Priest Rapids Hatchery Monitoring and Evaluation Annual Report for 2016-2017

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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 seventh 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 (2016-2017).

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 2016 was 116,388 fish. This is substantially higher than mean historic abundances. The historical mean and median escapement for 1991 through 2016 is 73,550 and 55,208 fish, respectively.

The 2016 returns to PRH volunteer trap totaled 28,786 fall Chinook salmon. A total of 4,324 fish that returned to the volunteer trap at PRH were ponded at the hatchery for broodstock. An additional 247 fish were ponded from the Angler Broodstock Collection (ABC) fishery and 366 fish were ponded from Priest Rapids Dam Off-Ladder-Adult-Fish-Trap (OLAFT) in an effort to increase the number of natural-origin broodstock. In total, 4,938 fish were spawned to meet egg-take goals for multiple hatchery programs. Most of the fish that were surplus to broodstock needs 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 and 3 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, 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 to have higher adult recruitment rates than the natural spawning fall Chinook salmon in the Hanford Reach of the Columbia River. Adult recruitment rate of brood year 2010 for PRH was the

highest that has been observed (61.69) for this program and was substantially higher than the fish spawning in the Hanford Reach (6.21).

PRH origin fish were estimated to make up 6.6% of the natural spawning population in the Hanford Reach during 2016. All hatchery fish combined (including fish released from Ringold Hatchery and strays from outside the Hanford Reach) comprised 11.5% 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 0.70 in 2016. This value was calculated using a gene flow model based on the Ford model and exceeded the PNI target of 0.67 for the third 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 million), 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, maintained, and funded by the Grant PUD. 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 U.S. Army Corps of Engineers (USACE) John Day Mitigation. An additional 3.7 million eyed eggs are provided 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 ~3.5 million subyearlings are transported to, acclimated, and released as subyearling smolts from RSH. In previous years, PRH has accommodated egg-takes and/or incubated eggs for the Yakama Nation (YN) upper river bright (URB) fall Chinook salmon releases in the lower Yakima River at their Prosser facility. Additional eggs have also been taken for other programs such as Umatilla Hatchery, WDFW's Salmon in the Classroom program, and to support various research projects.

A cooperative effort between Grant, Douglas, and Chelan County Public Utility Districts and Washington Department of Fish and Wildlife (WDFW) has resulted in an updated Monitoring and Evaluation Plan for PUD Hatchery Programs (Hillman et al. 2013). This document provides guiding principles and approaches for the monitoring and evaluation (M&E) of PRH. Objectives, hypotheses, measured and derived variables, and field methods that will be used to collect data are listed in this document.

This report of the PRH M&E program is the seventh annual report (Hoffarth and Pearsons 2012a, 2012b, Richards et al. 2013, Richards and Pearsons 2014, 2015, and 2016) and encompasses data collected during the Washington State fiscal year (FY) 2016 - 2017 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 Hanford Reach (indicated by stars).

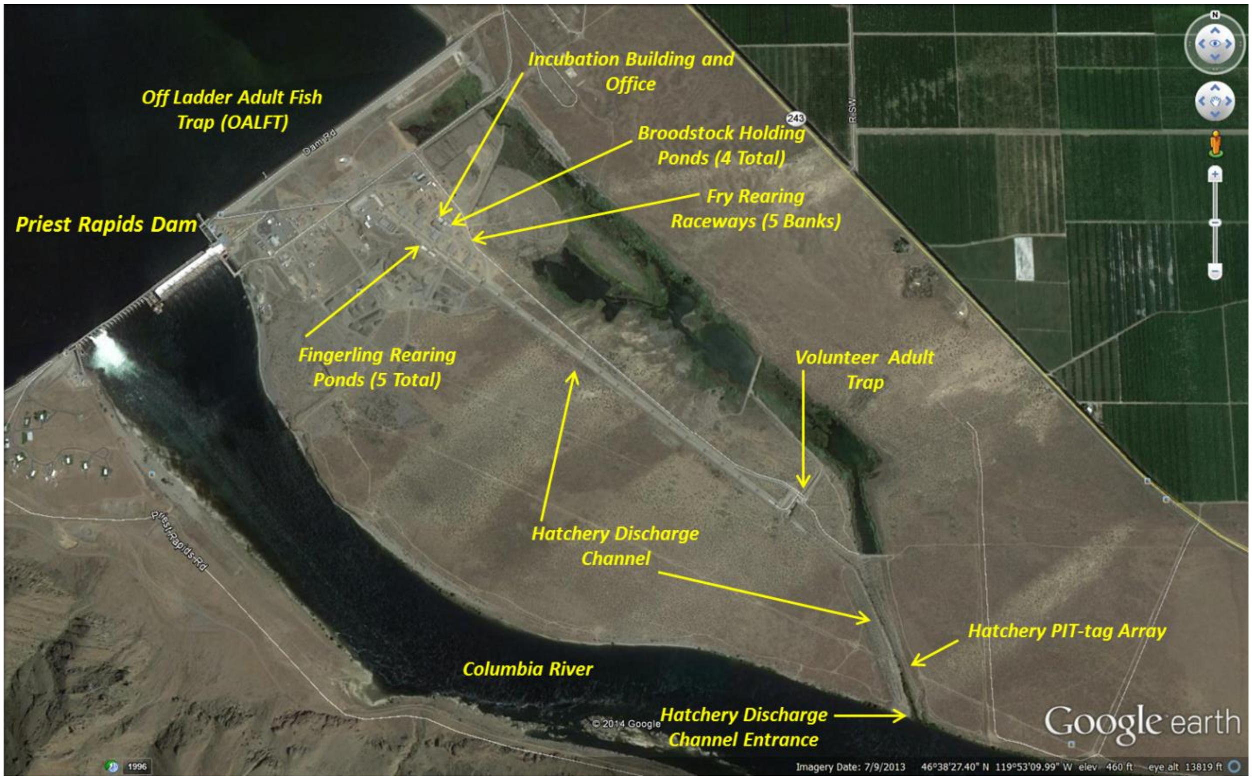

Figure 2 Priest Rapids Hatchery facility and Priest Rapids Dam Off Ladder Adult Fish Trap (OLAFT).

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 WFW 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.

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). The Hanford Reach extends 51 miles 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 has resulted in improvements in survival (Harnish et al. 2012, Harnish 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 having spent 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).

5.0 Sample Size Considerations

We attempted to strike an appropriate balance between statistical precision, logistics, and financial investment when setting sample size targets. A phased approach was used to collect biological samples with sufficient accuracy and precision. In general, we attempted to oversample the raw samples such as carcasses and trap recoveries and then use post season analysis to determine if sub-sampling was appropriate. The sample size target of systematic field sampling 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 sampled for the presence of CWT to maximize the precision of estimates generated from these data. Representative otolith samples by survey type were randomly selected as a sub-sample for processing 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 2016, randomly selected sub-samples of otoliths collected from the PRH volunteer trap and volunteer broodstock were submitted for processing. 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 selected 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

In 2016, 29,564 adult fall Chinook salmon were handled at PRH (Table 1). The 2016 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 12 through December 12, 2016. The last fish were hauled from the volunteer trap on December 5 with no fish entering the trap afterwards. In attempt to increase pNOB, the broodstock ponded generally excluded known hatchery fish (i.e., possessing an adipose clip and or CWT); hence, increasing the potential number of natural origin broodstock ponded. Hatchery staff ponded 2,243 known hatchery fish in the event that there were not enough adipose fin intact/non CWT broodstock available to meet program goals. Many 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.

Table 1 Source and disposition of Chinook salmon collected for broodstock at Priest Rapids Hatchery, Return Year 2016.

Collection Location	Gender	Collected	Trap Surplused	Trap Mortalities	Ponded	Spawned[1]	Pond Surplused	Pond Mortalities
Volunteer Trap (Sept 12-Dec 12)	Males	14,468	11,850	58	2,403	1,328	876	356
	Females	13,436	8,561	121	4,443	2,997	1,407	350
	Jacks	882	854	28	0	0	0	0
	Total	28,786	21,265	207	6,846	4,325	2,283	706
OLAFT (Sept 14-Nov 07)	Males	134	0	0	134	113	14	7
	Females	310	0	0	310	253	3	54
	Jacks	0	0	0	0	0	0	0
	Total	444	0	0	444	366	17	61
ABC (Oct 28,29&30)	Males	132	0	0	132	96	10	26
	Females	202	0	0	202	151	7	44
	Jacks	0	0	0	0	0	0	0
	Total	334	0	0	334	247	17	70
Facility	**Total**	**29,564**	**21,265**	**207**	**7,624**	**4,938**	**2,317**	**837**

[1] There were 157 males and 311 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 for adult fall Chinook salmon to the PRH volunteer trap was determined to help schedule future sampling and broodstock activities. Regular trap operations during 2016 should have provided unimpeded access to the trap. The return time in 2016 suggests it was a single modal peak return similar to patterns in 2015 (Figure 3). The annual return time prior to 2015 was typically a bi-modal peak in which a large proportion of fish returned in late September and late October.

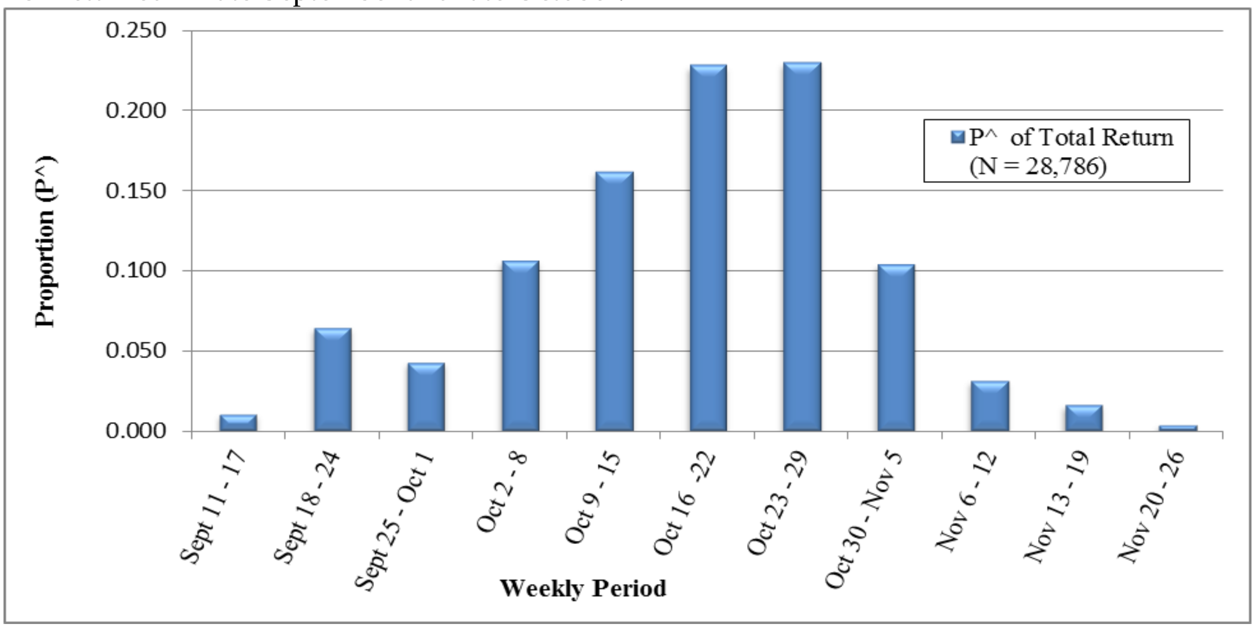

Figure 3 Weekly counts of fish adult Chinook salmon collected at the Priest Rapids Hatchery volunteer trap, 2016.

PRH has four adult salmon holding ponds. Ponds 1 and 2 were used to hold broodstock collected at the PRH Volunteer Trap. Pond 4 was used to hold broodstock collected from the ABC and OLAFT. Pond 3 was used on occasion to temporarily hold males collected from ABC and OLAFT. Several hundred adipose clipped adults were held in Pond 4 to facilitate hatchery- x-natural origin crosses during spawning. The PRH staff generally transported fish from the volunteer trap seven days per week to collect broodstock and or to surplus the excess fish. Male fall Chinook salmon, both adult and jack, typically comprised the majority of the fish surplused from the trap. Spawning days generally occurred on Mondays and Tuesdays each week from October 24 through December 5 (N = 10). The hatchery staff generally used the electro-anesthesia system for spawning fish. However, on November 8, they used a seine to collect fish out of pond 2 for spawning in order to expedite the day's operation.

The egg-take goal from the 2016 PRH brood was 13,329,318 eggs. The actual egg-take from the 2016 broodstock was 12,411,530 (93% of the goal). During routine spawn days, the eggs from two females were stripped into a five-gallon bucket and then the milt from a single male was mixed with the eggs. Two buckets of fertilized eggs were then combined to ensure fertilization. Fertilized eggs were then transferred to the incubation room, combined with multiple egg-takes, weighed to estimate numbers of eggs, and then placed in vertical incubation trays at roughly 7,000 eggs per tray.

Since 2014, a cooperative effort between WDFW and Grant PUD staff to perform real-time otolith reading (RTOR) coinciding with an alternative mating strategy occurred on November 7 and 8. This activity entailed examining 204 otoliths from unmarked males collected at OLAFT or the ABC fishery to identify 151 natural origin fish. These 151 males were used for 1x4 matings with unmarked 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 and then two, 5 gallon buckets of eggs were combined before being transferred to the incubation room. An estimated 2,220,002 green eggs were taken during the RTOR 1:4 crosses.

After shipping two large groups of eyed eggs to other facilities, fry from nine egg-takes were moved from the vertical trays in the incubation building to outdoor raceways between January 28 and March 14, 2017. 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 9 and June 19. All releases occurred at night. These fish migrate down the old one mile long spawning channel and then down the hatchery discharge channel to the Columbia River.

7.0 Origin of Adult Returns to Priest Rapids Hatchery

There were three sources for collection of adult Chinook salmon broodstock for PRH during the 2016 return: PRH volunteer trap, OLAFT, and ABC. The origin of fish collected at these locations was determined by examination of hatchery marks (i.e., otolith 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 a thermal mark or other hatchery marks and tags were classified as natural origin. Historically, the very low recovery (<1%) of CWT strays at PRH suggests that a high percentage of the fish not possessing any type of hatchery mark may be of natural origin (See Section 9.0). In some sections of the 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. It's believed that estimates of origin based on otolith sampling provides the most accurate data under the current marking regime at PRH due to discrepancies in the data associated with CWT results. The error rate associated with determination of origin by otoliths is reported at less than 1% (J. Grimm, WDFW Otolith Lab, personal communication). Each otolith is independently read by two experienced lab staff. Upon completion of the second read, any discrepancies are read a third time to resolve the conflict. If the marks are poor quality, three staff independently read the otoliths. The otolith marks created by the PRH fish culture staff are high quality and generally require only two readings. Most discrepancies related to otolith data are clerical in nature (data entry). Discrepancies associated with the data collected by the M&E team were generally clerical and easy to resolve and correct.

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 2016, the proportion of broodstock obtained from the PRH volunteer trap that was natural origin is estimated at 0.059. Overall, it is estimated that 0.028 of the fish surplused from the PRH volunteer trap were natural origin. The proportion of natural origin fish used as broodstock from the OLAFT and ABC was estimated to be 0.730 and 0.955, 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 2016, a minimum fork-length threshold of ~73 cm was generally used to reduce the number of age-2 and 3 broodstock collected at OLAFT along with the exclusion of hatchery marks and tags. Historical data suggests that a larger proportion of age-2 and 3 fall Chinook salmon returning to the Hanford Reach are of hatchery origin versus age-4 and 5 fish. Similarly, broodstock collected from the PRH volunteer trap were generally culled to exclude fish <73 cm with no hatchery marks or tags.

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 tages, and/or adipose clips, Brood Years 2013-2016.

Priest Rapids Hatchery Broodstock [1]			Estimate (95% CI)	
Brood 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]
Priest Rapids Hatchery Surplused from Trap			**Estimate (95% CI)**	
Brood 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]
Off Ladder Fish Trap Broodstock[1]			**Estimate (95% CI)**	
Brood 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]
Angler Broodstock Collection Broodstock [1]			**Estimate (95% CI)**	
Brood 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]

[1] Includes only fish that were spawned.
[2] Origin based on the absence of otolith marks, coded-wire tags, or adipose clips.
[a] This data was 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] This data is 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 have until recent years frequently 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.

All Chinook salmon returning to PRH and broodstock collected from the OLAFT and ABC were sampled for the presence of CWT. A total of 4,669 CWT fish were recovered from Chinook salmon sampled at PRH in 2016, of which 297 were obtained from the broodstock collected from the PRH volunteer trap (Appendix B and Appendix C). The broodstock collected from the PRH volunteer trap were generally culled to exclude CWT fish. Therefore, this CWT group is not representative of the volunteer broodstock. There were seven CWT recovered in the ABC broodstock and subsequently surplused. The ABC fish were not screened for a CWT during collection but were later scanned for CWT at the hatchery. The staff collecting the OLAFT fish effectively screened out CWT fish during the brood stock collection. The juvenile mark rate expansions of CWT at PRH in 2016 suggest that 93.6% 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 6.4% of the unaccounted fish could potentially be natural origin (Table 3).

During return year 2016, PRH origin CWT tags accounted for 91.2% of the total return to the PRH volunteer trap. There were 11 natural origin CWT Hanford Reach fall Chinook salmon recovered at the hatchery in 2016; all were excluded from the broodstock while sorting out adipose clipped fish. 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 11 CWT recoveries.

Table 3 Estimated proportion of hatchery and natural origin adult Chinook salmon returning to the Priest Rapids Hatchery volunteer trap based on coded-wire tag expansion. The entire collection was sampled for coded-wire tags, Return Years 2005-2016.

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
Mean	**28,027**	**0.663**	**0.011**	**0.331**
Median	**19,586**	**0.647**	**0.006**	**0.355**

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

8.0 Brood stock 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 4,938 fish were spawned from the three sources of broodstock. In general, hatchery origin broodstock tend to be younger than natural origin broodstock (Table 4). The historical broodstock age compositions are not directly comparable to the 2012 through 2015 broodstock age compositions due to inconsistent methodology for assigning origin. Prior to

2012, the origin of broodstock was estimated by adult CWT recoveries which in turn were expanded by the specific juvenile tag rates.

Table 4 Age composition for hatchery and natural origin fall Chinook salmon spawned at Priest Rapids Hatchery (includes all sources of broodstock), Return Years 20017-2016. 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

[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)

In recent years, the broodstock selected from the PRH volunteer trap consisted primarily of age-4 fish (Table 5). The hatchery origin broodstock for return years 2012 and 2013 had higher proportions of age-3 fish due to the scarcity of older fish returning to the trap. The hatchery and natural origin fish broodstock recovered and high-graded at the OLAFT were primarily age-4 (Table 6). Adipose clipped fish and all jack were generally excluded from the fish collected from the ABC fishery. In recent years, both the PRH origin and natural origin fish spawned from the ABC broodstock were mostly age-4 (Table 7).

Table 5 **Age composition for hatchery and natural origin fall Chinook broodstock collected from the Priest Rapids Hatchery volunteer trap, Return Years 2012-2016.**

Return Year	Origin[1]	Age Composition					
		N	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
Mean	**Natural**	**36**	**0.000**	**0.224**	**0.669**	**0.103**	**0.004**
	Hatchery	**619**	**0.000**	**0.303**	**0.612**	**0.085**	**0.000**

[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 2012-2016.**

Return Year	Origin[1]	Age Composition					
		N	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
Mean	**Natural**	**176**	**0.010**	**0.217**	**0.589**	**0.179**	**0.006**
	Hatchery	**84**	**0.021**	**0.315**	**0.522**	**0.138**	**0.004**

[1] Origin determined from "in-sample" otoliths, adipose clips and/or coded-wire tags.
[a] One age-6 female assigned to natural origin based on the absence of marks or tags. The 2006 brood year was not otolith marked.

Table 7 Age composition for hatchery and natural origin fall Chinook salmon broodstock collected form Angler Broodstock Collection, Return Years 2012-2016.

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
Mean	**Natural**	**125**	**0.000**	**0.306**	**0.558**	**0.136**	**0.000**
	Hatchery	**16**	**0.012**	**0.504**	**0.484**	**0.000**	**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. Both the hatchery origin and natural origin age-3 fish collected at the OLAFT appear to be slightly larger than age-3 fish collected at other locations. This may be due to the size high-grading processes.

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 2016. 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			78	73	3	594	79	4	106	85	6	0		
	Hatchery	0			133	71	4	437	80	4	79	84	5	0		
OLAFT	Natural	0			9	76	2	105	81	4	38	89	6	3	95	8
	Hatchery	0			5	79	1	36	82	5	14	86	8	1	99	0
ABC	Natural	0			14	66	5	59	79	6	17	89	4	0		
	Hatchery	0			2	67	3	3	80	4	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 volunteer broodstock for the Priest Rapids Hatchery program. N = sample size and SD = standard deviation, Return Years 2012-2016.**

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		

[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. The 2016 broodstock population was comprised of 68.9% females, resulting in an overall male to female ratio of 0.45:1.00 which is lower than the historic mean ratio of 0.53:1.00 (Table 10). This lower ratio of males to females resulted from the 138 matings of 1-male x 4-females during the real-time otolith read/alternative mating strategy study.

Table 10 **Number of male and female hatchery fall Chinook salmon broodstock at Priest Rapids Hatchery, Return Years 2001-2016. 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
Mean	**1,703**	**3,219**	**0.53:1.00**

[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 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 slightly varying amounts of interstitial water which might overestimate the egg count.

Fecundity for the 2016 broodstock averaged 3,649 eggs per female which is similar to that observed in 2015 but less than the historical mean of 3,966 (Table 11). Pre-spawn egg loss was often observed during the electro-anesthetic and pneumatic fish euthanizing process and may contribute to the reduced fecundity of fish in recent years.

Table 11 **Mean fecundity of fall Chinook salmon collected for broodstock at Priest Rapids Hatchery, Return Years 2001-2016.**

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
2007[a]	5,067,319	1,249	4,057

Return Year	Egg-Take	Viable Females	Fecundity/Female
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
Mean	**12,317,812**	**3,121**	**3,966**

Fecundities of individual females were taken from sub-samples at PRH during the spawn of 2010 through 2016 broodstock to estimate fecundity by length and age. For the 2013 through 2016 brood year data, we show comparisons between hatchery and natural origin fall Chinook salmon sampled at PRH which 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. Comparisons between age classes are not representative of the females spawned from 2013 through 2016 broodstock populations.

M&E staff performed the fecundity estimates on green eggs during the spawn days. 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. This sample size 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 2016 to provide a simple linear regression to predict fecundity based on fork-length (natural and hatchery 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.

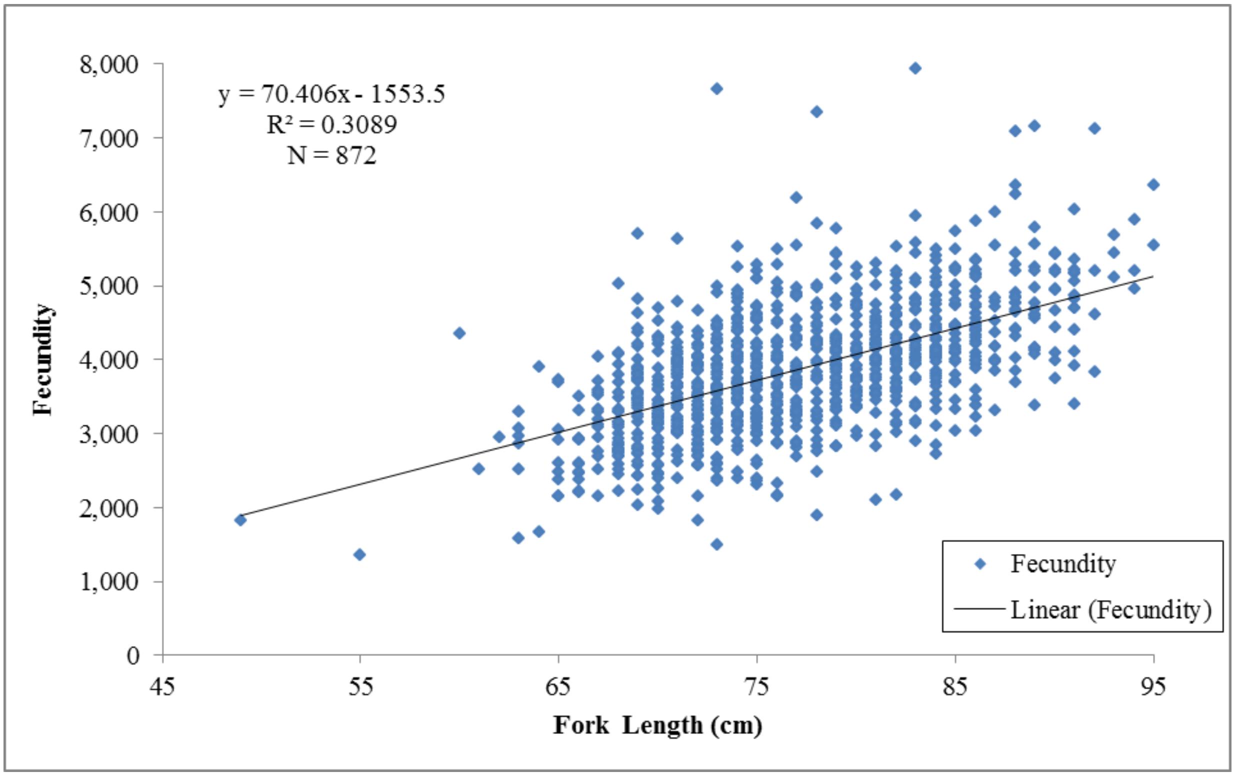

Figure 4 Linear relationship between fecundity and fork length for combined samples of natural and hatchery origin fall Chinook salmon spawned at Priest Rapids Hatchery, Return Years 2010-2016.

Fecundity samples collected in years 2010 through 2012 were not identified as to the origin of the females. For years 2013 through 2016, 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 2010-2016. 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	0	73	4,126	755	5	4,416	407
2015	1	3,169	382	53	3,662	606	25	4,746	691
2016	14	3,192	559	101	3,676	639	36	4,173	693
Mean	61	3,435	711	74	3,977	764	12	4,545	649

The data collected from return years 2013 through 2016 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 andFigure 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.

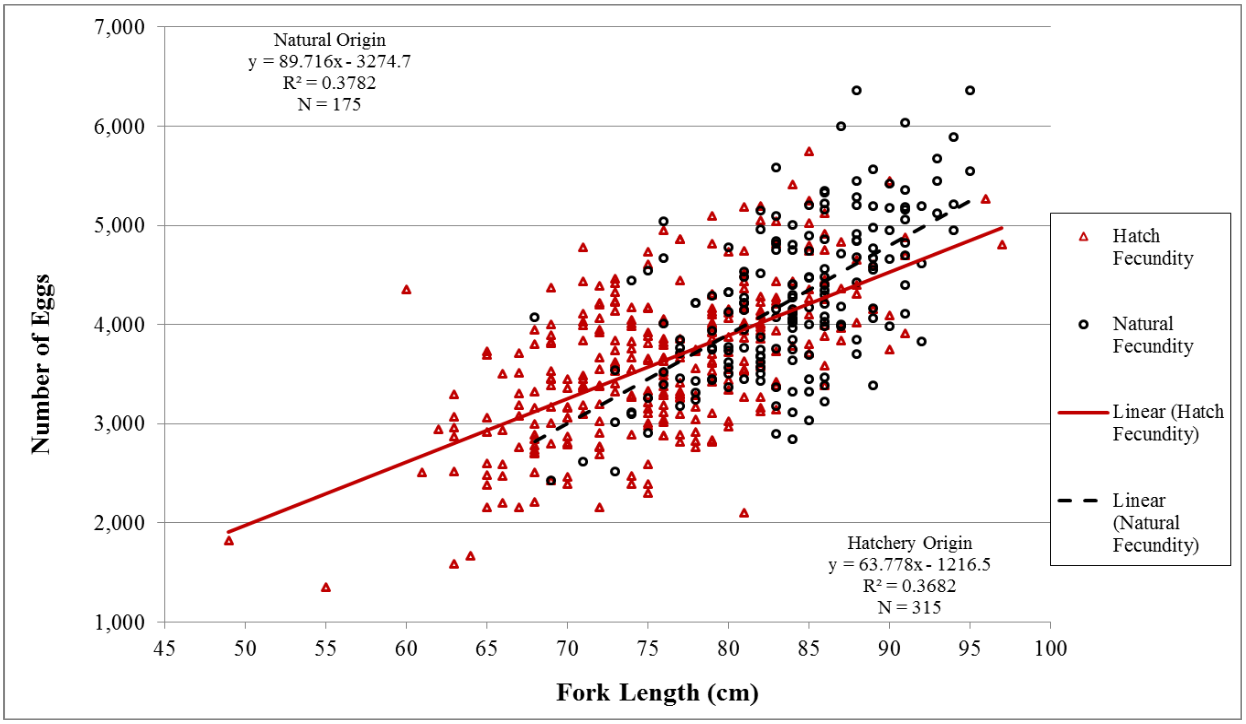

Figure 5 Fecundity versus fork length for natural and hatchery origin fall Chinook salmon sub-sampled at Priest Rapids Hatchery, Return Years 2013-2016.

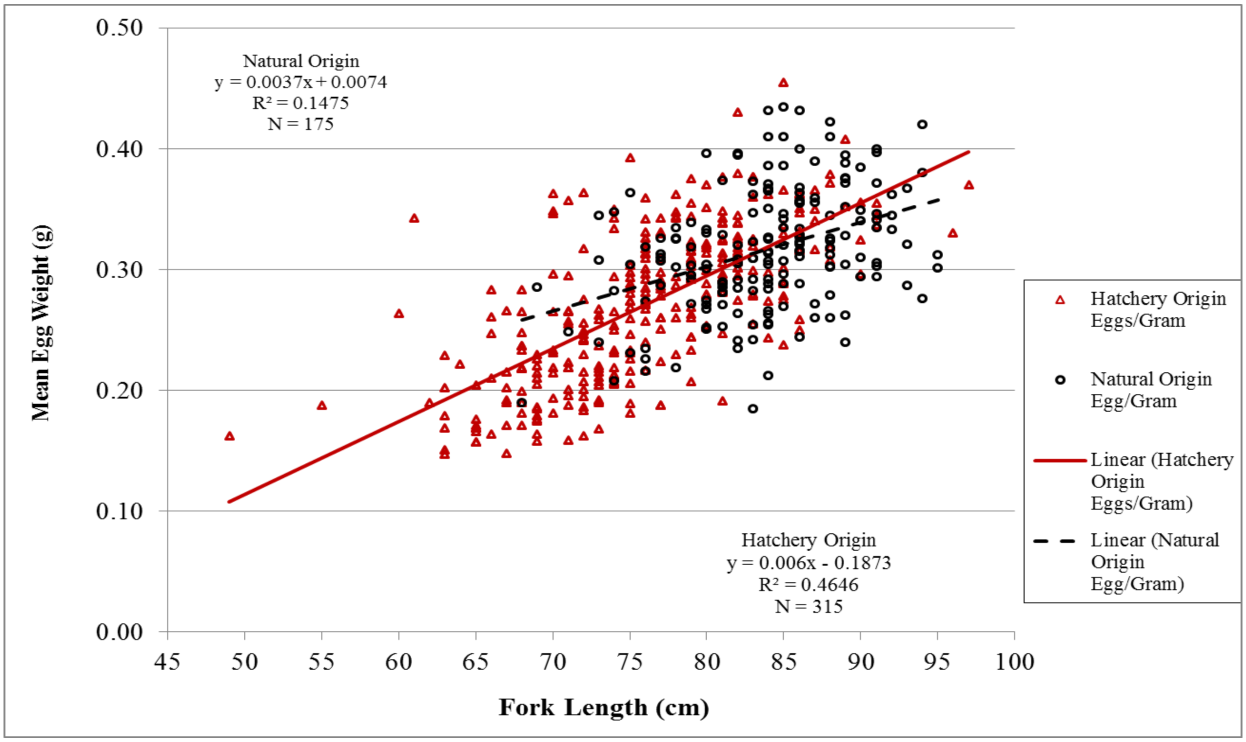

Figure 6 **Mean egg weight versus fork length for natural and hatchery origin fall Chinook salmon sub-sampled at Priest Rapids Hatchery, Return Years 2013-2016.**

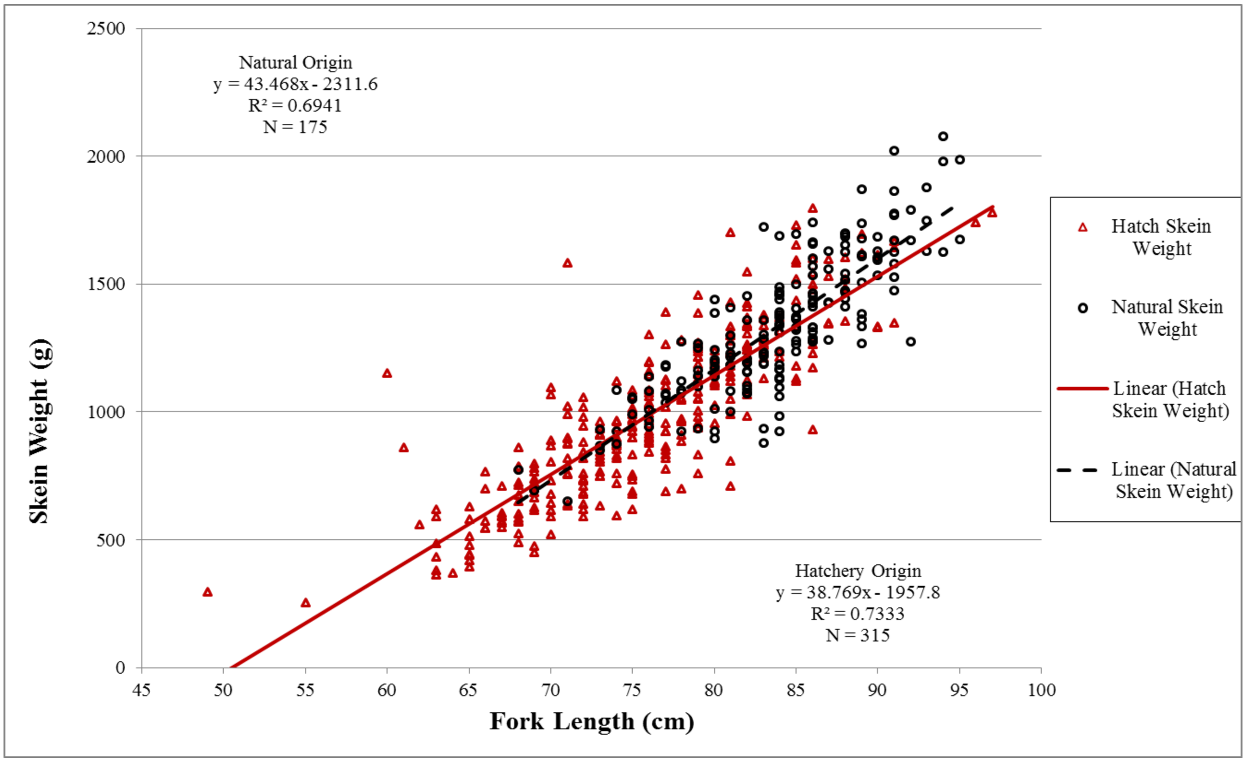

Figure 7 **Total egg mass weight versus fork length for natural and hatchery origin fall Chinook salmon sub-sampled at Priest Rapids Hatchery, Return Years 2013-2016.**

9.0 Hatchery Rearing

9.1 Number of Eggs Taken

In 2016, an estimated total of 12,411,530 eggs were collected at PRH (Table 13). The egg-take goal for return year 2016 was 13,329,318. 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.

PRH incubates approximately 8.4 million eyed eggs to produce the 7.3 million smolt release at the hatchery. Roughly 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.

Table 13 Number of eggs taken from fall Chinook salmon broodstock collected at Priest Rapids Hatchery, Return Years 1984-2016.

Return Year	Number of Eggs Taken	Return Year	Number of Eggs Taken
1984	10,342,000	2001	10,750,000
1985	10,632,000	2002	12,180,000
1986	22,126,100	2003	12,814,000
1987	24,123,000	2004	12,753,500
1988	16,682,000	2005	14,085,000
1989	13,856,500	2006	13,511,200
1990	9,605,000	2007	5,067,319
1991	6,338,000	2008	12,643,600
1992	11,156,400	2009	13,074,798
1993	14,785,000	2010	11,903,407
1994	16,074,600	2011	12,693,000
1995	17,345,900	2012	12,398,389
1996	14,533,500	2013	13,276,000
1997	17,007,000	2014	14,321,818
1998	13,981,300	2015	12,692,400
1999	16,089,600	2016	12,411,530
2000	15,359,500	**9 year (08-16) Mean[1]**	**12,823,882**

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

9.2 Number of Acclimation Days

The 2016 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 2017. The egg-takes for the 2016 brood were distributed into eleven batches associated with the dates in which fish were spawned. The number of acclimation days ranged from 97 for the later egg-takes to 116 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 2016.

Batch	Egg Tray to Raceway Transfer Date	Release Date	Number of Days
1	January 27 into Bank E	May 23	116
2	January 27 into Bank E	May 23	116
3	February 14 into Bank E	May 23	98
	February 14 into Bank D	May 25	100
	February 14 into Bank C	June 9	118
6	February 28 into Bank C	June 9	104
	February 28 Bank B	June 12	111
	February 28 Back A	June 19	111
7	February 28 into Bank A	June 19	111
8	March 14 into Bank A	June 19	97
9	March 14 into Bank A	June 19	97
10	March 14 into Bank A	June 19	97
11	March 14 into Bank A	June 19	97

9.3 Annual Releases, Tagging and Marking

The annual release of fall Chinook salmon smolts from PRH range 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 2016 release goal for PRH is 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 2016, PRH released an estimated 7,242,054 subyearling fall Chinook salmon from the 2015 broodstock (Table 16). Fish were released between June 16 and June 24.

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. All smolts associated with the USACE John Day mitigation have been adipose clipped, but only small fractions included a CWT. Poor returns in 2007 precluded the production of USACE John Day mitigation fish for the 2008 release.

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 sampling at PRH and in the Hanford Reach should provide increased precision in the determination of PRH origin returns to the hatchery and Hanford Reach compared to CWT estimates. Given sufficient samples sizes, the otolith mark rate of 100% may provide better estimates than those from CWTs.

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. 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).

WDFW operates the OLAFT at Priest Rapids Dam three days per week beginning in July and continuing through mid to late October. This project began in 1986 and was designed to sample steelhead to (1) determine upriver run size, (2) estimate hatchery to natural origin (wild) fish ratios, (3) determine age class distribution, and (4) evaluate the need for managing returning hatchery steelhead consistent with ESA recovery objectives. In 2009, WDFW began sampling fall Chinook salmon at the trap for run composition assessment. Beginning in 2010, the OLAFT was used to collect potential natural origin fall Chinook salmon for incorporation into the broodstock at PRH.

Table 15 Number of marked, unmarked, and tagged fall Chinook salmon smolts released from Priest Rapids Hatchery, Brood Years 1977-2016.

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]

Brood Year	Total Released	Non Ad-Clip Released	AD/CWT	CWT Only	AD Only	PIT
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]
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]	7,039,543	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 [c]
2016[a]	7,006,251	3,045,689	603,539	603,864	2,710,302	42,858 [d]

[a] Entire release was otolith marked
[b] Low returns to PRH precluded the production of the USACE adipose clipped release.
[c] PIT tagged are included in the Non Ad-Clip totals
[d] PIT tagged are not included in the Non Ad-Clip totals

9.4 Fish Size and Condition at 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 2016 broods were collected by M&E staff the day prior to release for each pond. We attempted to collect representative samples by capturing multiple groups of fish with a cast net from the lower, middle, and upper third of the 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 2016 brood averaged 49 fish per pound with an mean fork length of 89 mm, and a mean CV of 6.1 (Table 16). For brood years 1991 through 2016, smolts released from PRH have averaged 48 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 1991-2016.

Brood year	Release Year	Fork Length (mm)		Mean Weight		N
		Mean	CV	Grams (g)	Fish/pound	
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

Brood year	Release Year	Fork Length (mm) Mean	CV	Mean Weight Grams (g)	Fish/pound	N
2001	2002	96	6.9	10.1	45	1,500
2002	2003	95	6.9	9.5	48	1,500
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
Mean		**95**	**7.3**	**9.4**	**48**	**1,479**

9.5 Survival Estimates

The survival proportion (P^) for egg to juvenile release for brood year 2016 was 0.819 which is lower than the historic mean of 0.852 (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 2016 was 0.899 which is similar to the historical mean of 0.901.

In 2016, survival P^ of fish ponded for broodstock was 0.843 which is similar to the historic mean of 0.846. The trapping operations in 2014 through 2016 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 1989-2016.

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

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
1999				0.759	0.897	0.997	0.995	0.888
2000				0.868	0.898	0.995	0.985	0.884
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	0.870	0.970	0.973	0.817
2015	0.841	0.810	N/A	0.830	0.917	0.977	0.965	0.827
2016	0.873	0.782	N/A	0.843	0.899	0.973	0.964	0.819
Mean	**0.834**	**0.838**	**0.705**	**0.823**	**0.892**	**0.980**	**0.963**	**0.852**

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 detection rates 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 brood were initiated at 9PM for each pond. All weir boards were pulled by 3AM. Releases occurred irregularly between May 23 and June 19. We anticipated river flows during May and June to exceed 240kcfs which results in the inundation of the PRH array. A temporary two antenna array was installed at a higher elevation near the upper end of the discharge channel to complement the PRH array. The overall detection rate was 95.4% for the combined release of all ponds, ranging from 89.7% to 97.5%.

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 2011-2016.

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
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

Brood Year	Tag File	Tagging Date	Release Date	# Tagged	# of Tags Recovered from Facility Mortalities	# of Unique Detections	% Detected
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**

10.0 Adult Fish Pathogen Monitoring

At spawning, adult fall Chinook are sampled for infectious hemotopoietic necrosis virus (IHNV), infectious pancreatic necrosis (IPN), viral hemorrhagic septicemia (VHS), paramyxovirus, aquaroviruses, as well as *Renibacterium salmoninarum*, the causative agent for bacterial kidney disease (BKD). Viral and bacterial inspections included sampling the ovarian fluid and kidney/spleen for pathogens (AFS-FHS 2014). 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. All results of viral testing in 2016 were negative (Table 19). The risk of BKD was assayed using the enzyme linked immunosorbent assay (ELISA) for *R. salmoninarum* antigen (Elliot 2012). Results of adult broodstock BKD monitoring in 2016 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 samples was in the Low category between 0.10 and 0.199 (Table 20).

Table 19 Viral inspections of fall Chinook salmon broodstock at Priest Rapids Hatchery, Return Years 1991-2016.

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

Year	Date(s)	Stock	Life stage	Ovarian Fluid	Kidney/Spleen	Results
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

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 2008-2016.

Year	Stock		%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%

10.1 Juvenile Fish Health Inspections

Juvenile fish are inspected for the presence of pathogens and other conditions on a monthly basis following ponding (AFS-FHS 2014). The 2016 brood year juveniles were generally healthy throughout the rearing period (Table 21). Inspection results for brood years 1995 through 2009 are provided in Appendix D.

Table 21 Juvenile fish health inspections for Priest Rapids Hatchery fall Chinook salmon, Brood Years 2006-2016.

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
24-May-12	Priest Rapids	2011	Healthy
11-Feb-13	Priest Rapids	2012	Healthy
3-Mar-13	Priest Rapids	2012	Healthy

Date	Stock	Brood Year	Condition
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 Ponds 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

11.0 Redd Survey

Fall Chinook salmon redd surveys were performed in the Hanford Reach during 2016 by staff with Environmental Assessment Services, LLC under contract with Mission Support Alliance. WDFW M&E staff performed fall Chinook salmon redd surveys in the PRH discharge channel during 2016.

11.1 Hanford Reach Aerial Redd Counts

Aerial redd counts in the Hanford Reach were performed by Mission Support Alliance on October 23, November 6, 13, and 20 during 2016 (Nugent 2017). 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 surveys occurred on Sundays when outflows at Priest Rapids Dam were lowered to nearly 40 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 good; however, a cloudy plume stretched along the eastern shore from the White Bluffs down to Richland during the last three flights (USDOE In Press). The peak fall Chinook Salmon redd count for the Hanford Reach in 2016 was 13,268 (Table 22).

Table 22 Summary of fall Chinook salmon peak redd counts for the 1948-2016 aerial surveys in the Hanford Reach, Columbia River.

Year	Redds	Year	Redds	Year	Redds	Year	Redds
1948	787	1967	3,267	1986	8,291	2005	7,891
1949	313	1968	3,560	1987	8,616	2006	6,508
1950	265	1969	4,508	1988	8,475	2007	4,023
1951	297	1970	3,813	1989	8,834	2008	5,588
1952	528	1971	3,600	1990	6,506	2009	4,996
1953	139	1972	876	1991	4,939	2010	8,817
1954	160	1973	2,965	1992	4,926	2011	8,915

Year	Redds	Year	Redds	Year	Redds	Year	Redds
1955	60	1974	728	1993	2,863	2012	8,368
1956	75	1975	2,683	1994	5,619	2013	17,398
1957	525	1976	1,951	1995	3,136	2014	15,951
1958	798	1977	3,240	1996	7,618	2015	20,678
1959	281	1978	3,028	1997	7,600	2016	13,268
1960	258	1979	2,983	1998	5,368		
1961	828	1980	1,487	1999	6,068		
1962	1,051	1981	4,866	2000	5,507		
1963	1,254	1982	4,988	2001	6,248		
1964	1,477	1983	5,290	2002	8,083		
1965	1,789	1984	7,310	2003	9,465		
1966	3,101	1985	7,645	2004	8,468		
						Mean (2007 - 2016)	**10,228**

11.2 Redd Distribution

The main spawning areas observed during the 2016 counts were located near Vernita Bar and among Islands 4-6 (Table 23 & Figure 8). Historical redd counts by location from 2001 through 2016 are included in Appendix E of this report.

Table 23 Number of fall Chinook salmon redds counted in difference reaches on the Hanford Reach area of the Columbia River during October 2016 through November 2016 aerial redd counts. (Data provided by Mission Support Alliance).

General Location	Start KM	End KM	Total Length	23-Oct	6-Nov	13-Nov	20-Nov	Max Count	Avg. Redd Per River KM
Islands 17-21	545	558	13	0	0	0	0	0	0
Islands 11-16	558	573	15	0	380	830	861	861	57
Islands 8-10	587	593	6	35	1,020	1,685	1,735	1,735	289
Near Island 7	593	594	1	0	650	660	670	670	670
Island 6 (lower half)	594	599	5	54	1,135	1,805	1,807	1,807	361
Island 4, 5 and upper 6	599	602	3	68	2,140	2,262	2,270	2,270	757
Near Island 3	602	604	2	30	380	550	600	600	300
Near Island 2	604	606	2	40	810	1,120	1,140	1,140	570
Near Island 1	606	608	2	10	253	300	340	340	170
Near Coyote Rapids	608	619	11	13	185	252	255	255	23
Midway (China Bar)	620	630	10	4	60	60	80	80	8
Near Vernita Bar	630	635	5	220	3,140	3,400	3,500	3,500	700
Near Priest Rapids Dam	635	638	3	0	7	10	10	10	3
Total	--	--	--	**474**	**10,160**	**12,934**	**13,268**	**13,268**	

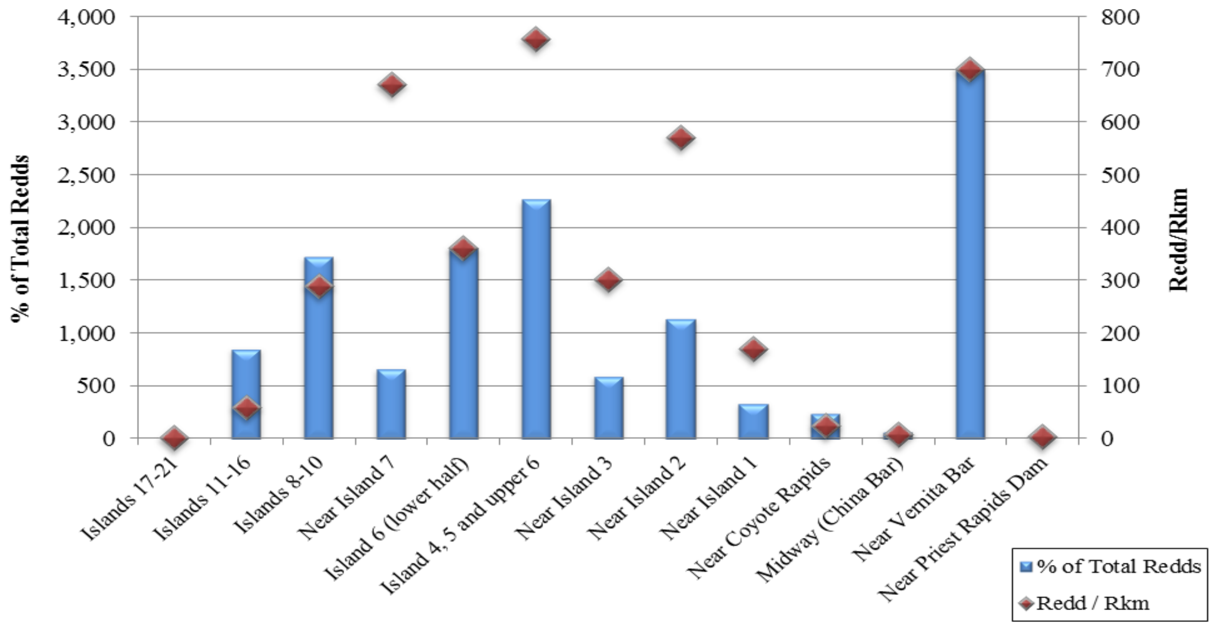

Figure 8 **Distribution of fall Chinook salmon redd counts by location for the 2016 aerial surveys in the Hanford Reach, Columbia River (Data provided by Mission Support Alliance).**

11.3 Spawn Timing

Based on aerial redd counts and Vernita Bar spawning ground surveys, fall Chinook salmon spawning in the Hanford Reach during 2016 began in late October and ended in late November. River temperatures below Priest Rapids Dam varied from 15.4°C (October 20) to 12.3°C (November 20) 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 2016 return year was 116,388 fish (Table 24). This is lower than recent annual returns but still the fourth highest return since 1991 (Table 25). The historical mean and median escapement for 1991 through 2016 is 73,550 and 55,208 fish, respectively. 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 2016, the estimated 9 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 2016.**

	Return Year 2016		
Count Source	**Adult**	**Jack**	**Total**
McNary Ladder Counts	239,791	24,870	264,661
Adjusted Priest Rapids Adult Passage[1]	35,464	2,759	38,223
Ice Harbor Adult Passage	36,713	13,066	49,779
Prosser Adult Passage	5,214	464	5,678
Priest Rapids Hatchery	27,904	882	28,786
PRH discharge channel	44	0	44

Count Source	Return Year 2016 Adult	Jack	Total
Wanapum Tribal Fishery	35	1	36
Ringold Springs Hatchery	5,314	65	5,379
Yakima River Escapement (Below Prosser)	1,087	97	1,184
Yakima River Sport Harvest	922	31	953
Hanford Sport Harvest	16,859	1,068	17,927
Angler Broodstock Collection	284	0	284
Total Non-Hanford Reach Escapement	**129,840**	**18,433**	**148,273**
Hanford Reach Escapement	**109,951**	**6,437**	**116,388**

[1] Gross passage count reduced 13.53% 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 1991-2016.

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	9	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
2013	10	17,398	174,651
2014	12	15,951	183,749
2015	13	20,678	266,327
2016	9	13,268	116,388
Mean	**9**	**8,013**	**73,550**
Median	**9**	**7,054**	**55,208**

[1] Escapement includes adults and jacks

11.5 Hatchery Discharge Channel Redd Counts

The M&E staff conducted redd counts in the PRH discharge channel on October 29, November 9, November 21, and December 2, 2016. Similar to historical observations, the majority of spawning activity was located in a 200 meter section of the discharge channel downstream adjacent to the volunteer trap. A peak count of 22 redds occurred on the December 5 survey. We observed superimposition occurring during multiple surveys; thus making it difficult to determine the total number of redds in a given survey. Viewing conditions during each survey were good to excellent.

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. The recent record returns to the Hanford Reach have necessitated an increased level of effort to attain the 10% sampling goal.

Carcass surveys were performed from November 3 through December 9, 2016. All recovered carcasses were sampled for the presence of a CWT. Of those, 20% were sampled (i.e., random systematic 1:5 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.

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)

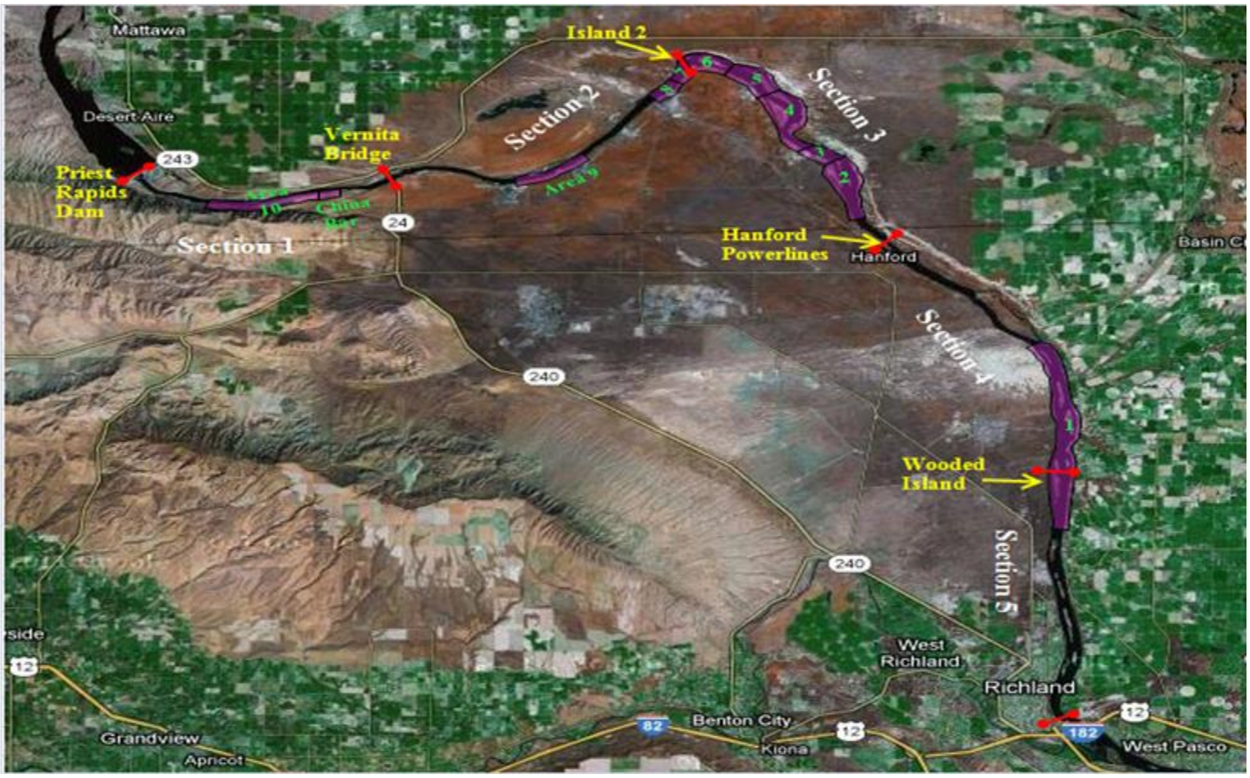

Figure 9 **Location of aerial redd index areas and river surveys section in the Hanford Reach.**

12.1 Hanford Reach Carcass Survey: Section 1 – 5

Staff recovered a record 8,886 fall Chinook salmon in the Hanford Reach in 2016; equating to 7.6% of the estimated fall Chinook salmon escapement (Table 26). The recovery rate was lower than expected due to unusually high river flows which regularly made it difficult to locate carcasses. The annual number of fall Chinook salmon carcass recovered in the Hanford Reach for the period of 1991 through 2016 is provided in Appendix F.

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, 2010-2016.**

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
Mean	**1,917**	**0.016**	**754**	**0.005**	**3,542**	**0.028**	**3,627**	**0.030**	**1,793**	**0.015**	**11,634**	**0.093**	**140,777**

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 which provided greater chances to recover carcasses.

Table 27 Number of carcass surveys conducted by section in the Hanford Reach, Return Years 2010-2016.

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
Mean	**22**	**9**	**29**	**28**	**16**	**104**

12.1.1 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 to the Hanford Reach (see Section 14 - Redd Surveys). The calculations for estimating the escapement to the Hanford Reach are given in Appendix G.

We recently 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. For example, there were no redds identified in Section 5 but 1,459 carcasses were recovered in that section. It is likely that sections 1 and 3 which have the greatest number of redds and largest spawning escapement end up with a net loss of carcasses to downstream sections. In 2016, 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 H.

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 2016.

Survey Section	Total Number of Redds	Total Number of Carcasses	Spawning Escapement[1]	Proportion of Escapement Sampled
1	3,590	1,141	31,492	0.036
2	595	513	5,219	0.098
3	8,222	2,796	72,124	0.039
4	861	2,977	7,553	0.394
5	0	1,459	0	0.000
Total	**13,268**	**8,886**	**116,388**	0.076

[1] Calculated based on proportion of redds by section

12.1.2 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) to non-marked carcasses. Estimates for both methods are given for the 2012 - 2016 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. The expansion of CWT recoveries suggest that 8.7% of the fall Chinook salmon carcasses recovered in the 2016 Hanford Reach stream surveys were hatchery origin (Table 29). This estimate is similar to those of previous years excluding 2013. The expanded CWT recovery data suggest the hatchery origin component of the escapement included 6.9% from PRH, 1.2% from RSH and 0.6% from other hatcheries. The highest proportions of hatchery origin carcasses recovered were in Sections 1, and 3, respectively.

Table 29 Numbers of natural and hatchery origin fall Chinook salmon carcasses sampled within Sections 1 through 5 of Hanford Reach based on expansions of coded-wire tag recoveries, Return Years 2010-2016.

Return Year	Origin	Hanford Reach Sections # 1	# 2	# 3	# 4	# 5	Total	Proportion of Sampled
2010	Natural	1,751	473	3,020	3,242	909	9,395	0.960
	Hatchery	81	46	116	125	28	396	0.040
	Proportion	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	0.935
	Hatchery	231	5	86	147	75	544	0.065
	Proportion	0.146	0.031	0.033	0.056	0.053	0.065	
2012	Natural	1,142	149	1,526	2,081	1,510	6,408	0.927
	Hatchery	49	0	159	132	166	506	0.073
	Proportion	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	0.783
	Hatchery	610	386	411	879	550	2,836	0.217
	Proportion	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	0.945
	Hatchery	213	70	280	244	112	918	0.055
	Proportion	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	0.928
	Hatchery	259	114	442	378	89	1,282	0.072
	Proportion	0.089	0.139	0.071	0.064	0.046	0.072	
2016	Natural	1,108	256	2,585	2,866	684	8,111	0.913
	Hatchery	162	33	257	211	111	775	0.087
	Proportion	0.142	0.064	0.092	0.071	0.076	0.087	
Mean	**Natural**	**1,721**	**629**	**3,299**	**3,340**	**1,537**	**10,613**	**0.913**
	Hatchery	**229**	**93**	**250**	**302**	**162**	**1,037**	**0.087**
	Proportion	**0.115**	**0.090**	**0.074**	**0.082**	**0.092**	**0.089**	

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 annual marks on the otoliths beginning with progeny of brood year 2007. For the 2013 - 2016 returns, age-2 through 6 PRH origin carcasses recovered 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 11.4% of fall Chinook salmon carcasses recovered in the 2016 Hanford Reach stream survey were hatchery origin (Table 30). For recent years, the hatchery proportions were generally higher in the upstream survey sections.

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 2012-2016.

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	
2015 Biological sample rate = 1:7 N = 2,485	PRH[1]	47	12	61	55	13	188	0.076
	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	
Mean Proportion	**PRH[1]**	**0.147**	**0.11**	**0.089**	**0.07**	**0.094**	**0.094**	**0.094**
	Other Hatchery[2]	**0.031**	**0.036**	**0.038**	**0.05**	**0.044**	**0.042**	**0.048**

Year	Origin	# 1	# 2	# 3	# 4	# 5	Total	Proportion of Sample
	All Hatchery	***0.178***	***0.145***	***0.127***	***0.12***	***0.139***	***0.136***	***0.142***
	Natural	**0.849**	**0.862**	**0.886**	**0.893**	**0.886**	**0.881**	**0.858**
	Proportion	**0.176**	**0.142**	**0.148**	**0.127**	**0.137**	**0.142**	

[a] Estimate of origin based on random sub-sample of biological sample.

[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 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.

12.2 Priest Rapids Dam Pool Carcass Survey: Section 6

In total, eight carcass surveys were performed in Section 6 during return year 2016 (Table 31). Surveys were scheduled once or twice a week between early November and mid-December.

Table 31 Number of fall Chinook salmon carcasses sampled within Section 6 (Priest Rapids Dam Pool).

Year	Section 6	
	# of Carcasses	# of Surveys
2010	123	8
2011	69	7
2012	72	4
2013	407	7
2014	237	7
2015	155	6
2016	139	8
Mean	**172**	**7**

12.2.1 Number sampled: Section 6

Survey crews recovered 139 Chinook salmon in Section 6 during return year 2016 (Table 31). 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 recover.

12.2.2 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 G).

The 2016 fall Chinook salmon spawning escapement estimate for Section 6 is 13,162 fish. Overall, roughly 1% of the total estimated spawning escapement in Section 6 was sampled in 2016 (Table 32).

Table 32 Carcasses sampled, total spawning escapement and proportion of escapement for fall Chinook salmon in Section 6 (Priest Rapids Dam Pool), return years 2010-2016.

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
Mean	**7**	**172**	**26,185**	**0.007**

12.2.3 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 49.6% of the fall Chinook salmon spawning in Section 6 were hatchery origin of which 95.7% were PRH origin (Table 33).

Table 33 Origin of fall Chinook salmon spawning in Section 6 (Priest Rapids Dam Pool), Return Years 2012-2016.

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 N = 155	PRH[1]	83	0.535
	Other Hatchery[2]	3	0.019
	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
	PRH[1]	**62**	**0.411**

Year	Origin	Total	Proportion of Sample
Means N = 137	**Other Hatchery[2]**	**4**	**0.026**
	Total Hatchery	***79***	***0.523***
	Natural[3]	**72**	**0.477**

[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.

12.3 Hatchery Discharge Channel: Sections 7 and 8 Carcass Survey

During return year 2016, crews performed one 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 November 28 when discharge levels in the channel were still high.

12.3.1 Number sampled: Sections 7 and 8

Survey crews recovered 33 carcasses in Section 7 and 26 in Section 8 (Table 34). All fish recovered were scanned for the presence of a CWT.

Table 34 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 2010-2016.

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
Mean	**66**	**2**	**79**	**6**	**145**	**8**

12.3.2 Proportion of Escapement Sampled: Section 7 and 8

The 2016 fall Chinook salmon spawning escapement index for Sections 7 and 8 is 44 fish (Table 35). The spawning escapement for these Sections was calculated using the expansion factor of two fish/redd, based on a 0.9 male/female sex ratio including jacks, as estimated from the Hanford Reach 2016 escapement. Therefore, the assumption is made that each of the 22 redds represents one female and one male. We assume that most of the carcasses recovered in Section 8 drifted downstream from Section 7. In addition, it is likely a portion of carcasses from Sections 7 and 8 drift downstream into Sections 1 and 2.

Table 35 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 2016.

Section	Total Number of Carcasses	Spawning Escapement	Escapement Sampled
# 7	3	44	0.227
# 8	7	0	
Total	**10**	**44**	**0.227**

12.3.3 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 66.7% of fall Chinook salmon recovered in Sections 7 and 8 were hatchery origin of which most all were PRH origin (Table 36).

Table 36 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 2012-2016.

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
Means	**PRH**	**14**	**0.416**
	Other Hatchery	**1**	**0.058**

Return Year	Origin	Total	Proportion of Sample
N = 35	***Total Hatchery***	***16***	***0.597***
	Natural	**19**	**0.403**

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 - 2016 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 - 2016 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. Annually, the sample sizes have been relatively small due to the low numbers of both hatchery and natural origin fall Chinook salmon PIT tagged. Beginning with the 2011 brood, the number of juveniles PIT tagged at PRH increased from 3,000 to roughly 43,000 annually

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 37). 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 37 The week that 10%, 50% (median), and 90% of the natural and hatchery origin fall Chinook salmon passed Bonneville Dam, 2010-2016. 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 2	Age 3	Age 4	Age 5
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	8	22	18	0
2011	10th Percentile	8-Aug	3-Sep	23-Aug			4-Sep	24-Aug	4-Aug
	50th Percentile	8-Sep	20-Sep	8-Sep			4-Sep	10-Sep	30-Aug
	90th Percentile	21-Sep	25-Sep	21-Sep			10-Sep	2-Oct	1-Sep
	N	6	7	10	0	0	2	65	3
2012	10th Percentile	31-Aug	6-Sep	13-Sep	7-Sep	14-Sep	4-Sep	28-Aug	27-Aug
	50th Percentile	16-Sep	11-Sep	13-Sep	7-Sep	23-Sep	16-Sep	5-Sep	8-Sep
	90th Percentile	27-Sep	21-Sep	19-Sep	7-Sep	10-Oct	26-Sep	21-Sep	19-Sep
	N	7	13	2	1	10	11	19	26
2013	10th Percentile	24-Aug	28-Aug	25-Aug		11-Sep	2-Sep	2-Sep	9-Aug
	50th Percentile	8-Sep	9-Sep	3-Sep		11-Sep	22-Sep	9-Sep	27-Aug
	90th Percentile	18-Sep	22-Sep	15-Sep		11-Sep	10-Oct	19-Sep	2-Oct
	N	40	55	16	0	1	29	22	10
2014	10th Percentile	6-Sep	4-Sep	5-Sep		24-Sep	10-Sep	3-Sep	29-Aug
	50th Percentile	16-Sep	13-Sep	12-Sep		25-Sep	11-Sep	12-Sep	1-Sep
	90th Percentile	28-Sep	25-Sep	23-Sep		1-Oct	28-Sep	26-Sep	15-Sep
	N	175	228	50	0	3	4	62	5
2015	10th Percentile	16-Oct	8-Sep	25-Aug	14-Sep		10-Sep	30-Aug	29-Aug
	50th Percentile	16-Oct	21-Sep	6-Sep	26-Sep		20-Sep	10-Sep	09-Sep
	90th Percentile	16-Oct	9-Oct	18-Sep	26-Sep		1-Oct	25-Sep	25-Sep
	N	1	345	323	2	0	5	13	32
2016	10th Percentile		30-Aug	8-Aug	14-Aug		21-Sep	28-Aug	31-Aug
	50th Percentile		13-Sep	7-Sep	1-Sep		21-Sep	10-Sep	7-Sep
	90th Percentile		6-Oct	19-Sep	15-Sep		14-Oct	19-Sep	14-Sep
	N	0	41	182	41	0	2	10	5

13.2 Age at Maturity

Prior to return year 2012, the age composition for hatchery origin returns to PRH was generated by pooling all of the sub-samples from the volunteer trap and ponded fish after expanding for differing demographic sample rates and sub-sample rates. Only one demographic sample rate was used annually in the Hanford Reach stream survey; precluding the need to expand and pool samples. In addition, the fish origin was assigned by location of survey due to the lack of identifiable hatchery marks and low CWT recoveries that were not 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.

The age compositions of the Hanford Reach escapement and the PRH returns are not directly comparable between locations without some adjustment. 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 I. 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 (Table 38).

The availability of otolith data combined with other hatchery mark data from the Hanford Reach carcass recoveries for the 2012 through 2016 return years provide the ability to estimate age compositions for both hatchery and natural origin fish within the Hanford Reach escapement (Table 40). 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 roughly 2,500 fish in order to capture more hatchery origin fish in the sub-sample. Regardless of the methodology, it appears that natural origin fish return at older ages than hatchery origin fish (Table 39 and Table 40). More specifically, the proportion of hatchery origin fish was higher than natural origin fish at ages 2 and 3, and the opposite was true for ages 4, 5, and 6 during brood years 2007-2011.

Table 38 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 1998-2011.

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

Brood Year	Source[1]	Age Composition				
		Age-2	Age-3	Age-4	Age-5	Age-6
	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	0.002	0.000
2009	Escapement	0.091	0.136	0.688	0.083	0.001
	PRH Returns	0.125	0.564	0.2410	0.071	0.000
2010	Escapement	0.020	0.269	0.441	0.265	0.006
	PRH Returns	0.108	0.386	0.468	0.038	0.000
2011[a]	Escapement	0.102	0.075	0.642	0.181	0.000
	PRH Returns	0.065	0.430	0.449	0.056	0.000
Mean 1998 - 2011	**Escapement**	**0.146**	**0.132**	**0.466**	**0.253**	**0.004**
	PRH Returns	**0.112**	**0.445**	**0.372**	**0.070**	**0.001**
Mean 2007 - 2011	**Escapement**	**0.096**	**0.181**	**0.554**	**0.167**	**0.002**
	PRH Returns	**0.124**	**0.472**	**0.364**	**0.040**	**0.000**

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

Table 39 Age compositions for natural and hatchery origin fall Chinook salmon sampled in the Hanford Reach escapement, Brood Years 2007-2011.

Brood Year	Origin[1]	N[2]	Male 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	0.660	0.076	0.000
	Hatchery	139	0.033	0.270	0.678	0.019	0.000
2010	Natural	2,093	0.008	0.361	0.454	0.176	0.000
	Hatchery	333	0.043	0.814	0.108	0.034	0.000
2011[a]	Natural	835	0.057	0.180	0.628	0.135	0.000
	Hatchery	72	0.123	0.252	0.626	0.000	0.000
Mean	Natural	1,214	0.036	0.297	0.545	0.129	0.000
	Hatchery	143	0.091	0.487	0.376	0.046	0.000
Brood Year	Origin[1]	N[2]	Female 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	0.000	0.117	0.679	0.204	0.000
	Hatchery	74	0.000	0.176	0.651	0.172	0.000
2009	Natural	486	0.000	0.033	0.789	0.175	0.003
	Hatchery	188	0.000	0.060	0.918	0.021	0.000
2010	Natural	1,934	0.000	0.026	0.542	0.432	0.000
	Hatchery	353	0.000	0.418	0.448	0.133	0.000
2011[a]	Natural	921	0.000	0.005	0.769	0.226	0.000
	Hatchery	118	0.000	0.028	0.972	0.000	0.000
Mean	Natural	1,013	0.000	0.046	0.697	0.257	0.001
	Hatchery	180	0.000	0.243	0.661	0.095	0.000
Brood Year	Origin[1]	N[2]	Gender Combined Age Composition				
			Age-2	Age-3	Age-4	Age-5	Age-6
2007	Natural	2,392	No Otolith Data	0.201	0.602	0.196	0.001
	Hatchery	288		0.656	0.225	0.119	0.000
2008	Natural	1,660	0.022	0.230	0.587	0.160	0.002
	Hatchery	123	0.100	0.224	0.535	0.141	0.000
2009	Natural	1,302	0.019	0.147	0.715	0.118	0.001
	Hatchery	327	0.012	0.136	0.831	0.021	0.000
2010	Natural	4,027	0.004	0.198	0.497	0.301	0.000
	Hatchery	686	0.022	0.617	0.278	0.084	0.000
2011[a]	Natural	1,756	0.025	0.084	0.706	0.185	0.000
	Hatchery	190	0.045	0.110	0.845	0.000	0.000
Mean	Natural	2,227	0.018	0.172	0.621	0.192	0.001
	Hatchery	323	0.036	0.349	0.543	0.073	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

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.

The availability of otolith marks in addition to other hatchery marks (i.e., otoliths, adipose clips, and CWTs) for the 2012 through 2016 return years provide the ability to estimate size at maturity for both hatchery and natural origin fish within the Hanford Reach escapement. Sub-sample sizes were determined as described in Section 7.

The size at maturity data is essentially complete for brood years 2007 through 2011. It appears that age-2 and 3 hatchery origin fish tend to be larger than natural origin fish. Likewise, age-4 and 5 natural origin fish tend to be larger than their hatchery origin counterparts (Table 42). This pattern is also seen in Table 41 with the exception that age-3 fish are similar size in the PRH and stream sample.

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 may are imperfect, we continue to present this information to maintain the longest data set available (Table 43).

Gender ratios (male/females) by brood year and origin of adult fall Chinook salmon sampled in the Hanford Reach carcass survey are given in (Table 43). Annually, higher male to female ratios have been observed in the natural origin fish than that of the hatchery origin fish. This may be the result of earlier age of maturity of hatchery origin fish and a size related bias of recovering carcasses in the Hanford Reach.

Table 40 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 1999-2011. 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	0
2003	Escapement	19	48	5	42	69	7	395	85	6	450	96	8			
	PRH Returns	12	49	6	93	70	6	215	83	6	20	91	4			
2004	Escapement	34	47	4	71	68	6	386	84	6	208	94	8	2	91	1

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
	PRH Returns	19	55	4	115	69	5	51	84	5	9	95	7			
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			
2006	Escapement	20	48	4	85	69	6	962	86	6	340	92	7			
	PRH Returns	3	45	3	42	71	4	170	84	6	13	92	7			
2007	Escapement	24	46	5	642	72	6	1,468	84	7	482	92	7	1	105	0
	PRH Returns	5	50	4	1,149	71	4	1,419	80	5	179	87	6			
2008	Escapement	34	50	4	243	70	5	620	84	7	72	92	8	1	84	0
	PRH Returns	22	52	5	652	69	4	573	81	6	1	84	0			
2009	Escapement	50	48	4	421	69	6	931	81	6	183	92	10			
	PRH Returns	308	48	4	1,690	68	5	218	77	5	70	86	7			
2010	Escapement	63	47	7	1,040	68	5	2,754	82	7	826	88	7	29	90	6
	PRH Returns	883	48	4	1,375	69	4	1,528	78	5	55	84	4			
2011[a]	Escapement	58	46	4	226	67	5	1,151	80	6	465	88	7			
	PRH Returns	111	47	3	694	67	4	355	77	5	201	84	6	1	87	0
Mean 99 -11	**Escapement**	**38**	**47**	**5**	**292**	**69**	**6**	**954**	**84**	**7**	**465**	**93**	**8**	**7**	**66**	**3**
	PRH Returns	**131**	**49**	**4**	**630**	**70**	**5**	**522**	**81**	**6**	**92**	**89**	**6**	**1**	**35**	**2**
Mean 07- 11	**Escapement**	**46**	**47**	**5**	**514**	**69**	**5**	**1,385**	**82**	**7**	**406**	**90**	**8**	**6**	**56**	**1**
	PRH Returns	**266**	**49**	**4**	**1,112**	**69**	**4**	**819**	**79**	**5**	**101**	**85**	**5**	**0**	**17**	**0**

[a] Does not include age-6 returns

Table 41 **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 2007-2011. N = sample size and SD = 1 standard deviation.**

Brood Year	Origin	Male 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			362	70	5	206	84	8	154	98	8	1	105	0
	Hatchery				44	72	4	16	82	5	6	93	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	33	45	4	325	68	6	855	83	8	238	94	8	4	97	8
	Hatchery	25	50	4	34	71	6	34	79	7	7	92	7	0		
2011[a]	Natural	33	45	4	175	66	5	413	67	8	137	94	7			
	Hatchery	25	50	4	19	68	4	31	69	6	7	88	7			
Mean	**Natural**	**23**	**47**	**4**	**264**	**68**	**5**	**371**	**80**	**8**	**119**	**97**	**7**	**3**	**101**	**4**
	Hatchery	**15**	**52**	**4**	**30**	**70**	**5**	**22**	**79**	**6**	**5**	**92**	**8**	**0**	**0**	**0**
Brood Year	**Origin**	**Female 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	0			83	72	5	376	83	5	326	89	5	0		
	Hatchery	0			48	72	4	48	80	4	8	86	6	0		
2008	Natural	0			36	70	3	344	83	5	49	88	5	1	84	0
	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	0
	Hatchery	0			12	68	4	49	78	6	4	85	4	0		
2010	Natural	0			44	71	5	82	87	5	550	85	4	20	89	5
	Hatchery	0			10	69	4	4	87	5	29	82	4	0		
2011[a]	Natural	0			7	67	5	626	80	5	282	85	5			
	Hatchery	0			4	65	2	76	77	4	35	84	4			
Mean	**Natural**	**0**			**43**	**70**	**5**	**307**	**83**	**5**	**258**	**87**	**6**	**7**	**82**	**2**
	Hatchery	**0**			**19**	**69**	**4**	**40**	**81**	**5**	**17**	**84**	**5**	**0**	**0**	**0**
Brood Year	**Origin**	**Gender 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			445	70	5	582	83	6	480	92	6	1	105	0
	Hatchery				92	72	4	64	81	4	14	89	6	0		
2008	Natural	22	49	4	170	69	5	604	84	6	74	92	6	1	84	0
	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	0
	Hatchery	2	55	5	46	70	5	70	78	7	6	89	5	0		
2010	Natural	33	45	4	369	68	6	937	83	8	788	88	5	24	90	7
	Hatchery	25	50	4	44	71	6	38	80	7	36	84	5	0		
2011[a]	Natural	33	45	4	182	66	5	1039	80	6	419	88	7			
	Hatchery	25	50	4	23	67	4	107	78	5	42	84	5			
Mean	**Natural**	**23**	**47**	**4**	**307**	**68**	**5**	**678**	**82**	**6**	**377**	**90**	**7**	**7**	**88**	**2**
	Hatchery	**15**	**52**	**4**	**50**	**70**	**5**	**61**	**80**	**5**	**21**	**86**	**6**	**0**	**0**	**0**

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

Table 42 Comparison male to female ratio of fall Chinook salmon sampled at Priest Rapids Hatchery and in the Hanford Reach stream surveys, Brood Years 2007-2011.

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	0.78:1
	Hatchery	1.60:1
2008	Stream	0.82:1
	Hatchery	1.89:1
2009	Stream	1.07:1
	Hatchery	2.57:1
2010	Stream	0.70:1
	Hatchery	1.47:1
2011[a]	Stream	0.71:1
	Hatchery	2.00:1
Mean	**Stream**	**0.90:1**
	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 2007-2011.

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[b]	Natural	0.94:1.00
	Hatchery	0.51:1:00
Mean	**Natural**	**1.05:1.00**
	Hatchery	**0.69:1:00**

[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 - 2016. For all years, we assume that fish not possessing any hatchery marks are natural origin fish.

The assessment of egg retention is compromised by the loss of eggs during the collection and transport of carcasses prior to sampling. 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 2010 through 2013 were determined by visual estimates; whereas, during 2014 through 2016, 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.

During the 2015 and 2016 surveys, 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 2015-2016.

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			

The adjusted spawn successes for the escapement between years 2010 and 2016 were generally greater than 97% (Table 45). The spawn success was lower for both hatchery and natural origin females in return year 2013 compared to other years. These observations coincide with an elevated pHOS which most likely resulted from high hatchery fish escapement and restrictive operations of the PRH volunteer trap during 2013. It is possible that a portion of these PRH origin females which were unable to enter the trap, died without spawning, and ended up being surveyed in the Hanford Reach carcass survey. The spawn success was high during 2014 and 2015 despite historically high record escapements to the Hanford Reach.

Table 45 Comparison of egg retention of natural and hatchery origin fall Chinook sampled in the Hanford Reach stream survey, Return Years 2010-2016.

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	96.4
	Total	995	969	18	6	2	0	97.4	99.1
Mean Natural Spawn Success (RY 2012 – 2016)								**95.5**	**98.3**
Mean Hatchery Spawn Success (RY 2012 – 2016)								**87.6**	**93.3**
Mean Combined Spawn Success (RY 2010 – 2016)								**94.5**	**97.4**

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 for tag recoveries on January 16, 2017 to provide CWT recoveries of PRH origin fish. The database for the 2009 brood should be complete for age-2 through age-5. The age-6 recovered during RY2016 may not be included until January 1, 2018 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 and 2010 show that adipose clipped fish from the DIT groups are being recovered in mark selective fisheries occurring in ocean, marine, and freshwater zones. Comparisons of the demographics between the DIT groups recovered at PRH are very similar (Appendix J). 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 2016, an estimated 17,927 fall Chinook salmon were harvested during this fishery; 16,859 adults and 1,068 jacks. Estimates generated from CWT recoveries from the Hanford Reach sport fishery suggest that 12.1% (2,177 fish) of the total sport harvest in the Hanford Reach was comprised of fall Chinook salmon released from PRH (Table 46). Likewise, fall Chinook salmon released from Ringold Springs Hatchery comprised 2.8% (992 fish) of the sport fishery. Strays from other hatcheries combined represent 0.9% (319 fish) of the harvest. Sport harvest monitoring in the Hanford Reach and lower Yakima includes surveying both adipose intact and adipose clipped fish for CWTs. Recent data from otolith sampling indicates that CWT expansions may underestimate the number of PRH origin fall Chinook salmon annually returning to PRH. A similar situation may occur when evaluating hatchery contributions to the sport fishery.

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 2010, 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 2009 and 2010 broods 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 2003-2016.**

Return Year	Harvest & 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
Mean	14,982	3,638	24.1	1,999	796	152	11.9	4.1	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 1997-2010. 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	P^ CWT
			Tribal		*Commercial*		*Recreational*			
	#	%	#	%	#	%	#	%		
1997	1,100	36.7	1,506	50.2	304	10.1	91	3.0	3,001	0.03
1998	6,580	48.4	3,956	29.1	1,066	7.8	1,981	14.6	13,583	0.03
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	0.03
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	0.03
2008	5,763	43.7	4,447	33.7	887	6.7	2,080	15.8	13,177	0.032
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	34275	32.0	7886	7.4	18299	17.1	107,044	0.089
Mean	**10,968**	**48.8**	**7,064**	**28.9**	**1,589**	**8.7**	**3,635**	**13.6**	**23,256**	**0.046**

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 target rates for straying given in the Monitoring and Evaluation Plan for PUD Hatchery Programs (Hillman et al. 2013):

1). Stray rate for PRH origin fall Chinook salmon should be less than 5% of total brood return.

2). 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.

3). 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.

With one exception, less than 5% of the PRH origin returns for each brood year were estimated to have spawned outside of the presumptive target spawning area (Table 48). The 2006 brood is the only cohort found at rates greater than 5% outside of the presumptive target area. For this cohort, 37% of the estimated strays occurred in the Chelan River. This estimate is based on the expansion of one PRH origin CWT fish recovered in the Chelan River escapement. 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.

Examination of 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 consisted of PRH origin fall Chinook salmon (

Table 49).

Table 48 **Estimated number and proportions of Priest Rapids Hatchery fall Chinook salmon spawning escapement to Priest Rapids Hatchery and streams within and outside of the presumptive target stream by brood year (1992-2010). 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: Target Hatchery		Homing: Target Stream[1]		Straying Outside of Target Stream	
		Number	Proportion	Number	Proportion	Number	Proportion
1992	9,037	7,630	0.844	1,037	0.115	370	0.041
1993	25,966	21,144	0.814	4,821	0.186	0	0.000
1994	1,692	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	13,552	10,034	0.740	3,517	0.260	0	0.000
1997	3,172	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	27,333	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	21,379	17,103	0.800	4,241	0.198	34	0.002
2006	1,001	634	0.633	0	0.000	367	0.367
2007	22,206	19,220	0.866	2,964	0.133	22	0.001
2008	11,867	9,002	0.759	2,864	0.241	0	0.000
2009	27,968	17,760	0.635	10,132	0.362	36	0.001
2010	99,571	68,231	0.685	40,574	0.407	63	0.001
Mean	18,585	13,266	0.748	5,731	0.233	78	0.024

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

Table 49 Proportion of fall/summer Chinook spawning populations by return year comprised of Priest Rapids Hatchery fall Chinook from 1998-2010 brood releases based on coded-wire tag recoveries.

Return Year	Presumptive Non-Target Stream													
	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	0.343	0	0.000	0	0.000
2002	0	0.000	0	0.000	0	0.000	0	0.000	274	0.468	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	0.031
2009	0	0.000	0	0.000	0	0.000	0	0.000	117	0.091	0	0.000	0	0.000
2010	0	0.000	0	0.000	0	0.000	0	0.000	359	0.328	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	19	0.000	0	0.000	0	0.000
2013	0	0.000	0	0.000	0	0.000	0	0.000	37	0.000	0	0.000	0	0.000
2014	0	0.000	0	0.000	0	0.000	0	0.000	30	0.000	0	0.000	0	0.000
2015	0	0.000	0	0.000	0	0.000	22	0.019	135	0.093	0	0.000	0	0.000
Mean	**0**	**0.000**	**0**	**0.000**	**0**	**0.000**	**1**	**0.001**	**82**	**0.083**	**0**	**0.000**	**4**	**0.002**

[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.

As previously described in Section 4, approximately 3,000 smolts at PRH have been 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 2013. The number of observed PRH PIT tagged adults should dramatically increase in the forthcoming years.

The majority of the PIT tagged PRH adults observed at McNary Dam have been observed at PRD and/or PRH. Very few fish have been detected in the Snake River, which is possibly the area of most 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 sites upstream of McNary Dam, Brood Years 1999-2013.

Brood Year	# PIT tagged	Number of last known detections of unique Priest Rapids Origin PIT tags by site												
		MCN	ICH	PRO	PRH	PRA	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			8	8	2							22
2010	3,000	8			34	23	5	1	3			3		77
2011 (age 2-5)	42,844	73			289	155	8	3	27	1		22	5	583
2012 (age 2-4)	42,908	97	1		441	120	6	1	18	1	1	14	2	702
2013 (age 2-3)	42,988	9		1	38	10				3	1		1	63

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
PRA	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

16.0 Genetics

Genetic tissue was collected from each Chinook salmon spawned at PRH during 2016 by staff from the Columbia River Inter-Tribal Fish Commission (CRITFC). In total 4,938 specimens were collected to support their work associated with genetic stock identification and parentage-based tagging. Tissue samples were numbered consistent with PRH M&E data so that biological information could be associated with genetic data. The tissue samples collected from return years 2011 through 2016 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. WDFW has not collected genetic samples since the 2010 return because of the large sampling and archiving effort by CRITFC.

17.0 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.

17.1 Estimate of pNOB

Estimates of pNOB based on otolith samples are limited to return years 2012 through 2016. 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.

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 2016 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 2012-2016.

Return Year	N	GCPUD pNOB	USACE pNOB	PRH and RSH 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
Mean	5,264	0.264	0.055	0.159	0.000

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

The 2016 broodstock included 4,938 adults which were comprised of 4,325 fish from the volunteer trap, 366 from the OLAFT and 247 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 high-graded fish collected from the PRH volunteer trap and held in another specific holding pond (Pond 1). 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 held in a specific pond (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 2016.

Program	Egg-Take	Facility Mean Fecundity	Natural Females	Hatchery Females	Natural Males	Hatchery Males	Total Natural	Total Hatchery	pNOB
GCPUD	4,050,782	3,921	224	809	80	437	304	1246	0.196
GCPUD Alt Mating[1]	2,220,002	3,369	162	497	153	24	315	521	0.377
GCPUD Combined	6,270,784	3,706	386	1,306	233	461	619	1,767	0.259
USACE – PRH	*1,903,631*	3,640	*18*	*505*	*19*	*224*	37	729	0.048
USACE – RSH	*4,204,716*	3,572	*96*	*1,081*	*51*	*545*	147	1,626	0.083
USACE Combined	6,108,347	3,593	114	1,586	70	769	184	2,355	0.072
Combined PRH and RSH Programs	12,379,131	3,392	500	2,892	303	1,230	803	4,122	0.163
Other Programs[2]	32,399	3,600	0	9	0	5	0	14	0.000

[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.

An alternative pNOB for calculating PNI was developed to account for the genetic influence on pNOB resulting from the PRH spawning protocol of spawning one male with one, two, or four females. It is intended to represent actual gene flow to the progeny instead of strictly the origin and number of parents. This information is presented in Appendix K for comparison to other conventional pNOB calculations.

17.2 Estimates of pHOS

Estimates of pHOS based on otolith samples are limited to return years 2012 through 2016. 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. 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 2012-2016.

Return Year	N	Total Escapement	Hatchery Origin Spawners (pHOS)			
			PRH	RSH	Other[1]	Total
2012	1,609	57,631	0.062	0.066	0.005	0.135
2013	927	126,744	0.203	0.054	0.018	0.275
2014	2,426	183,750	0.052	0.015	0.028	0.096
2015	2,485	266,347	0.076	0.017	0.004	0.097
2016	1,648	116,421	0.066	0.022	0.027	0.115
Mean	1,819	150,179	0.092	0.035	0.016	0.144

[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 salmon spawning naturally in the Hanford Reach. The primary source of pHOS originates from fish released from PRH. This source of PRH-pHOS was apportioned to the Grant PUD and USACE programs at PRH based on the annual mitigation requirement for the number of juveniles released by each program between brood year 2008 and 2012 (Table 54). An estimated 10,245 PRH origin fish spawned naturally in the Hanford Reach during the 2016 return year. Of these, 74.6% and 25.4% were allocated respectively to Grant PUD and USACE production at PRH. The USACE's 25.4% portion of PRH origin pHOS was combined with the pHOS associated with the USACE's RSH production to estimate the total pHOS associated with the USACE programs in the Hanford Reach.

The calculation of pHOS specific to each program includes proportions which are based on the entire population of natural origin fish in the denominators. Therefore this method of calculating program specific pHOS results in lower values than the population level pHOS and may only be useful for assessing the individual program's contribution of hatchery origin fish to the spawning population in the natural environment.

Table 54 Origin of pHOS apportioned by program source for fall Chinook salmon spawning naturally in the Hanford Reach, Return Years 2012-2016.

Return Year	Natural Origin	Hatchery Origin Spawners				pHOS by Source			
		Grant PUD[1]	USACE[1,2]	Other[3]	Total	Grant PUD[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

[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. The allocation of pHOS was based on the proportion of annual juvenile mitigation goals for each agency for brood years 2008 through 2012.
[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.

17.3 Estimates of PNI

We present a hierarchy of 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 includes all hatchery origin fish regardless of hatchery program or funding source.

Prior to return year 2012, pHOS, pNOB and PNI rates are 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 Section 10 of this report, this assumption significantly over estimates pNOB and PNI. This method of estimated pNOB for the 2015 and 2016 broodstock was not calculated due to high-grading to remove 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 Section 10. 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 L. 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 Year 2001-2016.

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

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 2012-2016 we present PNI estimates calculated from the multiple population gene flow model (Table 56). The output from this model suggests that the PNI values for return years 2014 and 2016 have exceeded the goal of 0.670.

Table 56 PNI estimates for the Hanford Reach fall Chinook salmon supplementation programs, Return Years 2012-2016. 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
	GCPUD[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
Mean	**0.265**	**0.055**	**0.159**	**0.073**	**0.054**	**0.016**	**0.144**	**0.660**

[1]Includes broodstock associated with GCPUD 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 GCPUD 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.

18.0 Natural and Hatchery Replacement Rates

The numbers of hatchery origin recruits (HOR) were 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. Therefore, the assumption was made that returns not accounted for by HOR CWT recoveries are NOR. Recent data indicates that that CWT data likely underestimates the true number of HORs; Hence, our assumption likely overestimates the number of 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 NOR.

For brood years 1996 through 2010, the HRR (14.24) has been consistently higher than the NRR (3.16) (Table 57). The HRR for BY 2010 including harvest was the highest that has been observed (61.69) and was substantially higher than the NRR (6.21). 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 1996-2010.

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	22,453	101,753	10.71	4.57	53,685	174,905	25.61	7.85
2008	2,959	29,058	11,935	41,809	4.03	1.44	25,234	79,330	8.53	2.73
2009	3,177	36,720	28,197	97,834	8.88	2.66	85,533	145,949	26.92	3.97
2010	3,348	86,982	99,402	280,205	29.69	3.22	206,551	540,151	61.69	6.21
Mean	2,967	55,415	19,024	76,835	6.32	1.70	42,801	141,771	14.24	3.16
Median	2,959	48,020	13,584	56,422	4.75	1.17	26,205	89,983	9.17	2.03

[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.

19.0 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 2010 brood year data was queried on January 16, 2017. This query should account for age 2 through 5 fall Chinook salmon sampled through December 2015. The lag in reporting field data for the 2016 return year likely excludes recoveries of a limited number of age-6 fish from the 2010 brood.

Annual SAR for hatchery fall Chinook salmon released from PRH for brood years 1992 through 2010 have a mean of 0.0062 with a median of 0.0040 (

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 1992-2010. Data includes coded-wire tag recoveries from adipose clipped fish.

Brood Year	Number of Tagged Smolts Released	Estimated Adult Captures	SAR
1992	194,622	448	0.0023
1993	185,683	1,479	0.0080
1994	175,880	108	0.0006
1995	196,189	1,786	0.0091
1996	193,215	762	0.0040
1997	196,249	183	0.0009
1998	193,660	946	0.0049
1999	204,346	1,573	0.0077
2000	200,779	370	0.0018
2001	219,926	1,810	0.0082
2002	355,373	669	0.0019
2003	399,116	352	0.0009
2004	200,072	100	0.0005
2005	199,445	1,718	0.0086
2006	202,000	100	0.0005
2007	202,568	2,391	0.0118
2008	218,082	740	0.0034
2009	619,568	7,820	0.0126
2010	605,000	18,620	0.0308
Mean	**261,146**	**2,209**	**0.0062**
Median	**200,779**	**762**	**0.0040**

Annual SAR for Hanford Reach natural origin fall Chinook salmon for brood years 1992 through 2010 had a mean of 0.0042 with a median of 0.0023 (Table 59). The SAR for the Hanford Reach natural origin 2010 brood is 0.0164 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 1992-2010. Data includes coded-wire tag recoveries from adipose clipped fish.

Brood Year	Number of Tagged Smolts Released	Estimated Adult Captures	SAR
1992	203,591	829	0.0041
1993	95,897	485	0.0051
1994	148,585	74	0.0005
1995	146,887	340	0.0023
1996	92,262	111	0.0012
1997	199,896	365	0.0018
1998	129,850	784	0.0060
1999	213,259	2,378	0.0112
2000	204,925	362	0.0018
2001	127,758	519	0.0041
2002	203,557	338	0.0017
2003	207,168	199	0.0010
2004	163,884	147	0.0009
2005	203,929	301	0.0015
2006	263,478	356	0.0007
2007	53,618	456	0.0085
2008	203,947	520	0.0025
2009	201,606	1,597	0.0079
2010	179,727	2,956	0.0164
Mean	**170,728**	**690**	**0.0042**
Median	**199,896**	**365**	**0.0023**

20.0 ESA/HCP Compliance

20.1 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 2016 fall Chinook broodstock collection activities, a total of 5 steelhead 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 2016.

		No Mark	Ad Only	Ad-RV	Total
Released	**Males**	1	0	0	1
	Females	1	1	2	4
	Sub Total	2	1	2	5
Killed	**Males**	0	0	0	0
	Females	0	0	0	0
	Sub Total	0	0	0	0
	Total	2	1	2	5

20.2 Hatchery Rearing and Release

The juvenile fall Chinook salmon from the 2016 brood year reared throughout their life-stages at PRH without incident. The 2017 smolt release totaled 7,022,271 URB fall Chinook salmon, representing 96% of the production objective and was compliant with the 10% overage allowable in ESA Section 10 Permit 1347.

20.3 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 majority of these fish are suitable for consumption and transported to Foodbanks (Table 61). In 2016, 72% of the surplus fish were used for human consumption.

Table 61 Disposition of Chinook salmon removed from Priest Rapids Hatchery volunteer trap, Return Years 2001-2016.

Return Year	Disposal of Mortalities and Treated Fish		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	13,42	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
Mean	**4,400**	**2,131**	**873**	**241**	**14,701**	**799**	**2,807**	**24,884**
Median	**5,398**	**45**	**0**	**280**	**3,548**	**502**	**298**	**17,719**

20.4 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 2016 through June 2017 collection and rearing periods.

20.5 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).

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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 2.026 for the different age/broods examined (Table 1). CWT Recovery bias appears to be reduced for brood years 2012 and 2013 relative to that of earlier years. The source of any bias is unknown but several factors may contribute to the variation in CWT Recovery bias shown in Table 1: 1) tag loss, 2) CWT detection efficiency, 3) inappropriate expansion estimates, or 4) differential survival of tagged fish. 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. On the day 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 are similar for each brood year (Table 2).

Table A.1 Estimate of coded-wire tags bias for Priest Rapids origin returns to the hatchery, Brood Years 2007- 2014.

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	21	1.095	4.620	R9500
2010	5	0.237	999	2,375	0.421	1.774	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	5	0.169	395	2,561	0.154	0.912	R9500
2011	4	0.169	2,988	19,909	0.150	0.887	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	4	0.177	2206	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	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	2	0.172	78	486	0.160	0.935	R9500

CWT Recovery Bias	Ages					
		2	**3**	**4**	**5**	**6**
	Mean	**0.830**	**0.795**	**0.812**	**1.344**	**4.620**
	Median	**0.839**	**0.768**	**0.864**	**1.161**	**4.620**

Table A.2. Proportions of coded-wire tagged fish reported ponded and the proportions of coded-wire tagged fish sampled at time of release, Brood Years 2014-15.

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%
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%

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 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; 0.4% 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- 2016.

Brood Year	Initial Device	QC Device	# Sampled	# Missed CWT	P^ CWT Missed
2013	T-Wand	Blue Wand	1,063	4	0.004
2014	R9500	T-Wand	2,000	3	0.002
2015	R9500	T-Wand	4,596	2	0.000
2016	R9500	T-Wand	5,943	3	0.001

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 setup 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 and 2016. During both 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. In 2015, 4,596 fish were sampled in this fashion and only 2 (0.04%) were found to possess a CWT that was not initially detected by the R9500 and diverted to the tote containing CWT fish. In 2016, only 3 of 5,943 (0.05%) were found to possess a CWT that was not detected by the R9500 and diverted to the tote containing CWT fish. Similar to observations in 2014, when these fish were rescanned by the R9500 they were correctly diverted to the tote containing CWT fish.

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 Chinook salmon broodstock spawned at Priest Rapids Hatchery during Return Year 2016.

Code	Tag #	BY	Run	Age	Stock	Release Location	CWT Release			Expansion		Escapement	
							Date	AD CWT	CWT Only	All CWT	AD CWT	#	%
635971	22	2010	Fall	6	Priest Rapids	Priest Rapids	2011	0	204,590	4.0	11.3	N/A	N/A
635972	14	2010	Fall	6	Priest Rapids	Priest Rapids	2011	0	199,600	4.0	11.3	N/A	N/A
636507	43	2012	Fall	4	Priest Rapids	Priest Rapids	2013	603,930	0	5.662	11.297	N/A	N/A
636508	176	2012	Fall	4	Priest Rapids	Priest Rapids	2013	0	601,009	5.662	11.297	N/A	N/A
636681	12	2013	Fall	3	Priest Rapids	Priest Rapids	2014	600,883	2,914	6.017	12.093	N/A	N/A
636682	27	2013	Fall	3	Priest Rapids	Priest Rapids	2014	0	603,819	6.017	12.093	N/A	N/A
090681	1	2012	Fall	4	Priest Rapids	Ringold	2013	214,873	5,943	14.706	15.113	N/A	N/A
090863	1	2013	Fall	3	Priest Rapids	Ringold	2011	222,740	2,784	15.096	15.287	N/A	N/A
090704	1	2012	Fall	4	Umatilla R	Umatilla R	2013	140,915	120	1.986	1.987	N/A	N/A
Total	**297**		**4,325**		**Volunteer Trap Broodstock Spawned**							N/A	N/A

Appendix C

Recovery of coded-wire tags collected from adult Chinook salmon surplus or mortalities from Priest Rapids Hatchery during Return Year 2016.

Code	Tag #	BY	Race	Age	Stock	Release Location	CWT Release			Expansion		Escapement	
							Date	AD CWT	CWT Only	All CWT	ADC WT	#	%
220238	1	2013	Fall	3	Lyons Ferry	Clearwater@lapwai	2014	100,911	0	1.370	4.118	**1**	0.0%
220240	5	2013	Fall	3	Lyons Ferry	Clearwater@lapwai	2015	0	202,383	1.370	4.118	**7**	0.0%
635274	1	2010	Fall	6	Priest Rapids	CR@Priest Rapids	2011	0	99,800	4.0	11.3	**4**	0.0%
635699	7	2010	Fall	6	Priest Rapids	CR@Priest Rapids	2011	203,682	409	3.972	11.282	**28**	0.1%
635764	1	2010	Fall	6	Priest Rapids	CR@Priest Rapids	2011	199,698	401	4.0	11.3	**4**	0.0%
635766	2	2010	Fall	6	Priest Rapids	CR@Priest Rapids	2011	0	204,091	4.0	11.3	**8**	0.0%
635970	1	2010	Fall	6	Priest Rapids	CR@Priest Rapids	2011	199,200	400	4.0	11.3	**4**	0.0%
635971	6	2010	Fall	6	Priest Rapids	CR@Priest Rapids	2011	0	204,590	4.0	11.3	**24**	0.1%
635972	1	2010	Fall	6	Priest Rapids	CR@Priest Rapids	2011	0	199,600	4.0	11.3	**4**	0.0%
635973	1	2010	Fall	6	Priest Rapids	CR@Priest Rapids	2011	0	200,099	4.0	11.3	**4**	0.0%
635974	3	2010	Fall	6	Priest Rapids	CR@Priest Rapids	2011	0	199,600	3.972	11.282	**12**	0.0%
636371	187	2011	Fall	5	Priest Rapids	CR@Priest Rapids	2012	0	598,031	5.912	11.848	**1106**	3.8%
636372	208	2011	Fall	5	Priest Rapids	CR@Priest Rapids	2012	595,608	0	5.912	11.848	**1230**	4.3%
636507	1060	2012	Fall	4	Priest Rapids	CR@Priest Rapids	2013	603,930	0	5.662	11.297	**6002**	20.9%
636508	1146	2012	Fall	4	Priest Rapids	CR@Priest Rapids	2013	0	601,009	5.662	11.297	**6489**	22.5%
636681	836	2013	Fall	3	Priest Rapids	CR@Priest Rapids	2014	600,883	2,914	6.017	12.093	**5031**	17.5%
636682	969	2013	Fall	3	Priest Rapids	CR@Priest Rapids	2014	0	603,819	6.017	12.093	**5831**	20.3%
636836	40	2014	Fall	2	Priest Rapids	CR@Priest Rapids	2015	604,425	425	5.826	11.660	**233**	0.8%
636837	38	2014	Fall	2	Priest Rapids	CR@Priest Rapids	2015	0	604,861	5.826	11.660	**221**	0.8%
090488	1	2010	Fall	6	Priest Rapids	CR@Ringold	2011	221,389	1,527	15.598	15.705	**16**	0.1%
090570	2	2011	Fall	5	Priest Rapids	CR@Ringold	2012	194,871	0	17.083	17.083	**34**	0.1%
090681	17	2012	Fall	4	Priest Rapids	CR@Ringold	2013	214,873	5,943	14.706	15.113	**250**	0.9%
90863	13	2013	Fall	3	Priest Rapids	CR@Ringold	2011	222,740	2,784	15.096	15.287	**196**	0.7%
635773	1	2011	Summer	5	Wells	CR@Wells	2013	289,476	522	1.0	1.0	**1**	0.0%
636505	2	2012	Summer	4	Wells	CR@Wells	2014	434,716	1,767	1.000	1.000	**2**	0.0%
636739	4	2013	Fall	3	Lyons Ferry	Grande Ronde R	2014	202,273	0	1.997	1.997	**8**	0.0%
610439	1	2011	Fall	5	Hanford URB Wild	Hanford Reach	2012	27,173	0			**0**	0.0%
610448	1	2012	Fall	4	Hanford URB Wild	Hanford Reach	2013	46,496	0			**0**	0.0%
610449	1	2012	Fall	4	Hanford URB Wild	Hanford Reach	2013	26,771	0			**0**	0.0%
610451	1	2012	Fall	4	Hanford URB Wild	Hanford Reach	2013	22,763	0			**0**	0.0%

Code	Tag #	BY	Race	Age	Stock	Release Location	CWT Release			Expansion		Escapement	
							Date	AD CWT	CWT Only	All CWT	ADC WT	#	%
610454	2	2013	Fall	3	Hanford URB Wild	Hanford Reach	2014	49,354	0			**0**	0.0%
610456	4	2013	Fall	3	Hanford URB Wild	Hanford Reach	2014	29,452	0			**0**	0.0%
610464	1	2014	Fall	2	Hanford URB Wild	Hanford Reach	2015	11,895	0			**0**	0.0%
220234	1	2013	Fall	3	Lyons Ferry	Lukes Gulch	2014	100,870	0	1.250	2.531	**1**	0.0%
636583	1	2012	Fall	4	Snake River	Lyons Ferry	2014	246,702	2,685	1.007	2.040	**1**	0.0%
220233	3	2013	Fall	3	Lyons Ferry	Magrudor Corridor	2014	102,430	0	1.253	2.469	**4**	0.0%
636173	1	2011	Summer	5	Methow	Similkameen R	2013		209,118	0.000	1.004	**1**	0.0%
635680	1	2011	Summer	5	Methow	Similkameen R	2013	206,700	1,553	1.0	1.0	**1**	0.0%
220337	1	2012	Fall	4	Lyons Ferry	Snake R	2014	88,140	0	1.003	1.003	**1**	0.0%
220342	1	2013	Fall	3	Lyons Ferry	Snake R	2014	98,628	0	2.727	2.727	**3**	0.0%
636737	2	2013	Fall	3	Lyons Ferry	Snake R	2014	202,329	1,071	1.130	1.136	**2**	0.0%
220336	1	2012	Fall	4	Snake R	Snake R@ Capt John	2014	0	86,280	1.011	2.172	**1**	0.0%
220343	3	2013	Fall	3	Lyons Ferry	Snake R@ Capt John	2014	0	99,142	2.554	5.056	**8**	0.0%
90818	3	2013	Fall	3	Snake R	Snake R@Hells Canyon	2014	191,092	525	4.757	4.771	**14**	0.0%
90888	2	2014	Fall	2	Snake R	Snake R@Hells Canyon	2015	244,342	268	4.279	4.284	**9**	0.0%
220347	1	2013	Fall	3	Lyons Ferry	Snake@Pittsburg	2014	100,063	0	2.009	4.006	**2**	0.0%
220358	1	2014	Fall	2	Lyons Ferry	Snake@Pittsburg	2015	0	96,274	2.058	4.098	**2**	0.0%
090585	1	2011	Fall	5	Umatilla Hatchery	Umatilla R	2012	154,611	0	1.694	1.694	**2**	0.0%
090655	2	2011	Fall	5	Umatilla Hatchery	Umatilla R	2013	50,112	613	1.040	2.046	**2**	0.0%
090657	1	2011	Fall	5	Umatilla Hatchery	Umatilla R	2013	88,668	359	1.005	2.025	**1**	0.0%
090658	1	2011	Fall	5	Umatilla Hatchery	Umatilla R	2013	0	223,550	1.005	2.025	**1**	0.0%
090682	3	2012	Fall	4	Umatilla R	Umatilla R	2014	0	229,652	1.040	2.046	**3**	0.0%
090683	2	2012	Fall	4	Umatilla R	Umatilla R	2014	102,499	1,784	1.040	2.046	**2**	0.0%
090684	3	2012	Fall	4	Umatilla R	Umatilla R	2014	49,266	200	1.040	2.046	**3**	0.0%
090704	11	2012	Fall	4	Umatilla R	Umatilla R	2013	140,915	120	1.986	1.987	**22**	0.1%
090705	10	2012	Fall	4	Umatilla R	Umatilla R	2013	166,640	0	1.986	1.987	**20**	0.1%
090816	19	2013	Fall	3	Umatilla River	Umatilla R	2014	168,393	824	1.875	1.880	**36**	0.1%
090817	13	2013	Fall	3	Umatilla River	Umatilla R	2014	163,114	0	1.875	1.880	**24**	0.1%
90870	3	2013	Fall	3	Umatilla R	Umatilla R	2015	210,611	0	1.027	1.030	**3**	0.0%
90871	2	2013	Fall	3	Umatilla R	Umatilla R	2015	114,305	462	1.027	1.030	**2**	0.0%
90917	1	2014	Fall	2	Umatilla R	Umatilla R	2015	161,668	0	4.040	4.040	**4**	0.0%
90944	4	2014	Fall	2	Umatilla R	Umatilla R	2016	483,071	975	1.007	1.009	**4**	0.0%
90945	4	2014	Fall	2	Umatilla R	Umatilla R	2016	227,783	1,256	1.007	1.013	**4**	0.0%

Code	Tag #	BY	Race	Age	Stock	Release Location	CWT Release			Expansion		Escapement	
							Date	AD CWT	CWT Only	All CWT	ADC WT	#	%
90946	3	2014	Fall	2	Umatilla R	Umatilla R	2016	105,561	531	1.002	1.007	**3**	0.0%
90909	45	NA	Fall	NA	ODFW	ODFW	NA	NA	NA	NA	NA	**NA**	0.0%
Total	**4714**		**28,786**	**Recovered at PRH**								**26,935**	93.6%

Appendix D

Juvenile fish health inspections for Priest Rapids Hatchery fall Chinook salmon, Brood Years 1998-2008. The description in the Condition column indicates the presence of a certain condition within at least one of the fish examined.

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

Appendix E

Summary of aerial fall Chinook salmon redd counts in the Hanford Reach, Columbia River, Washington.

Number and percent of fall Chinook salmon redds counted in different reaches of the Columbia River, 2001-2016. Data for years 2001-2010 was collected by staff with Pacific Northwest National Laboratory. Data for years 2011-2016 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**				**(07-16) Mean**
Islands 11-21	676	533	798	906	1,193	861				**638**
Islands 8-10	814	807	2,200	1,565	3,145	1,735				**1,261**
Near Island 7	670	700	655	1,100	800	670				**610**
Island 6 (lower)	1,181	1,375	3,340	2,530	2,315	1,807				**1,593**
Island 4, 5,6	1,524	1,195	2,650	2,080	2,540	2,270				**1,623**
Near Island 3	525	475	1,000	1,000	1,100	600				**561**
Near Island 2	653	528	1,700	2,050	1,900	1,140				**1,010**
Near Island 1	295	340	900	500	1,000	340				**405**
Coyote Rapids	44	29	520	500	765	255				**224**
China Bar	67	68	100	60	1,730	80				**353**
Vernita Bar	2,466	2,318	3,535	3,650	4,190	3,510				**2,521**
Total	**8,915**	**8,368**	**17,398**	**15,951**	**20,678**	**13,268**				**10,799**
Location	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**				**(07-16) Mean**
Islands 11-21	8%	6%	5%	6%	6%	6%				**6%**
Islands 8-10	9%	10%	13%	10%	15%	13%				**12%**
Near Island 7	8%	8%	4%	7%	4%	5%				**6%**
Island 6 (lower)	13%	16%	19%	16%	11%	14%				**15%**
Island 4, 5, 6	17%	14%	15%	13%	12%	17%				**15%**
Near Island 3	6%	6%	6%	6%	5%	5%				**5%**
Near Island 2	7%	6%	10%	13%	9%	9%				**9%**
Near Island 1	3%	4%	5%	3%	5%	3%				**4%**
Coyote Rapids	>1%	>1%	3%	3%	4%	2%				**2%**
China Bar	1%	1%	1%	0%	8%	1%				**3%**
Vernita Bar	28%	28%	20%	23%	20%	26%				**23%**

Appendix F

Historical numbers of Chinook salmon carcasses recovered during the annual Hanford Reach fall Chinook salmon carcass survey, Return Years 1991-2016.

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
Mean	**8,857**	**85,210**	**0.123**

Appendix G
Estimated escapements for fall Chinook spawning in Hanford Reach and Priest Rapids Dam pool, Return Year 2016.

2016 Hanford Reach Fall Chinook Escapement Estimate

Count Source		2016		
		Adult	Jack	Total
Adult Fish Counts	**McNary**[1]	239,791	24,870	264,661
	Wanapum[2]	24,088	2,015	26,103
	Priest Rapids[3]	41,013	3,191	44,204
	Fallback Adjustment[4]	5,549	432	5,981
	Ice Harbor[5]	36,713	13,066	49,779
	Prosser[6]	5,214	464	5,678
Hatcheries	Priest Rapids Hatchery	27,904	882	28,786
	Priest Rapids Hatchery Channel	10	0	10
	Angler Broodstock Collection	284	0	284
	Ringold Springs Hatchery	5,314	65	5,379
Harvest	Hanford Sport Harvest	16,859	1,068	17,927
	Yakima River Sport Harvest	922	31	953
	Wanapum Tribal Fishery	35	1	36
Escapement	Yakima River (Lower)[5]	1,087	97	1,184
	Hanford Reach + Priest Pool	121,361	7,181	128,542
	Priest Pool Return	11,376	744	12,120
	Hanford Reach Escapement	**109,984**	**6,437**	**116,421**

[1] McNaryDam 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. Grant PUD continued counts through Nov 15 but McNary counts ended on Oct 31. Allowed 5 days to account for difference in passage timing

[4] Fallback/Reascension Adjustment estimate (13.5%) based on 154 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

2016 Priest Rapids Pool Escapement

Count Source	2016		
	Adult	Jack	Total
Wanapum Adult Passage	24,764	2,096	26,860
Wanapum Dam Fallback Adjustment	Unknown	Unknown	Unknown
Priest Rapids Fallback Adjustment[2]	5,549	432	5,981
Wanapum Tribal Fishery Above PRD	35		35
OLAFT	444	0	444
Priest Rapids Pool Sport Fishery	250	61	311
Total	47,587	0	47,587
Priest Rapids Adult Passage[3]	41,013	3,191	44,204
Priest Rapids Dam Pool Escapement	**9,971**	**3,191**	**13,162**

[2] Fallback/Reascension Adjustment estimate (13.5%) based on 154 run of the river PIT tagged fish from the BO AFF 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 H
Carcass Drift Assessment

A common objective of hatchery monitoring and evaluation programs 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 the five reaches. 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 carcasses. 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 1).

Table H.1 Numbers of operculum-tagged Chinook salmon carcasses released and recovered by donor section 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	0.020	0.030	0.949		
	4	0.024	0.000	0.096	0.880	
	5	0.066	0.293	0.000	0.641	

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 2015 and 2016, we adjusted our approach in attempt to mimic post-spawn fish dying near redd locations and subsequently drifting downstream. Each year, we opercula-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). 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 from during November and early December. During 2015, crews recovered 39 (3.9%) tagged carcasses (Table 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, crews recovered 47 (4.8%) tagged carcasses (Table 3). The recovery rate was notably lower for fish released in Section 2 compared to the other sections. Similar to the results of 2015, large proportions of fish tagged and recovered during 2016 were found downstream of their adjacent donor section.

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

Table H.2 **Numbers of operculum-tagged Chinook salmon carcasses released and recovered by donor section 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 H.3 **Numbers of operculum-tagged Chinook salmon carcasses released and recovered by donor section 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	4		14
	4	7	1	12	5	25
	5	0	0	1	4	5
P^ Recovered for each Donor Section		0.076	0.007	0.051	0.035	0.048
Proportion Recovered by Section	1	0.150				
	2	0.000	0.000			
	3	0.500	0.000	0.235		
	4	0.350	1.000	0.706	0.556	
	5	0.000	0.000	0.059	0.444	
Proportion Recovered by Section into recipient Section	1	1.000				
	2	0.000	0.000			
	3	0.680	0.000	1.000		
	4	0.134	0.442	0.560	1.000	
	5	0.000	0.000	0.117	1.000	

Appendix I
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. In 2015 and 2016, 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 1-6). 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. The accumulation of additional data following the methods used in years 2015 and 2016 will benefit the analysis of possible size related carcass recovery bias.

Table I.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 I. 2 **Summary of mark recapture of post-spawn fall Chinook Salmon in the Hanford Reach, 2012. 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 #			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 I.3. **Summary of mark recapture of post-spawn fall Chinook Salmon in the Hanford Reach, 2013. 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 #		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 I.4 **Summary of mark recapture of post-spawn fall Chinook Salmon in the Hanford Reach, 2015. Post orbital to hypural plate length (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 I.5 Summary of mark recapture of post-spawn fall Chinook Salmon in the Hanford Reach, 2016. Post orbital to hypural plate length (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 I.6 Mark and recapture bias of post-spawn fall Chinoook Salmon in the Hanford Reach by size group (post orbital to hypural plate – POHL), Return Years 2011-13 and 2014-15. 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	0.05	-0.071
2016[b]	987	46	-0.043	0.035	-0.043	0.052
Mean	**1008**	**101**	**0.007**	**-0.008**	**0.012**	**-0.010**

[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 J
Demographic comparisons for double index tag groups released from Priest Rapids Hatchery, Brood Years 2009-2011.

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 marine, ocean, and freshwater zones designated by the Washington Department of Fish and Wildlife (WDFW). The Regional Mark Processing Center database was queried to identify mark selective fisheries occurring since 2010 that included recoveries of PRH DIT groups (Table 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. Comparisons between DIT groups within a brood year strongly suggest there is no difference in survival (Table 2). Similar comparisons for gender composition, age at maturity, as well as, size at age strongly suggest there is no difference between the DIT groups recovered at PRH for a given brood year (Tables 3, 4, and 5).

Table J.1. Regional Mark Processing Center location names of mark selective fisheries showing recoveries of Priest Rapids Hatchery origin coded-wire tagged adipose clipped fish from brood years 2009 – 2011.

Location Name		
1A (BUOY10 - BRIDGE)	COL R OR SPORT SEC 6	COL R WA SPORT SEC 2
1B (BRIDGE - BEAVER)	COL R OR SPORT SEC 7	COL R WA SPORT SEC 5
ASTORIA SPORT 2	COL R OR SPORT SEC 8	COL R WA SPORT SEC 8
BONNEVILLE POOL UPPER	COL R OR SPT SEC 10	COL R WA SPORT SEC 9
BROOKINGS SPORT 6	COL R PRIEST-WANAPUM	COL R WN SPORT SEC 1
COL R OR SPORT SEC 1	COL R ROCK I-ROCKY R	COLUMBIA R AT DESCHUTES
COL R OR SPORT SEC 2	COL R ROCKY R-WELLS	COOS BAY SPORT 5
COL R OR SPORT SEC 3	COL R WA SEC 4	COWLITZ R 26.0002
COL R OR SPORT SEC 4	COL R WA SEC 6	EDIZ HOOK
COL R OR SPORT SEC 5	COL R WA SEC 7	GARIBALDI SPORT 3
WILLAPA HARBOR	WINCHESTER B SPORT 5	JOHN DAY POOL LOWER
NEWPORT SPORT 4	MARINE AREA 3	MARINE AREA 1
PORT ANGELES -OUTER	MARINE AREA 4	MARINE AREA 2
SEKIU	SIMILKAMEEN R 490325	WELLS DAM- CHIEF JOE

Table J.2. Survival Comparisons between DIT Groups by brood year.

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	0.0027
	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
Mean	Ad-Clipped	0.0005	0.0023	0.0027	0.0004	0.0000	0.0059
	No Mark	0.0005	0.0024	0.0028	0.0004	0.0000	0.0061

Table J.3. Gender Composition of DIT Groups by brood year.

Brood Year	Males		Females	
	Ad-CWT	CWT Only	Ad-CWT	CWT Only
2009	0.720	0.720	0.280	0.280
2010	0.540	0.550	0.460	0.450
2011	0.491	0.521	0.473	0.527
Mean	**0.584**	**0.597**	**0.404**	**0.419**

Table J.4. Age Composition of DIT Groups by brood year.

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	2,787	0.145	0.526	0.242	0.088	0.000
2010	Ad-CWT	6,017	0.086	0.334	0.522	0.057	0.001
	CWT Only	11,087	0.089	0.346	0.504	0.060	0.001
2011	Ad-CWT	6,329	0.054	0.407	0.470	0.070	0.000
	CWT Only	3,016	0.057	0.413	0.474	0.056	0.000
Mean	**Ad-Clipped**	**4,665**	**0.092**	**0.420**	**0.412**	**0.075**	**0.000**
	No Mark	**5,630**	**0.097**	**0.428**	**0.407**	**0.068**	**0.000**

Table J.5 Size at age for DIT Groups by brood year.

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		
	CWT Only	404	48	4	1,465	66	5	674	77	6	244	84	6	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	0		
	CWT Only	188	47	4	1,369	66	5	1,571	77	5	185	82	6	0		
Mean	AD-CWT	**302**	**48**	**4**	**1,365**	**67**	**5**	**1,652**	**77**	**5**	**238**	**83**	**5**	**9**	**89**	**5**
	CWT Only	**526**	**48**	**4**	**2,225**	**67**	**5**	**2,610**	**77**	**5**	**364**	**83**	**6**	**14**	**81**	**6**

Appendix K
Alternative pNOB and PNI Estimates

An alternative pNOB was developed to account for the genetic influence on pNOB resulting from the PRH spawning protocol of spawning one male with one, two, or four females. It is intended to represent actual gene flow to the progeny instead of strictly the origin and number of parents. However, it should be noted that although PNI was intended to index gene flow, the alternative method of estimating pNOB as described below has not been used elsewhere and is currently undergoing review. The PNI calculation for the alternative pNOB method is PNI = Alt pNOB/(Alt pNOB + pHOS)

The alternative pNOB is calculated by assigning scores to the estimated matings of males and females based on origin during the spawning of the PRH broodstock.

The hatchery x hatchery matings = 0.0 points,

Hatchery x natural matings = 0.5 points, and

Natural x natural matings = 1.0 points.

The scores of all of the matings were averaged to generate the overall alternative pNOB. For example, the alternative pNOB calculation for the mating of one natural origin male x two hatchery origin females is (0.5 + 0.5) / 2 females) = 0.5, whereas the conventional pNOB calculation for this mating equals (1 natural / (1 natural + 2 hatchery) = 0.33.

The origin assignments of fish spawned were based on a combination of otolith marks, adipose clips, and CWTs (CWT0, as done for the conventional pNOB calculation previously discussed. The fish from the OLAFT and ABC were spawned with either fish from those collections or adipose intact broodstock fish from the PRH volunteer trap to try to reduce the number of matings with hatchery origin fish; hence, improving the pNOB for the Grant PUD program.

Similar to that done for estimates of pNOB by program, alternative pNOB and PNI estimates are given for the PRH facility as a whole and specific to the Grant PUD production associated with each brood year. The pHOS used for these estimates are given in Table 55.

The conventional and alternative pNOB values for Grant PUD production spawned at PRH and Grant PUD associated pHOS are presented in Table 1. Both methods of calculating PNI associated with the Grant PUD production provide PNI values in excess of the stated PNI target of 0.67 for most years.

Table K.1 Conventional and alternative calculations of pNOB and PNI associated with the production specific to Grant County PUD, Return Years 2012 – 2016

Conventional pNOB = pNOB/(NOB + HOB)			
Return Year	**GCPUD Broodstock Combined**	**GCPUD pHOS[1]**	**PNI**
2012	0.182	0.068	0.729
2013	0.225	0.151	0.598
2014	0.343	0.039	0.898
2015	0.313	0.057	0.846
2016	0.260	0.049	0.841
Alternative pNOB = Total Score / Total Matings			
Return Year	**GCPUD Broodstock**	**GCPUD pHOS[1]**	**PNI**
2012	0.197	0.068	0.744
2013	0.284	0.151	0.653
2014	0.423	0.039	0.916
2015	0.434	0.057	0.884
2016	0.356	0.049	0.879

[1]The proportion of the pHOS specific to the GCPUD mitigation smolt releases from PRH

Appendix L

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. Over the last fifteen years juvenile code-wire tag rates ranged from roughly 3% to 25% for PRH and roughly 6% for RSH. For many years, WDFW fish management staff has used 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 L.1 The number of PRH origin fish in the RY 2014 Hanford Reach escapement calculated form 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**