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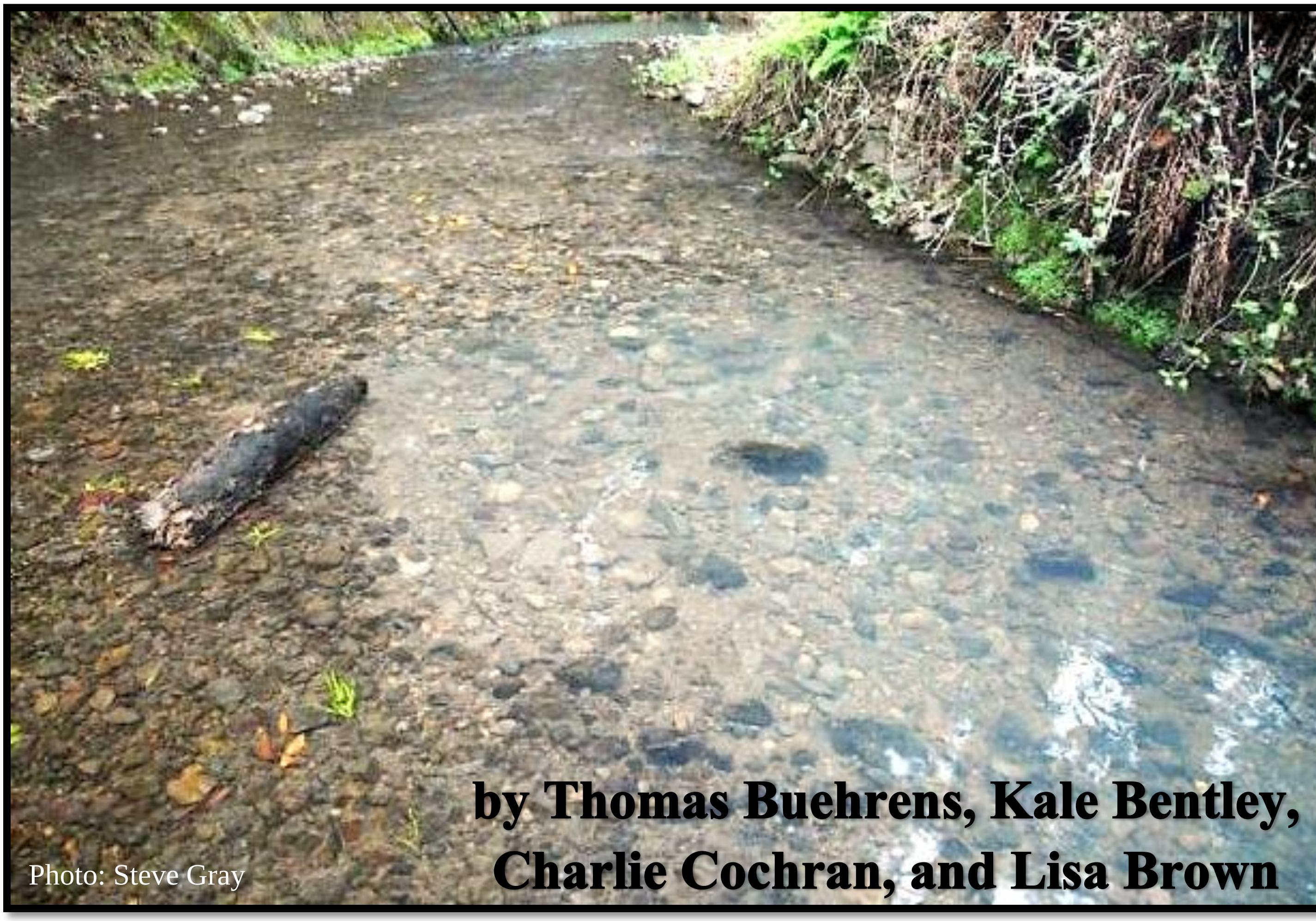
Estimates of Escapement for Wind River Coho Salmon, 2007–2015



Washington Department of FISH and WILDLIFE

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Estimates of Escapement for Wind River Coho Salmon, 2007 – 2015

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Table of Contents

List of Tables ii
List of Figures iii
Abstract 1
Introduction 2
Methods 3
    Data Collection 3
    Analytical Methods 6
Results 8
    Abundance and Proportion of Hatchery-Origin Spawners 8
    Proportion of Females 12
    Redds per Female 13
    Redd Distribution 13
Discussion 14
Recommendations 17
References 18

List of Tables

Table 1. Description of adult coho salmon spawning ground surveys by sub-reach conducted in the Wind River watershed from 2007 – 2015. 5

Table 2. Estimates of total coho salmon escapement among years (mean, SD, and quantiles of the posterior distribution).. 9

Table 3. Estimates of the percentage of hatchery-origin spawners (pHOS) among years (mean, SD, and quantiles of the posterior distribution). Note: estimates for 2007 – 2012 were the overall hierarchical estimate of pHOS since year-specific data were not available. 10

Table 4. Estimates of wild coho salmon escapement among years (mean, SD, and quantiles of the posterior distribution).. 11

Table 5. Estimates of the percentage of female spawners among years (mean, SD, and quantiles of the posterior distribution). 12

Table 6. Estimated number of redds per female (*RpF*) among years (mean, SD, and quantiles of the posterior distribution).. Estimates are based on WDFW data throughout the lower Columbia ESU from locations with paired weir counts or mark recapture estimates and redd counts upstream. Note: estimates for 2007 – 2009 and 2013 – 2015 are the overall hierarchical estimate of *RpF* since year-specific data were not available. 13

Table 7. Summary of new redd counts by survey section and year conducted in the Wind River, Washington. Note: from 2007 – 2013, Wind 1 and 2 were combined and therefore redds could not be separated.. 14

Table 8. Summary of hatchery-origin coho salmon recovered in the Wind River and their respective hatchery source among all carcass recoveries with a decoded CWT. Note: while these fish were recovered in the Wind River, their specific recovery sub-reach is currently unknown and therefore may not represent spawning individuals.. 16

List of Figures

Figure 1. The Lower Columbia River coho salmon Evolutionarily Significant Unit (ESU), its three Major Population Groups (MPGs), and each distinct independent population (DIP). Note: the White Salmon population is considered part of the Upper Gorge Tributaries Population. 3

Figure 2. The Upper Gorge Tributaries coho salmon population boundary, showing modeled coho salmon distribution (orange) based on the WDFW region 5 model and truncated based on the location of known fish passage barriers and habitat characteristics. Coho spawning ground survey reaches are shown in red. 4

Figure 3. Estimates of total coho salmon escapement (mean, quantiles, and 95% CI of the posterior distribution) among years (2007 – 2015)... 9

Figure 4. Estimates of the proportion of hatchery-origin spawners (pHOS) among years (2007 – 2015) based on coded wire tag presence or missing adipose fins (mean, quantiles, and 95% CI of the posterior distribution)... 10

Figure 5. Estimates of wild coho salmon escapement (mean, quantiles, and 95% CI of the posterior distribution) among years (2007 – 2015).. 11

Figure 6. Estimates of the proportion of spawners that were females (mean, quantiles, and 95% CI of the posterior distribution) among years (2007 – 2015). 12

Abstract

The Lower Columbia River (LCR) coho salmon Evolutionary Significant Unit (ESU) is composed of 24 distinct independent populations (DIP) split between three Major Population Groups (MPG) that are located in the states of Washington and Oregon. The Wind River watershed, which enters the Columbia River nine miles upstream of the Bonneville Dam, is part of the Upper Gorge DIP and Gorge MPG. Until the removal of Condit Dam on the White Salmon River in 2011, the Wind River basin contained the majority of habitat for coho salmon in the Upper Gorge DIP. Beginning in 2007, the Washington Department of Fish and Wildlife has conducted annual spawning ground surveys for adult coho salmon in the Wind River basin. The objectives of these surveys were to monitor Viable Salmon Population (VSP) parameters, including abundance, the proportions of hatchery-origin spawners (pHOS), sex ratio(proportion female spawners), and spatial distribution. Over the past nine years (2007 – 2015), the adult coho salmon spawner abundance (i.e., escapement) in the Wind River watershed has ranged from 28 to 92. Despite no hatchery releases in the Wind River, the median pHOS among years was 25%, leading to estimates of natural-origin escapement ranging from 21 to 70. Across all years, the median sex ratio was 55% females and ranged from 51 – 60%. Coho salmon are restricted to <10% of the total spawning and rearing habitat within the Wind River watershed, largely due to a natural-barrier falls located in the lower river. Within the accessible habitat reaches, coho spawn in both the Little Wind River, which is a tributary of main stem, as well as the main stem Wind River. Overall, the Wind River watershed consists of a relatively small sub-population of coho salmon due to limited and low quality habitat. Moving forward, it should be a priority to initiate adult coho monitoring in the White Salmon watershed that, along with Wind River monitoring, will allow for a more complete Upper Gorge DIP group abundance estimate.

Introduction

Coho salmon (*Oncorhynchus kisutch*) were historically present throughout all major tributaries and sub-basins in the lower Columbia River (LCR) basin (Myers et al. 2006, LCFRB 2010). However, over the past 200 years, populations have undergone dramatic changes. Overharvest, hydropower development, habitat degradation, and hatchery practices, along with oscillating ocean productivity, have reduced populations to small fractions of their historical abundances. As a result, coho salmon in the LCR Evolutionary Significant Unit (ESU) were listed as Threatened under the Endangered Species Act (ESA) in 2005. The LCR coho salmon ESU is composed of 24 populations split between three Major Population Groups (MPG) that are located in the states of Washington and Oregon (Figure 1). Within Washington, every one of the 17 LCR coho populations is estimated to be at a very high risk of extinction (LCFRB 2010).

Historically, coho salmon populations in the Lower Columbia region were primarily managed for fisheries to exploit abundant populations of hatchery-origin coho salmon that returned to numerous hatchery programs operated by Washington and Oregon. These hatchery programs supported fisheries with high harvest rates, sometimes in excess of 80 – 90% (Ford et al. 2010). Prior to the mid-1990s, hatchery-origin coho were not mass-marked, precluding their visual distinction from natural-origin fish. As a result little monitoring of natural-origin coho salmon populations occurred. Following mass-marking, monitoring of natural-origin populations was greatly simplified and after ESA-listing was mandated as part of fishery permitting and evaluation. Monitoring programs for natural-origin coho salmon populations intensified in the 2000s and have largely been geographically stratified according to the ESA population structure, which is sub-divided into ESUs, MPGs, and distinct independent populations (DIP or population). Particular emphasis has been placed on ensuring monitoring occurs for populations within every MPG, since recovery of the ESU depends on recovery of each of these geographic strata.

The Oregon Department of Fish and Wildlife (ODFW) began comprehensive monitoring of coho salmon populations in the LCR ESU in 2002. Minimum adult coho salmon estimates in Washington's portion of this ESU were limited primarily to counts at hatchery facilities and a few fish ladder traps. In the late 2000s, WDFW intensified monitoring efforts, initiating an ESU-wide monitoring program including trap counts, spawning ground surveys, and mark-recapture. Despite the widespread coverage of WDFW's ESU-wide monitoring program, it was focused on areas below Bonneville Dam and did not include the Upper Gorge population, which is a substantial portion of the Gorge MPG. In order to address this data gap, Salmon Recovery Funding Board (SRFB) funds were obtained and WDFW began spawning ground surveys for coho salmon in the Wind River basin in 2007. Until the removal of Condit Dam on the White Salmon River in 2011, the Wind basin contained the majority of habitat for coho salmon in this population (Figure 2).

The objectives of Wind River adult coho salmon monitoring were to estimate Viable Salmon Population (VSP) parameters, including abundance, proportions of hatchery spawners (pHOS), the sex ratio of all spawners, and the spawning distribution for the portion of the Upper Gorge Tributaries coho salmon population in the Wind River basin. To accomplish these objectives, WDFW conducted spawning ground surveys for coho salmon in the Wind River from 2007 – 2015 where redds were counted and biological data were collected from live and dead spawners.

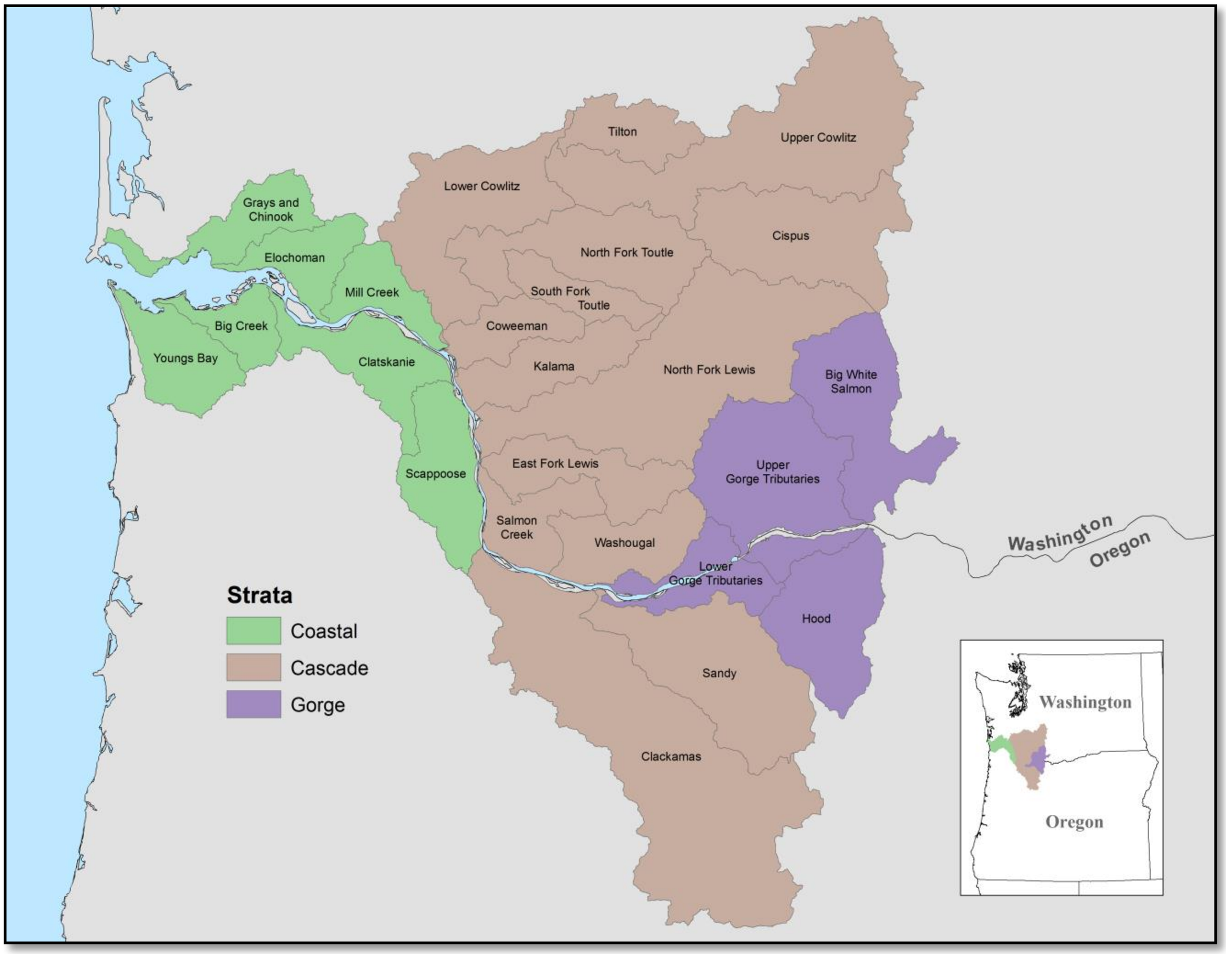

Figure 1. The Lower Columbia River coho salmon Evolutionarily Significant Unit (ESU), its three Major Population Groups (MPGs), and each distinct independent population (DIP). Note: the White Salmon population is considered part of the Upper Gorge Tributaries Population.

Methods

Data Collection

From 2007 – 2015, spawning ground surveys were conducted for adult coho salmon in the Wind River watershed, Washington. The Wind River watershed consists of the mainstem Wind River and smaller tributaries upstream of Shipherd Falls as well as the Little Wind River, which enters the mainstem Wind River at river-mile (RM) 1.3, which is 0.8 miles downstream of Shipherd Falls. Prior to the fall of 2007, the sampling frame for the coho spawning ground surveys was established for the Wind River watershed based on the spatial extent of coho habitat. In the Little Wind watershed, a logistic regression model was used to predict the uppermost extent of coho salmon habitat, above which streams are essentially too small to support consistent use (Fransen et al. 2006; Dan Rawding, WDFW, *unpublished data*). In the mainstem Wind River, coho salmon habitat extends upstream from the top of Bonneville Pool backwater to Shipherd Falls at RM 2.1. Historically, Shipherd Falls precluded the passage of all fish species other than summer steelhead and Pacific lamprey. Today, Shipherd Falls is laddered but current management does not allow coho salmon to be passed upstream of the falls. In total, the Wind

River watershed is estimated to contain 6.3 miles of modeled coho habitat, of which 4.2 miles exists in the Little Wind River (Figure 2). However, a landslide in the fall of 2007 created a migration barrier for coho salmon at approximate RM 1.5 that has appeared to have persisted over the past nine years. Additionally, a natural falls at RM ~1.8 may also be a barrier to coho migration and may warrant further evaluation (see *Recommendations*).

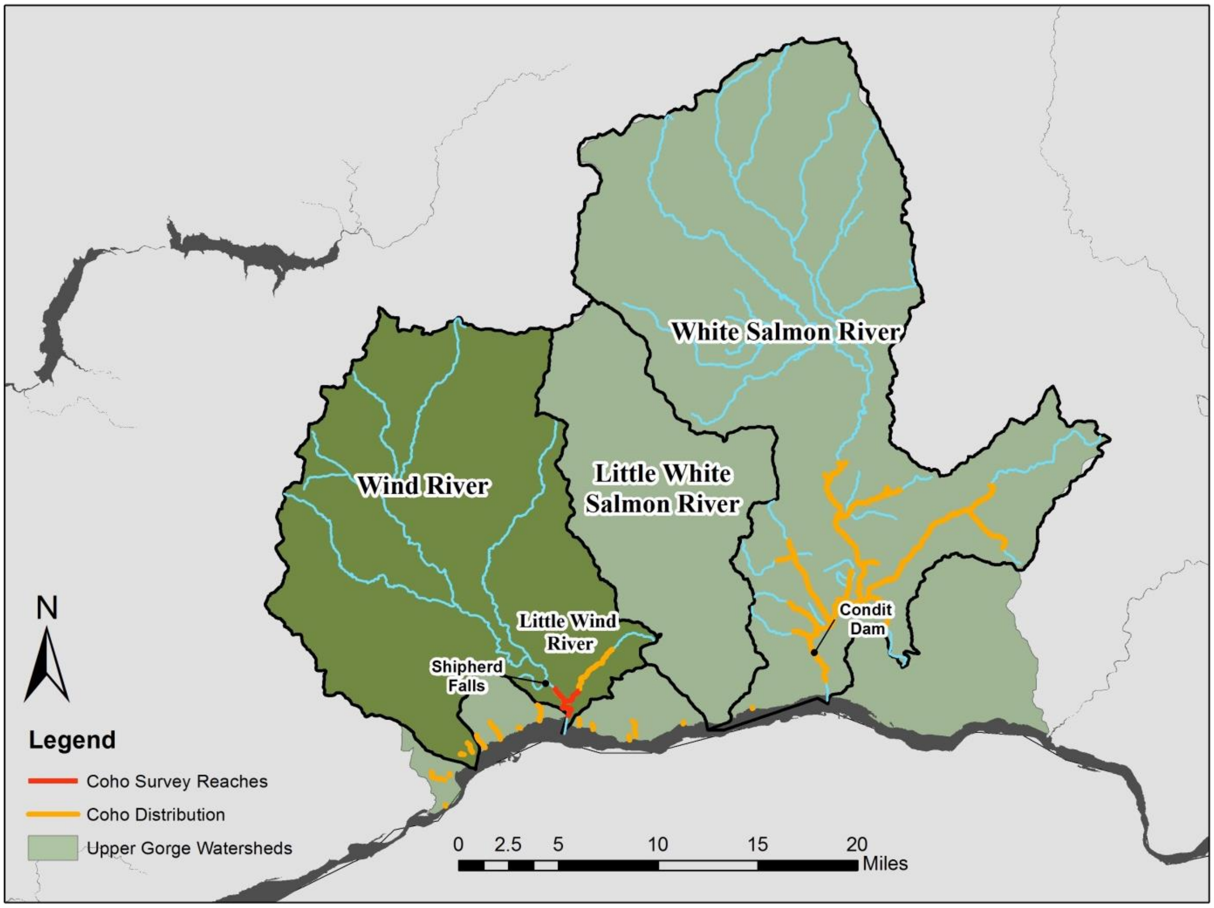

Figure 2. The Upper Gorge Tributaries coho salmon population boundary, showing modeled coho salmon distribution (orange) based on the WDFW region 5 model and truncated based on the location of known fish passage barriers and habitat characteristics. Coho spawning ground survey reaches are shown in red.

Spawning ground surveys were conducted weekly in the Wind River watershed and followed methods in Rawding et al. (2006a, 2006b), and Gallagher et al. (2007). The objectives of these surveys were to make a census count of new coho salmon redds, live spawners, and dead fish. Redd count data were collected for use in population abundance estimation while biological data from dead salmon were used for the estimation of the sex ratio and proportion of hatchery-origin spawners (pHOS). Surveys commenced prior to the beginning of coho salmon spawning (typically in early October) and continued weekly until the end of spawning activity (typically the end of December). During each survey, the entire lower 2.1 miles of the main stem Wind River and the lower 1.1 miles of the Little Wind were surveyed. The lower main stem was broken up into three sub-sections while the Little Wind consisted of one sub-section (Table 1).

During periodic surveys, an additional one mile reach of the Little Wind was surveyed (RM 1.1 to 2.1), which included areas below and above the landslide barrier (referred to as the Little Wind 2 or rather the "extended" survey reach).

Table 1. Description of adult coho salmon spawning ground surveys by sub-reach conducted in the Wind River watershed from 2007 – 2015.

River	Sub-Reach	Lower RM	Upper RM	Total RM
Wind (main stem)	Wind 1	0	0.69	0.69
	Wind 2	0.69	1.28	0.59
	Wind 3	1.28	2.16	0.88
Little Wind	Little Wind 1	0	1.09	1.09
	Little Wind 2*	1.09	2.1	1.01

* Also referred to as the "extended" survey reach

During each survey, surveyors typically located the upper most point in the reach and walked downstream to the coordinates at the end of the reach. All identifiable redds were flagged, and their location was recorded using a handheld GPS unit. The GPS unit was allowed to acquire satellite locations until an accuracy of ± 100 feet or less was obtained, but most often accuracies averaged 5 to 50 feet. In subsequent surveys, previously flagged redds were inspected to determine if they should be classified as "still visible" or "not visible". A redd was classified as "still visible" if it would have been observed and identified without the flagging present, and was recorded as "not visible" if it did not meet this criteria. These data were collected to allow us to estimate the time period redds were visible to surveyors.

In addition to redd counts, all live adult and jack salmonids were recorded by species (Crawford et al. 2007a). Salmon were identified as either spawning or holding. A fish was identified as holding if it was observed in an area not considered spawning habitat, such as pools or large cobble and boulder riffles (Parken et al. 2003). Salmon were classified as spawners if they were on redds or not classified as holders. Although these data are not currently used in abundance estimation for coho salmon in the Lower Columbia Region (which is based on redds), these data enable the development of an alternative estimator based on area under the curve (AUC) counts of spawners.

Counts were also made of all salmon carcasses that were encountered. All carcasses that were not totally decomposed were sampled for external tags and marks and biologically sampled for fork length, sex, adipose fin presence, and condition (extent of decomposition). Sex was determined based on morphometric differences between males and females and/or by cutting open the abdominal cavity to confirm sex and determine spawning success. The spawning success was approximated based on visual inspection, ranging from 100% to 0% success. A fish with 0% success was considered a pre-spawning mortality. Scale samples were collected by selecting scales from the preferred area as described in Crawford et al. (2007b) and Cooper et al. (2011).

All recovered carcasses were also sampled for CWT following standard protocols (NWMFT 2001). If a CWT was detected, the tag was collected by severing the snout from the rest of the body by cutting across the head straight down behind the eyes (Crawford et al. 2007b). The snout was placed in a plastic bag with a tag number linking the snout to biological data recorded on the scale card, stream survey card, or other datasheet. Snouts were stored in a freezer and periodically delivered to the WDFW CWT Lab in Olympia for processing and reporting of tag information to the Regional Mark Information System (RMIS). Ultimately, the origin of individual carcasses were classified using a combination of mark status (adipose fin present or absent) and tag status (CWT present or absent). A fish was classified as natural-origin if its adipose fin was present and it did not have a CWT while a hatchery-origin could either have both an adipose fin and CWT or lack an adipose fin but have a CWT.

Analytical Methods

The objectives of our analysis were to estimate the total spawner abundance, proportion of hatchery-origin spawners (pHOS), natural-origin spawner abundance, and sex ratio of Wind River coho salmon, which consists of spawning in the mainstem and Little Wind rivers. In order to calculate total abundance and its associated metrics, field-based redd counts needed to be expanded into total spawners.

First, redds counted in survey sections (i.e., samples) needed to be extrapolated across the entire spatial and temporal spawning distribution (i.e., sample frame). Although spawning ground surveys in the Wind River only routinely encompassed ~50% of the predicted coho habitat (100% of the main stem Wind and 27% of the Little Wind), the landslide in 2007 cut off almost all of the spawnable habitat outside of the survey reaches. Additionally, no coho redds were ever detected during the “extended” surveys on the Little Wind upstream of the landslide site. Therefore, it was assumed that each survey was a census of redds and no spatial or temporal expansion was necessary.

Second, total redds needed to be converted to females per redd (since only females construct redds). In the Lower Columbia Region, the number of females per redd for coho salmon was estimated at a number of locations from 2010 – 2012 where paired redd surveys and mark-recapture or census abundance estimates are made. With these paired surveys, the number of detected redds is a product of both females per redd and observer efficiency (since spawning ground surveyors can miss redds or redds can become obscured by flows and turbidity between surveys). Based on the study design, these two variables cannot be uncoupled and thus this metric is more appropriately referred to as “apparent” females per redd. Because estimates of apparent females per redd were only available in three years, we hierarchically estimated this metric allowing the uncertainty to be propagated to estimates in years where no year-specific estimate was available.

Third, the total number of females needed to be expanded to total spawners based on the sex ratio. Sex ratio was estimated using carcass recoveries from each individual year (2007 – 2015). However, because the total number of fish sampled in any given year may be low, leading to skewed observed sex ratios due to binomial sampling error, sex ratio was also hierarchically estimated.

Lastly, the total number of spawners was sub-divided by origin so that estimates of natural-origin and hatchery-origin spawners could be estimated. Although individual carcasses were sampled for origin in all nine years, we elected to only use three years of data (2013 – 2015) to estimate proportion of hatchery-origin spawners (pHOS). Specifically, CWT (i.e., origin) data are stored in RMIS but the recovery location of carcasses is only recorded at the river scale (i.e., Wind

River but not the specific sub-reach). Over the years, carcasses have not only been recovered on the spawning grounds by WDFW, but also by Pacific States Marine Fisheries Commission near the mouth of the Wind River. Therefore, a portion of the RMIS Wind River coho salmon may not have been recovered on the spawning grounds and thus the RMIS dataset may not be representative. In 2013, WDFW developed a corporate adult data base (known as "TWS") that allows the assignment of carcass recoveries to sub-reaches within a watershed. Although the TWS dataset consists of a smaller number of carcasses recoveries relative to the RMIS dataset, we elected to use the TWS dataset to estimate pHOS as we were able to sub-set and only use carcasses collected in spawning reaches. But because the TWS dataset was limited to three years and a limited number of carcass recoveries, estimates of pHOS were hierarchically estimated using carcasses recoveries within and among years.

The model used to estimate VSP parameters for Wind coho salmon is described below:

Escapement, *Esc*, was estimated by expanding the census count of new redds by regional estimates of redds per female, *RpF*, and the proportion of females among all spawners, *pF*, with the subscript *i* denoting year-specific parameters (eq.1):

1) $$Esc_i = New\ Redds_i / \ RpF_i \ / pF_i$$

The proportion of females, *pF*, was estimated hierarchically among years based on counts of female and total (non-jack) spawners made from carcasses found in the Wind basin in each year:

2) $$Females_i \sim binomial(pF_i, TotalSpawners_i)$$

Where each year's estimate had a beta distributed prior with shape parameters estimated across all years:

3) $$pF_i \sim beta(alpha, beta)$$

These shape parameters were given uninformative hyper-priors:

4) $$alpha \sim gamma(0.01{,}0.01)\ T(0{,}100)$$

5) $$beta \sim gamma(0.01{,}0.01)\ T(0{,}100)$$

The proportion of the total escapement, *Esc*, that were of natural-origin, *NOR esc*, was modeled identical to the proportion of females using equations 2 through 5, substituting the number of hatchery-origin fish, *pMark*, for the number of females in equation 2. The number of natural-origin spawners was estimated by multiplying total escapement by the proportion of wild spawners:

6) $$NOR\ Esc_i = Esc_i * (1 - \ pMark_i)$$

The number of redds per female, *RpF*, was specified by using year specific Lower Columbia region-wide estimates to parameterize a hyper-distribution, thereby allowing propagation of uncertainty in this parameter among years where no data were available. To accomplish this, redds per female in a particular year was defined by a beta distribution with year specific shape parameters:

7) $$RpF_i \sim beta(alpha2_i, beta2_i)$$

These year-specific beta shape parameters were drawn from a gamma distribution with common shape parameters across years:

8) $$alpha2_i \sim gamma(alpha\_shape, alpha\_rate)$$
9) $$beta2_i \sim gamma(beta\_shape, beta\_rate)$$

The gamma shape parameters were then given uninformative gamma hyper-priors:

10) $$alpha\_shape \sim gamma(0.01,0.01)\ T(0,100)$$
11) $$beta\_shape \sim gamma(0.01,0.01)\ T(0,100)$$

A Bayesian modeling framework was adopted for modeling coho salmon VSP parameters in the Wind River basin. The equations described herein combined into a single model which was estimated using Markov Chain Monte Carlo (MCMC) simulations to sample the posterior probability density functions of each parameter. We conducted our MCMC simulations using JAGS (Plummer 2003), which was operated using the R statistical programming environment R (R Development Core Team 2014) using the R2jags package (Su and Yajima 2015). We obtained 300,000 MCMC samples from three chains, discarding the first 10,000 samples as burn-in and thinning to retain one sample in every 100, leaving 27000 samples of the posterior distribution. We assessed chain convergence and stability by visually assessing trace-plots, calculating autocorrelation at various lags among posterior samples, and by calculating the Geweke statistic. The number of independent samples, as measured by effective sample size (ESS), was monitored to ensure a minimum of 4,000 was reached.

Results

Abundance and Proportion of Hatchery-Origin Spawners

Estimates of total adult coho salmon spawners (i.e., escapement) in the Wind River watershed were generated from 2007 – 2015 (Table 2, Figure 3). Across the nine years, the median (50% percentile) total abundance ranged from 28 to 92 spawners. Based on carcass recoveries (2013-15), we estimated the median percentage of adult coho salmon hatchery-origin spawners (pHOS) to be 25% and ranged from 24 – 28% (Table 3, Figure 4). Of the hatchery-origin carcasses recovered, only the fish from 2013 – 2015 (N=18) could currently be assigned back to a specific sub-reach within the Wind River and thus reliably be assigned as a spawner. Of these hatchery-origin carcasses, eight had CWTs and four were ultimately read and the rearing hatchery identified: two from Cascade Hatchery (near Eagle Creek, Oregon), one from Bonneville Hatchery (near Tanner Creek, Oregon), and one from Winthrop National Fish Hatchery (Winthrop, Washington). Based on the ratio of hatchery- to natural-origin spawners, we estimated the total number of natural-origin spawners (Table 4, Figure 5), which ranged from 21 to 70 individuals among the nine years.

Table 2. Estimates of total coho salmon escapement among years (mean, SD, and quantiles of the posterior distribution).

Year	Mean	SD	2.5%	25%	50%	75%	97.5%
2007	101	50	53	72	89	115	223
2008	69	46	33	47	59	78	157
2009	54	34	28	38	47	62	123
2010	31	8	20	26	30	35	51
2011	66	20	40	53	62	74	115
2012	75	56	34	49	62	84	194
2013	84	45	42	58	73	95	190
2014	31	17	17	23	28	35	69
2015	105	54	56	75	92	119	229

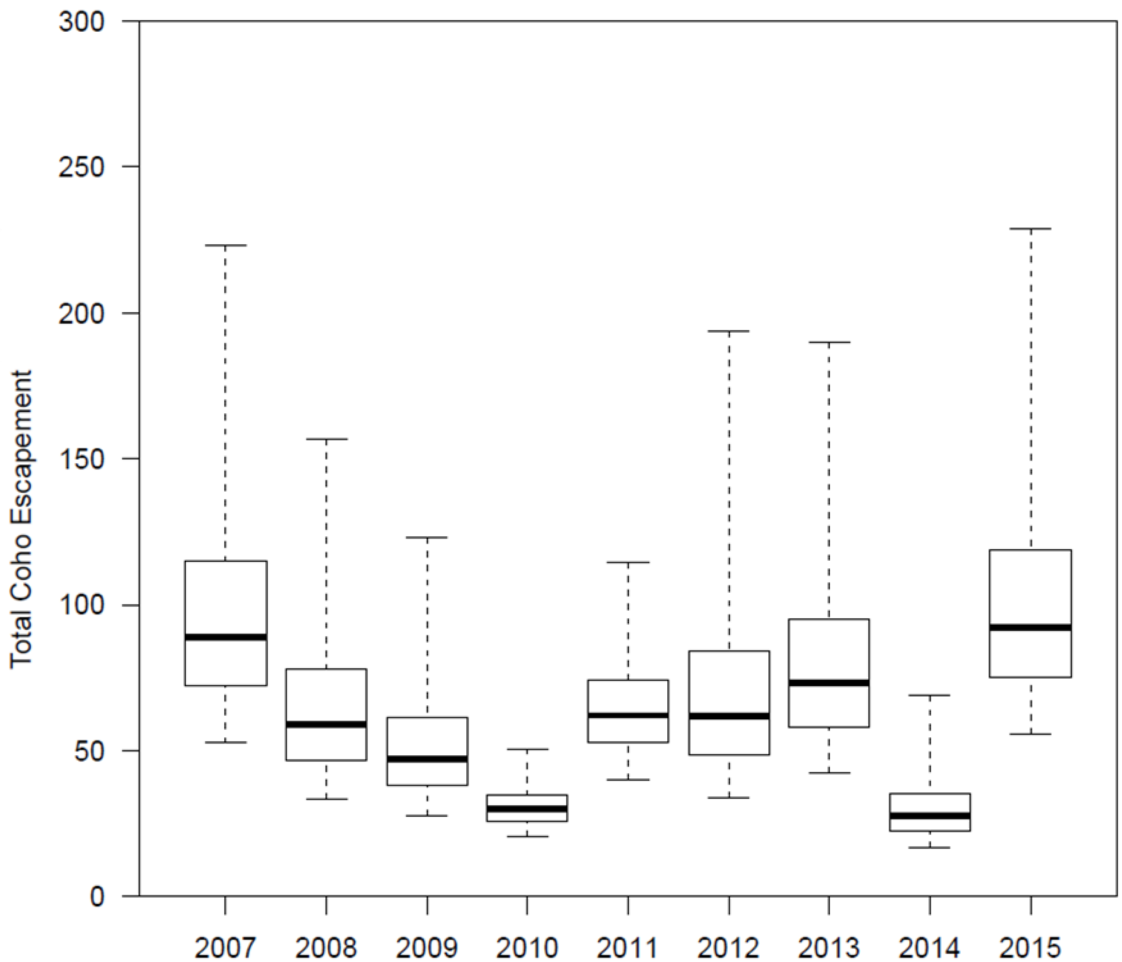

Figure 3. Estimates of total coho salmon escapement (mean, quantiles, and 95% CI of the posterior distribution) among years (2007 – 2015).

Table 3. Estimates of the percentage of hatchery-origin spawners (pHOS) among years (mean, SD, and quantiles of the posterior distribution). Note: estimates for 2007 – 2012 were the overall hierarchical estimate of pHOS since year-specific data were not available.

Year	Mean	SD	2.5%	25%	50%	75%	97.5%
2007	27%	13%	6%	18%	25%	33%	57%
2008	27%	13%	6%	18%	25%	33%	57%
2009	27%	13%	6%	18%	25%	33%	57%
2010	27%	13%	6%	18%	25%	33%	58%
2011	27%	13%	6%	18%	25%	33%	58%
2012	27%	13%	6%	18%	25%	33%	58%
2013	29%	9%	13%	22%	28%	34%	49%
2014	25%	7%	13%	20%	24%	29%	38%
2015	24%	6%	13%	20%	24%	28%	38%

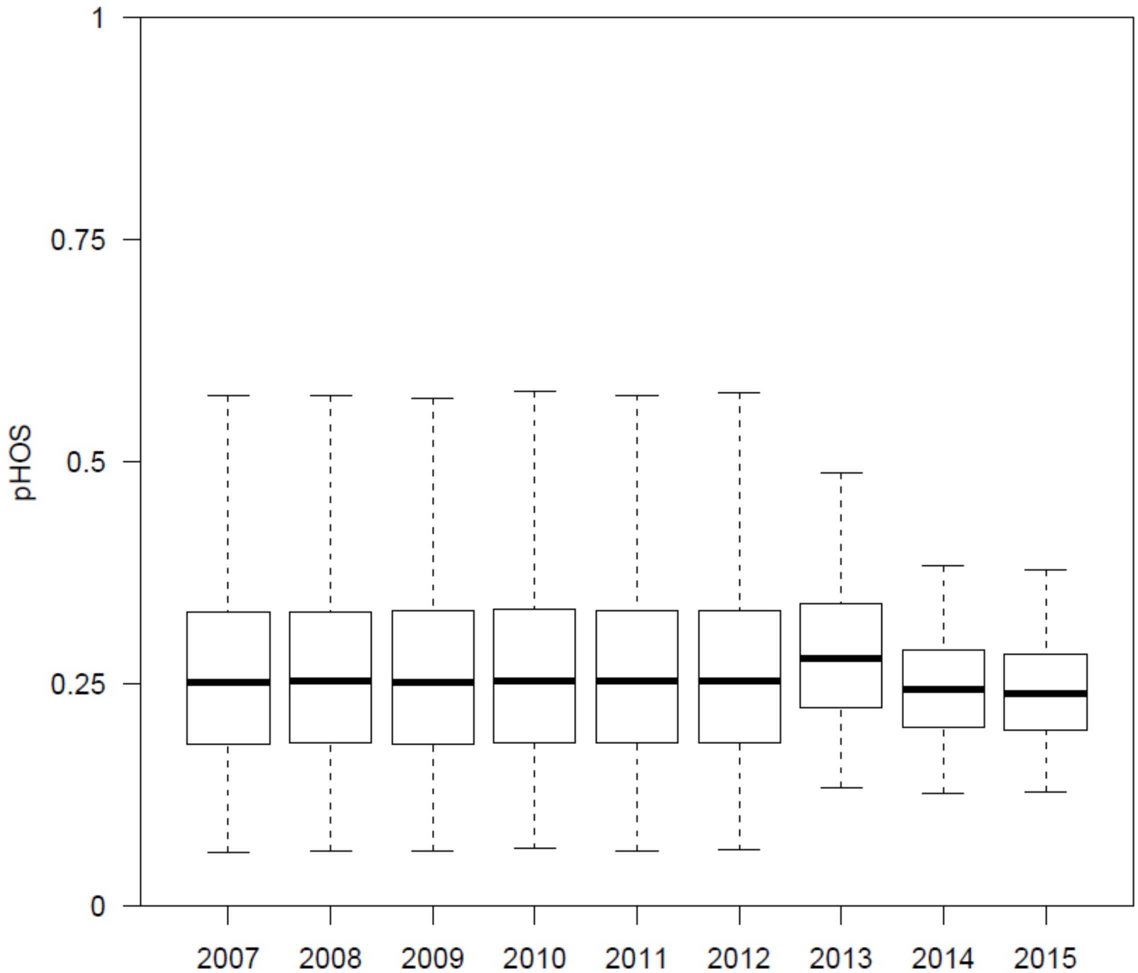

Figure 4. Estimates of the proportion of hatchery-origin spawners (pHOS) among years (2007 – 2015) based on coded wire tag presence or missing adipose fins (mean, quantiles, and 95% CI of the posterior distribution).

Table 4. Estimates of wild coho salmon escapement among years (mean, SD, and quantiles of the posterior distribution).

Year	Mean	SD	2.5%	25%	50%	75%	97.5%
2007	74	40	31	51	65	86	171
2008	50	37	20	33	43	58	120
2009	40	26	17	27	35	46	93
2010	23	7	11	18	22	27	39
2011	48	17	23	37	46	56	89
2012	55	42	21	35	45	63	144
2013	60	33	28	41	52	69	138
2014	24	13	12	17	21	27	52
2015	80	42	41	56	70	90	176

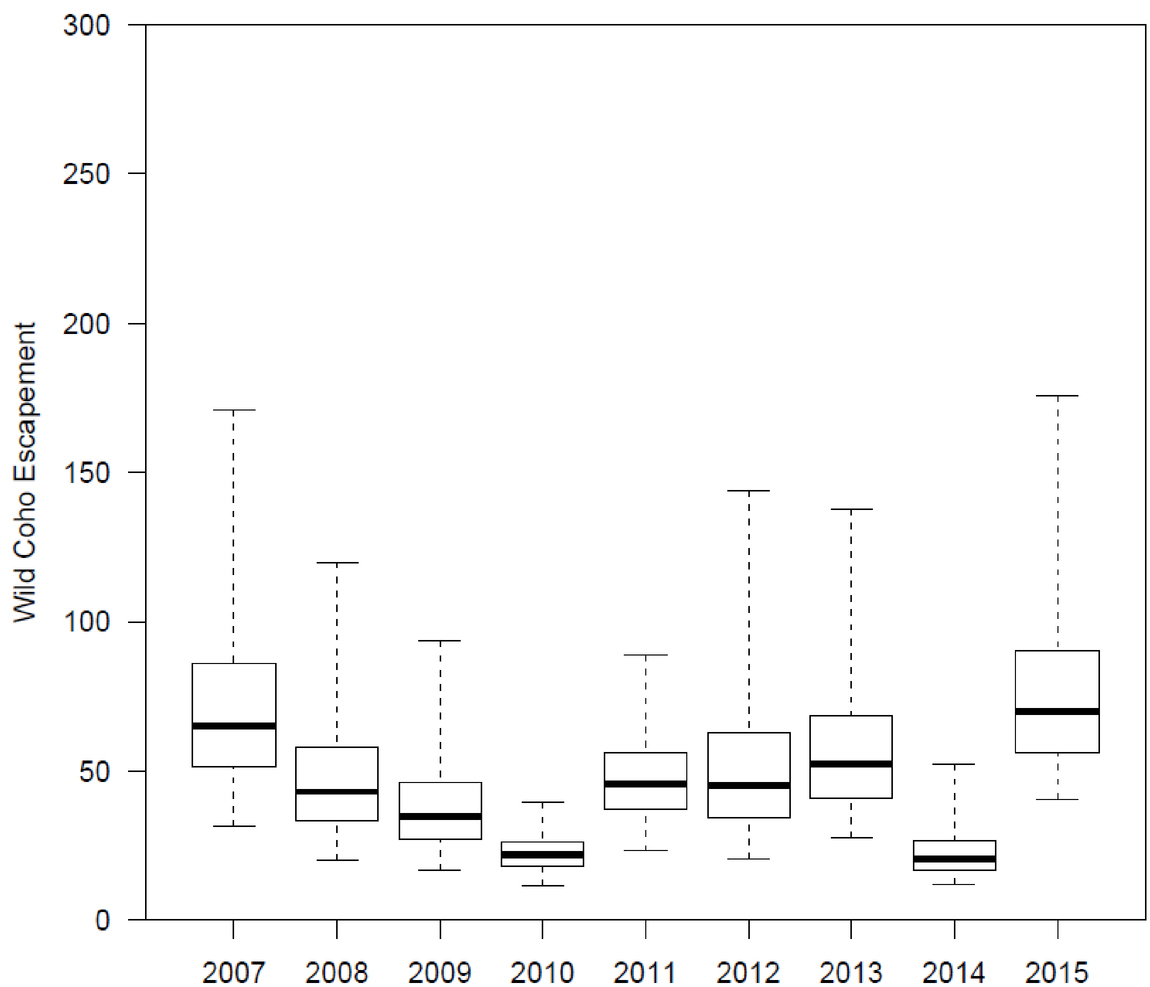

Figure 5. Estimates of wild coho salmon escapement (mean, quantiles, and 95% CI of the posterior distribution) among years (2007 – 2015).

Proportion of Females

Using carcass survey data, we estimated the percentage of total spawners that were females (i.e., sex ratio). Across all years, the median sex ratio was 55% females and ranged from 51 – 60 (Table 5, Figure 6).

Table 5. Estimates of the percentage of female spawners among years (mean, SD, and quantiles of the posterior distribution).

Year	Mean	SD	2.5%	25.0%	50.0%	75.0%	97.5%
2007	61%	8%	45%	55%	60%	66%	78%
2008	53%	10%	31%	47%	53%	59%	71%
2009	53%	8%	36%	48%	54%	59%	69%
2010	50%	8%	32%	45%	51%	56%	65%
2011	56%	10%	35%	50%	56%	62%	77%
2012	55%	11%	31%	48%	55%	62%	77%
2013	52%	9%	34%	47%	53%	58%	68%
2014	59%	7%	45%	54%	59%	64%	73%
2015	55%	7%	41%	50%	55%	59%	68%

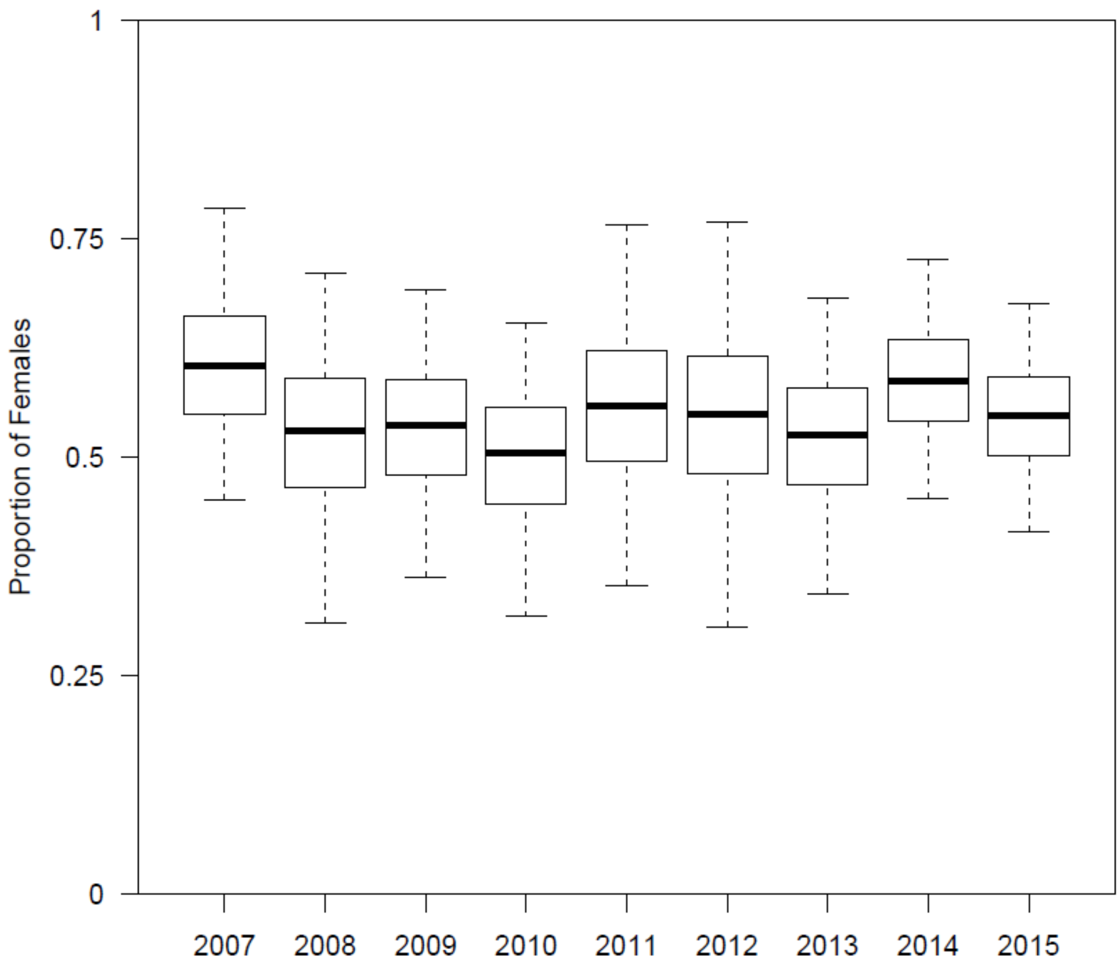

Figure 6. Estimates of the proportion of spawners that were females (mean, quantiles, and 95% CI of the posterior distribution) among years (2007 – 2015).

Redds per Female

Three years of data were available from the WDFW Lower Columbia River coho salmon monitoring program to generate year-specific estimates of redds per female (equation 7-11). Estimates of alpha2 were 27.24, 11.55, and 3.74 in 2010-2012, respectively. Estimates of beta2 were 30.72, 6.50, and 2.82 in 2010-2012, respectively. This resulted in year-specific estimates of redds per female ranging from 0.47 to 0.64 (Table 6), with a median hierarchical estimate of 0.56, which was applied to years without data.

Table 6. Estimated number of redds per female (*RpF*) among years (mean, SD, and quantiles of the posterior distribution).. Estimates are based on WDFW data throughout the lower Columbia ESU from locations with paired weir counts or mark recapture estimates and redd counts upstream. Note: estimates for 2007 – 2009 and 2013 – 2015 are the overall hierarchical estimate of *RpF* since year-specific data were not available.

Year	Mean	SD	2.5%	25.0%	50.0%	75.0%	97.5%
2007	0.56	0.17	0.23	0.44	0.56	0.68	0.87
2008	0.56	0.16	0.23	0.44	0.56	0.68	0.86
2009	0.56	0.16	0.23	0.45	0.57	0.68	0.86
2010	0.47	0.07	0.34	0.43	0.47	0.51	0.60
2011	0.64	0.11	0.41	0.57	0.64	0.72	0.84
2012	0.57	0.18	0.21	0.44	0.58	0.71	0.89
2013	0.56	0.17	0.23	0.44	0.56	0.68	0.87
2014	0.56	0.17	0.23	0.44	0.56	0.68	0.86
2015	0.56	0.17	0.23	0.44	0.56	0.68	0.86

Redd Distribution

Individual redd locations were summarized by year and survey section (Table 7). Across the nine years of surveys, the Little Wind River survey reach contained an average of 52% of the total redds, followed by the lower two main stem Wind River survey reaches (33%), which again were combined into one section in seven of the nine years. However, within years the total percentage of redds in the Little Wind survey reach ranged from 0 – 92% while the lower two reaches of the main stem Wind ranged from 0 – 82%. The proportion of redds in the upper-most main stem Wind survey reach (i.e., Wind 3) averaged 16% and ranged from 0 – 42%.

Table 7. Summary of new redd counts by survey section and year conducted in the Wind River, Washington. Note: from 2007 – 2013, Wind 1 and 2 were combined and therefore redds could not be separated.

	Survey Section				
Year	Wind 1	Wind 2	Wind 3	Little Wind 1	Total
2007	18	NA	8	4	30
2008	14	NA	2	1	17
2009	4	NA	6	4	14
2010	5	NA	2	0	7
2011	6	NA	6	10	22
2012	0	NA	2	17	19
2013	5	NA	0	16	21
2014	0	0	0	9	9
2015	1	1	0	26	28
Avg. Proportion	0.32	0.01	0.16	0.52	1.00

Discussion

This report provides the first estimates of abundance for any coho salmon population in the state of Washington located in the Upper Gorge distinct independent population (DIP). Currently, these estimates are considered preliminary, but will eventually be rolled up into complete region-wide report at which time they will be considered final. The ultimate goal will be to estimate annual abundance for the entire Upper Gorge DIP group, which consists of the Wind River watershed, White Salmon watershed, and other small streams that may potentially contain coho salmon. Therefore, moving forward it should be a priority to initiate adult coho monitoring in the White Salmon watershed that will allow for a more complete Upper Gorge DIP group abundance estimate.

Over the nine years of spawning ground surveys, we estimated annual coho salmon abundances that ranged from 22 to 73 wild spawners and 6 to 26 hatchery-origin spawners. These estimates suggest that the Wind River watershed supports a very small population of coho salmon. Although the Wind River watershed consists of over 75 miles of stream habitat, only a small fraction (8%; 6.3 miles) is hypothetically available to coho salmon for spawning and rearing. Upstream passage on the main stem Wind River is blocked by Shipherd Falls, which is a natural (waterfall) barrier to coho salmon. Additionally, the lower 0.5 miles of the main stem Wind River is inundated by the Bonneville Dam pool and therefore spawning is precluded. The Little Wind River contains 4.15 miles of modeled coho habitat, but a landslide has blocked upstream passage truncating the habitat availability to the lower 1.5 miles since 2007. Interestingly, high flows (a ~25 yr. recurrence interval flood) in the winter of 2015 have removed much of the landslide barrier and the first steelhead was observed upstream of the barrier last year. However, there may be another natural migration barrier on the Little Wind at river-mile 1.8 based on juvenile distribution surveys. Future surveys should be conducted to access this potential barrier and if deemed a true barrier the coho distribution model should be updated. Regardless, the entire Wind River basin provides low quality habitat for coho salmon, which prefer small tributaries for spawning and low gradient off-channel habitat for rearing juveniles, neither of which are habitat types that are abundant in the watershed, or in the Gorge MPG, for that matter.

Estimates of pHOS (i.e., proportion of hatchery-origin spawners) across years ranged from 24 – 28%, which is lower than many other Lower Columbia River (LCR) populations of coho salmon (see Rawding 2014, 2015). However, the proportion of hatchery origin spawners is relatively high given that there is not a coho hatchery or coho hatchery plants in the Wind River. Additionally, the estimates of pHOS reported here are undoubtedly underestimates because they have not been adjusted for hatchery fish that were neither adipose- nor CWT- marked. Regardless of mark type, the hatchery coho that were detected on the Wind River spawning grounds are strays from out-of-basin hatchery programs. Based on the currently limited number of carcasses recovered which can be assigned to a specific hatchery of origin (based on CWT) that were recovered during spawning ground surveys (N = 4), it is difficult to know the primary hatchery sources of these strays. However, since 1991, a total of 67 CWT positive adult coho have been recovered during expanded surveys on the Wind River, which include the unspawneable backwater area at the mouth of the river. Among all fish and years, recoveries came from 16 different hatchery sources and 22 release locations operated by five different agencies (Table 8). While these fish were recovered in the Wind River, their specific recovery sub-reach is currently unknown and therefore may not represent spawning individuals. Nonetheless, the Upper Gorge major population group is classified as a "Primary" population (LCFRB 2010). Therefore, the pHOS goal is <5% as suggested by the Hatchery Scientific Review Group (HSRG 2014). Since habitat is naturally limited for wild coho in the Wind River, the pHOS goal will likely not be achieved through recovery of the natural-origin population alone and would likely require modification of hatchery programs to reduce straying to the Wind River. Therefore, determining the source of these strays will likely be important in reducing pHOS.

Sex ratio was measured as the proportion of the spawners that were female from carcass recoveries on the spawning grounds. Across years, the sex ratio ranged from 51 – 60% females, which is higher than expected based on sex ratios from other LCR populations (see Rawding 2010, 2011, 2012), and based on observations of populations elsewhere (Holtby and Healey 1990) . Overall, the total number of carcass recoveries was low, ranging from 12 – 31 individuals, and limited to only three years (2013 – 2015). Therefore, the higher than expected sex ratio could be an artifact of small sample sizes or other unexplained factors in the Wind River. Had we used the mean sex ratio from all LCR populations, which has a median value of 45% among years, our estimates of total spawners would have only changed by 5 – 22 fish among years, or rather 22% (average change among years).

Our estimates of coho salmon escapement were based on spawning ground surveys of individually tracked redds and three biological metrics that allowed us to expand redd counts to total spawners. While we believe our estimates of escapement are relatively unbiased and provide an accurate portrayal of the status of coho salmon in the Wind River watershed, the metrics used to generate the estimates have a few potential limitations. First, our estimates of "apparent" redds per female were based on a regional index that contained no data from the Wind River. Apparent redds per female (RpF) is a parameter that includes both the actual numbers of redds each female constructs as well as the proportion of those that are observable during stream surveys. While it is unlikely that the average number of redds each female constructs varies substantially among populations, observer efficiency (i.e., the proportion of redds visible to surveyors to be counted) may vary substantially as a function of habitat types, flows, turbidity, surveyor experience, and other factors. Therefore, if observer efficiency in the Wind River is different than in the locations where RpF was estimated , our use of estimates from elsewhere may bias our abundance estimates. Second, our estimates of RpF were based on only three years of data. Although our hierarchical model incorporates among year uncertainty in this estimate, limited data may underestimate uncertainty in this parameter in some years, which can lead to an underestimate of variance and potential bias in abundance estimates. Third, estimates of pHOS were based on only three years of carcasses recovered during spawning ground surveys with small sample sizes. Similar to hierarchical estimates of redds per females, estimates of the proportion of hatchery-origin spawners and its associated variance may be biased and underestimated, respectively.

Table 8. Summary of hatchery-origin coho salmon recovered in the Wind River and their respective hatchery source among all carcass recoveries with a decoded CWT. Note: while these fish were recovered in the Wind River, their specific recovery sub-reach is currently unknown and therefore may not represent spawning individuals.

Operating Agency	Hatchery Source	Number of Recoveries	% of Total Recoveries
US Fish and Wildlife Service	Willard NFH	12	17.9%
	Little White Salmon NFH	4	6.0%
	Winthrop NFH	4	6.0%
	Warm Spring NFH	2	3.0%
	Cle Elum Ponds	1	1.5%
	Easton Ponds	1	1.5%
	Lost Creek Ponds	1	1.5%
Nez Perce Tribe	Cascade Hatchery	10	14.9%
	Dworska NFH	7	10.4%
	Eagle Creek NFH	5	7.5%
	Kooskia NFH	3	4.5%
OR Dept. of Fish and Wildlife	Bonneville Hatchery	1	1.5%
	Oxbow Hatchery	1	1.5%
WA Dept. of Fish and Wildlife	Wells Hatchery	3	4.5%
	Washougal Hatchery	1	1.5%
Yakama Nation	Leavenworth Hatchery	11	16.4%
Total	N = 16	67	100%

Although estimating VSP parameters for Wind River coho salmon involved some limitations in data quantity and the need to rely on regional redds per female data, these estimates provide valuable and novel information regarding the status and trends of Upper Gorge coho salmon and the Gorge MPG as a whole. While a small population, the Wind coho population must be considered in the context of the Gorge MPG in its entirety, which consists of very little coho salmon habitat both due to inundation from the Bonneville Pool, as well as due to the natural high gradient of Columbia tributaries in this reach, which rapidly descend from the cascade crest to near sea level over a short distance. Prior to the removal of Condit Dam on the White Salmon in 2011, the Wind River undoubtedly contained the largest extent of usable habitat in the Upper

Gorge population. Results reported herein suggest wild coho salmon abundance is low in the Upper Gorge and that recovery of this primary population may be limited by habitat availability and non-natal hatchery-origin coho straying. However, it is possible that newly accessible habitat in the White Salmon watershed will allow for considerable improvement in the status of Upper Gorge coho salmon.

Recommendations

1. Efforts should be made to identify funding to expand coho surveys to include areas of the White Salmon River recently made accessible by the removal of Condit Dam.

2. Efforts should be made to identify if other Upper Gorge coho habitat exists in small streams where distribution models suggest it may occur—many heavily degraded steep little creeks that have their historical coho habitat flooded in the Bonneville pool.

3. Future Wind River basin surveys in the Little Wind River should extend upstream to the uppermost modeled extent of coho habitat or until an anadromous barrier is reached, now that the landslide at RM 1.5 may no longer be a barrier. Specifically, further evaluation of the potential natural barrier near RM 1.8 should be a priority and if passage is possible then areas beyond falls should be explored and potentially added to future survey reaches.

4. Further evaluate source of coho hatchery-origin strays into Wind River once the Regional Mark Information System (RMIS) can be linked to WDFWs corporate TWS data base for all survey years.

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