Abundance and Productivity of Wind River Steelhead and Preliminary Assessment of their Response to Hemlock Dam Removal, 2018

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The Washington Department of Fish and Wildlife (WDFW) contribution to the Wind River watershed project is designed to measure the status and trends of threatened Wind River wild summer steelhead, as well as their responses to restoration actions in the watershed and its primary sub-basins. The Wind River is a 582 km^2 watershed that begins in Washington's Cascade Mountains as three sub-basins; Trout Creek, Panther Creek, and the upper mainstem Wind River, and enters the Columbia River 10 km above Bonneville Dam (Figure 1). Shipherd Falls, located at rkm 3, was historically passable only by summer steelhead. A constructed fishway allows additional fish passage, however only wild steelhead and spring Chinook from an upstream hatchery program are passed upstream.

Historical habitat degradation in the Wind watershed, which is mostly (77%) owned by the U.S. Forest Service, was primarily associated with forestry, including logging, splash damming, and road construction. These activities resulted in reduced abundance of instream woody debris, accelerated sedimentation and scour, and reduced channel stability and habitat complexity, particularly in alluvial reaches. On lower Trout Creek, the 6.7 m tall Hemlock Dam, equipped with an antiquated fish ladder, provided poor fish passage for adult steelhead, disrupted sediment transport, and inundated riverine habitat upstream.

In response to declining fish populations and degraded habitat conditions, a collaborative monitoring and habitat restoration program involving the Washington Department of Fish and Wildlife, United States Geological Survey – Western Fisheries Research Center (USGS), United States Forest Service (USFS), and the Underwood Conservation District (UCD) began in the 1990s. WDFW's life cycle monitoring program has included estimating smolt production in the three headwater sub-basins as well as at the mouth of the watershed since the mid-1990s, and adult total population abundance using a mark-resight approach since 2000. During that period, population abundance of adult steelhead above Shipherd Falls has ranged from ~200-1500, and smolt abundance has ranged from ~8,000-40,000. From 1992-2009 a fish trap was operated in Trout Creek within the Hemlock Dam fish ladder, enabling a census count of adult steelhead in the sub-basin above the dam. In 2009, USFS and Bonneville Power Administration (BPA) funded the removal of Hemlock Dam, and adult estimates have continued subsequently via mark-resight methods. The existence of abundance estimates prior to dam removal and other biological data collected in the Trout Creek sub-basin and other sub-basins provide a unique opportunity to measure the responses of steelhead populations. Other restoration actions since dam removal have been coordinated through the interagency collaboration to ensure mutual restoration and monitoring goals are achieved.

Fish Population RM&E

Adult and smolt abundance

- Wild steelhead smolt production was estimated for the Wind River and key sub-basins in 2018 using stratified mark-recapture data fitted to a Bayesian model which uses smoothed P-splines to estimate daily migration. A total of 29,336 smolts were estimated to emigrate from the Wind River basin, including 3,357 from the Trout Creek sub-basin, 816 from the Panther Creek sub-watershed, and 1,436 from the Upper Wind River, respectively. Smolts emigrating from Trout Creek, Panther Creek, and the Upper Wind River accounted for 11%, 3%, and 5% of the total smolt production from the Wind River.

The remaining smolt production of 23,728 (81%) emigrated from the middle and lower mainstem of the Wind River. A high percentage of the smolts produced from the middle and lower Wind River reaches immigrated into this area from the tributary sub-basins the previous spring. Wind Basin smolt abundance in 2018 was the 5th highest since monitoring began in 1995 and well above the average of approximately 23,000.

- The Wind River adult summer steelhead escapement estimate in spawn year 2018 was 242 using a mark-resight method termed the "Jumper" method. The wild winter steelhead escapement was estimated to be 10 adults based on expanded trap counts and redd surveys below Shipherd Falls. The summer steelhead population made a sharp decline in 2018 following returns of over 1,000 in 2016 and 2017. This decline is related to decreased smolt to adult return (SAR) rates brought on by poor ocean conditions (see SAR section).
- From spawn year 1993-2009 a census count of adult steelhead abundance in Trout Creek was made at the Hemlock Dam fish ladder. From 2010-2014, estimates were made using a mark-recapture resight study design that relied on detecting PIT tagged adults entering Trout Creek. With one PIT tag array, estimation of array detection efficiency was problematic. In 2015 the installation of a second Instream PIT Tag Detection System greatly improved our ability to estimate steelhead abundance in Trout Creek. Steelhead abundance was 36 adults in 2018. This represents a sharp decline from 2017 and in the trend that has followed dam removal.

Survival and productivity

- Steelhead smolts were PIT tagged as they emigrated from the Wind River starting in 2003 and were subsequently detected at Bonneville Dam, allowing for the estimation of smolt to adult return rate (SAR) to Bonneville Dam. For the years in which adult returns are complete and data have been analyzed (outmigration years 2003 to 2015 and return years 2004 to 2017) SARs ranged from a low of 1.0% (outmigration year 2015) to a high of 7.5% in 2009. These are minimum estimates because they have not been corrected for tag loss and tag-related mortality.
- Scales were collected from steelhead adults and juveniles through 2018. Age data from these scales in conjunction with adult and smolt abundance data allow us to link adults and smolts by brood year to reconstruct cohort survival and report on high level indicators (HLI) including adult to adult survival (recruits per spawner; RpS) and juveniles per spawner (JpS). Preliminary analyses of JpS were conducted in 2014 to estimate freshwater habitat productivity and capacity for Wind River steelhead. As of the spring of 2018, the return of adult recruits, which are up to 8 years in age, is complete through brood year 2010. Adult RpS was calculated for brood years through 2009. As scales for additional years are read, calculations for JpS and RpS will be updated.

Tributary Habitat Action Effectiveness

Hemlock Dam Removal Fish Response

- The USFS and BPA funded the removal of Hemlock Dam on Trout Creek in 2009 to improve the status of wild steelhead populations in the Wind River. Previous Wind River adult and juvenile steelhead monitoring in this watershed has occurred at multiple control and impact sites for up to 20 years, which allows the testing of over a dozen unique dam removal hypotheses through Before-After-Control-Impact (BACI) type designs. We are

aware of no other datasets of this quality, breadth, and duration to assess the response of wild salmonids to dam removal.

- WDFW and USGS have implemented Before-After Control-Impact (BACI) and before-after (BA) study designs to monitor steelhead population responses to dam removal since 2009. Several years of pre-dam removal data exist and we have collected post-dam removal data since 2009, however, final analysis and reporting of dam removal impacts have not yet been completed and will require additional years of data collection.
- The timeline for potential fish responses to Hemlock Dam removal is likely to vary as a function of the timing of steelhead biology (when life stages are present that have experienced post-dam removal conditions), study design, and data variability. These factors merit consideration in planning post-dam removal monitoring.
- Power analyses reveal that the amount of time required to detect significant changes in Trout Creek smolt and adult abundance vary but can be expected to require at least 10 years of post-dam removal monitoring because of inherent variability in fish abundance and survival, and the time required to collect multiple years of post-dam removal data on various fish response metrics.
- Although a formal statistical analyses of fish responses to Hemlock Dam removal is premature, preliminary qualitative results suggest that smolt and adult abundance i increasing in Trout Creek relative to other portions of the Wind basin.

Coordination and Data Management for RM&E

- WDFW supports the exchange and dissemination of fish and wildlife data and the goals outlined in the RM&E data management strategies roadmap through documentation and standardization our data collection methods, protocols, and analysis and storage of data in safe and secure statewide/regional databases.
- While the WDFW portion of the Wind Watershed Project has collected the data necessary to report on HLIs, producing accurate and precise estimates for these metrics over long-term projects requires development of indicator-specific analytical methods and standardized long term project databases from which to populate these analyses. WDFW continues to work to improve its data storage and analytical methods, but notes that its efforts in this area would be improved by a greater level of funding for these tasks, which has not been available in recent years.

INTRODUCTION

Fish Population RM&E

This project supports the Fish and Wildlife program fish population monitoring strategies by providing data to answer the following Management Questions**:**

1. *What are the status and trend of abundance of natural and hatchery origin fish populations?*
2. *What are the status and trend of juvenile abundance and productivity of fish populations?*
3. *What are the status and trend of spatial distribution of fish populations?*
4. *What are the status and trend of diversity of natural and hatchery origin fish populations?*

The wild summer steelhead (*Oncorhynchus mykiss*) abundance index in the Wind River declined from the 1980s through the 1990s (Busby et al. 1996, WDFW 1997). By the early 1990's a multi-agency technical advisory committee (TAC) was formed to investigate the cause of the decline and recommend actions that would lead to improved wild summer steelhead abundance. The TAC was originally composed of members from the United States Fish and Wildlife Service (USFWS), United States Forest Service (USFS), Washington Department of Fish and Wildlife (WDFW), and Yakama Nation (YN). In the late 1990s, the USFWS provided funding to the Underwood Conservation District (UCD) to establish a watershed council. The UCD and United States Geological Survey – Columbia River Research Laboratory (USGS-CRRL) were added to the original TAC, which was renamed the Technical Advisory Group (TAG) to support the Wind River Watershed Council. The Bonneville Power Administration (BPA) agreed to fund a collaborative monitoring and restoration effort on the Wind River in 1997 (Rawding et al. 1999) which has continued through the present (Rawding and Cochran 2001, 2005, 2006, 2008, 2009, 2010, 2011, 2012, Cochran et al. 2013, and Buehrens et al. 2014, 2015, and 2016). In this partnership, WDFW has been responsible for estimating Wind River natural-origin steelhead spawner abundance (NOSA) and smolt abundance. Through the collection of age data from scales and the use of PIT tags to track individual tagged fish, WDFW has begun developing methods to report on other high level indicators (HLI) including adult recruits per spawner (RpS), juveniles (smolts) per spawner (JpS), and smolt to adult return (survival) rate (SAR).

The objectives for WDFW were to:

1. Develop annual estimates of abundance in the Wind River basin for:
    b. Adult steelhead
    c. Smolts

   (*Addresses Questions 1 and 2)*

2. Collect adult and juvenile steelhead life history information in order to describe life history diversity and to estimate the productivity of cohorts and between life stages of those cohorts including:
    a. Smolt to adult survival
    b. Adult to adult survival (spawners per spawner)
    c. Juvenile recruits per spawner

   (*Addresses Questions 2and 4)*

3. Determine the spatial structure of steelhead populations

a. Estimate the abundance of smolts within four production areas (Trout Creek, Panther Creek, the upper Wind, and the mainstem below those sub-basins)
b. Estimate adult abundance within one sub-basin (Trout Creek) and at a watershed scale.

(*Addresses Question 3)*

Tributary Habitat RM&E

This project supports the Fish and Wildlife program fish population monitoring strategies by providing data to answer the following Management Questions:

1. *What are the relationships between tributary habitat actions and fish survival or productivity increases, and what actions are most effective?*
2. *Are tributary actions achieving the expected biological and environmental improvements in habitat?*

The USFS and BPA funded the removal of Hemlock Dam on Trout Creek in 2009 to improve the status of wild steelhead populations in the Wind River (USFS 2004). Previous Wind River adult and juvenile steelhead monitoring in the basin has occurred at multiple control sites and the impact site for up to 20 years. This extensive data set prior to the dam removal allows the testing of over a dozen unique dam removal hypotheses regarding abundance, productivity, survival, growth, and migration responses of Trout Creek juvenile and adult wild steelhead through Before-After-Control-Impact (BACI) (Stewart-Oaten et al. 1986) and Multiple-BACI designs involving replicate controls (Underwood 1994). We are aware of no other datasets in the Pacific Northwest of this quality, breadth, and duration to assess steelhead response to barrier or dam removal, which are often viewed as one of the most effective actions for wild salmon and steelhead recovery. In addition, a natural extension of the BACI design is to evaluate restoration actions as part of a basin-wide restoration strategy including the phasing of restoration actions to enable the use of sub-basins as the Upper Wind Watershed and Panther Creek as control watersheds during the assessment of fish responses to restoration in the Trout Creek sub-basin.

The removal of Hemlock dam is expected to increase abundance and productivity (survival) of steelhead by increasing survival of adult and juvenile steelhead migrants moving through the Hemlock Dam reach, and through increased spawning and rearing habitat made available by replacing the reservoir with a stream channel (USFS 2004).

The objectives for WDFW were to collect data to test null hypotheses including:

- (***Ho***): There is no difference in the proportion of adult spawners that spawn in Trout Creek (impact site) and the rest of the Wind Basin (control site) before and after dam removal
- (***Ho***): There is no change in the mean difference in smolt production between the upper Wind River (control site) and Trout Creek (impact site) before and after dam removal.
- (***Ho***): There is no change over time in the stock-recruit relationship between adult spawners and the smolts they produce in Trout Creek

(*Addresses Questions 1 and 2)*

Coordination and Data Management for RM&E

This project supports the Fish and Wildlife program fish population monitoring strategies by providing data to answer the following Management Questions:

1. *How has your work supported exchange and dissemination of fish and wildlife data or the development of a database to manage data that may be shared regionally, relative to the RM&E data management strategies roadmap?*
    a. *Identification of Management Questions and Strategies*
    b. *Documentation of Protocols*
    c. *Data Collection and Generation*
    d. *Data Entry*
    e. *Agency Data Storage*
    f. *Regional Sharing*
    g. *Reporting*

Goals of this project are:

1. Documentation and standardization of our data collection methods, protocols, and analysis
2. Storage of data in safe and secure statewide/regional databases
3. Sharing of fish data and indicators with regional managers and researchers

(*Addresses Question 1)*

METHODS

Methods used for standard data collection and analyses to estimate metrics and indicators which are reported on annually as part of this project are documented in the WDFW Wind River Steelhead Life Cycle Monitoring Protocol at MonitoringResources.org:

https://www.monitoringresources.org/Document/Protocol/Details/2128.

Brief overviews of the methods are provided herein. Data collection and analysis methods under development to make estimates for new metrics or indicators or to address emerging research questions are described in greater detail.

Data Collection Methods

- Collecting adult steelhead at Shipherd Falls on the Wind River v1.0 (ID: 5384) Draft
- Collecting juvenile steelhead in rotary screw traps on the Wind River v1.0 (ID: 5383) Draft
- Collection and mounting of scales from adult and outmigrant (smolt and transitional) steelhead v1.0 (ID: 5386) Draft
- Conducting steelhead redd surveys in the lower mainstem and Little Wind River v1.0 (ID: 5391) Draft
- Downstream snorkeling to collect adult steelhead index counts and mark-resight data v1.0 (ID: 5390) Draft
- Floy tagging adult steelhead v1.0 (ID: 5387) Draft
- Measuring Fish Length: Fork length v2.0 (ID: 4041) Published
- Method: Determining sex, race and origin of adult steelhead v1.0 (ID: 5385) Draft
- PIT tagging adult and juvenile steelhead v1.0 (ID: 5388) Draft

- Recording external marks, wounds and other biological, developmental and conditional comments on juvenile and adult steelhead in the Wind River v1.0 (ID: 5389) Draft

Data Analysis/Interpretation Methods

- Adult Salmonid Abundance Estimation Using Multiple Partial Capture/Sighting Events v1.0 (ID: 1569) Draft
- Estimating Smolt to Adult Return Rates for Wind River Steelhead v1.0 (ID: 5392) Draft
- Time-Stratified Juvenile Salmonid Abundance Estimation Using Partial Capture Trap(s): Darroch Estimator v1.0 (ID: 1563) Draft

Supplementary Methodological Details

Study Site

The Wind River is a 582 km^2 watershed which begins in Washington's southern Cascade Mountains as three distinct sub-basins; Trout Creek, Panther Creek, and the upper mainstem Wind River, and enters the Columbia River 10 km above Bonneville Dam (Figure 1). Shipherd Falls is located at rkm 3 and was historically passable only by summer steelhead. A fishway constructed in the 1950s provides passage to additional species, but only wild steelhead and spring Chinook that are part of an upstream hatchery program are allowed upstream. Other fish present above the falls include mountain whitefish, lampreys, sculpins, and introduced brook trout. Below the falls there are populations of fall Chinook salmon, coho salmon, and cutthroat trout, as well as occasional use by other species that are found in the mainstem Columbia River.

A diverse mixture of geomorphic, hydrological, and habitat conditions are found throughout the watershed. High gradient bedrock canyon reaches, which are used primarily for rearing by juvenile and for summer/fall holding by adult steelhead, occur in the lower mainstem and lower ends of its major tributaries, whereas low gradient alluvial reaches, which are used for spawning, occur higher in the basin but below its extreme headwaters. Habitat in the watershed is in relatively good condition compared with other regional watersheds, owing to its largely public ownership (77%) by the U.S. Forest Service. However, historical forestry practices, including logging, splash damming, and road construction, have resulted in habitat degradation associated with a reduced abundance of instream woody debris, accelerated sedimentation and scour, and reduced channel stability and habitat complexity, particularly in alluvial reaches. The 6.7 m tall Hemlock Dam on lower Trout Creek, equipped with an antiquated fish ladder, provided poor fish passage for adult steelhead, disrupted sediment transport, and inundated riverine habitat upstream from its construction until its removal in summer 2009.

WDFW established long-term smolt and adult monitoring programs in the 1990's which include smolt trapping the three major sub-basins as well as the lower mainstem, trapping and tagging adult steelhead at Shipherd Falls, and adult steelhead enumeration via snorkel counts during the summer and winter months (Figure 1). In addition, from 1992-2009, a fish trap was operated in the Hemlock Dam fish ladder, enabling a census count of adult steelhead in the Trout Creek sub-basin above the dam. Estimates in this sub-basin have continued subsequently via mark-resight methods.

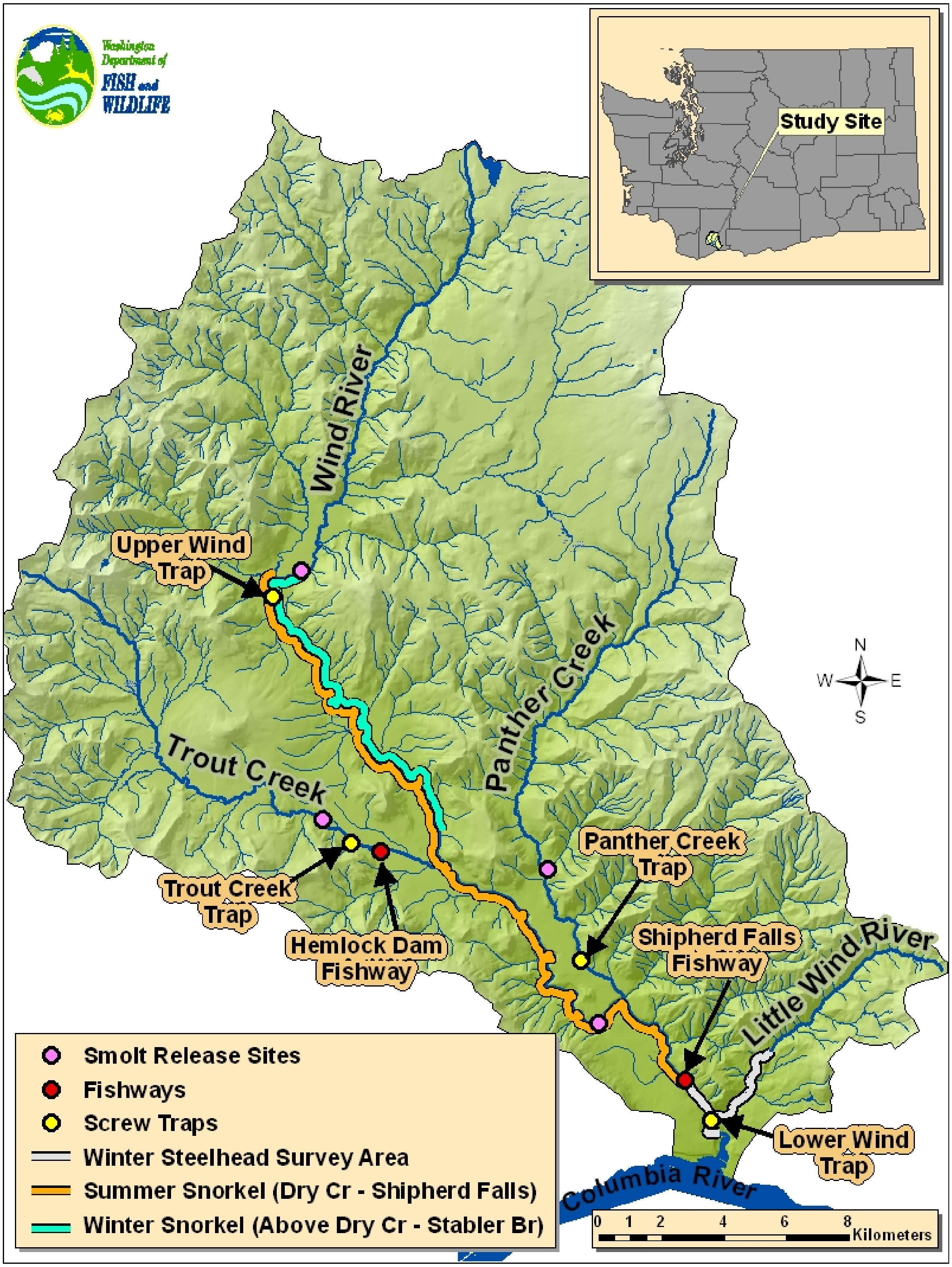

Figure 1. Wind River subbasin with adult and juvenile trapping sites, juvenile release sites, and snorkel and redd survey sections. Note: Hemlock Dam fishway was removed in summer 2009.

Adult Abundance

August snorkel surveys have been used to enumerate adult wild summer steelhead holding in the Wind River between Dry Creek and Shipherd Falls since 1988 (spawn year 1989). Beginning in 1999 (spawn year 2000), a trap in the Shipherd Falls fish ladder has been operated to capture and Floy® tag and PIT tag (starting in 2007) a portion of the population as they ascend the falls. The remainder of the population jumps Shipherd Falls during the "jumping period", which occurs from early summer through mid-fall (late-October to mid-November). Jumpers are not captured and tagged. Snorkel surveys are performed in August, September, and mid-winter, and these surveys enumerate tagged and untagged steelhead, enabling estimation of population abundance using mark-recapture (Petersen) estimators.

Annual estimates of Wind River wild summer steelhead population abundance have been made since 2000 based on four different mark-resight methods (Rawding and Cochran 2005). However, two of these methods relied on the use of a fish trap at Hemlock Dam in Trout Creek, which was removed in 2009. Consequently, WDFW now uses two methods to estimate adult summer steelhead abundance in the Wind River—the "jumper" method and the "winter snorkel" method; see Cochran et al. (2013) for full details. The "winter snorkel" method is the sum of two components: a Petersen estimate of abundance during the entire jumping period and the census count of steelhead ascending Shipherd Falls after the jumping period but before the end of the run. The "jumper method" is similar to the winter snorkel method, but is the sum of three components, a Petersen estimate of abundance from the beginning of the run through early September, the census count of steelhead ascending Shipherd Falls after the jumping period but before the end of the run, and an estimate of the number of steelhead passing Shipherd Falls between the September snorkel and the end of the jumping period. To estimate this final quantity, the census count of steelhead at the Shipherd Falls trap between the September snorkel and the end of the jumping period is expanded to account for the proportion of the run jumping the falls during this period. This is done by dividing the trap count between the September snorkel and the end of the jumping period by the "jumper ratio." The jumper ratio is calculated as the number of fish trapped at the falls between the August and September snorkels divided by the estimated total increase in abundance (Petersen estimates) between the two snorkel events (including those that jumped the falls). The two methods are employed to provide a measure of redundancy each year in case one method proves infeasible or data are compromised. Finally, a linear regression relating the final total abundance estimate (using the jumper method) to the August index reach snorkel count in each year since 1999 was used to expand index reach counts prior to1999 to produce complete abundance estimates for spawn years1989-1999.

Shipherd Falls historically separated winter and summer steelhead populations by acting as a physical barrier to most winter steelhead and consequently, wild winter steelhead abundance above Shipherd Falls is low compared to summer steelhead. Winter steelhead pass Shipherd Falls during a period when jumping was not successful, so the trap count from the beginning of the run through April 30 is assumed to include all winter steelhead passing Shipherd Falls through this date. The trap is removed each year to allow passage for large numbers of hatchery Spring Chinook returning to Carson National Fish Hatchery. The portion of the winter steelhead return during this period is estimated by expanding the trap counts through April 30 by the average timing from the North Fork Toutle River, a nearby basin where 100% of the return is counted in a trap (Rawding and Cochran, 2005). Spawning ground surveys are conducted below

Shipherd Falls and in the Little Wind River to estimate spawner abundance below Shipherd Falls by counting redds and assuming 1.62 fish per redd based on data from Snow Creek (WDFW, unpublished data).

Adult abundance in Trout Creek was assessed by census trap counts at the Hemlock Dam fishway from spawn years 1993-4 and 1998-2009. Since 2008 a PIT tag array located at the head of the reach formerly impounded by Hemlock Dam has detected PIT tagged adult steelhead as they migrate upstream. A snorkel survey is conducted in upper Trout Creek to count steelhead with Floy® tags applied at Shipherd Falls as well as untagged steelhead. Because all fish receiving a Floy® tag also receive a PIT tag, the ratio of Floy® tagged to untagged steelhead seen in the snorkel may be used to expand the count of PIT tagged adults counted at the lower Trout Creek PIT tag array to estimate the total abundance of steelhead passing the lower Trout Creek PIT tag array; the "PIT tag and Snorkel" method. However, this estimator assumes that no PIT tagged steelhead pass the lower Trout Creek array undetected.

For the last two years before Hemlock Dam was removed this "PIT tag and snorkel" method was used to estimate the abundance of wild steelhead in Trout Creek. A census count was also available from the dam's fish trap. During these two years, the PIT tag and snorkel abundance estimate was equal to 61% of the census count, indicating that 39% of the PIT tagged adults passed the antennas undetected. Between spawn years 2010 and 2014, improvements were made to the instream PIT tag arrays, which likely increased detection efficiency. Abundance estimates for this 5 year period were calculated both using 61% and 100% antenna efficiency. Beginning in spawn year 2015, a new PIT tag array was installed in upper Trout Creek allowing direct estimation of the lower Trout Creek PIT tag array (the proportion of PIT tagged adults detected at the upper Trout Creek array that had been previously detected at the lower Trout Creek array). This array efficiency estimator was used to expand the PIT tag count used in the PIT tag and snorkel method beginning in spawn year 2015.

See monitoring resources for details:
Adult Salmonid Abundance Estimation Using Multiple Partial Capture/Sighting Events v1.0 (ID: 1569) Draft

Smolt Abundance
Wind River wild steelhead smolt abundance is estimated for the entire Wind River basin, as well as Trout Creek, Panther Creek, and the Upper Wind River subbasin during the spring smolt migration season from March 15-June 15. At each site a portion of the outmigration is captured daily with rotary screw traps, PIT tagged, and released upstream to estimate trap efficiency. The Darroch estimator, a time stratified Lincoln-Petersen estimator which allows for delayed recaptures to occur in subsequent temporal strata, has been employed to make total abundance estimates (Bjorkstedt 2000, 2005, 2010) in previous years up through 2017. See monitoringresources.org for full details:
Estimating Smolt to Adult Return Rates for Wind River Steelhead v1.0 (ID: 5392) Draft

In 2018, however, a long outage due to high water in the second and third weeks of April created a gap in the mark-recapture datasets that could not be accurately compensated for using historical

timing data or the 2018 trap data alone. A Bayesian model described in Bonner and Schwartz (2011) was applied to daily stratified mark-recapture data that predicts expected daily migration as a smooth function of time. The model was implemented in an R package called BTSPAS (Bayesian Time-Stratified Population Analysis System).

Similar difficulties with missed periods were experienced in 2017 and the smolt outmigration estimates originally reported were generated in DARR using data stratified by week, followed by adjustments for prolonged outages using historical timing data (Buehrens and Cochran, 2017). During this reporting period the estimates for 2017 were revisited using BTSPAS as described above. The 2017 smolt estimates for the Wind Basin, Panther Creek, and the Upper Wind River were revised in BTSPAS and updated here. Model convergence could not be achieved with the 2017 Trout Creek dataset, therefore the original estimate is still reported.

Smolts per Spawner
Smolt abundance at each trap in each migration year was apportioned to parental brood years based on smolt age proportions estimated from a subsample of juveniles which were aged by reading their scale circuli. Smolts per spawner estimates were calculated as the smolt abundance divided by the adult abundance for the same basin (Trout Creek or Wind River Basin) for each adult spawn year. Preliminary spawner recruit analyses were completed on Wind River adult spawner and smolt recruit datasets including all brood years for which two year old smolts (~75% of Wind smolts) had been trapped (1993-2012 for Trout Creek and 1994-2012 for the Wind River). In brood years for which smolt trapping was not completed when one or three year old smolts would have out-migrated their abundance was estimated based on the abundance of two year-olds in their cohort and the mean proportion of those age classes in other years. Three spawner recruit models (Hockey Stick—Barrowman and Myers 2000; Ricker and Beverton-Holt—Hilborn and Walters 1992) were fit to the each time series assuming log-normal errors using maximum likelihood estimation and the model fits were compared using AIC (Burnham and Anderson 2002). Years with questionable adult estimates for Trout Creek were excluded from analysis. These included brood years 1995-1997 when the Hemlock Dam fish trap was not continuously operated, and 2010-2014 which rely on new, yet to be finalized, PIT tag mark-resight methods following Hemlock Dam removal.

RESULTS

Fish Population RM&E

Objective 1.a. Adult Abundance
Historically, four methods were used to estimate summer steelhead abundance in the Wind River (Cochran et al. 2013). However, since Hemlock Dam removal, we have used only the Jumper method and the Winter Snorkel methods. The Winter Snorkel is not possible to conduct in some years and usually has a greater coefficient of variation than the Jumper estimate. For these reasons we have adopted the Jumper method to derive the final estimates for assessment of stock status.

Additionally, a pattern has emerged in which the Winter Snorkel method has yielded larger estimates than the Jumper method in years of high population abundance (Table 2 and WDFW

unpublished data, winter snorkel 2013). Preliminary assessment of this phenomenon suggests that violations of a Petersen closed population mark-recapture assumption (all recaptured marks are recognized) may be occurring during winter snorkels. Floy® tags on summer steelhead lose their brightness and become less visible during winter snorkel surveys, making surveyors more prone to misclassify an unknown proportion of tagged fish as untagged when many fish are observed together. If this is the case then the re-sight efficiency would be artificially low, maiden observations would be artificially high, and the abundance estimate would be biased high. Further analysis of this issue will take place in the future and we will attempt to address it in the interim through use of longer tags and different color combinations that better maintain brightness and visibility during the winter.

In 2018 the abundance of summer steelhead above Shipherd Falls was estimated using only the Jumper method because suitable river conditions for a winter snorkel did not occur. The long-term hierarchical jumper multiplier from spawn years (SY) 2001-2018 (excluding outlier years 2000-2001 when low sample sizes led to outliers, 2013 when the August survey was not conducted, and 2017 for which the Jumper Ratio was 17.29 which was an outlier relative to previous years) was used to expand trap counts between September 9 and October 14, 2016.

The Jumper Ratio for spawn year 2018 was 6.38 (95% CI 3.84-12.76). As in past years, we used the hierarchical estimate (median = 5.59, 95% CI 2.64-17.67) to expand estimates because of uncertainty associated with interannual and within-year variation in the proportion of fish jumping Shipherd Falls (Table 1; Figure 2). It should be noted that this model does not account for uncertainty in snorkel abundance estimates, which could affect its results.

Table 1. Bayesian estimates of the annual and multi-year hierarchical Jumper ratio (rJ) Shipherd Falls between August and September snorkel surveys.

Year	Median	2.5% Quantile	97.5% Quantile
2002	4.07	3.21	5.35
2003	5.89	4.48	8.12
2004	10.81	6.16	22.25
2005	2.47	1.93	3.30
2006	10.82	5.88	26.48
2007	4.04	3.18	5.31
2008	5.37	3.67	8.63
2009	5.74	3.40	11.33
2010	3.63	2.89	4.76
2011	6.61	4.98	9.16
2012	4.17	3.06	6.07
2014	8.18	4.53	19.40
2015	7.37	4.91	12.29
2016	6.63	4.85	9.57
2018	6.38	3.84	12.76
Hierarchical	5.59	2.64	17.67

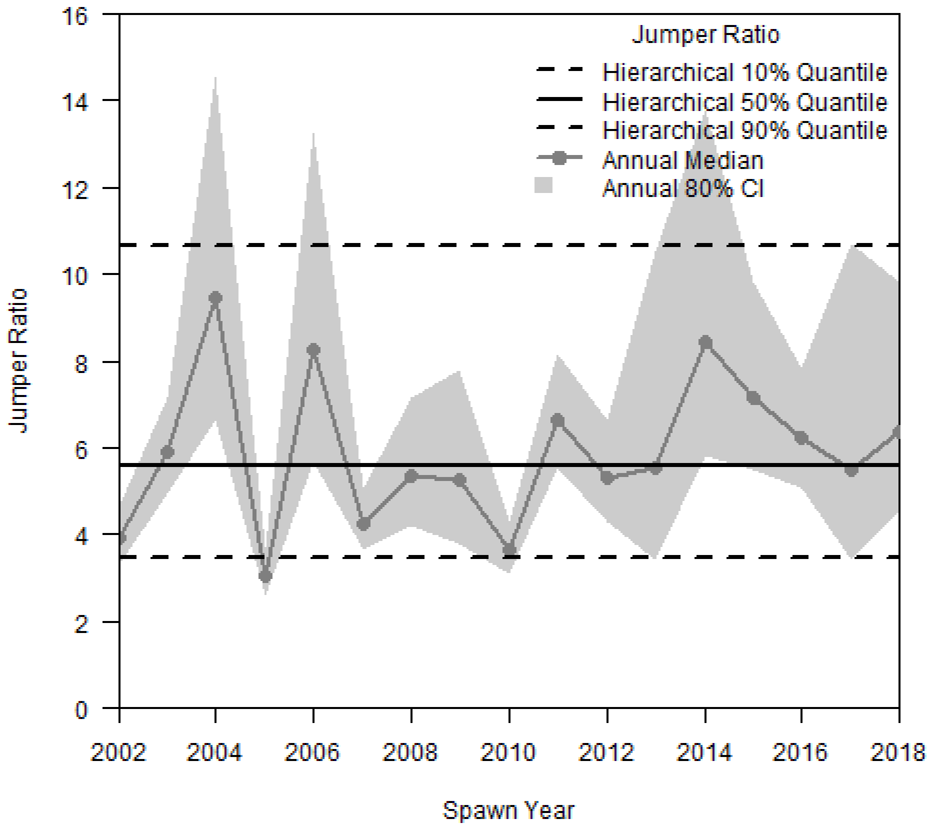

Figure 2. Jumper ratio—the ratio of the total increase in abundance between the August and September snorkel surveys divided by the Shipherd Falls trap count between snorkels.

Summer steelhead captured in the trap from October 19, 2017 through the end of trapping on April 30, 2018 were added on a 1:1 basis to the estimate of abundance at the end of the Jumping Period to complete the estimate of 242 (95% CI 199-285) adults (Table 1). Using the Jumper method, adult summer steelhead population estimates have ranged from a low of 218 in 2000 to a high of 1,507 in 2011 (Table 2). Estimates of uncertainty for the Jumper method include the variance component from the mark-recapture September abundance estimate but do not currently include a variance component for the expanded trap count between the fall snorkel survey and the end of jumping in late October or early November.

Table 2. Historical Snorkel Index Expansion, Winter Snorkel, and Jumper method estimates of Wind River wild adult summer steelhead escapement above Shipherd Falls for spawning years 1989 – 2018.

Spawn Year	Index Snorkel Expansion	Jumper[1]		Winter Snorkel & Trap[2]	
	Estimate	Estimate	(95% CI)	Estimate	(95% CI)
1989	1,016				
1990	561				
1991	596				
1992	535				
1993	677				
1994	468				
1995	543				
1996	466				
1997	734				
1998	320				
1999	323				
2000		222	(191-281)		
2001		496	(469-534)	478	(393-609)
2002		694	(649-749)	600	(517-726)
2003		1118	(1,064-1,184)		
2004		903	(863-947)		
2005		604	(541-698)	552	(489-642)
2006		666	(638-701)	607	(512-743)
2007		776	(737-826)	630	(513-826)
2008		646	(607-698)	517	(437-635)
2009		613	(575-664)	501	(433-597)
2010		771	(716-839)	806	(630-1182)
2011		1507	(1,317-1,768)		
2012		821	(767-889)	962	(818-1163)
2013		766	(707-843)	911	(628-1193)
2014		284	(224-344)		
2015		579	(490-690)	606	(459-752)
2016		1021	(907-1,158)		
2017		1070	(989-1,170)		
2018		242	(199-285)		

[1]A long term, hierarchical jumper multiplier was calculated using 2000-2018 trap and snorkel data, excluding outlier years or when few fish were tagged and the snorkel estimates were imprecise.
[2]Winter snorkel estimates including trap recaptures until 2009, after which they were mark-resight only following the removal of Hemlock Dam fish trap.

Winter steelhead passed Shipherd Falls during a period when jumping was not successful, so the trap count through April 30 was assumed to include all winter steelhead passing Shipherd Falls through this date. The trap is removed on April 30 in most years to allow passage for large numbers of hatchery Spring Chinook returning to Carson National Fish Hatchery. The remainder of the winter steelhead return was estimated by expanding trap counts through April 30 in the Wind River by the average timing from the North Fork Toutle River, a nearby basin where 100% of the return is counted in a trap (Rawding and Cochran, 2005). Approximately 92% of the adult wild winter steelhead pass the adult trap on the North Fork Toutle River by May 1 (WDFW unpublished data). Nine wild winter steelhead were caught in the trap through April 30, which expanded to an estimate of 10 using the Toutle River timing expansion. Winter steelhead accounted for 1% to 11% of the steelhead run above Shipherd Falls from 2000 to 2018 (Table 3). Wild, adult winter steelhead escapements have ranged from 5 to 53 adults since 2000 (Figure 3).

There is limited spawning habitat below Shipherd Falls relative to areas above. However, spawning ground surveys are conducted to estimate spawner abundance in this area in an attempt to account for all adults potentially producing juveniles available to be caught in our Lower Wind Smolt trap. The extended section of the Little Wind River (rkm 1.8-3.5) was not surveyed in 2018 because a landslide in the section has made it unsafe to traverse. The abundance estimate must therefore be considered a minimum. Five redds were counted in the surveyed reach which results in a (partial) abundance estimate of eight below Shipherd Falls. When added to the estimate from upstream of Shipherd Falls this brings the 2017 total winter steelhead escapement estimate to 18 (Table 4).

Expanding the bi-weekly survey to include a higher percentage of the stream, and/or conducting a peak count survey that covers most or all of the stream accessible to anadromous fishes would improve the precision and accuracy of the winter steelhead estimate. Unfortunately redd surveys in the Little Wind River and mainstem Wind River below Shipherd Falls range from difficult to impossible to conduct effectively and safely except in low water years, which have not occurred since 2007. The escapement of winter steelhead spawning below Shipherd Falls and in the Little Wind River was not estimated prior to 2006 and redd surveys conducted in 2001 through 2004 were incomplete due to limited resources and flow conditions.

Table 3. Wild winter steelhead trap counts at Shipherd Falls with expanded escapement estimates above Shipherd Falls for the periods following trap removal for spawn years 2000-2018; expansion based on average wild winter steelhead timing at the NF Toutle River trap.

Spawn year	Trap count	Final day of trap operation	Percent of passage prior to trap removal	Population estimate	Percent of adult steelhead population
2000	13	April 5	65%	20	9%
2001	49	April 30	92%	53	11%
2002	47	May 12	92%	51	7%
2003	25	April 30	92%	27	2%
2004	26	April 30	92%	27	3%
2005	20	May 4	92%	22	4%
2006	21	May 1	92%	23	3%
2007*	11	May 3	92%	13	2%

2008	6	May 3	92%	7	1%
2009	18	May 4	92%	20	4%
2010	28	May 3	92%	30	4%
2011	16	May 4	92%	17	1%
2012	19	May 12	92%	21	3%
2013	17	May 6	92%	18	2%
2014	5	April 30	92%	5	2%
2015	9	April 30	92%	10	2%
2016	8	April 30	92%	9	1%
2017	7	May 8	100%	7	1%
2018	9	April 30	92%	10	4%

** Timing expansion did not account for all winter steelhead in 2007. Estimate is a minimum escapement based on trap count plus two winter steelhead captured in Trout Creek.*

Table 4. Winter steelhead escapement estimates in the Wind River based on expanded trap data and redd surveys for 2018.

Section	Counted Redds	Total Redds	Fish Count	Expansion	Total Escapement
Little Wind River	5	5	0	1.62 fish/redd	8
Wind R. below Shipherd	0	0	0	1.62 fish/redd	0
Wind R. above Shipherd	NA	NA	9	92% of run	10
Wind Basin Escapement	NA	NA	NA	NA	18

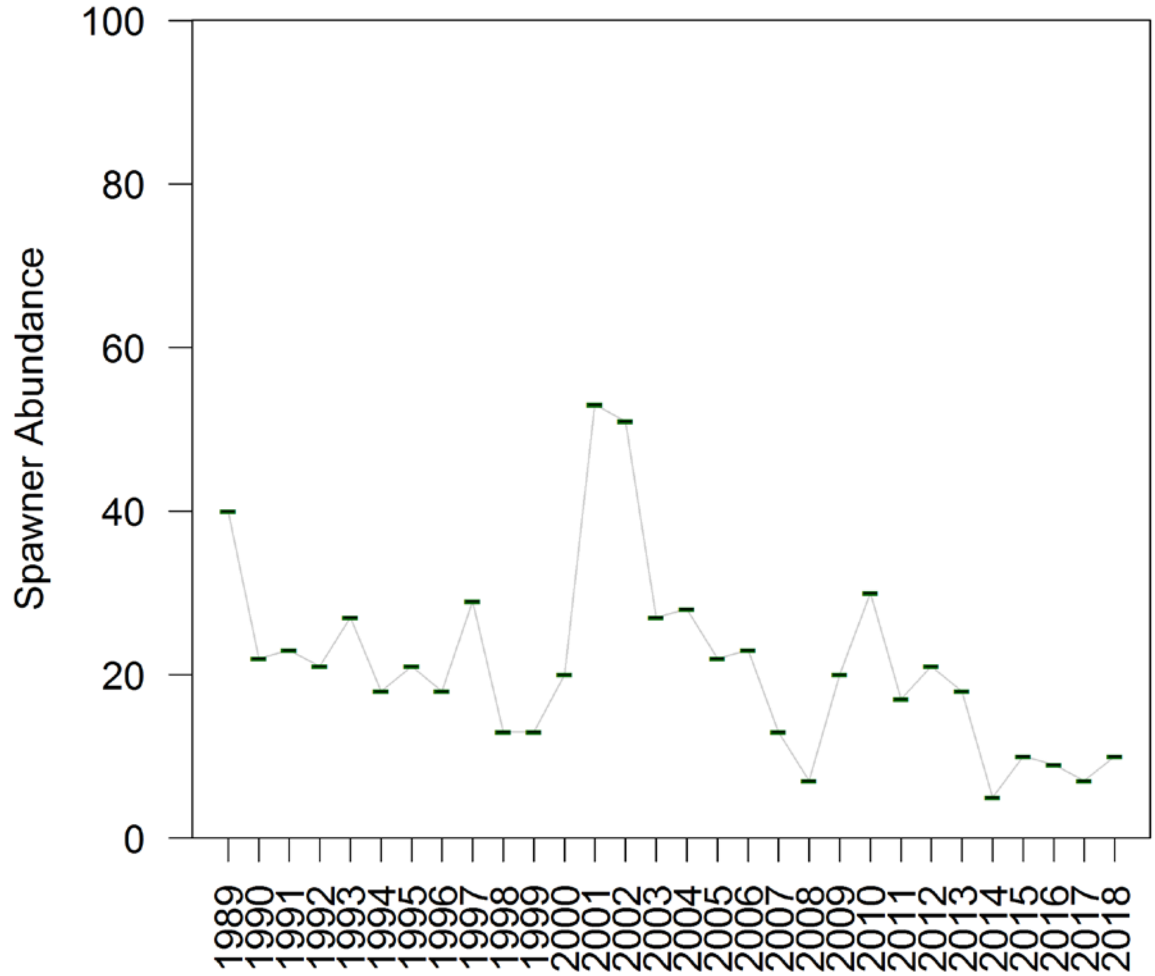

Figure 3. Wild winter steelhead adult counts at Shipherd Falls, 2000 - 2018. Data are fish trapped at the falls plus those estimated to have passed the falls during May when the trap was not operated because of high hatchery spring Chinook abundance.

Final estimates of total steelhead escapement to the Wind River above Shipherd Falls by spawn year are made by summing the Jumper estimate of summer steelhead abundance and the expanded Shipherd Falls winter run count (Figure 4). The total estimated escapement was 252 (95% CI 209-295) summer and winter steelhead in 2018.

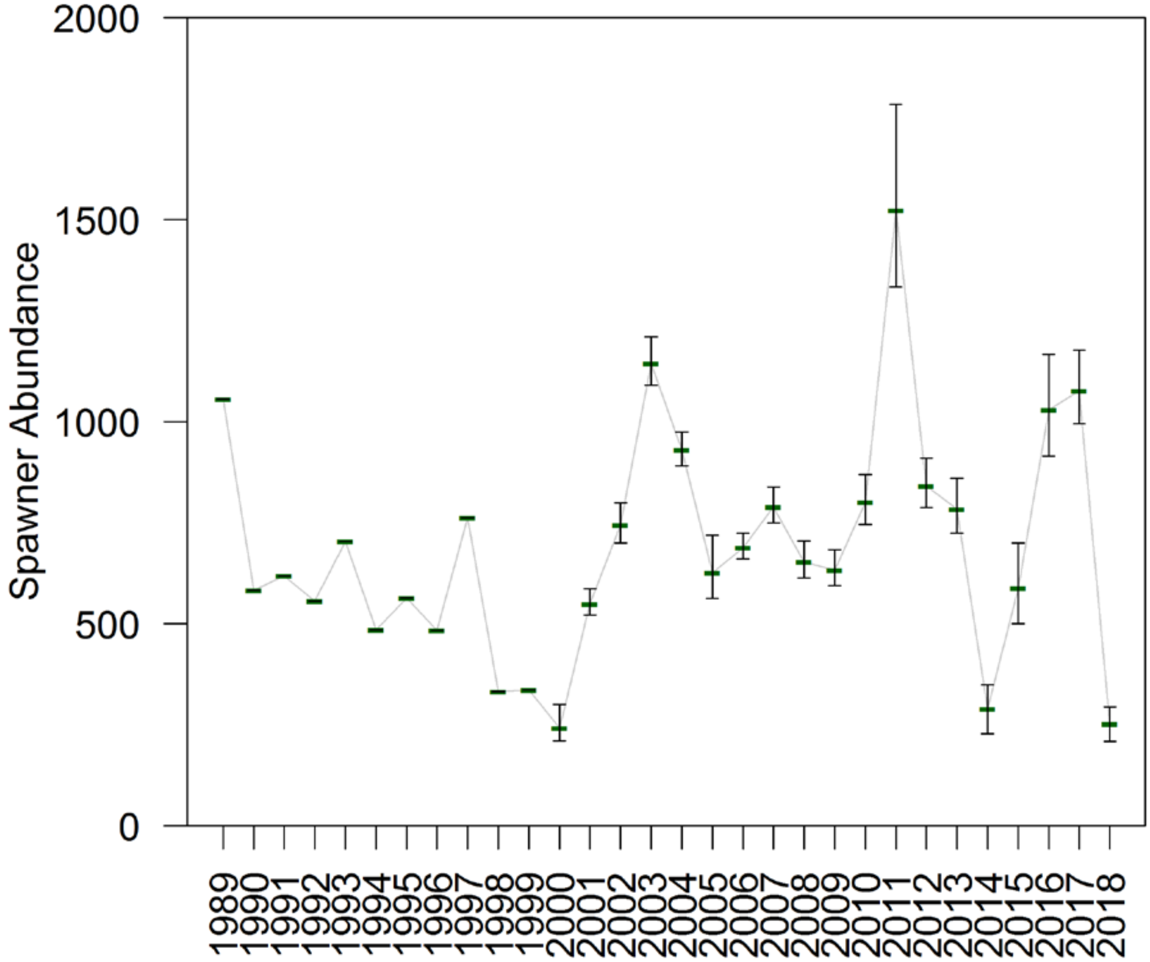

Figure 4. Total escapement of Wind River steelhead (winter and summer run) with 95% CI by spawn year from 1989-2018.

Complete estimates of uncertainty are not currently available for the Jumper method for summer steelhead (Table 1; Figure 4) or for the expanded trap counts of winter steelhead (Tables 4 and 5).

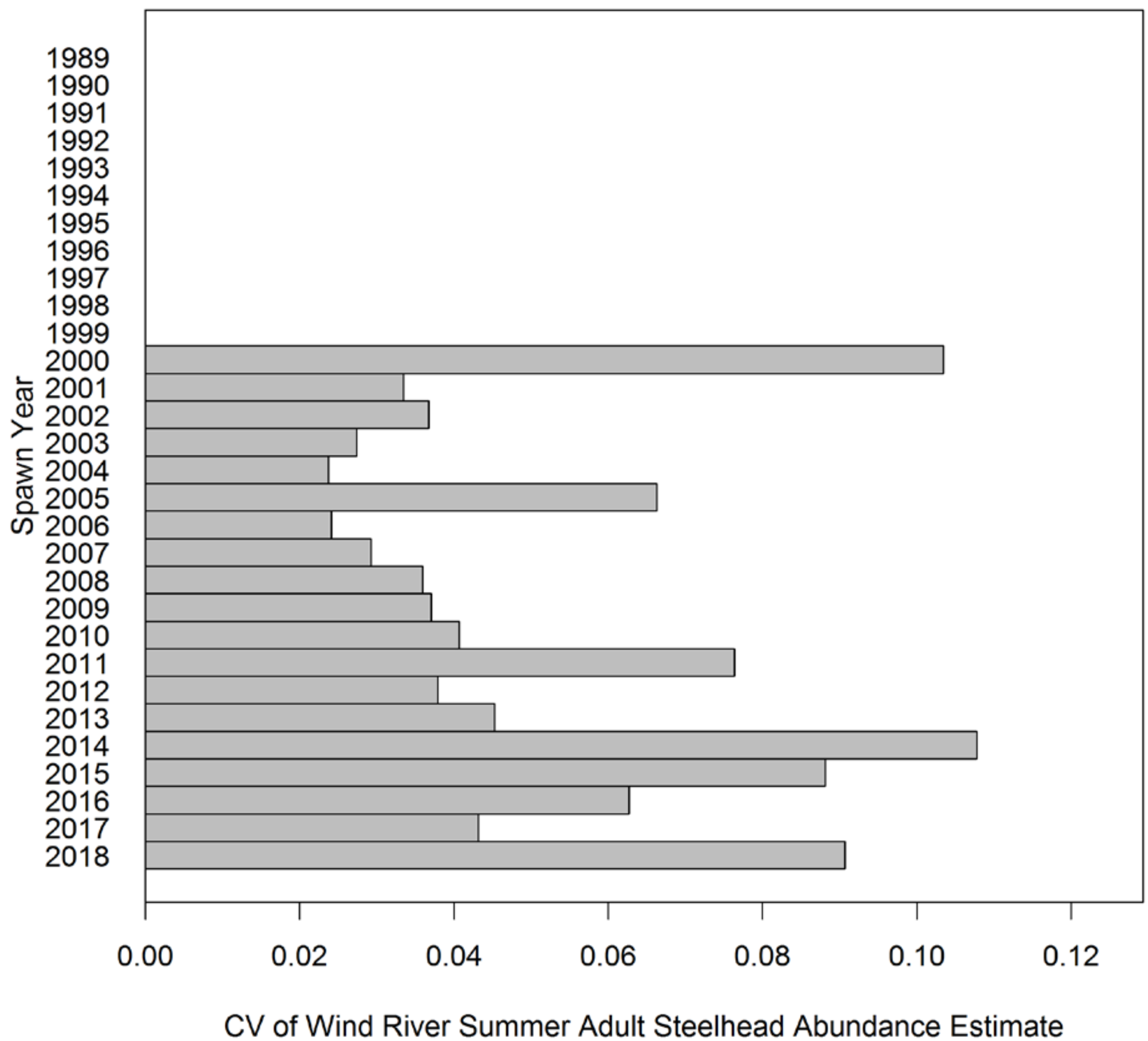

Figure 5. Estimates of the coefficient of variation for Wind River summer steelhead abundance estimates based on the Jumper method for spawn years 2000-2018 relative to the goal (CV < 10%). No estimates of CV are available currently for the index expansion estimates from 1989-1999.

Objective 1.b. Smolt Abundance

Smolt abundance was estimated for all four trap locations in the Wind River in 2018. Trap installation was completed on schedule. An extended period of high water, beginning on April 7, caused missed periods at all four sites ranging from 8-12 days (Table 5).

Table 5. Summary of missed and ineffective trap periods during the 2018 smolt outmigration in the Wind River basin.

Site	Date(s)	Nature of trapping problem	Cause
Lower Wind	4/8-4/19	Pulled cone	High water, hatchery chinook release
Trout Creek	4/7-4/19	Pulled cone	High water
Trout Creek	5/26	Screw stopper	Log caught in cone
Panther Creek	4/8-4/16	Pulled cone	High water
Upper Wind	4/8-4/17	Pulled cone	High water
Upper Wind	5/29	Screw stopper	Log caught in cone

Missed periods of such length are difficult to compensate for using the trap data alone. Use of historical timing data to estimate the proportion of fish migrating past the trap during an outage fails to account for variability in migration timing due to environmental variables. Therefore, mark-recapture data was stratified daily and expected migrants per day modeled as a function of time using Bayesian P-splines in BTSPAS as described in Bonner and Schwartz (2011). The model generates daily estimates unmarked migrants, and precision for both trapped and missed periods.

In 2018, the Wind River basin wild steelhead smolt estimate was 29,336, well above the 2000-2018 average of approximately 24,000 and the fifth highest emigration estimate since the monitoring program began (Figure 6, Table 5). The Trout Creek estimate (3,357) also exceeded the average of the time series (2,403). Migration estimates in Panther Creek and the Upper Wind River estimates (816, and 1,436, respectively) were similar to the average of the time series (987, and 1,732) (Tables 6-7).

The BTSPAS estimator was also used to re-analyze 2017 data when trap outages made estimation challenging. The revised Wind River basin wild steelhead smolt estimate for 2017 was 23,032 (originally 22,584), very close to the 1995-2016 mean of 22,587 (Figure 6, Table 5). The Trout Creek, Panther, Creek, and Upper Wind River estimates (2,741, 936 , and 1,182, respectively) were also similar to the average of the time series (2,438, 1008, and 1,785, respectively) (Tables 6-7). Originally reported estimates were 2,741, 1,060, and 1,338 in Trout Creek, Panther Creek and the Upper Wind River, respectively.

The lower Wind River screw trap is located ~2 km upstream from the Columbia River, and 100% of the steelhead spawning has occurred above this site in most years. The steelhead smolt outmigration is composed of both summer and winter steelhead but these two races cannot be distinguished using visual inspection of smolts. The smolt yields from Panther Creek, Trout Creek, and the Upper Wind River were 3%, 11%, and 5% of the total smolt production in 2018 from the Wind River. The remaining smolt production of 23,728 (81%) emigrated from the middle and lower mainstem of the Wind River above the lower Wind River trap and below the three upper traps.

Table 6. Smolt abundance estimates for outmigration year 2018 for naturally produced steelhead emigrating past three tributary/headwater traps (Panther and Trout Creeks and Upper Wind), a lower mainstem whole-basin trap (Lower Wind), and the area below the upper traps and above the whole-basin trap. Estimates were computed using PIT tag mark and recapture data to populate a time-stratified estimator.

Trap	Estimate Type	Date Range	Migration Estimate	95% CI	CV
Panther Creek	Daily stratified	3/27/18-6/2/18	816	(698-981)	9%
Trout Creek	Daily stratified	4/3/18-6/19/18	3,357	(2,962-3,752)	6%
Upper Wind	Daily stratified	4/3/18-6/24/18	1,436	(1,166-1,757)	10%
Lower Wind	Daily stratified	3/27/18-6/19/18	29,336	(21,613-44,053)	19%
Area between traps	Subtraction (Lower Wind-subbasins)	Various	23,728	(12,621-34,834)	24%

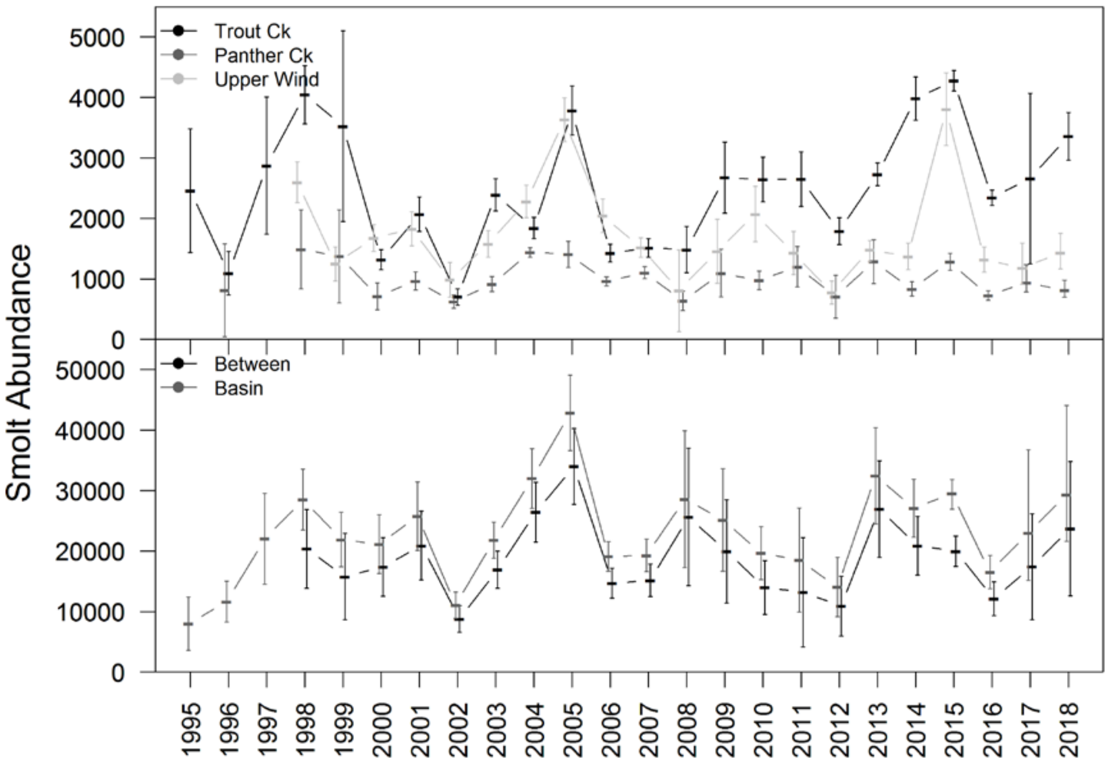

Figure 6. Steelhead smolt outmigration abundance estimates with 95% confidence limits for three tributary sub-basins (Trout Creek, Panther Creek, and Upper Wind), as well as the whole Wind River basin and the area between the tributary screw traps and the lower Wind River trap where the whole basin estimate is made, 1995-2018.

Table 7. Smolt abundance with 95% confidence intervals by migration year for each Wind River trapping site.

Migration Year	Basin		Between		Panther Ck.		Trout Ck.		Upper Wind	
	N	(95% CI)	N	(95% CI)	N	(95% CI)	N	95% CI	N	(95% CI)
1995	8,021	(3596-12445)					2,461	(1438-3484)		
1996	11,651	(8267-15035)			812	(47-1578)	1,093	(734-1452)		
1997	22,058	(14546-29571)					2,874	(1743-4006)		
1998	28,520	(23486-33554)	20,385	(13880-26890)	1,492	(837-2146)	4,046	(3566-4525)	2,598	(2260-2935)
1999	21,927	(17418-26435)	15,776	(8638-22914)	1,375	(603-2146)	3,525	(1948-5102)	1,251	(969-1532)
2000	21,135	(16299-25971)	17,421	(12572-22270)	715	(494-936)	1,321	(1156-1486)	1,678	(1455-1900)
2001	25,794	(20144-31444)	20,929	(15263-26595)	966	(817-1115)	2,071	(1786-2356)	1,828	(1547-2109)
2002	11,101	(8942-13260)	8,786	(6601-10972)	625	(514-736)	704	(569-838)	986	(697-1275)
2003	21,811	(18792-24831)	16,926	(13884-19968)	916	(789-1044)	2,391	(2124-2659)	1,578	(1359-1797)
2004	32,006	(27065-36946)	26,450	(21498-31401)	1,438	(1361-1515)	1,840	(1665-2016)	2,279	(2010-2547)
2005	42,846	(36626-49066)	34,017	(27769-40264)	1,410	(1194-1626)	3,786	(3383-4189)	3,634	(3270-3998)
2006	19,125	(16669-21581)	14,692	(12214-17169)	961	(883-1038)	1,428	(1280-1575)	2,045	(1765-2325)
2007	19,291	(16605-21978)	15,152	(12455-17850)	1,104	(1006-1202)	1,514	(1362-1667)	1,520	(1358-1682)
2008	28,582	(17270-39895)	25,654	(14314-36994)	636	(476-797)	1,486	(1103-1869)	806	(131-1481)
2009	25,177	(16698-33656)	19,947	(11422-28473)	1,096	(701-1491)	2,675	(2084-3266)	1,458	(931-1985)
2010	19,683	(15292-24075)	13,988	(9555-18422)	976	(821-1131)	2,645	(2276-3014)	2,074	(1616-2533)
2011	18,512	(9895-27130)	13,232	(4190-22273)	1,200	(864-1536)	2,651	(2199-3103)	1,430	(1071-1789)
2012	14,051	(9143-18960)	10,925	(6003-15847)	706	(353-1060)	1,791	(1568-2013)	776	(588-965)
2013	32,459	(24511-40407)	26,981	(19020-34941)	1,286	(921-1651)	2,731	(2544-2919)	1,481	(1287-1634)
2014	27,094	(22279-31909)	20,904	(16069-25738)	835	(715-954)	3,984	(3626-4341)	1,372	(1153-1591)
2015	29,532	(26912-31792)	19,986	(17463-22509)	1,283	(1142-1423)	4,277	(4107-4446)	3,807	(3205-4409)
2016	16,533	(13775-19291)	12,142	(9371-14912)	728	(650-807)	2,344	(2219-2469)	1,319	(1112-1319)
2017	23,032	(15,165-36,767)	17,526	(8,767-26,286)	966	(784-1,233)	2,659	(1,246-4,072)	1,182	(913-1,594)
2018	29,336	(21,613-44,053)	23,728	(12,621-34,834)	816	(698-981)	3,357	(2,962-3,752)	1,436	(1,166-1,757)

For small steelhead and salmon populations, precise smolt abundance estimates can be difficult to obtain. This occurs because it may be difficult to tag sufficient numbers of smolts or to recapture a sufficient number of tagged fish. However, estimates of precision are important for considering appropriate uses for data. Robson and Regier (1964) suggested 95% CI of ± 10% for research and ± 25% for management purposes. The International Pacific Salmon Fisheries Commission considered estimates with 95% CI of less than ±20% of the estimate to be good. Rawding (1997) conducted simulations based on Wind River trap locations, expected smolt abundance, and expected trap efficiency to establish levels of precision that could be achieved with current funding. These results indicated that for this study a 95% CI of ±20% of the estimate should be achievable in most years. An alternate expression of these results in terms of precision goals would be that the coefficient of variation (CV) should not exceed 10%. No precision goals have been developed for the adult monitoring program. However, we recommend a level of precision similar to those recommended for smolt estimates, which is that the 95% CI should be less than ± 20% of the estimate or a CV of less than 10%. Adult and juvenile abundance monitoring is designed to ensure tagging and recapture rates that will attain these goals, which also comply with NOAA guidance on precision (Crawford and Rumsey 2009).

The precision goal was met at the subbasin trap sites but not at the Lower Wind River trap or for the area between traps in 2018 (Table 5). The precision goal has been met 58% of the time (55/95) since 2000. Precision is a function of the number of releases and recaptures (Seber 1982), both of which are related to smolt abundance and trap efficiency. High stream flows in the Columbia River in the latter half of the 2018 outmigration inundated the lower reach of the Wind River to the riffle immediately upstream of the trap. The subsequent loss of velocity and trap cone speed produced poor trap efficiency at that site during the peak of the smolt migration and precision of the estimate was predictably poor as a result. Low smolt abundance in 2002 and 2011 and difficulties caused by high stream flows in 2008 through 2012 and 2017 were the other major factors for not meeting precision goals (Figure 7) over the history of the program. The level of precision at the lower Wind River site is problematic due to a poor channel configuration for effective trapping, and limited options for trap deployment elsewhere; consequently, we rely upon pooled marks from all traps to achieve precision goals. Difficulties in meeting this precision goal for the reach between the tributary and lower mainstem traps is largely a function of the estimation methodology, which does not involve trapping smolts, and is instead based upon subtracting tributary abundance estimates from the lower mainstem estimate. The precision goal for the project was met at a slightly higher rate of 64% of the total tributary and mainstem smolt estimates when the between traps estimate was not considered.

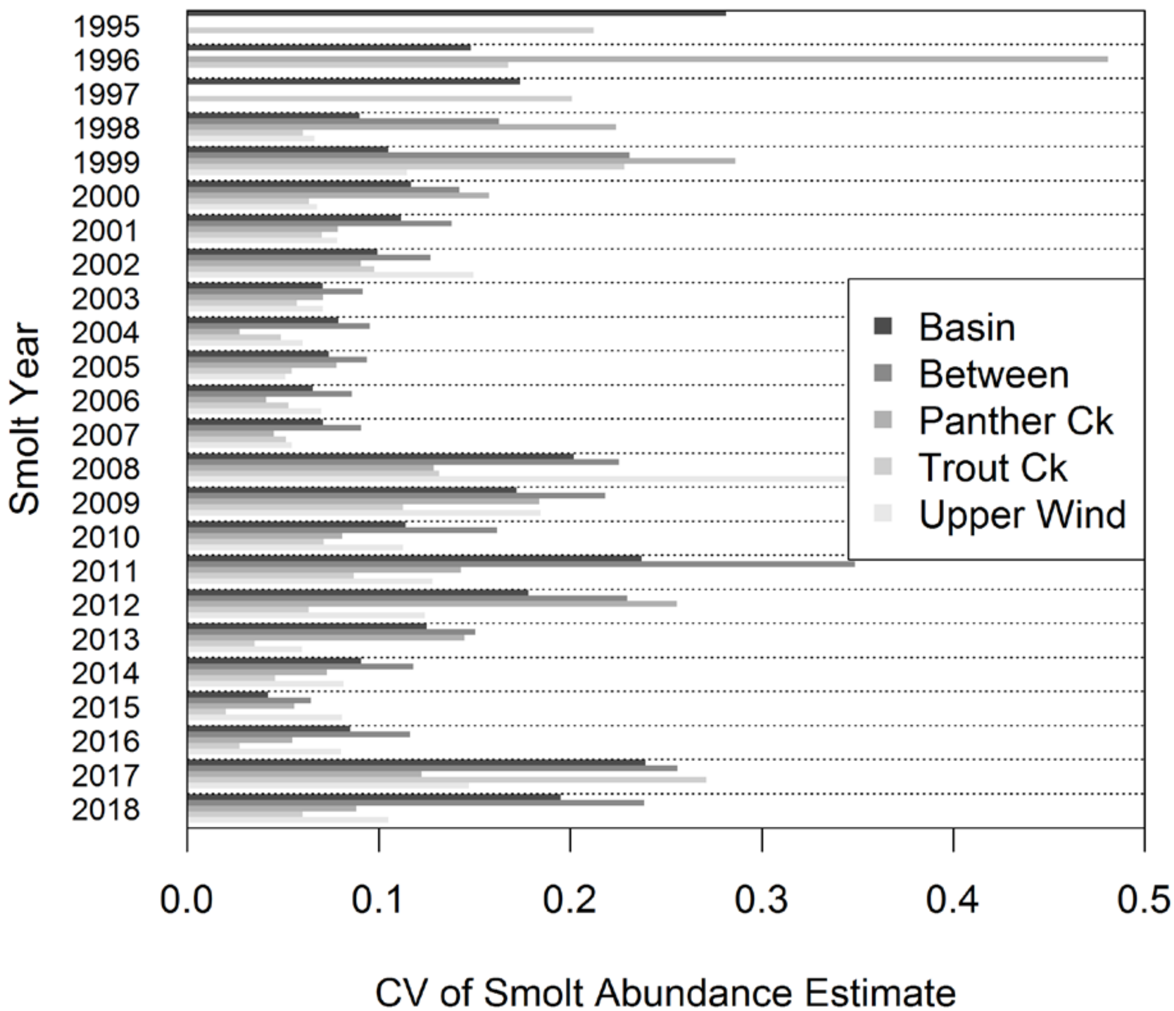

Figure 7. Estimated coefficients of variation associated with smolt abundance estimate by trap site in the Wind River basin, 2000-2018. The precision goal is CV < 10%.

Objective 2.a. Smolt to Adult Survival

The number of PIT tags released and subsequently detected as adults at the Bonneville Dam fish ladders (BON), and the estimated SAR for smolt outmigration years 2003 to 2014 are presented in Table 8. The SARs ranged from a low of 1.0 % (smolt outmigration year 2015) to a high of 7.5% for smolt outmigration year 2009 (Table 7, Figure 8). On average 85% of the Wind River steelhead spent two years in the ocean with 5% spending one year and 10% spending three years in the ocean before first returning to spawn (Figure 9).

Table 8. Summary statistics and SAR for Wind River wild steelhead from smolt traps to Bonneville Dam for 2003 to 2015 smolt outmigration years based on PIT tag detections as adults.

Year	Smolts Tagged	Tagged Adult Returns	1 ocean	2 ocean	3 ocean	SAR	CI 2.5%	CI 97.5%
2003	1351	39	1	36	2	2.9%	2.1%	3.9%
2004	2112	47	8	34	5	2.2%	1.7%	2.9%
2005	2104	38	4	33	1	1.8%	1.3%	2.4%
2006	1325	49	3	45	1	3.7%	2.7%	4.8%
2007	2747	158	13	138	7	5.8%	4.9%	6.7%
2008	1156	81	13	63	5	7.0%	5.6%	8.6%
2009	1348	102	12	82	8	7.5%	6.3%	9.1%
2010	2007	89	4	81	4	4.4%	3.6%	5.4%
2011	1409	25	3	21	1	1.8%	1.2%	2.6%
2012	1162	41	2	34	5	3.5%	2.6%	4.7%
2013	2618	104	9	87	8	4.0%	3.3%	4.8%
2014	2849	79	9	66	4	2.7%	2.2%	3.3%
2015	6002	53	7	42	4	1.0%	0.8%	1.2%

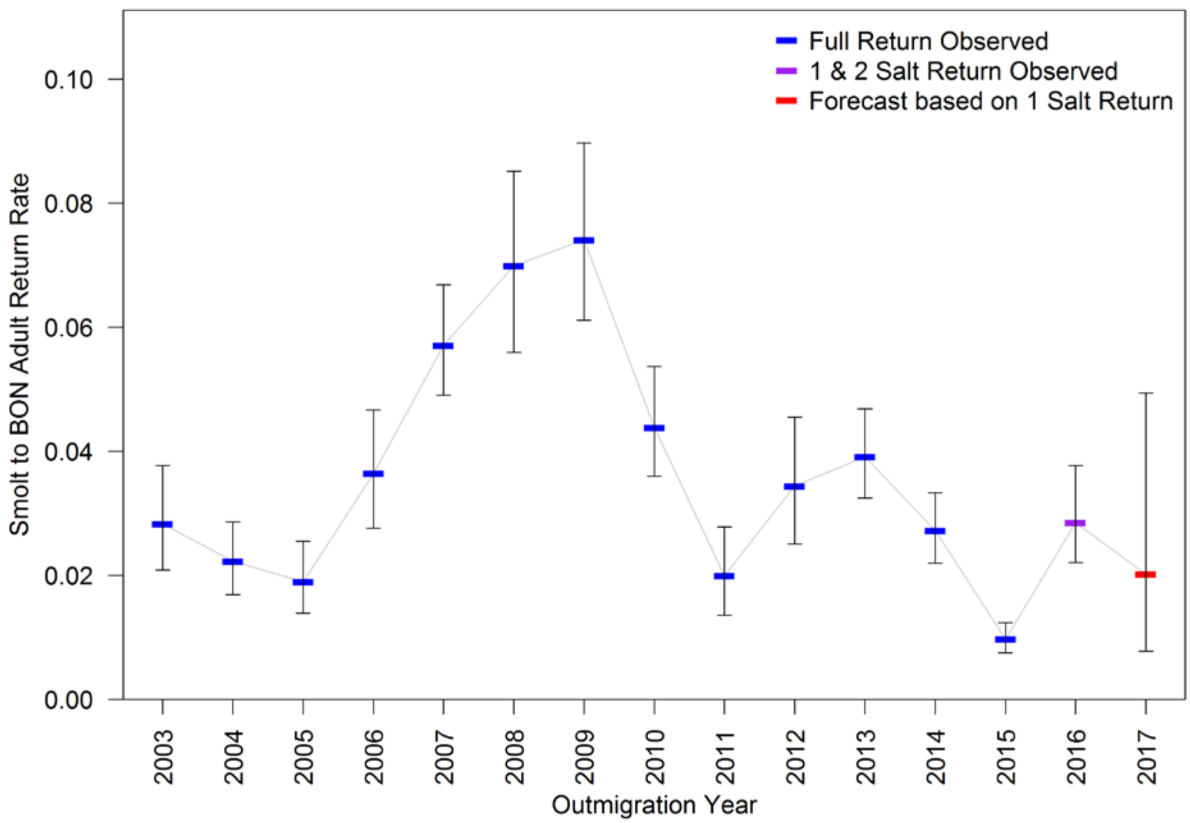

Figure 8. Smolt to adult return rates (SAR) with 95% CI based on PIT tag detections at Bonneville Dam for Wind River wild steelhead tagged as smolts at smolt traps from 2003 to 2017 outmigration years. Data are not adjusted for tagging related mortality or tag loss, which are thought to be minimal.

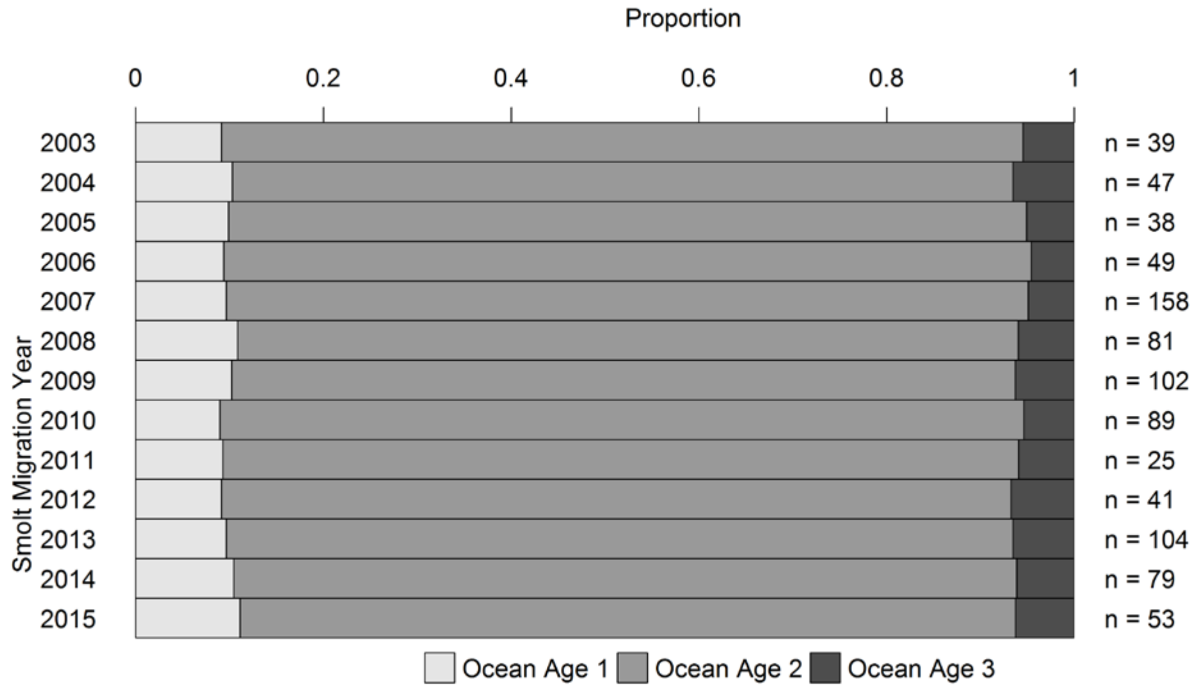

Figure 9. Ocean ages of returning maiden adult wild Wind River steelhead (sample sizes to right) from smolt outmigration years 2003 to 2015 based on returns of adults that were PIT tagged as smolts to BON (n = 28,188 smolts, and 905 adults).

Objective 2.b. Adult to Adult Survival (spawners per spawner)

Spawners per spawner ranged from 0.54 for brood year 2003 to 3.05 for brood year 1998, and generally followed a cyclical pattern, increasing the late 1990's before declining in the early 2000's and increasing again in the mid to late 2000's (Figure 10). Spawners ranged from 3-8 years in total age, with a mean between 5.12 and 5.46 for all years, meaning that all recruits from brood years through 2010 have returned by spawn year 2018. However, scales have only been aged through spawn year 2016, thus brood years through 2008 are complete and using average brood year age composition we are able to estimate brood year productivity through brood year 2009. Steelhead are iteroparous (may spawn more than once), so some of the recruits in the spawner per spawner ratio are counted twice. Incorporating repeat spawners in spawner per spawner estimates facilitates determining which brood years replaced themselves (productivity greater than 1). Iteroparous fish populations replace themselves at productivities less than 1 when only including maiden spawners, however, by including spawners as recruits both in their maiden year as well as during repeat spawning years, the productivity may be evaluated against 1.0 as the threshold required for replacement.

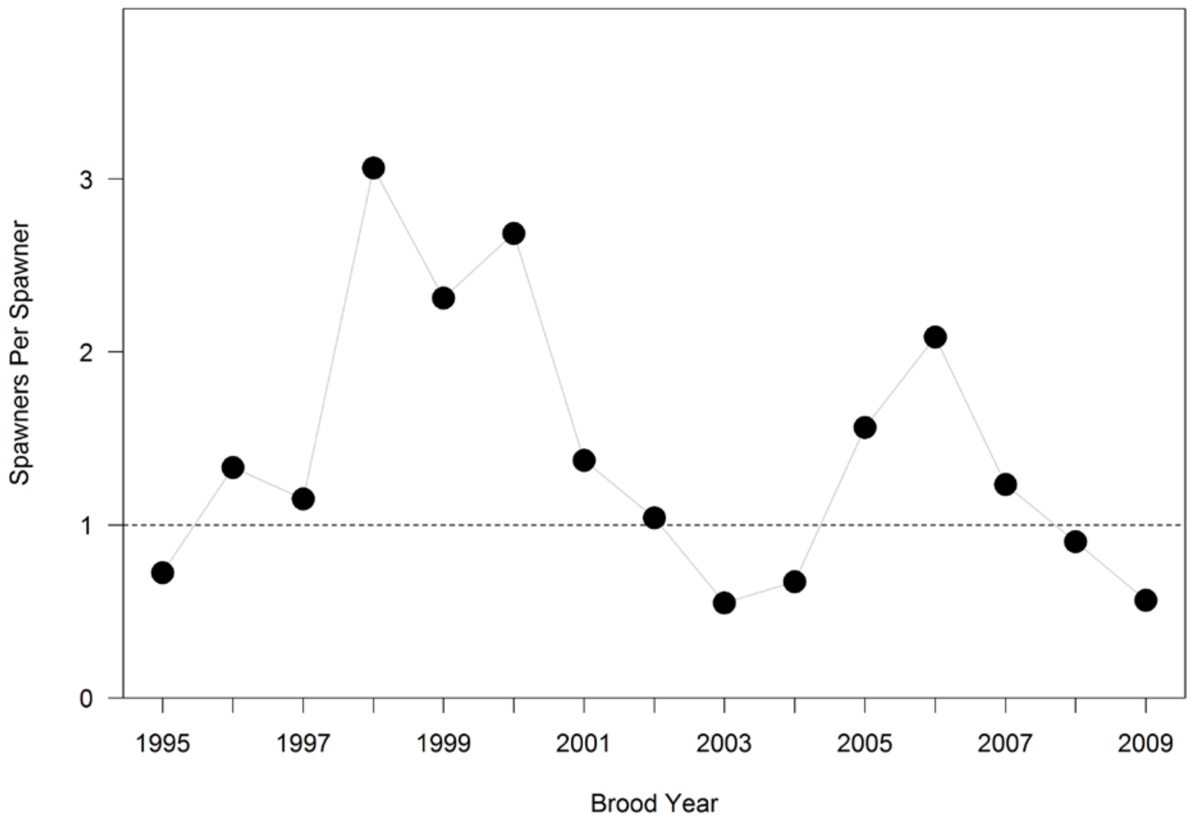

Figure 10. Wind River adult to adult survival (spawners per spawner). Data are based on assignment of adult abundance in each spawn year to their respective brood years based on a subsample of scale ages obtained from the Shipherd Falls fish trap. Recruits from brood years 1995 through 2009 returned by spawn year 2016. Data are plotted relative to 1.0; the population productivity leading to replacement (see results text).

Objective 2.c. Juveniles per Spawner

Per capita juvenile production, measured as smolts per spawner varied between 20 and 120 in Trout Creek and between 20 and 60 in the whole Wind River basin (Figure 11, bottom panel). Spawner-smolt recruit analyses were performed to estimate maximum per capita spawner productivity as well as total smolt capacity. Of the three spawner recruit models fit to the data, the Ricker model provided the best fit for the Trout Creek data, whereas the Hockey Stick and Ricker models provided the best fits for the data from the Wind River basin (Figure 11, top panel and Table 8). All models estimated greater productivity in Trout Creek (124-198 smolts per spawner) than in the Wind Basin (56-104). Estimates of smolt capacity ranged from 1,962-2,794 in Trout Creek and from 23,962-34,850 in the Wind Basin, with Hockey Stick models providing the lowest estimates and Beverton-Holt models providing the highest estimates in both basins.

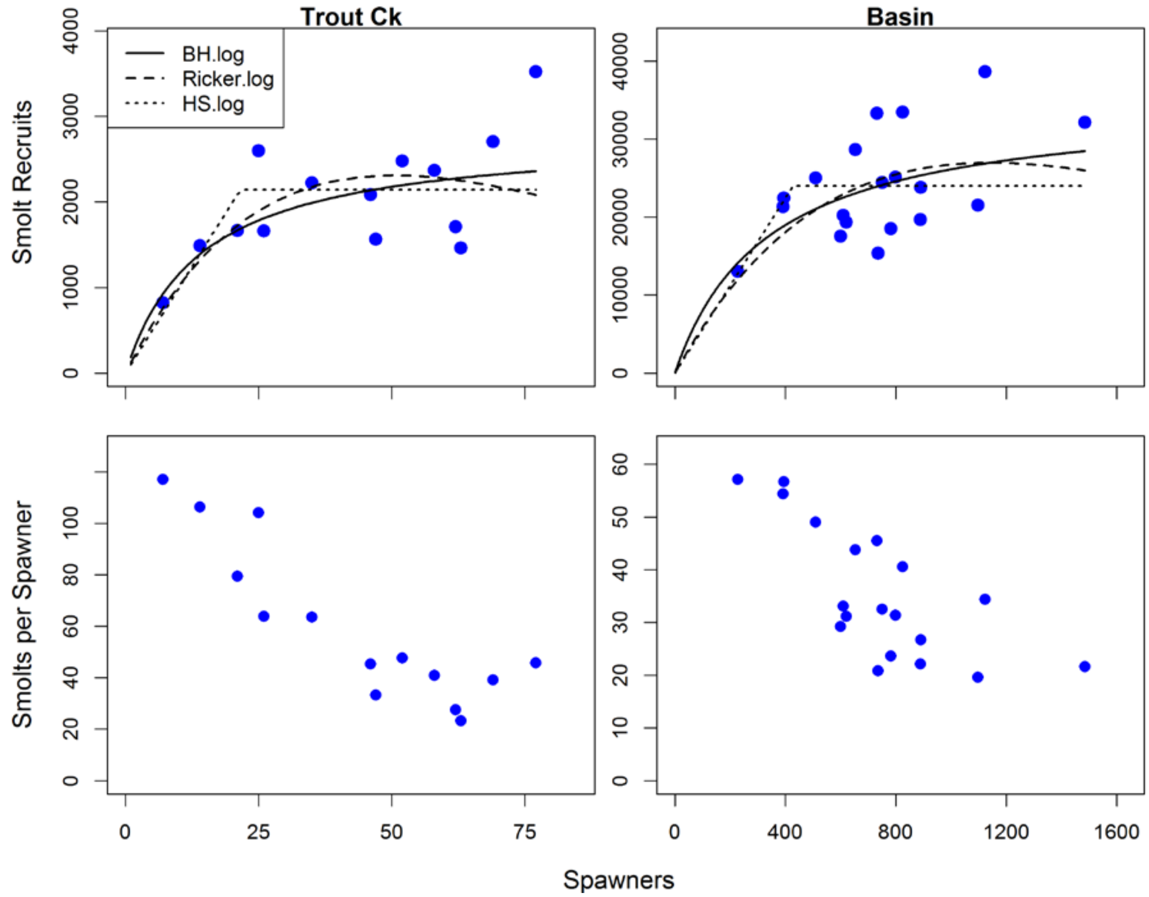

Figure 11. Wind River and Trout Creek wild steelhead smolt abundance (recruits) as a function of spawner abundance (top panels) and per capita smolt abundance (recruits per spawner) as a function of spawner abundance (bottom panels) for complete brood years (see methods) from 1992-2013. Fit lines are Beverton-Holt (BH), Ricker (Ricker), and Hockey Stick (HS) spawner recruit functions fit with log-normal error.

Table 9. Model selection criteria and estimates of smolt productivity and capacity made using three spawner recruit functions fit to Trout Creek and Wind River wild steelhead smolt and adult abundance data.

Model	df	AIC	Smolt Productivity	Smolt Capacity
Trout Creek				
Ricker	3	218.81	124	2309
BH	3	244.09	198	2794
HS	3	280.55	160	1962
Wind Basin				
HS	3	386.69	56	23962
Ricker	3	386.99	64	26940
BH	3	423.50	104	34850

Objective 3. Spatial Structure of Steelhead Populations

Adult and smolt abundance and survival estimates are made at basin and subbasin spatial scales and involve data collection at multiple sites and via continuous surveys in order to account for the spatial structure of Wind River steelhead populations. See results reported for objectives 1 &2.

Tributary Habitat RM&E

In this section we report on preliminary analyses assessing the effects of Hemlock Dam removal (2009) on steelhead populations in the Trout Creek sub-basin of the Wind River.

Timeline of Potential Fish Responses to Dam Removal

Although Hemlock Dam was removed in 2009, the amount of time required to observe potential fish population responses will likely vary as a function of biological time lags between the restoration action and its effects on various steelhead life history stages, as well as any continuing changes in habitat quality over time (Table 9). Before-dam removal data were collected for at least 10 years on several metrics that may be affected by dam removal. Data on these metrics continue to be collected, and for some metrics, such as the proportion of adult spawners using Trout Creek, we already have up to five years of post-dam removal data, whereas for others, such as adult to adult recruits (recruits per spawner), the first cohort of returns that experience post-dam removal conditions was completed in spawn year 2016. The timing of various biological responses therefore warrants consideration when expecting results demonstrating fish responses to dam removal.

Table 10. Collection timeline of before (B) and after (A) data for metrics of fish response to Hemlock Dam removal. Unshaded cells are data that will be collected in the future. Hemlock Dam was removed in 2009 but, due to biological time lags, data for various response metrics resulting from post-dam conditions become available after a variable number of years.

Metric	2000*-2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019-2020
Proportion of Adults using Trout Creek	B	A	A	A	A	A	A	A	A	A	A
Parr Abundance (index)	B	B	A	A	A	A	A	A	A	A	A
Smolt Abundance	B	B	B	A	A	A	A	A	A	A	A
Smolts Recruits per Spawner	B	B	B	A	A	A	A	A	A	A	A
Parr : Smolt Ratio	B	B	B	A	A	A	A	A	A	A	A
Adult Recruits per Spawner	B	B	B	B	B	B	B	A	A	A	A

*Some data available from 1992-2000

Power Analysis

In addition to the timing of biological responses, the study design, availability of suitable controls, magnitude of variability in the relationship between the treatment site and controls, and the level of statistical significance deemed acceptable, will influence the duration of post-dam removal monitoring required to detect effects. For this reason, we conducted power analyses based on Before-After (BA) and Before-After-Control-Impact (BACI) study designs to detect

differences in adult abundance and smolt abundance in Trout Creek relative to other areas of the Wind River basin.

The BACI design required fewer years of post-dam removal data than the BA design to have a 90% probability (β = 0.90) of detecting a significant change in adult abundance (α = 0.10) using a two-tailed t-test (Figure 12). For the BACI design the effect size required dropped from 36 to 13 adults (71% to 27% of the before-dam removal population size) as the number of years of post-dam removal monitoring increased from five to thirty. For the BA design, the effect size decreased from 43 to 16 adults (84% to 31% of the before-dam removal population size) with the same number of years of data (Figure 12).

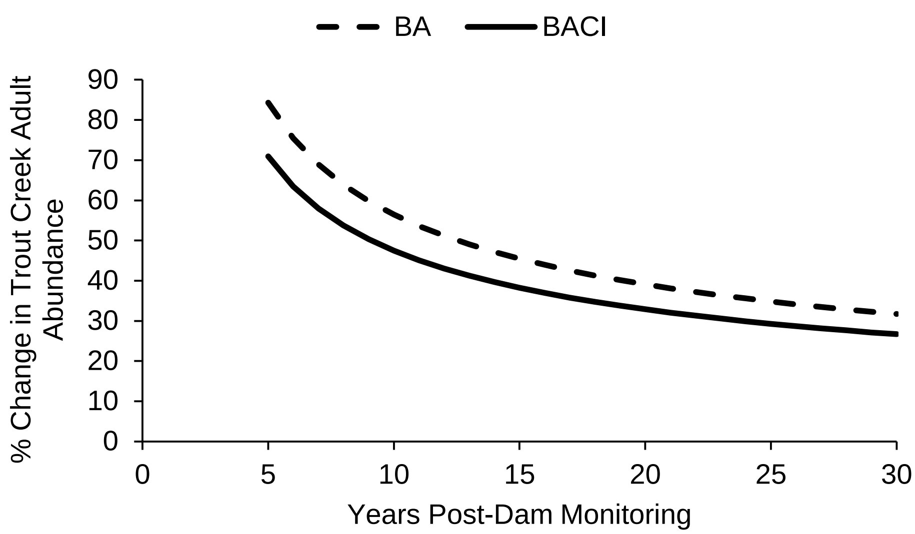

Figure 12. Power analysis comparing Before-After and Before-After-Control-Impact study designs for detecting an increase in the proportion and the abundance of Wind River steelhead spawning in Trout Creek with. Data are the number of years of post-dam removal data required to have a 90% probability (β = 0.90) of detecting a significant effect (α = 0.10) using a two-tailed t-test.

We conducted a similar power analysis for detecting changes in smolt abundance in Trout Creek relative to the upper Wind sub-basin. There is an 80% probability (β = 0.80) of detecting a significant (α = 0.10) post-dam removal difference of 431 smolts (24% increase in Trout Creek) after 8 years. These power analyses assume that the changes in abundance will be an immediate response to dam removal; a gradual change over time will require additional years of monitoring beyond those estimated by this power analysis.

Assessing Steelhead Responses to Dam Removal: Adult Abundance

From spawn year 1993-2009, Trout Creek adult steelhead abundance was measured as a census trap count except for partial counts requiring expansion in 1995 and 1997. Before dam removal from 2000-2009 a mean of 7.5% of Wind River steelhead spawned in Trout Creek. With few years of post-dam removal data, formal statistical analysis to detect effects of dam removal on adult steelhead populations in Trout Creek is premature. WDFW and USGS are still working to refine methods used to estimate spawner abundance in Trout Creek, which are necessary for

comparing trends in Trout Creek abundance to other portions of the Wind basin. Currently abundance estimates rely on detections of PIT tagged adult steelhead at instream PIT Tag Interrogation Systems (PTIS). These detections must then be expanded by a) the detection efficiency of the PTIS to account for undetected adult steelhead, and b) the proportion of PIT tagged steelhead adults in the Trout Creek basin to account for untagged adults.

Although methods have been developed to estimate detection efficiency at instream PTIS (e.g., Connolly et al. 2008), these methods rely upon meeting the assumption that each fish has an independent and identical probability of detection at the PTIS. This assumption is violated if power is lost to the PTIS during a portion of the run, or if fish swim around the PTIS during periods of high water. From 2008-2012 there were frequent winter power outages due to reliance on solar power, and high water occurs every year at the Trout Creek PTIS (named TRC), meaning that the assumptions required to estimate detection efficiency at the TRC in order to expand tagged adult detections were likely violated. Owing to the violation of these assumptions, it was not possible to estimate the efficiency of this array in an unbiased manner following Hemlock Dam removal. Therefore two estimates were generated for each year which were thought to bound the "true" abundance: 1) estimates assuming the array maintained the same efficiency that was measured in 2008-2009 prior to dam removal (61%), and 2) estimates assuming the array efficiency was 100% (Figure 13).

We have addressed these violations in two ways. First, beginning in 2012 the power source for TRC was changed to grid power which has all but eliminated power outages. Second, we deployed another PTIS in Trout Creek in 2014 that was located 8 km above the first reader. An alternative method for estimating PTIS detection efficiency relies upon calculating PTIS detection efficiency using data from two instream PTIS located at up and downstream locations which fish pass independent of one another. In this case detection efficiency of the lower PTIS may be estimated as the proportion of tagged fish detected at the upper PTIS which were previously detected at the lower PTIS. The installation of a second site has provided the needed ability to estimate detection efficiency in an unbiased manner.

In 2015-2018, with the installation of a new PIT tag array in upper Trout Creek (TR4), it was possible to independently estimate the lower Trout Creek PIT tag array detection efficiency (95%) for the first time since Hemlock Dam was removed, resulting in the generation of a single abundance estimate. In 2018 Trout Creek steelhead abundance was estimated to be 36 (95% CI 21-66) which corresponds to a CV of 33%. Although abundance estimates from 2010-2014 contain considerable uncertainty, steelhead abundance appeared to steadily increasing following Hemlock Dam Removal through 2017 (Figure 13). The sharp decline in 2018 corresponds with a similar decline in the Wind River basin as a whole.

In addition we are using data from the new site and working to develop statistical methods to make unbiased estimates of TRC detection efficiency for spawn years 2010-2014 prior to the installation of the new site.

Finally, we are working to improve methods used to estimate the proportion of marked steelhead in Trout Creek which is also used to expand detections of tagged adults. Proportions of tagged and untagged of adult steelhead in Trout Creek are estimated annually using by snorkel counts in

Trout Creek, however these counts result in limited sample sizes and imprecise estimates. Preliminary analyses suggest that the marked and unmarked steelhead proportions in the entire Wind River basin and Trout Creek do not differ (T. Buehrens, WDFW, unpublished data). Methods are under development to incorporate the Wind River basin marking rates into estimators for Trout Creek abundance using Bayesian methods.

Improvements in our ability to estimate detection efficiency and marking rates in Trout Creek are both contributing to an improved ability to satisfy the assumptions needed to make unbiased adult steelhead abundance estimates in Trout Creek, which will contribute to the assessment of steelhead responses to Hemlock Dam removal.

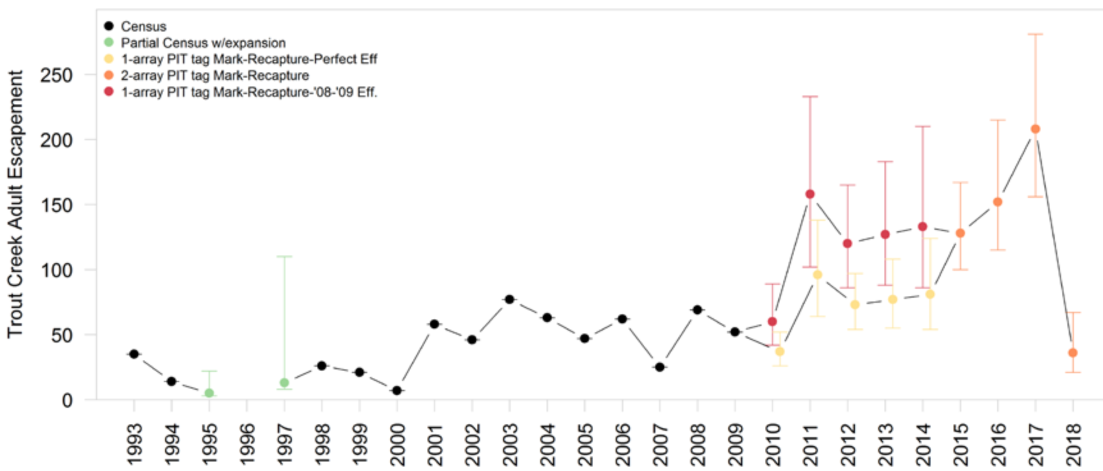

Figure 13. Trout Creek adult wild steelhead abundance from spawn year 1993-2018. From 1993-2009, estimates were Hemlock Dam fish ladder census counts except for in 1995 and 1997 when partial counts were expanded to estimate total abundance. From 2010-2014 two abundance estimates using PIT tag mark-recapture rely on different assumptions about PIT array efficiency; one assuming perfect efficiency, the other relying on an efficiency estimate for the single array generated from 2008-2009. Starting in 2015, two PIT tag arrays allowed unbiased estimation of array efficiency and the generation of a single abundance estimate.

Assessing Steelhead Responses to Dam Removal: Smolt Abundance

With few years of post-dam removal data, formal statistical analysis to detect effects of dam removal on steelhead smolt abundance in Trout Creek is premature. Qualitative examination of preliminary post-dam removal smolt abundance data suggest the abundances of steelhead in Trout Creek may be increasing relative to other sub-basins (Figure 6). From 2000-2009 the proportion of steelhead using Trout Creek out of the three trapped sub-basins was 40%. In comparison, between 2010 and 2013 that proportion in increased to 50% and in 2014 it was 64%, before declining to 45% in 2015, and increasing to 53% in 2016 and 2017 and finally 60% in 2018.

In addition to testing for changes in adult and smolt abundance in Trout Creek relative to other portions of the Wind River basin, we continue to collect data that will allow us to test for changes in juveniles per spawner, and other metrics reported in Table 9.

Coordination and Data Management for RM&E

This project has supported coordination and data management for RM&E through public processes, meetings, and by making data publically accessible. Internal coordination for this project occurs between WDFW, USGS, USFS, and UCD. Quarterly meetings provide coordination and data sharing between the parties and improve the chance for effective implementation of complex BACI study designs in concert with ongoing restoration work.

Data from fish population RM&E were used to support the development of local WDFW steelhead management plans for Region 5 (Lower Columbia Region). The Wind River steelhead RM&E data, summarization, and analyses led the WDFW Gorge Steelhead Work Group to recommend that the Wind River be designated as a wild fish gene bank, as one of three gene banks in the Lower Columbia DPS. WDFW adopted the Wind River formally as a wild steelhead gene bank in 2014.

Data collection methods and analysis for this project are primarily based on American Fisheries Society monitoring protocols (Johnson et al. 2007) and documented in previous reports (e.g., Cochran et al. 2013). In addition, we have developed draft versions of our data collection methods, data analysis methods, data collection protocols for juvenile outmigrant trapping, data collection protocols for adult trapping and surveys, data analysis protocols for juvenile abundance by age, and data analysis for adult abundance by age in monitoringmethods.org.

Many Wind River steelhead parr, smolts, and adults are PIT tagged, and recaptured within the basin and detected outside of the basin at Bonneville Dam (BON), in fisheries, and at bird colonies. Our tagging and recapture files are uploaded to the regional PIT tag database each year (PTAGIS). In addition to specific Wind River analyses these data are used to estimate fishery impacts and predation at Caspian tern and cormorant colonies. Since the data are publically available these may be used for other analyses that we are unaware of.

In addition to uploading data to PTAGIS, all data associated with the trapping, tagging, and recapture of juvenile and adult steelhead are stored in two WDFW databases. Juvenile data are stored in the juvenile migrant system (JMS) (formerly juvenile migrant exchange, or JMX) database. Adult data are stored in Traps, Weirs, and Surveys (TWS) database. Project data are stored on distributed version on the databases, which are periodically backed up to the WDFW–Region 5 server. At the end of the trapping season the distributed databases are merged into the corporate JMX and TWS databases. Summarized natural-origin adult steelhead escapement data are also uploaded and stored at the WDFW Salmonid Stock Inventory (SaSI).

The Wind River steelhead project was been used as a demonstration project for the Coordinated Assessments project. The purpose of this project is to develop high level indicators (HLI) for salmon and steelhead and store them in a Columbia River database at the Pacific States Marine Fisheries Commission (PSMFC). These data would be publicly accessible and are used by

National Oceanic and Atmospheric Administration (NOAA) Fisheries to determine the status of ESA listed steelhead in the lower Columbia River DPS.

DISCUSSION

Fish Population RM&E

Smolt Abundance

Steelhead smolt production in the Wind River has ranged from 20,000 to 30,000 smolts in most years since 2000 (Figure 6). In 2018 smolt production was above average in the Wind River and Trout Creek and approximately average in Panther Creek and the upper Wind River subbasins. Above average smolt abundance was expected in the Wind Basin given the above average adult escapement in parent brood year 2016 (age 2 smolts), and average adult escapement in parent brood year 2015 (age 3 smolts). The proportion of tributary subbasin smolts produced in Trout Creek (out of the Trout, Panther, and Upper Wind total) increased (60%) relative to the before-Hemlock Dam removal period average (40%) and relative to 2016 and 2017 (53%). This would be expected if Hemlock Dam removal has resulted in a greater portion of spawners using the Trout Creek subbasin (better seeding relative to other areas), or if improved habitat conditions (e.g., unrestricted movement for adults and juveniles both up and downstream, improved temperature and physical habitat) have benefited juveniles rearing in Trout Creek (e.g., increased productivity or capacity). Alternatively, stochastic processes or environmental conditions, such as historically low streamflows and warm temperatures in 2015, may have influenced steelhead smolt abundance. Future analysis investigating the connection between environmental variables (stream flow and temperature) and Wind River steelhead smolt production should be explored.

Adult Abundance and Smolt to Adult Returns

Adult spawner abundance in 2018 reversed the trend of recovery from the low abundance seen in 2014 and was the third lowest since the monitoring program began. The trend in adult abundance has corresponded reasonably well with the smolt to adult return rate time series, which shows that SARs decreased from the highest values measured in our time series in 2008-2009 (7-7.6%), which contributed to large adult returns in spawn years 2011 and 2012, to 1.8% in 2011, when most spawners in 2014 went to sea as smolts before recovering to 4% in 2013 when most 2016 spawners went to sea, and finally to 0.97% in 2015. Spawner abundance was expected to decline in spawn year 2018 because the majority of spawners in 2018 went to sea in 2015 when marine survival declined substantially to the lowest observed levels since robust monitoring began in the Wind River basin using PIT tags (2003).

Hemlock Dam Removal Response

The USFS and BPA funded the removal of Hemlock Dam on Trout Creek in 2009 to improve the status of wild steelhead populations in the Wind River. Previous Wind River adult and juvenile steelhead monitoring in this watershed has occurred at multiple control and impact sites for up to 20 years, which allows the testing of over a dozen unique dam removal hypotheses through Before-After-Control-Impact and Before-After study designs. We are aware of no other

datasets of this quality, breadth, and duration to assess the response of wild salmonids to dam removal.

We have completed preliminary analyses regarding the effects of Hemlock Dam removal on steelhead populations. We have also developed a timeline to describe potential fish responses to Hemlock Dam removal which related the timing of potential response metrics associated with steelhead life stages to the year in which those life stages would experience post-dam removal conditions. This timeline revealed that the amount of time post-dam removal to observe potential fish responses varied according to study design, data variability, and the biological metric in question. These factors merit consideration in planning post-dam removal monitoring. We conducted formal power analyses for smolt and adult abundance response metrics and this analysis suggested that the amount of time required to detect significant changes in Trout Creek vary but can be expected to require at least 10 years of post-dam removal monitoring, as the probability of detecting significant effects increased most prominently during that period.

In the initial years following Hemlock Dam removal, it was premature to conduct formal statistical analyses of fish responses. However, preliminary qualitative results suggest that smolt and adult abundance may be increasing in Trout Creek relative to other portions of the Wind basin. Formal analyses of fish responses are planned for the next (FY 2017) contract year.

ADAPTIVE MANAGEMENT

Fish Population RM&E

The purpose of WDFW adult and juvenile trapping is to monitor the population status of ESA listed steelhead in the Wind River and assess the effectiveness of habitat restoration actions. For over 20 years, adult and smolt abundances have been monitored in the watershed. Reports to date have been smolt and adult steelhead abundance summary reports. The database is now sufficient enough for a technical analysis of population status and we recommend that such an analysis be funded. After addressing the uncertainty in the mark-recapture estimates we recommend developing estimates of freshwater and total life cycle productivity for assessment of baseline habitat conditions using a spawner-recruit analysis. We have conducted preliminary analyses of Wind River spawners and smolt recruits to estimate freshwater habitat productivity and capacity using three common models of spawner-recruit dynamics. However, this approach should be extended to spawners and adult recruits to examine whole life cycle productivity and capacity. Additionally our current methods do not incorporate measurements of parameter uncertainty in spawner abundance, smolt abundance, or age structure.

Spawner-recruit modeling in the Wind River could be improved in several ways. The first step would be to extend the Bayesian mark-recapture approach to the August adult snorkel surveys conducted from 1988 to 1999 in order to obtain population estimates for these years by modifying the count expansion methods of Parken at al. (2003). Brood year smolt abundance estimates should incorporate uncertainty in smolt age composition by estimating annual age composition in a hierarchical multinomial model where year is treated as a random effect. Finally, a Bayesian spawner-recruit analysis should be conducted using a state-space modeling approach (Rivot et al. 2004) which accommodates measurement error in the parameter estimation procedure. This approach would have wide applications for adult and juvenile

population estimates in the Columbia Basin. Furthermore, the Columbia River Technical Recovery Teams have included measurement error in developing recovery goals, partitioning error into process and measurement could lead to alternate recovery goals and/or estimates of extinction risk.

The Ecosystem Diagnosis and Treatment (EDT) model (Lestelle et al.1996) was used extensively for subbasin recovery plans in the Wind River and other Columbia River tributaries. One of the key assumptions in the EDT model for Columbia River steelhead is that steelhead parr successfully rear in the mainstem Columbia River for one year before emigrating as smolts. Although the Columbia River has a large habitat capacity this type of low gradient habitat is not preferred by juvenile steelhead in Pacific northwest rivers (Gibbons et al. 1985). USGS-CRRL is PIT tagging steelhead parr in the upper Wind River and its tributaries, and this has proved to be successful at assessing survival by site (Pat Connolly USGS, pers. comm.). We recommend the continued PIT tagging of parr in the Upper Wind River and its tributaries and that up to 2,000 steelhead parr be tagged at the Lower Wind River screw trap to assess differences in parr survival between the Lower Wind site and upriver sites to address one of the key uncertainties in the EDT model for steelhead in the Columbia basin—whether the mainstem Columbia River provides viable rearing habitat (relative to tributaries) for steelhead between parr and smolt life stages.

In general, Wind River steelhead spawn in the upper mainstem or in tributaries. Their offspring rear in these locations for a period before emigrating to higher gradient reaches in the lower sections of their tributaries or to the Wind River canyon. Based on smolt yields, those parr that emigrate downstream apparently have good survival over the next year and may disproportionately contribute to the total smolt production from the Wind River subbasin. One caveat was the lack of information concerning the relatively low gradient reach from the upper Wind River smolt trap to the Stabler Bridge (rkm 30 to rkm 19). We recommend that an additional smolt-trapping site be added at the top of the Wind River canyon to determine if this area is used by juvenile steelhead for rearing. This trap should be operated through the summer to capture all the parr leaving this part of the basin.

One purpose of PIT tagging was to determine steelhead timing by race at Bonneville Dam to help with race classification at Shipherd Falls. However, the Shipherd Falls adult trap is left open from early May through early June because the size of the trap is too small to hold the large numbers of hatchery spring Chinook salmon arriving at this time of the year. An alternative to trapping is to install a PIT tag detector at the trap. PIT tag detection would provide needed information on steelhead passing the falls while the trap is not fishing, and would also help with assessment of hatchery spring Chinook salmon returns (of which a portion are PIT tagged) to CNFH by providing an in-season evaluation of adult returns for fisheries management. WDFW and USFWS installed and successfully operated a PIT tag interrogation system at Shipherd Falls for the 2009-10 run year but operation has not occurred since 2010 due to a reduction in USFWS funding.

In addition to providing status and trend information on ESA Threatened Wind River steelhead, long term steelhead life cycle data from WDFW’s Wind River project serve as a control dataset for wild steelhead within the Columbia Basin. The absence of hatchery steelhead and the limited

hydrosystem impacts (based on the river location only 15 km above Bonneville Dam) make data from the Wind Watershed Project ideal as a control or reference for understanding the influences of these factors on other populations. For this reason, we recommend continued funding of this project.

Coordination and Data Management for RM&E

The benefits to the fish and wildlife program from the Wind River steelhead project for coordination and data management for RME are many. We have developed biological reference points for steelhead enabling us to responsibly manage fishery impacts while providing recreational opportunity, and have shared the science behind these goals at the Summary of Escapement Goal Science Workshop in November 2010 in Portland, OR. Dam removals occur infrequently in the Pacific Northwest and BPA, USFS, and other spent well over $1M to remove Hemlock dam on Trout Creek, a key Wind River tributary. The Wind River steelhead monitoring program is in a unique position to test multiple hypotheses regarding steelhead response to dam removal, which could be used to provide insights into steelhead response from other dam removals. Presentations on this topic were made at the 2011 Annual American Fisheries Society in Seattle, the recent PNAMP meeting on Intensively Monitored Watersheds in the spring of 2013, and the Joint Aquatic Sciences Meeting in Portland in spring 2014. Our continued monitoring of steelhead and data sharing of VSP indicators has allowed NOAA to conduct multiple risk assessment of steelhead in the Lower Columbia River DPS. The use of statewide JMS and TWS databases, PTAGIS, and monitoring methods.org has allowed for better documentation and standardization of data collection and analysis, and more consistent reporting of high level indicators. The use of PIT tags in the Wind River is a unifying concept in the region's ability to assess survival, hydrosystem passage routes, and predation in a standardized approach. We have adapted the Wind River steelhead program to report on Coordinated Assessment indicators. We currently report on Natural Origin Spawner Abundance (NOSA) and Smolt to Adult Returns (SAR), Juveniles per Spawner (JpS) and for the first time in 2015, we reported on adult Recruits per Spawner (RpS).

While the WDFW portion of the Wind Watershed Project has collected the data necessary to report on HLIs, producing accurate and precise estimates for these metrics over long-term projects requires development of indicator-specific analytical methods and standardized long term project databases from which to populate these analyses. WDFW continues to work to improve its data storage and analytical methods, but notes that its efforts in this area would be improved by a greater level of funding for these tasks, which has not been available in recent years. Despite a lack of project funding, WDFW's Wind River project has served as a demonstration project for application development as part of the StreamNet Electronic Data Capture Project. This has included trial and adoption of electronic data capture, automated QA/QC, uploading to PTAGIS, and streamlined smolt analysis, and will soon incorporate Wind River adult steelhead data (See application screenshots; Appendix 2).

Additionally, we recommend that WDFW and other Wind project partners continue to engage in BPA's new Action Effectiveness Program, and other project scale monitoring efforts in order to identify opportunities for project scale monitoring in the Wind Basin that could both benefit from and contribute to our understanding of population and basin scales fish responses to restoration.

Recommendations

- Given its location in the Columbia Basin immediately above Bonneville, and its recent designation as a wild steelhead gene bank, consider designation of the Wind River as a long-term reference site for monitoring hatchery and hydrosystem impacts to steelhead populations.
- Continued funding of adult and smolt population estimates for status and trend information and evaluation of Hemlock Dam removal responses.
- Conduct state-space spawner-recruit analyses on both adult and smolt recruits which incorporate uncertainty in abundance and age estimates
- Continued PIT tagging of ~2,000 parr per year to assess parr survival and fill a gap in the Wind River steelhead life cycle model.
- Finalize development of a Wind River steelhead life cycle survival model to estimate life stage-specific survival in each cohort.

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APPENDICES

Appendix 1: Use of Data & Products

WDFW Wind River data are stored in the following locations:

- WDFW Salmonid Stock Inventory (SaSI): Final Adult escapement estimates:

https://fortress.wa.gov/dfw/score/score/species/population_details.jsp?stockId=6805
&
https://fortress.wa.gov/dfw/score/score/species/population_details.jsp?stockId=6810

- WDFW statewide Juvenile Migrant Exchange (JMX): all juvenile data; final juvenile estimates
- Wind Project Access Database: all data
- PTAGIS: all project juvenile and adult PIT tag data;
- Previous BPA reports: adult and smolt estimates

Appendix 2: Screenshots of Wind River Electronic Data Capture

Figure 14. Screenshot of Wind River project use of StreamNet electronic data capture application for smolt trap data.

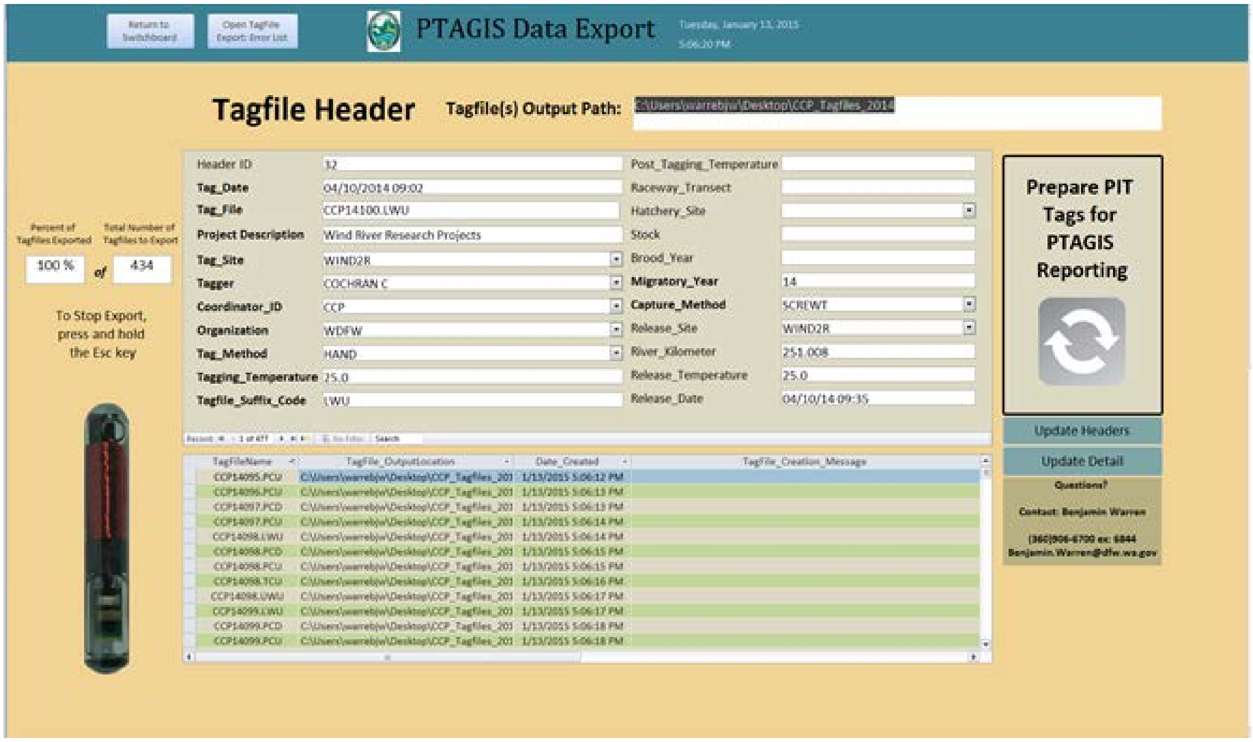

Figure 15. Screenshot of Wind River project use of StreamNet electronic data capture PTAGIS file generator application for smolt trap data.

Figure 16. Screenshot of Wind River project use of StreamNet electronic data capture smolt trap capture-recapture data summary matrix.