Priest Rapids Hatchery Monitoring and Evaluation Annual Report for 2018-2019

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Disclaimer

This report is provided as an annual data update of the Public Utility District No. 2 of Grant County, Washington's (Grant PUD's) monitoring and evaluation plan for Priest Rapids Hatchery. All data are provisional and subject to change as new data and analyses become available. Readers are cautioned to use data at their own risk and should consult the most current report to obtain the most current and accurate information. Data sets will become final when they are published in peer reviewed scientific journals.

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Executive Summary

This report is the ninth annual report dedicated to monitoring and evaluating the Priest Rapids Hatchery (PRH) production of fall Chinook salmon. The PRH is located below Priest Rapids Dam adjacent to the Columbia River and has been in operation since 1963. The monitoring and evaluation program associated with PRH is intended to evaluate the performance of the program in meeting hatchery and natural production goals. This report is intended to be cumulative, but also focus attention on the most recent year of data collection and production (2018-2019).

The PRH was originally built to mitigate for the construction and operation of Priest Rapids and Wanapum dams. The hatchery is operated as an integrated program for the purpose of increasing harvest while limiting undesirable risks to the naturally spawning population. The hatchery produces 5.6 million subyearling fall Chinook salmon for Public Utility District No. 2 of Grant County, Washington's (GPUD) mitigation requirement and 1.7 million subyearling fall Chinook salmon under contract with the United States Army Corps of Engineers for mitigation for the construction and operation of John Day Dam. These fish contribute significantly to a variety of fisheries, such as fisheries off the coasts of Alaska and Canada and fisheries in the Columbia River.

The estimated total escapement of fall Chinook salmon to the Hanford Reach in 2018 was 46,624 fish. This is lower than the mean abundances of the past few decades. The mean and median escapement for 1991 through 2018 was 74,126 and 56,459 fish, respectively.

The 2018 returns to PRH volunteer trap totaled 16,171 fall Chinook salmon. A total of 5,840 fish that returned to the volunteer trap at PRH were ponded at the hatchery for broodstock. An additional 1,221 fish from the Angler Broodstock Collection (ABC) fishery and 755 fish from Priest Rapids Dam Off-Ladder-Adult-Fish-Trap (OLAFT) were included in the broodstock in an effort to increase the number of natural-origin broodstock. In total, 5,836 fish were spawned to meet egg-take goals for multiple hatchery programs. The majority of the fish that were surplus to broodstock needs in recent years were provided to food-banks and tribes for consumption.

There were a number of similarities and differences of hatchery and natural origin fall Chinook salmon. The hatchery origin fish appeared to return at a younger age than natural origin fish. It appears that age-2 hatchery origin fish tend to be larger than natural origin fish of the same age. Likewise, age-4 and 5 natural origin fish tend to be larger than their hatchery origin counterparts. The number of eggs, egg size, and egg mass produced by hatchery and natural origin females of similar length was similar. With the exception of one year (2013), egg retention in female carcasses in the Hanford Reach has been low.

Hatchery origin fish released from PRH spawned throughout the Hanford Reach. In addition, the hatchery origin proportions of spawners relative to total spawners in the different sections of the Hanford Reach were similar. Recent evidence suggested that adult carcasses drift downstream of their spawning location and bias the estimated spawning distribution downstream. Stray rates into other populations appeared to be low based upon coded-wire tag recoveries and PIT tag detections of PRH adults in the Snake River were also low. However, there have been notable numbers of PIT tag detections of PRH adults above Priest Rapids Dam.

The PRH continued to contribute substantially to ocean and Columbia River fisheries and tends to have higher adult recruitment rates than the natural spawning fall Chinook salmon to the

Hanford Reach of the Columbia River. Adult recruitment rate of brood year 2012 for PRH was 41.24 versus 6.39 for fish spawning in the Hanford Reach.

PRH origin fish were estimated to make up 5.1% of the natural spawning population in the Hanford Reach during 2018. All hatchery fish combined (including fish released from Ringold Hatchery and strays from outside the Hanford Reach) comprised 7.1% of the fall Chinook salmon on the spawning grounds. Otolith recoveries at the PRH volunteer trap indicated that a very high percentage of fish returning to the PRH were of PRH origin. The proportion of natural influence (PNI) for Hanford Reach fall Chinook salmon including all hatcheries was 0.89 in 2018. This value was calculated using a gene flow model based on the Ford model and exceeded the PNI target of 0.67 for the fifth consecutive year. Adult management of fish at the PRH volunteer trap and alternative broodstock collection techniques to increase natural origin fish in the broodstock have contributed to improvements in PNI for the PRH program.

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1.0 Introduction

The Public Utility District No. 2 of Grant County, Washington (Grant PUD) produces and releases 5.6 million subyearling fall Chinook salmon smolts from Priest Rapids Hatchery (PRH) as part of its mitigation for the construction and operation of Priest Rapids and Wanapum dams. The mitigation is the result of three components: 1) inundation of historic spawning habitat (5,000,000), annual losses of fish that migrate through the project (325,543), and flow fluctuation impacts in the Hanford Reach (273,961). The PRH is located on the east bank of the Columbia River immediately downstream of Priest Rapids Dam (Figure 1 and Figure 2). The Washington Department of Fish & Wildlife (WDFW) operates PRH which is owned by the Grant PUD. Funding for operations and maintenance is provided by both the Grant PUD and the U.S. Army Corps of Engineers (USACE). This report describes the monitoring and evaluation of the PRH M&E program.

PRH also produces fish for other programs. PRH produces and releases 1.7 million subyearling smolts on-site for the USACE John Day Mitigation. An additional 4.1 million eyed eggs are targeted to provide fish for the USACE John Day Mitigation released at Ringold Springs Hatchery (RSH). The eggs for the RSH program are first transferred to Bonneville Hatchery for marking and ultimately ~3.7 million subyearlings are transported to, acclimated, and released as subyearling smolts from RSH. In recent years, PRH has accommodated egg-takes for fall Chinook salmon programs managed by either Yakama Nation (YN) or Umatilla Tribe as well as the WDFW's Salmon in the Classroom program and to support various research projects.

A Monitoring and Evaluation Plan for all Grant, Douglas, and Chelan County Public Utility Districts Hatchery Programs has been updated and approved by the committees that oversee the PUD hatchery programs (Hillman et al. 2017). This document provides guiding principles and approaches for the monitoring and evaluation (M&E) of all PUD hatchery programs including PRH. Objectives, hypotheses, measured and derived variables, and field methods that were used to collect data are listed in this document.

This report of the PRH M&E program is the ninth annual report (Hoffarth and Pearsons 2012a, 2012b, Richards et al. 2013, Richards and Pearsons 2014, 2015, 2016, 2017 and 2018) and encompasses data collected during the Washington State fiscal year (FY) 2018 - 2019 as well as earlier years where data were available. The data presented in this report are preliminary and subject to change as new data and analyses become available. Readers are encouraged to consult the most recent annual report in order to obtain the most current and accurate information.

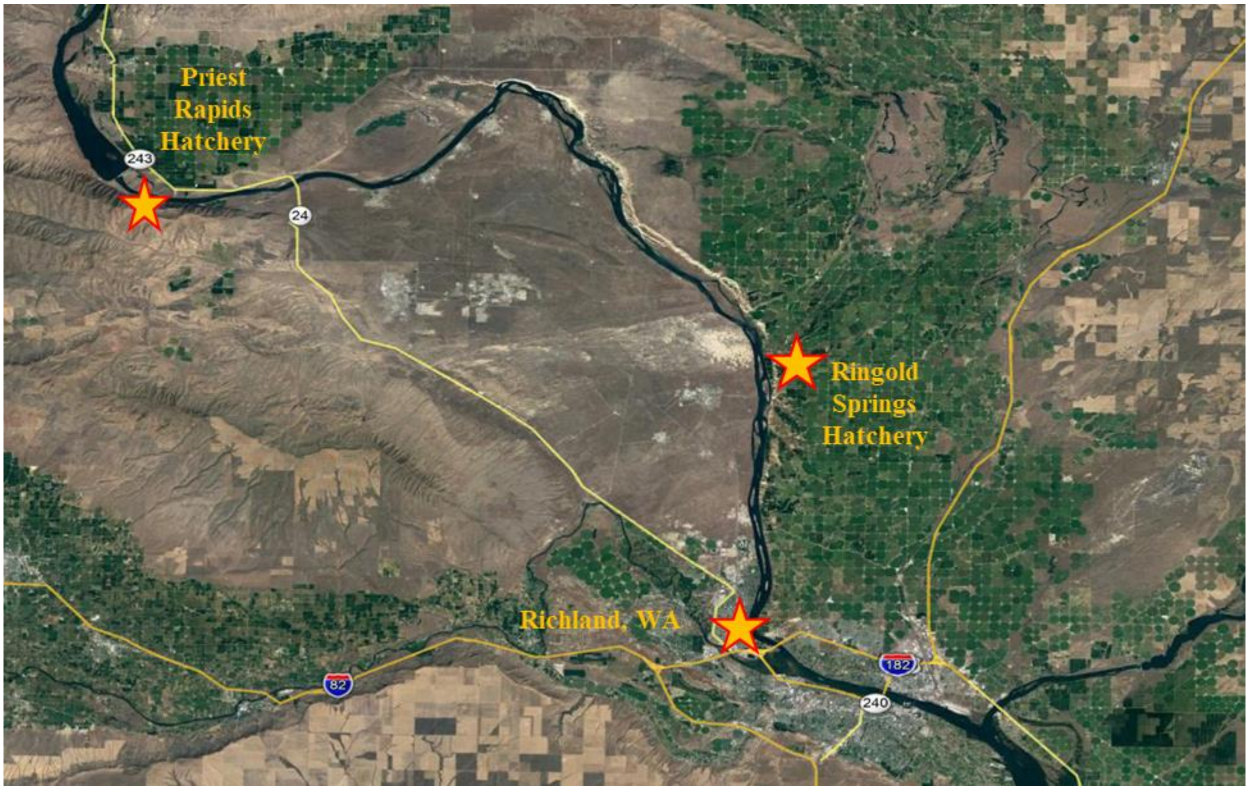

Figure 1 **Location of Priest Rapids and Ringold Spring hatcheries and the city of Richland Washington (indicated by stars).**

Figure 2 **Priest Rapids Hatchery facility and Priest Rapids Dam Off-Ladder Adult Fish Trap.**

2.0 Objectives

The objective of the PRH M&E plan is to evaluate the performance of the PRH program relative to the goals and objectives of the PRH program. The overarching goal of the PRH program is to meet Grant PUD's hatchery mitigation by producing fish for harvest while keeping genetic and ecological impacts within acceptable limits. The M&E objectives of the PRH program are described below.

Objective 1: Determine if conservation programs have increased the number of naturally spawning and naturally produced adults of the target population and if the program has reduced the natural replacement rate (NRR) of the supplemented population.

Objective 2: Determine if the proportion of hatchery fish on the spawning ground affects the freshwater productivity of supplemented stocks.

Objective 3: Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate, HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate, NRR) and the target hatchery survival rate.

Objective 4: Determine if the proportion of hatchery origin spawners (pHOS or PNI) is meeting management targets.

Objective 5: Determine if the run timing, spawn timing, and spawning distribution of the hatchery component is similar to the natural component of the target population or is meeting programs-specific objectives.

Objective 6: Determine if stray rate of hatchery fish is below the acceptable levels to maintain genetic variation among stocks.

Objective 7: Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program.

Objective 8: Determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.

Objective 9: Determine if hatchery fish were released at programmed size and number.

Objective 10: Determine if appropriate harvest rates have been applied to the conservation, safety-net, and segregated harvest programs to meet the HCP/SSSA goal of provided harvest opportunities while also contributing to population management and minimalizing risk to natural populations.

We also present information in this report about two regional objectives that relate to disease and ecological interactions.

3.0 Project Coordination

WDFW M&E staff partially assigned to PRH also conducts similar work at RSH. The M&E staff also works in conjunction with multiple WDFW groups that include PRH fish culture staff, the Columbia River Coded-Wire Tag Recovery Program (CRCWTRP), Region 3 Fish Management staff, the Supplementation Research Team in Wenatchee, and the Grant PUD biological science staff to complete many of the tasks included in the M&E Plan. In addition, samples collected at the hatchery and in the field were transported to and analyzed by WDFW laboratories including the WFDW Scale Reading Lab and the WDFW Otolith Lab. Coded-wire tags (CWT) were processed by the M&E staff either at the WDFW District 4 office or the PRH wet lab. Data and analyses collected in association with the PRH M&E and Hanford Reach population monitoring are incorporated into the WDFW Traps, Weirs, and Surveys (TWS) database which is administered by the WDFW staff stationed in the Region 5 Headquarters in Vancouver. Agency managers use these data for forecasting and managing fall Chinook salmon populations in the Columbia and Snake rivers and tributaries. WDFW and Grant PUD secured and held all environmental permits necessary for the work described in this report.

4.0 Life History – Hanford Reach Fall Chinook Salmon

The Hanford Reach is one of the last non-impounded reaches of the Columbia River and the location of the largest and most productive natural spawning fall Chinook salmon population in the United States (Harnish et al. 2012, Langshaw et al. 2015, Harnish 2017, Langshaw et al. 2017). The Hanford Reach extends ~81km from the city of Richland to the base of Priest Rapids Dam. Natural origin fall Chinook salmon emerge from the substrate in the spring and rear in the Hanford Reach until outmigration in the summer. Egg-to-fry survival has been estimated to be about 71% in the Hanford Reach (Oldenburg et al. 2012) and egg-to-pre-smolt survival has been estimated to be about 40.2% (Harnish et al. 2012) or more recently at 63.4% (Harnish, 2017). Both of these estimates are high when compared to other Chinook salmon populations and flow management within the Hanford Reach has resulted in improvements in survival (Harnish et al. 2012, Harnish 2017, Langshaw et al. 2017). The age at maturity for naturally produced fish in the Hanford Reach varies between age-1 mini-jack and age-6 adults: albeit recoveries of age-1 and 6 fish are generally rare. The age of fish reported in this document begins with the first birthday occurring the year after the parents spawned. The abundance of mini-jacks which mature as age-1 males is currently not known. Age-2 male fall Chinook salmon (a.k.a jacks) return to the Hanford Reach after spending roughly one year in the ocean. The majority of the natural origin adults return after spending three to four years in the ocean (age-4 and 5). A small portion, typically less than 2%, will spend up to five years in the ocean and return as age-6. The ocean distribution of natural and hatchery origin Hanford Reach upriver brights are similar and range from the northern California coast to the Gulf of Alaska (Norris et al. 2000, Weitkamp 2010). The majority of the adults migrate north of the Columbia River with the harvest primarily occurring in non-selective ocean and freshwater fisheries (Norris et al, 2000). Adults return to the mouth of the Columbia River between August and October and spawn in large cobble substrate between October and December (Langshaw et al. 2017).

5.0 Sample Size Considerations

We attempted to strike an appropriate balance between objectives, statistical precision, logistics, and financial investment when setting sample size targets. A variety of approaches were used for setting sample sizes and this depended upon the objective. For example, a phased subsampling approach was used in some cases to determine age and origin and 100% sampling occurred in others (e.g., CWT, otoliths in fecundity samples). A phased approach was used to collect some biological samples with sufficient accuracy and precision. In the phased approach, we attempted to collect an excess number of raw samples such as carcasses and trap recoveries and then use post season analysis to determine sub-sampling strategies for otolith decoding where appropriate. The sample size target of systematic field sampling for later otolith reading is 2,500 of the carcasses in the Hanford Reach, 1,000 at the hatchery trap, and 1,000 of the hatchery volunteer broodstock, and 200 broodstock collected from each other source such as OLAFT and ABC fishery.

All adult fall Chinook salmon recovered at PRH, in the Hanford Reach sport fishery, and in the stream surveys were screened for the presence of CWT to increase the number of CWT recoveries and maximize the precision of estimates generated from these data. Representative otolith samples by survey type were randomly selected as a sub-sample for decoding to estimate origin by age class if numbers allowed. In some cases, all otolith samples for a survey type were processed if the sampling rate provided relatively low numbers of otoliths collected or if there was a need for higher precision or accuracy. During return year 2018, randomly selected sub-samples of otoliths collected from the PRH volunteer trap and volunteer broodstock were submitted for decoding. The methodologies for selecting otolith sub-samples have differed between return years as field methods changed and as new analyses facilitated improvements in approaches. In general, we randomly select otoliths from various survey types to obtain roughly 120 otoliths for each age and gender. In some cases, all otoliths were submitted for stratified groups (age/gender) when specific age classes contain less than 100 samples. For example, typically all samples of age-5 and 6 fish were submitted because of the low number of fish represented in the field collected sample. The stratified sub-sample size refinement process is described in Richards and Pearsons (2014). The sub-sample groups often included fish possessing a CWT within the biological sample which increased the number of fish sampled for origin with no additional cost.

6.0 Current Operation at Priest Rapids Hatchery

The 2018 broodstock for PRH were collected at the hatchery volunteer trap, the OLAFT, and from the ABC fishery. The majority of the broodstock were collected from the PRH volunteer trap which was operated from September 10 through December 6, 2018. A total of 18,147 mature fall Chinook salmon were handled during broodstock collection activities (

Table 1). In attempt to increase pNOB for the Grant PUD program, to the extent possible, the broodstock ponded excluded adipose intact fish with a fork length less than 74 cm and known hatchery origin fish (i.e., possessing an adipose clip and or CWT). Prioritizing of these fish for the Grant PUD program results in the use on some known hatchery origin fish for the USACE program due to the lack of sufficient numbers of adipose fin intact/non CWT fish to meet the broodstock needs for both programs. A portion of these known hatchery origin fish ponded were surplused as they were replaced by adipose fin intact/non CWT fish during subsequent trapping and ponding operations. In total, 1,819 known hatchery origin fish from the PRH volunteer trap were spawned for the USACE program.

A portion of the fish intended for surplus from PRH were utilized for broodstock to support other fall Chinook salmon production by the Yakama Nation and additional production for the USACE. These fish include 66 females shipped to RSH and green eggs and milt from 1,088 fish spawned at PRH by the RSH staff. The PRH monitoring and evaluation (M&E) staff categorized and sampled these fish as surplus from PRH. The carcasses were utilized for pet food since they were treated with formalin during the period in which they were held for broodstock.

Table 1 Source and disposition of Chinook salmon collected for Grant PUD and USACE broodstock at Priest Rapids Hatchery, Return Year 2018. OLAFT=Off-ladder-adult-fish-trap, ABC=Angler broodstock collection.

Collection Location	Gender	Collected	Trap Surplused	Trap Mortalities	Ponded	Spawned[1]	Pond Surplused	Pond Mortalities
Volunteer Trap	Males	10,342	8,166	112	2,064	915	704	445
	Females	4,294	483	47	3,759	3,124	239	401
	Jacks	1,535	1,394	124	17	0	17	0
(Sept 10 – Dec 6)	**Total**	16,171	10,043	283	5,840	4,039	960	846
OLAFT	Males	426	0	0	426	399	6	21
	Females	329	0	0	329	311	3	15
(Sept 10 - Oct 25)	Jacks	0	0	0	0	0	0	0
	Total	755	0	0	755	710	9	36
ABC	Males	607	0	0	607	554	17	36
	Females	607	0	0	607	532	17	58
(Oct 23, 24 & 25)	Jacks	7	0	0	7	1	3	3
	Total	1,221	0	0	1,221	1,087	37	97
Facility	**Total**	**18,147**	**10,043**	**283**	**7,816**	**5,836**	**1,006**	**979**

[1] There were 9 males and 72 females taken directly from the trap and spawned. These fish are not included in the total fish ponded.

The pattern of arrival timing by week (Sunday through Saturday) for adult fall Chinook salmon to the PRH Volunteer Trap was determined to help schedule future sampling and broodstock activities. Trap operations during 2018 should have provided unimpeded access to the trap during most of each week. Rarely was the trap was closed for an entire day due exceeding its holding capacity during large spikes in returns. The 2018 collection numbers suggest that peak arrival to the PRH Volunteer Trap occurred during mid-October (Figure 3). The RY2014 – 18 average peak return timing occurred in late October and early November.

PRH has four adult salmon holding ponds. Ponds 1 and 2 were used to hold broodstock collected at the PRH Volunteer Trap. Pond 3 was used on occasion to temporarily hold males collected from ABC and OLAFT or surplus broodstock from the PRH Volunteer Trap. Pond 4 was used to hold broodstock collected from the ABC and OLAFT. The PRH staff generally transported fish from the volunteer trap on non-spawn days to collect broodstock and or to surplus the excess fish. Male fall Chinook salmon typically comprised the majority of the fish surplused from the trap. Spawn days generally occurred on Mondays and Tuesdays each week from October 22 through December 3 (N = 12). The electro-anesthesia (EA) system was regularly used for spawning fish in 2018. The recent modifications to components of center channel improved the speed in which fish could be loaded into the EA box.

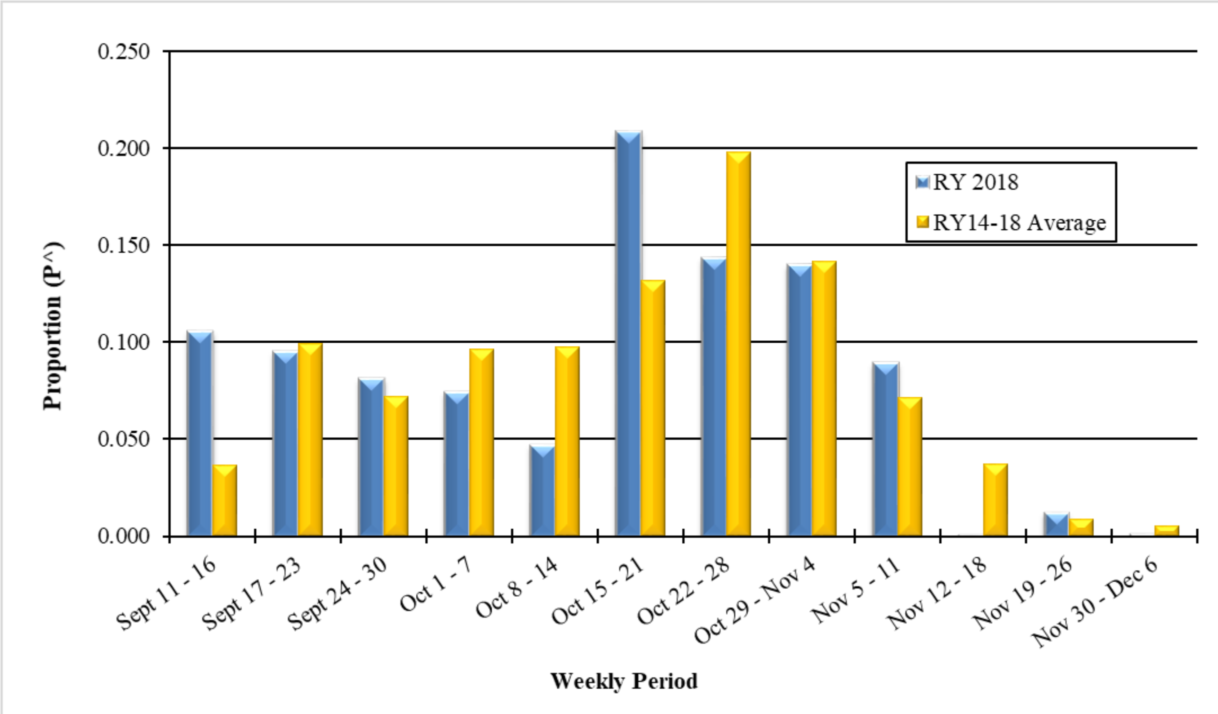

Figure 3 Proportion of annual returns by week of fish adult Chinook Salmon collected at the Priest Rapids Hatchery Volunteer Trap.

The egg-take goal from the 2018 PRH brood was 13,500,000 eggs. The actual egg-take for the Grant PUD and USACE programs was 14,821,007 (~110% of the goal). In general, the spawning protocol includes stripping eggs from two females into a five-gallon bucket and then adding milt from a single male. Two buckets of fertilized eggs were then combined to help ensure fertilization. Fertilized eggs were then transferred to the incubation room, weighed to estimate numbers of eggs, and then placed in vertical incubation trays at roughly 7,000 eggs per tray.

For years 2014 through 2017, a cooperative effort between WDFW and Grant PUD staff to perform real-time otolith reading (RTOR) coinciding with an alternative mating strategy has occurred on one or two spawn days during mid-November. This activity included examining otoliths from unmarked males collected at OLAFT or the ABC fishery to identify viable natural origin fish. These males were used for 1x4 matings with females collected either at the volunteer trap, OLAFT, or the ABC fishery. Milt from natural origin males was mixed with 4 females in a five-gallon bucket. Two buckets of fertilized eggs were then combined to help ensure fertilization before being transferred to the incubation room.

During 2018, the alternative mating strategy was intended to be implemented with all of the ABC males, but without the use of otolith reading. This was done because of the high proportion of natural origin fish that occur in the ABC brood and because it allows for the mating strategy to occur throughout the spawning season. The alternative mating strategy included utilizing all males collected in the ABC to the extent possible for 1x4 matings with females collected from either the ABC fishery, OLAFT, or volunteer trap. A total of 554 males collected from the ABC fishery were crossed with 1,292 females. Some males were crossed with fewer females because of the shortage of females

Roughly 4.41 million eyed eggs were shipped to Bonneville Hatchery for hatching and early rearing. For the combined programs at PRH, roughly 7.98 million fry moved from the vertical trays in the incubation building to outdoor raceways between January 28 and March 5, 2019. The fry were reared in the raceways until they were of sufficient size that a portion of them could be marked in some manner (i.e., adipose clipped and or tagged). Fish receiving marks and or tags were collected directly from the raceways banks and then released into the corresponding concrete rearing ponds (e.g., fish moved from raceway bank E to channel pond E). Fish not selected for marking were transferred from the raceway banks into the corresponding rearing ponds. The growth of smolts from ponds E and D was accelerated for early releases that occurred on May 23 and 25, respectively. The remaining smolts were released between June 10 and June 17. All releases occurred at night. These fish migrate down the old 1.6 km long spawning channel and then down the hatchery discharge channel to the Columbia River.

7.0 Origin of Adult Returns to Priest Rapids Hatchery

The origin of fish collected from the three locations was determined by examination of hatchery marks (i.e., otolith thermal marks, adipose clips, and CWTs) for the fish within the demographic sample groups. PRH origin fish were identified by their otolith mark or a CWT. The fish that did not possess an otolith mark or other hatchery marks and tags were classified as natural origin. Historically, the very low recovery (<1%) of non-adipose clipped CWT strays at PRH suggests that a high percentage of the fish not possessing any type of hatchery mark may be of natural origin. In some sections of this report, we make a simplifying assumption that fish without hatchery marks are of natural origin.

Similar to that observed in previous years, there is a discrepancy between estimates of origin based on CWT and those based on otoliths marks. It’s believed that estimates of origin based on otolith sampling may provide the most accurate data under the current marking regime at PRH due to discrepancies in the data associated with CWT results (Appendix A).

An examination of thermal mark accuracy was conducted for 2018 where 110 known origin otoliths were blindly examined amongst the Hanford Reach spawning survey. An overall error rate of 2.7% was detected from the known origin samples. All of the error was found to be false negatives (no mark was assigned when a mark should have been present n=3). The implications of this error is that natural-origin fish were overestimated and hatchery-origin fish are underestimated. Preliminary results suggest a directional bias which were similar to results found in Volk et al. (1999) for false negative error (1-5%).

We present estimates of abundance based on CWTs (1:1 sample rate) and estimates based on sub-samples of hatchery marked fish collected from specific groups (varying sample rates) to illustrate differences in the estimates for the proportions of natural and hatchery origin fish recovered at PRH as well as the potential for creating a method to correct the historical database that was generated using CWT recoveries.

7.1 Origin Based on Hatchery Marks

For return year 2018, the proportion of broodstock obtained from the PRH volunteer trap that was natural origin is estimated at 0.132. Overall, the proportion of natural origin fish surplused or removed as mortalities that originated from the PRH volunteer trap was estimated at 0.196 . The proportion of natural origin fish used as broodstock from the OLAFT and ABC was estimated to be 0.882 and 0.932, respectively. The estimated numbers of natural and hatchery origin broodstock spawned annually since return year 2013 are given in (Table 2).

For return years 2014 through 2018, a minimum fork-length threshold of ~73 cm was generally used to reduce the number of age-2 and 3 male broodstock collected at OLAFT and the PRH volunteer trap along with the exclusion of hatchery marks and tags. Historical data suggests that age-2 and 3 fall Chinook salmon returning to the Hanford Reach comprise a greater proportion of hatchery origin fish compared to age-4 and 5 fall Chinook salmon returning to the Hanford Reach.

Table 2 Total fish handled, numbers sampled, and estimates of hatchery and natural origin Chinook salmon collected at Priest Rapids Hatchery, Priest Rapids Dam Off-Ladder Adult Fish Trap, and Angler Broodstock Collection fishery. Origin determined by otolith thermal marks, presence of coded-wire tags, and/or adipose clips, Return Years 2013-2018.

Priest Rapids Hatchery Broodstock [1]			Estimate (95% CI)	
Return Year	**Total**	**(N)**	**Hatchery Origin**	**Natural Origin [2]**
2013	4,476	503	4,395 [4,319, 4,436]	81 [40, 157]
2014	4,427	574	4,228 [4,130, 4,294]	199 [133, 297]
2015	4,875	682	4,482 [4,368, 4,573]	393 [302, 507]
2016	4,324	827	4,067 [4,034, 4,095]	257 [227, 290]
2017	4,511	533	4,093 [3,967, 4,197]	417 [414, 543]
2018	4,039	717	3,478 [3,389, 3,594]	556 [440, 645]
Priest Rapids Hatchery Surplused from Trap			**Estimate (95% CI)**	
Return Year	**Total**	**(N)**	**Hatchery Origin**	**Natural Origin [2]**
2013[a]	37,355	608	36,085 [35,375, 36,533]	1,270 [822, 1,980]
2014[b]	73,352	639	69,024 [67,484, 70,271]	4,328 [3,081, 5,868]
2015[b]	57,625	619	54,646 [53,418, 55,551]	2,979 [2,075, 4,207]
2016[a]	24,461	1,033	23,790 [23,737, 23,837]	668 [619, 719]
2017[a]	13,301	1,426	11,954 [10,680, 10,803]	1,348 [1218, 1492]
2018[a]	12,137	1,001	9,811 [9443, 10,051]	2,326 [2,086, 2,694
Off Ladder Fish Trap Broodstock[1]			**Estimate (95% CI)**	
Return Year	**Total**	**(N)**	**Hatchery Origin**	**Natural Origin [2]**
2013	763	169	343 [242, 370]	420 [392, 416]
2014	825	225	143 [122, 166]	682 [659, 703]
2015	348	164	45 [29, 66]	303 [282, 319]
2016	366	211	99 [83, 117]	267 [249, 283]
2017	809	226	108 [78, 148]	701 [661, 731]
2018	710	195	84 [57, 121]	626 [589, 653]
Angler Broodstock Collection Broodstock [1]			**Estimate (95% CI)**	
Return Year	**Total**	**(N)**	**Hatchery Origin**	**Natural Origin [2]**
2013	308	293	59 [46, 75]	249 [233, 262]
2014	221	111	17 [9, 34]	204 [187, 212]
2015	301	141	11 [4, 26]	290 [275, 297]
2016	247	94	11 [6, 20]	236 [227, 241]
2017	348	171	33 [20, 52]	315 [296, 328]
2018	1,087	499	78 [56, 108]	1,007 [977, 1029]

[1] Includes only fish that were spawned.
[2] Origin based on the absence of otolith marks, coded-wire tags, or adipose clips.
[a] These data were collected from samples intermittently high-graded for broodstock and may not be representative of the entire return to the Priest Rapids Hatchery volunteer trap.
[b] These data are representative of the entire volunteer return to the Priest Rapids Hatchery volunteer trap.

7.2 Origin Based on Coded-Wire Tag Recoveries

The expansions of CWT recoveries at PRH until recent years have notably under estimated the returns of PRH origin fish by return year and brood year. This bias and steps taken to identify the source are provided in Appendix A. The CWT can originate from hatcheries throughout the basin as well as from tagging of natural origin fall Chinook salmon in the Hanford Reach.

All Chinook salmon returning to PRH and broodstock collected from the OLAFT and ABC were sampled for the presence of CWT. A total of 2,219 CWT fish were recovered from Chinook salmon sampled at PRH in 2018, of which 570 were recovered from the broodstock obtained from the PRH volunteer trap (Appendix B). The broodstock collected from the PRH volunteer trap were generally culled to exclude CWT fish for the purpose of increasing natural origin broodstock. Therefore, this CWT group is not representative of the volunteer broodstock. The ABC fish were not screened for a CWT during collection but were later scanned for CWT at the hatchery. There were nine CWT recovered from the ABC collection of which seven were surplused. The staff collecting the OLAFT fish attempted to screen out CWT fish during the brood stock collection. There were four CWT recovered from the OLAFT collection and included in the spawn. The juvenile mark rate expansions of CWT recovered adults at PRH in 2018 suggest that 76.0% of the returns to the PRH volunteer trap were hatchery origin fish. If we were to make the assumption that these CWT expansions accurately reflected the proportion of hatchery origin fish, then the remaining 24.0% of the unaccounted fish could potentially be natural origin (Table 3).

The juvenile mark rate expansions of CWT recovered adults at PRH in 2018 suggest that 76.0% of the returns to the PRH volunteer trap were hatchery origin fish with 2.7% derived from hatcheries other than PRH. There were 10 natural origin CWT Hanford Reach fall Chinook salmon recovered at the hatchery in 2018 of which eight were excluded from the broodstock while sorting out adipose clipped fish to increase the proportion of natural origin broodstock. There is not an expansion factor for the natural origin CWT fish so there was no attempt to estimate the proportion of natural origin fish based on these CWT recoveries.

Table 3 Estimated proportion of hatchery and natural origin adult Chinook salmon returning to the Priest Rapids Hatchery volunteer based on coded-wire tag expansion. The entire collection was sampled for coded-wire tags, Return Years 2005-2018.

Return Year	Returns to Priest Rapids Hatchery Volunteer Trap	Origin based on Coded-Wire Tag expansions		
		Priest Rapids Hatchery	Other Hatchery	Natural Origin[1]
2005	10,616	0.622	0.006	0.329
2006	8,223	0.490	0.006	0.436
2007	6,000	0.671	0.004	0.525
2008	19,586	0.491	0.008	0.409
2009	12,778	0.428	0.003	0.540
2010	19,169	0.602	0.003	0.486
2011	20,823	0.613	0.006	0.381
2012	28,039	0.692	0.004	0.304
2013	41,831	0.713	0.034	0.252
2014	77,259	0.809	0.020	0.170
2015	63,978	0.914	0.015	0.071
2016	28,786	0.912	0.024	0.064
2017	17,812	0.868	0.046	0.086
2018	16,171	0.737	0.023	0.240
Mean	**27,300**	**0.679**	**0.014**	**0.312**
Median	**20,205**	**0.671**	**0.006**	**0.329**

[1] The proportion not accounted for by coded-wire tag expansion is assumed to be of natural origin.

8.0 Broodstock Collection and Sampling

The broodstock collected at the PRH volunteer trap were systematically sampled at a rate of 1:5 for otoliths (origin), scales (age), gender, and length. The broodstock collected at the OLAFT and ABC were sampled at a 1:2 rate for otoliths (origin), scales (age), gender, and length.

8.1 Broodstock Age Composition

A combined total of 5,831 fish were spawned from the three sources of broodstock (i.e, PRH Volunteer Trap, ABC and OLAFT) to provide green eggs for the combined Grant PUD and USACE production at PRH and the USACE production at RSH. The broodstock age compositions reported for years prior to 2012 are not directly comparable to the 2012 through 2018 broodstock age compositions due to inconsistent methodology for assigning origin and selecting broodstock based on fork length (Table 4, Table 5, Table 6 and Table 7). Prior to 2012, the origin of broodstock was estimated by adult CWT recoveries which in turn were expanded by the specific juvenile tag rates. In addition, the broodstock age compositions for 2014 through 2018 are influenced by the inconsistent practice of selecting broodstock based on a 74 cm minimum fork length at OLAFT and the volunteer trap. In addition, jacks collected in the ABC fishery were seldom used for broodstock.

Table 4 Age composition for hatchery and natural origin fall Chinook salmon spawned at Priest Rapids Hatchery (includes all sources of broodstock), Return Years 2007-2018. Proportions calculated from expanded age compositions by origin for each source of broodstock to account for differing sample rates.

Return Year	Origin	Age Composition				
		Age-2	Age-3	Age-4	Age-5	Age-6
2007	Natural[1]	0.000	1.000	0.000	0.000	0.000
	Hatchery[1]	0.081	0.274	0.486	0.138	0.020
2008	Natural[1]	--	--	--	--	--
	Hatchery[1]	0.011	0.848	0.100	0.039	0.002
2009	Natural[1]	--	--	--	--	--
	Hatchery[1]	0.012	0.086	0.883	0.019	0.000
2010	Natural[1]	--	--	--	--	--
	Hatchery	0.016	0.755	0.111	0.118	0.000
2011	Natural[1]	--	--	--	--	--
	Hatchery[1]	0.010	0.229	0.753	0.008	0.000
2012	Natural[2]	0.032	0.435	0.400	0.131	0.002
	Hatchery[2]	0.006	0.487	0.376	0.130	0.000
2013	Natural[2]	0.000	0.446	0.517	0.037	0.000
	Hatchery[2]	0.001	0.658	0.339	0.002	0.000
2014	Natural[2]	0.000	0.045	0.886	0.070	0.000
	Hatchery[2]	0.000	0.064	0.897	0.039	0.000
2015	Natural[2]	0.000	0.183	0.506	0.305	0.006
	Hatchery[2]	0.000	0.210	0.680	0.110	0.000
2016	Natural[2]	0.000	0.101	0.761	0.138	0.000
	Hatchery[2]	0.000	0.099	0.700	0.196	0.007
2017	Natural[2]	0.000	0.130	0.618	0.252	0.000
	Hatchery[2]	0.000	0.074	0.663	0.258	0.005
2018	Natural[2]	0.000	0.448	0.419	0.130	0.003

Return Year	Origin	Age Composition				
		Age-2	Age-3	Age-4	Age-5	Age-6
	Hatchery[2]	0.000	0.361	0.526	0.105	0.008
Mean (2012-19)	Natural[2]	0.005	0.255	0.587	0.152	0.002
	Hatchery[2]	0.001	0.279	0.597	0.120	0.003

[1] Origin determined from coded-wire tag expansions of juvenile mark rate.
[2] Origin determined from presence of hatchery marks (i.e., coded-wire tags, adipose clips, and otoliths)

Table 5 Age composition for hatchery and natural origin fall Chinook broodstock collected from the Priest Rapids Hatchery volunteer trap, Return Years 2012-2018.

Return Year	Origin[1]	N	Age Composition				
			Age-2	Age-3	Age-4	Age-5	Age-6
2012	Natural	39	0.000	0.295	0.585	0.121	0.000
	Hatchery	646	0.000	0.477	0.389	0.134	0.000
2013	Natural	11	0.000	0.390	0.610	0.000	0.000
	Hatchery	497	0.000	0.656	0.342	0.002	0.000
2014	Natural	26	0.000	0.115	0.885	0.000	0.000
	Hatchery	548	0.000	0.065	0.899	0.036	0.000
2015	Natural	55	0.000	0.218	0.491	0.273	0.018
	Hatchery	627	0.000	0.215	0.668	0.116	0.000
2016	Natural	49	0.000	0.102	0.776	0.122	0.000
	Hatchery	778	0.000	0.100	0.763	0.136	0.000
2017	Natural	49	0.000	0.290	0.544	0.167	0.000
	Hatchery	484	0.000	0.075	0.662	0.258	0.005
2018	Natural	95	0.000	0.391	0.449	0.160	0.000
	Hatchery	622	0.000	0.351	0.535	0.106	0.008
Mean	**Natural**	**46**	**0.000**	**0.257**	**0.620**	**0.120**	**0.003**
	Hatchery	**600**	**0.000**	**0.277**	**0.608**	**0.113**	**0.002**

[1] Origin determined from "in-sample" otoliths, adipose clips and/or coded-wire tags.

Table 6 Age composition for hatchery and natural origin fall Chinook salmon broodstock collected from the Off Ladder Adult Fish Trap at Priest Rapids Dam, Return Years 2012-2018.

Return Year	Origin[1]	N	Age Composition				
			Age-2	Age-3	Age-4	Age-5	Age-6
2012	Natural	281	0.048	0.540	0.257	0.151	0.004
	Hatchery	219	0.106	0.687	0.136	0.071	0.000
2013	Natural	116	0.000	0.353	0.595	0.052	0.000
	Hatchery	85	0.000	0.588	0.400	0.012	0.000
2014	Natural	186	0.000	0.000	0.902	0.098	0.000
	Hatchery	39	0.000	0.000	0.870	0.130	0.000
2015	Natural	143	0.000	0.132	0.514	0.347	0.007
	Hatchery	21	0.000	0.211	0.563	0.226	0.000
2016	Natural	155	0.000	0.058	0.677	0.245	0.019
	Hatchery	56	0.000	0.089	0.643	0.250	0.018
2017	Natural	226	0.000	0.036	0.668	0.277	0.000

Return Year	Origin[1]	N	Age-2	Age-3	Age-4	Age-5	Age-6
		Age Composition					
	Hatchery	35	0.000	0.028	0.723	0.249	0.000
2018	Natural	172	0.000	0.518	0.397	0.085	0.000
	Hatchery	23	0.000	0.655	0.250	0.095	0.000
Mean	**Natural**	**183**	**0.007**	**0.234**	**0.573**	**0.179**	**0.004**
	Hatchery	**68**	**0.015**	**0.323**	**0.512**	**0.148**	**0.003**

[1] Origin determined from "in-sample" otoliths, adipose clips and/or coded-wire tags.

Table 7 Age composition for hatchery and natural origin fall Chinook salmon broodstock collected from Angler Broodstock Collection, Return Years 2012-2018.

Return Year	Origin[1]	N	Age-2	Age-3	Age-4	Age-5	Age-6
		Age Composition					
2012	Natural	59	0.000	0.542	0.339	0.119	0.000
	Hatchery	6	0.000	0.667	0.333	0.000	0.000
2013	Natural	237	0.000	0.511	0.468	0.021	0.000
	Hatchery	56	0.000	0.839	0.161	0.000	0.000
2014	Natural	102	0.000	0.126	0.830	0.044	0.000
	Hatchery	9	0.059	0.369	0.572	0.000	0.000
2015	Natural	136	0.000	0.196	0.499	0.305	0.000
	Hatchery	5	0.000	0.397	0.603	0.000	0.000
2016	Natural	90	0.000	0.156	0.656	0.189	0.000
	Hatchery	4	0.000	0.250	0.750	0.000	0.000
2017	Natural	16	0.000	0.127	0.561	0.312	0.000
	Hatchery	155	0.000	0.055	0.649	0.296	0.000
2018	Natural	463	0.000	0.433	0.417	0.143	0.006
	Hatchery	36	0.000	0.493	0.425	0.082	0.000
Mean	**Natural**	**158**	**0.000**	**0.299**	**0.539**	**0.162**	**0.001**
	Hatchery	**39**	**0.008**	**0.439**	**0.499**	**0.054**	**0.000**

[1] Origin determined from "in-sample" otoliths, adipose clips and/or coded-wire tags.

8.2 Length by Age Class of Broodstock

The mean fork length (cm) by age for each source of broodstock is provided in

Table 8 and Table 9. Both the hatchery origin and natural origin age-3 fish collected at the PRH volunteer trap appear to be slightly larger than age-3 fish collected at other locations. This may be due to the culling processes to reject age 2 and 3 males encountered at OLAFT and PRH based on fork length. Only jacks were culled from the ABC. The lengths of fish at age 4 were similar among different sources

Table 8 **Mean fork length (cm) at age (total age) of fall Chinook salmon sampled from each source of broodstock spawned at Priest Rapids Hatchery, Return Year 2018. N = sample size and SD = 1 standard deviation.**

Source of Broodstock	Origin[1]	Fall Chinook Fork Length (cm)														
		Age-2			Age-3			Age-4			Age-5			Age-6		
		N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
Volunteer Returns	Natural	0	--	--	50	71	4	53	79	5	17	84	5	0	--	--
	Hatchery	0	--	--	230	70	4	342	78	5	69	81	5	7	82	3
OLAFT	Natural	0	--	--	90	69	4	67	79	5	14	85	5	0	--	--
	Hatchery	0	--	--	15	68	2	6	77	8	2	82	5	0	--	--
ABC	Natural	0	--	--	196	68	5	198	79	5	66	85	6	3	90	1
	Hatchery	0	--	--	17	67	4	16	79	5	3	82	7	0	--	--

[1] It is assumed for this analysis that all fish not possessing an otolith mark, ad-clipped or hatchery origin coded-wire tag were natural origin.

Table 9 **Mean fork length (cm) at age (total age) of hatchery and natural origin fall Chinook salmon collected from broodstock originating from the Priest Rapids Hatchery volunteer trap. N = sample size and SD = 1 standard deviation, Return Years 2012-2018.**

Return Year	Origin[1]	Fall Chinook Fork Length (cm)														
		Age-2			Age-3			Age-4			Age-5			Age-6		
		N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
2012	Natural	0	--	--	12	71	4	25	82	4	5	86	4	0	--	--
	Hatchery	0	--	--	298	70	4	253	81	5	91	88	7	0	--	--
2013	Natural	0	--	--	4	76	4	7	78	4	0	--	--	0	--	--
	Hatchery	0	--	--	288	71	4	200	80	5	2	85	4	0	--	--
2014	Natural	0	--	--	3	74	2	23	80	5	0			0	--	--
	Hatchery	0	--	--	36	70	3	491	78	5	21	87	6	0	--	--
2015	Natural	0	--	--	12	74	7	30	79	6	15	86	4	1	87	0
	Hatchery	0	--	--	133	71	4	437	80	4	79	84	5	0	--	--
2016	Natural	0	--	--	78	73	3	594	79	4	106	85	6	0	--	--
	Hatchery	0	--	--	133	71	4	437	80	4	79	84	5	0	--	--
2017	Natural	0	--	--	15	73	4	26	79	4	8	81	8	0	--	--
	Hatchery	0	--	--	39	72	4	315	77	4	127	82	6	3	84	3
2018	Natural	0	--	--	50	71	4	53	79	5	17	84	5	0	--	--
	Hatchery	0	--	--	230	70	4	342	78	5	69	81	5	7	82	3
Mean	**Natural**	**0**	**--**	**--**	**28**	**73**	**4**	**101**	**79**	**5**	**21**	**84**	**5**	**0**	**87**	**0**
	Hatchery	**0**	**--**	**--**	**173**	**71**	**4**	**352**	**79**	**5**	**67**	**84**	**5**	**2**	**83**	**3**

[1]It is assumed for this analysis that all fish not possessing an otolith mark, ad-clipped or hatchery origin coded-wire tag were natural origin.

8.3 Gender Ratios

PRH staff sort and select broodstock from the trap to meet their egg-take goals and male-to-female spawner ratio which is generally 1:2. Additional broodstock were collected from the OLAFT and ABC. During 2018, the males collected from the ABC were initially utilized for 4x4 matings to increase the contributions of natural origin genes within the progeny. Eventually, many of the ABC males were used for 1x1 and 1x2 matings due to the lack of available females. The 2018 broodstock population was comprised of 68.0% females, resulting in an overall male to female ratio of 0.47:1.00, which is lower than the historic mean ratio of 0.52:1.00 (

Table 10).

Table 10 Number of male and female hatchery fall Chinook salmon broodstock at Priest Rapids Hatchery, Return Years 2001-2018. Ratios of males to females are also provided.

Return Year	Males (M)	Females (F)	M/F Ratio
2001	1,697	3,289	0.52:1.00
2002	1,936	3,628	0.53:1.00
2003	1,667	3,176	0.52:1.00
2004	1,688	3,099	0.54:1.00
2005	1,962	3,326	0.59:1.00
2006	1,777	3,322	0.53:1.00
2007	850	1,301	0.65:1.00
2008	1,823	3,195	0.57:1.00
2009	1,531	3,000	0.51:1.00
2010	1,809	3,447	0.52:1.00
2011	1,858	3,000	0.62:1.00
2012	1,749	3,225	0.54:1.00
2013	1,865	3,578	0.52:1.00
2014[a]	1,805	3,688	0.49:1:00
2015[a]	1,697	3,827	0.44:1:00
2016[a]	1,537	3,401	0.45:1.00
2017[a]	1,835	3,835	0.48:1.00
2018[a]	1,863	3,955	0.47:1.00
Mean	**1,711**	**3,255**	**0.52:1.00**

[a] Includes broodstock used in the 1-male x 4-females alternative mating strategy.

8.4 Fecundity

The annual mean fecundity for PRH was calculated as the proportion of the total number of females spawned to the total estimated take of green eggs. The total number of green eggs is calculated after the first pick of both live and dead eggs from the incubation trays. Fish culture staff weigh large lots of either dead or live eggs and then sub-sample the lots to calculate a mean individual egg weight. The number of eggs per lot is estimated by dividing the weight of the each egg lot by the calculated mean individual egg weight. The egg count for each lot is summed to estimate the facility egg-take. Each egg lot likely contained small and varying amounts of interstitial water which might overestimate the egg count.

Fecundity for the 2018 broodstock averaged 3,729 eggs per female which is similar to that observed in recent years but less than the historical mean of 3,919 (

Table 11). Pre-spawn egg loss was often observed during the electro-anesthetic and pneumatic fish euthanizing process (a physical strike to the head) and may contribute to the reduced fecundity of fish in recent years. In addition, the size and associated fecundity of Chinook salmon populations has been declining coast-wide and the reduction in fecundity at PRH may be the result of larger regional factors (Ohlberger et. al. 2018).

Table 11 Mean fecundity of fall Chinook salmon collected for broodstock at Priest Rapids Hatchery, Return Years 2001-2018.

Return Year	Egg-Take	Viable Females	Fecundity/Female
2001	10,750,000	3,161	3,401
2002	12,180,000	3,489	3,491
2003	12,814,000	3,078	4,163
2004	12,753,500	3,019	4,224
2005	14,085,000	3,211	4,386
2006	13,511,200	3,217	4,200
2007a	5,067,319	1,249	4,057
2008	12,643,600	3,074	4,113
2009	13,074,798	2,858	4,575
2010	11,903,407	3,342	3,562
2011	12,693,000	3,038	4,178
2012	12,398,389	3,053	4,061
2013	12,947,070	3,473	3,728
2014	14,321,183	3,563	4,019
2015	13,530,988	3,706	3,651
2016	12,411,530	3,401	3,649
2017	13,738,916	3,763	3,651
2018	14,821,007	3,975	3,729
Mean	**12,535,828**	**3,204**	**3,935**

Fecundities of individual females were taken from sub-samples at PRH during the spawn of 2010 through 2018 broodstock to estimate fecundity by length and age. For the 2013 through 2018 brood year data, we show comparisons between hatchery and natural origin fall Chinook salmon sampled at PRH that include fork length/fecundity, fork length/egg size (weight) and fork length, and gamete mass. For these years, we attempted to stratify the females sampled by fork length categories to obtain fecundity samples for all sizes of fish to better estimate the relationship between length and fecundity. However, the broodstock selection protocols in recent year have reduced the availability of females under 64 cm. Some fecundity data were obtained from females not used for broodstock (i.e., surplused) in order to bolster sample sizes. Therefore, comparisons between age classes are not representative of the females spawned from 2013 through 2018 broodstock populations.

M&E staff performed the fecundity estimates on green eggs. The entire gamete mass was drained of most all ovarian fluid and weighed within 0.1 gram. Sub-sample sizes ranged between years from 60 or 100 green eggs which were counted out and weighed within 0.01 gram to estimate individual egg weight (g) for each female. Post brood year 2013, sample sizes were 100 eggs, which was determined to be sufficient based upon previous work that examined different samples sizes (Richards and Pearsons, 2014). The total fecundity of each female was estimated by dividing the weight of the total egg mass by the calculated mean individual egg weight. Each sample of the total egg mass likely contained slight varying amounts of ovarian fluid which might over estimate fecundity.

The fecundity data was pooled for return year 2010 through 2018 to provide a simple linear regression to predict fecundity based on fork-length (natural and hatchery origin females combined). This data shows a strong positive correlation between size and fecundity (Figure 4).

The regression formula may be useful for coarse predictions of egg production for different size fish.

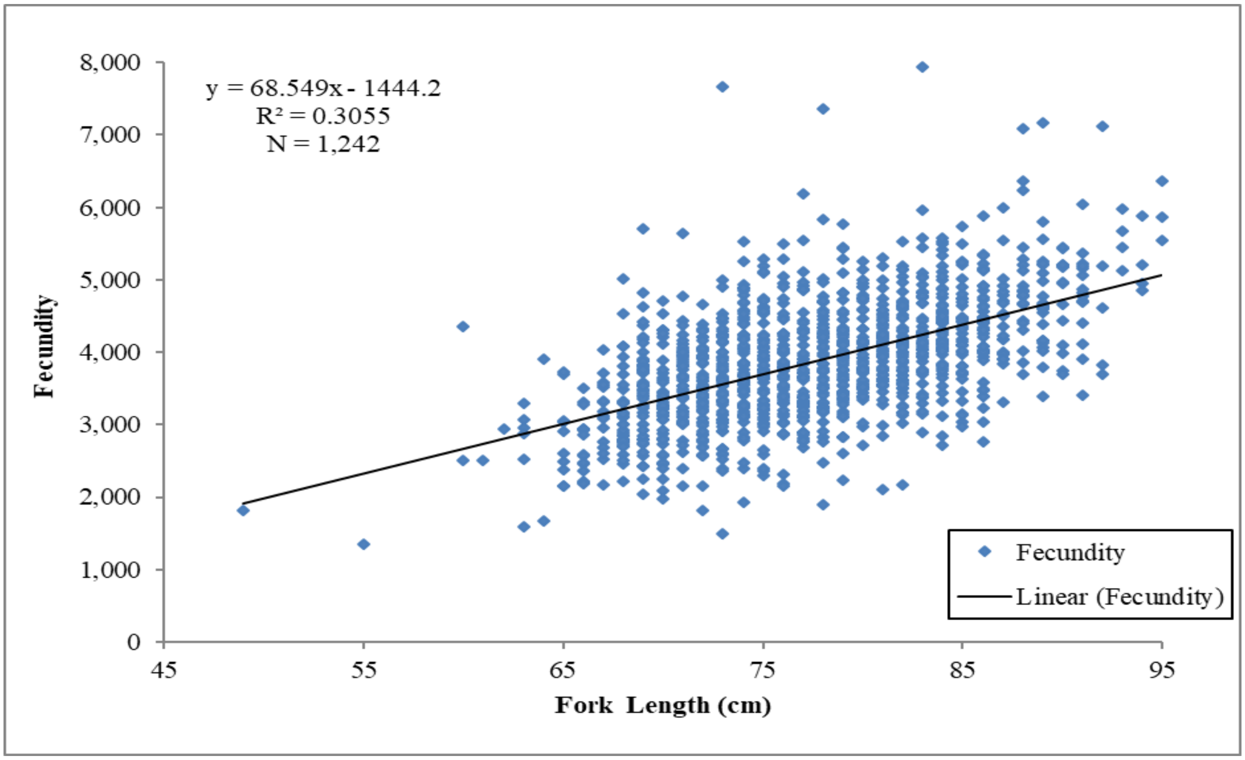

Figure 4 **Linear relationship between fecundity and fork length for combined samples of natural and hatchery origin fall Chinook salmon spawned at Priest Rapids Hatchery, Return Years 2010-2018.**

Fecundity samples collected at PRH for years 2010 through 2012 were not identified as to the origin of the females. For years 2013 through 2018, fecundity samples were taken from the broodstock at PRH to collect data associated with fecundity by size, age and origin (hatchery or natural).

Females were selected from both the PRH volunteer broodstock as well as from ponds which possessed broodstock primarily from the OLAFT and ABC. For the most part, the origin of fish during sampling was unknown. Therefore, we made a concerted effort to select females that were not adipose clipped so as to increase the chances of obtaining natural origin fish which were less common than hatchery origin fish. The origins of females sampled for fecundity were determined by hatchery marks (i.e., otoliths, adipose clips and CWTs). We make the assumption that fish not possessing any type of hatchery marks were of natural origin.

The mean fecundity by age is given in Table 12. This information is useful for forecasting potential egg-takes based on the numbers and age composition of the forecasted return.

Table 12 Mean fecundity at age for fall Chinook salmon sampled at the Priest Rapids Hatchery, Return Years 2010-2018. N = sample size and SD = 1 standard deviation.

Return Year	Age-3			Age-4			Age-5		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
2010	273	3,658	834	17	3,664	585	1	4,217	--
2011	30	3,538	842	206	4,276	884	1	4,380	--
2012	2	3,639	882	3	4,282	1089	0	--	--
2013	105	3,488	768	68	4,152	788	4	5,339	805
2014	1	3,358	--	73	4,126	755	5	4,416	407
2015	5	3,169	382	53	3,662	606	25	4,746	691
2016	14	3,192	559	101	3,676	639	36	4,173	693
2017	0	--	--	65	3,754	689	31	4,163	712
2018	17	3,997	771	80	3,876	757	26	3,850	689
Mean	**50**	**3,505**	**720**	**74**	**3,941**	**755**	**14**	**4,411**	**666**

The data collected from return years 2013 through 2018 were pooled to increase the number of samples for a given fork length. The linear relationships between fork length and variables including fecundity, mean egg weight, and total egg mass weight for natural and hatchery origin females subsampled are plotted Figure 5, Figure 6 and Figure 7. All relationships show a positive correlation with fork length. In addition, the relationships between fish size and egg data were similar for hatchery and natural origin fish.

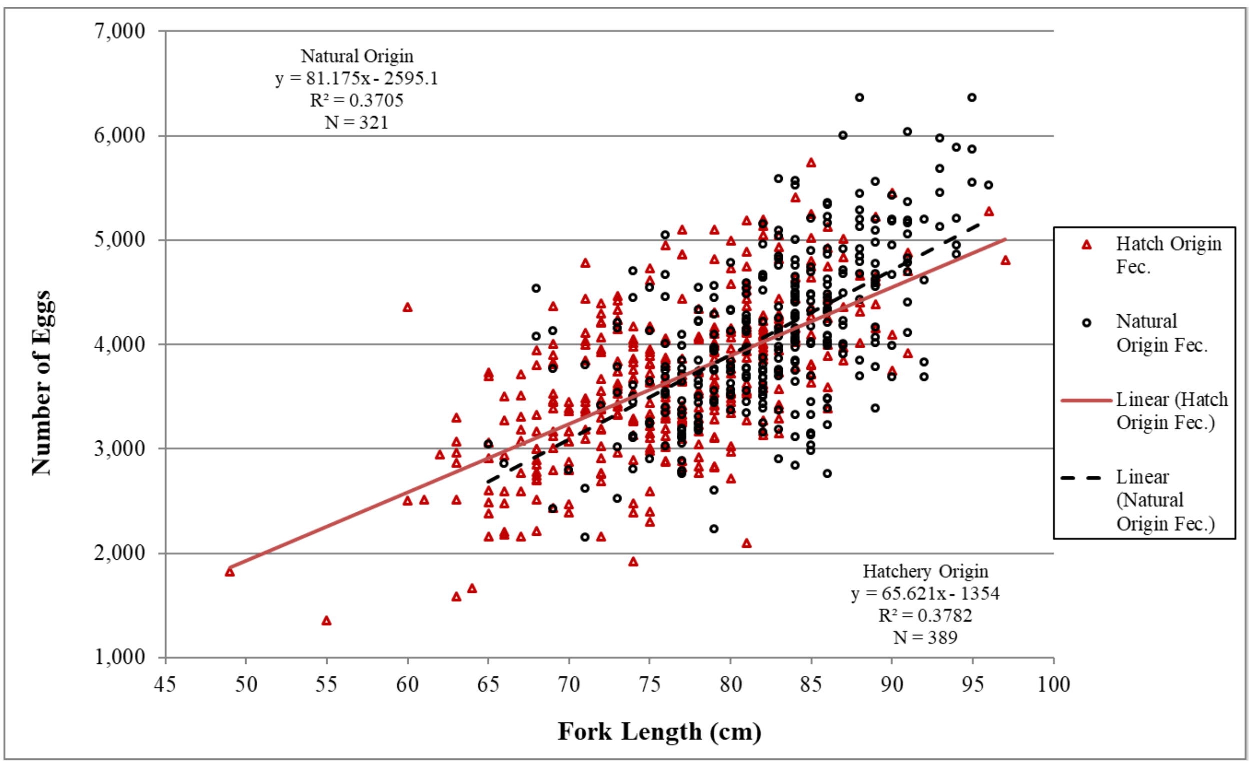

Figure 5 Fecundity versus fork length for natural and hatchery origin fall Chinook Salmon sub-sampled at Priest Rapids Hatchery, Return Years 2013-2018.

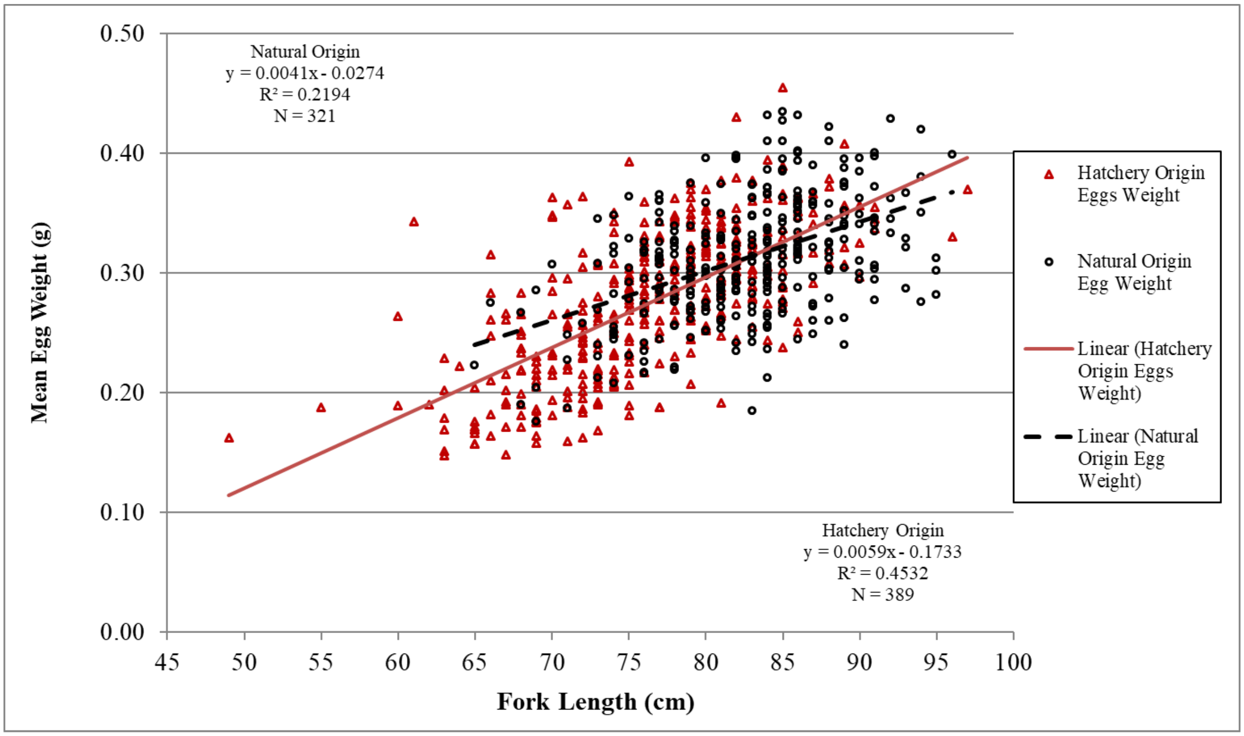

Figure 6 **Mean egg weight versus fork length for natural and hatchery origin fall Chinook Salmon sub-sampled at Priest Rapids Hatchery, Return Years 2013-2018.**

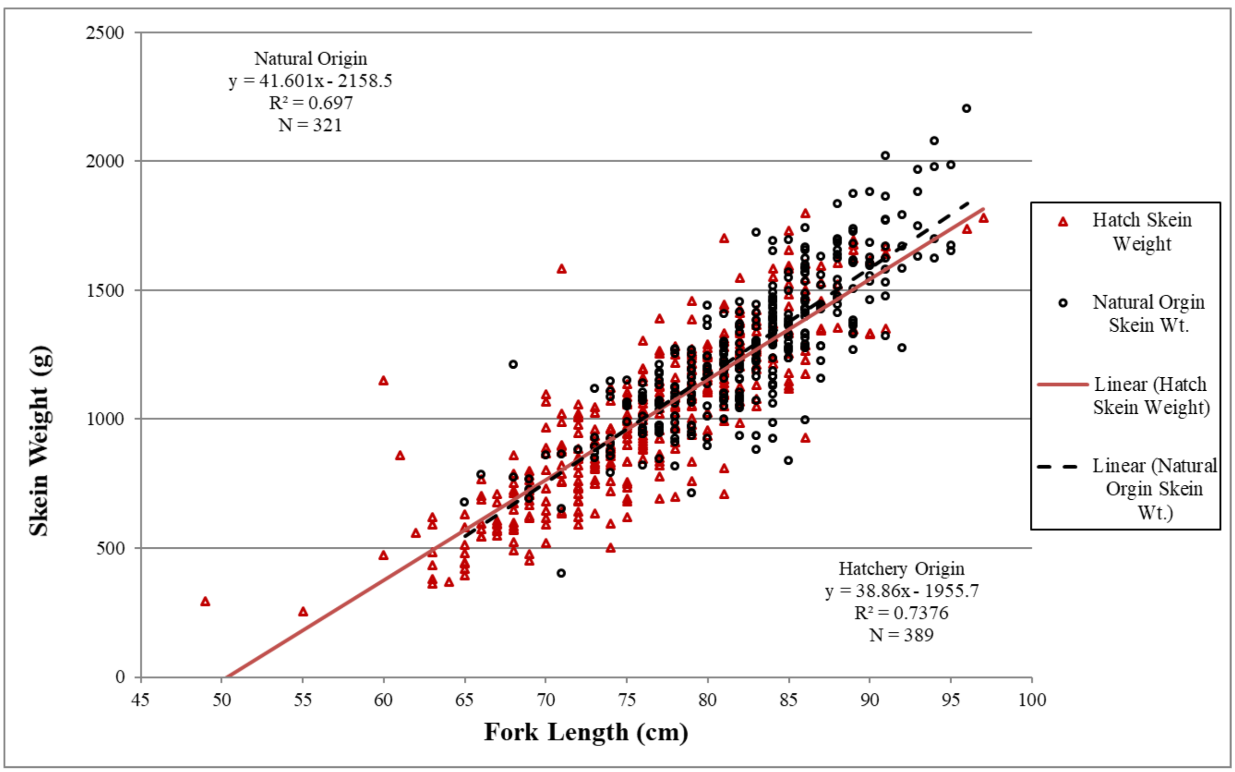

Figure 7 **Total egg mass weight versus fork length for natural and hatchery origin fall Chinook Salmon sub-sampled at Priest Rapids Hatchery, Return Years 2013-2018.**

9.0 Hatchery Rearing

9.1 Number of Eggs Taken

In 2018, an estimated 14,821,007 eggs were collected at PRH (Table 13). The egg-take goal for return year 2018 was 13,530,000. The egg-take goal is calculated annually based on current program needs. This goal is established to meet the fall Chinook salmon production goals at both PRH and RSH as well as provide eggs for the Salmon in the Classroom Program. Many of the green eggs taken in excess of the goal were earmarked for production at Little White Salmon and Klickitat hatcheries.

PRH incubates approximately 8.4 million eyed eggs to produce the 7.3 million smolt release at the hatchery. An additional 4.1 million eyed eggs are needed to meet the program goal of eyed eggs delivered to Bonneville Hatchery for the 3.5 million subyearling releases from RSH. There was roughly an additional 1,639,815 green eggs taken to which produced 1,540,011 eyed eggs. This surplus production was provided for transfer to the Little White Salmon and Klickitat hatcheries.

Table 13 Number of eggs taken from fall Chinook Salmon broodstock collected at Priest Rapids Hatchery, Return Years 1984-2018.

Return Year	Number of Eggs Taken		Return Year	Number of Eggs Taken
1984	10,342,000		2002	12,180,000
1985	10,632,000		2003	12,814,000
1986	22,126,100		2004	12,753,500
1987	24,123,000		2005	14,085,000
1988	16,682,000		2006	13,511,200
1989	13,856,500		2007	5,067,319
1990	9,605,000		2008	12,643,600
1991	6,338,000		2009	13,074,798
1992	11,156,400		2010	11,903,407
1993	14,785,000		2011	12,693,000
1994	16,074,600		2012	12,398,389
1995	17,345,900		2013	13,276,000
1996	14,533,500		2014	14,321,818
1997	17,007,000		2015	13,530,988
1998	13,981,300		2016	12,411,530
1999	16,089,600		2017	13,738,916
2000	15,359,500		2018	14,821,007
2001	10,750,000		**10 year (09-18) Mean[1]**	**13,216,985**

[1]Began annual egg-takes starting in return year 2008 for the 3.5 million Ringold Springs Hatchery Program

9.2 Number of Acclimation Days

The 2018 brood were incubated on a combination of well and river water before being transferred to intermediate concrete raceways and then transferred to the concrete holding ponds for final acclimation before release into the Columbia River in late May and June 2019. The egg-takes for the 2018 brood were distributed into twelve batches associated with the dates in which fish were spawned. The number of rearing-acclimation days ranged from 103 for the later egg-takes to 124 for the earlier egg-takes (Table 14).

Table 14 Number of days fall Chinook salmon fry were reared at Priest Rapids Hatchery prior to release, Brood Year 2018.

Batch	Egg Tray to Raceway Transfer Date	Release Date	Number of Days
1	All eggs shipped to Bonneville		
2	All eggs shipped to Bonneville		
3	January 28 into Bank E	May 22	113
4	January 28 into Bank E	May 22	113
5 Split	February 4 into Bank E	May 24	109
5 Split	February 4 into Bank D	May 24	109
6	February 5 into Bank D	May 24	108
7	February 5 into Bank C	June 10	124
8	February 19 into Bank B	June 13	113
9	February 19 into Bank B	June 13	113
10	March 5 into Bank A	June 17	103
11	March 5 into Bank A	June 17	103
12	March 5 into Bank A	June 17	103

9.3 Annual Releases, Tagging, and Marking

The annual release of fall Chinook salmon smolts from PRH has ranged considerably since the initial release of roughly 2.38 million smolts from the 1979 brood year to over roughly 10.30 million from the 1982 brood year (Table 15). The 2018 release goal for PRH was 7,299,504 smolts. This goal includes a recent increase in the Grant PUD mitigation from 5,000,000 to 5,599,504 combined with the ongoing USACE's John Day mitigation of 1,700,000 smolts.

In 2019, PRH released an estimated 7,213,916 subyearling fall Chinook salmon from the 2018 broodstock (Table 16). Fish were released between May 22 and June 17.

Various mark types and rates have occurred at PRH over the years for both the Grant PUD and USACE mitigation fish. In 1976, PRH began adipose fin clipping and coded-wire tagging a portion of the juvenile fall Chinook released to determine PRH contributions to ocean and river fisheries. The smolt production at PRH associated with the USACE mitigation increased the number of adipose clipped smolts released by ~1.7 million starting with brood year 2006. The number of coded-wire tagged fish released from PRH increased to >1.2 million fish starting with brood year 2009 of which ~600,000 were adipose clipped. An additional 1 million adipose clipped smolts were included in the release since brood year 2011.

All PRH releases for both mitigation programs were 100% otolith marked beginning with the 2008 release. All intra-annual releases from PRH have the same annual otolith pattern, but the pattern differs between years. The eyed eggs produced for the RSH program have received an otolith mark for brood years 2010 through 2016. Otolith marking of the RSH production was discontinued beginning with the 2017 brood due to the problematic timing of completing the thermal mark prior to shipping eyed eggs to Bonneville Hatchery for hatching and early rearing.

Since 1987, the U.S. Section of the Pacific Salmon Commission (PSC) has supported a coordinated project which seeks to capture and CWT 200,000 naturally produced juvenile fall Chinook salmon in the Hanford Reach (Fryer 2017). Fish are collected with seines over a ten day period between late May and early June. Fish are approximately 40-80 mm long at the time of capture. Recoveries from these tagged fish are used to estimate harvest exploitation rates and interception rates for Hanford Reach natural origin fall Chinook salmon. These data have also more recently been used to estimate the number of natural origin juveniles produced in the Hanford Reach (Harnish et al. 2012, Harnish 2017).

Table 15 Number of marked, unmarked, and tagged fall Chinook salmon smolts released from Priest Rapids Hatchery, Brood Years 1977-2018.

Brood Year	Total Released	Non Ad-Clip Released	AD/CWT	CWT Only	AD Only	PIT
1977	150,625	0	147,338	0	3,287	
1978	153,840	0	152,532	0	1,308	
1979	3,005,654	2,858,509	147,145	0		
1980	4,832,591	4,581,054	251,537	0		
1981	5,509,241	5,198,365	310,876	0		
1982	10,296,700	9,888,989	407,711	0		
1983	9,742,700	9,517,263	222,055	0	3,382	
1984	6,363,000	6,253,240	106,960	0	2,800	
1985	6,048,000	5,843,176	203,534	0	1,290	
1986	7,709,000	7,506,142	201,843	0	1,015	
1987	7,709,000	7,501,578	196,221	0	11,201	
1988	5,404,550	5,200,080	201,608	0	2,862	
1989	6,431,100	6,224,770	194,530	0	11,800	
1990	5,333,500	5,134,031	199,469	0		
1991	7,000,100	6,798,453	201,647	0		
1992	7,134,159	6,939,537	194,622	0		
1993	6,705,836	6,520,153	185,683	0		
1994	6,702,000	6,526,120	175,880	0		1,500 [c]
1995	6,700,000	6,503,811	196,189	0		3,000 [c]
1996	6,644,100	6,450,885	193,215	0		3,000 [c]
1997	6,737,600	6,541,351	196,249	0		3,000 [c]
1998	6,504,800	6,311,140	193,660	0		3,000 [c]
1999	6,856,000	6,651,664	204,336	0		3,000 [c]
2000	6,862,550	6,661,771	200,779	0		3,000 [c]
2001	6,779,035	6,559,109	219,926	0		3,000 [c]
2002	6,777,605	6,422,232	355,373	0		3,000 [c]
2003	6,814,560	6,415,444	399,116	0		3,000 [c]
2004	6,599,838	6,399,766	200,072	0		3,000 [c]
2005	6,876,290	6,676,845	199,445	0		3,000 [c]
2006	6,743,101	4,912,487	202,000	0	1,628,614	3,000 [c]
2007 [a]	4,548,307	4,344,926	202,568	0	813 [b]	3,000 [c]
2008 [a]	6,788,314	4,850,844	218,082	0	1,719,388	2,994 [c]
2009 [a]	6,776,651	3,413,334	619,568	1,026,561	1,717,188	1,995 [c]
2010 [a]	6,798,390	3,383,859	602,580	1,108,990	1,702,961	3,000 [c]
2011 [a]	7,056,948	3,094,666	595,608	598,031	2,768,643	42,844 [c]

Brood Year	Total Released	Non Ad-Clip Released	AD/CWT	CWT Only	AD Only	PIT
2012 [a]	6,822,861	2,905,694	603,930	601,009	2,712,228	42,908 [c]
2013 [a]	7,267,248	3,347,417	603,417	603,439	2,712,975	42,908 [c]
2014 [a]	7,039,544	3,125,734	600,688	600,730	2,712,392	42,621 [c]
2015 [a]	7,242,054	3,317,992	602,116	601,770	2,720,176	42,999 [d]
2016 [a]	7,006,252	3,045,689	603,539	603,864	2,710,302	42,858 [d]
2017 [a]	7,987,222	4,067,088	602,725	607,287	2,710,121	42,978 [c]
2018 [a]	7,213,916	3,311,964	603,788	601,893	2,696,272	42,990 [c]

[a] Entire release was otolith marked
[b] Low returns to PRH precluded the production of the USACE adipose clipped release.
[c] PIT tagged fish were included within the other mark group totals
[d] PIT tagged fish were not adipose clipped and reported as a unique group.

9.4 Fish Size and Condition of Release

The data associated with fish size and condition at release from PRH prior to brood year 2013 was obtained from the hatchery staff. The mean fish weight was obtained by weighing groups of roughly 300 fish sampled from each pond to the nearest gram and then dividing the group weight by the total number of fish weighed. The fork length of each fish from the group weight was measured to the nearest millimeter to calculate mean length and coefficient of variation. Samples from each of the rearing ponds were taken the day of release. The results were pooled to provide mean estimates for the facility as a whole. The size and condition data for the 2013 through 2018 broods were collected by M&E staff the day prior to or day of release for each pond. We attempted to collect representative samples by capturing multiple groups of fish with a cast net from five sections evenly distributed within each rearing pond. Each fish sampled was individually weighed to the nearest 0.1 gram and measured for fork length to the nearest millimeter. The results were pooled to provide mean estimates for the facility as a whole.

The goal for PRH is to release fall Chinook salmon smolts at 50 fish per pound. At release, the smolts from the 2018 brood averaged 51 fish per pound with a mean fork length of 90 mm, and a mean CV of 7.4 (Table 16). For brood years 1991 through 2018, smolts released from PRH have averaged 49 fish per pound with a mean fork length of 95 and a mean CV of 7.3.

Table 16 Mean length (FL, mm), weight (g and fish/pound), and coefficient of variations (CV) of fall Chinook smolts released from Priest Rapids Hatchery, Brood Years 1991-2018.

		Fork Length (mm)		Mean Weight		
Brood year	**Release Year**	**Mean**	**CV**	**Grams (g)**	**Fish/pound**	**N**
1991	1992	93	8.7	8.3	55	1,500
1992	1993	92	8.6	8.3	54	1,500
1993	1994	95	6.9	9.3	49	1,500
1994	1995	96	6.7	9.7	47	1,500
1995	1996	97	6.6	10	45	1,500
1996	1997	95	11	8.7	52	1,500
1997	1998	103	8.9	10.1	45	1,500
1998	1999	95	6.5	9.6	48	1,500
1999	2000	93	6.6	8.9	51	1,500
2000	2001	97	6.3	10.2	45	1,500
2001	2002	96	6.9	10.1	45	1,500
2002	2003	95	6.9	9.5	48	1,500

Brood year	Release Year	Fork Length (mm) Mean	CV	Mean Weight Grams (g)	Fish/pound	N
2003	2004	96	6.8	9.6	48	1,500
2004	2005	95	5.9	9.4	48	1,500
2005	2006	98	6.3	10.1	45	1,500
2006	2007	98	7.0	9.9	46	1,500
2007	2008	101	8.3	10.2	45	1,200
2008	2009	94	6.7	9.3	49	1,500
2009	2010	94	7.3	9.2	49	1,500
2010	2011	92	9.1	9.7	47	1,500
2011	2012	94	7.1	9.2	49	1,500
2012	2013	95	7.6	9.7	47	1,500
2013	2014	92	8.4	9.0	50	648
2014	2015	91	6.6	8.7	52	1,728
2015	2016	92	6.1	9.3	49	1,595
2016	2017	89	6.1	9.3	49	1,788
2017	2018	91	6.6	9.2	50	1,633
2018	2019	90	7.4	9.0	51	2,382
Mean		**95**	**7.3**	**9.4**	**49**	**1,517**

9.5 Survival Estimates

The survival proportion (P^) for fertilized egg to juvenile release for brood year 2018 was 0.903 which is higher than the historic mean of 0.870 (Table 17). The green egg to eyed egg stage is the most critical life stage at PRH during incubation/juvenile rearing because the greatest level of loss annually occurs at this stage. The green egg to eyed egg survival P^ for brood year 2018 was 0.943 which is higher than the historical mean of 0.903.

In 2018, survival P^ of fish ponded for broodstock was 0.869 which is higher than the historic mean of 0.846. The trapping operations in 2014 through 2018 were carried out in a manner which generally reduced fish densities in the trap; possibly resulting in reduced ponding mortality.

Table 17 Hatchery life stage survival (P^) for fall Chinook salmon at Priest Rapids Hatchery, Brood Years 1989-2018.

Brood year	PRH Volunteers Ponded to Spawned: Female	Male	Jack	Total	Unfertilized to Eyed Egg	Eyed egg to Ponding	Ponding to Release	Fertilized Egg to Release
1989				0.919	0.866	0.976	0.950	0.821
1990				0.947	0.869	0.996	0.984	0.852
1991				0.973	0.948	0.993	0.998	0.922
1992				0.952	0.945	0.991	0.965	0.901
1993				0.917	0.941	0.984	0.974	0.902
1994				0.710	0.935	0.985	0.953	0.878
1995				0.897	0.914	0.980	0.962	0.862
1996				0.908	0.924	0.997	0.983	0.897
1997				0.900	0.915	0.996	0.970	0.790
1998				0.834	0.914	0.998	0.970	0.884
1999				0.759	0.897	0.997	0.995	0.888
2000				0.868	0.898	0.995	0.985	0.884

Brood year	PRH Volunteers Ponded to Spawned				Unfertilized to Eyed Egg	Eyed egg to Ponding	Ponding to Release	Fertilized Egg to Release
	Female	Male	Jack	Total				
2001	0.776	0.732	0.665	0.757	0.886	0.994	0.975	0.859
2002	0.835	0.829	0.705	0.828	0.880	0.995	0.979	0.858
2003	0.893	0.817	0.698	0.858	0.882	0.989	0.989	0.868
2004	0.958	0.915	0.646	0.845	0.881	0.975	0.985	0.846
2005	0.890	0.890	0.782	0.886	0.914	0.976	0.991	0.884
2006	0.918	0.924	0.695	0.913	0.897	0.975	0.981	0.859
2007	0.967	0.748	0.642	0.861	0.858	0.996	0.981	0.898
2008	0.943	0.896	0.877	0.924	0.902	0.973	0.877	0.877
2009	0.848	0.901	0.916	0.864	0.912	0.977	0.891	0.891
2010	0.803	0.831	0.803	0.809	0.913	0.985	0.977	0.841
2011	0.611	0.847	0.737	0.679	0.903	0.985	0.985	0.875
2012	0.643	0.786	0.630	0.688	0.873	0.970	0.962	0.787
2013	0.698	0.660	0.333	0.684	0.884	0.983	0.951	0.806
2014	0.830	0.880	N/A	0.847	0.865	0.933	0.978	0.913
2015	0.841	0.810	N/A	0.830	0.917	0.934	0.985	0.919
2016	0.873	0.782	N/A	0.843	0.899	0.825	0.989	0.816
2017	0.820	0.824	N/A	0.821	0.917	0.942	0.985	0.928
2018	0.831	0.895	N/A	0.869	0.943	0.978	0.924	0.903
Mean	**0.832**	**0.832**	**0.702**	**0.846**	**0.903**	**0.976**	**0.969**	**0.870**

9.6 Juvenile PIT Tag Detections at the Priest Rapids Hatchery Array

Roughly 3,000 sub-yearlings at PRH were annually PIT tagged and released from PRH for brood years 1995 through 2010 to assess timing, migration speed, and juvenile survival from PRH to McNary Dam. The analysis for these measures is reported annually by the Fish Passage Center and can be found at *www.fpc.org/documents/FPC_memos.html.*

Beginning with the 2011 brood, approximately 40,000 additional juveniles were annually PIT tagged and released to bolster the data collected for estimation of juvenile abundance at release and adult straying. These tags can also be used to estimate adult migration timing, conversion rates from Bonneville Dam to McNary Dam to PRH, smolt to adult survival rates, as well as fallback and re-ascension estimates at McNary, Ice Harbor, and Priest Rapids dams. The annual detections at the PRH array of unique tags and rates by tag group are given in Table 18. Prior to the 2012 release (brood year 2011), a PIT tag array consisting of six antennas was installed in the hatchery discharge channel to detect both juvenile out-migrants and adult returns. The detection rates reported below account for the relatively few shed PIT tags found in the rearing raceways. Prior to the release of the 2016 brood, the mortalities routinely recovered from the rearing ponds were not scanned for PIT tags. This prohibits us from knowing the actual total number of PIT tagged fish released. Hence, the overall proportion of released PIT tagged fish detected would likely be higher than reported if we knew the actual number of live PIT tagged fish that left the ponds.

The overall detection rate for the releases of the 2011 brood year was 70.4%. The releases occurred over an eight day period, with only two days of consecutive releases. Detection rates for the 2011 brood year release may have been reduced as a result of the array being inundated by high river elevations during portions of releases. The overall detection rate for the 2012 brood year was 3.4%. The low detection rates were likely due to force releasing all of the smolts in four consecutive days which appears to have overwhelmed the PIT tag detection equipment. The restricted release period was necessitated by the construction schedule of the new hatchery.

A concerted effort was made during both the 2013 and 2014 brood year releases to improve the PIT tag detection efficiency at the PRH array. First, the automatic upload function of the array was discontinued to reduce the usage demand on the system's processor. Secondly, the five releases from the hatchery were conducted over a fourteen day period beginning on June 12 to spread out over time the number of PIT tags passing the array. This was managed by pulling the individual weir boards for each pond over a two day period. The percentage of PIT tagged subyearlings detected for the 2013 and 2014 brood years were 92.9% and 94.5%, respectively.

The releases of the 2015 brood occurred every two days between June 16 and June 24, 2016 to accommodate a day versus night release evaluation. During the evaluation, all weir boards for a given pond where incrementally pulled over an eight hour period on the date of release. Overall, 84.3% of the PIT tagged subyearlings were detected. The detected rate between release groups varied from 33.6% to 97.0%. These values are lower than the previous two years. It's possible that forced releases over an eight hour period may have resulted in high rates of tag collision at the array resulting in poor detection efficiency.

The releases of the 2016, 2017 and 2018 broods were initiated at 9PM for each pond. All weir boards were pulled by 3AM. Releases occurred irregularly between May 22 and June 20. The overall detection rates these broods ranged from 86.8% to 95.4%.

Table 18 Number of sub-yearlings PIT tagged, mark, and release dates, and the number of unique tags detected at the array in the Priest Rapids discharge channel, Brood Years 2011-2018.

Brood Year	Tag File	Tagging Date	Release Date	# Tagged	# of Tags Recovered from Facility Mortalities	# of Unique Detections	% Detected
2011	CSM12114.A01	4/23/2012	6/20/2012	9937	No Data	6,277	63.2
2011	CSM12114.A04	4/23/2012	6/14/2012	9948	No Data	6,674	67.1
2011	CSM12114.A03	4/24/2012	6/15/2012	9997	No Data	6,963	69.7
2011	CSM12115.A02	4/24/2012	6/16/2012	9967	No Data	8,115	81.4
2011	CSM12115.A02	5/30/2012	6/20/2012	1000	No Data	499	49.9
2011	SMP12151.PR2	5/30/2012	6/16/2012	998	No Data	806	80.8
2011	SMP12152.PR3	5/31/2012	6/12/2012	996	No Data	810	81.3
			Totals	42,844	**N/A**	**30,144**	**70.4**
2012	CSM13143.A06	5/23/2013	6/14/2013	9,982	No Data	317	3.2
2012	CSM13143.A07	5/23/2013	6/13/2013	9,983	No Data	267	2.7
2012	CSM13144.A08	5/24/2013	6/12/2013	9,974	No Data	335	3.4
2012	CSM13144.A09	5/24/2013	6/15/2013	9,977	No Data	325	3.3
2012	SMP13149.PR1	5/29/2013	6/15/2013	997	No Data	131	13.1
2012	SMP13149.PR2	5/29/2013	6/14/2013	996	No Data	33	3.3
2012	SMP13150.PR3	5/30/2013	6/12/2013	999	No Data	48	4.9
			Totals	**42,908**	**N/A/**	**1,456**	**3.4**
2013	CSM14148.PRA	5/28/2014	6/25/2014	7,994	21	7,215	90.5
2013	CSM14148.PRB	5/28/2014	6/23/2014	7,998	14	7,215	92.5
2013	CSM14149.PRC	5/29/2014	6/18/2014	7,996	11	7,443	93.2
2013	CSM14149.PRD	5/29/2014	6/16/2014	7,993	6	7,662	95.9
2013	CSM14149.PRE	5/29/2014	6/12/2014	7,998	7	7,407	92.7

Brood Year	Tag File	Tagging Date	Release Date	# Tagged	# of Tags Recovered from Facility Mortalities	# of Unique Detections	% Detected
2013	SMP14148.PR1	5/29/2014	6/25/2014	996	0	914	91.8
2013	SMP14148.PR2	5/29/2014	6/18/2014	994	0	927	93.3
2013	SMP14149.PR3	5/30/2014	6/12/2014	998	0	951	95.3
			Total	**42,967**	**59**	**39,908**	**92.9**
2014	CSM15147.PRE	5/27/2015	6/12/2015	7,999	169	7,438	95.0
2014	CSM15147.PRD	5/27/2015	6/15/2015	7,996	39	7,685	96.6
2014	CSM15147.PRC	5/27/2015	6/18/2015	7,996	63	7,524	94.8
2014	CSM15147.PRB	5/28/2015	6/22/2015	7,998	50	7,696	96.8
2014	CSM15147.PRA	5/28/2015	6/25/2015	7,994	31	7,447	93.5
2014	SMP15140.PR1	5/20/2015	6/25/2015	993	0	940	94.7
2014	SMP15140.PR2	5/20/2015	6/18/2015	998	0	946	94.8
2014	SMP15141.PR3	5/21/2015	6/12/2015	999	0	935	93.6
			Total	**42,973**	**352**	**40,611**	**95.3**
2015	CSM16153.PRE	6/01/2016	6/16/2016	7,996	13	6,032	75.6
2015	CSM16153.PRD	6/01/2016	6/18/2016	7,998	224	7,537	97.0
2015	CSM16153.PRC	6/01/2016	6/20/2016	7,985	137	6,777	86.4
2015	CSM16154.PRB	6/02/2016	6/22/2016	7,993	13	7,136	89.4
2015	CSM16154.PRA	6/02/2016	6/24/2016	7,990	26	6,590	82.7
2015	SMP16153.PR1	6/01/2016	6/24/2016	995	88	513	56.6
2015	SMP16153.PR2	6/01/2016	6/20/2016	998	5	795	80.1
2015	SMP16154.PR3	6/02/2016	6/16/2016	1001	109	300	33.6
			Totals	**42,956**	**615**	**35,680**	**84.3**
2016	BMI17129.PRE	5/09/2017	5/23/2017	7,996	18	7,279	91.2
2016	BMI17129.PRD	5/09/2017	5/25/2017	7,998	7	7,790	97.5
2016	BMI17143.PRC	5/23/2017	6/09/2017	7,981	32	7,714	97.0
2016	BMI17143.PRB	5/23/2017	6/12/2017	7,995	24	7,633	95.8
2016	BMI17144.PRA	5/24/2017	6/19/2017	7,995	46	7,633	96.0
2016	SMP17128.PR1	5/08/2017	5/23/2017	600	0	538	89.7
2016	SMP17129.PR2	5/09/2017	5/25/2017	600	0	579	96.5
2016	SMP17144.PR3	5/24/2017	6/09/2017	598	0	568	95.0
2016	SMP17144.PR4	5/24/2017	6/12/2017	601	0	581	96.7
2016	SMP17144.PR5	5/24/2017	6/19/2017	600	2	570	95.3
			Totals	**42,964**	**129**	**40,885**	**95.4**
2017	BMI2018128PRE	5/08/2018	5/23/2018	7,999	24	6,681	83.5
2017	BMI2018128PRD	5/08/2018	5/25/2018	7,997	11	6,957	87.0
2017	BMI2018149PRC	5/29/2018	6/11/2018	7,997	6	7,435	93.0
2017	BMI2018150PRB	5/30/2018	6/14/2018	7,997	15	6,916	86.5
2017	BMI2018151PRA	5/31/2018	6/20/2018	7,994	16	6,725	84.1
2017	SMP2018129002	5/09/2018	5/23/2018	599	4	508	84.8
2017	SMP2018129001	5/09/2018	5/25/2018	597	1	524	87.8
2017	SMP2018149PR3	5/29/2018	6/11/2018	599	1	556	92.8
2017	SMP2018149PR4	5/29/2018	6/14/2018	597	0	510	85.4
2017	SMP2018150PR5	5/30/2018	6/20/2018	597	0	505	84.6
			Totals	**42,973**	**78**	**37,317**	**86.8**
2018	BMI2019128PRE.XML	5/8/2018	5/22/2019	7,998	26	7240	90.5
2018	BMI2019128PRD.XML	5/8/2018	5/24/2019	8,001	61	7387	92.3
2018	BMI2019148PRC.XML	5/28/20179	6/10/2019	7,996	19	6743	84.3
2018	BMI2019149PRB.XML	5/29/2019	6/13/2109	7,998	19	7314	91.4
2018	BMI2019150PRA.XML	5/30/2019	6/17/2019	7,999	15	7665	95.8

Brood Year	Tag File	Tagging Date	Release Date	# Tagged	# of Tags Recovered from Facility Mortalities	# of Unique Detections	% Detected
2018	SMP2019127001.XML	5/7/2019	5/22/2019	600	2	580	96.7
2018	SMP2019128002.XML	5/8/2019	5/24/2019	599	4	577	96.3
2018	SMP2019148003.XML	5/28/2019	6/10/2019	599	0	568	94.8
2018	SMP2019149004.XML	5/29/2019	6/13/2109	599	2	580	96.8
2018	SMP2019149005.XML	5/29/2109	6/17/2019	601	2	598	99.5
			Totals	**42,990**	**150**	**39,252**	**91.3**

10.0 Adult Fish Pathogen Monitoring

At spawning, a portion of the adult fall Chinook broodstock are sampled for infectious hemotopoietic necrosis virus (IHNV), infectious pancreatic necrosis virus (IPNV), viral hemorrhagic septicemia virus (VHSV), paramyxovirus, aquaroviruses, as well as *Renibacterium salmoninarum*, the causative agent for bacterial kidney disease (BKD). Viral and bacterial screening included sampling the ovarian fluid and kidney/spleen for pathogens. All results of viral testing in since 1991 were classified as negative (Table 19).

Table 19 Viral inspections of fall Chinook salmon broodstock at Priest Rapids Hatchery, Return Years 1991-2018.

Year	Date(s)	Stock	Life stage	Ovarian Fluid	Kidney/Spleen	Results
1991	28-Oct, 4, 13-Nov	Priest Rapids	Adult	150	60	Negative
1992	2,9-Nov	Priest Rapids	Adult	150	60	Negative
1993	25-Oct, 1-Nov	Priest Rapids	Adult	150	60	Negative
1994	7-Nov	Priest Rapids	Adult	60	60	Negative
1995	9,13,19,21-Nov	Priest Rapids	Adult	160	160	Negative
1996	17-Nov	Priest Rapids	Adult	60	60	Negative
1997	17-Nov	Priest Rapids	Adult	60	60	Negative
1998	16-Nov	Priest Rapids	Adult	60	60	Negative
1999	8-Nov	Priest Rapids	Adult	60	60	Negative
2000	13-Nov	Priest Rapids	Adult	60	60	Negative
2001	13-Nov	Priest Rapids	Adult	60	60	Negative
2002	13-Nov	Priest Rapids	Adult	60	60	Negative
2003	17-Nov	Priest Rapids	Adult	60	60	Negative
2004	8-Nov	Priest Rapids	Adult	60	60	Negative
2005	14-Nov	Priest Rapids	Adult	60	60	Negative
2006	6-Nov	Priest Rapids	Adult	60	60	Negative
2007	5-Nov	Priest Rapids	Adult	60	60	Negative
2008	3-Nov	Priest Rapids	Adult	60	60	Negative
2009	2-Nov	Priest Rapids	Adult	60	60	Negative
2010	15-Nov	Priest Rapids	Adult	60	60	Negative
2011	7,14, 21-Nov	Priest Rapids	Adult	180	180	Negative
2012	5-Nov	Priest Rapids	Adult	60	60	Negative
2013	18-Nov	Priest Rapids	Adult	60	60	Negative
2014	18-Nov	Priest Rapids	Adult	60	60	Negative
2015	11-Nov	Priest Rapids	Adult	60	60	Negative
2016	8-Nov	Priest Rapids	Adult	60	60	Negative
2017	1,3,8-Nov	Priest Rapids	Adult	268	268	Negative
2018	5-Nov	Priest Rapids	Adult	60	60	Negative

Annual testing for BKD was initiated with the 2008 broodstock to address concerns associated with shipping eyed-eggs to Bonneville Hatchery for the USACE RSH production. The risk of BKD was assayed using the enzyme linked immunosorbent assay (ELISA) for *R. salmoninarum* antigen (Elliot 2012). Adult broodstock BKD monitoring in 2018 indicated that 59 of the 60 (98.3%) females tested had ELISA values less than an optical density of 0.10 (Below Low); 1 of the 60 (1.7%) samples was in the Low category between 0.10 and 0.199 (Table 20). Since 2008, tests have shown very low percentages of fish with values greater than 0.10.

Table 20 ELISA test results to determine risk of bacterial kidney disease of adult female fall Chinook salmon broodstock at Priest Rapids Hatchery, Return Years 2008-2018.

Year	Stock	N	%Below-Low	% Low	% Mod	% High
2008	Priest Rapids	60	100.0%	0.0%	0.0%	0.0%
2009	Priest Rapids	60	100.0%	0.0%	0.0%	0.0%
2010	Priest Rapids	60	100.0%	0.0%	0.0%	0.0%
2011	Priest Rapids	135	100.0%	0.0%	0.0%	0.0%
2012	Priest Rapids	60	98.3%	0.0%	1.7%	0.0%
2013	Priest Rapids	60	100.0%	0.0%	0.0%	0.0%
2014	Priest Rapids	60	100.0%	0.0%	0.0%	0.0%
2015	Priest Rapids	60	98.3%	1.7%	0.0%	0.0%
2016	Priest Rapids	60	98.3%	1.7%	0.0%	0.0%
2017[a]	Priest Rapids	268	99.6%	0.4%	0.0%	0.0%
2018	Priest Rapids	60	98.3%	1.7%	0.0%	0.0%

[a] Oregon Department of Fish and Wildlife tested 268 adults originating from PRH and incorporated into the Umatilla-John Day Mitigation Program for BKD. These fish were trapped at PRH and then transported and spawned at RSH in early November

10.1 Juvenile Fish Health Inspections

Juvenile fish are inspected for the presence of pathogens and other conditions following ponding (AFS-FHS 2014). The results of the examinations of juveniles from brood years 2010 through 2018 are summarized in Table 21. During 2019, the juveniles in raceway banks C, D, and E were subject to elevated mortality during early rearing. Juveniles in raceway pond E appeared healthy upon release. Juveniles in raceway pond D showed no significant disease issues; however, elevated mortalities were observed prior to release. The presence of bacterial gill disease in very low levels appeared in raceway ponds A, B, and C. Historical inspection results for brood years 1995 through 2009 are provided in Appendix C.

Table 21 Juvenile fish health inspections for Priest Rapids Hatchery fall Chinook salmon, Brood Years 2006-2018.

Date	Stock	Brood Year	Condition
18-Feb-10	Priest Rapids	2009	Coagulated Yolk Syndrome observed in some fish sampled
1-Apr-10	Priest Rapids	2009	Healthy
19-May-10	Priest Rapids	2009	Healthy
25-Mar-11	Priest Rapids	2010	Healthy
18-Apr-11	Priest Rapids	2010	Healthy
06-Jun-11	Priest Rapids	2010	Healthy
01-Mar-12	Priest Rapids	2011	Healthy
26-Apr-12	Priest Rapids	2011	Healthy

Date	Stock	Brood Year	Condition
24-May-12	Priest Rapids	2011	Healthy
11-Feb-13	Priest Rapids	2012	Healthy
3-Mar-13	Priest Rapids	2012	Healthy
29-Apr-13	Priest Rapids	2012	Healthy
28-May-13	Priest Rapids	2012	Healthy
27-Mar-14	Priest Rapids	2013	Dropout Syndrome present
23-Apr-14	Priest Rapids	2013	Dropout Syndrome present
29-May-14	Priest Rapids	2013	Healthy
26-Feb-15	Priest Rapids	2014	Coagulated Yolk Syndrome observed in some fish sampled
26-Mar-15	Priest Rapids	2014	Healthy
21-Apr-15	Priest Rapids	2014	Healthy
28-May-15	Priest Rapids	2014	Healthy
22-June-15	Priest Rapids	2014	Columnaris present in some fish sampled from Channel Pond B.
24-Feb-16	Priest Rapids	2015	Healthy
15-Mar-16	Priest Rapids	2015	Coagulated Yolk Syndrome observed in some fish sampled
15-June-16	Priest Rapids	2015	Mild Ich infection but healthy and ready for release
24-Feb-17	Priest Rapids	2016	Presence of bacterial gill disease in Raceway Bank D and E
21-Mar-17	Priest Rapids	2016	Presence of bacterial gill disease in Raceway Pond B2
6-June-17	Priest Rapids	2016	Mild Ich infection in Channel Ponds A, B, C
21-Mar-18	Priest Rapids	2017	Healthy
19-Apr-18	Priest Rapids	2017	Bacterial gill dieses present in Raceway Pond C4
7-May-18	Priest Rapids	2017	Bacterial gill dieses present in Raceway Ponds C2 and C3
17-May-18	Priest Rapids	2017	Re-examine of Raceway Ponds C2 and C3 found fish healthy
17-May-18	Priest Rapids	2017	Pre-release examine Raceway Ponds D and E found fish healthy C2 and C3 found fish healthy
6-June-18	Priest Rapids	2017	Pre-release examine of Raceway Ponds A and B found fish healthy
2-Feb-19	Priest Rapids	2018	Examinations of Raceway Banks C, D, E resulted from reports of elevated mortalities. Some fish were found to appear thin and pin-headed. Results of internal necropsies were within normal limits.
5-May-19	Priest Rapids	2018	Pre-release examinations of Raceway Pond E found fish healthy
5-May-19	Priest Rapids	2018	Pre-release examinations of Raceway Pond D resulted in no significant findings of diseases however elevated mortalities were observed. Mortalities examined showed lower levels of coelomic fat and ingesta in GI tracts compared to live fish examined.
6-June-19	Priest Rapids	2018	Pre-release examinations of Raceway Ponds A, B, and C found very low levels of bacterial gill disease

11.0 Redd Survey

Fall Chinook salmon redd surveys were performed in the Hanford Reach during 2018 by staff with Mission Support Alliance under contract with the United States Department of Energy. WDFW M&E staff performed fall Chinook salmon redd surveys in the PRH discharge channel during 2018.

11.1 Hanford Reach Aerial Redd Counts

Aerial redd counts in the Hanford Reach were performed by Mission Support Alliance on October 22, November 5, and 16 during 2018 (USDOE In Press). Redd counts should be considered an index of the total number of redds in the Hanford Reach. Redds may not be visible during flights due to wind, turbidity, ambient light, and depth. The first two surveys occurred on a Tuesday. The last survey occurred on Monday. None of the surveys took advantage of the low Sunday outflows at Priest Rapids Dam when flows were lowered to nearly 47 kcfs in conjunction with the Vernita Bar Settlement Agreement surveys performed by Grant PUD and WDFW. It is reported that viewing conditions during the surveys were generally fair on the last flight; high clouds and light wind. The peak fall Chinook Salmon redd count for the Hanford Reach in 2018 was 5,429 (Table 22).

Table 22 Summary of fall Chinook salmon peak redd counts for the 1948-2018 aerial surveys in the Hanford Reach, Columbia River.

Year	Redds	Year	Redds	Year	Redds	Year	Redds	Year	Redds
1948	787	1963	1,254	1978	3,028	1993	2,863	2008	5,588
1949	313	1964	1,477	1979	2,983	1994	5,619	2009	4,996
1950	265	1965	1,789	1980	1,487	1995	3,136	2010	8,817
1951	297	1966	3,101	1981	4,866	1996	7,618	2011	8,915
1952	528	1967	3,267	1982	4,988	1997	7,600	2012	8,368
1953	139	1968	3,560	1983	5,290	1998	5,368	2013	17,398
1954	160	1969	4,508	1984	7,310	1999	6,068	2014	15,951
1955	60	1970	3,813	1985	7,645	2000	5,507	2015	20,678
1956	75	1971	3,600	1986	8,291	2001	6,248	2016	13,268
1957	525	1972	876	1987	8,616	2002	8,083	2017	8,646
1958	798	1973	2,965	1988	8,475	2003	9,465	2018	5,429
1959	281	1974	728	1989	8,834	2004	8,468		
1960	258	1975	2,683	1990	6,506	2005	7,891		
1961	828	1976	1,951	1991	4,939	2006	6,508		
1962	1,051	1977	3,240	1992	4,926	2007	4,023		
								Mean (2009 - 2018)	**10,724**

11.2 Redd Distribution

The main spawning areas observed during the 2018 counts were located near Vernita Bar and among Islands 4-6 (Table 23 & Figure 8). Historical redd counts by location from 2001 through 2018 are included in Appendix D of this report.

Table 23 Number of all Chinook salmon redds counted in difference reaches on the Hanford Reach area of the Columbia River during October 2018 through November 2018 aerial redd counts. (Data provided by Mission Support Alliance).

General Location	Start KM	End KM	Total Length	22-Oct	5-Nov	16-Nov	Max Count	Avg. Redd Per River KM
Islands 17-21	545	558	13	0	0	0	0	0
Islands 11-16	558	573	15	0	4	88	88	6
Islands 8-10	587	593	6	1	94	485	485	81
Near Island 7	593	594	1	3	22	350	350	350
Island 6 (lower half)	594	599	5	9	400	950	950	190
Island 4, 5 and upper 6	599	602	3	6	293	605	605	202

General Location	Start KM	End KM	Total Length	22-Oct	5-Nov	16-Nov	Max Count	Avg. Redd Per River KM
Near Island 3	602	604	2	0	125	310	310	155
Near Island 2	604	606	2	4	300	550	550	275
Near Island 1	606	608	2	0	70	170	170	85
Near Coyote Rapids	608	619	11	0	40	51	51	5
Midway (China Bar)	620	630	10	0	9	25	25	3
Near Vernita Bar	630	635	5	15	1,120	1,840	1,840	368
Near Priest Rapids Dam	635	638	3	0	4	5	5	2
Total	--	--	--	**38**	**2,481**	**5,429**	**5,429**	--

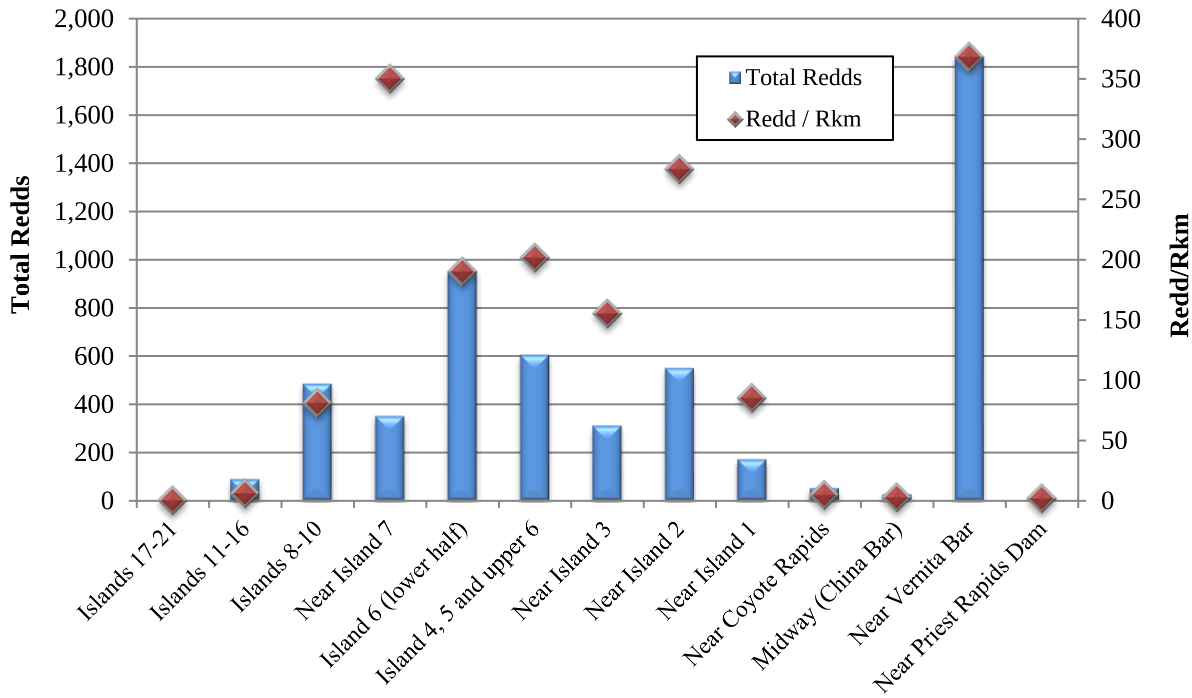

Figure 8 **Distribution of fall Chinook salmon redd counts by location for the 2018 aerial surveys in the Hanford Reach, Columbia River. (Data provided by Mission Support Alliance).**

11.3 Spawn Timing

Based on aerial redd counts and Vernita Bar spawning ground surveys, fall Chinook salmon spawning in the Hanford Reach during 2018 began in late October and ended in late November. River temperatures below Priest Rapids Dam varied from 15.4°C (October 20) to 10.3°C (November 25) during the spawning period which is typical to that of previous years.

11.4 Escapement

The estimated total escapement of fall Chinook salmon to the Hanford Reach for the 2018 return year was 46,624 fish (Table 24). The historical mean and median escapement for 1991 through 2018 is 74,126 and 56,459 fish, respectively (Table 25). The estimated adult Chinook salmon per redd is calculated by dividing the adult escapement to the Hanford Reach by peak number of redds reported in the redd survey. The estimated annual escapements to the Hanford Reach were not adjusted for pre-spawn mortality. For 2018, the estimated nine fish per redd was the same as the historical mean.

Table 24 Calculation of escapement estimates for fall Chinook salmon in the Hanford Reach, Columbia River 2018.

Count Source	Return Year 2018 Adult	Jack	Total
McNary Ladder Counts	100,801	13,645	114,446
Adjusted Priest Rapids Adult Passage[1]	15,170	1,770	16,940
Ice Harbor Adult Passage	16,599	4,544	21,143
Prosser Adult Passage	1,117	74	1,191
Priest Rapids Hatchery	14,636	1,535	16,171
Wanapum Tribal Fishery	20	3	23
Ringold Springs Hatchery	545	254	799
Yakima River Escapement (Below Prosser)	323	21	344
Yakima River Sport Harvest	205	25	230
Hanford Sport Harvest	8,672	1,074	9,746
Angler Broodstock Collection	1235	0	1,235
Total Non-Hanford Reach Escapement	**58,522**	**9,300**	**67,822**
Hanford Reach Escapement	**42,279**	**4,345**	**46,624**

[1] Gross passage count reduced 16.2% to correct for estimated over counts resulting from fallbacks and re-ascension. The adjustments to adult fish passage were estimated by analysis of the PIT tag detections at PIT tag arrays located in the adult fish ways of the Priest Rapids Dam adult fishway and the discharge channel for Priest Rapids Hatchery.

Table 25 Escapement for fall Chinook salmon in the Hanford Reach, Return Years 1991-2018.

Return Year	# Fish per Redd	Redds	Total Escapement[1]
1991	11	4,939	52,196
1992	9	4,926	41,952
1993	13	2,863	37,347
1994	11	5,619	63,103
1995	18	3,136	55,208
1996	6	7,618	43,249
1997	6	7,600	43,493
1998	7	5,368	35,393
1999	5	6,068	29,812
2000	9	5,507	48,020
2001	10	6,248	59,848
2002	10	8,083	84,509
2003	11	9,465	100,508
2004	10	8,468	87,696
2005	9	7,891	71,967
2006	8	6,508	51,701
2007	6	4,018	22,272
2008	5	5,618	29,058
2009	7	4,996	36,720
2010	10	8,817	87,016
2011	8	8,915	75,256
2012	7	8,368	57,710

Return Year	# Fish per Redd	Redds	Total Escapement[1]
2013	10	17,398	174,651
2014	12	15,951	183,749
2015	13	20,678	266,327
2016	9	13,268	116,388
2017	9	8,646	73,759
2018	9	5,429	46,624
Mean	**9**	**7,943**	**74,126**
Median	**8**	**7,054**	**56,459**

[1] Escapement includes adults and jacks

11.5 Hatchery Discharge Channel Redd Counts

The M&E observed 42 redds during the survey in the PRH discharge channel on December 13, 2018. Similar to historical observations, the majority of spawning activity was located in a 200 meter section of the discharge channel adjacent to the volunteer trap. We observed superimposition occurring during multiple brief site visits during November; thus making it difficult to determine the total number of redds in the formal survey. Viewing conditions during the survey were good.

12.0 Carcass Surveys

Prior to 2010, the carcass surveys in the Hanford Reach were generally performed by two boat crews of two staff operating seven days a week. Beginning in 2010, with support of the PRH M&E Program, the effort was increased to three boats with a three-person crew operating seven days per week. The extra staffing was necessary to maintain the overall sampling efficiency given the additional effort required to pull otoliths from fish sampled and achieve hatchery M&E objectives. The sampling goal for obtaining sufficient number of CWTs is 10% of the escapement.

Carcass surveys were performed from November 3 through December 13, 2018. All recovered carcasses were screen for the presence of a CWT which was collected if present. Roughly 50% of the fish recovered were sampled (i.e., random systematic 1:2 rate) for scales (age), otoliths, gender, length, and egg retention. All carcasses recovered were chopped in half after sampling to prevent the chance of double sampling during subsequent surveys.

Similar to methods used since 2010, the carcass survey crews recorded the sections in which carcasses were recovered in the Hanford Reach and adjacent areas. The Hanford Reach survey is divided into Sections 1 through 5 (Figure 9). The Priest Rapids Pool is designated as Section 6. The PRH discharge channel and the area of the Columbia River immediately below the discharge channel are designated as Sections 7 and 8, respectively. The fall Chinook salmon carcasses recovered in Section 8 were likely wash outs from the hatchery discharge channel.

- Section 1. Priest Rapids Dam to Vernita Bridge (14 km)
- Section 2. Vernita Bridge to Island 2 (19 km)
- Section 3. Island 2 to Powerline Towers at Hanford town site (21 km)
- Section 4. Power line Towers to Wooded Island (21 km)
- Section 5. Wooded Island to Interstate 182 Bridge (19 km)
- Section 6. Priest Rapids Pool (34 km)

- Section 7. Priest Rapids Hatchery discharge channel (0.5 km)
- Section 8. Columbia River at the mouth of the Hatchery discharge channel (0.5 km)

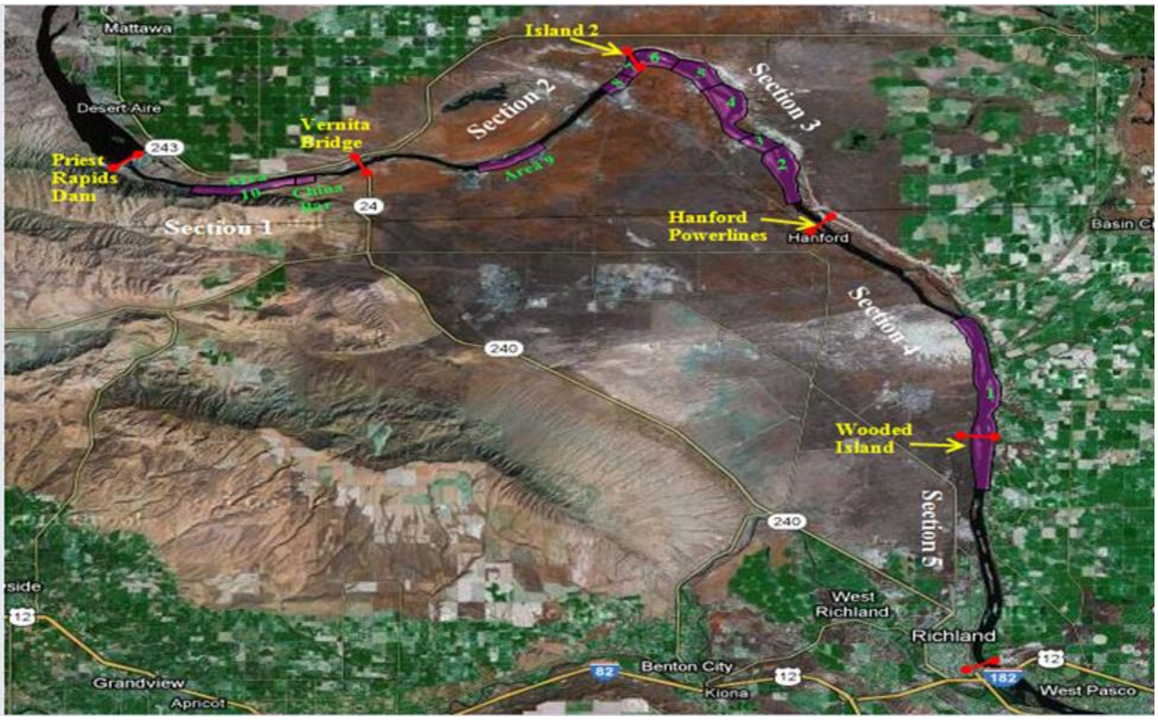

Figure 9 **Location of aerial redd index areas (green area numbers) and river boat carcass survey sections in the Hanford Reach.**

12.1 Hanford Reach Carcass Survey: Section 1 – 5

Staff recovered 2,771 fall Chinook salmon carcasses in the Hanford Reach in 2018; equating to 5.9% of the estimated fall Chinook salmon escapement (Table 26). The annual number of fall Chinook salmon carcass recovered in the Hanford Reach for the period of 1991 through 2018 is provided in Appendix E.

Table 26 **Numbers and proportions of total escapement of fall Chinook salmon carcasses surveyed for coded-wire tags within each survey section on the Hanford Reach, Return Years, 2010-2018.**

Return Year	# 1		# 2		# 3		# 4		# 5		Total Sampled		Escapement
	N	P^	N	P^	N	P^	N	P^	N	P^	N	P^	
2010	1,832	0.021	519	0.006	3,129	0.036	3,362	0.039	937	0.011	9,779	0.112	87,016
2011	1,581	0.021	160	0.002	2,606	0.035	2,622	0.035	1,422	0.019	8,391	0.111	75,256
2012	1,091	0.019	149	0.003	1,685	0.029	2,213	0.038	1,676	0.029	6,814	0.118	57,715
2013	2,182	0.012	1,973	0.011	2,844	0.016	3,774	0.022	2,298	0.013	13,071	0.075	174,651
2014	2,682	0.015	1,142	0.006	5,544	0.030	4,573	0.025	2,815	0.015	16,756	0.091	183,680
2015	2,913	0.011	823	0.003	6,187	0.023	5,868	0.022	1,947	0.007	17,738	0.067	266,346
2016	1,141	0.010	513	0.004	2,796	0.024	2,977	0.026	1,459	0.013	8,886	0.076	116,388
2017	1,098	0.015	346	0.005	1,275	0.170	1850	0.025	1,022	0.014	5,591	0.076	73,759
2018	635	0.229	113	0.041	920	0.332	720	0.260	383	0.138	2,771	0.059	46,624
Mean	**1,684**	**0.039**	**638**	**0.009**	**2,998**	**0.077**	**3,107**	**0.055**	**1,551**	**0.029**	**9,977**	**0.087**	**120,159**

The survey effort was not equal for each section. Sections 3 and 4 were surveyed the most because these sections generally contain the largest number of carcasses (Table 27). As each season progresses, crews focused their effort in sections that provided greater chances to recover carcasses.

Table 27 Number of carcass surveys conducted by section in the Hanford Reach, Return Years 2010-2018.

Return Year	# 1	# 2	# 3	# 4	# 5	Total
2010	21	6	26	26	11	90
2011	33	5	38	29	13	118
2012	19	4	26	28	24	101
2013	18	15	16	17	13	79
2014	23	17	30	31	24	125
2015	23	8	35	37	13	116
2016	18	11	29	27	15	100
2017	19	14	30	31	17	111
2018	20	9	31	22	17	99
Mean	**22**	**10**	**29**	**28**	**16**	**104**

12.2 Proportion of Escapement Sampled: Section 1-5

The spawning escapement for sections 1 through 5 was estimated by the proportion of redds counted in aerial surveys to the estimated escapement of natural spawners in the Hanford Reach (see Section 14 - Redd Surveys). The calculations for estimating the escapement to the Hanford Reach are given in Appendix F.

We have identified through the carcass bias assessment that an unknown number of carcasses drift into downstream sections after spawning. The recovery of these carcasses may confound the estimate of the spawning escapement sampled by section as shown in Table 28. As seen in prior years there were no redds identified in Section 5 but hundreds of carcasses were recovered in that section. It is likely that sections 1 and 3, that have the greatest number of redds and largest spawning escapement, end up with a net loss of carcasses to downstream sections. In 2018, we continued a pilot study to evaluate the magnitude and distribution of post spawn carcass drift. The preliminary results of this study are included in the Appendix G.

Table 28 Number of redds and carcasses, total spawning escapement, and proportion of escapement sampled for fall Chinook salmon in Section 1 through 5 of the Hanford Reach, Return Year 2018.

Survey Section	Total Number of Redds	Total Number of Carcasses	Spawning Escapement[1]	Proportion of Escapement Sampled
1	1,870	635	16,059	0.040
2	221	113	1,898	0.138
3	3,250	920	27,911	0.025
4	88	720	756	0.471
5	0	383	0	--
Total	5,429	**2,771**	46,624	0.059

[1] Calculated based on proportion of redds by section

12.3 Carcass Distribution and Origin

Two methods were used to estimate the origin of carcasses recovered in the sections 1 through 5. The first method includes the expansion of pooled CWT recoveries using juvenile tag rates and survey sample rate. The second method includes calculating the proportion of combined hatchery marks (i.e., otolith mark, adipose clips, and CWTs) in the sampled population. Estimates for both methods are given for the 2012 - 2018 adult returns: these years include otolith marks for all ages of PRH origin fish.

The assumption was made that all Chinook salmon not accounted by hatchery origin CWT expansions were of natural origin. This assumption may underestimate the number of hatchery carcasses recovered in the annual surveys. We have compelling evidence to suggest this is the case with annual returns to PRH prior to return year 2014. The expansion of CWT recoveries suggests that 5.9% of the fall Chinook salmon carcasses recovered in the 2018 Hanford Reach stream surveys were hatchery origin (Table 29). This estimate is lower than the mean pHOS (9.1%) value generated from CWT recoveries for years 2010 through 2018. The expanded CWT recovery data suggest the hatchery origin component of the escapement included 4.9% from PRH, 0.3% from RSH and 0.7% from other hatcheries. The highest proportions of hatchery origin carcasses recovered based on CWT recoveries were in Sections 2, and 1, respectively.

The second estimate of origin of carcasses recovered is based on the proportion of hatchery marked to non-marked fish. For this method, we assume that all hatchery origin carcasses recovered are marked in some manner (e.g., otolith marks, CWT, and adipose clips) and that we are able to accurately detect these marks and tags.

PRH has marked their entire juvenile releases with thermal marks on the otoliths beginning with progeny of brood year 2007: Hence, all PRH origin returns since 2013 were otolith marked. The age-6 PRH origin fish were not otolith marked during return year 2012. However, since there were no age-6 fish recovered in the carcass surveys or at PRH, it is assumed that few, if any PRH origin age-6 fish spawned in the Hanford Reach. Adipose clipped Chinook salmon without a CWT and without a thermal otolith mark were classified as strays from other hatcheries. The natural origin fish were identified by either a Hanford Reach origin CWT or by the presence of an adipose fin and the absence of an otolith mark. The demographic sample data suggests that 6.9% of fall Chinook salmon carcasses recovered in the 2018 Hanford Reach stream survey were hatchery origin (Table 30). For recent years, the hatchery proportions were generally higher in the upstream survey sections.

Table 29 Numbers of natural and hatchery origin fall Chinook salmon carcasses sampled within Section 1 through 5 of Hanford Reach based on expansions of coded-wire tag recoveries, Return Years 2010-2018.

Return Year	Hanford Reach Sections						
	Origin	# 1	# 2	# 3	# 4	# 5	Total
2010	Natural	1,751	473	3,020	3,242	909	9,395
	Hatchery	81	46	116	125	28	396
	Proportion Hatchery	0.044	0.089	0.037	0.037	0.030	0.040
2011	Natural	1,350	155	2,520	2,475	1,347	7,847
	Hatchery	231	5	86	147	75	544
	Proportion Hatchery	0.146	0.031	0.033	0.056	0.053	0.065
	Natural	1,142	149	1,526	2,081	1,510	6,408

Return Year	Origin	# 1	# 2	# 3	# 4	# 5	Total
		Hanford Reach Sections					
2012	Hatchery	49	0	159	132	166	506
	Proportion Hatchery	0.041	0.000	0.094	0.060	0.099	0.073
2013	Natural	1,572	1,587	2,433	2,895	1,748	10,235
	Hatchery	610	386	411	879	550	2,836
	Proportion Hatchery	0.280	0.196	0.145	0.233	0.239	0.217
2014	Natural	2,469	1,072	5,264	4,329	2,703	15,838
	Hatchery	213	70	280	244	112	918
	Proportion Hatchery	0.079	0.061	0.050	0.053	0.040	0.055
2015	Natural	2,654	709	5,745	5,490	1,858	16,456
	Hatchery	259	114	442	378	89	1,282
	Proportion Hatchery	0.089	0.139	0.071	0.064	0.046	0.072
2016	Natural	1,108	256	2,585	2,866	684	8,111
	Hatchery	162	33	257	211	111	775
	Proportion Hatchery	0.142	0.064	0.092	0.071	0.076	0.087
2017	Natural	1,015	260	1,173	1,648	863	4,958
	Hatchery	83	86	102	202	175	649
	Proportion Hatchery	0.076	0.249	0.080	0.109	0.169	0.116
2018	Natural	578	101	881	694	355	2,608
	Hatchery	57	12	39	26	28	163
	Proportion Hatchery	0.090	0.106	0.043	0.037	0.073	0.059
Mean	**Proportion**	**0.128**	**0.158**	**0.075**	**0.091**	**0.111**	**0.099**

Table 30 Origin of Chinook salmon carcasses recovered in the Hanford Reach by section based on recoveries of marked and unmarked carcasses within the biological sample, Return Years 2012-2018.

Year	Origin	# 1	# 2	# 3	# 4	# 5	Total	Proportion of Sample
2012 Biological sample Rate 1:4 N = 1,609	PRH[1]	23	2	26	18	38	107	0.067
	Other Hatchery[2]	10	2	25	45	22	104	0.065
	Total Hatchery	**33**	**4**	**51**	**63**	**60**	**211**	**0.131**
	Natural[3]	228	30	347	460	333	1,398	0.869
	Proportion Hatchery	0.126	0.118	0.128	0.120	0.153	0.131	
2013[a] Biological sample rate = 1:5 and then randomly sub-sampled, N = 712	PRH[1]	32	19	34	30	32	147	0.206
	Other Hatchery[2]	6	3	16	21	6	52	0.073
	Total Hatchery	**38**	**22**	**50**	**51**	**38**	**199**	**0.279**
	Natural[3]	76	84	113	155	85	513	0.721
	Proportion Hatchery	0.333	0.208	0.307	0.248	0.309	0.279	
2014[a] Biological sample rate = 1:5 and then randomly sub-sampled, N = 2,426	PRH[1]	37	7	45	35	11	135	0.056
	Other Hatchery[2]	12	5	16	32	18	83	0.034
	Total Hatchery	**49**	**12**	**61**	**67**	**29**	**218**	**0.090**
	Natural[3]	347	142	711	612	396	2208	0.910
	Proportion Hatchery	0.124	0.078	0.079	0.099	0.068	0.090	
	PRH[1]	47	12	61	55	13	188	0.076

Year	Origin	# 1	# 2	# 3	# 4	# 5	Total	Proportion of Sample
2015 Biological sample rate = 1:7 N = 2,485	Other Hatchery[2]	6	2	17	20	7	52	0.021
	Total Hatchery	**53**	**14**	**78**	**75**	**20**	**240**	**0.097**
	Natural[3]	346	101	792	752	254	2,245	0.903
	Proportion Hatchery	0.133	0.122	0.090	0.091	0.073	0.097	
2016 Biological sample rate = 1:5 N = 1,743	PRH[1]	27	12	42	22	10	113	0.066
	Other Hatchery[2]	9	6	31	23	13	82	0.048
	Total Hatchery	**36**	**18**	**73**	**45**	**23**	**195**	**0.114**
	Natural[3]	182	80	465	534	257	1,518	0.886
	Proportion Hatchery	0.165	0.184	0.136	0.078	0.082	0.114	
2017 Biological sample rate = 1:3 N = 1,813	PRH[1]	42	19	21	19	16	117	0.065
	Other Hatchery[2]	7	2	4	14	6	33	0.018
	Total Hatchery	**49**	**21**	**25**	**33**	**22**	**150**	**0.083**
	Natural[3]	311	86	391	564	311	1,663	0.917
	Proportion Hatchery	0.136	0.196	0.060	0.055	0.066	0.083	
2018 Biological sample rate = 1:2 N = 1,325	PRH[1]	28	6	11	11	6	63	0.047
	Other Hatchery[2]	7	2	8	10	2	29	0.022
	Total Hatchery	**35**	**8**	**19**	**21**	**8**	**92**	**0.069**
	Natural[3]	245	72	422	318	177	1,236	0.931
	Proportion Hatchery	0.127	0.100	0.043	0.062	0.043	0.069	
Mean Proportion	**PRH[1]**	**0.132**	**0.109**	**0.079**	**0.057**	**0.078**	**0.083**	
	Other Hatchery[2]	**0.032**	**0.035**	**0.041**	**0.050**	**0.035**	**0.040**	
	Total Hatchery	**0.164**	**0.144**	**0.120**	**0.107**	**0.113**	**0.123**	
	Natural[3]	**0.837**	**0.856**	**0.880**	**0.893**	**0.887**	**0.877**	

[a] Estimate of origin based on random sub-sample of biological sample.
[1] Priest Rapids Hatchery fish were identified by either the presence Priest Rapids Hatchery otolith mark or coded-wire tag
[2] Other hatchery strays were identified as adipose clipped Chinook salmon without a Priest Rapids Hatchery coded-wire tag and without a thermal otolith mark or by the presence of other hatchery coded-wire tags.
[3] Natural origin fish were identified by either a Hanford Reach origin coded-wire tag or by the presence of an adipose fin and the absence of an otolith mark.

12.4 Priest Rapids Dam Pool Carcass Survey: Section 6

Carcass surveys performed in Section 6 on November 17 and 27 during return year 2018 (Table 31**Error! Reference source not found.**).

12.5 Number Sampled: Section 6

Survey crews recovered 57 Chinook salmon in Section 6 during return year 2018 (Table 31**Error! Reference source not found.**). All fish recovered were scanned for the presence of a CWT. Carcass recoveries in the lower portion of the pool suggest that carcasses drift downstream of the spawning areas below Wanapum Dam into deeper water where they are difficult to locate and recover.

12.5.1 Proportion of Escapement Sampled: Section 6

The spawning escapement for Section 6 was calculated by subtracting from the Priest Rapids Dam fall Chinook salmon passage count, the fall Chinook salmon passage at Wanapum Dam, tribal and sport harvest of fall Chinook salmon in the Priest Rapids Dam pool, and the estimated fallback of fall Chinook salmon at Priest Rapids Dam (Appendix F).

The 2018 fall Chinook salmon spawning escapement estimate for Section 6 is 2,876 fish. Overall, 2% of the total estimated spawning escapement in Section 6 was sampled in 2018 (Table 31).

Table 31 Carcasses sampled, total spawning escapement and proportion of escapement for fall Chinook salmon in Section 6 (Priest Rapids Dam Pool), Return Years 2010-2018.

Return Year	# of Surveys	# of Carcasses	Spawning Escapement	Escapement Sampled
2010	8	123	11,121	0.011
2011	7	69	11,362	0.006
2012	4	72	21,919	0.003
2013	7	407	62,237	0.007
2014	7	237	25,179	0.009
2015	6	155	38,313	0.004
2016	8	139	13,162	0.011
2017	5	40	1,788	0.022
2018	2	57	2,876	0.020
Mean	**6**	**144**	**20,884**	**0.010**

12.5.2 Carcass Origin: Section 6

Similar to those methods described in detail in the previous section, the carcasses included in the 1:1 demographic sample were identified as hatchery origin based on a combination of hatchery marks and tags (i.e., otoliths marks, adipose clips, and CWTs). Natural origin carcasses were identified by the absence of any hatchery mark or the presence of a natural origin CWT. An estimated 16.1% of the fall Chinook salmon carcasses recovered in Section 6 were hatchery origin of which most all were PRH origin (Table 32).

Table 32 Origin of fall Chinook salmon spawning in Section 6 (Priest Rapids Dam Pool), Return Years 2012-2018.

Year	Origin	Total	Proportion of Sample
2012 N = 70	PRH[1]	18	0.257
	Other Hatchery[2]	2	0.029
	Total Hatchery	**20**	**0.286**
	Natural[3]	50	0.714
2013 N = 98	PRH[1]	62	0.633
	Other Hatchery[2]	5	0.051
	Total Hatchery	**67**	**0.684**
	Natural[3]	31	0.316
2014 N = 229	PRH[1]	81	0.354
	Other Hatchery[2]	5	0.022
	Total Hatchery	**86**	**0.376**
	Natural[3]	143	0.624
2015	PRH[1]	83	0.535
	Other Hatchery[2]	3	0.019

Year	Origin	Total	Proportion of Sample
N = 244	**Total Hatchery**	**155**	**0.555**
	Natural[3]	69	0.445
2016 N = 134	PRH[1]	66	0.475
	Other Hatchery[2]	3	0.022
	Total Hatchery	**69**	**0.496**
	Natural[3]	65	0.468
2017 N = 40	PRH[1]	15	0.375
	Other Hatchery[2]	1	0.025
	Total Hatchery	**16**	**0.400**
	Natural[3]	24	0.600
2018 N = 56	PRH[1]	8	0.143
	Other Hatchery[2]	1	0.018
	Total Hatchery	**9**	**0.161**
	Natural[3]	47	0.839
Mean Proportions	**PRH[1]**		**0.396**
	Other Hatchery[2]		**0.024**
	Total Hatchery		**0.420**
	Natural[3]		**0.575**

[1] Priest Rapids Hatchery fish were identified by either the presence of thermal otolith mark or by the presence of a PRH origin coded-wire tag

[2] Other hatchery strays were identified as adipose clipped Chinook salmon without a Priest Rapids Hatchery coded-wire tag and without a thermal otolith mark.

[3] Natural origin fish were identified by either a Hanford Reach origin coded-wire tag or by the presence of an adipose fin and the absence of an otolith mark.

12.6 Hatchery Discharge Channel: Section 7 and 8 Carcass Survey

During return year 2018, crews performed two carcass surveys in Section 8 by boat and one carcass survey in Section 7 by foot. It has been observed that many carcasses drift out of the discharge channel under full flow conditions. Performing carcass surveys in the discharge channel when it is at full flow is difficult and dangerous due to poor footing and high velocities. Staff performed the one survey in Section 7 on December 13 when discharge levels in the channel were still high. It’s likely a portion of the carcasses may have drifted out of the discharge channel by the date that it was surveyed.

12.7 Number sampled: Section 7 and 8

Survey crews recovered 3 carcasses in Section 7 and 0 in Section 8 (Table 33). All fish recovered were scanned for the presence of a CWT.

Table 33 The number of fall Chinook salmon carcass surveys within Section 7 (Priest Rapids Hatchery Discharge Channel) and Section 8 (Columbia River at the confluence of the hatchery discharge channel), Return Years 2010-2018.

Return Year	Section 7		Section 8		Total	
	# of Carcasses	# of Surveys	# of Carcasses	# of Surveys	# of Carcasses	# of Surveys
2010	87	1	123	9	210	10
2011	123	2	80	8	203	10
2012	99	3	108	10	207	13
2013	105	3	159	4	264	7
2014	9	1	52	7	61	8
2015	33	1	26	2	59	3
2016	3	1	7	1	10	2
2017	9	1	16	1	25	2
2018	3	1	0	2	3	3
Mean	**50**	**2**	**63**	**5**	**116**	**6**

12.7.1 Proportion of Escapement Sampled: Section 7 and 8

The 2018 fall Chinook salmon spawning escapement index for Sections 7 and 8 is 80 fish (Table 34). The spawning escapement for these Sections was calculated using the expansion factor of one female/redd and a 0.9 male/female sex ratio including jacks, as estimated from the Hanford Reach 2018 escapement. Therefore, the assumption is made that each of the 42 redds represents one female and 0.9 males. In the past, we assumed that most of the carcasses recovered in Section 8 drifted downstream from Section 7. Since no carcasses were recovered in Section 8 it is likely a portion of carcasses from Sections 7 and 8 drift downstream into Sections 1 and 2.

Table 34 Number of carcasses sampled, total spawning escapement and proportion of escapement sampled for fall Chinook salmon within Section 7 (Priest Rapids Hatchery Discharge Channel) and Section 8 (Columbia River at confluence of the hatchery discharge channel), Return Year 2018.

Section	Total Number of Carcasses	Spawning Escapement	Escapement Sampled
# 7	3	80	0.038
# 8	0	0	
Total	**3**	**80**	**0.038**

12.7.2 Carcass Distribution and Origin: Section 7 and 8

The demographic sample rate was set at 1:1 to account for the low numbers of carcasses recovered. As described in detail previously, the carcasses included the demographic sample were identified as hatchery origin based on a combination of hatchery marks and tags (i.e., otoliths marks, adipose clips, and CWTs). Natural origin carcasses were identified by the absence of any hatchery mark or the presence of a natural origin CWT.

It is estimated that 33.0% of fall Chinook salmon recovered in Sections 7 and 8 were hatchery origin of which all were PRH origin (Table 35).

Table 35 The origin of Chinook salmon carcasses recovered within Section 7 (Priest Rapids Hatchery Discharge Channel) and Section 8 (Columbia River at the confluence of the hatchery discharge channel), Return Years 2012-2018.

Return Year	Origin	Total	Proportion of Sample
2012 N = 70	PRH	18	0.257
	Other Hatchery	2	0.029
	Total Hatchery	**20**	**0.286**
	Natural	50	0.714
2013 N = 33	PRH	28	0.848
	Other Hatchery	2	0.061
	Total Hatchery	**30**	**0.909**
	Natural	3	0.091
2014 N= 5	PRH	3	0.600
	Other Hatchery	0	0.000
	Total Hatchery	**3**	**0.600**
	Natural	2	0.400
2015 N= 59	PRH	19	0.322
	Other Hatchery	2	0.034
	Total Hatchery	**21**	**0.356**
	Natural	38	0.644
2016 N=6	PRH	4	0.667
	Other Hatchery	1	0.167
	Total Hatchery	**5**	**0.833**
	Natural	1	0.167
2017 N=6	PRH	6	0.750
	Other Hatchery	0	0.000
	Total Hatchery	**6**	**0.750**
	Natural	2	0.250
2018 N = 3	PRH	1	0.333
	Other Hatchery	0	0.000
	Total Hatchery	**1**	**0.333**
	Natural	2	0.667
Means Proportions	**PRH**		**0.518**
	Other Hatchery		**0.021**
	Total Hatchery		**0.539**
	Natural		**0.461**

13.0 Life History Monitoring

Migration timing of hatchery and natural origin Hanford Reach fall Chinook salmon is estimated from arrival timing at Bonneville Dam based on PIT tag observations at the adult fish ladder for both PRH and Hanford Reach origin fall Chinook salmon.

Life history characteristics of Hanford Reach fall Chinook salmon were assessed by examining carcasses on spawning grounds, fish collected or examined at broodstock collection sites, and by reviewing tagging data and fisheries statistics.

For the 2012 - 2018 returns, the origin of fall Chinook salmon for the comparison of age and length at maturity is based on a combination of hatchery marks and tags (i.e., otolith, adipose clips, and CWT). PRH origin fall Chinook Salmon were identified by either the presence of an otolith mark specific to PRH or by the presence of a PRH origin CWT. Adipose clipped Chinook salmon without a CWT and without an otolith mark were classified as fish from other hatcheries. The natural origin fish were identified by either a Hanford Reach origin CWT or by the presence of an adipose fin combined with the absence of any hatchery marks. The age composition for both the natural and hatchery origin fall Chinook salmon recovered in return years 2012 - 2018 were assembled from the carcass recoveries in sections 1-8 of the Hanford Reach.

In order to make coarse comparisons between hatchery and natural origin fish prior to return year 2012, the designation of origin required the assumption that all fish collected in the Hanford Reach, except for those that were of known hatchery origin (e.g., adipose clipped or possessed a CWT), were natural origin. We know this was not the case, but we were not able to identify all of the hatchery origin fish in the demographic samples and it was assumed that the majority of the fish sampled in the stream surveys were natural origin.

13.1 Migration Timing

PIT tag observations for both PRH and Hanford Reach natural origin adult fall Chinook salmon at the PIT tag arrays in the Bonneville Dam adult fish ladders were used to assess arrival timing. The PIT tag observation data was obtained from the PTAGIS website. Arrival date for each unique tagged adult was based on its first observation date and time at Bonneville Dam. The data presented encompasses return years 2010 – 2018. The annual number of adult PIT tag observations at Bonneville Dam vary for both hatchery and natural origin fish as a result of varying size tag groups, smolt to adult survival, and PIT tag detection efficiencies at the adult fishways. Roughly 3,000 juveniles were PIT tagged at PRH annually for release years 2005 – 2010. The annual tag group was roughly 43,000 since 2011. The annual tag size for the Hanford Reach natural origin juvenile fall Chinook Salmon have ranged from a high of 22,433 in 2007 to a low of 4,183 in 2013. There was not a tag group for natural origin fish in 2006.

The adult PIT tag detections at Bonneville Dam are useful to compare migration timing between Hanford Reach natural origin and PRH origin fall Chinook salmon because harvest and other losses upstream of Bonneville Dam reduce the number of potential detections at upstream sites.

The 10^{th}, 50^{th}, and 90^{th} percentiles of the annual migration timing to Bonneville Dam are given in (

Table 36). The observation sample size of both groups of PIT tagged fish at Bonneville Dam can be small and therefore, may not be representative of the populations. However, this may be the best migration information currently available.

Table 36 **The week that 10%, 50% (median), and 90% of the natural and hatchery origin fall Chinook salmon passed Bonneville Dam, 2010-2018. Migration timing is based on PIT tag passage of Hanford natural origin and Priest Rapids Hatchery in the adult fish ladder at Bonneville Dam.**

Return Year	Origin	Hanford Reach Fall Chinook Migration Time (Date)									
		Priest Rapids Origin					Hanford Reach Natural Origin				
		Age 2	Age 3	Age 4	Age 5	Age 6	Age 2	Age 3	Age 4	Age 5	Age 6
2010	10th Percentile	28-Aug	26-Aug	--	24-Aug	--	31-Aug	5-Sep	25-Aug	--	--
	50th Percentile	9-Sep	17-Sep	--	4-Sep	--	21-Sep	17-Sep	9-Sep	--	--
	90th Percentile	15-Sep	24-Sep	--	6-Sep	--	4-Oct	6-Oct	15-Sep	--	--
	N	5	20	0	3	0	8	22	18	0	0
2011	10th Percentile	8-Aug	3-Sep	23-Aug	--	--	--	4-Sep	24-Aug	4-Aug	4-Aug
	50th Percentile	8-Sep	20-Sep	8-Sep	--	--	--	4-Sep	10-Sep	30-Aug	30-Aug
	90th Percentile	21-Sep	25-Sep	21-Sep	--	--	--	10-Sep	2-Oct	1-Sep	1-Sep
	N	6	7	10	0	0	0	2	65	3	3
2012	10th Percentile	31-Aug	6-Sep	13-Sep	7-Sep	--	14-Sep	4-Sep	28-Aug	27-Aug	27-Aug
	50th Percentile	16-Sep	11-Sep	13-Sep	7-Sep	--	23-Sep	16-Sep	5-Sep	8-Sep	8-Sep
	90th Percentile	27-Sep	21-Sep	19-Sep	7-Sep	--	10-Oct	26-Sep	21-Sep	19-Sep	19-Sep
	N	7	13	2	1	0	10	11	19	26	26
2013	10th Percentile	24-Aug	28-Aug	25-Aug	--	--	11-Sep	2-Sep	2-Sep	9-Aug	9-Aug
	50th Percentile	8-Sep	9-Sep	3-Sep	--	--	11-Sep	22-Sep	9-Sep	27-Aug	27-Aug
	90th Percentile	18-Sep	22-Sep	15-Sep	--	--	11-Sep	10-Oct	19-Sep	2-Oct	2-Oct
	N	40	55	16	0	0	1	29	22	10	10
2014	10th Percentile	6-Sep	4-Sep	5-Sep	--	--	24-Sep	10-Sep	3-Sep	29-Aug	29-Aug
	50th Percentile	16-Sep	13-Sep	12-Sep	--	--	25-Sep	11-Sep	12-Sep	1-Sep	1-Sep
	90th Percentile	28-Sep	25-Sep	23-Sep	--	--	1-Oct	28-Sep	26-Sep	15-Sep	15-Sep
	N	175	228	50	0	0	3	4	62	5	5
2015	10th Percentile	16-Oct	8-Sep	25-Aug	14-Sep	--	--	10-Sep	30-Aug	29-Aug	29-Aug
	50th Percentile	16-Oct	21-Sep	6-Sep	26-Sep	--	--	20-Sep	10-Sep	9-Sep	9-Sep
	90th Percentile	16-Oct	9-Oct	18-Sep	26-Sep	--	--	1-Oct	25-Sep	25-Sep	25-Sep
	N	1	345	323	2	0	0	5	13	32	32
2016	10th Percentile	--	30-Aug	8-Aug	14-Aug	--	--	21-Sep	28-Aug	31-Aug	31-Aug
	50th Percentile	--	13-Sep	7-Sep	1-Sep	--	--	21-Sep	10-Sep	7-Sep	7-Sep
	90th Percentile	--	6-Oct	19-Sep	15-Sep	--	--	14-Oct	19-Sep	14-Sep	14-Sep
	N	0	41	182	41	0	0	2	10	5	5
2017	10th Percentile	10-Sep	5-Sep	5-Sep	31-Aug	27-Sep	24-Sep	12-Sep	26-Aug	5-Sep	--
	50th Percentile	20-Sep	18-Sep	14-Sep	12-Sep	27-Sep	24-Sep	12-Sep	12-Sep	15-Sep	--
	90th Percentile	31-Oct	9-Oct	24-Sep	18-Sep	27-Sep	24-Sep	12-Sep	3-Nov	11-Oct	--
	N	8	19	63	48	1	1	1	19	13	0
2018	10th Percentile	5-Sep	8-Sep	30-Aug	31-Aug	--	--	--	12-Sep	31-Aug	--
	50th Percentile	20-Sep	20-Sep	3-Sep	31-Aug	--	--	--	12-Sep	15-Sep	--
	90th Percentile	19-Oct	8-Oct	27-Sep	10-Sep	--	--	--	12-Sep	26-Oct	--
	N	10	37	13	2	0	0	0	1	5	0

13.2 Age at Maturity

Prior to return year 2012, the fish origin was assigned by location of survey due to the lack of identifiable hatchery marks and low CWT recoveries that may not have been representative of natural origin fish. Hence, the age composition for natural origin returns was generated from all the samples collected within the carcass survey regardless of true origin. Likewise, the age composition for hatchery origin fish was generated from all samples collected at PRH regardless of true origin. These 2007- 2013 brood year data suggests that between the two surveys, the proportions of age 2 fish were similar, higher for age 3 fish at the hatchery, and lower for ages 4, 5, and 6 fish in the hatchery survey (Table 37).

The age compositions of the Hanford Reach escapement and the PRH returns are not directly comparable between locations without some adjustment or verification with another method. There is likely a recovery bias against smaller/younger fish in the stream surveys (Zhou 2002; Murdoch et al. 2010; Richards and Pearsons, 2013). Hence, the age composition for the Hanford Reach escapement is likely biased towards larger/older fish. Results and brief discussion for the pilot carcass bias assessments are given in Appendix H. All fish recovered from the PRH volunteer trap are available for systematic sampling; reducing the potential bias of the age composition data. Although this dataset is imperfect, the dataset is maintained for future reference should a method be established to correct the data for associated age and origin bias or if it is verified with another method.

The availability of otolith data combined with other hatchery mark data from the Hanford Reach carcass recoveries for the 2012 through 2018 return years provide the ability to estimate age compositions for both hatchery and natural origin fish within the demographic sample for the Hanford Reach escapement (**Error! Reference source not found.**). However, the hatchery origin age composition may be influenced by the low number of hatchery origin fish present in the demographic samples which is further reduced by sub-sampling the demographic origin. In addition, the age composition for both groups may be biased towards larger fish due to potential size recovery biases in the carcass surveys. Larger demographic samples per return year are required to better represent the age composition data before conclusions can be made. Beginning with return year 2014, the sub-sample size to determine origin was increased substantially to include up to 2,500 fish in order to capture more hatchery origin fish in the sub-sample. Within the demographic sample of the escapement, the proportion of hatchery origin fish was higher than natural origin fish at ages 2 and 3, and lower for ages 4, 5, and 6 during brood years 2007-2013.

13.3 Size at Maturity

Prior to return year 2012, the size (fork length) at maturity comparisons between fall Chinook salmon recovered at PRH and the Hanford Reach stream survey were calculated in a similar manner as the age composition data for the same time period. Likewise, the assignment of origin was based on the survey (i.e., stream or hatchery). The estimates based on this method may not be representative of natural and hatchery origin fish due to possible size bias during recovery of carcasses.

Comparisons of the size at maturity data between the two surveys for brood years 2007 through 2013 suggests that ages 2 and 3 fish are similar in size and that ages 4, 5, and 6 fish are smaller in the hatchery survey (Table 39). The demographic for the 2012 through 2018 return years provide the ability to estimate size at maturity for both hatchery and natural origin fish within the

Hanford Reach escapement. These data suggest that either by gender or combined genders, hatchery origin fish are larger at age 2, similar at age 3, and smaller at ages 4, 5, and 6. (

Table 40a and Table 40b).

Table 37 Age compositions for fall Chinook salmon sampled in the Hanford Reach escapement compared to fall Chinook salmon sampled at Priest Rapids Hatchery (genders combined), Brood Years 1998-2013.

Brood Year	Source[1]	Age Composition				
		Age-2	Age-3	Age-4	Age-5	Age-6
1998	Escapement	0.119	0.097	0.420	0.346	0.018
	PRH Returns	0.034	0.575	0.353	0.038	0.000
1999	Escapement	0.123	0.089	0.390	0.392	0.005
	PRH Returns	0.061	0.366	0.432	0.140	0.001
2000	Escapement	0.262	0.081	0.290	0.359	0.009
	PRH Returns	0.070	0.303	0.467	0.152	0.007
2001	Escapement	0.152	0.149	0.488	0.206	0.005
	PRH Returns	0.061	0.506	0.309	0.122	0.002
2002	Escapement	0.178	0.154	0.568	0.099	0.001
	PRH Returns	0.103	0.386	0.466	0.043	0.001
2003	Escapement	0.249	0.170	0.248	0.331	0.000
	PRH Returns	0.041	0.443	0.355	0.160	0.000
2004	Escapement	0.216	0.064	0.406	0.311	0.003
	PRH Returns	0.133	0.398	0.406	0.063	0.000
2005	Escapement	0.151	0.082	0.306	0.458	0.003
	PRH Returns	0.116	0.572	0.284	0.028	0.000
2006	Escapement	0.109	0.052	0.632	0.206	0.000
	PRH Returns	0.331	0.325	0.314	0.030	0.000
2007	Escapement	0.109	0.230	0.490	0.171	0.001
	PRH Returns	0.103	0.483	0.381	0.033	0.000
2008	Escapement	0.159	0.193	0.511	0.137	0.000
	PRH Returns	0.221	0.497	0.279	0.003	0.000
2009	Escapement	0.091	0.136	0.688	0.083	0.001
	PRH Returns	0.124	0.557	0.243	0.076	0.000
2010	Escapement	0.020	0.269	0.441	0.265	0.006
	PRH Returns	0.104	0.368	0.492	0.036	0.000
2011	Escapement	0.102	0.075	0.641	0.180	0.002
	PRH Returns	0.064	0.434	0.445	0.056	0.001
2012	Escapement	0.186	0.276	0.367	0.169	0.002
	PRH Returns	0.184	0.556	0.217	0.042	0.001
2013[a]	Escapement	0.349	0.172	0.375	0.105	--
	PRH Returns	0.137	0.450	0.367	0.046	--
Mean 1998 – 2013	**Escapement**	**0.161**	**0.143**	**0.454**	**0.239**	**0.004**
	PRH Returns	**0.118**	**0.451**	**0.363**	**0.067**	**0.001**
Mean 2007 - 2013	**Escapement**	**0.145**	**0.193**	**0.502**	**0.159**	**0.002**

Brood Year	Source[1]	Age Composition				
		Age-2	Age-3	Age-4	Age-5	Age-6
	PRH Returns	**0.134**	**0.478**	**0.346**	**0.042**	**0.000**

[1]The origin is assigned by survey
[a] Does not include age-6 returns

Table 38 Age compositions by sex for natural and hatchery origin fall Chinook salmon sampled in the Hanford Reach escapement, Brood Years 2007-2013.

Brood Year	Males[1]	N[2]	Age Composition				
			Age-2	Age-3	Age-4	Age-5	Age-6
2007	Natural	1,093	No otolith data	0.377	0.483	0.139	0.002
	Hatchery	121		0.801	0.116	0.083	0.000
2008	Natural	1,234	0.044	0.336	0.502	0.118	0.000
	Hatchery	49	0.255	0.299	0.353	0.092	0.000
2009	Natural	816	0.034	0.231	0.66	0.076	0.000
	Hatchery	139	0.033	0.27	0.678	0.019	0.000
2010	Natural	2,097	0.008	0.361	0.454	0.176	0.000
	Hatchery	333	0.043	0.814	0.108	0.034	0.000
2011	Natural	838	0.182	0.157	0.547	0.112	0.002
	Hatchery	72	0.113	0.232	0.577	0.078	0.000
2012	Natural	858	0.058	0.527	0.319	0.095	0.001
	Hatchery	86	0.077	0.683	0.223	0.017	0.000
2013[a]	Natural	517	0.03	0.458	0.449	0.063	--
	Hatchery	44	0.067	0.629	0.271	0.033	--
Mean	**Natural**	**1,065**	**0.059**	**0.350**	**0.488**	**0.111**	**0.001**
	Hatchery	**121**	**0.098**	**0.533**	**0.332**	**0.051**	**0.000**
Brood Year	**Females[1]**	**N[2]**	**Age Composition**				
			Age-2	**Age-3**	**Age-4**	**Age-5**	**Age-6**
2007	Natural	1,299	No otolith data	0.047	0.706	0.247	0.000
	Hatchery	167		0.532	0.317	0.151	0.000
2008	Natural	426	0	0.117	0.679	0.204	0.000
	Hatchery	74	0	0.176	0.651	0.172	0.000
2009	Natural	486	0	0.033	0.789	0.175	0.003
	Hatchery	188	0	0.06	0.918	0.021	0
2010	Natural	1,934	0	0.026	0.542	0.432	0.000
	Hatchery	353	0	0.418	0.448	0.133	0.000
2011	Natural	926	0	0.005	0.775	0.217	0.002
	Hatchery	118	0	0.022	0.782	0.195	0.000
2012	Natural	1,072	0	0.133	0.536	0.33	0.001
	Hatchery	165	0	0.382	0.479	0.138	0.000
2013[a]	Natural	693	0	0.055	0.873	0.072	--
	Hatchery	91	0	0.219	0.586	0.195	--
Mean	**Natural**	**977**	**0.000**	**0.059**	**0.700**	**0.240**	**0.001**
	Hatchery	**165**	**0.000**	**0.258**	**0.597**	**0.144**	**0.000**
Brood Year	**Sex Combined[1]**	**N[2]**	**Age Composition**				
			Age-2	**Age-3**	**Age-4**	**Age-5**	**Age-6**
2007	Natural	2,392	No Otolith	0.201	0.602	0.196	0.001
	Hatchery	288		0.656	0.225	0.119	.000
2008	Natural	1,660	0.022	0.23	0.587	0.16	0.002
	Hatchery	123	0.1	0.224	0.535	0.141	0.000
2009	Natural	1,302	0.019	0.147	0.715	0.118	0.001

Brood Year	Males[1]	N[2]	Age Composition				
			Age-2	Age-3	Age-4	Age-5	Age-6
	Hatchery	327	0.012	0.136	0.831	0.021	0.000
2010	Natural	4,052	0.004	0.185	0.501	0.304	0.006
	Hatchery	686	0.022	0.617	0.278	0.084	0
2011	Natural	1,764	0.088	0.079	0.665	0.166	0.002
	Hatchery	190	0.038	0.093	0.713	0.156	000.0
2012	Natural	1,930	0.030	0.335	0.424	0.209	0.002
	Hatchery	251	0.030	0.5	0.378	0.091	0.000
2013[a]	Natural	1,210	0.016	0.271	0.646	0.067	--
	Hatchery	135	0.025	0.369	0.471	0.136	--
Mean	**Natural**	**2,044**	**0.030**	**0.207**	**0.592**	**0.174**	**0.002**
	Hatchery	**286**	**0.038**	**0.371**	**0.490**	**0.107**	**0.000**

[1]Origin based on the presence of otoliths marks, hatchery coded-wire tags, and adipose clips present in the sub-sample.
[2] N equals the number fish included in the demographic sample for a specific brood year. Sample rates varied between return years; therefore the age composition is based on pooled sample data expanded for total returns by year.
[a] Does not include age-6 returns

Table 39 Mean fork length (cm) at age (total age) of fall Chinook salmon sampled in the Hanford Reach escapement compared to fall Chinook salmon sampled at Priest Rapids Hatchery, Brood Years 1999-2013. N = sample size and SD = 1 standard deviation.

Brood Year	Origin	Fall Chinook fork length (cm)														
		Age-2			Age-3			Age-4			Age-5			Age-6		
		N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
1999	Escapement	83	44	4	227	70	6	1,423	86	7	1,085	93	7	22	103	10
	PRH Returns	85	46	5	488	70	5	762	84	6	170	92	6	2	94	11
2000	Escapement	17	44	4	118	65	7	428	82	6	669	94	8	6	96	9
	PRH Returns	25	44	5	136	69	6	196	82	6	58	93	7	2	103	10
2001	Escapement	32	44	5	251	69	6	1,157	84	6	288	93	7	18	97	5
	PRH Returns	121	48	4	1,040	69	5	628	81	6	183	91	6	9	94	9
2002	Escapement	31	46	4	229	70	6	194	86	8	239	95	8	2	99	6
	PRH Returns	80	52	4	281	70	5	246	84	6	61	91	6	1	73	--
2003	Escapement	19	48	5	42	69	7	395	85	6	450	96	8	0	--	--
	PRH Returns	12	49	6	93	70	6	215	83	6	20	91	4	0	--	--
2004	Escapement	34	47	4	71	68	6	386	84	6	208	94	8	2	91	1
	PRH Returns	19	55	4	115	69	5	51	84	5	9	95	7	0	--	--
2005	Escapement	25	50	5	202	70	6	532	84	7	744	96	8	5	96	6
	PRH Returns	31	49	4	429	73	4	428	84	6	180	91	6	0	--	--
2006	Escapement	20	48	4	85	69	6	962	86	6	340	92	7	0	--	--
	PRH Returns	3	45	3	42	71	4	170	84	6	13	92	7	0	--	--
2007	Escapement	24	46	5	642	72	6	1,468	84	7	482	92	7	1	105	--
	PRH Returns	5	50	4	1,149	71	4	1,419	80	5	179	87	6	0	--	--
2008	Escapement	34	50	4	243	70	5	620	84	7	72	92	8	1	84	--
	PRH Returns	22	52	5	652	69	4	573	81	6	1	84	0	0	--	--
2009	Escapement	50	48	4	421	69	6	931	81	6	183	92	10	1	73	--
	PRH Returns	308	48	4	1,690	68	5	218	77	5	66	86	7	0	--	--
2010	Escapement	63	47	7	1,040	68	5	2,754	82	7	826	88	7	25	90	6
	PRH Returns	883	48	4	1,375	69	4	1,413	78	5	55	84	4	1	65	--

Brood Year	Origin	Fall Chinook fork length (cm)														
		Age-2			Age-3			Age-4			Age-5			Age-6		
		N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
2011	Escapement	58	46	4	266	67	5	1,151	80	6	465	88	7	8	91	12
	PRH Returns	111	47	3	694	67	4	355	77	5	109	84	6	1	87	--
2012	Escapement	79	47	4	489	67	5	936	80	6	670	85	7	9	89	5
	PRH Returns	335	48	5	607	67	5	568	78	5	484	81	6	4	81	3
2013[a]	Escapement	9	47	6	241	67	6	818	77	6	284	85	7	--	--	--
	PRH Returns	40	44	6	464	67	5	1,610	75	5	112	82	6	--	--	--
Mean 99 -13	**Escapement**	**39**	**47**	**5**	**304**	**69**	**6**	**944**	**83**	**6**	**467**	**92**	**8**	**7**	**93**	**6**
	PRH Returns	**139**	**48**	**4**	**617**	**69**	**5**	**590**	**81**	**6**	**113**	**88**	**6**	**2**	**85**	**8**
Mean 07- 13	**Escapement**	**47**	**47**	**5**	**517**	**68**	**6**	**1,343**	**81**	**6**	**485**	**88**	**8**	**9**	**90**	**6**
	PRH Returns	**280**	**48**	**4**	**997**	**68**	**5**	**931**	**78**	**5**	**168**	**84**	**6**	**2**	**78**	**3**

[a] Does not include age-6 returns

Table 40a **Mean fork length (cm) at age (total age) of natural and hatchery origin fall Chinook salmon that spawned naturally in the Hanford Reach, Brood Years 2007-2013. N = sample size and SD = 1 standard deviation.**

Brood Year	Males by Origin	Fork Length (cm)														
		Age-2			Age-3			Age-4			Age-5			Age-6		
		N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
2007	Natural	No otolith Data			364	70	5	205	84	8	143	98	9	0	--	--
	Hatchery				44	72	4	16	82	5	6	94	7	0	--	--
2008	Natural	22	49	4	134	69	5	260	85	8	25	99	7	0	--	--
	Hatchery	8	52	3	20	69	5	7	86	4	2	91	15	0	--	--
2009	Natural	3	48	3	325	68	6	123	82	6	40	99	7	0	--	--
	Hatchery	2	55	5	34	71	6	21	79	10	2	96	6	0	--	--
2010	Natural	31	45	4	291	68	7	855	83	8	135	94	8	4	97	8
	Hatchery	28	49	5	58	69	6	35	79	8	7	92	7	0	--	--
2011	Natural	31	45	4	176	66	5	403	81	8	137	94	7	3	104	3
	Hatchery	27	49	5	19	68	4	31	80	6	7	88	7	0	--	--
2012	Natural	45	47	4	312	67	6	316	80	8	140	92	8	1	88	--
	Hatchery	7	49	5	49	69	5	25	83	6	3	88	10	0	--	--
2013[a]	Natural	8	47	6	179	67	6	269	79	8	48	91	9	--	--	--
	Hatchery	1	50	--	23	67	6	17	77	6	0	--	--	--	--	--
Mean	**Natural**	**23**	**47**	**4**	**254**	**68**	**6**	**347**	**82**	**8**	**95**	**95**	**8**	**1**	**96**	**6**
	Hatchery	**12**	**51**	**5**	**35**	**69**	**5**	**22**	**81**	**6**	**4**	**92**	**9**	**0**	**--**	**--**
Brood Year	**Females by Origin**	**Fork Length (cm)**														
		Age-2			**Age-3**			**Age-4**			**Age-5**			**Age-6**		
		N	**Mean**	**SD**	**N**	**Mea**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**
2007	Natural	No otolith Data			83	72	5	375	83	5	314	89	4	0	--	--
	Hatchery				48	72	4	48	80	4	8	85	5	0	--	--
2008	Natural	0	--	--	36	70	3	344	83	5	49	88	5	1	84	--
	Hatchery	0	--	--	23	70	5	21	82	4	7	85	6	0	--	--
2009	Natural	0	--	--	44	71	5	105	80	4	82	87	11	1	73	--
	Hatchery	0	--	--	12	68	4	49	78	6	4	85	4	0	--	--
2010	Natural	0	--	--	33	71	5	999	87	5	528	85	4	20	89	5

Brood Year	Males by Origin	Fork Length (cm)														
		Age-2			Age-3			Age-4			Age-5			Age-6		
		N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
	Hatchery	0	--	--	22	69	4	144	79	5	29	82	4	0	--	--
2011	Natural	0	--	--	7	67	5	597	80	5	283	85	5	5	84	7
	Hatchery	0	--	--	4	65	2	72	77	4	34	84	4	0	--	--
2012	Natural	0	--	--	77	68	3	449	80	4	480	83	6	0	--	--
	Hatchery	0	--	--	42	68	3	83	78	6	38	81	5	0	--	--
2013[a]	Natural	0	--	--	20	67	6	457	77	5	218	84	5	--	--	--
	Hatchery	0	--	--	12	67	4	58	75	5	12	80	7	--	--	--
Mean	**Natural**	**0**	**--**	**--**	**43**	**69**	**5**	**475**	**81**	**5**	**279**	**86**	**6**	**5**	**83**	**3**
	Hatchery	**0**	**--**	**--**	**23**	**68**	**4**	**68**	**78**	**5**	**19**	**83**	**5**	**0**	**--**	**--**

[a] Brood year does not include age-6 returns

Table 41b Mean fork length (cm) at age (total age) of natural and hatchery origin fall Chinook salmon that spawned naturally in the Hanford Reach, Brood Years 2007-2013. N = sample size and SD = 1 standard deviation.

Brood Year	Origin	Sex Combined Fork Length (cm)														
		Age-2			Age-3			Age-4			Age-5			Age-6		
		N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
2007	Natural	No otolith Data			447	70	5	580	83	6	457	92	6	0	--	--
	Hatchery				92	72	4	64	81	4	28	87	6	0	--	--
2008	Natural	22	49	4	170	69	5	604	84	6	74	92	6	1	84	--
	Hatchery	8	52	3	43	70	5	28	83	4	9	86	8	0	--	--
2009	Natural	3	48	3	369	68	6	228	81	5	122	91	10	1	73	--
	Hatchery	2	55	5	46	70	5	70	78	7	6	89	5	0	--	--
2010	Natural	31	45	4	324	69	6	1854	82	8	763	88	5	24	90	7
	Hatchery	29	50	6	80	69	6	179	79	7	36	84	5	0	--	--
2011	Natural	31	45	4	183	66	5	1000	80	6	420	88	7	8	91	12
	Hatchery	28	50	6	23	67	4	103	78	5	41	84	5	0	--	--
2012	Natural	46	47	4	389	67	5	760	80	6	624	85	7	--	--	--
	Hatchery	7	49	5	91	68	4	108	79	6	41	81	6	--	--	--
2013[a]	Natural	8	47	6	199	67	6	726	77	6	266	85	6	--	--	--
	Hatchery	1	50	--	35	67	5	75	76	5	12	80	7	--	--	--
Mean	**Natural**	**24**	**47**	**4**	**297**	**68**	**5**	**822**	**81**	**6**	**389**	**89**	**7**	**7**	**85**	**5**
	Hatchery	**13**	**51**	**5**	**59**	**69**	**5**	**90**	**79**	**5**	**25**	**84**	**6**	**0**	**--**	**--**

[a] Brood year does not include age-6 returns

13.4 Gender Composition for Adult Escapement

Prior to return year 2012, the gender ratio comparisons between fall Chinook salmon recovered at PRH and the Hanford Reach stream survey were based on the survey type (i.e., stream or hatchery). Although the estimates based on this method are imperfect, we continue to present this information to maintain the longest data set available (Table 42).

Gender ratios (male/females) by brood year and origin of adult fall Chinook salmon sampled in the Hanford Reach carcass survey are presented in (Table 43). Annually, higher male to female ratios have been observed in the natural origin fish than that of the hatchery origin fish.

Table 42 **Comparisons male to female ratio of fall Chinook salmon sampled at Priest Rapids Hatchery and in the Hanford Reach stream surveys, Brood Years 1996-2013.**

Brood Year	Origin	Male[1] : Female Ratio
1996	Stream	0.94:1
	Hatchery	1.98:1
1997	Stream	0.48:1
	Hatchery	1.88:1
1998	Stream	0.66:1
	Hatchery	1.38:1
1999	Stream	0.71:1
	Hatchery	2.15:1
2000	Stream	1.51:1
	Hatchery	2.40:1
2001	Stream	0.67:1
	Hatchery	2.31:1
2002	Stream	1.40:1
	Hatchery	1.94:1
2003	Stream	1.25:1
	Hatchery	1.64:1
2004	Stream	1.17:1
	Hatchery	1.63:1
2005	Stream	0.87:1
	Hatchery	2.15:1
2006	Stream	0.75:1
	Hatchery	2.57:1
2007	Stream	0.84:1
	Hatchery	1.60:1
2008	Stream	1.01:1
	Hatchery	1.89:1
2009	Stream	1.13:1
	Hatchery	2.57:1
2010	Stream	1.02:1
	Hatchery	1.47:1
2011	Stream	0.89:1
	Hatchery	2.00:1
2012	Stream	0.99:1
	Hatchery	1.82:1
2013[a]	Stream	1.06:1
	Hatchery	1.91:1
Mean	**Stream**	**0.92:1**
	Hatchery	**1.97:1**

[1] Includes both adult males and jacks.
[a] Includes age-2 through 5.

Table 43 Comparison male to female ratio of fall Chinook salmon sampled in the Hanford Reach stream surveys, Brood Years 2007-2013.

Brood Year	Origin	Male[1] : Female Ratio
2007[a]	Natural	0.86:1.00
	Hatchery	0.74:1.00
2008	Natural	1.07:1.00
	Hatchery	0.64:1.00
2009	Natural	1.37:1.00
	Hatchery	0.56:1.00
2010	Natural	1.02:1.00
	Hatchery	1.01:1.00
2011	Natural	0.94:1.00
	Hatchery	0.51:1.00
2012	Natural	1.05:1.00
	Hatchery	0.65:1.00
2013[b]	Natural	1.15:1.00
	Hatchery	0.58:1.00
Mean	**Natural**	**1.07:1.00**
	Hatchery	**0.67:1:00**

[1] Includes both adult males and jacks. [a] Does not include age-2. [b] Includes age-2 through 5.

13.5 Egg Retention

All female Chinook included in the demographic sample for the Hanford Reach stream surveys were examined for egg retention to assess spawn success. The females sampled were partitioned into the egg retention categories of 0%, 25%, 50%, 75% and 100%. The assignment of origin for each female for years 2010 and 2011 were based on the presence or absence of an adipose fin. The adipose intact group may include non-adipose clipped fish from PRH. A combination of hatchery marks (i.e., adipose clips, CWTs, and otolith marks were used to identify hatchery origin fish in years 2013 - 2018. For all years, we assume that fish not possessing any hatchery marks are natural origin fish.

The assessment of egg retention is influenced by the loss of eggs during the collection and transport of carcasses prior to sampling. Therefore, our estimates of egg retention are likely to be underestimates and our estimates of egg loss are likely to be overestimates. In addition, the methods for quantifying egg retention and assignment of origin for each female have varied between years. The amount of egg retention for years 2004 through 2013 were determined by visual estimates; whereas, during 2014 through 2018, the amount of retention was based on egg counts when the gametes were not completely intact. For these recent data sets, the percent of egg retention was calculated by dividing the amount of egg retained by an estimated fecundity based on length versus fecundity regressions by origin (Hatchery or Natural). An explanation of these regressions is provided in the fecundity section of this report.

Starting in return year 2015, staff recorded visual observations of egg retention based on the standard egg retention categories to make comparisons with egg retention based on egg counts. The data from the egg counts were categorized into the standard egg retention categories based on the following ranges: 1 = 100-88%, 2 = 87-63%, 3 = 62-38%, 4 = 37-11%, and 5 = 10-0%. This comparison may allow us to assess the egg retention estimates based on methods used prior to 2015. The difference between two methods was less than 1 percentage point by category for each year (Table 44), which provides some confidence that the visual methods of the past may provide reasonable indices of spawning success.

Table 44 Comparison of egg retention of natural and hatchery origin fall Chinook sampled in the Hanford Reach stream survey, Return Years 2015-2018.

Survey Year	Egg Retention Categories	% by Category based on Egg Counts	% by Category based on Visual Observations	Difference between Actual and Observed (%)
2015	1 – 100%	0.0	0.4	-0.4
	2 – 75%	0.3	0.5	-0.2
	3 – 50%	0.6	0.6	0.0
	4 – 25%	1.5	1.6	-0.1
	5 – 0%	97.7	96.9	0.8
	N = 1,405			
2016	1 – 100%	0.0	0.2	-0.2
	2 – 75%	0.2	0.3	-0.1
	3 – 50%	0.6	1.1	-0.5
	4 – 25%	1.8	1.2	0.6
	5 – 0%	97.4	97.2	0.2
	N = 995			
2017	1 – 100%	0.0	0.0	0.0
	2 – 75%	0.2	0.2	0.0
	3 – 50%	0.3	0.3	0.1
	4 – 25%	1.3	1.1	0.2
	5 – 0%	98.2	98.5	-0.3
	N = 1,180			
2018	1 – 100%	0.1	0.7	-0.5
	2 – 75%	0.3	0.1	0.1
	3 – 50%	0.3	0.1	0.1
	4 – 25%	0.7	0.5	0.1
	5 – 0%	98.7	98.5	0.1
	N = 758			

We calculated an adjusted mean spawn success for the female escapement for years 2004 through 2018. In addition, an adjusted mean spawn success was calculated for the natural and hatchery origin female escapement for years 2012 through 2018. The calculations for the adjustment includes weighting the mean spawn success by the percentage of females sampled within each of the five egg retention categories. The mean adjusted spawn success for year 2004 through 2018 was 98.1% which is comparable to the value (98.7%) for natural origin females for years 2012 through 2018 (Table 45). For most years, the adjusted spawn success was lower for hatchery origin females than that of natural origin females.

Table 45 Comparison of egg retention of natural and hatchery origin fall Chinook sampled in the Hanford Reach stream survey, Return Years 2010-2018.

Return Year	Origin	Females Sampled	Egg Retention Categories 0 %	25%	50%	75%	100%	No Egg Retention (%)	Adj Spawn Success for Escapement (%)
2004	Combined	1,176	1,151	NA	21	NA	4	97.9	98.8
2005	Combined	1,323	1,310	NA	6	NA	7	99.0	99.2
2006	Combined	352	343	NA	8	NA	1	97.4	98.6
2007	Combined	454	443	NA	8	NA	3	97.6	98.5
2008	Combined	No spawn success data collected							
2009	Combined	499	484	NA	5	NA	10	97.0	97.5
2010	Combined	1,173	1,147	6	13	1	6	97.8	98.7
2011	Combined	1,264	1,203	1	52	5	3	95.2	97.4
2012[b]	Natural	681	658	14	5	1	3	96.6	98.6
	Hatchery	90	89	0	0	0	1	98.9	98.9
	Total	771	747	14	5	1	4	96.9	98.6
2013[b]	Natural	461	392	51	9	3	6	85.0	94.5
	Hatchery	224	144	39	11	13	17	64.3	81.3
	Total	685	536	90	20	16	23	78.2	90.1
2014[b]	Natural	1,082	1,074	1	0	0	7	99.3	99.3
	Hatchery	153	141	3	0	0	9	92.2	93.6
	Total	1,235	1,215	4	0	0	16	98.4	98.6
2015[b]	Natural	1256	1237	14	3	2	0	98.5	99.5
	Hatchery	149	135	7	5	2	0	90.6	96.1
	Total	1,405	1,372	21	8	4	0	97.7	99.1
2016[b]	Natural	857	842	7	3	1	0	98.2	99.5
	Hatchery	138	127	11	3	1	0	92.0	96.4
	Total	995	969	18	6	2	0	97.4	99.1
2017[b]	Natural	1,071	1,062	8	1	0	0	99.2	99.8
	Hatchery	109	100	5	2	2	0	91.7	96.6
	Total	1,180	1,162	13	3	2	0	98.5	99.5
2018[b]	Natural	712	705	4	2	1	0	99.0	99.6
	Hatchery	46	43	1	0	1	1	93.5	95.7
	Total	758	748	4	2	1	0	98.7	99.6
Mean Natural Spawn Success (RY 2012 – 2018)								**96.5**	**98.7**
Mean Hatchery Spawn Success (RY 2012 – 2018)								**89.0**	**94.1**
Mean Combined Spawn Success (RY 2004 – 2018)								**96.3**	**98.1**

The measure for reporting egg retention changed from that used for previous years beginning in 2010
[b] Origins were determined the presence or absence of otolith marks, adipose clips and CWTs

14.0 Contribution to Fisheries

The contribution of fish produced at PRH to fisheries was estimated by querying the Regional Mark Processing Center (RMPC) database. This is central repository for all CWT and otherwise associated release, catch, sample, and recovery data of anadromous salmonids in the greater Pacific Coast Region of the United States of America. The Regional Mark Information System database (RMIS) within the RMPC provides specific recovery data for individual tag codes, along with the sample rate used to derive the estimated total number of recoveries by fishery type.

The CWT data reported to RMPC are expanded by sample rates generated by the agency reporting the data. In some cases, the estimated number of tags reported is less than the number actually observed. This typically occurs when the sample rate is unknown, not reported, or biased (Gilbert Lensegrav, WDFW, personal communication). In these instances, the observed number was used instead of the estimated number to calculate the numbers of PRH origin fish recovered by location.

The RMIS database was queried on April 22, 2019 to provide CWT recoveries for active broods of PRH origin fish. The database for the 2012 brood should be complete for age-2 through age-5. The age-6 recovered during RY2018 may not be included until January 1, 2020 due to the lag in reporting field data to RMPC.

Beginning with the 2010 release year, portions of the non-adipose clipped smolts released from PRH received a CWT as part of a double index tag (DIT) study to evaluate the effect of various mark-selective fisheries occurring in Oregon, Washington, and British Columbia waters (PSC 2013). We are currently reviewing the data reported to the RMPC database to evaluate the results of the double index tagging for the PRH origin fish. Data for brood years 2009 through 2014 (some are incomplete due to time lag for reporting) show that adipose clipped fish from the DIT groups are being recovered in mark selective commercial and sport fisheries occurring in ocean, marine and freshwater zones. Comparisons of the demographics between the DIT groups recovered at PRH are very similar (Appendix I). Therefore, mark selective fisheries do not appear to markedly influence the demographic data collected at PRH.

Fall Chinook salmon released from PRH supplement Pacific Ocean harvest for both commercial and sport fisheries from Washington to Southeast Alaska as well as Columbia River commercial, sport, and treaty tribal harvest. The Hanford Reach sport fishery for fall Chinook salmon is an extremely popular fishery. This fishery typically runs annually from August 1 to late October. In 2018, an estimated 9,746 fall Chinook salmon were harvested during this fishery; 8,672 adults and 1,074 jacks. Estimates generated from CWT recoveries from the Hanford Reach sport fishery suggest that 14.0% (1,367 fish) of the total sport harvest in the Hanford Reach was comprised of fall Chinook salmon released from PRH (Table 46). In comparison, fall Chinook salmon released from Ringold Springs Hatchery comprised 1.0% (102 fish) of the sport fishery. Strays from other hatcheries combined represent 2.2% (217 fish) of the harvest. Sport harvest monitoring in the Hanford Reach and lower Yakima includes surveying both adipose intact and adipose clipped fish for CWT sampling.

The CWT data for PRH origin fall Chinook salmon that were marked with an adipose clip were reviewed to assess contributions to marine and freshwater, commercial, tribal, and sport fisheries. The largest proportion of the harvest of PRH origin fall Chinook salmon occurred in ocean fisheries followed by Zone-6 tribal harvest. For brood years 1997 through 2012, 49% of the reported harvest was taken in ocean fisheries and the other 51% in the Columbia River fisheries (Table 47). The adipose clip CWT rate for the broods after 2008 notably increased from previous brood years. Not all CWT surveys locations check harvested adipose intact fish for the presence of a CWT. Therefore, the data presented in Table 47 includes harvest estimates based on recoveries of adipose clipped CWT tagged fish.

Table 46 Hatchery fall Chinook salmon contributions to harvest in the Hanford Reach fall Chinook salmon fishery. Coded-wire tag recoveries provided from RMIS database were expanded by sample rate and juvenile tag rate, Return Years 2003-2018.

Return Year	Harvest & CWT Sampling			CWT Expansions			% of Harvest		
	Harvest	Sampled	%	PRH	RSH	Other Hatcheries	PRH	RSH	Other Hatcheries
2003	7,190	1,848	25.7	510	424	43	7.1	5.9	0.6
2004	8,787	2,255	25.7	276	62	23	3.1	0.7	0.3
2005	7,974	1,834	23.0	1,200	265	35	15.0	3.3	0.4
2006	4,508	1,296	28.7	683	66	10	15.1	1.5	0.2
2007	6,466	1,812	28.0	929	50	89	14.4	0.8	1.4
2008	7,013	1,593	22.7	304	66	22	4.3	0.9	0.3
2009	8,806	1,741	19.8	520	0	10	5.9	0.0	0.1
2010	12,499	2,475	19.8	1,157	399	10	9.3	3.2	0.1
2011	14,262	2,715	19.0	1,558	663	121	10.9	4.6	0.8
2012	18,854	3,615	19.2	3,974	1,974	237	21.1	10.5	1.3
2013	27,630	5,555	20.2	6,570	3,947	537	23.8	14.3	1.9
2014	32,417	8,319	25.7	3,987	1,419	332	12.3	4.4	1.0
2015	35,419	10,327	29.2	4,144	992	319	11.7	2.8	0.9
2016	17,927	5,544	30.9	2,177	822	339	12.1	4.6	1.9
2017	12,368	4,435	38.6	1,585	843	105	12.8	6.8	0.8
2018	9,756	3,639	37.3	1,367	102	217	14.0	1.0	2.2
Mean	**14,982**	**3,691**	**25.9**	**1,972**	**799**	**149**	**12.0**	**4.3**	**0.8**

Table 47 Priest Rapids Hatchery coded-wire tag recoveries provided from RMIS by brood year and harvest type expanded by sample rate and juvenile tag rate, Brood Years 1997-2012. Data only includes coded-wire tag recoveries from adipose clipped fish expanded by the juvenile tag rate.

Brood Year	Ocean Fisheries		Columbia River Fisheries						Total Harvest	Ad-CWT Rate
			Tribal		*Commercial*		*Recreational*			
	#	%	#	%	#	%	#	%		
1997	1,100	36.7	1,506	50.2	304	10.1	91	3.0	3,001	0.030
1998	6,580	48.4	3,956	29.1	1,066	7.8	1,981	14.6	13,583	0.030
1999	14,190	54.6	5,908	22.8	2,410	9.3	3,458	13.3	25,966	0.029
2000	4,938	61.5	1,583	19.7	1,099	13.7	412	5.1	8,032	0.032
2001	17,758	56.5	6,612	21.1	1,554	4.9	5,484	17.5	31,408	0.052
2002	3,779	50.6	1,240	16.6	576	7.7	1,869	25.0	7,464	0.052
2003	1,871	54.6	570	16.6	226	6.6	757	22.1	3,424	0.059
2004	562	49.3	364	31.9	214	18.8	0	0.0	1,140	0.059
2005	10,699	52.1	5,975	29.1	998	4.9	2,871	14.0	20,543	0.030
2006	1,023	44.1	713	30.7	288	12.4	298	12.8	2,322	0.029
2007	13,838	44.4	10,620	34.1	2,160	6.9	4,523	14.5	31,141	0.030
2008	5,763	43.7	4,447	33.7	887	6.7	2,080	15.8	13,177	0.032

Brood Year	Ocean Fisheries		Columbia River Fisheries						Total Harvest	Ad-CWT Rate
			Tribal		*Commercial*		*Recreational*			
	#	%	#	%	#	%	#	%		
2009	24,872	43.4	21,121	36.8	2,581	4.5	8,761	15.3	57,335	0.091
2010	46,584	43.5	34,275	32.0	7,886	7.4	18,299	17.1	107,044	0.089
2011	18,235	44.2	11,813	28.6	3,874	9.4	7,310	17.7	41,232	0.084
2012	29,017	55.7	13,390	25.7	610	1.2	9,040	17.4	52,056	0.089
Mean	**12,551**	**49.0**	**7,756**	**28.7**	**1,671**	**8.3**	**4,202**	**14.1**	**26,179**	**0.051**

15.0 Straying

The distribution of PRH origin fish spawning in areas outside of the target stream is presented to assess the level of straying and potential impacts on other populations. The presumptive target spawning location for PRH origin fish includes the section of Columbia River from McNary Dam to Wanapum Dam as well as the lower Yakima River below Prosser Dam.

The spawning escapement of PRH origin fish by brood year is determined from CWT recoveries collected during spawning surveys. The CWT recoveries are expanded by the juvenile mark rates and survey sampling rates to estimate the number of PRH origin fish recovered on spawning grounds.

The stray rates (i.e., fish that spawned outside of the presumptive target area ÷ total escapement) for each brood year were calculated from the estimated recoveries of PRH origin fish from spawning grounds within and outside of the presumptive target area. CWT recoveries at non-target hatcheries and adult fish traps are not included. These fish were not considered strays because these fish were not able to leave the facilities on their own volition.

There are three stray rate metrics for recipient populations given in the Monitoring and Evaluation Plan for PUD Hatchery Programs based on return year stray rates and brood year stray rates (Hillman et al. 2017). The two stray rates based on return year for PRH origin fish are as follows:

1). Stray rate for PRH origin fall Chinook salmon should be less than 5% of the spawning escapement for other non-target independent populations based on run year.

2). Stray rate for PRH origin fall Chinook salmon should be less than 10% of the spawning escapement of any non-target streams within the independent population based on run year.

3). The donor stray rate for each hatchery brood year is monitored to determine if hatchery operations affect the homing and straying of specific brood years but does not include a specific target

The CWT recoveries by return year for presumptive non-target streams or areas suggest that PRH fall Chinook salmon seldom exceeded more than 5% of the spawning escapement for other independent populations of fall Chinook salmon. However, for multiple return years, greater than 5% of the spawning escapement for the Chelan River may have consisted of PRH origin fall Chinook salmon

Table 48). The Chelan River spawning population is a mix of both summer and fall Chinook salmon strays and is not considered an independent population. This location was included to show contributions of PRH strays to this group of fish. With one exception (brood year 2006), less than 5% of the PRH origin returns for each brood year are estimated to have spawned outside of the presumptive target spawning area (

Table 49).

Table 48 Proportion of fall/summer Chinook spawning populations by return year (2000-2017) comprised of Priest Rapids Hatchery fall Chinook from 1998-2015 brood releases based on coded-wire tag recoveries.

	Presumptive Non-Target Stream													
Return Year	Snake Fall Chinook		Yakima Fall Chinook		Wenatchee Summer Chinook		Entiat River[1]		Chelan River[1]		Methow Summer Chinook		Okanogan Summer Chinook	
	#	P^	#	P^	#	P^	#	P^	#	P^	#	P^	#	P^
2000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
2001	0	0.000	0	0.000	0	0.000	0	0.000	334	0.339	0	0.000	0	0.000
2002	0	0.000	0	0.000	0	0.000	0	0.000	274	0.471	0	0.000	0	0.000
2003	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
2004	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
2005	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
2006	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
2007	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
2008	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	57	0.016
2009	0	0.000	0	0.000	0	0.000	0	0.000	228	0.177	0	0.000	0	0.000
2010	0	0.000	0	0.000	0	0.000	0	0.000	359	0.322	0	0.000	0	0.000
2011	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
2012	0	0.000	0	0.000	0	0.000	0	0.000	50	0.038	0	0.000	0	0.000
2013	0	0.000	0	0.000	0	0.000	0	0.000	102	0.062	0	0.000	0	0.000
2014	0	0.000	0	0.000	0	0.000	0	0.000	83	0.075	0	0.000	0	0.000
2015	0	0.000	0	0.000	0	0.000	22	0.019	320	0.222	0	0.000	0	0.000
2016	11	0.000	0	0.000	0	0.000	0	0.000	49	0.054	0	0.000	0	0.000
2017	0	0.000	0	0.000	0	0.000	0	0.000	89	0.211	0	0.000	0	0.000
Mean	**0.61**	**0.000**	**0**	**0.000**	**0**	**0.000**	**1**	**0.001**	**105**	**0.110**	**0**	**0.000**	**3**	**0.001**

[1]The Chelan and Entiat River spawning populations are a mix of both summer and fall Chinook salmon strays and are not considered independent populations. These locations were included to show contributions of PRH strays to these groups of fish.

Table 49 Estimated number and proportions of Priest Rapids Hatchery fall Chinook salmon spawning escapement to Priest Rapids Hatchery and stream within and outside of the presumptive target stream by brood year (1992-2012). Coded-wire tag recoveries are expanded by juvenile mark rate and survey sample rate for each brood year.

Brood Year	Number of PRH Origin Recoveries	Homing				Straying Outside of Target Stream	
		Target Hatchery		Target Stream[1]			
		Number	Proportion	Number	Proportion	Number	Proportion
1992	9,037	7,630	0.844	1,037	0.115	370	0.041
1993	25,965	21,144	0.814	4,821	0.186	0	0.000
1994	1,693	1,385	0.818	308	0.182	0	0.000
1995	30,655	23,414	0.764	7,207	0.235	34	0.001
1996	13,551	10,034	0.740	3,517	0.260	0	0.000
1997	3,173	2,690	0.848	483	0.152	0	0.000
1998	18,167	11,833	0.651	5,867	0.323	467	0.026
1999	27,334	15,467	0.566	11,867	0.434	0	0.000
2000	4,759	3,690	0.775	1,069	0.225	0	0.000
2001	25,375	15,875	0.626	9,469	0.373	31	0.001
2002	5,288	3,769	0.713	1,519	0.287	0	0.000
2003	3,034	2,034	0.670	949	0.313	51	0.017
2004	1,133	1,133	1.000	0	0.000	0	0.000
2005	21,378	17,103	0.800	4,241	0.198	34	0.002
2006	1,001	641	0.640	0	0.000	367	0.367
2007	22,206	19,220	0.866	2,964	0.133	22	0.001
2008	11,866	9,002	0.759	2,864	0.241	0	0.000
2009	28,153	18,373	0.653	14,689	0.522	22	0.001
2010	107,961	67,940	0.629	40,574	0.376	327	0.003
2011	49,396	37,477	0.759	13,258	0.268	95	0.002
2012	71,635	59,189	0.826	12,341	0.172	105	0.001
Mean	**22,989**	**16,621**	**0.751**	**6,621**	**0.238**	**92**	**0.022**

[1] Target stream includes the Columbia River between McNary and Wanapum dams as well as the Yakima River below Prosser Dam.

As previously described in Section 4, approximately 3,000 smolts at PRH were annually PIT tagged at PRH from brood years 1995 through 2010. The annual release of PIT tagged smolts was increased to ~43,000 beginning with brood year 2011. The last known observations of individual PIT tag adult fall Chinook salmon originating from PRH at detection locations above McNary Dam are given in Table 50 for brood years 1999 through 2015. The number of observed PRH PIT tagged adults is increasing as anticipated due to the increased number of tags.

The majority of the PIT tagged PRH adults observed at McNary Dam have been observed at Priest Rapids Dam (PRD) adult fishways and/or PRH. Very few fish have been detected in the Snake River, which is an area of high concern for straying. In addition, notable proportions of the returns for several brood years have been observed at sites upstream of PRD. It is unclear whether fish spawned outside of the target areas because fish could return to a target location after being detected at a PIT tag array outside of the target stream without being detected again.

Observations for PIT tagged presumptive Hanford Reach natural origin adults show very few detections above PRD.

Table 50 Last observations of unique PIT tagged adult fall Chinook from Priest Rapids Hatchery at detection sties upstream of McNary Dam, Brood Years 1999-2015.

Brood Year	# PIT tagged	Number of last known detections of unique Priest Rapids Origin PIT tags by site												
		MCN	ICH	PRO	PRH	PRD	RIA	LWE	RRF	EBO	ENL	WEA	LMR	Total
1999	3000	9				7	1					1		18
2000	3000	3				4								7
2001	3000	5				6								11
2002	3000	7				1								8
2003	3000													0
2004	3000													0
2005	3000	9				4	1							14
2006	3000													0
2007	3,000	20			1	12	2		2			1	1	39
2008	2,994	5				6			1					12
2009	1,995	4			16		2							22
2010	3,000	6			36	22	5	1	4			3		77
2011	42,844	73			289	155	8	3	27	1		22	5	583
2012	42,908	97			441	120	6	1	18	1	1	14	2	701
2013 (age 2-5)	42,988	14		1	56	11	1		1	3	1	1	1	90
2014 (age 2-4)	42,621	8			29	8			2			2		49
2015 (age 2-3)	42,999	9			32	4	1		3			1		50

MCN	McNary Dam Adult Fishways RKM 470	LWE	Lower Wenatchee River RKM 754
ICH	Ice Harbor Dam Adult Fishways RKM 522	RRF	Rocky Reach Dam Adult Fishway RKM 763
PRO	Prosser Diversion Dam RKM 539	EBO	East Bank Hatchery Outfall RKM 764
PRH	Priest Rapids Hatchery Outfall RKM 635	ENL	Lower Entiat River RKM 778
PRD	Priest Rapids Dam Adult Fishways RKM 639	WEA	Well Dam Adult Fishways RKM 830
RIA	Rock Island Dam Adult Fishways RKM 730	LMR	Lower Methow River at Pateros RKM 843

15.1 Genetics

Genetic tissue was collected from each Chinook salmon spawned at PRH during 2018 by staff from the Columbia River Inter-Tribal Fish Commission (CRITFC). In total 5,831 specimens were collected at PRH to support their work associated with genetic stock identification and parentage-based tagging. The tissue samples collected from return years 2011 through 2018 is currently being archived by CRITFC. During 2010, WDFW staff collected 100 genetic tissue samples from both the Priest Rapids Hatchery broodstock and naturally spawning broodstock from the Hanford Reach.

15.2 Proportion of Natural Influence

The intent of integrated hatchery programs is to achieve management objectives while having hatchery and natural origin fish share a common gene pool. Gene flow and the associated risks within and between the hatchery and natural environments can be estimated using a simple ratio estimator using the proportion of natural origin fish in the hatchery broodstock (pNOB) and the proportion of hatchery origin fish in the natural spawning escapement (pHOS). This ratio of pNOB/(pHOS+pNOB) is termed the Proportionate Natural Influence (PNI). The larger the PNI ratio, the greater selection that the natural environment has on the population relative to that of the hatchery environment. Alternatively, PNI estimates addressing gene flow from multiple sources/hatchery programs can be calculated from a multiple population gene flow model based on the Ford model which has been extended to three or more populations (Busack 2015, 2016).

In order for the natural environment to dominate selection, PNI for either calculation should be greater than 0.5 and for integrated hatchery programs the Hatchery Scientific Review Group (HSRG) recommends a PNI ≥ 0.67 (HSRG/WDFW/NWIFC 2004). The HSRG recommends a minimum target of 0.15 for the proportion of natural origin Chinook salmon to be incorporated into the hatchery broodstock (pNOB) as well as a maximum target of 0.30 for the proportion of hatchery origin Chinook allowed to spawn in the natural environment (pHOS) for the Hanford Reach if it is to be managed as an integrated hatchery program.

Several estimates of PNI have been calculated to show the contributions of multiple programs on the overall PNI for the Hanford Reach. These programs include the hatchery production associated with the Grant PUD and USACE mitigation and the influence of strays. The different PNI estimates are based on pNOB and pHOS estimates specific to each source of spawning adults. The methods used to allocate pNOB and pHOS are described in the following sections.

15.3 Estimate of pNOB

Otolith marking began with the 2007 brood. Therefore, otolith marks are only available for specific age classes of PRH origin fish during return years 2010 and 2011 and do not provide representative samples for estimating pNOB for the PRH broodstock. Thus, estimates of pNOB based on otolith samples are limited to return years 2012 through 2018

The annual pNOB for fish spawned at PRH and used for Grant PUD and USACE smolt releases into the Hanford Reach during return years 2012 through 2018 is provided in Table 51.

Table 51 Origin of broodstock and pNOB apportioned to program for fall Chinook salmon spawned at Priest Rapids Hatchery, Return Years 2012-2018.

Return Year	N	GCPUD pNOB	USACE pNOB	GCPUD and USACE Combined pNOB	Other Programs pNOB[1]
2012	4,974	0.182	0.057	0.119	N/A
2013	5,442	0.225	0.026	0.127	N/A
2014	5,443	0.343	0.076	0.206	0.000
2015	5,524	0.313	0.045	0.179	0.000
2016	4,938	0.259	0.073	0.163	0.000
2017	5,668	0.433	0.091	0.254	0.000
2018	5,836	0.650	0.156	0.387	0.141
Mean	**5,404**	**0.344**	**0.075**	**0.205**	**0.028**

[1] Represents pNOB associated with egg-takes utilized outside of the Hanford Reach.

The 2018 broodstock included 5,836 fish, some of which with used for off-site production for other programs. The Grant PUD and USACE programs utilized 5,143 fish from the broodstock that comprised of 4,037 fish from the volunteer trap, 713 from the OLAFT and 1,086 from the ABC. In general, broodstock from ABC and OLAFT are held in a specific holding pond (Pond 4) and mated with fish from this pond or with fish collected from the PRH volunteer trap and held in holding ponds 1 and 2. The fish culturists segregate the progeny resulting from these matings for release from PRH. Brood stock utilized for non-Grant PUD programs are collected from the PRH volunteer trap and generally held in pond 2. Large portions of the progeny from the pond 2 broodstock are shipped to other facilities for use by other programs.

Grant PUD funds the collection of non-marked or tagged broodstock from the ABC and OLAFT with the intent of improving the pNOB associated with the production of their 5.6 million smolt mitigation requirement. The inclusion of these fish contributed greatly to the Grant PUD program's egg-take goal and the resulting pNOB (

Table 52).

Table 52 Origin of broodstock and pNOB apportioned to program for fall Chinook salmon spawned at Priest Rapids Hatchery, Brood Year 2018.

Program	Egg-Take	Facility Mean Fecundity	Natural Females	Hatchery Females	Natural Males	Hatchery Males	Total Natural	Total Hatchery	pNOB
GCPUD	1,490,034	3,811	293	98	346	45	639	143	0.817
GCPUD Alt Mating[1]	5,012,051	3,879	613	679	308	17	921	696	0.569
GCPUD Combined	6,502,085	3,863	906	777	654	62	1,560	839	0.650
USACE – PRH	1,990,935	3,708	76	461	209	66	285	527	0.351
USACE – RSH	4,671,080	3,627	74	1,214	69	575	143	1,789	0.074
USACE Combined	6,662,015	3,650	151	1,674	277	642	428	2,316	0.156
Combined PRH and RSH Programs	13,164,100	3,753	1,056	2,452	932	703	1,988	3,155	0.387
Other Programs[2]	1,656,907	3,634	26	430	72	165	98	595	0.141

[1] Alternative mating strategy incorporates 1 natural origin male x 4 females.
[2] Includes eggs from presumed hatchery x hatchery crosses shipped to educational organizations.

15.4 Estimates of pHOS

Otolith marking began with the 2007 brood. Hence, otolith marks are only available for specific age classes of PRH origin fish during return years 2010 and 2011 and do not provide representative samples for estimating population level pHOS. Thus, estimates of pHOS based on otolith samples are limited to return years 2012 through 2018. The population level pHOS estimates for recent annual Hanford Reach spawning escapements are presented

Table 53.

Table 53 Proportion of hatchery Chinook salmon on the spawning grounds (pHOS) in the Hanford Reach, Brood Years 2012-2018.

Return Year	N	Total Escapement	Hatchery Origin Escapement (pHOS)			
			PRH	RSH	Other[1]	Total
2012	1,609	57,715	0.062	0.066	0.005	0.135
2013	927	174,841	0.203	0.054	0.018	0.275
2014	2,426	183,807	0.052	0.015	0.028	0.096
2015	2,485	266,328	0.076	0.017	0.004	0.097
2016	1,648	116,287	0.066	0.022	0.027	0.115
2017	1,813	73,759	0.063	0.017	0.001	0.081
2018	1,208	42,277	0.051	0.005	0.015	0.071
Mean	**1,731**	**130,716**	**0.082**	**0.028**	**0.014**	**0.124**

[1] Includes fish from other hatcheries based on presence of a coded-wire tag or adipose clip fish without an otolith mark.

Estimates for pHOS were calculated for contributing sources of hatchery origin fall Chinook escapement in the Hanford Reach (Table 54). The pHOS associated with the PRH origin escapement was apportioned between the Grant PUD and USACE programs at PRH based on the annual program release goals from PRH of 5.6 million for Grant PUD and 1.7 million for USACE. The pHOS estimate for return year 2018 includes 2,232 PRH origin fish in the escapement. Of these, 74.6% and 25.4% were allocated respectively to Grant PUD (1,760 fish) and USACE (599 fish) programs at PRH. The USACE's 25.4% portion of the PRH origin escapement was combined with the escapement associated with the USACE's RSH program (242 fish) to estimate the pHOS associated with the USACE programs in the Hanford Reach. There were 696 hatchery fish in the escapement associated with other hatchery programs located outside of the Hanford Reach.

Table 54 Origin of pHOS apportioned by program source for fall Chinook salmon spawning naturally in the Hanford Reach, Return Years 2012-2018.

Return Year	Natural Origin	Hatchery Origin Spawners				pHOS by Source			
		GCPUD[1]	USACE[1,2]	Other[3]	Total	GCPUD[1]	USACE[1,2]	Other[3]	Combined
2012	50,072	3,943	3,598	261	7,803	0.068	0.062	0.005	0.135
2013	126,782	26,507	18,427	3,123	48,057	0.152	0.105	0.018	0.275
2014	166,183	7,185	5,262	5,120	17,567	0.039	0.029	0.028	0.096
2015	240,511	15,101	9,669	1,065	25,835	0.057	0.036	0.004	0.097
2016	103,033	5,732	4,513	3,143	13,388	0.049	0.039	0.027	0.115
2017	67,807	3,463	2,409	79	5,951	0.047	0.033	0.001	0.081
2018	42,277	1,760	841	696	3,297	0.038	0.018	0.015	0.071
Mean	**113,809**	**9,099**	**6,388**	**1,927**	**17,414**	**0.064**	**0.046**	**0.014**	**0.124**

[1]Estimated number of PRH origin fish that spawned naturally in the Hanford Reach. Of these, 74.6% and 25.4% were apportioned to Grant PUD-PRH and USACE-PRH, respectively.
[2]Includes hatchery origin fish released from Ringold Springs Hatchery.
[3]Includes hatchery origin fish released from other hatcheries based on the presence of a hatchery mark without an otolith mark.

15.5 Estimates of PNI

We present PNI estimates based on pNOB and pHOS values calculated to reflect differing methodologies driven by the type of data available to assign origin of adult Chinook salmon returns. The population level PNI for the Hanford Reach provided for each method includes all hatchery origin fish regardless of hatchery program or funding source.

Prior to return year 2012, pHOS, pNOB and PNI rates were based on CWT recoveries from the adult returns. Historically, we used juvenile mark rate expansions of CWT recoveries in the hatchery and stream surveys for these calculations. The pNOB estimated from CWT requires the assumption that fish unaccounted for by the juvenile mark rate expansions are natural origin fish. As discussed in Appendix A of this report, this assumption may over estimates pNOB and PNI. This method of estimated pNOB for the 2015 through 2018 broodstock was not calculated due to culling fish possessing a CWT and or an adipose clip. Hence, the broodstock origin is poorly represented by CWT.

The pHOS estimates based on juvenile mark rate expansions of CWT recoveries also likely underestimate the presences of PRH and RSH origin fish as explained in Appendix A. For comparison, we present CWT based estimates of PNI derived from CWT adult-to-adult expansions for PRH and RSH origin adult recoveries at their respective hatcheries. An explanation of methods is given in Appendix J. Estimates of pNOB, pHOS, and PNI based on both methods of CWT expansions are presented in

Table 55.

The pHOS and pNOB estimates from limited otolith datasets for recent complete brood years are more similar to the estimates produced by adult-to-adult CWT expansions versus juvenile mark rate expansions of CWT recoveries of returning adults.

Table 55 PNI of the Hanford Reach fall Chinook salmon supplementation program based on expanded coded-wire tag recoveries of all fish surveyed, Return Years 2001-2018.

Return Year	pNOB[1]	pHOS[1]	pNOB[2]	pHOS[2]	PNI based on pNOB[1] and pHOS[1]	PNI based on pNOB[2] and pHOS[2]
2001	0.155	0.094	0.046	0.066	0.622	0.411
2002	0.145	0.101	0.046	0.125	0.589	0.269
2003	0.132	0.099	0.046	0.117	0.571	0.282
2004	0.229	0.081	0.046	0.099	0.739	0.317
2005	0.370	0.106	0.046	0.156	0.777	0.229
2006	0.507	0.057	0.046	0.124	0.899	0.271
2007	0.326	0.041	0.046	0.065	0.888	0.414
2008	0.501	0.046	0.046	0.087	0.916	0.346
2009	0.568	0.077	0.046	0.174	0.881	0.209
2010	0.392	0.040	0.046	0.076	0.907	0.377
2011	0.381	0.076	0.046	0.154	0.836	0.230
2012	0.304	0.074	0.119[a]	0.118	0.871	0.529
2013	0.252	0.217	0.127[a]	0.287	0.537	0.300
2014	0.443	0.054	0.206[a]	0.069	0.888	0.760
2015	N/A[3]	0.072	0.179[a]	0.075	N/A[3]	0.691
2016	N/A[3]	0.092	0.163[a]	0.097	N/A[3]	0.627
2017	N/A[3]	0.116	0.254[a]	0.102	N/A[3]	0.713
2018	N/A[3]	0.071	0.372[a]	0.091	N/A[3]	0.803

pNOB[1] Assumes that all fish not accounted for by juvenile coded-wire tag expansions are natural origin.
pHOS[1] based on hatchery origin coded-wire recoveries expanded by juvenile mark rate and survey sample rate.
pNOB[2] is assigned to years 2001 – 2011 based on an average proportion of natural origin returns to PRH for return years 2012 -2014 as determined by otolith and other hatchery marks.
pHOS[2] is based on an adult coded-wire tag expansion rate for PRH and RSH origin adults recovered in the Hanford Reach escapement combined with juveniles coded-wire tag mark rate expansions for other hatchery strays. Both groups were expanded by the survey sample rate.
[3] Brood stock was generally high-graded to remove coded-wire tagged fish during ponding.
[a]pNOB of broodstock used for production of PRH and RSH programs as determined from otoliths and other hatchery marks.

For return years 2012-2018 we present PNI estimates calculated from the multiple population gene flow model (Busack 2015) and otoliths (Table 56). This is our best estimate for PNI. The output from this model indicates that the PNI values for return years 2014 and 2018 have exceeded the goal of 0.670.

Table 56 PNI estimates for the Hanford Reach fall Chinook salmon supplementation programs based on otoliths, Return Years 2012-2018. Calculated from multiple population gene flow model based on the Ford model which has been extended to three or more populations.

Return Year	pNOB			pHOS			pHOS	PNI
	GCPUB[1]	USACE[2]	Facility[3]	GCPUD[4]	USACE[5]	Other[6]	Reach[7]	Population[8]
2012	0.182	0.057	0.119	0.068	0.062	*0.005*	0.135	0.599
2013	0.225	0.027	0.127	0.152	0.105	*0.018*	0.275	0.463
2014	0.343	0.076	0.206	0.039	0.029	*0.028*	0.096	0.775
2015	0.313	0.045	0.179	0.057	0.036	*0.004*	0.097	0.762
2016	0.259	0.072	0.163	0.049	0.039	*0.027*	0.115	0.700
2017	0.433	0.091	0.254	0.047	0.033	*0.001*	0.081	0.835
2018	0.650	0.156	0.387	0.038	0.018	*0.015*	0.071	0.891
Mean	0.344	0.075	0.205	0.064	0.046	0.014	0.124	0.718

[1]Includes broodstock associated with Grant PUD production at PRH.
[2] Includes broodstock associated with USACE production at PRH and RSH.
[3] Includes broodstock spawned at PRH for all production
[4] Includes pHOS associated with Grant PUD mitigation smolt releases at PRH
[5] Includes pHOS associated with USACE mitigation smolt releases at PRH and RSH
[6] Includes pHOS associated with strays from hatcheries outside of the Hanford Reach
[7] Population level pHOS in the Hanford Reach
[8] Population level PNI for the Hanford Reach. Assumes strays from hatcheries outside of the Hanford Reach have an associated pNOB of zero.

16.0 Natural and Hatchery Replacement Rates

The numbers of hatchery origin recruits (HOR) are estimated from CWT recoveries for brood year returns to the PRH and the Hanford Reach of the Columbia River. The recovered CWTs are expanded by sample rate of the survey and then by the juvenile tag rate. CWTs recovered from natural origin recruits (NOR) originating from the Hanford Reach are difficult to expand accurately because the juvenile tag rates are unknown. While imperfect, we make the assumption that returns not accounted for by HOR CWT recoveries are NOR.

Hatchery replacement rates (HRR) were calculated as the ratio of HOR to the parent broodstock at PRH. This broodstock is an estimate of the number of fish spawned at PRH to produce the target release of subyearling fall Chinook salmon. Similarly, natural replacement rates (NRR) for the Hanford Reach URB fall Chinook salmon were calculated as the ratio of NOR to the parent population spawning naturally in the Hanford Reach natural environment. This spawning population is based on the escapement estimate to the Hanford Reach without adjustments for spawn success.

Harvest estimates for HOR were calculated from the proportion of the expanded CWT recoveries in the fisheries to the total number of the expanded CWTs recoveries included in fisheries, stream surveys, and hatchery racks. The CWT recoveries are expanded by sample rate of the survey and juvenile mark rate for the CWT group. Since there is not a CWT mark rate for NOR, the harvest rates for PRH origin returns (HOR) were used as an indicator for similar brood years of NORs.

The HRR and NRR for brood year 2012, includes harvest, was 41.24 and 6.34, respectively (

Table 57). In comparison, the HRR and NRR for brood year without harvest was 23.33 and 2.78, respectively. The HRR should be greater than or equal to 5.30 (the target value in Murdoch and Peven 2005).

Table 57 Broodstock spawned at Priest Rapids Hatchery, estimated escapement to the Hanford Reach, natural and hatchery origin recruits (NOR and HOR), and natural and hatchery replacement rates (NRR and HRR, with and without harvest) for natural origin fall Chinook salmon in the Hanford Reach, Brood Years 1996-2012.

Brood Year	Broodstock Spawned	Hanford Reach Escapement[1]	Harvest not included				Harvest included[2]			
			HOR	NOR	HRR	NRR	HOR	NOR	HRR	NRR
1996	2,859	43,249	13,584	28,849	4.75	0.67	26,205	59,899	9.17	1.38
1997	2,726	43,493	3,002	44,416	1.10	1.02	6,037	88,349	2.21	2.03
1998	3,027	35,393	18,464	93,999	6.10	2.66	31,932	222,865	10.55	6.30
1999	2,619	29,812	27,093	115,237	10.34	3.87	52,099	240,090	19.89	8.05
2000	2,619	48,020	4,665	56,422	1.78	1.17	12,508	89,983	4.78	1.87
2001	3,621	59,848	25,059	71,359	6.92	1.19	55,789	129,548	15.41	2.16
2002	3,630	84,509	5,277	47,813	1.45	0.57	12,744	81,600	3.51	0.97
2003	3,003	100,508	3,021	31,788	1.01	0.32	5,974	64,307	1.99	0.64
2004	3,014	87,696	1,109	22,747	0.37	0.26	3,262	34,465	1.08	0.39
2005	2,898	71,967	21,107	64,011	7.28	0.89	61,122	97,777	21.09	1.36
2006	2,911	51,701	998	54,288	0.34	1.05	3,347	77,344	1.15	1.50
2007	2,096	22,274	22,184	101,753	10.58	4.57	52,832	175,404	25.21	7.87
2008	2,959	29,058	11,867	41,809	4.01	1.44	25,166	79,116	8.51	2.72
2009	3,177	36,720	28,154	97,834	8.86	2.66	85,489	145,874	26.91	3.97
2010	3,320	87,016	97,567	281,364	29.38	3.23	209,338	526,972	63.05	6.06
2011	3,121	75,256	49,396	168,864	15.83	2.24	90,628	371,161	29.04	4.93
2012	3,008	57,715	70,175	160,185	23.33	2.78	124,058	368,804	41.24	6.39
Mean	2,939	56,720	23,689	87,220	7.98	1.80	50,502	167,856	17.61	3.45
Median	2,959	51,701	18,464	64,011	6.10	1.19	31,932	97,777	10.55	2.16

[1] Includes estimated adult and jack escapement to the Hanford Reach natural environment.
[2] Harvest rates for NORs was estimated using the HRRs harvest rates for similar brood years as an indicator stock.

17.0 Smolt-to-Adult Survivals

Smolt-to-adult survival ratios (SAR) were calculated by dividing the expanded number of adults possessing a CWT recovered by the number of CWT smolts released. This estimate could be biased low for both hatchery and natural origin fish because of some of CWT bias identified previously in this report. The following data was obtained from the RMPC's RMIS online database: http://www.rmpc.org/. The SAR by brood year data was re-queried on September 9, 2019. This query should account for age 2 through 6 fall Chinook salmon sampled through December 2017. The lag in reporting field data for the 2018 return year likely excludes recoveries of a limited number of age-6 fish from the 2012 brood and ages- 4 and 5 from brood 2013.

Annual SAR for hatchery fall Chinook salmon released from PRH for brood years 1992 through 2013 have a mean of 0.0070 with a median of 0.0062 (Table 58). The SAR for the PRH origin 2010 brood is 0.0304, which is the highest SAR on record for PRH releases.

Table 58 **Smolt-to-adult Survival Ratios (SAR) for Priest Rapids Hatchery fall Chinook salmon, Brood Years 1992-2013. Data includes all coded-wire tag recoveries from adipose clipped fish.**

Brood Year	Number of Tagged Smolts Released	Estimated Adult Captures	SAR
1992	194,622	456	0.0023
1993	185,683	1,474	0.0079
1994	174,033	108	0.0006
1995	196,089	1,789	0.0091
1996	193,195	762	0.0039
1997	196,203	184	0.0009
1998	193,545	943	0.0049
1999	204,506	1,578	0.0077
2000	200,784	368	0.0018
2001	219,918	1,829	0.0083
2002	355,373	672	0.0019
2003	399,119	352	0.0009
2004	200,072	96	0.0005
2005	199,445	1,763	0.0088
2006	202,000	96	0.0005
2007	202,568	2,338	0.0115
2008	218,011	727	0.0033
2009	619,568	7,904	0.0128
2010	603,790	17,809	0.0295
2011	595,608	7,341	0.0123
2012	603,930	9,978	0.0165
2013	603,797	4,528	0.0075
Mean	307,357	2,868	0.0070
Median	202,284	1,209	0.0062

Annual SAR for Hanford Reach natural origin fall Chinook salmon for brood years 1992 through 2013 had a mean of 0.0053 with a median of 0.0027 (Table 59). The SAR for the Hanford Reach natural origin 2010 brood is 0.0180 which is the highest SAR on record for the Hanford Reach natural origin stock.

Table 59 **Smolt-to-adult Survival Ratios (SAR) for Hanford Reach natural origin fall Chinook salmon, Brood Years 1992-2013. Data includes all coded-wire tag recoveries from adipose clipped fish. Source Regional Mark Processing Center.**

Brood Year	Number of Tagged Smolts Released	Estimated Adult Captures	SAR
1992	203,591	820	0.0040
1993	95,897	486	0.0051
1994	148,585	74	0.0005
1995	146,887	340	0.0022
1996	92,262	110	0.0012
1997	199,896	358	0.0018
1998	129,850	783	0.0060
1999	213,259	2,367	0.0111
2000	204,925	362	0.0018

Brood Year	Number of Tagged Smolts Released	Estimated Adult Captures	SAR
2001	127,758	519	0.0041
2002	203,557	340	0.0017
2003	207,168	201	0.0010
2004	163,884	143	0.0009
2005	203,929	381	0.0019
2006	263,478	357	0.0017
2007	53,618	446	0.0083
2008	203,947	556	0.0027
2009	201,606	1,616	0.0080
2010	179,727	2,919	0.0178
2011	166,610	1,063	0.0064
2012	148,107	1,769	0.0119
2013	179,952	452	0.0025
Mean	**177,180**	**828**	**0.0053**
Median	**179,952**	**452**	**0.0027**

18.0 ESA/HCP Compliance

18.1 Broodstock Collection

Section 10(a)(1)(B) Permit 1347 authorizes collection of fall Chinook broodstock at the OLAFT for the Priest Rapids hatchery program with an incidental take limit of 10 steelhead (an aggregate of hatchery or wild). Due to the absence of an identified steelhead take limit for operation of the PRH volunteer trap in permit 1347 and through ongoing coordination with NOAA Fisheries, the 10 fish take limit for broodstock collection at the OLAFT, on an interim basis (until a new permit is issued), has been re-conceptualized to include broodstock collection at the PRH volunteer trap, and in the ABC fishery. During the 2018 fall Chinook broodstock collection activities, a total of 5 steelhead, one of which was not adipose clipped, were encountered at the PRH volunteer trap with no incidental mortality reported. No steelhead mortalities were associated with broodstock collection at the OLAFT or in the ABC fishery (Table 60).

Table 60 Recoveries and disposition of steelhead at the Priest Rapids Hatchery volunteer trap, Return Year 2018.

		No Mark	Ad Only	Ad-RV	Total
Released	Males	1	1	1	3
	Females	0	1	1	2
	Sub Total	1	2	2	5
Killed	Males	0	0	0	0
	Females	0	0	0	0
	Sub Total	0	0	0	0
	Total	**1**	**2**	**2**	**5**

18.2 Hatchery Rearing and Release

The juvenile fall Chinook salmon from the 2018 brood year reared throughout their life-stages at PRH without incident. The reported smolt release for the 2018 brood totaled 7,213,916 URB fall Chinook salmon, representing 99% of the production objective and was compliant with the 10% overage allowable in ESA Section 10 Permit 1347.

18.3 Distribution of Surpluses, Mortalities, and Spawned, Adult fall Chinook Salmon from Priest Rapids Hatchery

All adult Chinook salmon recovered at PRH are eventually distributed to multiple organizations depending on the condition and treatment of the individual fish while at the hatchery. A large number of these fish are suitable for consumption and transported to Foodbanks (Table 61). A total of 8,997, roughly 49% of the carcasses handled at PRH, were transported off station for human consumption.

Table 61 Disposition of Chinook salmon removed from Priest Rapids Hatchery volunteer trap, Return Year 2001-2018.

Return Year	Disposal of Mortalities		WDFW Nutrient Enhancement Projects	Donations to Educational Programs & Research	Donations to Foodbanks	Donations to Tribes	Sold to Fish Buyers	Fish Removed from Priest Rapids Hatchery
	Pet Food	Landfill						
2001	0	6,597	2,054	0		525	6,139	15,315
2002	0	6,572	2,192	0	3,130	502	0	12,396
2003	0	5,144	3,211	9	881	98	0	9,343
2004	350	2,661	2,756	88	9,371		595	15,821
2005	153	5,635	318	2	0		4,503	10,611
2006	0	5,467	0	250	0	340	2,146	8,203
2007	2,595	0	0	0	0	159	3,345	6,099
2008	5,384	90	0	340	0	375	13,428	19,617
2009	5,846	0	0	310	0	201	6,502	12,859
2010	5,412	1,937	1,937	452	3,548	8	8,259	21,553
2011	6,951	0	1,500	412	11,217	588	0	20,668
2012	7,554	0	0	460	20,628		0	28,642
2013	10,108	0	0	489	31,647	626	0	42,870
2014	10,805	0	0	237	67,684	783	0	79,509
2015	7,402	0	0	398	52,987	4,228	0	65,015
2016	7,833	0	0	411	19,424	1,948	0	29,616
2017	10,905	0	0	436	6,413	1,505	0	19,259
2018	8,670	0	0	480	8,647	350	0	18,147
Mean	**4,998**	**1,895**	**776**	**265**	**13,857**	**816**	**2,495**	**24,197**
Median	**5,629**	**0**	**0**	**325**	**6,413**	**502**	**0**	**18,703**

18.4 Hatchery Effluent Monitoring

Per ESA Permits 1196, 1347, and 1395, permit holders shall monitor and report hatchery effluents in compliance with applicable National Pollution Discharge Elimination Systems (NPDES) (EPA 1999) permit limitations. There were no NPDES violations reported at Grant PUD Hatchery facilities during the September 2018 through June 2019 collection and rearing periods.

18.5 Ecological Risk Assessment

One of the regional objectives in the Grant PUD M&E plan is to conduct an ecological risk assessment on non-target taxa of concern to determine if additional M&E is necessary (Pearsons and Langshaw 2009). The methodology that was used to assess risks was presented in Pearsons et al. (2012) and Pearsons and Busack (2012). This objective was completed through an approved report that summarized the methods and results of the risk assessment (Mackey et al. 2014).

19.0 Acknowledgments

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Appendix A
Evaluation of Coded-Wire Tag Bias

We annually evaluate bias associated with estimates of the number of hatchery origin returns to PRH generated using coded-wire tags (CWT). Results from demographic sampling of the fall Chinook returns for 2010 through 2014 indicate that estimates of hatchery contributions to broodstock, the terminal sport fishery, and to escapement of the Hanford Reach and to the PRH trap calculated from otolith marks were substantially different from estimates generated using CWTs expanded by sampling rates and juvenile mark rates. This was of significant concern because many estimates such as stray rate, survival, origin, and harvest are dependent upon estimates generated from CWTs.

To assess the level of CWT recovery bias for any brood year, we used the following equation:

$$\text{CWT Recovery Bias} = \frac{(\text{\# of PRH Origin CWT Fish Recovered} \,/\, \text{\# of PRH Origin Fish Collected})}{\text{CWT Mark Rate for Brood Year}}$$

Where:

# of PRH origin fish collected = Estimate of the number of PRH origin fish for a specific age/brood year as determined by otoliths, scale aging, and expansion and pooling of age samples to represent total returns by age

# of PRH Origin CWT Fish Recovered = Number of PRH origin CWT fish for a specific age/brood recovered at the hatchery (100% sample rate)

CWT Mark Rate = CWT marking rate for the specific brood year which is the number of CWT placed in fish divided by the estimated total number of fish at the time of marking.

If no CWT bias exists, the proportion of PRH CWT returns to the PRH CWT mark rate should equal 1.000. The values for CWT Recovery bias ranged from 0.573 to 4.620 for the different age/broods examined (Table A.1). Even though the datasets are not complete for recent brood years, it appears that the CWT Recovery bias is less pronounced since brood year 2011. The source of any bias is likely due to inappropriate expansion rate estimates resulting from non-representative placement of CWT groups within the general population of rearing in the channel ponds. However, several other factors may contribute to the variation in CWT Recovery bias such as tag loss, CWT detection efficiency, or differential survival of tagged fish. In addition, the estimate of bias may be influenced by the level of precision of the estimated # of PRH origin fish collected which varies for each age class of a given brood year due to size of the otolith sub-sample pulled from the demographic sample. In some cases, there are relatively few samples for age-2 and 5 fish for a given brood year for this estimate.

Verification of the juvenile CWT rate at time of release is necessary to determine level of potential bias associated with reported juvenile CWT rates. Sampling for CWT rates at time of release has occurred at PRH since brood year 2014. Shortly prior to release, roughly 1,000 subyearlings from each of the five rearing ponds were captured and scanned with a V-detector to determine the proportions of adipose clipped CWT fish and adipose intact CWT fish within the sample. These proportions at release were compared to the proportions reported as ponded. In general, these two groups of proportions were generally similar for each brood year with the exception brood year 2018 (Table A.2). The results of the quality control sampling for the 2018 brood year found that the observed CWT rates were higher than the expected rates for rearing ponds D and E.

Table A.1 Estimate of coded-wire tags bias for Priest Rapids origin returns to the hatchery, Brood Years 2007- 2016.

Brood	Age	Proportion CWT Marked	# of PRH Origin CWT Fish Recovered	Estimated # of PRH origin Fish Collected	Proportion of PRH Origin Brood Return CWT	Proportion of PRH CWT Returns to the PRH CWT Mark Rate (CWT Recovery Bias)	Primary Detector Type
2007	5	0.045	48	928	0.052	1.161	Blue Wand
2007	4	0.045	280	10,977	0.026	0.573	Blue Wand
2007	3	0.045	410	14,073	0.029	0.654	Blue Wand
2007	2	No otolith data collected during return year 2009					
2008	5	0.032	2	31	0.065	2.026	Blue Wand
2008	4	0.032	81	3,029	0.027	0.840	Blue Wand
2008	3	0.032	124	5,606	0.022	0.695	Blue Wand
2008	2	0.032	57	2,578	0.022	0.694	Blue Wand
2009	5	0.243	407	1,980	0.206	0.846	R9500
2009	4	0.243	1,081	6,025	0.179	0.739	Blue Wand
2009	3	0.243	2,309	13,713	0.168	0.693	Blue Wand
2009	2	0.243	628	3,083	0.204	0.839	Blue Wand
2010	6	0.237	23	20	1.150	4.851	R9500
2010	5	0.237	999	2,375	0.421	1.778	R9500
2010	4	0.237	8,719	39,621	0.220	0.928	R9500
2010	3	0.237	5,828	32,014	0.182	0.768	Blue Wand
2010	2	0.237	1,498	8,932	0.168	0.707	Blue Wand
2011	6	0.169	10	47	0.213	0.258	R9500
2011	5	0.169	395	2,520	0.157	0.927	R9500
2011	4	0.169	2,988	19,536	0.153	0.904	R9500
2011	3	0.169	2,596	19,692	0.132	0.779	R9500
2011	2	0.169	349	3,008	0.116	0.686	R9500
2012	6	0.177	7	19	0.368	2.086	R9500
2012	5	0.177	1,913	11,259	0.170	0.961	R9500
2012	4	0.177	2,206	13,821	0.160	0.904	R9500
2012	3	0.177	5,933	34,082	0.174	0.986	R9500
2012	2	0.177	1,910	11,259	0.170	0.961	R9500
2013	5	0.166	109	527	0.207	1.245	R9500
2013	4	0.166	1,530	8,695	0.164	0.998	R9500
2013	3	0.166	1,805	10,967	0.165	0.991	R9500
2013	2	0.166	545	3,327	0.164	0.986	R9500
2014	4	0.172	407	2,685	0.152	0.883	R9500
2014	3	0.172	483	3,289	0.147	0.856	R9500
2014	2	0.172	78	462	0.169	0.984	R9500
2015	3	0.167	1,343	8,596	0.156	0.936	R9500
2015	2	0.167	183	1,219	0.150	0.899	R9500

Brood	Age	Proportion CWT Marked	# of PRH Origin CWT Fish Recovered	Estimated # of PRH origin Fish Collected	Proportion of PRH Origin Brood Return CWT	Proportion of PRH CWT Returns to the PRH CWT Mark Rate (CWT Recovery Bias)	Primary Detector Type
2016	2	0.171	138	1,061	0.130	0.760	R9500

CWT Recovery Bias		Ages				
		2	3	4	5	6
	Mean	**0.820**	**0.822**	**0.857**	**1.279**	**2.648**

Table A.2. Proportions of coded-wire tagged juvenile fish reported ponded and the proportions of coded-wire tagged fish sampled at time of release, Brood Years 2014-18.

Coded-wire sampling at release, Brood Year 2014						
# of Fish	**Pond E**	**Pond D**	**Pond C**	**Pond B**	**Pond A**	**Total**
Fish Released	1,425,371	1,457,198	1,400,956	1,444,918	1,311,100	7,039,543
N =	1,040	1,024	1,018	1,023	1,565	5,670
CWT Only Sampled	98	85	79	67	220	549
Ad-CWT Sampled	102	69	73	86	165	495
Proportion of Release Tagged						
CWT Only	8.5%	8.3%	8.6%	8.2%	9.0%	8.5%
Ad-CWT	8.5%	8.2%	8.6%	8.7%	8.7%	8.5%
Proportion of Sample Tagged						
CWT Only	9.4%	8.3%	7.8%	6.5%	14.1%	9.7%
Ad-CWT	9.8%	6.7%	7.2%	8.4%	10.5%	8.7%
Coded-wire sampling at release, Brood Year 2015						
# of Fish	**Pond E**	**Pond D**	**Pond C**	**Pond B**	**Pond A**	**Total**
Fish Released	1,445,733	1,448,510	1,507,753	1,512,437	1,327,621	7,242,054
N =	1,015	995	991	1,048	1,021	5,070
CWT Only Sampled	91	86	77	62	76	392
Ad-CWT Sampled	71	87	79	71	80	388
Proportion of Release Tagged						
CWT Only	8.1%	8.6%	8.3%	7.5%	9.1%	8.3%
Ad-CWT	8.3%	8.6%	7.7%	8.0%	9.1%	8.3%
Proportion of Sample Tagged						
CWT Only	9.0%	8.6%	7.8%	5.9%	7.4%	7.7%
Ad-CWT	7.0%	8.7%	8.0%	6.8%	7.8%	7.7%

Table A.2 Continued

Coded-wire sampling at release, Brood Year 2016						
# of Fish	**Pond E**	**Pond D**	**Pond C**	**Pond B**	**Pond A**	**Total**
Fish Released	1,401,157	1,455,960	1,450,776	1,487,339	1,211,019	7,006,251
N =	1,031	1,317	2,228	1,117	1,181	6,874
CWT Only Sampled	119	103	205	116	120	663
Ad-CWT Sampled	101	96	224	112	117	650
Proportion of Release Tagged						
CWT Only	8.6%	8.3%	8.3%	8.1%	10.0%	8.6%
Ad-CWT	8.6%	8.3%	8.3%	8.1%	10.0%	8.6%
Proportion of Sample Tagged						
CWT Only	11.5%	7.8%	9.2%	10.4%	10.2%	9.6%
Ad-CWT	9.8%	7.3%	10.1%	10.0%	9.9%	9.5%
Coded-wire sampling at release, Brood Year 2017						
# of Fish	**Pond E**	**Pond D**	**Pond C**	**Pond B**	**Pond A**	**Total**
Fish Released	1,632,887	1,573,080	1,615,297	1,588,038	1,594,137	8,003,439
N =	1,046	1,260	1,022	1,173	1,044	5,545
CWT Only Sampled	88	143	74	87	85	477
Ad-CWT Sampled	81	164	71	77	67	460
Proportion of Release Tagged						
CWT Only	7.5%	7.6%	7.5%	7.6%	7.6%	7.6%
Ad-CWT	7.2%	7.7%	7.5%	7.6%	7.6%	7.5%
Proportion of Sample Tagged						
CWT Only	8.4%	11.3%	7.2%	7.4%	8.1%	8.6%
Ad-CWT	7.7%	13.0%	6.9%	6.6%	6.4%	8.3%
Coded-wire sampling at release, Brood Year 2018						
# of Fish	**Pond E**	**Pond D**	**Pond C**	**Pond B**	**Pond A**	**Total**
Fish Released	1,471,868	1,452,947	1,430,194	1,464,134	1,394,773	7,213,916
N =	1,201	1,197	1,099	1,100	1,100	5,697
CWT Only Sampled	192	136	99	83	92	602
Ad-CWT Sampled	200	158	99	109	91	657
Proportion of Release Tagged						
CWT Only	8.2%	8.2%	8.4%	8.3%	8.7%	8.3%
Ad-CWT	8.2%	8.2%	8.5%	8.3%	8.7%	8.4%
Proportion of Sample Tagged						
CWT Only	16.0%	11.4%	9.0%	7.5%	8.4%	10.6%
Ad-CWT	16.7%	13.2%	9.0%	9.9%	8.4%	11.5%

Assessment of CWT detection efficiency has been conducted annually at PRH since 2010 during adult fish sampling with enhancement to these procedures developed over time. In 2013, M&E staff randomly selected a total of 1,063 quality control fish being surplused with no CWT detected using the T-wand (Table A.3). These fish were then re-scanned with the older blue-wand. If CWT was detected using a blue wand the fish was again scanned using the T-wand. In such a manner the missed CWT could be inferred as a result of operator error or the inability of the T-wand to detect the CWT. On a few occasions the T-wand did not detect a CWT identified by the blue-wand. In these instances, the snouts were removed from the fish to increase the likelihood of detection and then passed through a V-detector. Similar to quality control results for previous years, there were only a few (4 tags) of the sample CWT detections observed in the quality control fish sampled that were not detected initially by the T-wands.

Table A.3 Quality control results for coded-wire tag detection at Priest Rapids Hatchery, Brood Years 2013- 2018.

Brood Year	Initial Device	QC Device	# Sampled	# Missed CWT
2013	T-Wand	Blue Wand	1,063	4
2014	R9500	T-Wand	2,000	3
2015	R9500	T-Wand	4,596	2
2016	R9500	T-Wand	5,943	3
2017	R9500	T-Wand	1,744	3
2018	R9500	T-wand	1,679	6

During 2013 and 2014, we found the T-wands to be overly sensitive leading to false positive detections and additional work related to processing snouts to extract CWTs. On October 2, 2014 we set up two series R9500 detectors to expedite scanning for CWTs (Figure 1). The detectors were checked for proper operation each day prior to scanning any fish. Informal quality control checks occurred daily during the first two weeks of operation in order to identify the detection efficiency of each detector. These checks involved running 100 fish through each machine and then re-scanning the fish with the T-wands. A total of 2,000 fish were passed through the R9500 units of which 422 were identified to possess a CWT. Of these fish, 419 signaled positive for a CWT during the initial scanning. The three fish possessing a CWT that were not identified by the R9500 during the initial scanning were correctly detected when re-ran though the detectors. The missed fish were likely the result of passing fish through the detectors too rapidly which can interfere with the operation of the flip gates.

R9500 detectors were used to scan the vast majority of fish surplused at PRH during 2015 through 2018. During each of these years, the first group of fish handled each day was used to test the CWT detection of each R9500 detector. The test fish that a CWT was not detected were re-scanned with a T-wand to assess the performance of the R9500 detectors. The results for all three years suggest that very few possessing a CWT are missed by the R9500 detectors.

The methods describe here do not provide a definitive estimate of undetected CWTs for fish sampled at PRH. We make an assumption, that if the CWT detection wands and R9500 units do not detect a CWT in a given fish, then it did not possess a tag. Based on this assumption, the CWT detection efficiency at PRH is likely greater than 99%. Therefore, the magnitude of the CWT recovery bias expressed in Table 1 is not likely due to poor CWT detection efficiency.

Figure 1. Series R9500 Coded-wire tag detectors used at Priest Rapids Hatchery, 2014

Appendix B
Recovery of coded-wire tags collected from adult returns to the Priest Rapids Hatchery Volunteer Trap during Return Year 2018

						CWT Release			Expansion		Return to PRH	
Code	**# of Tags**	**BY**	**Race**	**Age**	**Stock**	**Date**	**AD CWT**	**CWT Only**	**All CWT**	**AD CWT**	**#**	**%**
220389	1	2016	Fall	2	Snake R	2018	0	77,407	1.026	2.097	**1**	0.0%
220241	4	2015	Fall	3	Snake R	2016	0	101,622	1.096	2.208	**4**	0.0%
220243	6	2015	Fall	3	Snake R	2016	0	102,279	1.115	2.250	**7**	0.0%
220253	1	2016	Fall	2	Snake R	2017	0	103,975	1.120	2.261	**1**	0.0%
220262	1	2016	Fall	2	Snake R	2017	0	104,357	1.135	2.299	**1**	0.0%
220256	2	2016	Fall	2	Snake R	2017	0	201,745	1.832	5.549	**4**	0.0%
220384	1	2016	Fall	2	Snake R	2017	0	107,414	1.865	3.793	**2**	0.0%
220371	2	2015	Fall	3	Snake R	2016	0	99,175	1.998	4.025	**4**	0.0%
220255	2	2015	Fall	3	Snake R	2016	0	201,269	2.085	6.280	**4**	0.0%
637148	10	2016	Fall	2	PRH	2017	0	105,860	5.254	9.828	**53**	0.3%
637186	14	2016	Fall	2	PRH	2017	0	121,147	5.991	11.990	**84**	0.5%
637185	3	2016	Fall	2	PRH	2017	0	121,273	6.003	12.008	**18**	0.1%
637187	18	2016	Fall	2	PRH	2017	0	120,901	6.150	12.299	**111**	0.7%
610452	1	2013	Fall	5	Hanford R	2014	19,917				**0**	0.0%
610472	3	2015	Fall	3	Hanford R	2016	23,133				**0**	0.0%
90868	1	2013	Fall	5	Umatilla R	2015	28,925		1.027	1.030	**1**	0.0%
610469	4	2015	Fall	3	Hanford R	2016	33,661				**0**	0.0%
610478	1	2016	Fall	2	Hanford R	2017	34,034				**0**	0.0%
90867	1	2013	Fall	5	Umatilla R	2015	35,771		1.0	1.0	**1**	0.0%
200119	3	2014	Summer	4	Up Col	2016	36,869	6,603	1.179	1.390	**4**	0.0%
90866	1	2013	Fall	5	Umatilla R	2015	50,191	202	1.027	1.030	**1**	0.0%
610468	1	2015	Fall	3	Hanford R	2016	57,063				**0**	0.0%
636647	1	2013	Summer	5	Up Col	2015	95,388	740	1.008	1.017	**1**	0.0%
220367	1	2015	Fall	3	Snake R	2016	100,540		2.542	2.549	**3**	0.0%
220242	1	2015	Fall	3	Snake R	2016	101,522	1,386	1.096	2.208	**1**	0.0%
220249	1	2015	Fall	3	Snake R	2016	101,709	1,128	1.054	3.162	**1**	0.0%
220244	4	2015	Fall	3	Snake R	2016	101,775	1,334	1.115	2.250	**4**	0.0%
220252	1	2016	Fall	2	Snake R	2017	103,567	1,589	1.120	2.261	**1**	0.0%
220261	2	2016	Fall	2	Snake R	2017	103,854	2,135	1.135	2.299	**2**	0.0%
90946	4	2014	Fall	4	Umatilla R	2016	105,561		1.002	1.007	**4**	0.0%
220251	1	2015	Fall	3	Snake R	2017	106,506		1.047	3.162	**1**	0.0%
636809	1	2014	Summer	4	Up Col	2016	108,882		1.003	1.003	**1**	0.0%
637179	34	2016	Fall	2	PRH	2017	120,250		5.824	11.652	**198**	1.2%
637182	19	2016	Fall	2	PRH	2017	120,931		6.150	12.299	**117**	0.7%
637181	12	2016	Fall	2	PRH	2017	121,000		5.991	11.990	**72**	0.4%
637180	5	2016	Fall	2	PRH	2017	121,250		6.003	12.008	**30**	0.2%
637183	7	2016	Fall	2	PRH	2017	121,606		5.254	9.828	**37**	0.2%
90917	1	2014	Fall	4	Umatilla R	2015	161,668		4.040	4.040	**4**	0.0%
91010	19	2015	Fall	3	Umatilla R	2016	167,390		1.0	1.6	**19**	0.1%
91011	1	2016	Fall	2	Umatilla R	2017	169,016	655	1.0	1.0	**1**	0.0%
90981	33	2015	Fall	3	Umatilla R	2016	170,546		1.018	1.019	**34**	0.2%
91084	2	2016	Fall	2	Umatilla R	2017	174,325		1.013	1.013	**2**	0.0%
636664	1	2013	Summer	5	Up Col	2015	182,682	4,320	1.010	1.034	**1**	0.0%

Code	# of Tags	BY	Race	Age	Stock	CWT Release Date	AD CWT	CWT Only	Expansion All CWT	AD CWT	Return to PRH #	%
636882	1	2014	Fall	4	Snake R	2015	188,831	1,389	1.074	1.082	**1**	0.0%
90982	6	2015	Fall	3	RSH	2016	191,257		7.688	7.688	**46**	0.3%
90983	7	2015	Fall	3	RSH	2016	191,257		7.7	7.7	**54**	0.3%
200126	1	2015	Summer	3	Up Col	2017	191,661	16,231	1.023	1.110	**1**	0.0%
200133	1	2016	Summer	2	Up Col	2017	191,945	22,821	1.009	1.130	**1**	0.0%
637199	1	2016	Fall	2	Snake R	2017	195,781	312	2.164	2.168	**2**	0.0%
636737	1	2013	Fall	5	Snake R	2014	202,329	1,071	1.130	1.136	**1**	0.0%
91138	2	2016	Fall	2	Snake R	2017	206,301	109	5.026	5.029	**10**	0.1%
637217	1	2016	Summer	2	Up Col	2018	207,006	891	1.008	1.012	**1**	0.0%
200120	1	2014	Summer	4	Up Col	2016	213,508	16,753	1.009	1.088	**1**	0.0%
90945	24	2014	Fall	4	Umatilla R	2016	227,783		1.007	1.013	**24**	0.1%
90921	2	2014	Fall	4	RSH	2015	227,976		15.726	15.751	**31**	0.2%
91013	3	2015	Fall	3	Snake R		247,407		4.208	4.215	**13**	0.1%
91113	3	2016	Fall	2	RSH	2017	247,675		5.639	5.639	**17**	0.1%
90944	10	2014	Fall	4	Umatilla R	2016	483,071		1.007	1.009	**10**	0.1%
636681	68	2013	Fall	5	PRH	2014	603,797		6.017	12.093	**409**	2.5%
636507	5	2012	Fall	6	PRH	2013	603,930		5.662	11.297	**28**	0.2%
636836	213	2014	Fall	4	PRH	2015	604,850		5.826	11.660	**1241**	7.7%
636967	679	2015	Fall	3	PRH	2016	605,429		5.982	11.960	**4062**	25.1%
636508	2	2012	Fall	6	PRH	2013		601,009	5.662	11.297	**11**	0.1%
637184	16	2016	Fall	2	PRH	2017		120,350	5.824	11.652	**93**	0.6%
636837	194	2014	Fall	4	PRH	2015		604,861	5.826	11.660	**1130**	7.0%
636968	664	2015	Fall	3	PRH	2016		605,056	5.982	11.960	**3972**	24.6%
636682	41	2013	Fall	5	PRH	2014		603,819	6.017	12.093	**247**	1.5%
90681	1	2012	Fall	6	RSH	2013			14.706	15.113	**15**	0.1%
90863	2	2013	Fall	5	RSH	2014			15.096	15.287	**30**	0.2%
90909	38			2018	ODFW						**0**	0.0%
Total	**2,219**		**16,171**	**Fish recovered at PRH**								

Appendix C

Juvenile fish health inspections for Priest Rapids Hatchery fall Chinook salmon, Brood Years 1998-2018. The description in the Condition column indicates the presence of a certain condition within at least one of the fish examined.

Hatchery/Stock	Date	Brood	Condition
Priest Rapids	23-Feb-99	1998	Healthy
	22-Mar-99	1998	Healthy
	23-Apr-99	1998	Healthy
	25-May-99	1998	Dropout Syndrome & Bacterial Gill Disease
	08-Jun-99	1998	Bacterial Kidney Disease
Priest Rapids	06-Mar-00	1999	Healthy
	14-Apr-00	1999	Healthy
	16-May-00	1999	Healthy
	12-Jun-00	1999	Healthy
Priest Rapids	23-Feb-01	2000	Healthy
	05-Apr-01	2000	Healthy
	07-May-01	2000	Healthy
	06-Jun-01	2000	Healthy
Priest Rapids	13-Feb-02	2001	Healthy
	01-Mar-02	2001	Coagulated Yolk Syndrome
	22-Apr-02	2001	Healthy
	10-Jun-02	2001	Healthy
Priest Rapids	07-Mar-03	2002	Healthy
	15-Apr-03	2002	Healthy
	02-Jun-03	2002	Healthy
Priest Rapids	01-Apr-04	2003	Healthy
	06-May-04	2003	Healthy
	07-Jun-04	2003	Healthy
Priest Rapids	11-Mar-05	2004	Healthy
	14-Apr-05	2004	Healthy
	1-Jun-05	2004	Healthy
Priest Rapids	6-Mar-06	2005	Healthy
	25-Apr-06	2005	Healthy
	13-Jun-06	2005	Healthy
Priest Rapids	9-Mar-07	2006	Healthy
	19-Apr-07	2006	Healthy
	1-Jun-07	2006	Healthy
Priest Rapids	12-Feb-08	2007	Coagulated Yolk Syndrome observed in some fish sampled
	23-Apr-08	2007	Healthy
	4-Jun-08	2007	Healthy
Priest Rapids	12-Feb-09	2008	Coagulated Yolk Syndrome observed in some fish sampled
	22-Apr-09	2008	Healthy
	8-Jun-09	2008	Healthy
Priest Rapids	18-Feb-10	2009	Coagulated Yolk Syndrome observed in some fish sampled
	1-Apr-10	2009	Healthy
	19-May-10	2009	Healthy
Priest Rapids	25-Mar-11	2010	Healthy
	18-Apr-11	2010	Healthy
	06-Jun-11	2010	Healthy
Priest Rapids	01-Mar-12	2011	Healthy
	26-Apr-12	2011	Healthy

Hatchery/Stock	Date	Brood	Condition
	24-May-12	2011	Healthy
Priest Rapids	11-Feb-13	2012	Healthy
	3-Mar-13	2012	Healthy
	29-Apr-13	2012	Healthy
	28-May-13	2012	Healthy
Priest Rapids	27-Mar-14	2013	Dropout Syndrome present
	23-Apr-14	2013	Dropout Syndrome present
	29-May-14	2013	Healthy
Priest Rapids	26-Feb-15	2014	Coagulated Yolk Syndrome observed in some fish sampled
	26-Mar-15	2014	Healthy
	21-Apr-15	2014	Healthy
	28-May-15	2014	Healthy
	22-June-15	2014	Columnaris present in some fish sampled from CH Pond B.
Priest Rapids	24-Feb-16	2015	Healthy
	15-Mar-16	2015	Coagulated Yolk Syndrome observed in some fish sampled
	15-June-16	2015	Mild Ich infection but healthy and ready for release
Priest Rapids	24-Feb-17	2016	Presence of bacterial gill disease in Raceway Bank D and E
	21-Mar-17	2016	Presence of bacterial gill disease in Raceway Pond B2
	6-June-17	2016	Mild Ich infection in Channel Ponds A, B, C
Priest Rapids	21-Mar-18	2017	Healthy
	19-Apr-18	2017	Bacterial gill dieses present in Raceway Pond C4
	7-May-18	2017	Bacterial gill dieses present in Raceway Ponds C2 and C3
	17-May-18	2017	Re-examine Raceway Ponds C2 and C3 found fish healthy
	17-May-18	2017	Pre-release examine Raceway Banks D and E found fish healthy C2 and C3 found fish healthy
	6-June-18	2017	Pre-release examine of Raceway Banks A and B found fish healthy
Priest Rapids	2-Feb-19	2018	Examines of Raceway Banks C, D, E resulted from reports of elevated mortalities. Some fish were found to appear thin and pin-headed. Results of internal necropsies were within normal limits.
	5-May-19	2018	Pre-release examine of Raceway Pond E found fish healthy
	5-May-19	2018	Pre-release examine of Raceway Pond D resulted no significant findings of dieses however elevated mortalities were observed. Mortalities examined showed lower levels of coelomic fat and ingesta in GI tracts compared to live fish examined.
	6-June-19	2018	Pre-release examines of Raceway Ponds A, B, and C found very low levels of bacterial gill disease
	2-Feb-19	2018	Examines of Raceway Banks C, D, E resulted from reports of elevated mortalities. Some fish were found to appear thin and pin-headed. Results of internal necropsies were within normal limits.
	5-May-19	2018	Pre-release examine of Raceway Pond E found fish healthy

Appendix D

Number and percent of fall Chinook salmon redds counted in different reaches of the Columbia River, 2001-2018. Data for years 2001-2010 was collected by staff with Pacific Northwest National Laboratory. Data for years 2001-2018 was collected by staff with Environmental Assessment Services, LLC.

Location	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Islands 11-21	297	509	554	337	708	36	302	371	176	562
Islands 8-10	480	865	1,133	867	1,067	435	338	416	722	870
Near Island 7	350	280	455	415	500	873	311	360	380	457
Island 6 (lower)	750	940	1,241	1,084	1,229	289	615	753	878	1,135
Island 4, 5,6	1,130	1,165	1,242	1,655	1,130	934	655	960	796	1,562
Near Island 3	460	249	475	325	345	1,305	152	230	285	244
Near Island 2	780	955	850	960	895	523	455	555	459	657
Near Island 1	35	235	270	330	255	253	47	148	160	324
Coyote Rapids	16	63	354	180	304	150	10	29	34	49
China Bar	20	25	85	75	28	52	3	35	1,090	299
Vernita Bar	1,930	2,755	2,806	2,240	1,430	1,658	1,135	1,731	16	2,658
Total	**6,248**	**8,041**	**9,465**	**8,468**	**7,891**	**6,508**	**4,023**	**5,588**	**4,996**	**8,817**
Location	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Islands 11-21	5%	6%	6%	4%	9%	1%	8%	7%	4%	6%
Islands 8-10	8%	11%	12%	10%	14%	7%	8%	7%	14%	10%
Near Island 7	6%	3%	5%	5%	6%	13%	8%	6%	8%	5%
Island 6 (lower)	12%	12%	13%	13%	16%	4%	15%	13%	18%	13%
Island 4, 5, 6	18%	14%	13%	20%	14%	14%	16%	17%	16%	18%
Near Island 3	7%	3%	5%	4%	4%	20%	4%	4%	6%	3%
Near Island 2	12%	12%	9%	11%	11%	8%	11%	10%	9%	7%
Near Island 1	1%	3%	3%	4%	3%	4%	1%	3%	3%	4%
Coyote Rapids	>1%	1%	4%	2%	4%	2%	>1%	1%	1%	1%
China Bar	>1%	>1%	1%	1%	>1%	1%	>1%	1%	22%	3%
Vernita Bar	31%	34%	30%	26%	18%	25%	28%	31%	>1%	30%
Location	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**		**(09-18) Mean**
Islands 11-21	676	533	798	906	1,193	861	280	88		665
Islands 8-10	814	807	2,200	1,565	3,145	1,735	900	485		1,418
Near Island 7	670	700	655	1,100	800	670	670	350		678
Island 6 (lower)	1,181	1,375	3,340	2,530	2,315	1,807	900	950		1,718
Island 4, 5,6	1,524	1,195	2,650	2,080	2,540	2,270	911	605		1,725
Near Island 3	525	475	1,000	1,000	1,100	600	500	310		637
Near Island 2	653	528	1,700	2,050	1,900	1,140	790	550		1,097
Near Island 1	295	340	900	500	1,000	340	330	170		465
Coyote Rapids	44	29	520	500	765	255	80	51		253
China Bar	67	68	100	60	1,730	80	75	25		397
Vernita Bar	2,466	2,318	3,535	3,650	4,190	3,510	3210	1,845		2,839
Total	**8,915**	**8,368**	**17,398**	**15,951**	**20,678**	**13,268**	8,646	5,429		11,893
Location	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**		**(09-18) Mean**
Islands 11-21	8%	6%	5%	6%	6%	6%	3%	2%		6%
Islands 8-10	9%	10%	13%	10%	15%	13%	10%	9%		12%
Near Island 7	8%	8%	4%	7%	4%	5%	8%	6%		6%
Island 6 (lower)	13%	16%	19%	16%	11%	14%	10%	17%		14%
Island 4, 5, 6	17%	14%	15%	13%	12%	17%	11%	11%		15%
Near Island 3	6%	6%	6%	6%	5%	5%	6%	6%		5%
Near Island 2	7%	6%	10%	13%	9%	9%	9%	10%		9%
Near Island 1	3%	4%	5%	3%	5%	3%	4%	3%		4%
Coyote Rapids	>1%	>1%	3%	3%	4%	2%	1%	1%		2%
China Bar	1%	1%	1%	0%	8%	1%	1%	>1%		3%
Vernita Bar	28%	28%	20%	23%	20%	26%	37%	>1%		24%

Appendix E

Historical numbers of Chinook salmon carcasses recovered during the annual Hanford Reach fall Chinook salmon carcass survey, Return Years 1991-2018.

Return Year	Total Recoveries	Total Escapement	Proportion of Escapement Recovered
1991	2,519	52,196	0.048
1992	2,221	41,952	0.053
1993	3,340	37,347	0.089
1994	5,739	63,103	0.091
1995	3,914	55,208	0.071
1996	4,529	43,249	0.105
1997	5,053	43,493	0.116
1998	4,456	35,393	0.126
1999	4,412	29,812	0.148
2000	10,556	48,020	0.220
2001	6,072	59,848	0.101
2002	8,402	84,509	0.099
2003	13,573	100,840	0.135
2004	11,030	87,696	0.126
2005	8,491	71,967	0.118
2006	5,972	51,701	0.116
2007	3,115	22,272	0.140
2008	5,455	29,058	0.188
2009	5,318	36,720	0.145
2010	9,779	87,016	0.112
2011	8,391	75,256	0.111
2012	6,814	57,710	0.118
2013	13,071	174,651	0.075
2014	16,756	183,749	0.091
2015	17,738	266,346	0.086
2016	8,886	116,421	0.076
2017	5,591	73,759	0.076
2018	2,771	46,624	0.059
Mean	**7,284**	**74,140**	**0.109**
Median	**5,856**	**56,459**	**0.108**

Appendix F
Estimated escapements for fall Chinook spawning in Hanford Reach and Priest Rapids Dam pool, Return Year 2018.

Count Source		2018 Hanford Reach Fall Chinook Escapement Estimate		
		Adult	Jack	Total
Adult Fish Counts	**McNary**[1]	100,801	13,645	114,446
	Wanapum[2]	11,229	1,570	12,799
	Priest Rapids[3]	18,103	2,112	20,215
	Priest Rapids Fallback Adjustment[4]	2,933	342	3,275
	Ice Harbor[5]	16,599	4,544	21,143
	Prosser[6]	1,117	74	1,191
Hatchery	Priest Rapids Hatchery	14,636	1,535	16,171
	Angler Broodstock Collection	1,235	0	1,235
	Ringold Springs Hatchery	545	254	799
Harvest	Hanford Sport Harvest	8,672	1,074	9,746
	Yakima River Sport Harvest	205	25	230
	Wanapum Tribal Fishery	20	3	23
Escapement	Yakima River (Lower)[7]	323	21	344
	Hanford Reach + Priest Pool	45,431	4,544	49,975
	Priest Pool Return	3,154	200	3,354
	Hanford Reach Escapement	42,279	4,345	46,624

[1] McNary Dam fish counts: August 9 - October 31

[2] Wanapum Dam fish counts, August 14 through November 5

[3] Priest Rapids Dam fish counts, August 18 through November 5. GCPUD continued counts through Nov 15 but McNary counts ended on Oct 31. Allowed 5 days to account for difference in passage timing

[4] Fallback/Re-ascension Adjustment estimate (16.2%) based on 131 run of the river PIT tagged fish from the BOAFF and the lower Columbia River test fishery observed at Priest Rapids Dam and Priest Rapids Hatchery PIT tag arrays

[5] Ice Harbor counts ended on Oct 31

[6] Prosser counts, August 16 through November 5

[7] Escapement estimated by carcass counts versus Escapement regression (2000-2018)

Count Source	2018 Priest Rapids Pool Escapement		
	Adult	Jack	Total
Priest Rapids Adult Passage[3]	18,103	2,112	20,215
Priest Rapids Fallback Adjustment[2]	2,933	342	3,275
Wanapum Adult Passage[1]	11,229	1,570	12,799
Wanapum Dam Fallback Adjustment	Unknown	Unknown	Unknown
Wanapum Tribal Fishery Above PRD	54	0	54
OLAFT	787	0	787
Priest Rapids Pool Sport Fishery	392	32	453
Priest Rapids Dam Pool Escapement	**2,708**	**168**	**2,876**

[1] Wanapum Dam fish counts, August 14 through November 5.

[2] Fallback/Reascension Adjustment estimate (16.2%) based on 131 run of the river PIT tagged fish from the BOAFF and the lower Columbia River test fishery observed at Priest Rapids Dam and Priest Rapids Hatchery PIT tag arrays.

[3] Priest Rapids passage for fall Chinook based on counts from August 18 through November 15.

Appendix G
Carcass drift assessment

A common objective of hatchery monitoring and evaluation programs in the upper Columbia Watershed is to identify the spawning distribution of both hatchery and natural origin fish. Initially, we believed that the proportion of hatchery origin spawners (pHOS) could be calculated for each of five reaches within the Hanford Reach:

- Reach 1. Priest Rapids Dam to Vernita Bridge (14 km)
- Reach 2. Vernita Bridge to Island 2 (19 km)
- Reach 3. Island 2 to Powerline Towers at Hanford town site (21 km)
- Reach 4. Power line Towers to Wooded Island (21 km)
- Reach 5. Wooded Island to Interstate 182 Bridge (19 km),

However, previous carcass bias assessments within the Hanford Reach suggest a substantial amount of downstream carcass drift into lower reaches (Richards and Pearsons, 2013). Hence, it is uncertain that the carcass recovery locations directly represent spawner distributions in some locations. In order to gain a better understanding of natural post-spawn carcass drift, we tried two different approaches for tagging and releasing carcasses: tagging fish in place or releasing tagged fish over known spawning areas.

During 2014, we used a long pole to floy-tag 993 carcasses in place without moving them (Richards and Pearsons, 2015). Tagging occurred from October 26 through November 23. This prevented the collection of accurate size and gender data as many carcasses tagged were underwater. We anticipated that some carcasses would move downstream as river flows fluctuated. Recovery efforts occurred from November 1 through December 19. Recovery rates ranged from 31 – 37 % for donor Sections 1, 2, and 4 (Table G.1).

Table G.1 Numbers of floy-tagged Chinook salmon carcasses released and recovered by donor reach within the Hanford Reach, Return Year 2014

		Donor Section 1	Donor Section 2	Donor Section 3	Donor Section 4	Totals
Fish Tagged by Donor Section		486	107	225	176	994
Fish Recovered by Recipient Section	1	143				146
	2	1	32			34
	3	3	1	35		39
	4	4	0	4	60	68
	5	1	1	0	4	6
P^ Recovered for each Donor Section		0.319	0.327	0.173	0.364	0.295
Proportion Recovered by Section	1	0.942				
	2	0.006	0.943			
	3	0.019	0.029	0.897		
	4	0.026	0.000	0.103	0.938	
	5	0.006	0.029	0.000	0.063	
Proportion Recovered by Section into recipient Section	1	1.000				
	2	0.007	0.993			
	3	0.021	0.031	0.948		
	4	0.025	0.000	0.097	0.879	
	5	0.066	0.297	0.000	0.636	

Donor Section 3 had the lowest recovery rate at 17%. We found that many tagged carcasses did not move from the tag sites; hence the results suggest that carcass drift was occurring at very low rates. We now believe that large portions of carcasses remain in their initial location of deposition.

During years 2015 through 2018, we adjusted our approach in attempt to mimic post-spawn fish dying near redd locations and subsequently drifting downstream. Each year, we operculum-tagged roughly 1,000 intact carcasses, collected size and gender data and then redistributed them in the proximity of specific spawning areas within Sections 1 – 4 (Figure G.1). Tagging occurred primarily in November for both years. Depths at release were visually estimated to range from 1 to 7 meters. River flow m/s at release was not measured. No fish were released in eddies or slack water. Released carcasses were generally observed sinking quickly to the bottom and then slowly drifting downstream. Recovery efforts occurred during November and early December. During 2015, crews recovered 39 (3.9%) tagged carcasses (Table G.2). The recovery rate was notably lower for fish released in Section 4 compared to the other sections. Although the numbers recovered were low, results show that large proportion of tagged fish recovered were found downstream of their adjacent donor section. During 2016, 2017, and 2018 crews recovered 4.6%, 4.3%, and 8.1% of the tagged carcasses, respectively (Table G.3) (Table G.4) (Table G.5). The recovery rate was notably lower for fish released in Section 2 compared to the other sections. Large proportions of tagged fish recovered during the study were found downstream of their adjacent donor section.

Figure G.1 Operculum Tagged Male fall Chinook in the Hanford Reach, 2015 Carcass Drift assessment.

Table G.2 Numbers of operculum-tagged Chinook salmon carcasses released and recovered by donor reach within the Hanford Reach, Return Year 2015

		Donor Section 1	Donor Section 2	Donor Section 3	Donor Section 4	Totals
Fish Tagged by Donor Section		231	62	343	362	998
Fish Recovered by Recipient Section	1	4				4
	2	0	1			1
	3	6	3	4		13
	4	2	0	13	4	19
	5	0	0	1	1	2
P^ Recovered for each Donor Section		0.052	0.065	0.052	0.014	0.039
Proportion Recovered by Section	1	0.333				
	2	0.000	0.250			
	3	0.500	0.750	0.222		
	4	0.167	0.000	0.722	0.800	
	5	0.000	0.000	0.056	0.200	
Proportion Recovered by Section into Recipient Section	1	1.000				
	2	0.000	1.000			
	3	0.340	0.509	0.151		
	4	0.099	0.000	0.428	0.474	
	5	0.000	0.000	0.217	0.783	

Table G.3 Numbers of operculum-tagged Chinook salmon carcasses released and recovered by donor reach within the Hanford Reach, Return Year 2016

		Donor Section 1	Donor Section 2	Donor Section 3	Donor Section 4	Totals
Fish Tagged by Donor Section		263	138	332	254	987
Fish Recovered by Recipient Section	1	3				3
	2	0	0			0
	3	10	0	3		13
	4	7	2	10	5	24
	5	0	0	1	4	5
P^ Recovered for each Donor Section		0.076	0.014	0.042	0.035	0.046
Proportion Recovered by Section	1	0.150				
	2	0.000	0.000			
	3	0.500	0.000	0.214		
	4	0.350	1.000	0.714	0.556	
	5	0.000	0.000	0.071	0.444	
Proportion Recovered by Section into recipient Section	1	1.000				
	2	0.000	0.000			
	3	0.700	0.000	0.300		
	4	0.134	0.382	0.273	0.212	
	5	0.000	0.000	0.138	0.862	

Table G4 **Numbers of operculum-tagged Chinook salmon carcasses released and recovered by donor reach within the Hanford Reach, Return Year 2017**

		Donor Section 1	Donor Section 2	Donor Section 3	Donor Section 4	Totals
Fish Tagged by Donor Section		290	137	227	327	981
Fish Recovered by Recipient Section	1	0				0
	2	2	0			2
	3	3	2	3		8
	4	1	2	11	8	22
	5	1	1	5	3	10
P^ Recovered for each Donor Section		0.024	0.036	0.084	0.034	0.043
Proportion Recovered by Section	1	0.000				
	2	0.286	0.000			
	3	0.429	0.400	0.158		
	4	0.143	0.400	0.579	0.727	
	5	0.143	0.200	0.263	0.273	
Proportion Recovered by Section	1	0.000				
	2	1.000	0.000			
	3	0.434	0.405	0.160		
	4	0.077	0.216	0.313	0.393	
	5	0.163	0.228	0.299	0.310	

Table G5 **Numbers of operculum-tagged Chinook salmon carcasses released and recovered by donor reach within the Hanford Reach, Return Year 2018**

		Donor Section 1	Donor Section 2	Donor Section 3	Donor Section 4	Totals
Fish Tagged by Donor Section		222	53	192	159	626
Fish Recovered by Recipient Section	1	0				0
	2	1	0			1
	3	14	6	1		21
	4	4	1	8	13	26
	5	0	0	1	2	3
P^ Recovered for each Donor Section		0.09	0.13	0.05	0.09	0.081
Proportion Recovered by Section	1	0.00				
	2	0.05	0.00			
	3	0.74	0.86	0.10		
	4	0.21	0.14	0.80	0.87	
	5	0.00	0.00	0.10	0.13	
Proportion Recovered by Section	1	0.000				
	2	1.00	0.00			
	3	0.43	0.51	0.06		
	4	0.10	0.07	0.40	0.43	
	5	0.00	0.00	0.43	0.57	

Appendix H
Carcass bias assessment results

Carcass surveys of Chinook salmon are conducted each fall to characterize fish spawning in the Hanford Reach. However, it is possible that carcasses collected during surveys do not represent the spawning population. There could be carcass collection bias against smaller/younger fish or males in the stream surveys (Zhou 2002; Murdoch et al. 2010; Richards and Pearsons, 2013). If true, this bias may compromise estimates associated with age and gender compositions by origin as well as escapement estimates of hatchery and natural origin fish. We began a pilot project to evaluate potential size and sex recovery bias in 2011. This work has occurred annually with the exception of 2014 when measurements were not taken on the mark sample so a bias estimate could not be estimated.

The methods for collecting, sampling, and releasing tagged carcass associated with this evaluation have varied slightly between years. In general, roughly 1,000 carcasses were collected for demographic data and tagged with numbered plastic tags. Depending on the year, the tagged fish were either systematically released either near shore or mid river or over known active redd locations.

The release strategy for years 2011-2013 included releasing tagged carcass either near shore or mid-channel near the point of initial recovery. Carcasses released near shore had higher proportions of recaptures compared to fish released mid channel. It was not uncommon for carcasses released near shore to be recovered the following day in the same vicinity of their release. During years 2015 through 2017 we released tagged carcasses over active redd locations to better match the natural disposition of post spawn carcasses. After release into the river, the carcasses generally sunk quickly and gradually moved downstream along the bottom in a similar manner to that of post-spawn fish.

The annual recovery rates of tagged carcasses decreased annually from a high of 17.2% in 2011 to a low of 3.8% in 2015 (Tables H.1-H.7). The annual recovery rates may be influenced by the release method and by reduced chances of recovering tagged carcasses during large spawning escapements of fall Chinook salmon to the Hanford Reach.

In general, the level of carcass recovery bias was low and varied between years; suggesting that carcass samples collected may be reflective of the spawning population.

Table H.1 Summary of mark recapture of post-spawn fall Chinook salmon in the Hanford Reach, 2011. Post orbital to hypural plate length (POHL) calculated from linear regression equation for fork length versus known POHL.

			Release Locations							
			Bank			**Mid Channel**			**Total Released**	
Released #			500			493			993	
Recaptured #			110			61			171	
Recapture P^			**0.220**			**0.124**			**0.172**	
Mark Release Fall Chinook Salmon										
POHL	**<47 cm**		**47 - 58 cm**		**59 - 69 cm**		**> 69cm**		**Total**	
Gender	**#**	**P^**	**#**	**P^**	**#**	**P^**	**#**	**P^**	**#**	**P^**
Male	26	0.026	66	0.066	172	0.173	137	0.138	401	0.404
Female	0	0.000	14	0.014	331	0.333	247	0.249	592	0.596
Total	**26**	**0.026**	**80**	**0.081**	**503**	**0.507**	**384**	**0.387**	**993**	**1.000**
Recaptures										
Male	3	0.018	10	0.058	34	0.199	26	0.152	73	0.427
Female	0	0.000	2	0.012	53	0.310	43	0.251	98	0.573
Total	**3**	**0.018**	**12**	**0.070**	**87**	**0.509**	**69**	**0.404**	**171**	**1.000**
Bias										
Male	0.009		0.008		-0.026		-0.014		-0.023	
Female	0.000		0.002		0.023		-0.003		0.023	
Total	**0.009**		**0.010**		**-0.002**		**-0.017**		**0.000**	

Table H.2 Summary of mark recapture of post-spawn fall Chinook salmon in the Hanford Reach, 2012. POHL calculated from linear regression equation for fork length versus know POHL.

			Release Locations							
			Bank			**Mid Channel**			**Total Released**	
Released #			489			500			989	
Recaptured #			103			34			137	
Recapture P^			**0.211**			**0.068**			**0.139**	
Mark Release Fall Chinook Salmon										
POHL	**<47 cm**		**47 - 58 cm**		**59 - 69 cm**		**> 69cm**		**Total**	
Gender	**#**	**P^**	**#**	**P^**	**#**	**P^**	**#**	**P^**	**#**	**P^**
Male	49	0.050	172	0.174	157	0.159	142	0.144	520	0.526
Female	0	0.000	31	0.031	192	0.194	246	0.249	469	0.474
Total	**49**	**0.050**	**203**	**0.205**	**349**	**0.353**	**388**	**0.392**	**989**	**1.000**
Recaptures										
Male	10	0.073	25	0.182	20	0.146	19	0.139	74	0.540
Female	0	0.000	5	0.036	22	0.161	36	0.263	63	0.460
Total	**10**	**0.073**	**30**	**0.219**	**42**	**0.307**	**55**	**0.401**	**137**	**1.000**
Bias										
Male	-0.023		-0.009		0.013		0.005		-0.014	
Female	0.000		-0.005		0.034		-0.014		0.014	
Total	**-0.023**		**-0.014**		**0.046**		**-0.009**		**0.000**	

Table H.3 Summary of mark recapture of post-spawn fall Chinook salmon in the Hanford Reach, 2013. POHL calculated from linear regression equation for fork length versus know POHL.

			Release Locations							
			Bank				**Mid Channel**		**Total Released**	
Released #			552				521		1,073	
Recaptured #			69				45		114	
Recapture P^			**0.125**				**0.086**		**0.106**	
Mark Release Fall Chinook Salmon										
POHL	**<47 cm**		**47 - 58 cm**		**59 - 69 cm**		**> 69cm**		**Total**	
Gender	**#**	**P^**	**#**	**P^**	**#**	**P^**	**#**	**P^**	**#**	**P^**
Male	206	0.192	332	0.309	183	0.170	60	0.056	781	0.727
Female	1	0.001	55	0.051	184	0.171	55	0.051	295	0.274
Total	**206**	**0.192**	**387**	**0.360**	**367**	**0.341**	**115**	**0.107**	**1,075**	**1.000**
Recaptures										
Male	16	0.140	42	0.368	19	0.167	8	0.070	85	0.746
Female	0	0.000	5	0.044	19	0.167	5	0.044	29	0.254
Total	**16**	**0.140**	**47**	**0.412**	**38**	**0.333**	**13**	**0.114**	**114**	**1.000**
Bias										
Male	0.051		-0.060		0.004		-0.014		-0.019	
Female	0.001		0.007		0.004		0.007		0.020	
Total	**0.051**		**-0.052**		**0.008**		**-0.007**		**0.000**	

Table H.4 Summary of mark recapture of post-spawn fall Chinook salmon in the Hanford Reach, 2015, POHL.

Total Release in Mid-Channel Redd Locations, RY2015										
Released #			997							
Recaptured #			38							
Recapture P^			**0.038**							
Mark Release Fall Chinook Salmon										
POHL	**<47 cm**		**47 - 58 cm**		**59 - 69 cm**		**> 69cm**		**Total**	
Gender	**#**	**P^**	**#**	**P^**	**#**	**P^**	**#**	**P^**	**#**	**P^**
Male	39	0.039	128	0.128	183	0.184	172	0.173	522	0.524
Female	1	0.001	37	0.037	287	0.288	151	0.151	476	0.477
Total	**39**	**0.039**	**165**	**0.165**	**470**	**0.471**	**323**	**0.324**	**997**	**1.000**
Recaptures										
Male	0	0.000	6	0.158	9	0.237	8	0.211	23	0.605
Female	0	0.000	1	0.026	7	0.184	7	0.184	15	0.395
Total	**0**	**0.000**	**7**	**0.184**	**16**	**0.421**	**15**	**0.395**	**38**	**1.000**
Bias										
Male	0.039		-0.030		-0.053		-0.038		-0.082	
Female	0.001		0.011		0.104		-0.033		0.083	
Total	**0.039**		**-0.019**		**0.050**		**-0.071**		**0.000**	

Table H.5 Summary of mark recapture of post-spawn fall Chinook salmon in the Hanford Reach, 2016, POHL.

Total Release in Mid-Channel Redd Locations, RY2016										
Released #	987									
Recaptured #	46									
Recapture P^	**0.047**									
Mark Release Fall Chinook Salmon										
POHL	**<47 cm**		**47 - 58 cm**		**59 - 69 cm**		**> 69cm**		**Total**	
Gender	**#**	**P^**	**#**	**P^**	**#**	**P^**	**#**	**P^**	**#**	**P^**
Male	43	0.044	171	0.173	181	0.183	119	0.121	514	0.521
Female	0	0.000	35	0.035	334	0.338	104	0.105	473	0.479
Total	**43**	**0.044**	**206**	**0.209**	**515**	**0.522**	**223**	**0.226**	**987**	**1.000**
Recaptures										
Male	4	0.087	7	0.152	11	0.239	4	0.087	26	0.565
Female	0	0.000	1	0.022	15	0.326	4	0.087	20	0.435
Total	**4**	**0.087**	**8**	**0.174**	**26**	**0.565**	**8**	**0.174**	**46**	**1.000**
Bias										
Male	-0.043		0.021		-0.056		0.034		-0.044	
Female	0.000		0.014		0.012		0.018		0.044	
Total	**-0.043**		**0.035**		**-0.043**		**0.052**		**0.000**	

Table H.6 Summary of mark recapture of post-spawn fall Chinook salmon in the Hanford Reach, 2017, POHL.

Total Release in Mid-Channel Redd Locations, RY2017										
Released #	981									
Recaptured #	42									
Recapture P^	**0.043**									
Mark Release Fall Chinook Salmon										
POHL	**<47 cm**		**47 - 58 cm**		**59 - 69 cm**		**> 69cm**		**Total**	
Gender	**#**	**P^**	**#**	**P^**	**#**	**P^**	**#**	**P^**	**#**	**P^**
Male	11	0.011	173	0.176	193	0.197	121	0.123	498	0.508
Female	0	0.000	38	0.039	342	0.349	103	0.105	483	0.492
Total	**11**	**0.011**	**211**	**0.215**	**535**	**0.545**	**224**	**0.228**	**981**	**1.000**
Recaptures										
Male	0	0.000	7	0.167	15	0.357	4	0.095	26	0.619
Female	0	0.000	3	0.071	11	0.262	2	0.048	16	0.381
Total	**0**	**0.000**	**10**	**0.238**	**26**	**0.619**	**6**	**0.143**	**42**	**1.000**
Bias										
Male	0.011		0.010		-0.160		0.028		-0.111	
Female	0.000		-0.033		0.087		0.057		0.111	
Total	**0.011**		**-0.023**		**-0.074**		**0.085**		**0.000**	

Table H.7 Summary of mark recapture of post-spawn fall Chinook salmon in the Hanford Reach, 2018, POHL.

Total Release in Mid-Channel Redd Locations, RY2018										
Released #	626									
Recaptured #	51									
Recapture P^	**0.0815**									
Mark Release Fall Chinook Salmon										
POHL	**<47 cm**		**47 - 58 cm**		**59 - 69 cm**		**> 69cm**		**Total**	
Gender	**#**	**P^**	**#**	**P^**	**#**	**P^**	**#**	**P^**	**#**	**P^**
Male	18	0.029	147	0.235	100	0.160	44	0.070	293	0.494
Female	1	0.002	22	0.035	217	0.347	77	0.123	317	0.506
Total	**19**	**0.030**	**169**	**0.270**	**317**	**0.506**	**121**	**0.193**	**626**	**1.000**
Recaptures										
Male	2	0.039	4	0.078	5	0.098	14	0.275	25	0.490
Female	0	0.000	8	0.157	0	0.000	18	0.353	26	0.510
Total	**2**	**0.039**	**12**	**0.235**	**5**	**0.098**	**32**	**0.627**	**51**	**1.000**
Bias										
Male	-0.010		0.157		0.062		-0.205		0.004	
Female	0.002		-0.122		0.347		-0.230		-0.004	
Total	**-0.009**		**0.035**		**0.408**		**-0.434**		**0.000**	

Table H.8 Mark and recapture bias post-spawn fall Chinook salmon in the Hanford Reach by size group (POHL), Return Years 2011-2013 and 2014-2018. Bias = P^ Released – P^ Recovered.

Return Year	**# Tagged**	**# Recovered**	**Post Orbital to Hypural Plate Length Size Groups**			
			<47 cm	**47 - 58 cm**	**59 - 69 cm**	**> 69cm**
2011[a]	993	171	0.009	0.010	-0.002	-0.017
2012[a]	989	137	-0.023	-0.014	0.046	-0.009
2013[a]	1073	114	0.051	-0.052	0.008	-0.007
2015[b]	997	38	0.039	-0.019	0.050	-0.071
2016[b]	987	46	-0.043	0.035	-0.043	0.052
2017[b]	981	42	0.011	-0.023	-0.074	0.085
2018[b]	626	51	-0.009	0.035	0.408	-0.434
Mean	**949**	**86**	**0.005**	**-0.004**	**0.056**	**-0.057**

[a] Marked fish were released near shore or in mid Channel in roughly equal proportions. Lengths were calculated from linear regression equation for fork length versus known POHL
[b] Marked fish were released over the top of known redd locations.

Appendix I
Demographic comparisons for double index tag groups released from Priest Rapids Hatchery, Brood Years 2009-2015.

Double Index Tag (DIT) groups of fall Chinook salmon have been released annually from Priest Rapids Hatchery (PRH) starting with the progeny of the 2009 brood. Adipose clipped fish from these DIT groups have been recovered in various mark selective fisheries (MSF) occurring in ocean, marine, and freshwater zones. The Regional Mark Processing Center database was queried to identify mark selective fisheries occurring since 2012 that included recoveries of PRH DIT groups (Table I.1). Detailed descriptions of these fisheries are available at websites maintained by the RMPC, Oregon Department of Fish and Game, and WDFW. The level of contribution to these fisheries, some of which are summer Chinook salmon fisheries, is beyond the scope of this document.

Survival estimates for DIT groups from release and recovery at PRH was calculated by dividing the total DIT recoveries at PRH for each brood year (ages 1 – 6) by the corresponding number of juveniles marked for each DIT group. Similarities in gender composition, survival, age at maturity, and size at age between DIT groups within a brood year strongly suggest there is no difference for fish recovered at PRH (Tables I.2, I.3, I.4, and I.5).

Table I.1 Regional Mark Processing Center mark selective fisheries showing recoveries of Priest Rapids Hatchery origin coded-wire tagged adipose clipped fish from brood years 2009-2015.

Sampling Agency	Fishery
Alaska Dept. of Fish and Game	Ocean Selective Troll
Oregon Dept. of Fish and Game	Ocean Sport Columbia River Sport Columbia River Test Net Columbia River Purse Seine Columbia River Gillnet
Washington Dept. of Fish and Wildlife	Marine Sport Columbia River Sport

Table I.2 Gender Composition of DIT groups by brood year. Brood years 2013-2015 not complete. Data current through Return Year 2018.

	Males		Females	
Brood Year	**Ad-CWT**	**CWT Only**	**Ad-CWT**	**CWT Only**
2009	0.720	0.717	0.280	0.283
2010	0.539	0.546	0.461	0.454
2011	0.644	0.638	0.356	0.362
2012	0.641	0.643	0.359	0.357
2013	0.634	0.645	0.366	0.355
2014	0.633	0.613	0.367	0.387
2015	0.838	0.855	0.162	0.145
Mean	0.664	0.665	0.336	0.335

Table I.3 **Smolt to adult return proportion comparisons between DIT Groups by brood year. Brood years 2013-2015 not complete. Data current through Return Year 2018.**

Brood Year	Mark plus CWT	P^ Survival by Age Age 2	Age 3	Age 4	Age 5	Age 6	Total
2009	Ad-Clipped	0.0004	0.0014	0.0006	0.0003	0.0000	0.0026
	No Mark	0.0004	0.0014	0.0007	0.0002	0.0000	0.0027
2010	Ad-Clipped	0.0009	0.0033	0.0052	0.0006	0.0000	0.0100
	No Mark	0.0009	0.0035	0.0050	0.0006	0.0000	0.0100
2011	Ad-Clipped	0.0003	0.0021	0.0024	0.0004	0.0000	0.0051
	No Mark	0.0003	0.0023	0.0026	0.0003	0.0000	0.0055
2012	Ad-Clipped	0.0015	0.0046	0.0017	0.0003	0.0000	0.0082
	No Mark	0.0017	0.0052	0.0019	0.0003	0.0000	0.0092
2013	Ad-Clipped	0.0005	0.0014	0.0012	0.0001	--	0.0032
	No Mark	0.0004	0.0016	0.0013	0.0001	--	0.0034
2014	Ad-Clipped	0.0001	0.0004	0.0004	--	--	0.0008
	No Mark	0.0001	0.0004	0.0003	--	--	0.0008
2015	Ad-Clipped	0.0001	0.0011	--	--	--	0.0013
	No Mark	0.0002	0.0011	--	--	--	0.0013
Mean	**Ad-Clipped**	**0.0005**	**0.0021**	**0.0020**	**0.0003**	**0.0000**	**0.0046**
	No Mark	**0.0006**	**0.0022**	**0.0021**	**0.0003**	**0.0000**	**0.0047**

Table I.4 **Age composition of DIT Groups by brood year. Brood years 2013-2015 not complete. Data current through Return Year 2018.**

Brood Year	DIT Group	N	Age Composition (Genders Combined) Age-2	Age-3	Age-4	Age-5	Age-6
2009	Ad-CWT	1,648	0.137	0.520	0.244	0.099	0.000
	CWT Only	2,792	0.145	0.526	0.242	0.088	0.000
2010	Ad-CWT	6,012	0.086	0.334	0.522	0.057	0.001
	CWT Only	11,000	0.089	0.346	0.504	0.060	0.001
2011	Ad-CWT	3,022	0.054	0.406	0.469	0.070	0.000
	CWT Only	3,318	0.057	0.413	0.474	0.056	0.000
2012	Ad-CWT	4,954	0.182	0.564	0.213	0.039	0.001
	CWT Only	5,510	0.183	0.570	0.209	0.038	0.000
2013	Ad-CWT	1,926	0.145	0.438	0.382	0.035	0.000
	CWT Only	2,076	0.128	0.464	0.388	0.020	0.000
2014	Ad-CWT	496	0.081	0.486	0.433	0.000	0.000
	CWT Only	478	0.079	0.510	0.408	0.000	0.000
2015	AD-CWT	765	0.114	0.886	0.000	0.000	0.000
	CWT Only	771	0.125	0.875	0.000	0.000	0.000
Mean	**Ad-Clipped**	**N/A**	0.114	0.454	0.376	0.052	0.001
	No Mark	**N/A**	0.115	0.529	0.318	0.037	0.001

Table I.5 Size at age for DIT Groups by brood year. Brood years 2013-2015 not complete. Data current through Return Year 2018.

Brood Year	DIT Group	Fall Chinook fork length (cm)														
		Age-2			Age-3			Age-4			Age-5			Age-6		
		N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
2009	AD-CWT	226	49	4	857	67	5	402	78	5	163	85	5	0	0	0
	CWT Only	404	48	4	1,465	66	5	674	77	6	244	84	6	0	0	0
2010	AD-CWT	519	48	4	2,011	68	4	3,138	77	5	340	81	5	9	89	5
	CWT Only	985	48	4	3,840	68	5	5,585	77	5	663	82	5	14	81	6
2011	AD-CWT	162	47	4	1,227	66	5	1,417	76	5	210	82	6	5	84	2
	CWT Only	188	47	4	1,369	66	5	1,571	77	5	185	82	6	3	85	4
2012	AD-CWT	904	49	5	2794	67	5	1055	78	5	194	82	5	5	83	2
	CWT Only	1006	50	5	3139	67	5	1153	78	5	209	81	6	2	95	11
2013	AD-CWT	279	45	5	843	66	5	736	75	5	68	81	--	--	--	--
	CWT Only	266	45	5	963	66	5	804	75	5	41	80	--	--	--	--
2014	AD-CWT	40	49	3	241	66	5	214	76	5	--	--	--	--	--	--
	CWT Only	38	50	4	244	66	5	195	76	5	--	--	--	--	--	--
2015	AD-CWT	87	45	4	678	66	5	--	--	--	--	--	--	--	--	--
	CWT Only	96	44	4	675	66	5	--	--	--	--	--	--	--	--	--
Mean	**AD-CWT**	**316**	**47**	**4**	**1235**	**66**	**5**	**1160**	**77**	**5**	**195**	**82**	**6**	**7**	**84**	**5**
	CWT Only	**425**	**47**	**4**	**1673**	**66**	**5**	**1665**	**77**	**5**	**268**	**82**	**6**	**6**	**84**	**8**

Appendix J

Explanation of methods for calculating adult-to-adult expansions based on coded-wire tag recoveries at Priest Rapids Hatchery

Expanding adult coded wire tag (CWT) recoveries of either PRH or RSH origin fish by the corresponding brood's juvenile CWT rates has historically resulted in an under estimate of adult returns to locations within the Hanford Reach for each brood. A variety of factors may contribute to this problem; however, inappropriate juveniles tag expansion rates resulting from non-representative placement of tag groups within the general population is likely the greatest contributing factor. For many years, WDFW fish management staff have addressed the issues related to problematic juvenile tag rates by employing adult-to-adult CWT expansions for the PRH origin returns to PRH for run-reconstruction associated with their annual fall Chinook salmon forecast. We used similar methods to expand PRH and RSH origin adult CWT recoveries in the vicinity of Hanford Reach to calculate PNI. An example of the calculations for the adult-to-adult expansion for the 2010 brood during return year 2014 is provided below. We make the assumption that the total number of PRH origin returns to PRH can be determined by removing other hatchery fish from the return: this is done by expanding the few other hatchery CWT recoveries by their corresponding juvenile CWT rates. Other hatchery CWT groups often have tag rates exceeding 50%; therefore, we assume juvenile tag rate expansions are representative for these groups. In addition, we make the assumption that very few natural origin fish return to PRH.

$$\text{Adult-to-Adult Expansion}_{BY2010} = \frac{\text{Total}_{BY2010}\text{ CWT Recoveries at PRH}}{\text{Total}_{BY2010}\text{ PRH Origin Returns to PRH}}$$

$$\text{Adult-to-Adult Expansion}_{BY2010} = \frac{8{,}719}{41{,}348} = 0.211$$

We then use the Adult-to-Adult Expansion $_{BY2010}$ to expand all recoveries of PRH $_{BY2010}$ in the Hanford Reach stream survey for return year 2014. This method is duplicated for each brood present in the given return year for both PRH and RSH to determine the total number of PRH and RSH origin fish in the escapement. The estimated number of PRH origin fish in the RY2014 Hanford Reach escapement based on the adult-to-adult expansion is higher than the number calculated using the conventional juvenile tag rate (Table 1).

Table K.1 The number of Priest Rapids Hatchery origin fish in the RY 2014 Hanford Reach escapement calculated from Adult-to-Adult Expansions versus Juvenile Tag Rates.

BY	CWT Recovered	Adult-to-Adult Exp	Expanded CWT	Survey Sample Rate	Total PRH origin in Escapement
2009	5	0.216	23	0.1063	218
2010	139	0.211	659	0.1063	6,197
2011	18	0.127	142	0.1063	1,333
2012	5	0.160	31	0.019	1,645
Adult-to-Adult Exp estimate for PRH origin fish in the Hanford Reach Escapement					**9,393**
Juvenile Tag Rate estimate for PRH origin fish in the Hanford Reach Escapement					**7,934**