apparent residence time and apparent females per redd were generated for the stream given the proximity of the hatchery and potential staging at Drano Lake (Appendix A). Based on PCE, median (% CV) abundance for the stream was 235.30 (16.82) adults with females greatly outnumbering males (Table 12). Nearly 82% of the adult abundance was NORs as median pHOS for the stream was 0.18 (53.15).

On the Wind River, adult EFT Chinook were observed on the spawning grounds from September 25th to October 9th in 2018. Peak count of lives and deads in the reference sections was 52 adults, which occurred on October 2nd. A total of five EFT Chinook carcasses were sampled. Three of the carcasses were females, and none of them were pre-spawn mortalities. A total of 40 redds were observed when EFT Chinook were present on the spawning grounds. No apparent female per redd estimate was generated for the stream given that individual redds were not tracked. Median (% CV) apparent residence time was estimated as 6.11 (16.86) days. Based on AUC, median abundance for the stream was 62.77 (11.07) adults with females slightly outnumbering males (Table 12). Approximately 39% of these adults were NORs as median pHOS for the stream was 0.61 (29.80, Table 12).

Median abundance for the entire Upper Gorge EFT Chinook population was 299.60 (13.43) adults in 2018. There were four-times as many females as males, largely due to the sex ratio observed in the LWS River (Table 12). Approximately 73% of adults were NORs as median pHOS for the entire population was 0.27 (33.23). Scales were taken from a total of 16 EFT Chinook carcasses for aging. Most adults in the population were 3- or 4-year-olds based on scale aging data and CWTs (Table 12).

In 2018, adult URB Chinook were observed in the Little White Salmon (LWS) from October 10th to November 19th. Peak count of deads only in the reference sections was 68 fish, which occurred on November 19th. Of the 91 URB Chinook carcasses sampled, 38 were females and 53 were males. One female was identified to be a pre-spawn mortality. A total of 163 redds were observed when adult URB Chinook were present on the spawning grounds. No estimates of apparent residence time and apparent females per redd were generated for the stream given the proximity of the hatchery and potential staging at Drano Lake (Appendix A). Based on PCE, median (% CV) abundance for the stream was 520.60 (16.54) adults with males outnumbering females (Table 12). Nearly 36% of the adult abundance was NORs as median pHOS for the stream was 0.64 (8.19).

On the Wind River, adult URB Chinook were observed on the spawning grounds from October 16th to November 29th in 2018. Peak count of lives and deads in the reference sections was 257 adults, which occurred on November 19th. A total of 68 URB Chinook carcasses were sample with 46 identified as female and 22 identified as male. No pre-spawn mortalities were observed among the female carcasses. A total of 71 redds were observed when URB Chinook were present on the spawning grounds. No apparent female per redd estimate was generated for the stream given that individual redds were not tracked. Median (% CV) apparent residence time was estimated as 5.78 (17.49) days. Based on AUC, median abundance for the stream was 525.20 (18.19) adults with females outnumbering males (Table 12). Approximately 50% of these adults were HORs as median pHOS for the stream was 0.50 (12.04, Table 12).

Median (% CV) abundance for the entire Upper Gorge URB Chinook population was 1053.00 (12.31) adults in 2018. The number of females slightly outnumbered the number of males (Table 12). Approximately 43% of adults were NORs as median pHOS for the entire population was 0.57 (7.12). Scales were taken from a total of 159 URB Chinook carcasses for aging. Most adults in the population were Age-3 and Age-4 based on scale aging data and CWTs (Table 12).

Table 12. Mean, median, standard deviation (SD), and 95% credible interval (CI) parameter estimates for the Upper Gorge Fall Chinook population in survey years 2018 and 2019.

Parameter			**2018**				**2019**	
	Mean	**Median**	**SD**	**95% CI**	**Mean**	**Median**	**SD**	**95% CI**
Little White Salmon Early Fall/Tule								
Abundance	238.42	235.30	40.10	(168.70 – 324.20)	330.26	293.45	141.64	(182.20 – 692.07)
Females	201.42	199.20	41.32	(126.60 – 288.00)	288.83	256.20	128.12	(151.90 – 615.53)
Males	37.01	32.19	24.28	(4.80 – 96.69)	41.43	32.87	32.84	(4.92 – 129.70)
NORs	191.68	189.70	44.74	(111.9 – 287.10)	209.47	187.90	97.65	(91.83 – 454.91)
HORs	46.75	42.97	24.83	(10.30 – 105.50)	120.79	105.90	69.05	(38.44 – 293.53)
pHOS	0.20	0.18	0.11	(0.04 – 0.44)	0.36	0.36	0.12	(0.15 – 0.61)
Wind Early Fall/Tule								
Abundance	64.11	62.77	7.10	(54.76 – 81.48)	545.43	524.50	92.57	(424.99 – 781.93)
Females	36.66	36.79	11.90	(13.66 – 59.78)	276.65	268.20	56.98	(191.50 – 413.40)
Males	27.45	26.47	11.70	(7.46 – 51.90)	268.79	260.80	55.60	(184.70 – 399.80)
NORs	25.98	25.01	11.78	(6.47 – 50.90)	345.72	333.95	66.60	(249.80 – 517.50)
HORs	38.13	38.50	12.14	(14.64 – 61.42)	199.72	193.40	46.11	(128.50 – 307.20)
pHOS	0.59	0.61	0.18	(0.23 – 0.90)	0.37	0.36	0.06	(0.26 – 0.48)
Population Early Fall/Tule								
Abundance	302.53	299.60	40.62	(231.20 – 390.41)	875.69	842.30	169.17	(658.70 – 1300.00)
Females	238.07	235.80	42.93	(159.40 – 327.50)	565.48	537.50	140.08	(387.40 – 910.43)
Males	64.46	60.62	26.92	(23.05 – 128.00)	310.21	300.45	64.54	(210.40 – 461.41)
NORs	217.66	215.40	46.30	(133.90 – 316.40)	555.19	534.20	118.71	(390.50 – 842.51)
HORs	84.88	81.96	27.55	(38.85 – 147.20)	320.51	307.20	82.36	(200.30 – 515.00)
pHOS	0.28	0.27	0.09	(0.13 – 0.49)	0.37	0.36	0.06	(0.26 – 0.49)
Age-3 NORs	106.28	102.60	36.44	(46.49 – 187.10)	437.57	421.30	96.79	(299.00 – 665.03)
Age-4 NORs	108.32	104.70	37.58	(46.03 – 191.00)	113.97	105.90	45.17	(51.49 – 222.70)
Age-5 NORs	3.06	0.54	6.40	(0.00 – 22.12)	3.64	0.70	7.73	(0.00 – 24.22)
Age-6 NORs	0.00	0.00	0.00	(0.00 – 0.00)	0.00	0.00	0.00	(0.00 – 0.00)
Age-3 HORs	58.67	56.05	21.06	(25.05 – 106.50)	262.56	252.10	68.81	(161.80 – 427.32)
Age-4 HORs	24.74	21.43	15.59	(4.48 – 64.14)	56.01	50.50	28.50	(19.43 – 125.30)
Age-5 HORs	1.47	0.14	3.62	(0.00 – 11.32)	1.94	0.20	4.76	(0.00 – 14.85)
Age-6 HORs	0.00	0.00	0.00	(0.00 – 0.00)	0.00	0.00	0.00	(0.00 – 0.00)
Little White Salmon Upriver Brights								
Abundance	530.18	520.60	87.69	(388.80 – 729.51)	906.97	888.70	109.93	(745.50 – 1168.00)
Females	222.90	218.30	45.70	(147.30 – 324.50)	580.89	569.45	72.99	(469.00 – 750.41)
Males	307.28	301.05	57.90	(213.10 – 441.30)	326.07	320.20	44.15	(258.00 – 429.50)
NORs	190.61	186.00	43.19	(118.30 – 288.50)	243.95	239.30	35.83	(187.40 – 327.50)
HORs	339.57	333.50	61.73	(237.30 – 480.30)	663.02	649.50	82.11	(540.10 – 858.50)
pHOS	0.64	0.64	0.05	(0.54 – 0.74)	0.73	0.73	0.02	(0.69 – 0.77)
Wind Upriver Brights								
Abundance	535.38	525.20	97.39	(372.69 – 747.11)	4424.93	4307.00	841.77	(3169.95 – 6434.08)
Females	358.91	351.80	72.44	(241.70 – 517.50)	1815.44	1768.00	357.48	(1286.00 – 2651.03)
Males	176.47	171.60	43.90	(104.60 – 277.00)	2609.55	2536.00	504.50	(1859.95 – 3796.05)
NORs	266.84	262.40	58.31	(170.70 – 395.90)	1584.73	1542.00	313.93	(1114.98 – 2334.03)
HORs	268.54	263.10	59.00	(172.00 – 401.51)	2840.27	2762.00	549.33	(2020.00 – 4141.03)
pHOS	0.50	0.50	0.06	(0.38 – 0.62)	0.64	0.64	0.02	(0.60 – 0.68)
Population Upriver Brights								
Abundance	1065.56	1053.00	131.13	(839.40 – 1350.00)	5331.96	5214.00	848.32	(4051.00 – 7336.03)
Females	581.81	575.70	85.54	(434.40 – 767.91)	2396.34	2351.00	364.03	(1841.00 – 3252.03)
Males	483.75	477.70	72.77	(360.00 – 639.60)	2935.63	2861.00	506.47	(2176.00 – 4142.08)
NORs	457.45	451.05	72.82	(333.80 – 616.81)	1828.67	1787.00	315.69	(1352.98 – 2579.15)
HORs	608.11	601.30	85.00	(462.30 – 793.60)	3503.28	3427.00	555.30	(2665.98 – 4818.08)
pHOS	0.57	0.57	0.04	(0.49 – 0.65)	0.66	0.66	0.02	(0.62 – 0.69)

Age-3 NORs	176.67	173.50	37.47	(112.40 – 258.51)	496.51	484.70	98.71	(342.30 – 724.81)
Age-4 NORs	212.68	209.50	45.04	(136.20 – 311.30)	1262.89	1231.00	227.15	(918.68 – 1816.03)
Age-5 NORs	66.84	64.02	22.42	(31.38 – 116.80)	68.29	64.54	24.01	(32.59 – 124.91)
Age-6 NORs	1.26	0.13	2.87	(0.00 – 9.70)	0.98	0.08	2.60	(0.00 – 7.75)
Age-3 HORs	239.58	235.30	45.82	(162.10 – 342.51)	1626.96	1584.00	283.28	(1204.00 – 2309.00)
Age-4 HORs	212.87	209.50	41.80	(140.20 – 305.30)	1836.25	1798.00	289.40	(1392.98 – 2511.08)
Age-5 HORs	154.43	151.00	35.58	(94.59 – 232.91)	39.04	35.99	18.05	(13.97 – 83.17)
Age-6 HORs	1.24	0.13	2.92	(0.00 – 9.13)	1.03	0.08	2.86	(0.00 – 8.33)
Total Fall Chinook Spawners								
Abundance	1368.00	1363.00	130.00	(1133.00 – 1641.00)	6208.00	6172.00	664.00	(5016.00 – 7603.00)
NORs	541.00	535.00	81.50	(397.00 – 722.00)	2378.00	2354.00	340.00	(1780.00 – 3117.00)
HORs	827.00	821.00	101.00	(647.00 – 1039.00)	3829.00	3788.00	567.00	(2840.00 – 5049.00)
pHOS	0.61	0.61	0.05	(0.51 – 0.69)	0.62	0.62	0.05	(0.52 – 0.71)

In 2019, adult EFT Fall Chinook were observed in the Little White Salmon (LWS) from September 27th to October 31st. Peak count of deads was 25 fish, which occurred on October 31st. Of the 14 EFT Chinook carcasses sampled, 13 were females and 1 was a male. No sampled females were pre-spawn mortalities. A total of 143 redds were observed when EFT Chinook were present on the spawning grounds. No estimate of apparent females per redd was generated for the stream since redds were not tracked, and no apparent residence time was estimated for the stream. Based on PCE, median (% CV) abundance for the stream was 293.45 (42.89) adults with females greatly outnumbering males (Table 12). Nearly 64% of the adult abundance was NORs as median pHOS for the stream was 0.36 (33.02).

On the Wind River, adult EFT Chinook were observed on the spawning grounds from September 26th to October 23rd in 2019. Peak count of lives and deads was 392 adults, which occurred on October 17th. A total of 71 Tule Chinook carcasses were sampled with 36 identified as females and 35 assigned as males. No pre-spawn mortalities were observed. A total of 232 redds were counted when EFT Chinook were present on the spawning grounds, but no apparent female per redd estimate was generated given that individual redds were not tracked. Median (% CV) apparent residence time was estimated as 5.49 (14.51) days. Based on AUC, median abundance for the stream was 524.50 (16.97) adults with females slightly outnumbering males (Table 12). Approximately 64% of these adults were NORs as median pHOS for the stream was 0.36 (15.51).

Median abundance for the entire Upper Gorge EFT Chinook population was 842.30 (19.32) adults in 2019. There were nearly twice as many females as males, largely due to the sex ratio observed in the LWS River (Table 12). Approximately 72% of adults were NORs as mean pHOS for the entire population was 0.36 (15.85). Scales were taken from a total of 77 EFT Chinook carcasses for aging. Most adults were 3-year-olds based on scale aging data and CWTs (Table 12).

In 2019, adult URB Chinook were observed in the Little White Salmon (LWS) from October 31st to December 18th. Peak count of deads only in the reference sections was 400 fish, which occurred on November 26th. Of the 507 URB Chinook carcasses sampled, 325 were females and 182 were males. Nineteen females were identified to be pre-spawn mortalities. A total of 912 redds were observed when adult URB Chinook were present on the spawning grounds. No estimates of apparent residence time and apparent females per redd were generated for the stream given the proximity of the hatchery and potential staging at Drano Lake (Appendix A). Based on PCE, median (% CV) abundance for the stream was 888.70 (12.12) adults with females greatly outnumbering males (Table 12). The majority of adults were HORs as median pHOS for the stream was 0.73 (2.90).

On the Wind River, adult URB Chinook were observed on the spawning grounds from October 17th to December 16th in 2019. Peak count of lives and deads in the reference sections was 1949 adults, which occurred on November 14th. A total of 583 URB Chinook carcasses were sampled. Of the carcasses sampled, 239 were females and 344 were males. Three female carcasses were identified as pre-spawn mortalities. A total of 947 redds were observed when URB Chinook were present on the spawning grounds. No apparent female per redd estimate was generated for the stream given that individual redds were not tracked. Median (% CV) apparent residence time was estimated as 7.17 (17.01) days. Based on AUC, median abundance for the stream was 4307.00 (19.02) adults with males outnumbering females (Table 12). Approximately 36% of these adults were NORs as median pHOS for the stream was 0.64 (3.19, Table 12).

Median abundance for the entire Upper Gorge URB Chinook population was 5214.00 (15.91) adults in 2019, with males slightly outnumbering females (Table 12). Approximately 34% of adults were NORs as median pHOS for the entire population was 0.66 (2.67). Scales were taken from a total of 986 URB Chinook carcasses for aging. Most adults in the population were Age-3 or Age-4 based on scale aging data and CWTs (Table 12).

Total adult Fall Chinook spawner abundance (median (% CV))) was 1363.00 (9.50) in 2018, and nearly four times as high in survey year 2019 at 6172.00 (10.70) adults. The number of NORs was lower than the number of HORs in both years as median pHOS was 0.61 and 0.62, respectively (Table 12). Median EFT and URB Chinook spawner abundances observed in 2018 and 2019 were comparable to adult spawner abundances observed over the past ten years (Figure 17). For most years, HOR URBs have had the highest abundance with the largest year being 2013 (Figure 17). Similar trends in abundances have been observed for both EFT and URB Chinook in the Upper Gorge population.

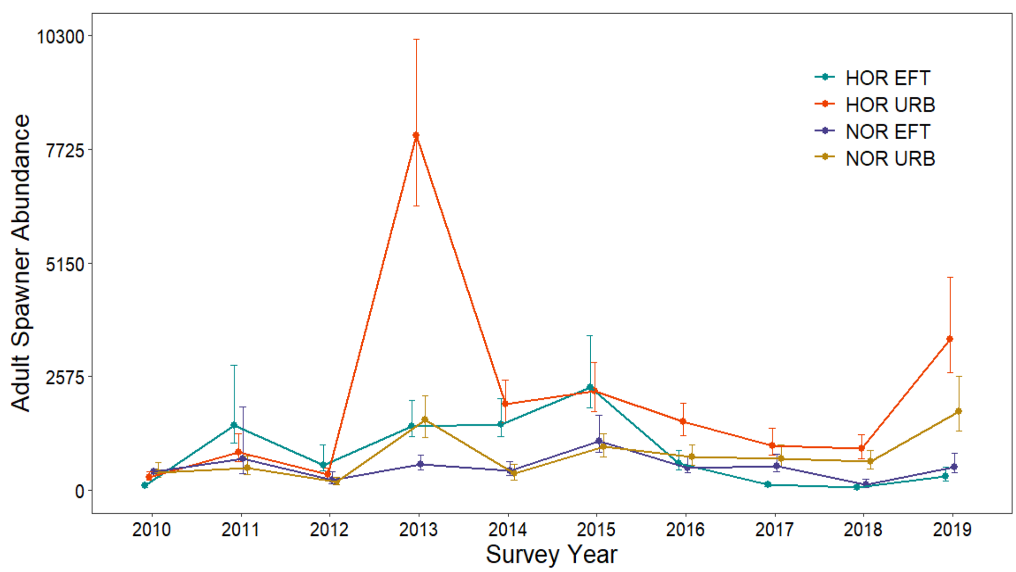

Figure 17. Estimated adult abundances of hatchery-origin (HOR) and natural-origin (NOR) early fall/tule (EFT) Chinook and upriver bright (URB) Chinook salmon that spawned in survey years 2010 – 2019 for the Upper Gorge population. Point estimates are medians and error bars represent the 95% credible intervals.

White Salmon

In addition to designated Spring Chinook and EFT Chinook populations, a high abundance of URB Chinook (a stock of LFB Chinook) have been established, presumably via straying from nearby hatchery programs utilizing that stock, and now use the spawning grounds in the White Salmon River. Given the inability to completely differentiate EFT and URB Chinook that temporally and spatially overlap, adult abundances are reported based on presumed run from field calls given the observed phenotypes and timing of spawning. Collective estimates of total spawner abundances by origin and observed pHOS are also presented for the Upper Gorge Fall Chinook population (Table 13).

Monitoring of Spring Chinook populations in the White Salmon River was implemented in 2013 (Olk and Wilson 2019). In 2018, Spring Chinook adults were observed on the spawning grounds from August 8th to September 24th. Peak count of lives and deads in the reference sections was 28 fish, which occurred on September 4th. A total of 6 carcasses were sampled on the spawning grounds. The sex composition of sampled carcasses was six females and zero males. No pre-spawn mortalities were observed. A total of 29 redds were observed while Spring Chinook were present on the spawning grounds. No apparent females per redd estimate was generated given that individual redds were not tracked throughout the season. Median (% CV) apparent residence time was 6.65 (19.04) days. Based on AUC, median adult abundance was 81.03 (20.96) with females greatly outnumbering males (Table 13). Approximately 8% of the returns were NORs as median pHOS for the entire stream was 0.92 (11.70). Scales were taken from all 6 carcasses, but age compositions were largely determined by compositions observed in previous survey years. Most adults were 4-year-olds based on scale aging data and CWTs (Table 13).

In 2019, adult Spring Chinook were observed on the spawning grounds from August 26th to September 16th. Peak count of lives and deads in the reference sections was 2 fish, which occurred on September 3rd. No carcasses were recovered on the spawning grounds. No redds were observed while Spring Chinook were present on the spawning grounds so no apparent females per redd estimate was generated. The median (% CV) apparent residence time was 5.51 (27.92) days. Based on AUC, median abundance was 4.00 (32.21) adults (Table 13). With so few adults, males outnumbered females, but only by 1.5 fish. There was one more NOR adult than HOR so median pHOS was low (0.29 (70.69)). As a result of zero carcass recoveries and low abundances, the age composition of spawners could not be estimated directly or hierarchically.

Table 13. Mean, median, standard deviation (SD), and 95% credible interval (CI) parameter estimates for the White Salmon Spring Chinook population in survey years 2018 and 2019.

Parameter	2018				2019			
	Mean	Median	SD	95% CI	Mean	Median	SD	95% CI
Abundance	83.77	81.03	17.55	(58.07 – 125.00)	3.91	4.00	1.26	(2.00 – 7.04)
Females	73.37	71.53	17.89	(43.93 – 113.90)	1.31	1.07	1.06	(0.04 – 3.91)
Males	10.40	7.74	9.62	(0.30 – 34.71)	2.61	2.49	1.26	(0.56 – 5.57)
NORs	9.42	6.68	9.14	(0.21 – 33.99)	2.60	2.60	1.28	(0.54 – 5.56)
HORs	74.35	72.53	17.83	(45.13 – 115.10)	1.31	1.31	1.07	(0.04 – 3.90)
pHOS	0.89	0.92	0.10	(0.61 – 0.99)	0.33	0.29	0.24	(0.01 – 0.84)
Age-4 NORs	2.39	0.00	5.50	(0.00 – 19.28)	N/A[1]	N/A[1]	N/A[1]	N/A[1]
Age-5 NORs	2.32	0.06	5.10	(0.00 – 17.85)	N/A[1]	N/A[1]	N/A[1]	N/A[1]
Age-6 NORs	2.33	0.05	5.27	(0.00 – 18.26)	N/A[1]	N/A[1]	N/A[1]	N/A[1]
Age-4 HORs	70.84	69.13	17.99	(40.39 – 111.20)	N/A[1]	N/A[1]	N/A[1]	N/A[1]
Age-5 HORs	1.18	0.01	3.47	(0.00 – 11.45)	N/A[1]	N/A[1]	N/A[1]	N/A[1]
Age-6 HORs	1.18	0.01	3.53	(0.00 – 11.38)	N/A[1]	N/A[1]	N/A[1]	N/A[1]

[1]No scales were collected for aging and number of live fish encountered was too low to accurately estimate ages for the 2019 returns.

Comparing survey years, adult abundances were considerably higher in 2018 than observed in 2019 (Table 13). The number of NOR Spring Chinook adults in the White Salmon River declined in 2014, and has been low ever since ranging from 1 to 40 adults per year (Figure 18). HOR abundance has fluctuated with some years being slightly higher than others, but abundances are often less than 150 total adults. The highest return year to-date over the past seven years was 2014 for HORs and 2013 for NORs (Figure 18). Overall, Spring Chinook abundances in the White Salmon are comparable to abundances observed with other Spring Chinook populations in the LCR Chinook ESU except for re-introduction areas above hydro-systems in the Cowlitz and Lewis rivers.

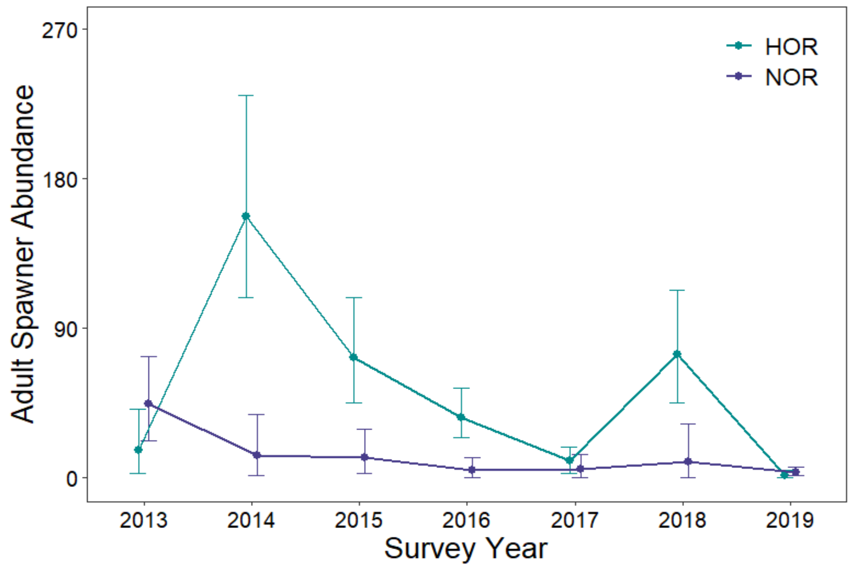

Figure 18. Estimated adult abundances of hatchery-origin (HOR) and natural-origin (NOR) Spring Chinook salmon that spawned in survey years 2013-2019 for the White Salmon population. Spring Chinook VSP monitoring in this basin wasn't initiated until 2013 (Olk and Wilson 2019). Point estimates are medians and error bars represent the 95% credible intervals.

In 2018, adult EFT Chinook were observed on the spawning grounds from September 17th to November 5th. Peak count of lives and deads in the reference sections was 46 fish, which occurred on October 15th. A total of 24 EFT carcasses were sampled on the spawning grounds. The sex composition of the recovered carcasses was 4 males and 20 females with 2 females identified as pre-spawn mortalities. A total of 520 redds were observed while EFT Chinook were present on the spawning grounds. No apparent females per redd estimate was generated given that individual redds were not tracked throughout the season. Median (% CV) apparent residence time was 5.89 (21.91) days. Based on AUC, median adult abundance was 189.60 (22.20) with four-times as many females as males (Table 14). Approximately 57% of the adults were NORs as median pHOS for the entire stream was 0.43 (22.81). Scales were taken from the 24 carcasses for aging. Almost all adults were 3-year-olds based on scale aging data and CWTs (Table 14).

In 2018, adult URB Chinook were observed on the spawning grounds from October 8th to November 27th. Peak count of lives and deads in the reference sections was 500 adults, which occurred on November 13th. A total of 218 URB carcasses were sampled on the spawning grounds. The sex composition of the recovered carcasses was 64 males and 154 females, with two females identified as pre-spawn mortalities. A total of 1227 redds were observed while URB Chinook were present on the spawning grounds. No apparent females per redd estimate was generated given that individual redds were not tracked throughout the season. Median (% CV) apparent residence time was 7.23 (24.37) days. Based on AUC, median adult abundance was 2323.00 (26.34) with four-times as many females returning as males (Table 14). Approximately 41% of the adults were NORs as median pHOS for the stream was 0.59 (5.64). Scales were taken from 199 carcasses for aging. The majority of adults were 4-year-olds based on scale aging data and CWTs (Table 14).

Table 14. Mean, median, standard deviation (SD), and 95% credible interval (CI) parameter estimates for the White Salmon Fall Chinook population in survey years 2018 and 2019.

Parameter	2018 Mean	2018 Median	2018 SD	2018 95% CI	2019 Mean	2019 Median	2019 SD	2019 95% CI
Early Fall/Tule								
Abundance	194.35	189.60	43.14	(123.90 – 294.22)	627.18	617.70	136.42	(392.57 – 928.21)
Females	156.76	152.90	37.84	(95.85 – 243.00)	445.24	436.85	105.62	(266.50 – 679.01)
Males	37.59	34.86	17.43	(11.79 – 79.27)	181.94	175.05	58.79	(89.78 – 316.40)
NORs	110.35	106.30	31.33	(59.23 – 182.20)	382.85	374.60	96.63	(221.00 – 593.95)
HORs	83.98	80.68	27.06	(40.07 – 146.41)	244.26	236.40	71.96	(128.70 – 404.91)
pHOS	0.43	0.43	0.10	(0.25 – 0.63)	0.39	0.39	0.08	(0.25 – 0.55)
Age-3 NORs	39.07	36.47	16.91	(13.59 – 78.93)	313.21	304.90	83.75	(174.10 – 501.50)
Age-4 NORs	70.39	67.39	23.91	(32.94 – 125.10)	67.74	62.05	33.95	(20.15 – 148.91)
Age-5 NORs	0.90	0.03	2.52	(0.00 – 8.01)	1.90	0.06	5.25	(0.00 – 16.98)
Age-6 NORs	0.00	0.00	0.00	(0.00 – 0.00)	0.00	0.00	0.00	(0.00 – 0.00)
Age-3 HORs	66.50	63.32	23.13	(30.78 – 119.40)	208.09	200.65	64.55	(106.00 – 352.90)
Age-4 HORs	16.94	14.66	10.47	(3.40 – 42.86)	35.07	30.78	21.36	(6.76 – 88.16)
Age-5 HORs	0.53	0.00	1.62	(0.00 – 5.14)	1.10	0.01	3.73	(0.00 – 10.49)
Age-6 HORs	0.00	0.00	0.00	(0.00 – 0.00)	0.00	0.00	0.00	(0.00 – 0.00)
Upriver Brights								
Abundance	2437.01	2323.00	641.92	(1507.00 – 3990.00)	9235.50	8835.00	2498.76	(5517.50 – 15320.00)
Females	1648.69	1573.00	441.71	(1014.00 – 2722.08)	6964.12	6663.50	1888.99	(4140.95 – 11530.25)
Males	788.39	752.95	222.26	(463.30 – 1320.03)	2271.36	2174.00	634.33	(1319.98 – 3816.03)
NORs	991.40	944.15	271.99	(593.09 – 1652.03)	2058.33	1968.00	576.73	(1194.00 – 3437.15)
HORs	1445.58	1379.00	392.83	(879.10 – 2407.05)	7177.16	6870.00	1947.40	(4277.95 – 11910.00)
pHOS	0.59	0.59	0.03	(0.53 – 0.66)	0.78	0.78	0.02	(0.75 – 0.81)
Age-3 NORs	152.88	142.90	57.87	(69.26 – 297.02)	256.90	241.90	92.48	(121.10 – 475.82)
Age-4 NORs	556.47	528.55	160.13	(318.70 – 946.65)	1689.50	1613.00	478.07	(974.89 – 2846.00)
Age-5 NORs	269.49	253.35	89.41	(138.40 – 484.81)	110.54	101.20	51.20	(40.55 – 233.41)
Age-6 NORs	12.56	8.59	12.83	(0.35 – 45.83)	1.39	0.00	4.78	(0.00 – 13.54)
Age-3 HORs	381.86	362.10	119.31	(210.50 – 671.70)	900.95	860.00	268.57	(497.90 – 1541.03)
Age-4 HORs	630.44	598.45	186.62	(364.19 – 1089.03)	6098.30	5835.00	1656.54	(3626.98 – 10100.50)
Age-5 HORs	420.11	399.90	128.61	(231.80 – 734.73)	162.91	152.00	65.37	(69.50 – 322.41)
Age-6 HORs	13.18	9.07	13.24	(0.47 – 48.54)	15.00	10.10	15.56	(0.45 – 58.04)
Total Fall Chinook Spawners								
Abundance	2631.00	2588.00	451.00	(1871.00 – 3612.00)	9897.00	9630.00	2073.00	(6640.00 – 14758.00)
NORs	1102.00	1078.00	229.00	(728.00 – 1616.00)	2443.00	2370.00	588.00	(1516.00 – 3785.00)
HORs	1529.00	1481.00	390.00	(908.00 – 2422.00)	7453.00	7172.00	1997.00	(4377.00 – 12182.00)
pHOS	0.58	0.58	0.08	(0.42 – 0.72)	0.75	0.75	0.07	(0.60 – 0.86)

In 2019, adult EFT Chinook were observed on the spawning grounds from September 11th to October 30th. Peak count of lives and deads in the reference sections was 150 fish, which occurred on October 14th. A total of 43 carcasses were sampled on the spawning grounds. The sex composition of sampled carcasses was 12 males and 31 females with four of the females identified as pre-spawn mortalities. A total of 568 redds were observed while EFT Chinook were present on the spawning grounds. No apparent females per redd estimate was generated given that individual redds were not tracked throughout the season. Median (% CV) apparent residence time was 5.57 (21.94) days. Based on AUC, median abundance was 617.70 (21.75) adults with over twice as many females returning as males

(Table 14). Approximately 61% of the adults were NORs as mean pHOS for the entire stream was 0.39 (19.52). Scales were taken from 40 of the carcasses for aging. The majority of adults were 4-year-olds based on scale aging data and CWTs (Table 14).

In 2019, adult URB Chinook were observed on the spawning grounds from October 24th to December 2nd. Peak count of lives and deads in the reference sections was 2847 adults, which occurred on November 12th. A total of 722 URB carcasses were sampled on the spawning grounds. The sex composition of the recovered carcasses was 174 males and 548 females, with two females identified as pre-spawn mortalities. A total of 2819 redds were observed while URB Chinook were present on the spawning grounds. No apparent females per redd estimate was generated given that individual redds were not tracked throughout the season. Median (% CV) apparent residence time was 5.37 (25.66) days. Based on AUC, median adult abundance was 8835.00 (27.06) with three-times as many females as males (Table 14). Approximately 22% of the adults were NORs as median pHOS for the stream was 0.78 (2.01). Scales were taken from 663 carcasses for aging. The majority of adults were 4-year-olds based on scale aging data and CWTs (Table 14).

Comparing survey years, adult abundances were significantly higher in 2019 for both EFT and URB Chinook (Table 14). The number of HORs increased in 2019 for URB Chinook, but decreased for EFT Chinook. NORs always outnumbered HORs for EFT Chinook, but HORs greatly outnumbered NORs for URB Chinook. The observed sex ratio was comparable between years with females outnumbering males (Table 14). Total adult Fall Chinook spawner abundance (median (% CV))) was 2588.00 (17.43) in 2018, and over three-and-a-half times as high in survey year 2019 at 9630.00 (21.53) adults. The total number of NORs was lower than the number of HORs in both years as median pHOS was 0.58 and 0.75, respectively (Table 14). Median abundances observed in 2018 and 2019 were comparable to abundances observed over the past ten years (Figure 19). For most years, HOR URBs have had the highest abundance with the largest year being 2019 (Figure 19). Similar trends in abundances have been observed for both EFT and URB Chinook in the White Salmon population.

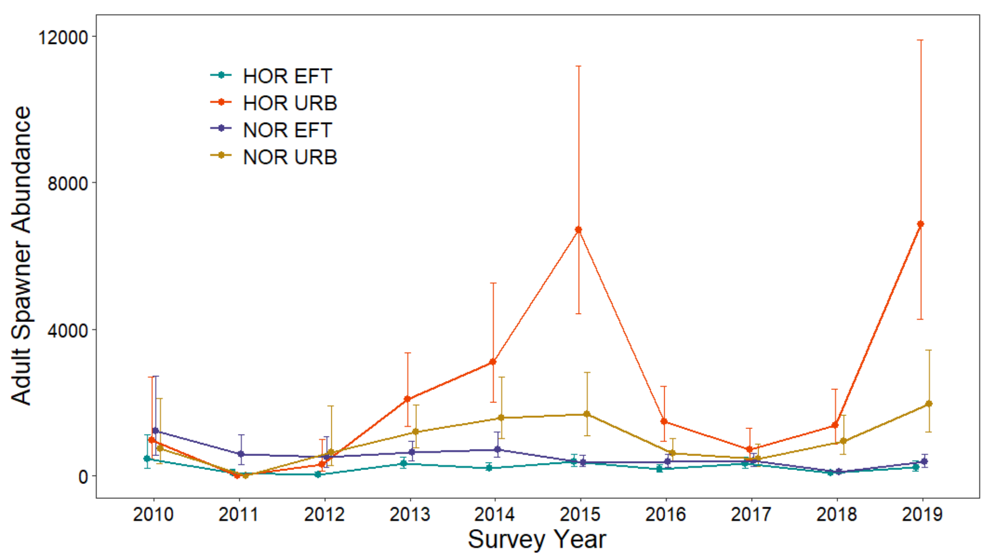

Figure 19. Estimated adult abundances of hatchery-origin (HOR) and natural-origin (NOR) early fall/tule (EFT) Chinook and adult upriver bright (URB) Chinook salmon that spawned in survey years 2010 – 2019 for the White Salmon population. Point estimates are medians and error bars represent the 95% credible intervals.

Recovery Goals and Weir Guideline Updates

NOR Abundance Targets

In the ESA Recovery Plan (NMFS 2013), NMFS coordinated with stakeholders to set minimum target viability levels (primary, contributing, or stabilizing) for each Spring and Fall Chinook population in the LCR Chinook ESU based on historical abundances, baseline VSP parameters, current habitat conditions, and growth potential in terms of hatchery influences and harvest effects. One recovery goal assigned for each population includes target adult NOR spawner abundances based on assigned viability levels. These adult NOR abundance targets vary from 100 to 1800 adults for Spring Chinook populations, and 500 to 7300 adults for Fall Chinook populations (see Table 7-4 in NMFS 2013). To assess how close populations are to these minimum NOR spawner abundance recovery goals, the 5-year (2015-2019) geometric means of NOR spawners were plot as percentages of the recovery goals (Figure 20) using the smoothed abundance data reported in WDFW's SaSI and the 2020 State of the Salmon report (https://stateofsalmon.wa.gov/; https://github.com/tbuehrens/WDFW_SOS_Analysis). Based on the recovery plot (Figure 20), four Fall Chinook populations within the LCR Chinook ESU have exceeded their adult NOR spawner abundance goal targets set by NMFS. An additional nine populations are making progress towards their recovery goals. For all extant Spring Chinook populations that WDFW monitors, the North Fork Lewis Spring Chinook population has the lowest NOR abundance and is the furthest from its recovery goal. For Fall Chinook, the Lower Gorge early fall/tule Chinook population is the furthest from its adult NOR spawner recovery goal (Figure 20).

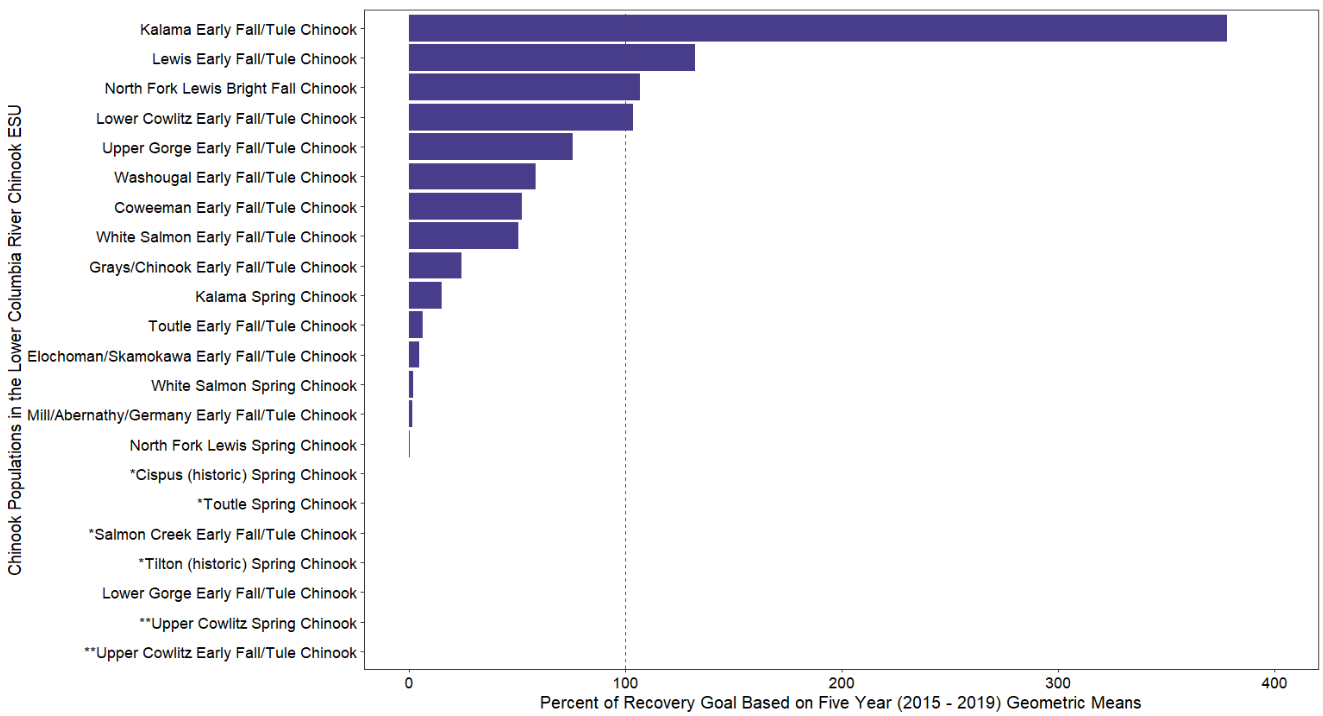

Figure 20. The percent of the natural-origin spawner abundance recovery goal set by NMFS (red line) that has been achieved for Fall and Spring Chinook salmon populations in the Lower Columbia River Chinook Evolutionarily Significant Unit (ESU) based on the 5-year (2015-2019) geometric means of the smoothed abundances reported in the 2020 State of the Salmon report. Populations with a (*) are either extirpated or not monitored due to low abundances. Recovery statuses for the Upper Cowlitz Spring and Fall Chinook populations (**) were beyond the scope of this report given fish passage limitations into the basin. Note that natural-origin fish assumed to be of Upriver Bright origin were not included in the natural-origin abundance estimates for the Gorge strata populations when evaluating ESA recovery goals.

Expected pHOS Levels

In the Mitchell Act BiOp, NMFS identified several expected pHOS levels (or limits) for spawner populations where NOR Chinook are expected to be impacted by Mitchell Act-funded hatchery fish (see Tables 3 and 91 in NMFS 2017). The pHOS levels/limits range from 0.10 to 0.50 based on 4-year running means (Table 15), and were developed after estimating mean pHOS (2010-2015) and evaluating the relative contribution of hatcheries to each population. Comparing mean pHOS estimated in the BiOp to the current 4-year running mean (2016-2019) for each population, pHOS has decreased in all populations aside from the Lewis Tule and the Kalama Spring Chinook populations. Currently, mean pHOS from one population (Lower Cowlitz) is under the BiOp limit (Table 15). Comparing mean pHOS estimated above the weirs only for populations where weirs are operating, one population (Elochoman/Skamokawa) has a mean pHOS below the population level BiOp rate (Table 15).

Table 15. Mean proportion of hatchery-origin spawners (pHOS), limits/expected levels presented in the Mitchell Act Biological Opinion (BiOp), current 4-year running mean pHOS (95% credible intervals (CI)) estimates, and mean pHOS above the weir only estimates (where applicable) for Spring (SPR) and early fall/tule (EFT) run Chinook salmon populations in the Lower Columbia River Evolutionarily Significant Unit.

Population	**Run**	**Mean pHOS from 2010-2015 (Prior to BiOp)**	**pHOS Limit or Expected Level in BiOp[1]**	**Mean pHOS from 2016-2019 (95% CI)**	**Mean pHOS Above Weir Only from 2016-2019 (95% CI)**
Coweeman	EFT	0.15	< 0.10	0.14 (0.08, 0.23)	0.12 (0.06, 0.21)
Lower Cowlitz	EFT	0.27	< 0.30	0.18 -	- -
Elochoman/Skamokawa	EFT	0.79	< 0.50	0.67 (0.54, 0.78)	0.30 (0.16, 0.50)
Grays/Chinook	EFT	0.73	< 0.50	0.53 (0.40, 0.66)	0.51 (0.32, 0.69)
Kalama	EFT	0.84	< 0.10	0.41 (0.38, 0.45)	0.29 (0.26, 0.33)
Kalama	SPR	0.00	< 0.10	0.61 -	- -
Lewis	EFT	0.34	< 0.10	0.46 (0.41, 0.51)	0.28[2] -
Mill/Germany/Abernathy	EFT	0.89	< 0.50	0.84 (0.79, 0.89)	- -
Toutle	EFT	0.64	< 0.30	0.56 (0.46, 0.65)	0.31 (0.21, 0.43)
Washougal	EFT	0.65	< 0.30	0.34 (0.27, 0.42)	0.54 (0.45, 0.63)

[1]Assigned limits are based on a four-year running mean (NMFS 2017).
[2]Estimate is for above the weir in 2019 only as this was the first year of weir operation in Cedar Creek.

Summaries and Recommendations

Summing survey years 2018 and 2019, a total of approximately 2100 Spring Chinook, 26600 early fall/tule (EFT) Chinook, and 60600 late fall/bright (LFB) Chinook adult NOR and HOR spawners were estimated for the LCR Chinook salmon populations that are monitored by WDFW. In 2018, NOR Fall Chinook spawners outnumbered HOR Fall Chinook spawners in ten of the LCR Chinook populations. Comparatively, NOR spawners outnumbered HORs in nine of the Fall Chinook populations in 2019. For Spring Chinook populations, HOR spawners outnumbered NORs in both years except for both years on the Kalama River and 2019 in the White Salmon River. No drastic skews in sex ratios were observed for any of the LCR Fall Chinook populations; however, females outnumbered males in nine of the Fall Chinook populations in 2018, and eight of the Fall Chinook populations in 2019. For Spring Chinook populations, sex ratio data was scarce due to low NOR and HOR abundances on the spawning grounds resulting in few carcasses being sampled.

Based on the five-year running geometric means, four of the thirteen extant LCR Fall Chinook populations are above their minimum adult NOR spawner abundance recovery goals with five additional populations being within 25-75% of their abundance goals. All the LCR Spring Chinook populations are far from their NOR spawner recovery goals with three populations believed to be extirpated. While there have been improvements within the WDFW Chinook monitoring program, results from survey years 2018 and 2019 indicate additional work can be done to improve Chinook recovery within the LCR region. Specific issues to address in the upcoming survey years include:

1) **Addressing low NOR Spring Chinook abundances.** All the Spring Chinook salmon populations in the LCR Chinook ESU are far from their NOR recovery goals with some populations having only a handful of NORs returning annually. Little work has been done recently to address factors that may be limiting NOR Spring Chinook recovery. WDFW personnel will work on incorporating additional monitoring into annual protocols to try and identify factors potentially limiting NOR Spring Chinook abundances including examining habitat quality, examining whether HOR fish are displacing NOR fish during spawning, and/or assessing potential impacts of release mortality during mark-selective fisheries as several of these Spring Chinook populations have active mainstem and tributary fisheries.

2) **Addressing low Fall Chinook population abundance in the Lower Gorge.** While some Fall Chinook populations have abundances near their recovery goals, the Lower Gorge population has the lowest abundance of EFT Chinook in the LCR Chinook ESU. However, the population does have a high number of Upriver Bright Chinook (a stock of LFB Chinook) that are not considered part of the LCR Chinook ESU. Little work has been done to determine whether the LFB Chinook are having an influence on the NOR EFT Chinook recovery. Future monitoring plans could be crafted to identify why EFT Chinook abundances are so low, and identify any potential effects of the established Upriver Bright stock on the EFT Chinook population.

3) **Understanding the influences of LFB Chinook on the EFT Chinook populations.** In addition to the Lower Gorge population mentioned above, LFB Chinook abundances (stocks of Upriver Bright and Select Area Bright Chinook) are high in several tributaries where NOR EFT Chinook abundances are low. In the White Salmon River, research has shown that Upriver Bright Chinook and EFT Chinook can be genetically distinct, but that hybridization does occur (Smith and Engle 2011; Smith et al. 2021). However, aside from teasing out genetic relationships, limited work has been done to understand any potential behavioral impacts that the Upriver Bright Chinook adults are

having on the EFT Chinook adults during spawning. Although the Upriver Bright Chinook adults typically spawn later in the season, competition between the late-spawning EFT Chinook and early-spawning Upriver Bright Chinook could occur, as well as spawning overlap where Upriver Bright Chinook utilize spawning grounds where EFT Chinook have already spawned (e.g., redd superimposition). Future work examining for potential impacts such as these during the spawning season could be beneficial for understanding why EFT Chinook abundances are low when Upriver Bright and EFT Chinook spawn sympatrically.

4) Identifying whether there is a separate LFB Chinook run becoming established in the Washougal River. Results from survey years 2018 and 2019 as well as those from 2013-2017 found in Wilson et al. (2020) show that the annual Fall Chinook run in the Washougal River typically lasts until December. However, EFT Chinook do not typically spawn that late in the season in any other tributary within the LCR Chinook ESU. Alternatively, the late run of fish into the tributary has been hypothesized to be straying LFB Chinook (e.g., mainstem Ives/Pierce, Sandy River (OR population), or above Bonneville stocks) based on spawning time and phenotypic characteristics, but no genetic work has been done to document both EFT and LFB Chinook stocks in the basin. Future work aimed at teasing out any potential LFB adult abundances from the adult EFT Chinook abundance estimates will improve accuracy when discussing pHOS levels, weir efficiencies, and how close the Washougal EFT Chinook population is to recovery.

5) Full implementation of Mitchell Act BiOp guidelines. The guidelines outlined in the Mitchell Act BiOp have not been fully implemented, particularly in terms of the number of weirs proposed by NMFS. WDFW will continue to have discussions with NMFS, and develop a timeline for full implementation, particularly for weir operations in Southwest Washington. Currently, full implementation for operating the required weirs is expected no later than 2024 dependent upon available Mitchell Act funding.

6) Examining alternative criteria within the populations in addition to pHOS goals. As discussed in the results, several populations are near, but not quite meeting their target pHOS goals outlined in the Mitchell Act BiOp. However, a large hindrance to those populations meeting their pHOS goals is low NOR abundances. The pHOS goals alone do not always provide all the information needed to accurately represent how HOR fish may be impacting NOR population recovery. For instance, one monitoring metric that should be considered is understanding the spatial and temporal distribution of HOR spawners when NOR adults are spawning as more overlap has been hypothesized to lead to more issues. Future monitoring may require development of additional recovery measures that account for population sizes as well as the direct influence that HOR spawners have on NOR spawners to accurately determine what role HOR fish may be having on population recovery.

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Appendix A: Maps of Chinook survey areas, weirs, and hatchery locations

Appendix A includes maps taken from Wilson et al. (2020) indicating locations of annual spawning ground and/or aerial surveys conducted by WDFW for monitoring adult Chinook salmon populations in the Lower Columbia River Chinook Evolutionarily Significant Unit. Maps show the distributions of Chinook within each basin (gold lines), and where the two survey types (standard or supplemental) were conducted. Maps also include the locations of the seven resistance-board weirs currently operating for Fall Chinook management, and the locations of barriers including hatcheries, ladder traps, and/or fish collection facilities. Maps were not provided for the Salmon Creek Fall Chinook, Tilton (historic) Spring Chinook, Cispus (historic) Spring Chinook, and Toutle Spring Chinook populations given that these populations are believed to be extirpated and were not surveyed in 2018 and 2019.

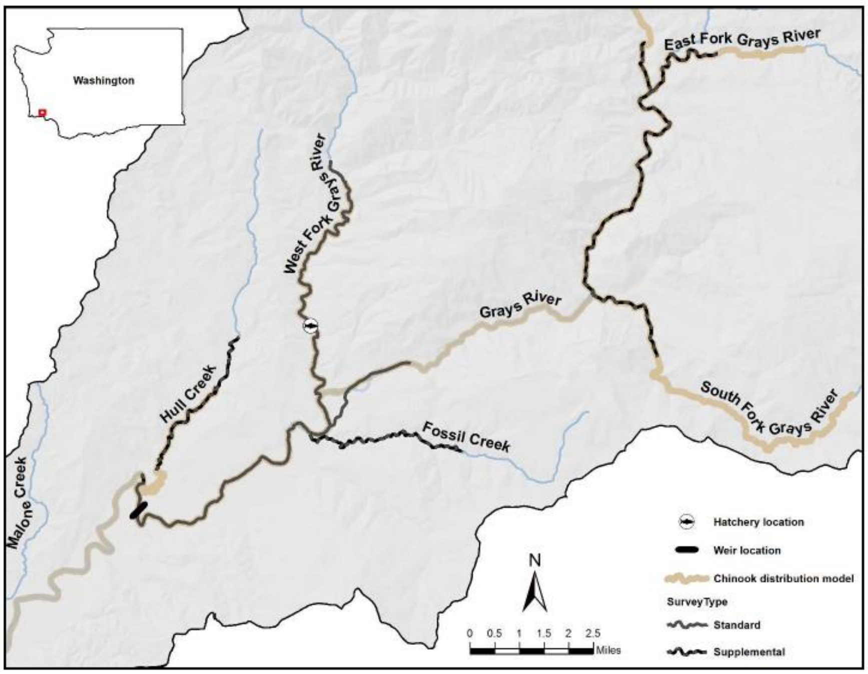

Figure A1. Map of the Grays/Chinook basin taken from Wilson et al. (2020) to show where spawning ground surveys were conducted for Fall Chinook salmon monitoring in 2018 and 2019. The locations of the weir and hatchery are also denoted. See Wilson et al. (2020) for additional information regarding survey locations.

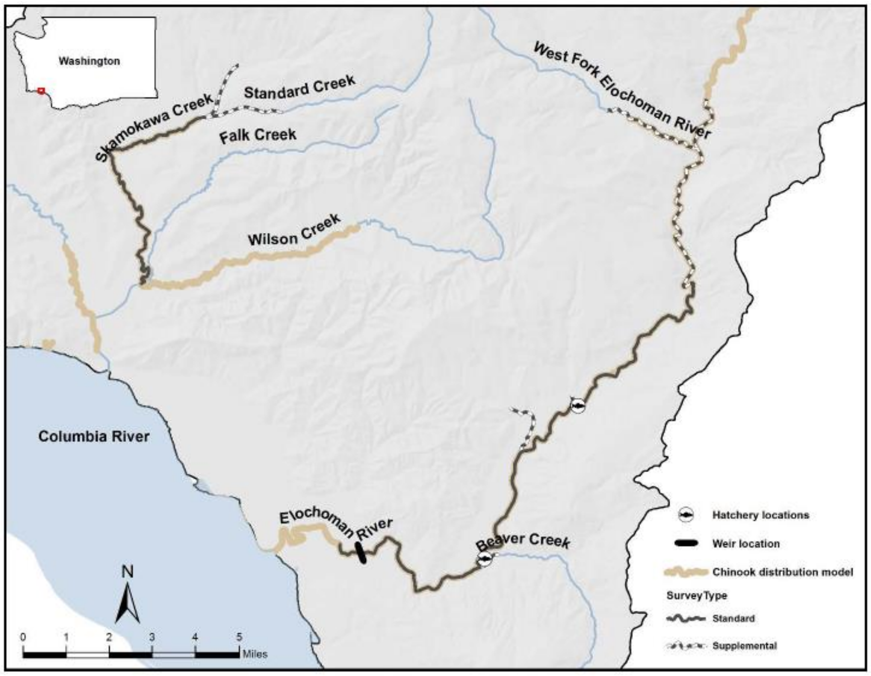

Figure A2. Map of the Elochoman/Skamokawa basin taken from Wilson et al. (2020) to show where spawning ground surveys were conducted for Fall Chinook salmon monitoring in 2018 and 2019. The locations of the weir and hatcheries are also denoted. See Wilson et al. (2020) for additional information regarding survey locations.

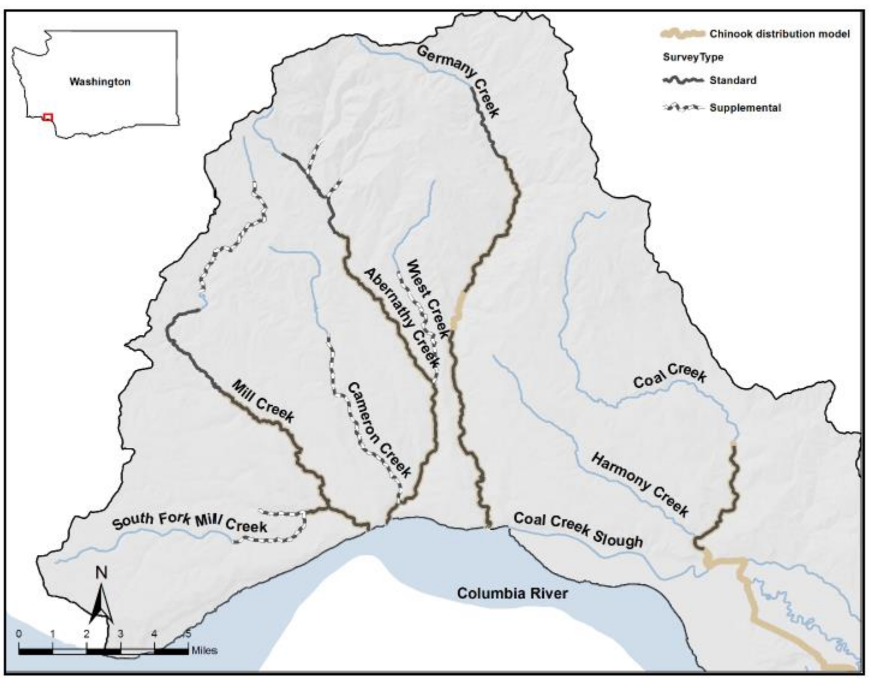

Figure A3. Map of the Mill/Germany/Abernathy basin taken from Wilson et al. (2020) to show where spawning ground surveys were conducted for Fall Chinook salmon monitoring in 2018 and 2019. See Wilson et al. (2020) for additional information regarding survey locations.

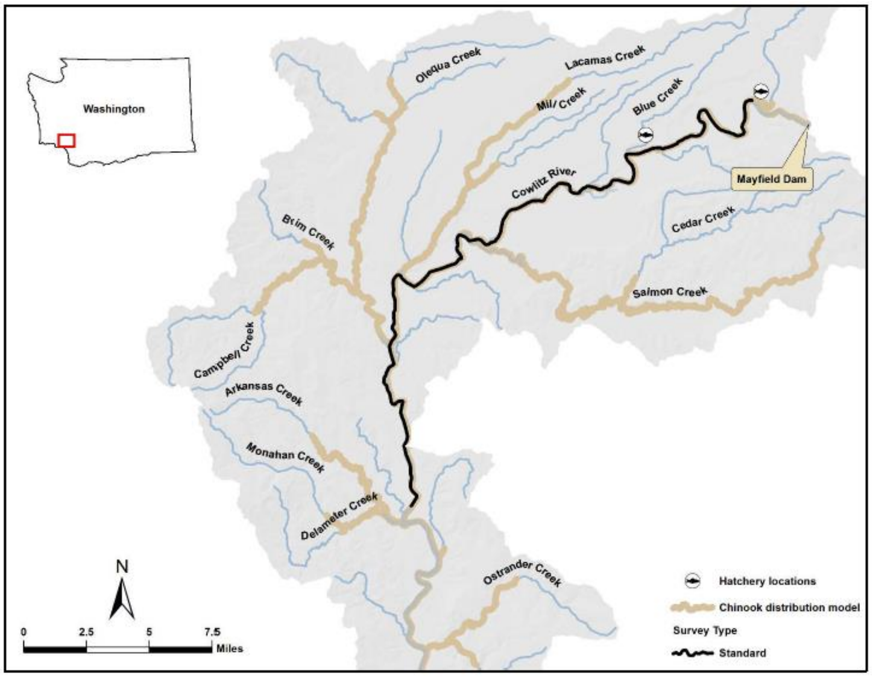

Figure A4. Map of the Lower Cowlitz basin taken from Wilson et al. (2020) to show where spawning ground surveys were conducted for Fall and Spring Chinook salmon monitoring in 2018 and 2019. The locations of the hatcheries are also denoted. See Wilson et al. (2020) and Serl et al. (2019, 2020) for additional information regarding survey locations.

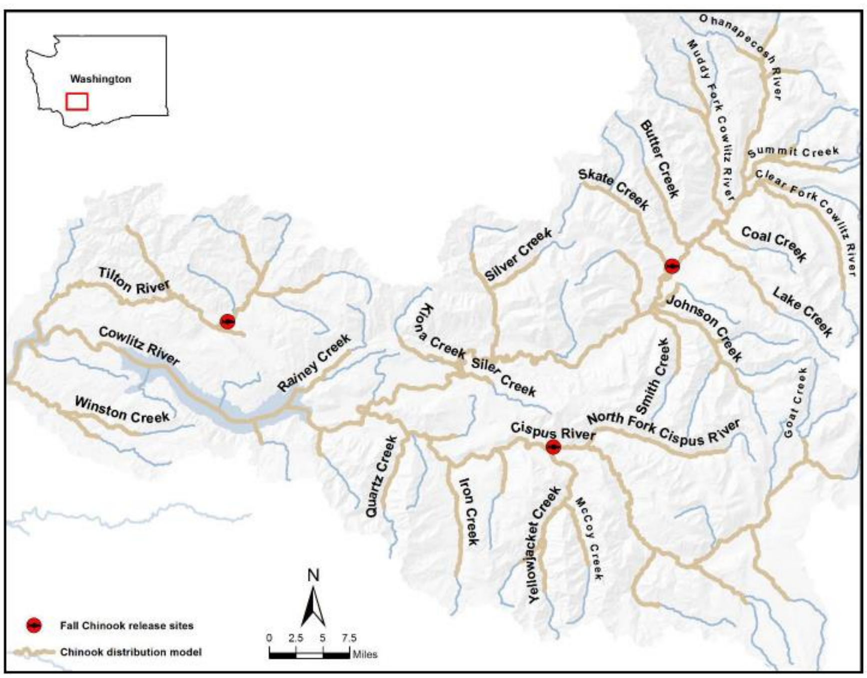

Figure A5. Map of the Upper Cowlitz basin taken from Wilson et al. (2020) showing where Fall Chinook salmon were released after transport from the Cowlitz Salmon Hatchery/Barrier Dam. See Wilson et al. (2020) and Serl et al. (2019, 2020) for additional information regarding release locations.

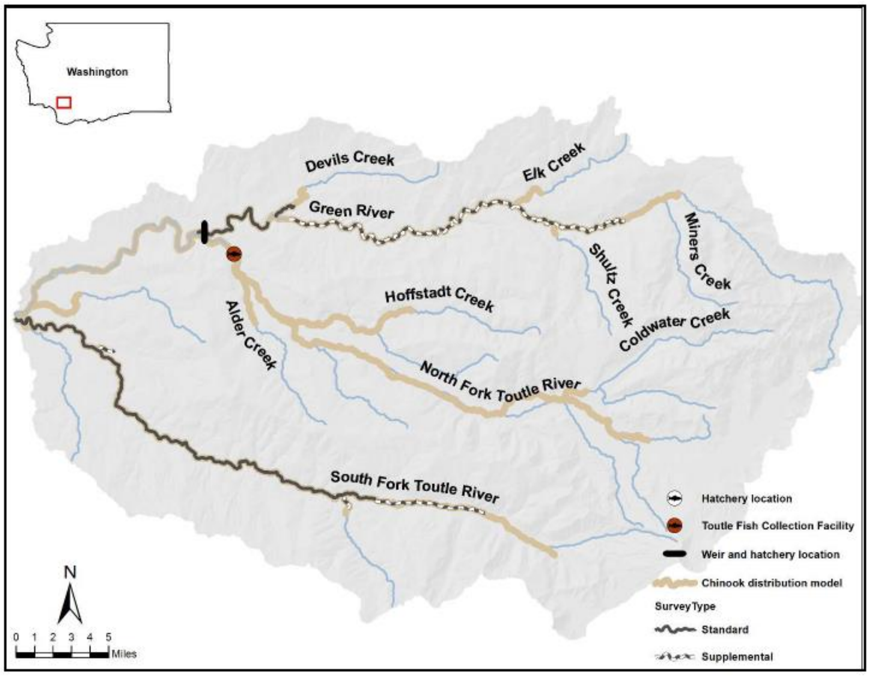

Figure A6. Map of the Toutle basin taken from Wilson et al. (2020) to show where spawning ground surveys were conducted for Fall Chinook salmon monitoring in 2018 and 2019. The locations of the weir and hatchery/fish collection facility are also denoted. See Wilson et al. (2020) for additional information regarding survey locations.

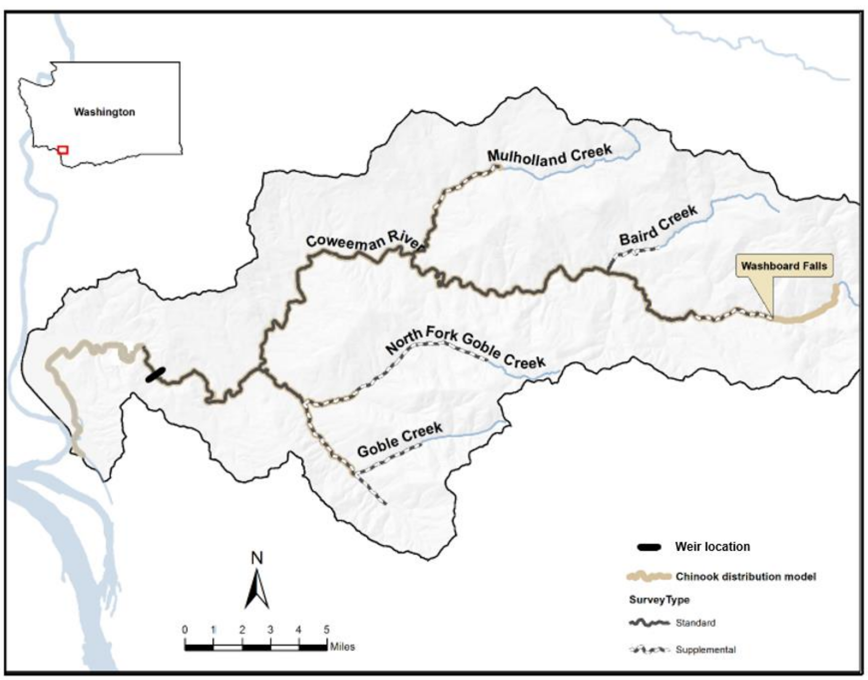

Figure A7. Map of the Coweeman basin taken from Wilson et al. (2020) and modified to show where spawning ground surveys were conducted for Fall Chinook salmon monitoring in 2018 and 2019. The location of the weir is also denoted. See Wilson et al. (2020) for additional information regarding survey locations.

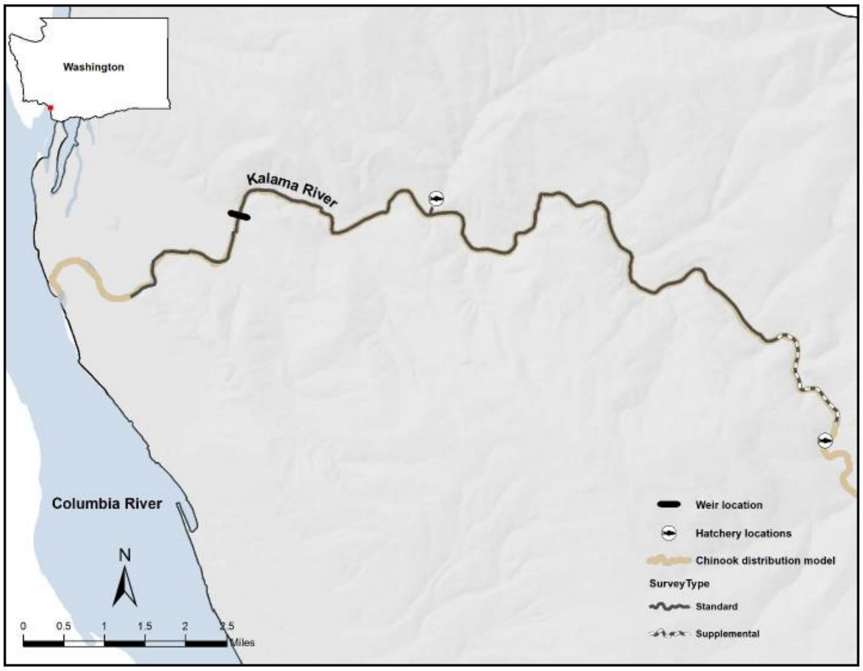

Figure A8. Map of the Kalama River taken from Wilson et al. (2020) to show where spawning ground surveys were conducted for Spring and Fall Chinook salmon monitoring in 2018 and 2019. The locations of the weir and hatchery are also denoted. See Wilson et al. (2020) for additional information regarding survey locations.

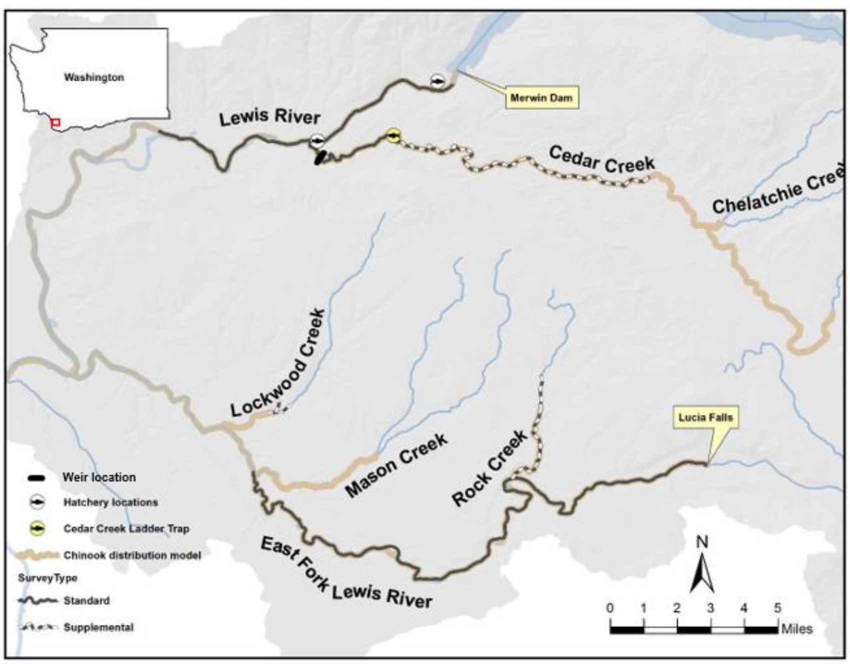

Figure A9. Map of the Lewis basin taken from Wilson et al. (2020) and modified to show where spawning ground surveys were conducted for Spring and Fall Chinook salmon monitoring in 2018 and 2019. The locations of the weir (2019 only), ladder trap, and hatcheries are also denoted. See Wilson et al. (2020) for additional information regarding survey locations.

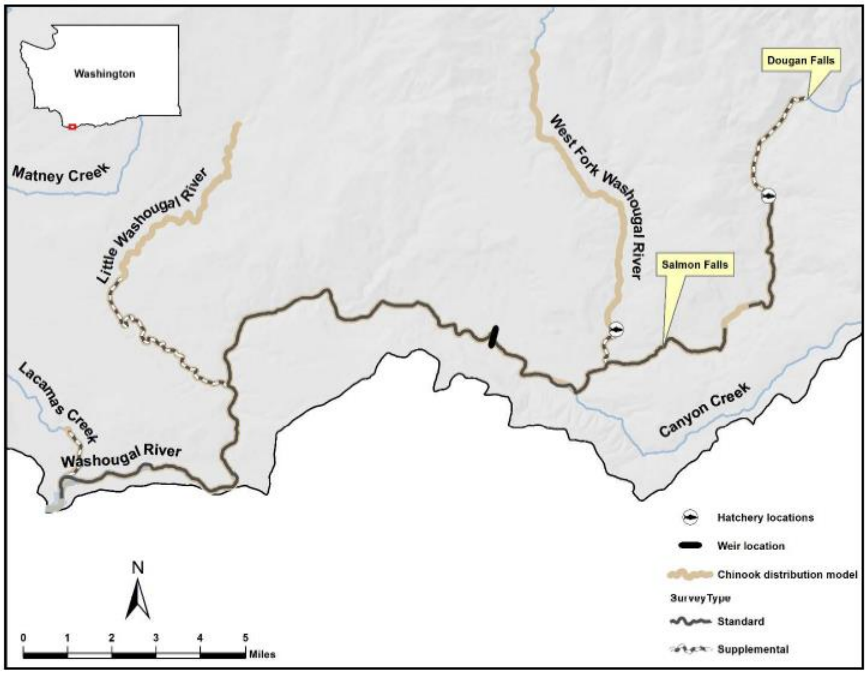

Figure A10. Map of the Washougal basin taken from Wilson et al. (2020) to show where spawning ground surveys were conducted for Fall Chinook salmon monitoring in 2018 and 2019. The locations of the weir and hatcheries are also denoted. See Wilson et al. (2020) for additional information regarding survey locations.

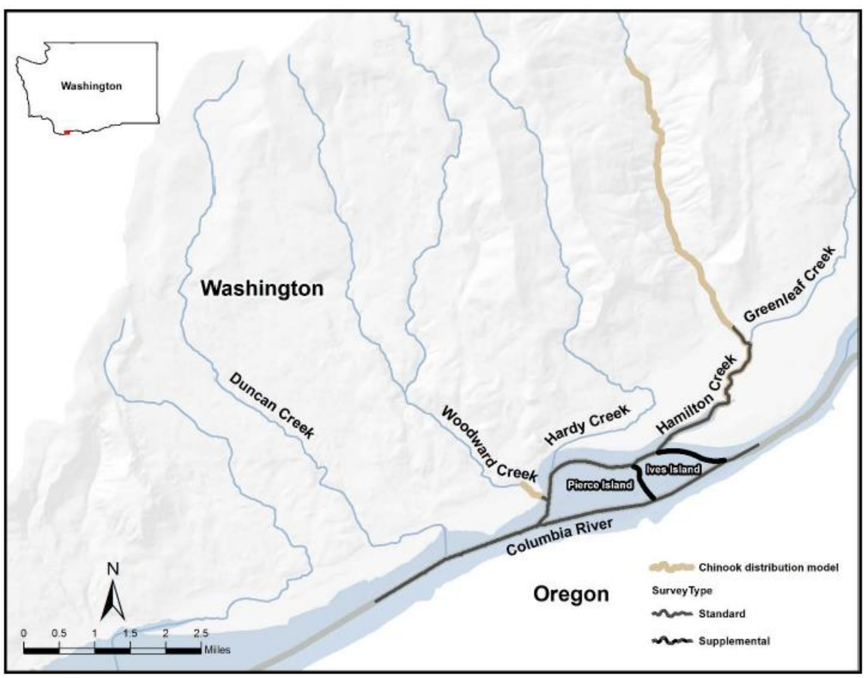

Figure A11. Map of the Lower Gorge sampling area taken from Wilson et al. (2020) to show where spawning ground surveys were conducted for Fall Chinook salmon monitoring in 2018 and 2019. See Wilson et al. (2020) for additional information regarding survey locations.

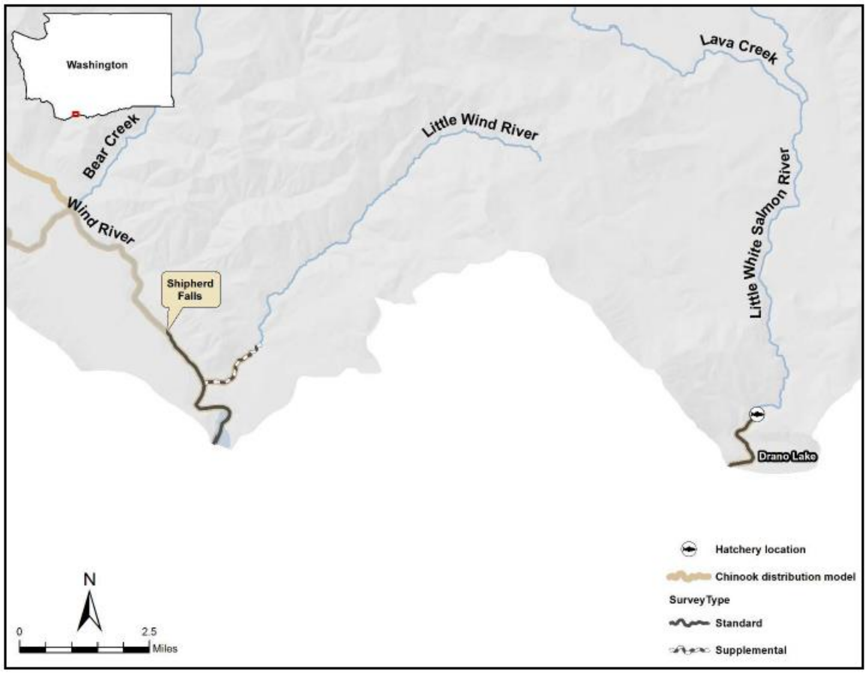

Figure A12. Map of the Upper Gorge sampling area taken from Wilson et al. (2020) to show where spawning ground surveys were conducted for Fall Chinook salmon monitoring in 2019 and 2019. The location of the hatchery is also denoted. See Wilson et al. (2020) for additional information regarding survey locations.

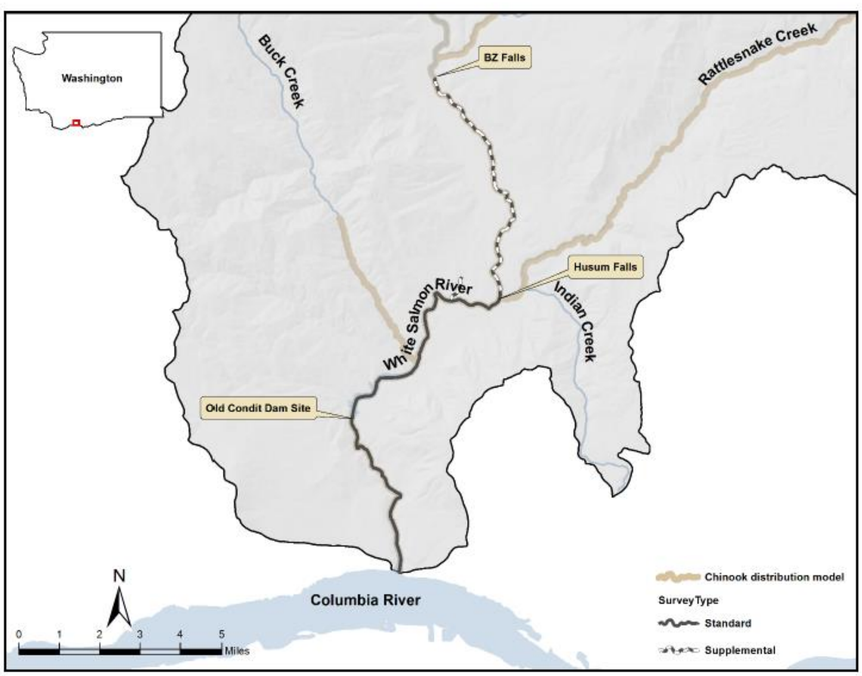

Figure A13. Map of the White Salmon basin taken from Wilson et al. (2020) to show where spawning ground surveys were conducted for Spring and Fall Chinook salmon monitoring in 2018 and 2019. See Wilson et al. (2020) and Olk and Wilson (2019) for additional information regarding survey locations.

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